The TRUE Block Scale experiment – A status report

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Abstract

One component in the Tracer Retention Understanding Experiments at the SKB Äspö Hard Rock Laboratory is the TRUE Block Scale experiment which focuses on the 10–100 m length scale. The objectives of TRUE Block Scale were to increase understanding and capability to predict transport and retention fracture networks. An iterative approach was adopted which included drilling, characterisation of five exploration boreholes. The results indicate that it is possible to build relatively robust hydrostructural models of a rock volume on a 300 m length scale. using a few and relatively unsophisticated characterisation techniques (registration of pressure responses, borehole TV (BIPS) and high resolution flow logging). It was found that the basic hydrostructural entities of the investigated rock block were identified using data from the first three boreholes. Tracer dilution tests proved to be an effective means to identify suitable tracer injection sections for any given sink. Subsequent experiments have successfully demonstrated the possibility to run well-controlled, quantitative experiments with radioactive sorbing tracers in interpreted single structures and networks of deterministic fractures/structures over length scales < 100m. A Perquisite for design, performance and associated model prediction and evaluation of the performed tests was a robust hydrostructural model. The breakthrough curves from performed tracer indicate that the longer and more complex source-sink set-ups show more profound indications of matrix diffusion, with near –3/2 slopes in log-log plots. It is also noted, as in the case of TRUE-1, that diffusion effects are augmented for the more sorbing tracers. Numerical modelling of the TRUE Block Scale experiments was performed with a wide range of approaches/concepts. The results indicate successful outcome of model predictions in relation to experimental data on a length scale < 15 m. The correspondence between the predicted and the *in situ* results are not as good for the two longer flow paths, 35 and 100 m, respectively.

1 Introduction and background

For the Operating Phase of the SKB Äspö Hard Rock Laboratory (HRL), the Swedish Nuclear Fuel and Waste Management Company (SKB) initiated the Tracer Retention Understanding Experiments (TRUE) with the objective to improve the understanding of radionuclide transport and retention processes in fractured crystalline rock. Overall objectives included enhancement of confidence in models for transport of sorbing radionuclides in performance assessment (PA), and to show that pertinent transport data can be obtained from site characterisation or field experiments, and that laboratory results can be related to retention parameters obtained *in situ*. A basic drive from PA has been to obtain *in situ* data on transport and retention of sorbing radionuclides at different length scales. In addition, the address of multiple scales which is embedded in

TRUE is relevant for taking the step from experimental scales to site scale (100–1000 m). The first test cycle of the Tracer Retention Understanding Experiments, TRUE-1, which recently has been concluded (Winberg et al., 2000/ and which is the focus of the present international seminar, focused on transport and retention in an interpreted single fracture in the detailed scale (<10 m). This scale can be seen to represent the environment experienced by released radionuclides in the immediate vicinity of a deposition borehole. The block scale can be regarded as the natural extension where transport from the near canister environment to the connecting network of fractures and structures on the 10–100 m length scale is addressed. Hence, the multi-party TRUE Block Scale project was initiated in 1996. The project is expected to be concluded towards the end of 2001.

2 Specific objectives and performance

In the TRUE Block Scale experiment /Winberg, 1997; Winberg ed., 2000/ the experiences from TRUE-1 have been transferred and tested on a larger length scale, and somewhat longer transport times. The specific objectives were 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.

The project is divided in five basic stages; Scoping, Preliminary Characterisation, Detailed Characterisation, Tracer Test and Evaluation /Reporting. After the series of characterisation and experimental stages /Winberg ed., 2000/, the TRUE Block Scale is presently in an evaluation and reporting stage and final reports are due early 2002.

3 Characterisation and hydrostructural models

During the course of the basic characterisation of the TRUE Block Scale Rock volume (200x300x150m) a total of 5 boreholes have been drilled from two levels in the laboratory. The geometry of these boreholes are to a large extent restricted by the location and geometry of existing underground works. The characterisation strategy employed has been an iterative one. This implies that each new borehole position and geometry is the result of preceding borehole characterisation and core logging. The data have subsequently been used in the updating of the existing hydrostructural model and numerical model analysis based on the model. The results have subsequently formed the platform for decision as to the need for a new borehole and its geometry /Andersson et al., in prep I/. This approach differs from that employed during the First TRUE Stage where the complete borehole array of 4 boreholes was drilled in close sequence. Only temporary multi-packer systems were used to collect pressure responses in this case.

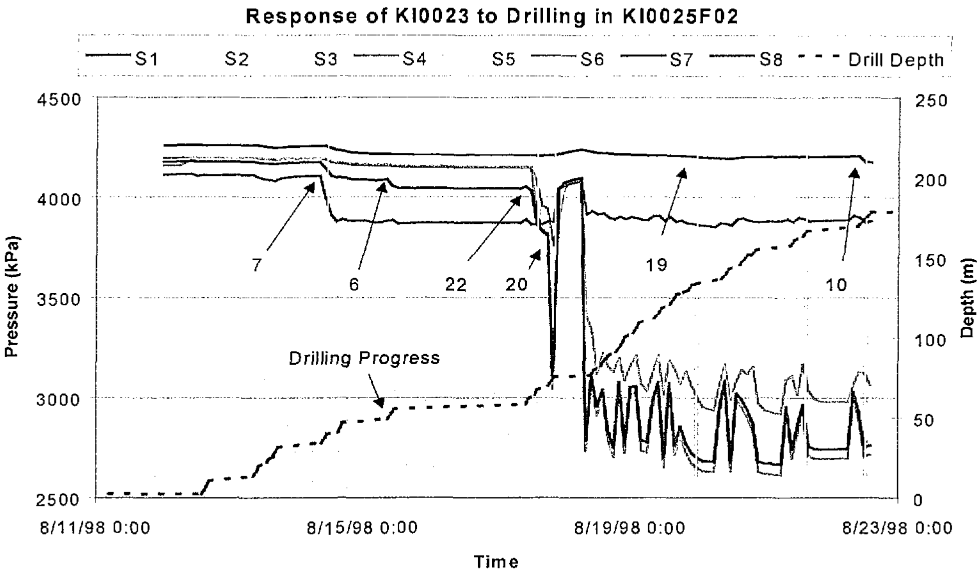

Figure 3c-22. *Pressure responses in the packed off borehole KI0023B to drilling of borehole KI0025F02. Dashed line indicates drilling progress as a function of time.*

Over the duration of the TRUE programme, successive refinements and modifications of the characterisation and experimental methodology have been made, but overall the important components in the basic characterisation remain the same. It was identified already during the First TRUE Stage that the basis for successfully designing, performing, and evaluating *in situ* tracer tests over the length scales considered is a sound and robust hydrostructural model complemented by a good hydraulic understanding of the studied system. In building the TRUE Block Scale hydrostructural models, the key elements have been integration of cross-hole pressure responses (collected during drilling and interference tests), cf. Figure 3c-22, and borehole TV imaging (BIPS), and results from high-resolution borehole flow-logging /Andersson et al., in prep./, cf. Figure 3c-23, the latter introduced during TRUE Block Scale. The most recent hydrostructural model is shown in Figure 3c-24 /Hermanson and Doe, 2000/. It has been identified that the important structures of the most recent hydrostructural model were identified during the first three boreholes. The additional two boreholes served to refine the model and to contribute additional source sections for tracer experiments. Fractures which could not be assigned to deterministic structures/fractures interpreted to extend between multiple boreholes were assigned to a stochastic background fracture population. The material properties, e.g. in terms of transmissivity, have been obtained through various types of single hole and cross-hole hydraulic tests /Winberg ed., 2000/. Hydraulic boundary conditions have been inferred either from larger scale numerical models or from measurements of hydraulic head in packed-off borehole sections.

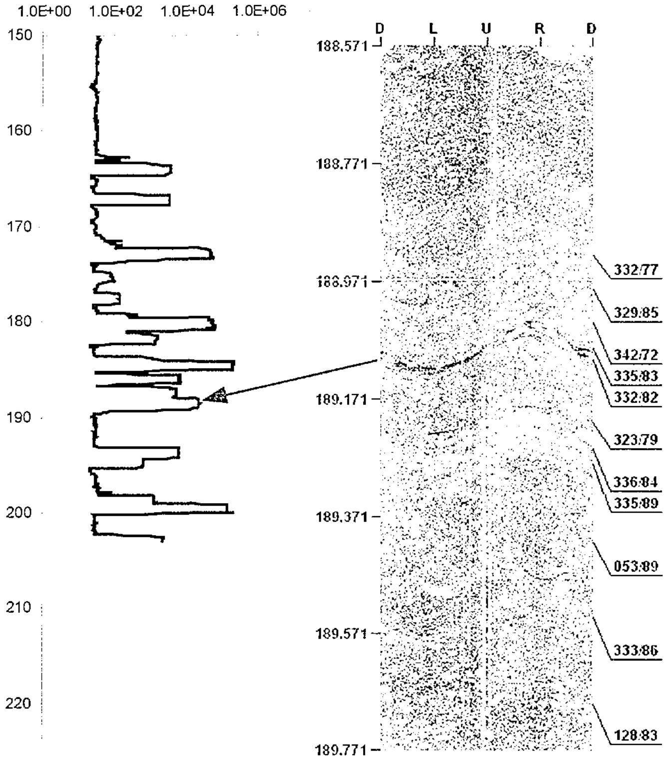

Figure 2-3B The last 75 m (150 – 225 m) of the POSIVA flow log of KI0025F02 with an example of a correlation with the BIPS image of a fault at 189 m depth.

Figure3c-23. *Posiva flow log (left) and corresponding BIPS log. Note that the length scales of the two images are not the same.*

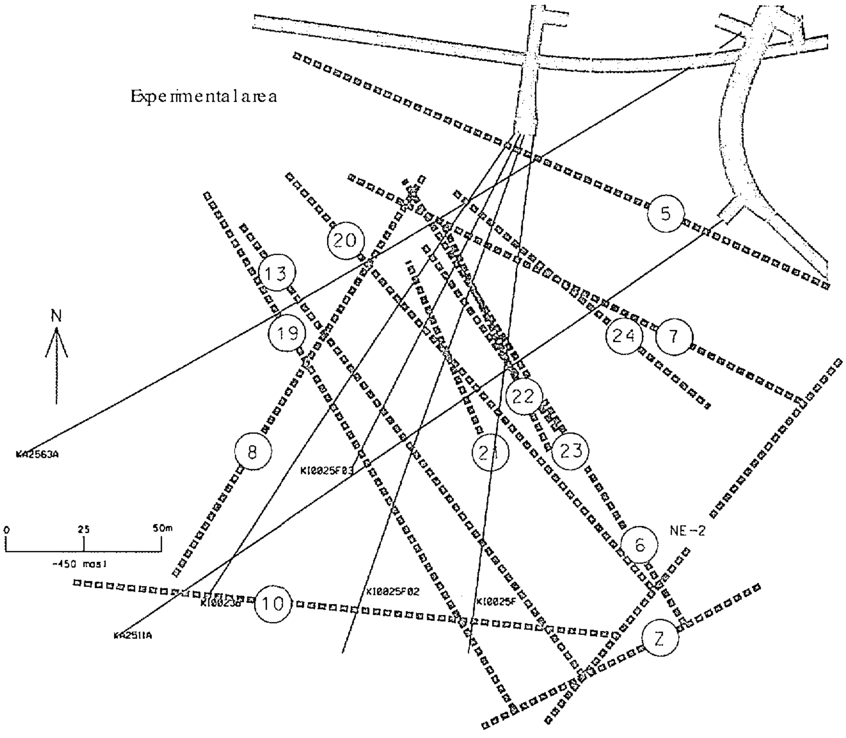

Figure3c-24. *TRUE Block Scale hydrostructural model (March 2000).*

4 Hypotheses to be tested

Before the onset of the tracer tests programme a number of questions were posed;

Q1) "What is the conductive geometry of the defined target volume for tracer tests within the TRUE Block Scale rock volume? Does the most recent structural model reflect this geometry with sufficient accuracy to allow design and interpretation of the planned tracer tests?"

Q2) "What are the properties of fractures and fracture zones that control transport in fracture networks?"

Q3) "Is there a discriminating difference between breakthrough of sorbing tracers in a detailed scale single fracture, as opposed to that observed in a fracture network in the block scale?" Based on the defined questions a number of hypotheses were posed to be addressed by the *in situ* experiments;

H1) "The major conducting structures of the target volume for tracer tests in the TRUE Block Scale rock volume trend northwest and are subvertical. Being subvertical, and subparallel, they do not form a conductive network in the designated target volume. For the purpose of testing fracture network flow and transport effects in the current borehole array, second-order NNW features are required to provide the necessary connectivity between the major conducting NW structures!"

H2a) "Fracture intersections have distinctive properties and have a measurable influence on transport in fracture/feature networks. These distinctive properties may make the intersection a preferential conductor, a barrier, or a combination of both!"

H2b) "In-plane heterogeneity and anisotropy have a measurable influence on transport of solutes in a block scale fracture network!"

H3) "It is not possible to discriminate between breakthrough curves of sorbing tracers in a single fracture from those obtained in a network of fractures"!

It was identified that the available borehole array and its position in relation to the hydrostructural model only would allow partial address of the role of fracture intersection zones (FIZ). Success expectancy in relation to Hypothesis 2 should therefore be limited already at the onset of the *in situ* tests. It is however expected that comparison between breakthrough curves from source-sink pairs in individual structures with those collected in fracture networks will provide an indication on the role of the FIZs.

5 Tracer tests

Tracer tests in the block scale were conducted already as part of the Preliminary Characterisation stage and clearly showed the prospect of performing tracer tests in a network over a length scale of 15 m. This finding was further augmented during the Detailed Characterisation Stage when a series of four injections of conservative dye tracers were made over variable source-sink distances and complexity (in terms of

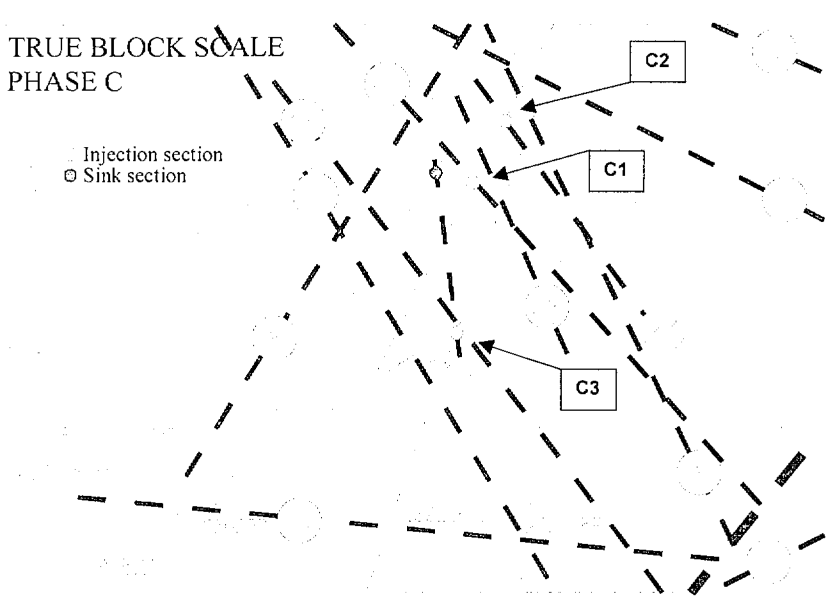

Figure 3c-25. Detail of Tracer Test area.

number of structures involved). The results of these tests clearly demonstrated feasibility to carry out tracer tests with high mass recovery in block scale fracture networks. A tracer test area was possible to delineate including Structures #20, #13 and #21–#23, cf. Figures 3c-24 and 3c-25, where Structure #20 constitutes the main conductive structure in the studied area.

With the available block scale and TRUE-1 results in hand the basic issues for the subsequent tracer tests were defined. These questions were used to pose hypotheses to be addressed by the tests, cf. Section 3. The Tracer Test Stage is divided into three defined phases; Phase A where the best suited sink location, section KI0023B:P6 (Structure #20), was selected and an elaborate programme of tracer dilution tests at ambient and pumped conditions were carried out /Andersson et al., 2000a/. The combined anomalies from pressure interference and tracer dilution tests were used to select the most suitable injection points for tracer. During Phase A the tracer tests were not driven to maximum mass recovery. Hence a Phase B /Andersson et al., 2000b/ was carried out with conconservative tracers to identify those source-sink pairs which provided a recovery > 80%, the latter defined as the lower limit for tests with radioactive sorbing tracers. Figure 3c-26 compiles breakthrough curves from tests performed with conservative tracers. It is evident from the figure that for longer transport times (longer distances, more complexity/heterogeneity) the late time log-log slope shows more distinct evidence of effects of matrix diffusion (slope ~ -3/2). Phase B also included tests with dissolved He-3 gas employing two different flow rates. The results compared to a reference conservative dye tracer showed a marked retardation for the more diffusive He tracer compared to the conservative dye, interpreted as a manifestation of diffusion /Andersson et al., 2000b; Andersson et al., in prep. II/, cf. Figure 3c-27. Subsequently, a Phase C with four different tracer injections in three source-sink pairs were carried out at maximum possible flow rate, 2.1 l/min, in the selected sink section /Andersson et al., in prep./. The source sections employed and tracers used are listed in Table 3c-2. The location of the different sections are shown in plane view Figure 3c-25. A compilation of the *in situ* breakthrough curves from injections C1 and C4 are presented in Figure 3c-28.

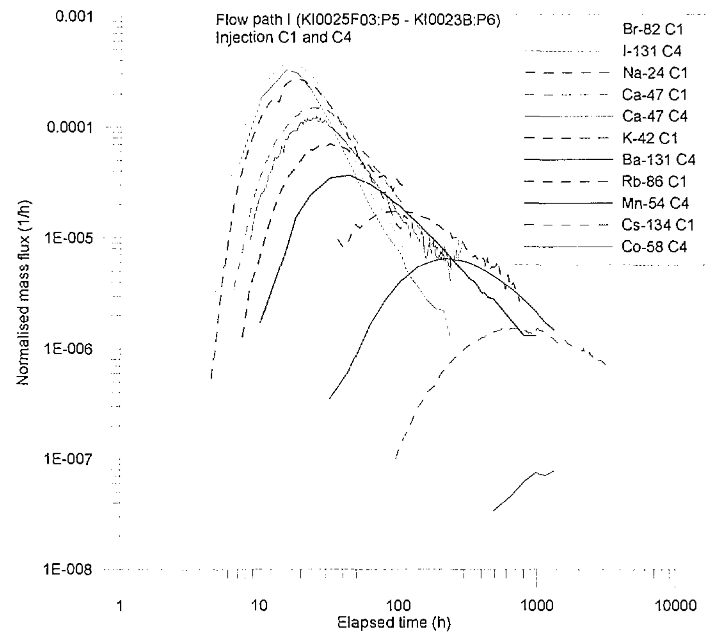

Figure3c-26. Family of conservative breakthrough curves from different tracer test campaigns.

Table 3c-2. Performance of Phase C tracer tests (C1 through C-4) /Andersson et al., in prep./. The structural notation and interpretation refers to the March 2000 model /Hermanson and Doe, 2000/. Distances within brackets are calculated along the structures.

Test #	Source-Sink pairs	Structures	Flow geometry	Inj. Flow (ml/min)	Pump flow (ml/min)	Tracers used	Distance (m)
C-1	KI0025F03:P5 – KI0023B:P6	20, 21	Forced injection	45	1950	$^{82}\mathrm{Br}^{-}$, $^{24}\mathrm{Na}^{+}$, $^{42}\mathrm{K}^{+}$, $^{47}\mathrm{Ca}^{2+}$, $^{86}\mathrm{Rb}^{+}$, $^{134}\mathrm{Cs}^{+}$, Uranine	14 (16)
C-2	KI0025F03:P7 – KI0023B:P6	23, 20, 21	Forced injection	10	1950	$^{186}\mathrm{ReO}_4^{-}$, $^{47}\mathrm{Ca}^{2+}$, $^{131}\mathrm{Ba}^{2+}$, $^{137}\mathrm{Cs}^{+}$ Naphtionate	17 (97)
C-3	KI0025F02:P3 – KI0023B:P6	21	Passive injection	1.8	1950	HTO, $^{22}\mathrm{Na}^{+}$, $^{85}\mathrm{Sr}^{2+}$, $^{83}\mathrm{Rb}^{+}$, $^{133}\mathrm{Ba}^{2+}$	33 (33)
C-4	KI0025F03:P5 – KI0023B:P6	20, 21	Forced injection	45	1950	$^{82}\mathrm{Br}^{-}$, $^{131}\mathrm{I}^{-}$, $^{47}\mathrm{Ca}^{2+}$, $^{131}\mathrm{Ba}^{2+}$, $^{54}\mathrm{Mn}^{2+}$, $^{57}\mathrm{Co}^{2+}$, $^{65}\mathrm{Zn}^{2+}$	14 (16)

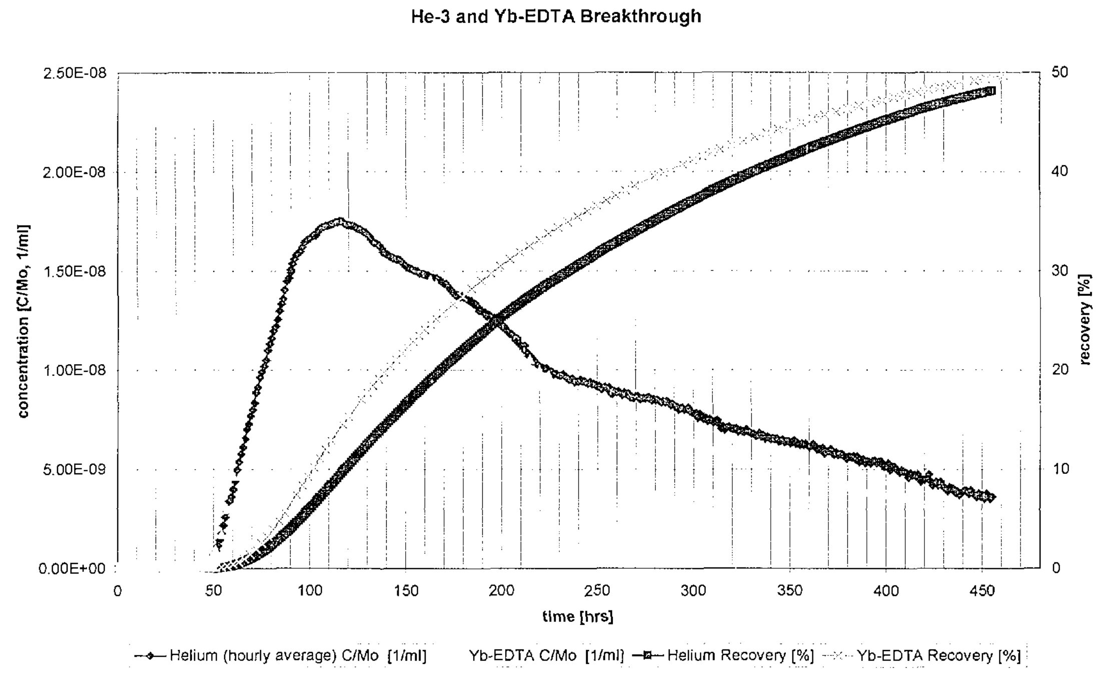

Figure 3c-27. He-3 and Yb-EDTA breakthrough curves (linear scales), Test B-2a.

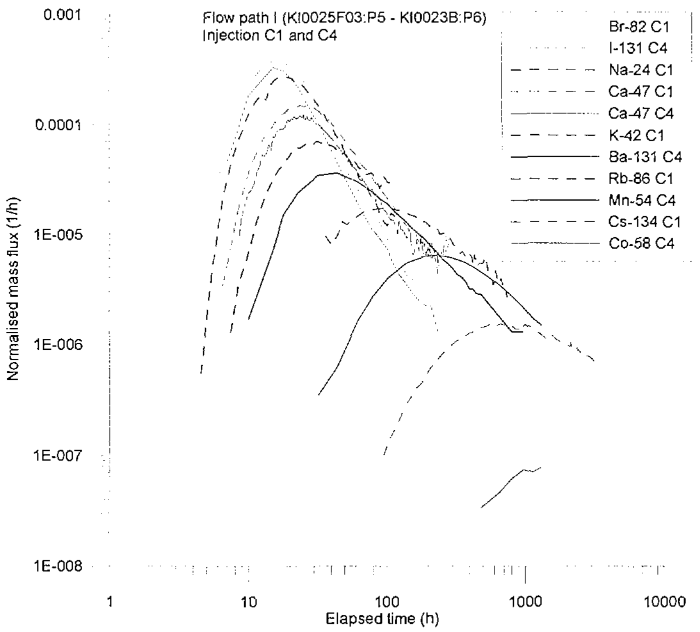

Figure 3c-28. Collection of breakthrough curves for radioactive sorbing tracers for injections C1 and C4 in source-sink pair I (L=16 m).

6 Laboratory investigations

A comprehensive mineralogical and geochemical analysis programme has been carried out on geological material from the borehole intercepts with structures involved in the tracer tests. Structures # 20 and #22 are interpreted as major geological structures with cataclasite and mylonite and also include fault breccia. Calcite and pyrite have grown on fracture surfaces and on breccia pieces in these structures. Clay mineralogy combined with stable isotope analyses indicate that the fractures in the two structures are hydrothermal in origin and have been conductive during long periods of time, or during repeated events/periods.

No specific laboratory investigations in terms of batch sorption and through-diffusion experiments have been performed on site-specific material from the structures involved in the TRUE Block Scale tracer experiments. Instead results from generic and site-specific material from Feature A (TRUE-1) /Byegård et al., 1998; Byegård et al., 2001/ which resembles Structures #20 and #22 and have been imported and used. These data include sorption experiments conducted on different size fractions and, likewise, through-diffusion measurements made on variable sample thicknesses, 1–4 cm /Byegård et al., 1998/. In the case of TRUE Block Scale, where fault breccia has been collected from relevant structures, K_d values for breccia material fractions have been evaluated from cation-exchange capacities estimated from the mineralogy in combination with the ambient hydrogeochemistry /Andersson et al., in prep. I/. Additional laboratory work includes measurement of porosity and porosity distributions using water saturation and impregnation of rock samples with ^{14}C-labelled polymethylmethacrylate (^{14}C-PMMA) /Siitari-Kauppi et al., 1998/.

7 Conceptual models of conductive fractures

Fractures at Äspö have typically been subject to variable amounts of tectonisation (indicated by the occurrence of cataclasites and/or mylonites) and variable degrees of chemical alteration (alteration of biotite to chlorite, saussuritisation of plagioclase, oxidation of magnetite to hematite, etc.). Almost all studied structures/fractures show alteration and tectonisation of the wall rock, and most intercepts follow mylonites.

Conceptual model development for fractures and their immediate surroundings has been concentrated to fractures exposed in tunnel openings and on the ground surface /Mazurek et al., 1997/, to the Feature A studied in TRUE-1 /Winberg et al., 2000/, and the structures involved in the tests with sorbing tracers in TRUE Block Scale /Andersson et al., in prep. I/. Some of the latter structures are comparable to Feature A, although they are slightly more complex, more transmissive, and wider. PMMA studies performed on Feature A material indicate a porosity of about 1–2% in the rim zone close to the fracture surface (locally the porosity is much higher) and a sharp gradient towards the interior where the porosity is about one order of magnitude lower some 1–2 cm from the surface of Feature A /Byegård et al., 2001/. A high porosity gradient and an increased pore connectivity near fracture surfaces may result in markedly increased

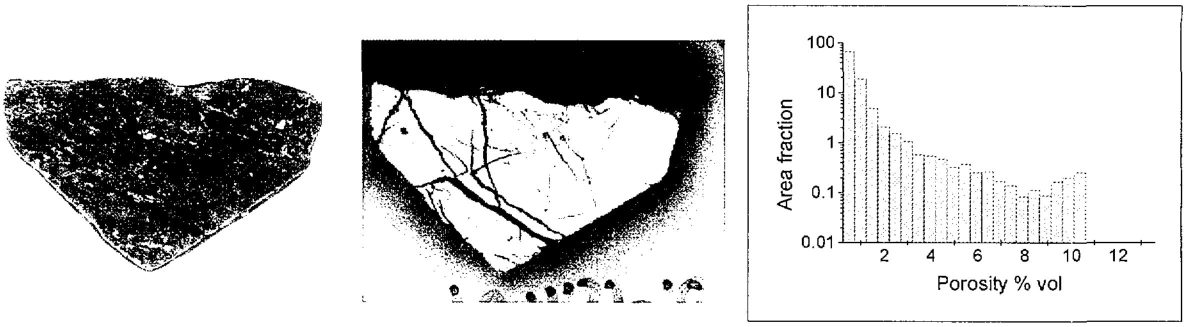

Figure 3c-29. TRUE Block Scale: Composite showing a cut surface of a cm sized PMMA impregnated fault breccia piece, the associated autoradiograph and the a histogram accounting for the area distribution of porosity. The total porosity assessed from the exposed surface is 0.8% /Andersson et al., in prep. I/.

diffusivity and sorption capacity compared to intact rock away from the fracture surfaces /Byegård et al., 2001/. Fault breccia has been recovered from some structures in the TRUE Block Scale studies. PMMA analyses performed on fault breccia pieces (1–3 cm) and fault breccia fragments (1–2 mm) show porosities in the order of 0.4–0.8% (with small areas with highs of about 10%), cf. Figure 3c-29, and 1.3–11%, respectively /Andersson et al., in prep. I/. In general, the porosity constitutes micro-fractures and porous mineral phases (secondary or altered minerals).

8 Numerical modelling

Although numerical modelling has been part of each update of the hydrostructural model it is only following the most recent model updates that numerical modelling has been employed more extensively, and employing different model concepts. The block scale tracer tests are presently subject to evaluation using five different model approaches which include stochastic continuum, discrete feature network, cannel

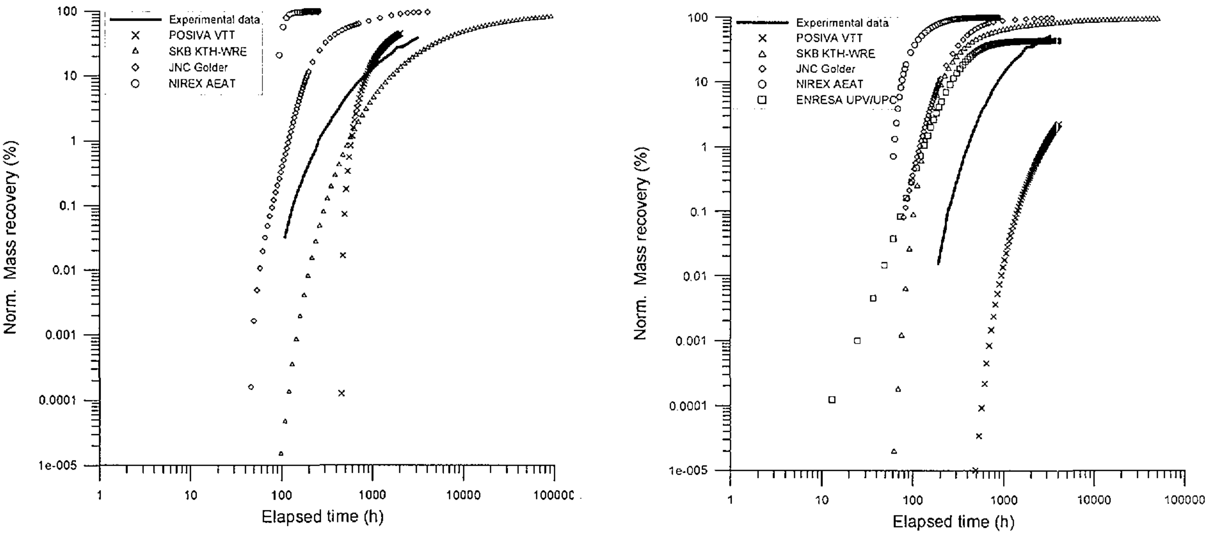

***Figure3c-30.** TRUE Block Scale Phase C : Comparison between predicted cumulative normalised mass recovery (%) and the corresponding experimental break-through. a) C1 (^{137}Cs), b) C3 (^{86}Sr), cf. Figure 3c-25.*

network and two approaches which are more performanec assessment-related; the LaSAR approach /Cvetkovic et al., 1999; Cvetkovic et al., 2000/ extended to the block scale and the so-called POSIVA approach /Hautojärvi and Taivassalo, 1994/. The ability to make reasonable predictions on a 15-m length scale was demonstrated when some of the models used in TRUE-1 were applied to the shortest (L=17 m) and least complex of the block scale source-sink pairs, cf. Figure 3c-30a. In the case of a longer (L=35 m) and more complex source-sink pair the models performed less well, cf. Figure 3c-30b.

9 Retention in the block scale

The results of the TRUE-1 *in situ* experiments /Winberg et al., 2000/ showed that radioactive sorbing tracers of the alkali and alkaline metal groups (for which ion exchange is the main sorption mechanism), Na, Ca, and Sr were transported only slightly retarded compared to the reference conservative tracers over transport distances of about 5 m, whereas Rb and Ba were moderately retarded, and Cs and Co were strongly retarded. A similar relative order of retention was also noted in the laboratory /Byegård et al., 1998/. In TRUE Block Scale, a similar pattern emerges for a single-structure flow path over a length scale of about 15 m (C1). However, no breakthroughs of ^{83}Rb (C3) and ^{137}Cs (C2), cf. Table 3c-2, have been observed after some six months of pumping for the two longer and more complex TRUE Block Scale flow paths, 35 and 100 m long, respectively, cf. Figure 3c-25. This in contrast to performed model predictions which overall project breakthrough for the two tracers. Continued sampling and employment of developed techniques to lower the measurement limit are expected to reveal whether the above observations in fact are true indications of a more pronounced retention on a larger scale. Possible explanations for the observed higher retention may arise from differences in mineralogy, more pronounced effects of fault breccia compared to conditions prevailing in Feature A at the TRUE-1 site, or a higher degree of heterogeneity.

10 Conclusions

The analysis of the characterisation data from the TRUE Block Scale rock volume has shown that it is possible to build relatively robust hydrostructural models of a rock volume on a 300 m length scale using a few and relatively unsophisticated characterisation techniques. These comprise registration of pressure responses collected during drilling and subsequent cross-hole interference tests, borehole TV (BIPS) and so-called POSIVA high resolution flow logging. It was found that the basic hydrostructural entities of the investigated rock block were identified using data from the first three boreholes. The additional two boreholes contributed additional geometrical refinement and identification of conductive structures of second order importance. Further refinement and parameterisation of the model have been achieved using various single hole and multiple hole cross-hole interference tests. The latter tests in many cases included tracer dilution tests. By comparing results of tracer dilution tests (in terms of flow rate) at pumped conditions with the corresponding values obtained at ambient conditions proved to be an effective means to identify suitable tracer injection sections for any given sink.

The TRUE Block Scale tracer experiments have successfully demonstrated the possibility to run well-controlled, quantitative experiments with radioactive sorbing tracers in interpreted single structures and networks of deterministic fractures/structures over length scales < 100m. Perquisites for design, performance and associated model prediction and evaluation of the performed tests is a robust hydrostructural model of the investigated network of structures.

The breakthrough curves from performed tracer experiments with conservative tracers in short (spatially and temporally) single feature sink-source setups are essentially devoid of indications of effects of diffusion. In contrast, the longer and more complex source-sink set-ups show more profound indications, with near –3/2 slopes in log-log plots. It is also noted, as in the case of TRUE-1, that diffusion effects are augmented for the more sorbing tracers.

Numerical modelling of the TRUE Block Scale experiments has been performed with a wide range of approaches/concepts ranging from analytical models, stochastic continuum, discrete fracture network and channel network models, to more performance assessment type model approaches. The results indicate successful outcome of model predictions in relation to experimental data on a length scale < 15 m. The correspondence between the predicted and the *in situ* results are not as good for the two longer flow paths, 35 and 100 m, respectively. The ongoing evaluation of the TRUE Block Scale experiments is expected to help assess the relative role of different retention processes and available pore spaces and increase the predictive capability on a 100 m length scale.

11 Acknowledgements

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12 References

Andersson P, Ludvigsson J-E, Wass E, Holmqvist M, 2000a. Interference tests, dilution tests and tracer tests (Phase A). Äspö Hard Rock Laboratory, International Progress Report IPR-00-28, Swedish Nuclear Fuel and Waste Management Co.

Andersson P, Wass E, Homqvist M, Fierz T, 2000b. Tracer tests, Phase B. Äspö Hard Rock Laboratory, International Progress report IPR-00-29, Swedish Nuclear Fuel and Waste Management Co.

Andersson et al. in prep I. TRUE Block Scale Project Final Report no. 1(4) – Characterisation and model development. SKB TR-XX-XX, Swedish Nuclear Fuel and Waste Management Co.

Andersson et al. in prep. II. TRUE Block Scale Project Final Report no. 2(4) – Tracer tests in the block scale. SKB TR-XX-XX, Swedish Nuclear Fuel and Waste Management Co.

Andersson P, Byegård J, Holmqvist M, Skålberg M, Wass E, Widestrand H, in prep. Tracer tests, Phase C. Äspö Hard Rock Laboratory, International Progress Report IPR-01-XX, Swedish Nuclear Fuel and Waste Management Co.

Cvetkovic V, Selroos J-O, Cheng H, 1999. Transport of reactive solute in single fractures. J. Fluid Mech., Vol. 318, pp. 335–356.

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

Byegård B, Johansson H, Skålberg M, Tullborg E L, 1998. The interaction of sorbing and non-sorbing tracers with different Äspö rock types – Sorption and diffusion experiments in the laboratory scale. SKB TR-98-18, Swedish Nuclear Fuel and Waste Management Co.

Byegård J, Widestrand H, Skålberg M, Tullborg E-L, Siitari-Kauppi M, 2001. Complementary investigation of diffusivity, porosity and sorbtivity of Feature A site-specific material. Äspö Hard Rock Laboratory, International Cooperation Report ICR-01-04, Swedish Nuclear Fuel and Waste Management Co.

Hermanson J, Doe T D, 2000. March'00 structural and hydraulic model based on borehole data from KI0025F03. Äspö Hard Rock Laboratory, International Progress Report IPR-00-34, Swedish Nuclear Fuel and Waste Management Co.

Hautojärvi A, Taivassalo V, 1994. The INTRAVAL Project – Analysis of the Tracer Experiments at Finnsjön by the VTT/TVO Project Team. Report YJT-94-24, Nuclear Waste Commission of Finnish Power Companies, December 1994, Helsinki.

Mazurek M, Bossart P, Eliasson T, 1997. Classification and characterisation of water-conducting features at Äspö: Results of investigations on the outcrop scale. Äspö Hard Rock Laboratory, International Cooperation Report ICR-97-01, Swedish Nuclear Fuel and Waste Management Co.

Siitari-Kauppi M, Flitsiyan E S, Klobes P, Meyer K, Hellmuth K-H, 1998. Progress in physical rock matrix characterization; Structure of the pore space. In : I G McKinley and C McCombie (eds) : Scientific Basis for Nuclear Waste Management XXI, Mat. Res. Soc. Symp. Proc., Vol. 506, pp. 671–678.

Winberg A, 1997. Test plan for the TRUE Block Scale experiment. Äspö Hard Rock Laboratory, International Cooperation Report ICR 97-02, Swedish Nuclear Fuel and Waste Management Co.

Winberg A, Andersson P, Hermanson J, Byegård J, Cvetkovic V, Birgersson L, 2000. Final report of the first stage of the Tracer Retention Understanding Experiments. SKB TR-00-07, ISSN 1404-0344, Swedish Nuclear Fuel and Waste Management Co.

Winberg A ed., 2000. Final report of the detailed characterisation stage – Compilation of premises and outline of programme for tracer tests in the block scale. Äspö Hard Rock Laboratory, International Cooperation Report ICR-00-02, Swedish Nuclear Fuel and Waste Management Co.