

TECHNISCHER BERICHT 81-10

Stripa Project

Migration in a single fracture
Preliminary experiments in Stripa

Harald Abelin
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Royal Institute of Technology, Department of Chemical
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Das Stripa-Projekt ist ein Projekt der Nuklearagentur der OECD. Unter internationaler Beteiligung werden von 1980-84 Forschungsarbeiten in einem unterirdischen Felslabor in Schweden durchgeführt. Diese sollen die Kenntnisse auf folgenden Gebieten erweitern:

- hydrogeologische und geochemische Messungen in Bohrlöchern
- Ausbreitung des Grundwassers und Transport von Radionukliden durch Klüfte im Gestein
- Chemische Zusammensetzung des Grundwassers in grosser Tiefe
- Verhalten von Materialien, welche zur Abdichtung von Endlagern eingesetzt werden sollen

Seitens der Schweiz beteiligt sich die Nagra an diesen Untersuchungen.

The Stripa Project is organized as an autonomous project of the Nuclear Energy Agency of the OECD. In the period from 1980-84 an international cooperative programme of investigations is being carried out in an underground rock laboratory in Sweden. The aim of the work is to improve our knowledge in the following areas:

- hydrogeological and geochemical measurement methods in boreholes
- flow of groundwater and transport of radionuclides in fissured rock
- geochemistry of groundwater at great depths
- behaviour of backfill material in a real geological environment

Switzerland is represented in the Stripa Project by Nagra.

Le projet Stripa est un projet autonome de l'Agence pour l'Energie Nucléaire de l'OCDE. Il s'agit d'un programme de recherche avec participation internationale qui sera effectué entre 1980 et 1984 dans un laboratoire souterrain en Suède. Le but de ces travaux est d'améliorer et d'étendre les connaissances dans les domaines suivants:

- mesures hydrogéologiques et géochimiques dans les trous de forage
- écoulement des eaux souterraines et transport des radionucléides dans les roches fracturées
- chimie des eaux souterraines à grande profondeur
- comportement dans un environnement réel des matériaux de bourrage pour dépôts de déchets radioactifs

La Suisse est représentée dans le projet Stripa par la Cédra.

STRIPA PROJECT

81-03

Migration in a single fracture. Preliminary experiments in Stripa

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Engineering, Stockholm, Sweden.

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INTERNAL REPORT



An OECD/NEA International project managed by:
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MIGRATION IN A SINGLE FRACTURE,
PRELIMINARY EXPERIMENTS IN STRIPA

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April 1981

This report concerns a study which was conducted for the Stripa project. The conclusions and viewpoints presented in the report are those of the author(s) and do not necessarily coincide with those of the client.

A list of other reports published in this series is attached at the end of this report. Information on previous reports is available through SKBF/KBS.

SUMMARY

A method of tracer injection and of water collection to be used in the main investigation of "Migration in a single fissure" has been tested and found to function well. With this injection equipment it is possible to introduce tracers into the fissure as a step or a pulse. The injection can be done either under natural pressure or with over pressure.

The collection of water sampled can be done under anoxic atmosphere. Injection of Rhodamine-WT and Na-Fluorescein with over pressure has been performed.

It has been found that Rhodamine-WT is influenced in some way along the flow path. Rhodamine-WT thus cannot be used to characterize the water residence time without a knowledge of the interaction mechanisms.

Based on the experiences from this investigation the equipment and operation will be somewhat modified for use in the main investigation.

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1. BACKGROUND

The bedrock is one of the most important barriers of a final repository for radioactive waste. It limits the amount of water which can contact and leach the waste. If and when any radionuclides are leached from the waste, the majority of the important radionuclides will interact chemically or physically with the bedrock and will be considerably retarded. The interaction and the retardation depends on the velocity of the water, the sorption rates and equilibria of the reactions as well as the surface area of the rock in contact with the moving water.

Practically all studies on radionuclide migration in the bedrock are based upon the assumption that the flow can be described as porous media flow. This might be true for very large distances where the flow would encounter a multitude of channels and some averaging may be conceivable on the scale considered. However, no large scale tracer tests have been performed in fissured crystalline rock with known flow paths. Transport over short distances, i.e. in the near field of a canister, most probably occurs in individual fissures. On an intermediate scale where more than a few fissures conduct the flow, well type tracer tests alone cannot give the detailed information needed to understand dispersion and sorption phenomena in fissured rock.

It has therefore been decided to investigate flow and sorption in readily identifiable fissures which can be excavated for a detailed examination of flow paths and sorption sites.

2. PURPOSE

The study to be performed has the following main objectives:

- o To observe the movement of nonsorbing and sorbing tracers under controlled and well defined conditions in a real environment.
- o To interpret the movement of the tracers in such a way that the results become useful for the prediction of radionuclide migration.
- o To obtain a basis for comparing laboratory data on sorption with observations in a real environment.
- o To develop good techniques for small volume sampling of water and techniques for investigating fissure surfaces with sorbed tracers.
- o To gather experience with stable tracers before using radioactive tracers.

3. PROPOSED INVESTIGATION

The Stripa mine is excellently suited for performing tracer test in single fissures as well as in a network of interconnected fissures. The water constantly flows into the tunnels, and this natural movement can be utilized in the tracer tests. The water found in the Stripa bedrock is old and has a water chemistry which is in all major respects (pH, Eh, major ions) similar to the groundwaters to be expected in the Swedish bedrock.

Old waterbearing fissures have been found in and near the tunnels now in use. As the tunnels are well below the water table, the fissures have been conducting water for a very long time and thus are as well "equilibrated" as we can reasonably achieve in a sorption experiment.

4. LOCATING A SUITABLE FRACTURE

A suitable fracture is one that meets the following requirements:

- o High enough waterflow.
- o Plane.
- o The intersection with the drift should preferably be seen all the way round the drift.
- o There should be no other fracture in the close surroundings.

When a suitable fracture is found it is necessary to determine if the fracture continues for the distance to be used in the investigation. This can be done by drilling an injection hole which intersects the fracture at the expected distance, sealing off the inner parts of the hole with a packer and injecting a non sorbing tracer. Figure 1 shows some different kinds of fractures.

If no tracer is found the fracture is of either type C or D. By logging the drillcore it should be possible to determine which of the types, C or D it is. If tracer is found in other fractures

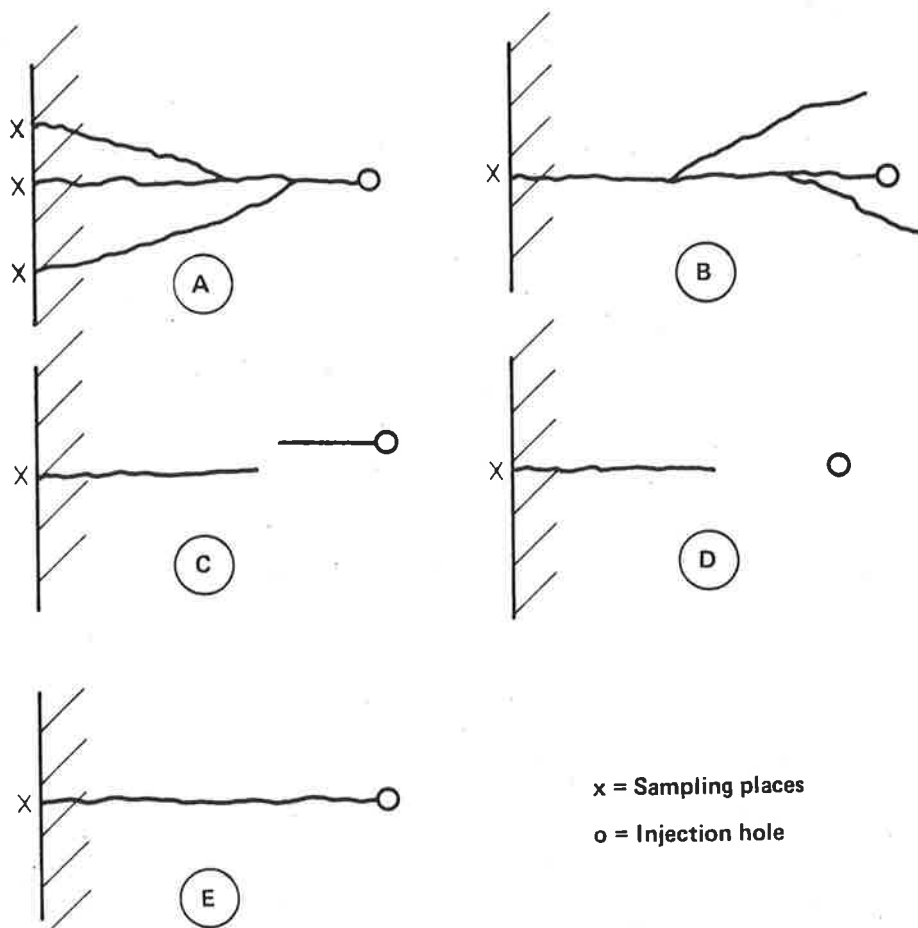
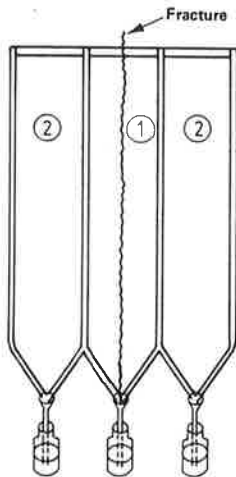


Figure 1. Different types of fractures.

beside the actual fracture it is an A type fracture. Both type B and E should carry tracer in the actual fracture. To determine if it is B or E is more difficult but a measurement of the waterflow from the injection hole and the fracture could give some indications of which type it is.

The area which has been investigated for a suitable fracture is the test site at the 360 m level in the Stripa mine. Due to good ventilation in the test area nearly all the water flowing out of the fractures evaporates, which makes them all look dry. To stop the evaporation the investigated fractures were sealed by a plastic film. See figure 2.



Water seeping out of the fracture was collected and measured. Plastic film could be glued on to both sides of the actual fracture to measure any water flow in the nearest surroundings of the fracture. During the measurements of the water-flows we noticed that some water leaked out under the plastic film wetting the surface around the plastic film. This leakage is probably caused by capillarity in the shallow blasting fractures.

Eight fractures have been investigated (see appendix 1). Four of the eight fractures had flowing water. The water-flow from the fractures varied with time. This could be due to the above mentioned leakage.

Figure 2. Fracture covered with plastic film. Some of the fractures which from the beginning seemed to carry water did not give any water when covered with plastic.

The water in the fracture was probably not coming out of the fracture but instead flowing along the fracture from a higher point.

One more suitable fracture was found. It is located in the ventilation drift, see figure 3. It was impossible to measure the waterflow there as this would have interfered with the other investigations going on there.

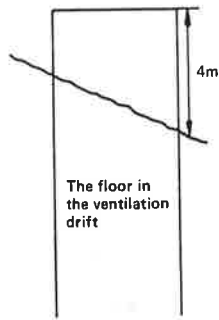


Figure 3. Fracture in ventilation drift.

For the preliminary investigation we chose to use the fracture named number 5. This fracture is located at the entrance of the Luleå drift. This fracture has the highest water-flow of the investigated fractures, 18 ml/h and m of fracture. This fracture is easily accessible for drilling of holes and injection, as well as collection of water. It has a disadvantage of not being seen all around the face of the drift.

For the actual investigation another fracture will be selected which fills all the requirements mentioned above earlier.

5. INJECTION AND SAMPLING TECHNIQUES

The technique used in this preliminary investigation is the same as that which will be used in the main investigation. When a suitable fracture has been found, an injection hole is drilled that intersects the fracture at a certain distance from the face of the drift. Sampling holes are drilled in the fracture plane, see figure 4. The natural water-flow is towards the drift. Tracers are introduced into the fracture from the injection hole either by injection with overpressure or by circulation under natural pressure. Groundwater and eventual tracers are collected in a series of sampling holes. By having a series of sampling holes the transverse dispersion of the tracers can be observed in addition to the axial dispersion.

5.1

Injection

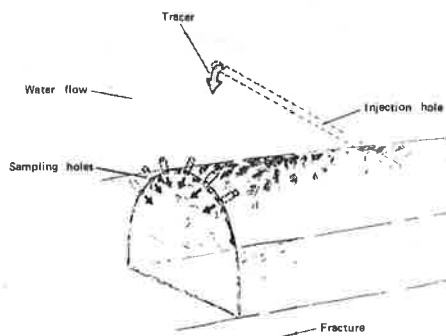


Figure 4. Drift with intersecting fracture.

The injection hole is sealed off just below the fracture with an inflatable packer, see figure 5. To minimize the volume sealed off by the packer, we use a dummy to fill out the space above the fracture. This dummy could be replaced by a mechanical packer. With the mechanical packer it is not only possible to fill out the space, it would also seal off the volume not in use and prevent any leakage into or out from the injection compartment.

The introduction of tracers in the fracture could be done in two different ways:

1. By circulating tracers in the injection compartment under natural pressure.
2. By injecting tracers with a certain amount of overpressure. The injected volume and the injection flow are measured.

The technique used in this preliminary investigation was injection with overpressure.

5.2 Sampling

Each sampling hole has a mechanical packer (see figure 5) with a funnel on top. It is possible to purge the sampling holes with nitrogen. The water from the sampling holes are collected with a fractional collector which can be kept under an anoxid atmosphere.

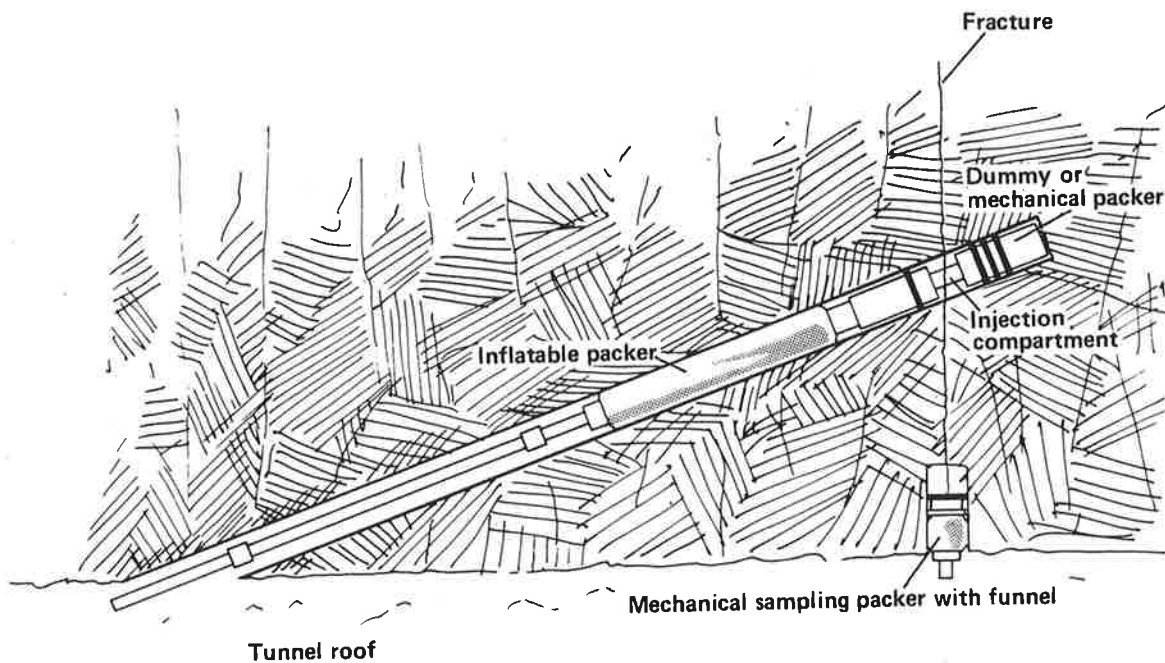


Figure 5. Injection and sampling techniques.

For a more detailed description of the equipment see under heading "Equipment".

6. DRILLING OF HOLES

The drilling was done by "Hålmeter AB", Stockholm. The method used was core drilling. A 9 m long injection hole with diam. 0.076 m and six 0.7 m long sampling holes diam 0.08 m were drilled, see figure 6. The time needed for this was two and a half weeks.

There were some problems in getting the sampling holes in the same plane as the fracture. When the new sampling holes are going to be drilled we will first use a drill with a smaller diameter to determine the direction of the fracture and when this is done the actual sampling holes will be drilled. The new sampling holes will be drilled deeper or closer to each other to minimize the effects of capillarity which occur in the shallow blasting fractures.

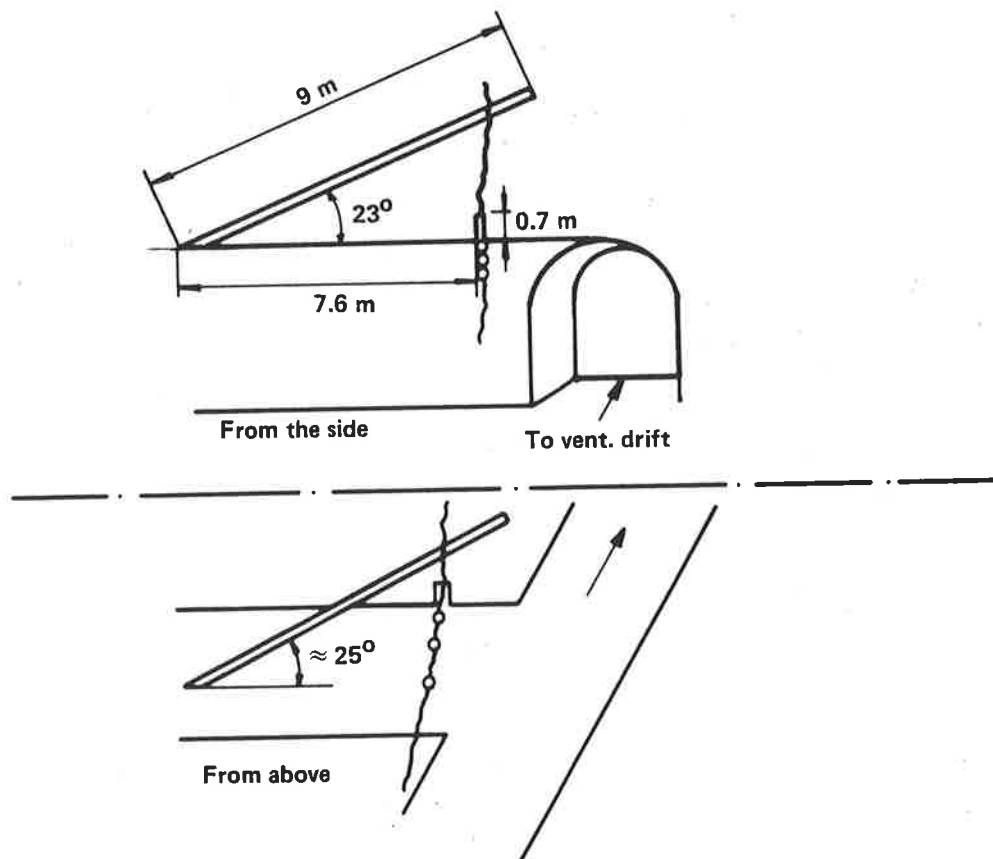


Figure 6. Drillings of sampling holes and injection hole.

7. EQUIPMENT

The equipment could be divided into three main parts.

- o Injection equipment (1).
- o Packer and sampling devices (2).
- o Fractional collector with anoxic box (3).

See figure 7 for installation of equipment at the test site.

The three main parts of the equipment are described below.

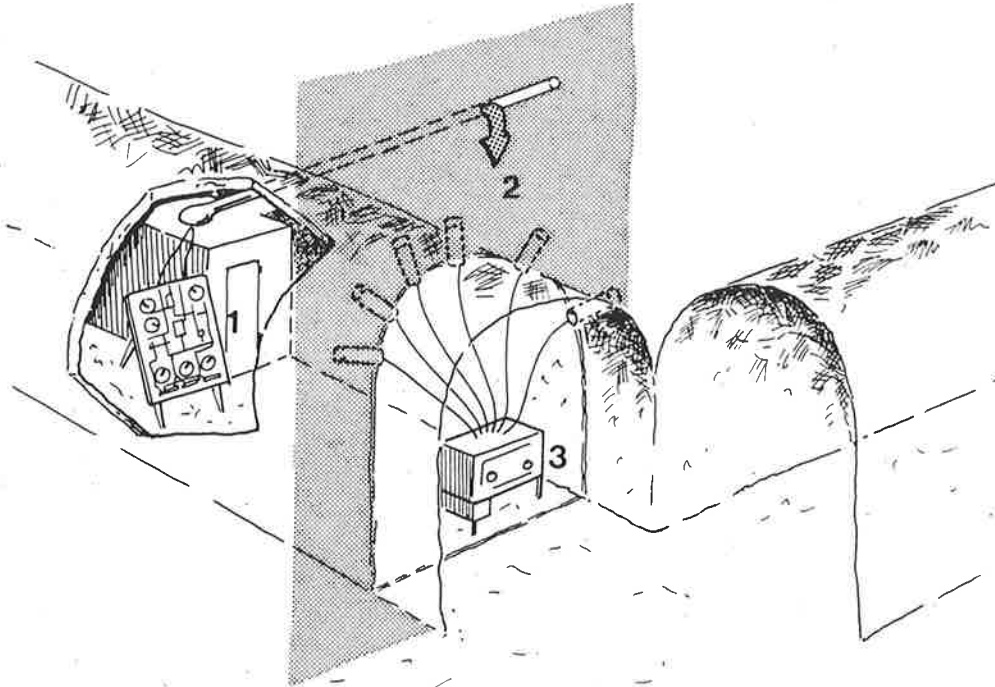


Figure 7. Test site at 360 m level.

7.1 Injection equipment

The main parts of the injection equipment are:

- o The pressure vessels and valves.
- o Circulation pump.
- o Nitrogen supply.

See figure 8.

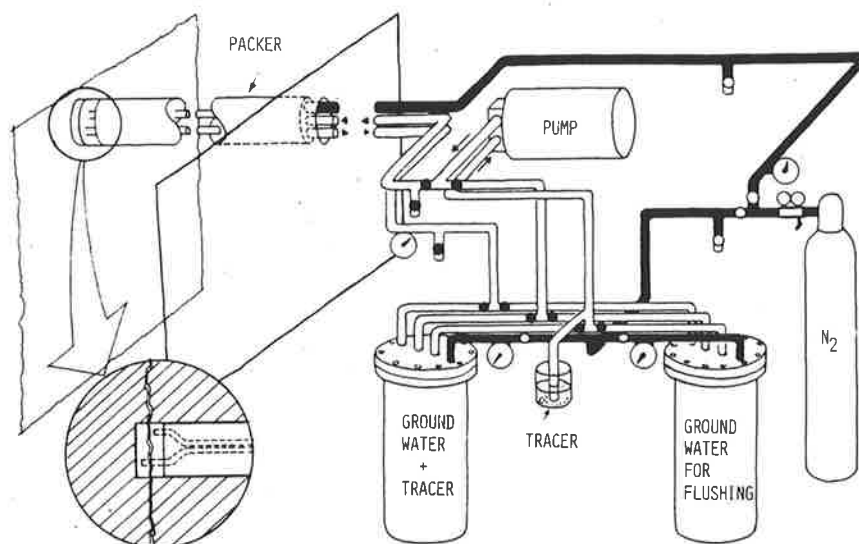


Figure 8. Injection equipment.

A detailed plan of the valves and tubing is given in appendix 2. With this equipment it is possible to make either step or pulse injection of tracers into the fracture, as well as seepage injection under natural pressure in the injection compartment. The overpressure used for injecting tracers is produced by nitrogen from a container. It is possible to measure the flowrate of tracer solution by means of a nylon tube where the length of tube emptied during a certain time gives the flowrate. By the use of a sufficiently long tube, the total volume of tracer solution injected can be measured. It is possible to connect and disconnect parts of the equipment without having to stop the running test.

The materials used in the equipment are:

- o Nylon tubing.
- o Valves and tubeconnectors of brass.
- o Pressure vessels of stainless steel.

7.2 Packer and sampling devices

The packer used to seal off the bottom of the injection hole is a Lynes Grouting packer, see figure 9. The upper part of the packer has been sealed off with a stainless steel plate edged with a sealing ring (1).

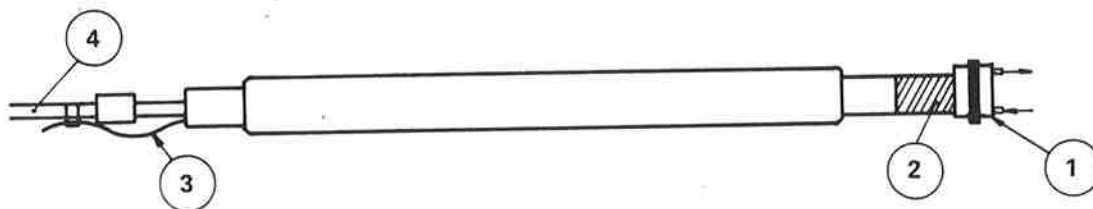


Figure 9. Packer used in injection hole.

The plate has one inlet and outlet for circulation of tracers. Because the packer ended with a tube about 0.15 m long we had to put on a dummy (2) to minimize the stagnant volume. The packer is inflated with nitrogen (3). It is put in place with the aid of an iron tubing (4) which contains the inlet and outlet tubing.

In the sampling holes mechanical packers were chosen, see figure 10. This packer is expanded by compressing the rubber sleeve at one end by means of a threaded plate. At the top of the packer there is a PVC funnel which collects the water coming into the sampling hole. There is also a gas inlet for purging the hole with nitrogen. The funnel has got a sealing ring to stop water from passing the funnel. The sealing ring also minimizes the stagnant water volume.

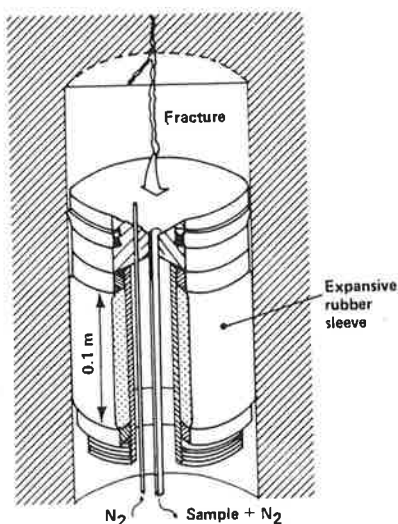


Figure 10. Sampling packer.

8. COLLECTING EQUIPMENT

From each of the sampling packer a nylon tube leads the water to the fractional collector. Each tube goes to a separate row of test tubes.

The fractional collector is enclosed in an anoxic box. The preliminary runs were made without an anoxic atmosphere.

The time intervall between collection of water samples can be varied from 1 min to 6 h, which allows time between change of a set of tubes from 48 min and up to 12 days.

A disadvantage with the fractional collector we used is that it is not possible to use test tubes of different sizes at the same time. With a water-flow rate varying with a factor 30 between the sampling holes we either

got overflow in some test tubes or did not get enough water for analysis in other tubes.

During the test runs in Stripa mine we noticed water coming out beside the sampling packers. This water was probably drawn past the packer by capillarity in the fracture (see figure 11).

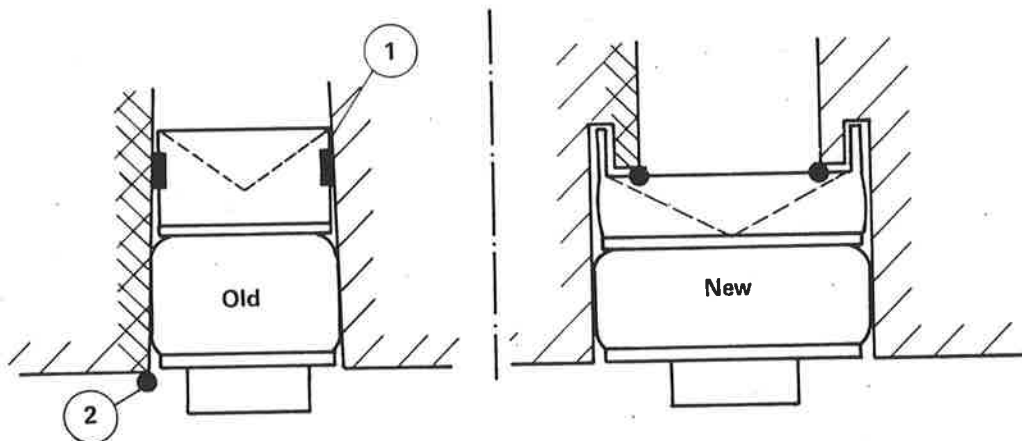


Figure 11. Modification of sampling packer.

We have decided to make a modification of the sampling packer. The old model has two disadvantages.

- o The first droplets containing tracer is diluted in the stagnant water volume between funnel and wall (1).
- o Water passes the packer by capillarity in the fracture (2).

With the new model of sampling devices we hope to decrease both these problems. The modified sampling devices will need holes drilled with two different diameters.

9. TRACERS

9.1 General

Stable tracers will be used throughout in the field experiments. Except for very few nuclides, notably Np, Pu, and Tc, all the objectives stated can be achieved with less effort. "Hot" experiments are run parallel in the laboratories in a supporting investigation. These latter experiments are funded by PRAV.

Four classes of tracers will be used:

- o Particles: Plastic pellets $\sim 0.4 \mu\text{m}$ are used to simulate the movement of particulate matter.

- o High molecular weight solutes: Blue Dextran M = 2 000 000 or Albumine is used to simulate the movement of high molecular weight organic nonsorbing matter.
- o Nonsorbing tracers: Various Rhodamines, Uranine, Br⁻ (I)
- o Sorbing tracers:

Cs	I
Sr (Ba)	II
Eu (Nd)	III
Th	IV
?	V
U	IV and VI

The nonsorbing and sorbing tracers by themselves or by similarity cover (valency and chemistry) all major radionuclides of interest except Np, Pu and Tc.

In the preliminary investigation only the following nonsorbing tracers were used: Chrome-EDTA, Na fluorescein, Rhodamine-WT.

We chose to use coloured dyes because of the possibility to detect them without any instruments. Later on we may use Br⁻ (I) as nonsorbing tracers. The concentration of tracers used in the injections correspond to an absorbance of about 70 for Na fluorescein, 60 for Rhodamine and 880 for Chrome-EDTA. The higher concentration of Chrome-EDTA was a mistake caused by malfunctioning analysis equipment.

9.2 Analysis

The quantitative analysis of the tracers was done with a spectrophotometer in the UV and visible light range. The detection levels of the different tracers were

Chrome-EDTA	0.5 ppm
Na-fluorescein	~ 2 ppm
Rhodamine-WT	~ A 1/400 000 of original concentration.

The samples with a high concentration of tracers were diluted up to a factor 100 before analysis.

Due to overlapping between the different tracer absorbances the result could not be read directly but had to be calculated from measurements at three wavelength.

The spectrophotometer was poorly tuned at the beginning of the analysis but was retuned when this was noticed. Analysis done on samples from 90 h after start of injection and forward has been done with a correctly tuned spectrophotometer. Due to this bad tuning we injected a too high concentration of chrome-EDTA which later on made the analysis of the other tracers more uncertain and difficult.

Another phenomena that was noticed was that the wavelength for maximum absorption changed with concentration. This happened both for Na-fluorescein and Chrome-EDTA, see figure 12.

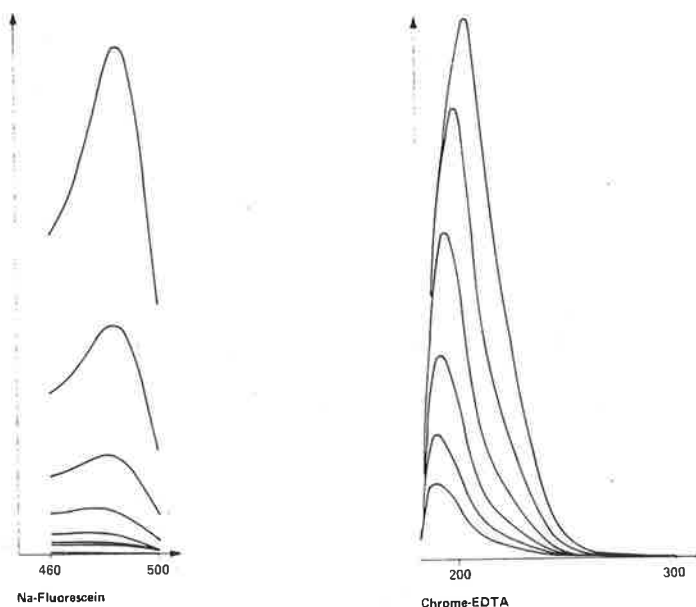


Figure 12. Change of maximum wavelength with different concentration.

9.3 Test of sorption and stability

All the analysis done during this test have been done with a poorly tuned spektrophotometer. The analysis of chrome-EDTA has been done with AA (Atomic Absorption) analysis on chrome.

To determinate if the tracers would sorb on granite, on the materials used in the equipment or by itself change its absorbance with time, laboratory tests were done.

Tracer and crushed granite, tracer and equipment materials and just tracer and water were put in separate E-flasks. This was done in an anoxic atmosphere. The flasks were shaken continuously. Samples were taken out for analysis.

Before analysis could be made on samples taken out from flasks containing granite they had to be centrifuged to remove small dispersed particles.

Out of the four tested tracers only Rhodamine-B seems to have a pronounced sorption. Even Rhodamine-WT seems to have a slight sorption. From these results we decided to use Chrome-EDTA, Na-fluorescein and Rhodamine-WT in the preliminary investigation.

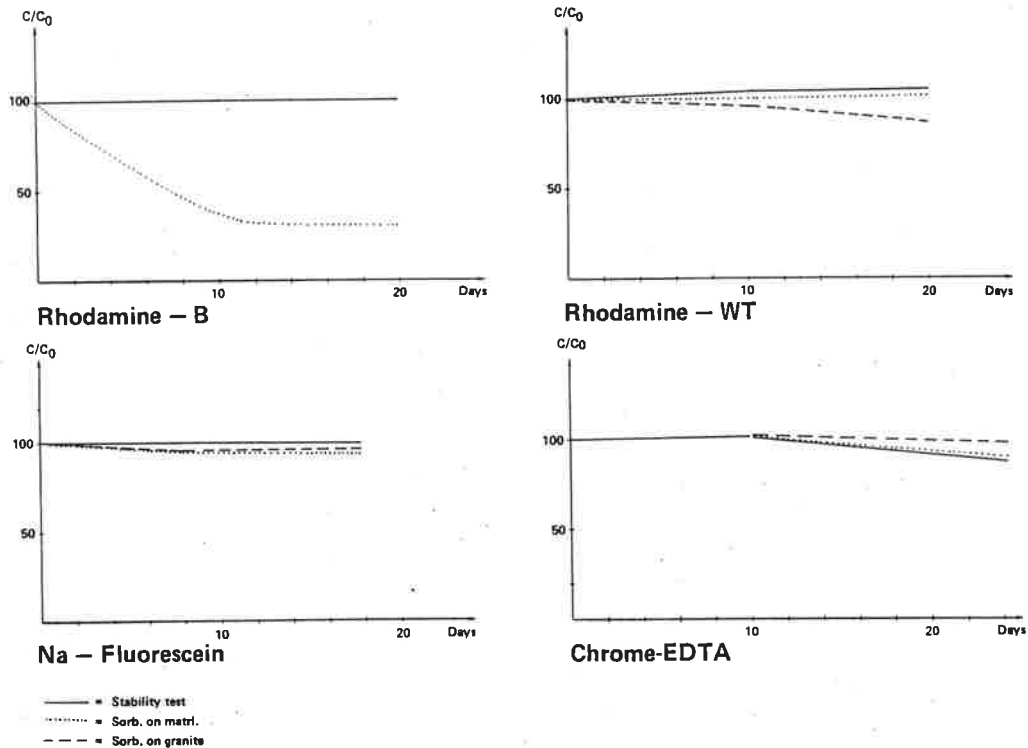


Diagram 1. Results from stability and sorption tests.

These results could be misleading due to the high concentration of tracer used. The materials or the crushed granite could become saturated with a decrease of tracers within the accuracy of the analysing method. *)

New sorbing tests will be performed with concentrations 100 times less than those used before. The analysis will be made by measuring changes in fluorescence.

10. EXPERIMENTAL

After drilling of the injection hole and sampling holes, the connection between the injection hole and the sampling holes was established. This was done by sealing off the injection hole with an inflatable packer and filling up the sealed off part with water containing tracers. The tracer used was Na-fluorescein. After a week the pressure in the injection hole was nearly stable. A tracer was injected out into the fissure by applying overpressure. It took less than 20 h for detectable amounts of the tracer to reach the sampling holes when the pressure was increased by 0.22 MPa in the injection hole. The tracer injection was continued to see if it would

*) The accuracy is about ± 0.1 .

arrive in all sampling holes. The tracer did eventually arrive in three of the six sampling holes. After this the packer was taken out of the injection hole. The hole was flushed with water and sealed off again.

To eliminate most of the gas in the injection hole the packer was installed in the following way.

1. The packer was put in its proper position and the the inner part of the injection hole was flushed with nitrogen.
2. The packer was pushed to the bottom of the injection hole expelling the nitrogen.
3. The packer was inflated with a low pressure and water was pumped in pressing the packer outwards to its proper position again.
4. At the proper position the packer was inflated with a high pressure.

As the dummy for reducing the sealed off volume was not fabricated in time we had to work with an injection compartment of 10 l instead of 0.3 l. Due to this it was impossible to flush the total volume properly with water or to inject tracers under well defined conditions.

An attempt was made to clean the fracture from tracer by injection of clean water. (All the water used in the experiments has been collected from the rock and kept under anoxic conditions.) After one week the injection of water was ended. There was then still tracer coming out of the sampling holes although at a low concentration. Rhodamine-WT was injected under the same overpressure as used before, 0.22 MPa. The duration of the injection was eight days. During this injection several breakdowns of the equipment occurred. No Rhodamine was detected in the water from the sampling holes until 10 days after the injection started. During Christmas holiday the fracture was once more flushed with clean water. This time for a period of 21 days but overpressure was used only the first days. After Christmas holiday the pressure in the injection hole had decreased to the stable level of 0.28 MPa. When we had the natural pressure in the injection hole we took the opportunity to test if it was possible to inject some tracer by just circulating it under natural pressure in the injection hole. For this test chrom-EDTA was used because there was still some Rhodamine and fluorescein in the fracture. After 72 h of circulation there was still no chrome-EDTA in the water from the sampling holes. It was then decided to inject Rhodamine-WT and Na-fluorescein simultaneously under overpressure. As an approximate time for the water residence time was known a suitable time intervall for the fractional collector could be selected. After 90 h the injection was stopped and the

injection hole was flushed. Pressure was set to the natural pressure 0.28 MPa. We are still (March 1981) collecting water from the sampling holes.

11. EXPERIMENTAL RESULTS

11.1 Data on water-flow, pressures and test for connection

Injection hole

After the injection hole had been drilled the water-flow from the injection hole was measured. A small mechanical packer was inserted near the end of the injection hole. The water-flow was found to be approximately 100 ml/h. When installing the inflatable packer an attempt was made to measure the water-flow from different parts of the injection hole. The packer was set at different depths according to the fractures found in the drill-core, see appendix 3. When drilling the injection hole we expected to intersect the fracture at the depth of 8.7 m. We did intersect a fracture at 8.5 m. The drilling was stopped at a depth of 9.1 m. The fracture at 8.5 m did not seem to give any water. Most of the water came from a fracture at 7.03 m. There was no need for a more precise investigation of the injection hole until it was established if there were any connections between the injection hole and the sampling holes. The natural pressure in the injection hole was found to be 0.28 MPa.

Sampling holes

With the injection hole sealed off by a packer and with natural pressure within the sealed off part of the hole the water-flows from the sampling holes were measured. See table 1. The sampling holes are numbered 1-6, see figure 13.

Test of connection

When injecting Na-fluorescein with an overpressure of 0.22 MPa it took less than 20 h for the first of the tracer to reach sampling hole No. 4 and No. 5. The injection was continued and tracer eventually arrived in hole No. 3 too. No tracer was found in the remaining three holes.

<u>Sampling hole No.</u>	<u>Water flow ml/h</u>
1	~ 0
2	~ 0.2
3	~ 5
4	~ 83
5	~ 28
6	~ 0

Table 1. Water-flow from sampling holes.

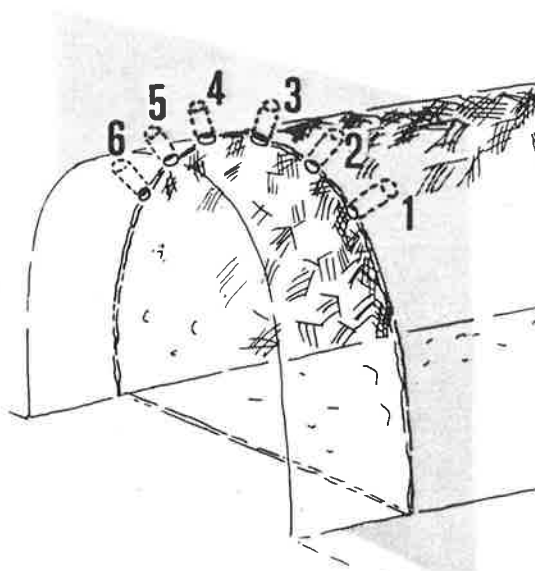


Figure 13. Numbering of sampling holes. Holes seen from drift leading to ventilation drift facing the Luleå drift.

11.2 First test run (Rhodamine-WT)

Rhodamine-WT was used as a tracer. We knew that if this was a true nonsorbing tracer it would arrive in detectable concentrations in the sampling holes in less than 20 h. The injection was done under an overpressure of 0.22 MPa. It took Rhodamine-WT more than 200 h to reach the sampling holes. This is ten times more than the time needed for Na-fluorescein. Because of several breakdowns of the equipment no firm conclusions can be drawn from this test.

11.3 Second test (Chrome-EDTA)

Before the second test clean water was injected and the pressure was allowed to decrease to natural pressure. With natural pressure 0.28 MPa in the injection hole Chrome-EDTA was circulated for 72 h. Chrome-EDTA was used because there was still some Na-fluorescein in the water coming from the sampling holes. No chrome-EDTA was found in the sampling holes during the duration of this test (72 h). This test was directly followed by the third test.

11.4 Third test (Na-fluorescein and Rhodamine-WT)

In the third and last test run Na-fluorescein and Rhodamine were injected at the same time for 90 h. The overpressure used was 0.22 MPa. After the injection the injection hole was flushed with clean water and the pressure was decreased to natural pressure.

Due to the difference in water-flow from the sampling holes only water from hole No. 4 and No. 5 was collected. The results from this test are presented in diagrams 2 and 3.

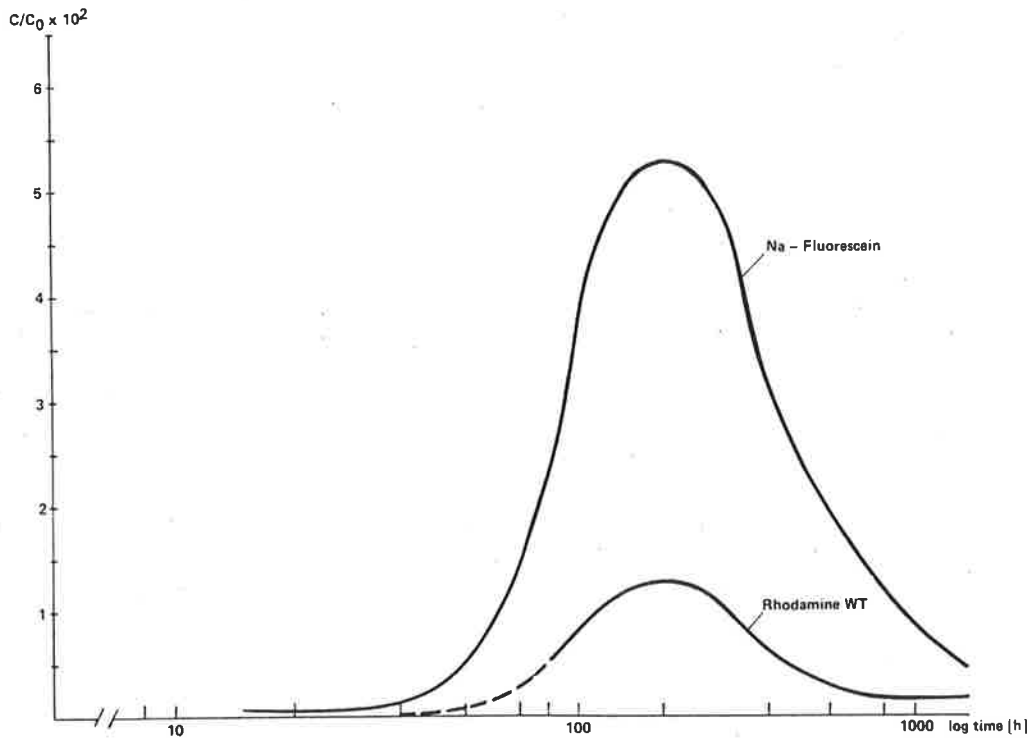
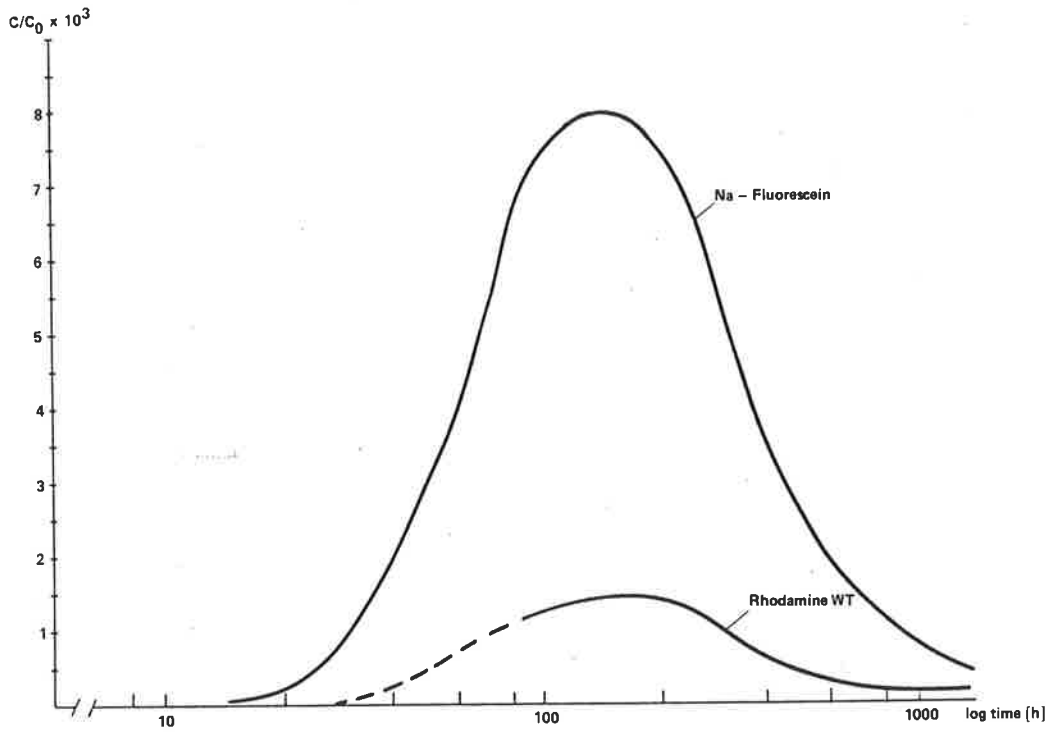


Diagram 2. Tracer concentration versus time for sampling holes No. 4 and 5.

Diagram 2 shows the breakthrough curves for Rhodamine and Fluorescein in holes 4 and 5 respectively. Diagram 3 shows the breakthrough of Fluorescein in holes 4 and 5.

It can be seen from diagram 2 that Rhodamine-WT appears later and more diluted in both holes.

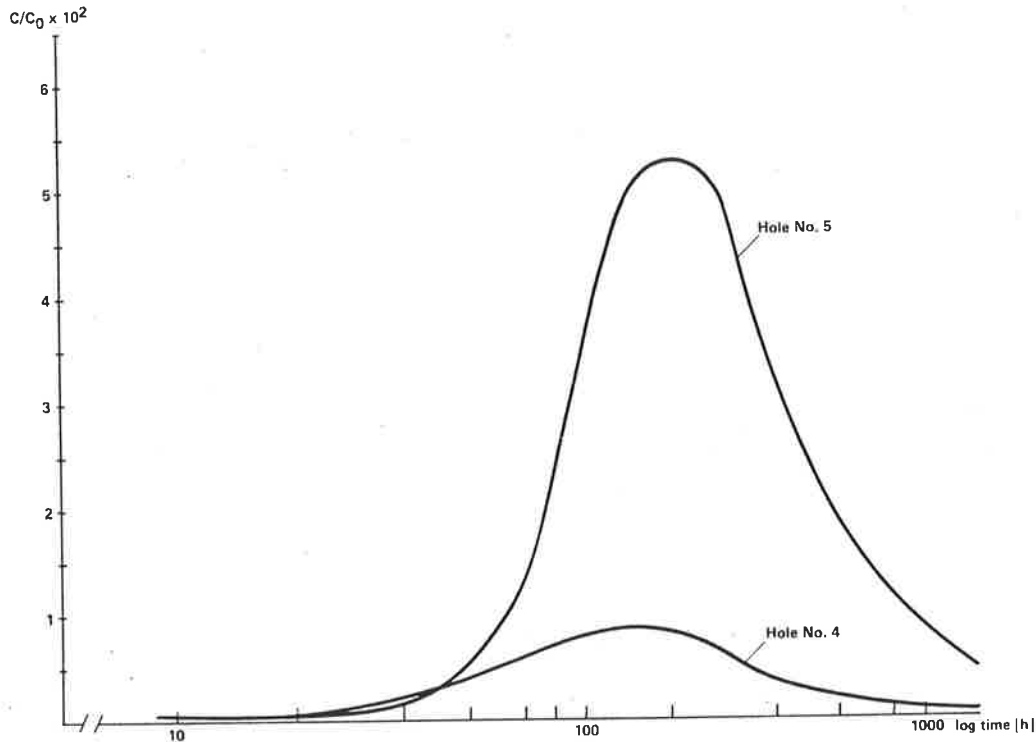


Diagram 3. Comparison of Fluorescein response from hole No. 4 and No. 5.

Diagram 3 shows the difference in breakthrough time and dilution between hole No. 4 and No. 5.

12. TENTATIVE INTERPRETATION

The very different flow rates to the various collecting holes indicate a considerable channeling. The mean travel time for Fluorescein is about 100 and 200 h for holes 4 and 5 respectively. From this, the known flow rates in the collection holes (83 and 28 ml/h), the collection length along the perimeter ~ 0.7 m, the hydraulic head and geometry, the hydraulic conductivity and equivalent fissure width for flow can be determined. Ideal radial flow in a single fissure is assumed.

$$K_{pf} = 0.5 \ln\left(\frac{r_2}{r_1}\right) \cdot (r_2^2 - r_1^2) / t_w (h_2 - h_1) \quad (1)$$

$$v_{r1} = 0.5 \frac{1}{t_w} \left(\frac{r_2^2}{r_1} - r_1 \right) \quad (2)$$

$$\delta_f = Q_r / l_{r1} v_{r1} \quad (3)$$

K_{pf}	is the hydraulic conductivity of the fissure	m/s
t_w	is the mean water residence time (assumed to be equal to fluorescein residence time)	s
h_2, h_1	pressure head in point 2 and 1 respectively (28 m and 0)	m
v_{r1}	water velocity at point 1 (fissure outlet in tunnel)	m/s
r_2, r_1	radial distance from center of tunnel (6 m and 2.25 m)	m
δ_f	fissure width for flow	m
Q_r	water flow rate	m^3/s
l_{r1}	collecting length (0,7 m)	m

The results are shown in table 2 below:

Hole No.	K_{pf} m/s	δ_f m	δ_1 m
4	$1.4 \cdot 10^{-6}$	$1.8 \cdot 10^{-3}$	$0.0013 \cdot 10^{-3}$
5	$0.7 \cdot 10^{-6}$	$1.2 \cdot 10^{-3}$	$0.001 \cdot 10^{-3}$

Table 2.

An equivalent fissure width for laminar flow in a parallel walled fissure with the same hydraulic conductivity δ_1 can also be determined:

$$\delta_1 = \sqrt{K_{pf} \cdot 12\nu/g} \quad (4)$$

This is also shown in table 2.

ν is the kinematic viscosity of water $1 \cdot 10^{-6}$ Ns/m^2 .

g is the gravitational constant 9.81 m/s^2 .

It can be concluded that this type of laminar flow resistance is not the main cause of the total resistance.

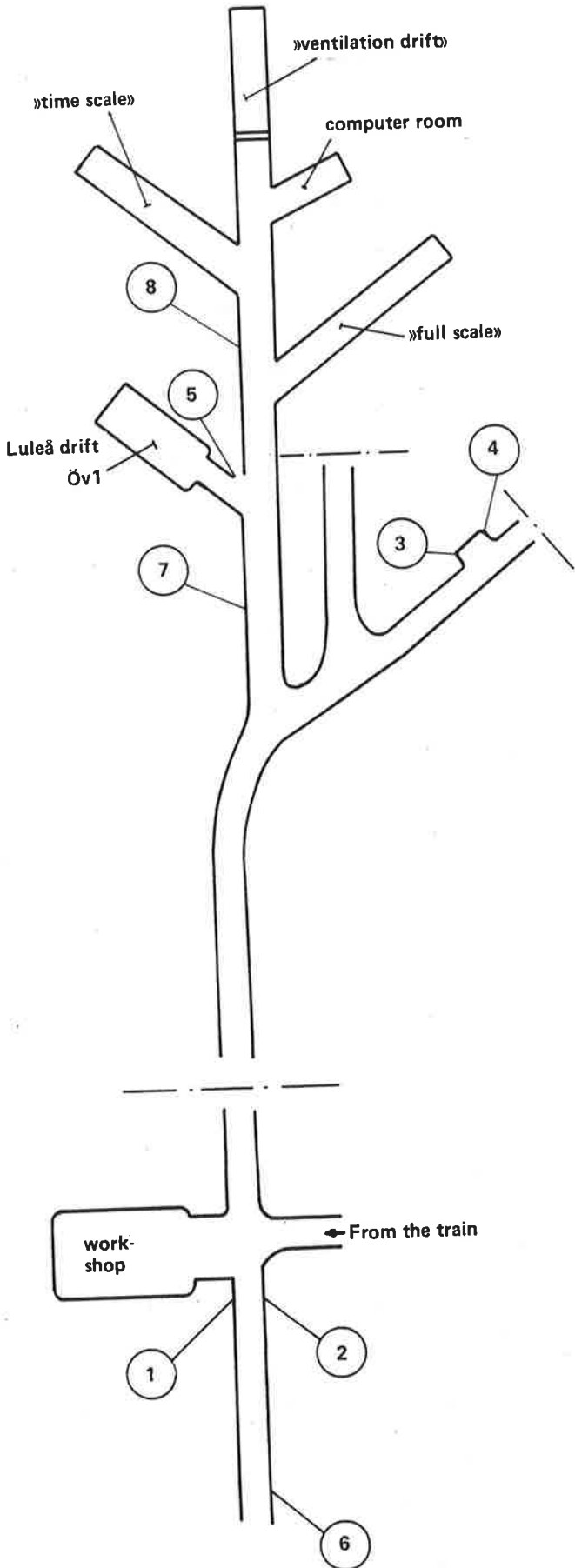
Rhodamine-WT is influenced in some way along the flow path as the peak height is lower than that of fluorescein. Rhodamine-WT thus cannot be used to characterize the water residence time without a knowledge of the interaction mechanisms.

13. AUXILIARY INVESTIGATIONS

The groundwater used in the preliminary investigation was taken from borehole R1 in the ventilation drift (see appendix 1). Two samples of this water was analyzed, one by "Scandiaconsult AB", Sweden and the other one by "Institutt for Energiteknik", Norway. The latter analysis was done by neutron activation.

The results are presented in appendix 4.

Map over fractures which have been sealed off with plastic film.

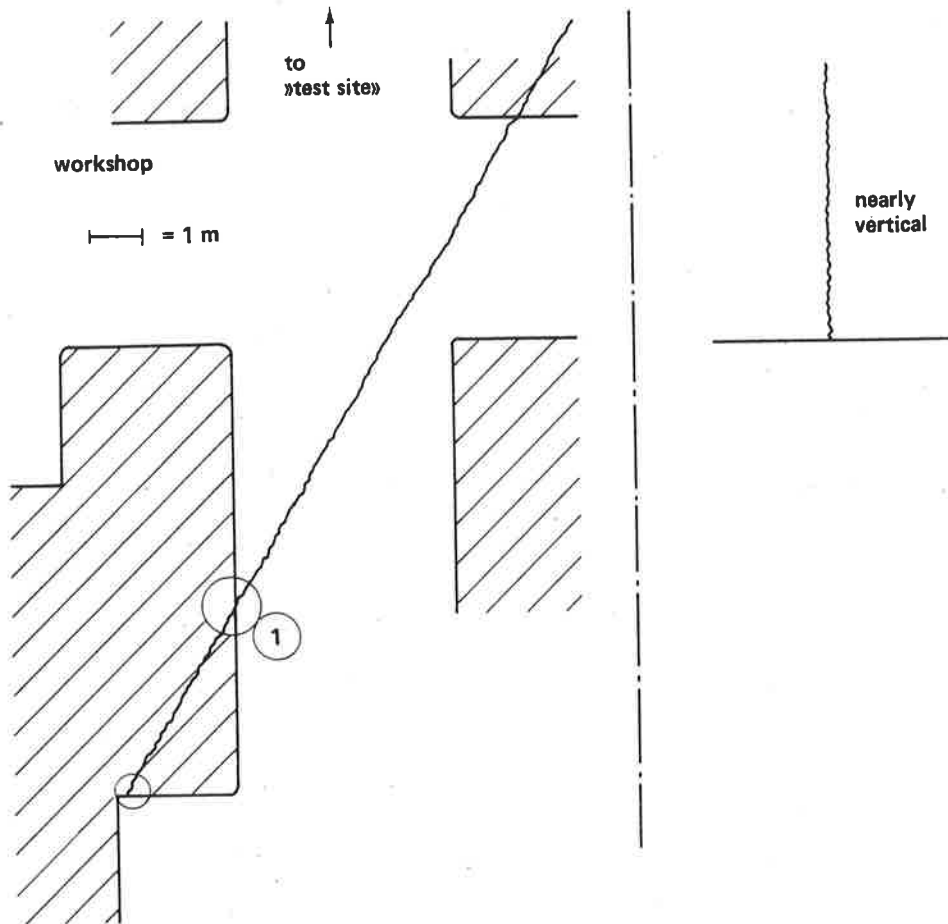


Fracture No.	Waterflow ml/h and m fracture
1	0.7-2.8
2	0.6-1.1
3	0
4	0
5	18
6	0
7	0
8	0

Numbers in \bigcirc is the number of the fracture.
 For more detailed maps over the fractures see following pages.
 On fractures 3 4 8 6 and 7 there are no maps because they did not have any waterflow.

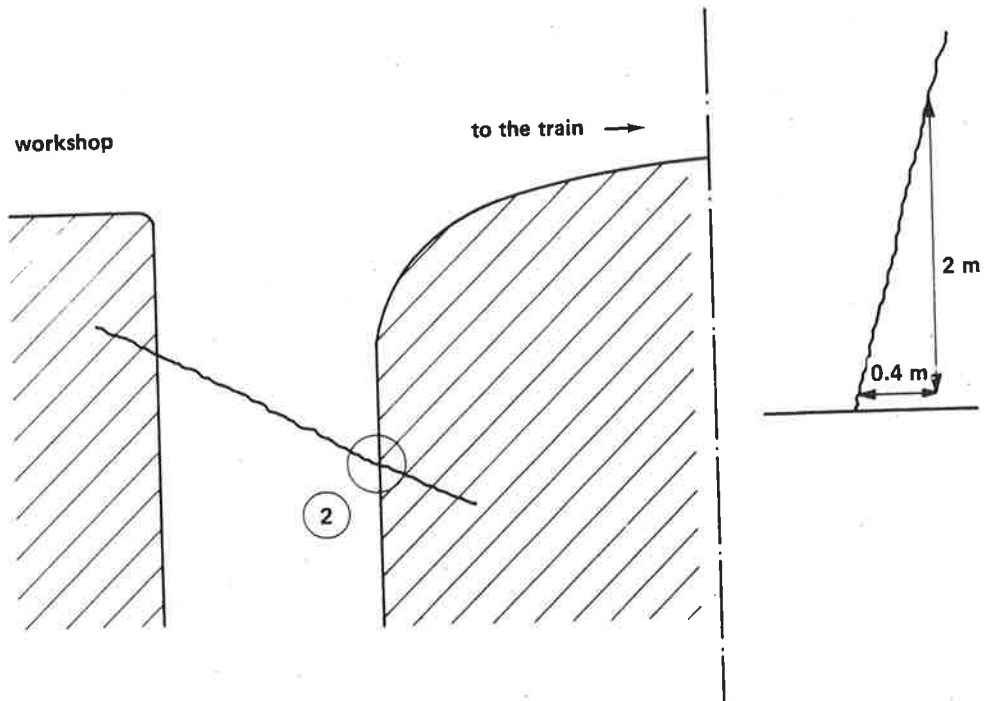
FRACTURE No. 1

Waterflow: Varying from 0.7 to 2.8 ml/h/m fracture.



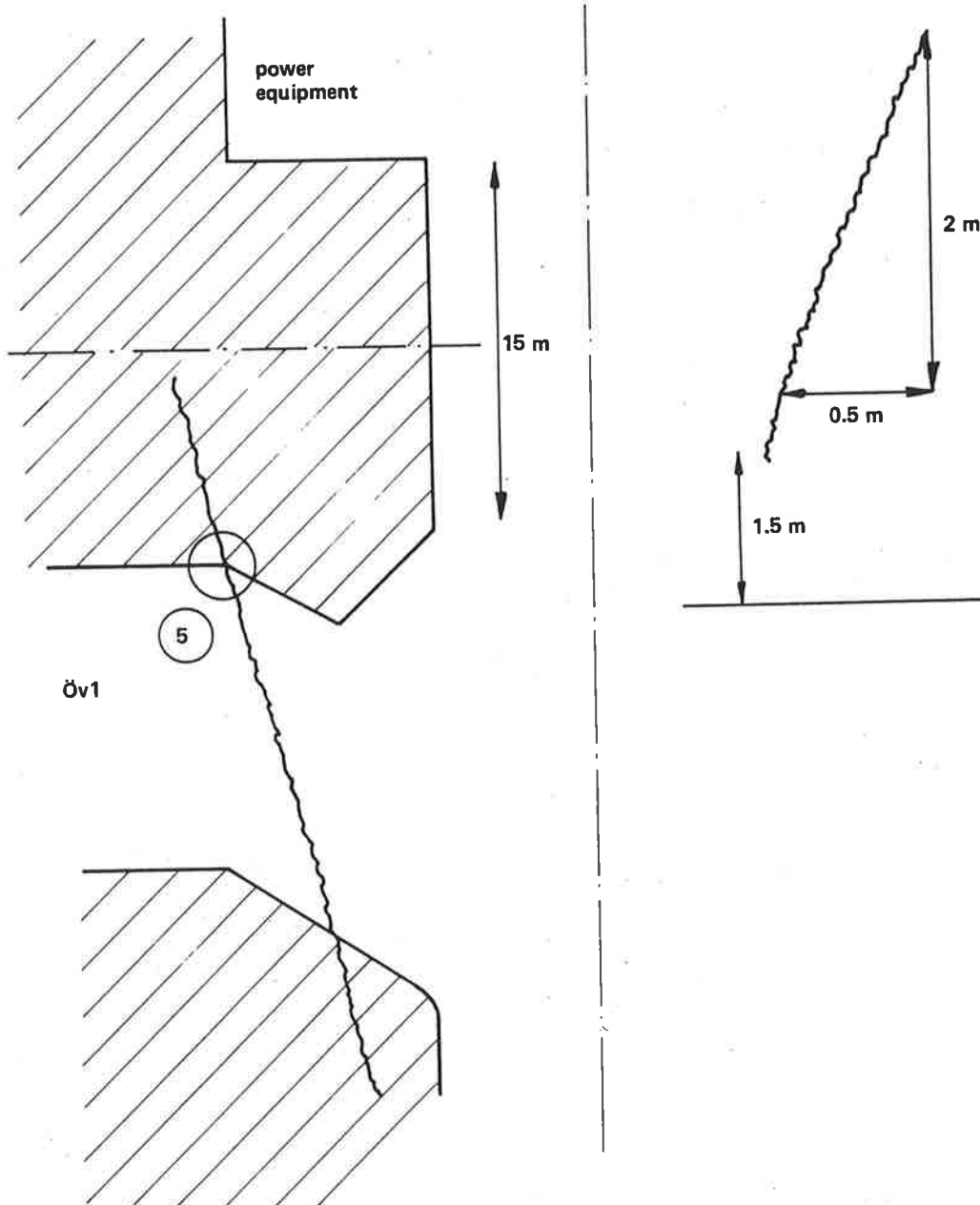
FRACTURE No. 2

Waterflow: Varying from 0.6 to 1.1 ml/h/m fracture
(the plastic film not tight at the upper
edge).

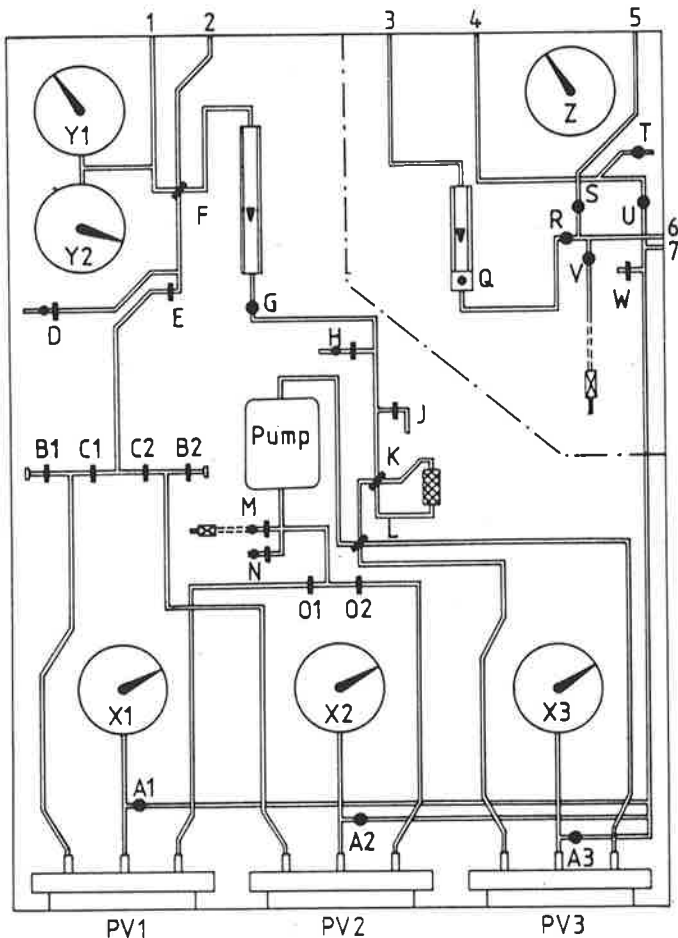


FRACTURE No. 5

Waterflow: 18 ml/h/m fracture.
This fracture was chosen for the preliminary runs.



Appendix 2
The valve table
1(2)



- 1 tube from injection hole.
- 2 tube to injection hole.
- 3 low pressure (LP) nitrogen to sampling holes.
- 4 high pressure (HP) nitrogen for inflation of packer.
- 5 LP nitrogen to glove box.
- 6 LP nitrogen inlet.
- 7 HP nitrogen inlet.

Nitrogen flow net.

A1,A2,A3 HP inlet to pressure vessels (PV).

B1,B2 spare inlet to PV 1.2.

C1,C2 inlet PV 1.2.

D sampling valve after injection hole.

E inlet to PV 1.2.

F 4-way valve connecting injection hole with valve table.

G control valve for water-flow.

H sampling valve before injection hole.

J spare outlet valve for pump.

K filter in/out.

L pressure transient absorber in/out.

M inlet valve to pump with quick connector.

N spare inlet to pump.

O1,O2 outlet from PV 1.2.

R,S LP nitrogen.

V quick connector LP.

W spare outlet HP.

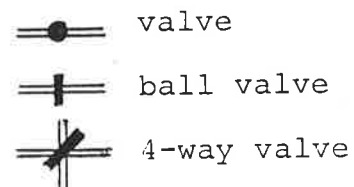
T outlet inflatable packer.

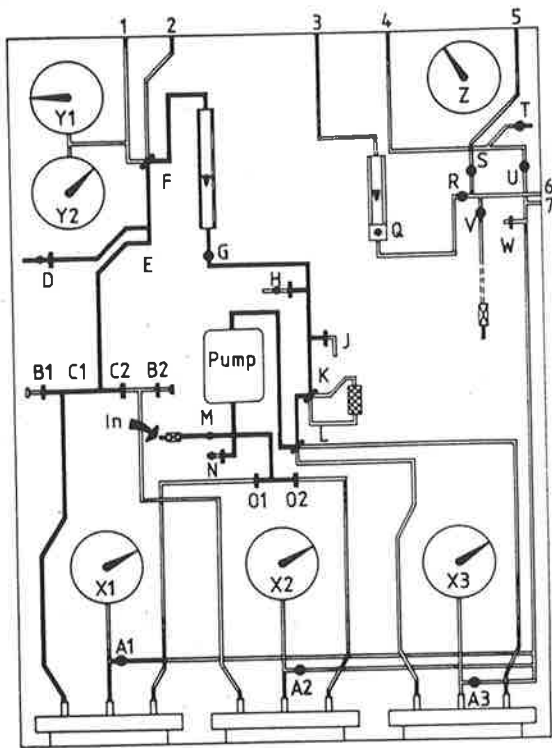
U inlet inflatable packer.

X1,X2,X3, gauges for pressure vessels.

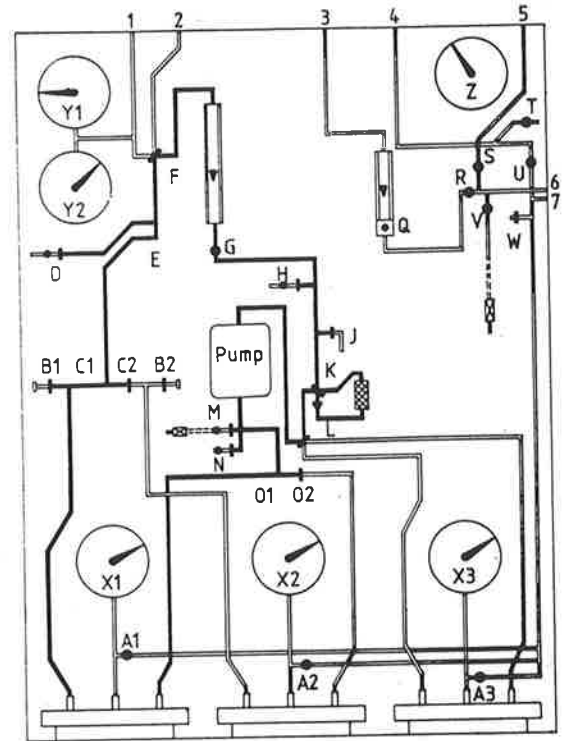
Y1,Y2 gauges for injection hole.

Z gauge for inflation pressure of packer.

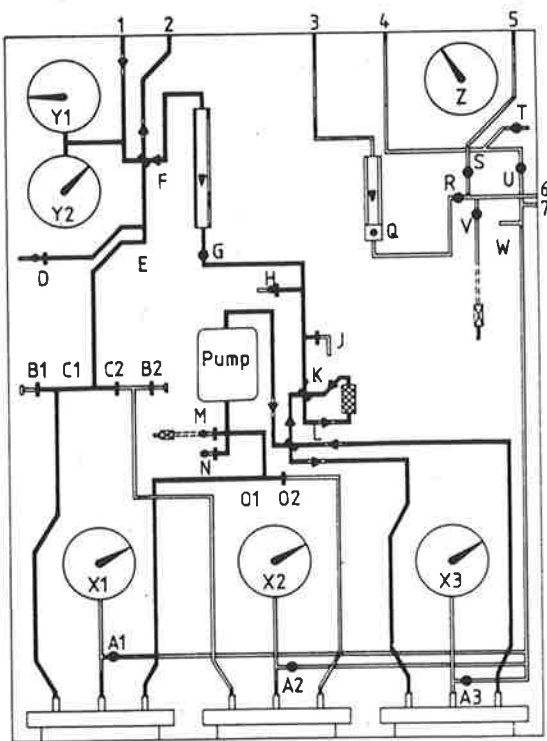




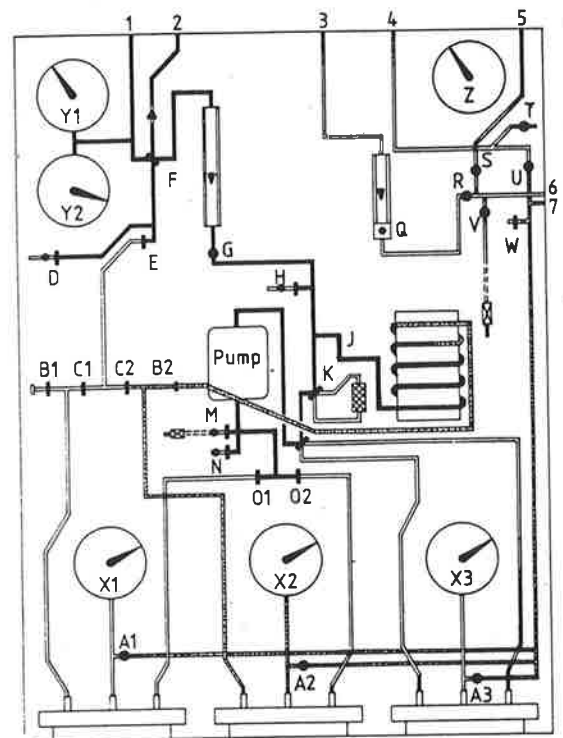
A. Tracer and water are pumped from glove box via quick connector M to PV 1.



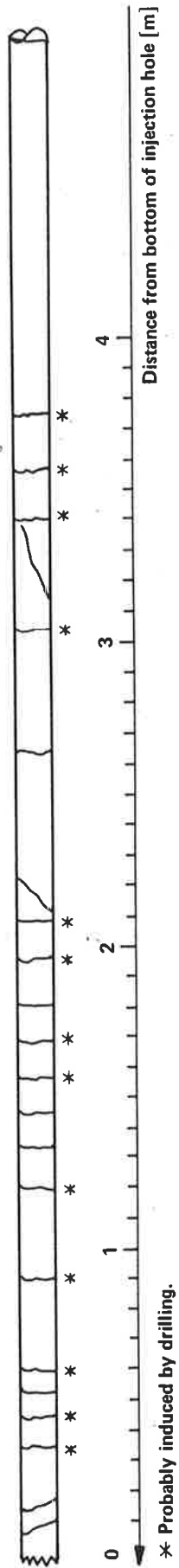
B. Tracer and water are circulated within the injection equipment to get good mixing.



C. Tracer solution is circulated in injection hole under natural or overpressure.



D. Tracer is injected under overpressure, no circulation. Injected volume measured by length of tubing emptied between B2 and J. Pressure supplied by PV 2.



	Scandiaconsult Sweden (mg/l)	Institutt for energiteknikk Norway (ppm)
Na	490	
K	0.24	
Ca	14	
Mg	0.29	
Fe (totl.)	0.12	<0.2
Fe ²⁺	<0.01	
Mn	<0.01	
Cl	35	22.5
F	3.8	
I		0.011
Br		0.44
O ₂	<0.1	
La		<0.001
U		0.013
Nd		<0.01
Cs		<0.002
Sr		<0.1
Eu		<0.0005
Th		<0.002
pH	7.2	7.92*
Conductivity	30	mS/m
Permanganate consumption	3.9	
Alkalicity (HCO ₃)	91	
NH ₄	<0.01	
SO ₄	2	
NO ₃	<0.02	
NO ₂	<0.001	
PO ₄	0.01	
SiO ₂	12	
H ₂ S	<0.1	

The analysis made in Norway is by Neutron activation.

* This value was given by Department of Inorganic Chemistry, KTH. The Department of Inorganic Chemistry also made an assessment of dissolved oxygen and measured E_h . The water sample contained dissolved oxygen and had E_h varying from +155 mV to +235 mV.

STRIPA PROJECT - PREVIOUS PUBLISHED REPORTS

- TR 81-01 "Summary of defined programs"
L Carlsson and T Olsson
Geological Survey of Sweden, Uppsala, Sweden
I Neretnieks
Royal Institute of Technology, Stockholm,
Sweden
R Pusch
University of Luleå, Sweden
November, 1980
- TR 81-02 "Annual report 1980"
Swedish Nuclear Fuel Supply Co/Division
Nuclear Fuel Safety SKBF/KBS
Stockholm April, 1981