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Äspö Hard Rock Laboratory

Prototype Repository

Instrumentation for gas and water sampling in buffer and backfill. Tunnel Section I

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October 2001

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PROTOTYPE REPOSITORY

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Instrumentation for gas and water sampling in buffer and backfill. Tunnel Section I

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Abstract

The Prototype Repository is an international, EC-supported activity with the objective to investigate, on a full-scale, the integrated performance of engineered barriers and near-field rock of a simulated deep repository. This is done in crystalline rock regarding heat evolution, mechanics, water flow, water chemistry, gas evolution and microbial processes under natural and realistic conditions at approximately 450 m depth below the ground surface. The test site is a 65 m long TBM-bored drift from which six 1.75m diameter deposition holes extended downwards to about 8 m depth in accordance with the KBS-3 concept. The test site is divided in two parts; an inner 40 m long section (Section I) with 4 deposition holes and an outer section (Section II) with two deposition holes. Stiff and tight plugs will separate the two sections and they will isolate Section II from the rest of the Äspö Hard Rock Laboratory.

The report describes the instrumentation for gas and water sampling in the buffer and backfill of Section I.

Two types of sample collectors have been installed.

- 12 static sample collectors have been placed in the bentonite in deposition hole number 1. The sample collectors consist of a titanium cup, on which a titanium filter is placed on the top. Pore water from the bentonite will after saturation of the material, flow through the filter and into the cup. When the test is over and the excavation of the bentonite has started, the cups will be located and the water will be analyzed.
- 7 active samplers have been installed in the 30/70 mixture, 5 in the backfill, one on top of deposition hole number 1 and one on the top of deposition hole number 3. These samplers are similar to those described above, except for a tube, made of PEEK, that connects the bottom of the cup with the adjacent G-tunnel. This makes it possible to take in situ samples during the test period.

Sammanfattning

Prototypförvaret är ett internationellt, EC-stött projekt med syfte att I full skala undersöka den integrerade funktionen hos ingenjörersbarriärer och närfältsberg i ett simulerat slutförvar i kristallint berg med hänsyn till värmeutveckling, mekanik, vattengenomströmning, vattenkemi, gasbildning och mikrobiologi under naturliga och realistiska förhållanden på ca 450m djup. Försöksplatsen är en 65m lång TBM-borrad ort från vilken sex vertikala deponeringshål med 1.75m diameter och 8m djup borrats i enlighet med KBS-3 konceptet. Testplatsen är delad i två delar; en inre 40m lång sektion (sektion I) med 4 deponeringshål och en yttre del (sektion II) med två deponeringshål. Stela och täta pluggar separerar sektionerna och sektion II från resten av Äspölaboratoriet.

Denna rapport beskriver instrumenteringen för gas- och vattenprovtagning i bufferten och återfyllningen i sektion I.

Två sorters provtagare har installeras:

- 12 permanenta provtagare har installerats i bentoniten i deponeringshål nummer 1. Provtagarna består av titanbehållare med titanfilter i toppen. Porvatten från bentoniten kommer efter vattenmättnad att via filtret fylla behållaren. När testet avslutas och bentoniten grävs ur kommer behållarna att lokaliseras och vattnet analyserat.

- 7 aktiva provtagare har placerats i 30/70-blandningen, 5 i återfyllen i tunneln samt en i toppen på deponeringshål nummer 1 och en i toppen på deponeringshål nummer 3. Dessa provtagare är identiska med den sort som beskrivs ovan så när som på en PEEK-slang som förbinder botten av respektive behållare med den näraliggande G-tunneln. Detta möjliggör löpande provtagning under hela testperioden.

Contents

List of Figures

List of Tables

1 Background

1.1 Äspö Hard Rock Laboratory

To prepare for the location of a site and licensing of a deep repository SKB has constructed an underground research laboratory.

In the autumn of 1990, SKB began the construction of the Äspö Hard Rock Laboratory (Äspö HRL), near Oskarshamn in the south-eastern part of Sweden. A 3.6 km long tunnel was excavated in crystalline rock down to a depth of approximately 460 m, see Figures 1-1 and 1-2.

The laboratory was completed in 1995 and research concerning the disposal of nuclear waste in crystalline rock has since then been carried on.

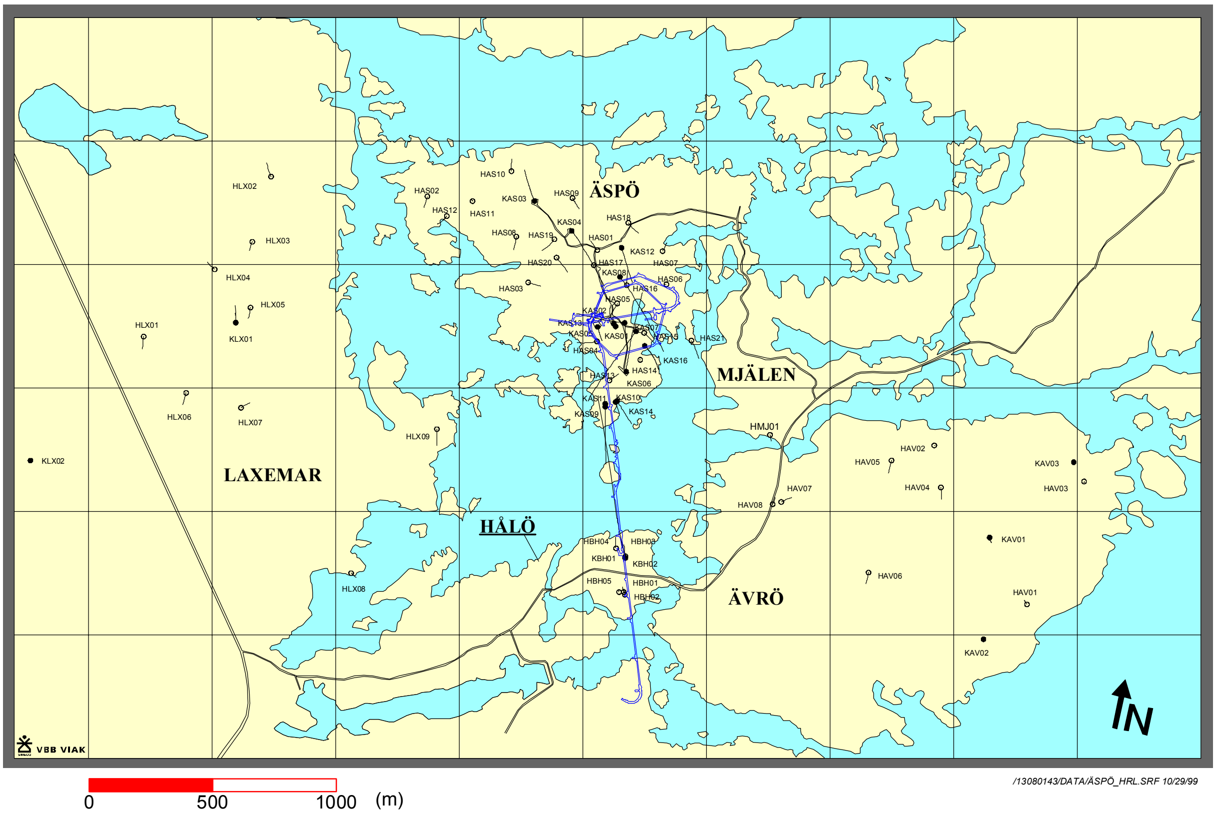

Figure 1-1. *Plan view over Äspö Hard Rock Laboratory.*

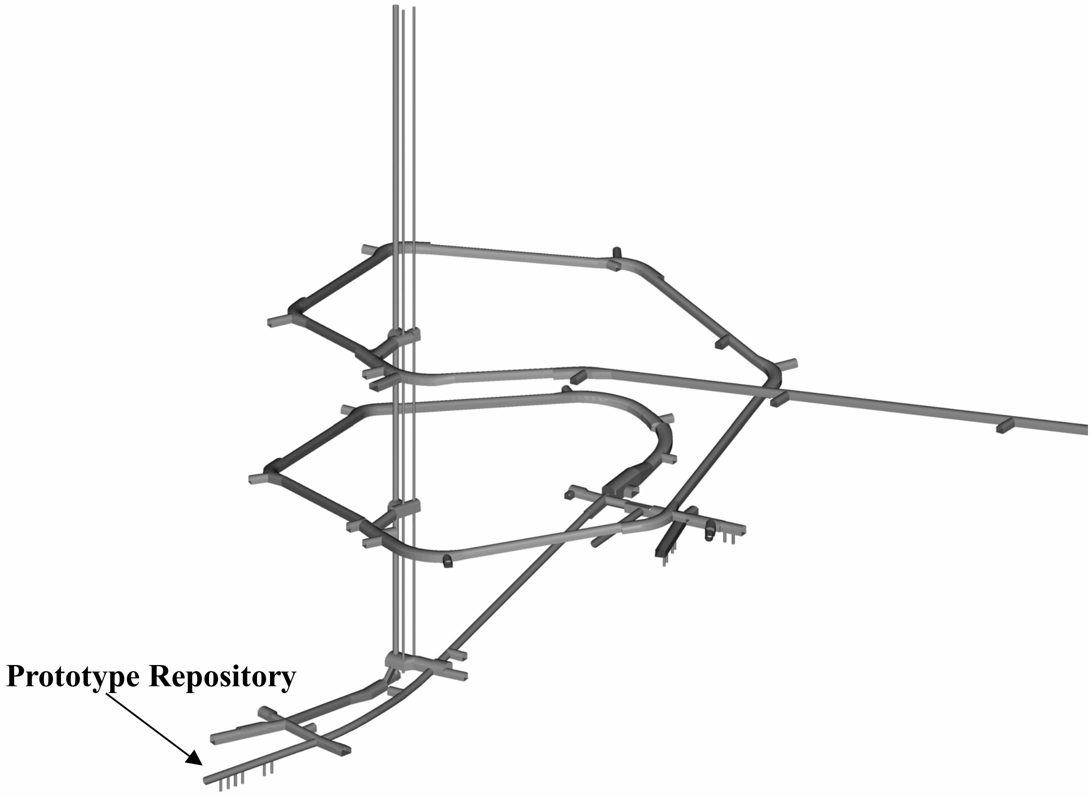

Figure 1-2. *Overview of the Äspö tunnel. The Prototype Repository is located at 450 m depth below the ground surface. The vertical lines show the elevator and ventilation shafts from the ground surface.*

1.2 Prototype Repository

The Äspö HRL is an essential part of the research, development, and demonstration (RD&D) work performed by SKB in preparation for construction and operation of the deep repository. Within the scope of the SKB program for RD&D 1995, SKB has decided to carry out the Prototype Repository with the aim of testing important components in the SKB deep repository system on a full scale and in a realistic environment.

The Prototype Repository is focused on testing and demonstrating the function of the SKB deep repository system. Activities aimed at contributing to development and testing of the practical, engineering measures required to rationally perform the steps of a deposition sequence are also included. However, efforts in this direction are limited, since these matters are addressed in the Demonstration of Repository Technology project and to some extent in the Backfill and Plug Test.

The project plan and the project description of the Prototype Repository are described in Svemar and Pusch (2000) and Persson and Broman (2000).

1.2.1 General objectives

The Prototype Repository should simulate as many aspects as possible of a real repository, for example regarding geometry, materials, and rock environment. The Prototype Repository is a demonstration of the integrated function of the repository components. Results will be compared with models and assumptions to their validity.

The major objectives for the Prototype Repository are:

- To simulate part of a future KBS-3 deep repository to the extent possible regarding geometry, design, materials, construction and rock environment except that radioactive waste is simulated by electric heaters.
- To test and demonstrate the integrated function of the repository components under realistic conditions on a full scale.
- To develop, test and demonstrate appropriate engineering standards and quality assurance methods.
- To accomplish confidence building as the capability of modelling EBS performance.

1.2.2 Objectives with this report

The instrumentation for gas and water sampling in buffer and backfill is done mainly in two stages. The inner part of the Prototype Repository, Section I, was instrumented during the autumn 2001 and Section II will be instrumented during the spring 2002. The general geometry of the Prototype Repository is illustrated in Figure 1-3. This report describes the instrumentation of Section I. Chapter 2 gives a brief description of the objectives for the hydrochemical and microbial sampling and Chapter 3 describes the instrumentation in Section I.

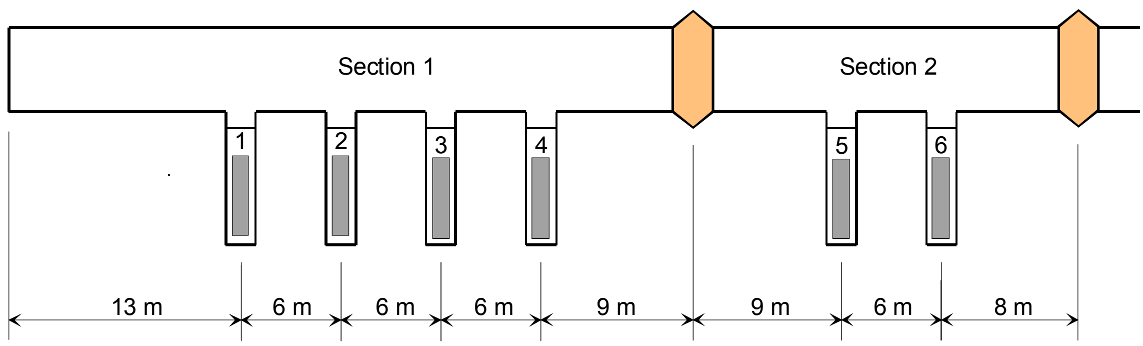

Figure 1-3. *Schematic view of the layout of the Prototype Repository and deposition holes (not to scale).*

2 Objectives for the hydrochemical sampling

Both the chemical stability of backfill material and the corrosion rate of the canister are important areas of uncertainty in repository safety and performance assessment. These are processes that depend on the hydrochemical characteristics of the near field. The solubility and migration characteristics of several radionuclides are also highly dependent on the chemical composition of the groundwater. Other factors affecting radionuclide mobility are the hydraulic and mineralogical properties of the rock. A suitable description of the chemical environment is required in order to demonstrate the proper function of the engineered barriers of the Prototype Repository.

Micro-organisms have the capability to reduce important groundwater components such as sulphate to sulphide and to produce and consume gases. Relevant microbial reactions should be included in the performance assessment for a HLW repository. The Prototype Repository will not be a sterile environment and microbial activity that influence the hydrochemical situation must, therefore, be studied.

The objectives for the hydrochemical sampling program, which is discussed in Puigdomenech and Pedersen (1999), are:

- Monitoring the chemical/microbial function of the Prototype Repository
- Verification of chemical/microbiological Models & Hypotheses
- Effect of temperature field on groundwater-rock interactions
- Bentonite redox chemistry
- Microbes
- Colloids
- Redox

To attain these objectives it is important to avoid chemical and microbial contamination of the samples. To study the redox conditions it is important to prevent atmospheric O_2 from diffusing into the sampling system. By using PEEK in the tubes, the system is expected to be diffusion tight. Bentonite packers in boreholes could possibly induce massive contamination of the Prototype near field with bentonite colloids, and this would jeopardize the chemical monitoring. Therefore, boreholes have been instrumented with bentonite packers where the bentonite was enclosed in rubber containers.

3 Equipment and instrumentation of buffer and backfill

3.1 Overview of instrumentation

3.1.1 Brief description of the equipment

Two types of sample collectors have been installed.

- 12 sample collectors have been placed in the bentonite in deposition hole number 1. The sample collectors consist of a titanium cup, on which a titanium filter is placed on the top (Figure 3-1). Pore water from the bentonite will after saturation of the material, flow through the filter and into the cup. When the test is over and the excavation of the bentonite has started, the cups will be located and the water will be analyzed.
- 7 additional samplers: five in the backfill, one on top of deposition hole number 1 and one on the top of deposition hole number 3. Same equipment as above, except for a tube, made of PEEK, that connects to the bottom of the cup (Figure 3-2). This makes it possible to take in situ samples during the test period.

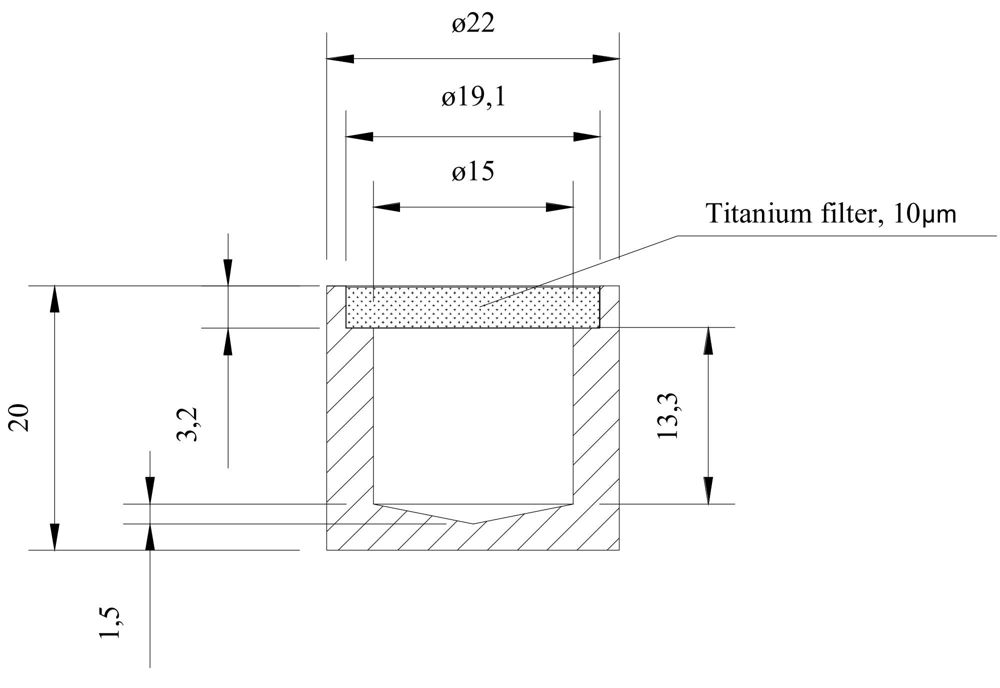

***Figure 3-1**. Titanium cup type 1 with filter (dimensions in mm).*

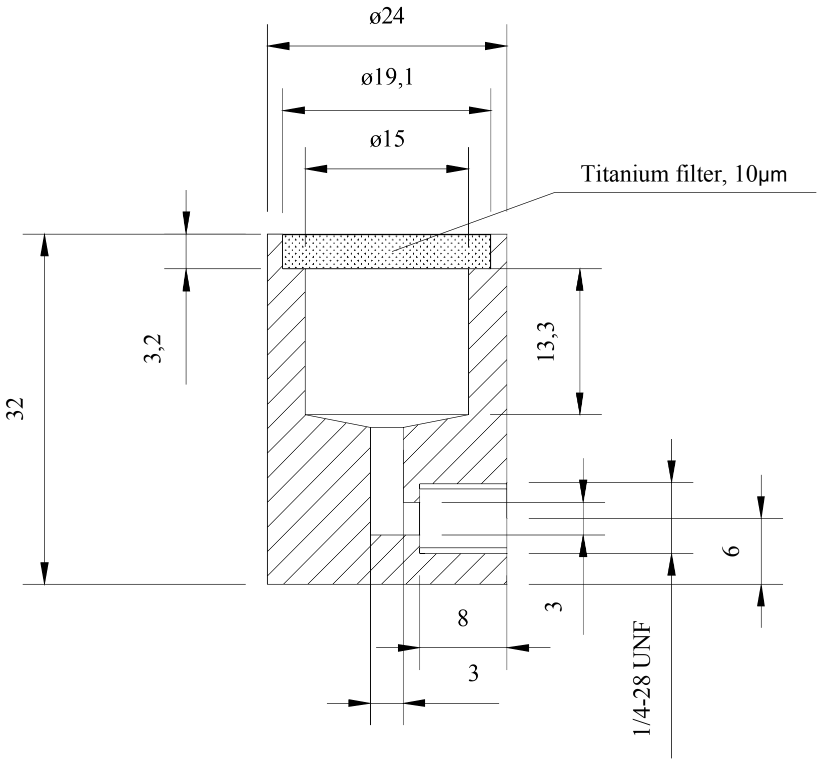

Figure 3-2. *Titanium cup type 2 with filter (dimensions in mm).*

3.1.2 Choice of materials

To prevent diffusion of gases such as atmospheric O_2 and to avoid microbial degradation, only corrosion resistant metals (such as titanium) and compact plastic materials, e.g. PEEK, have been used as tubing material to collect the Prototype Repository waters.

3.1.3 Strategy for describing the position of each device in the deposition holes

The position of each titanium cup is described according to the same system as other sensors in the bentonite.

The instrumented deposition holes in Section I are termed DA3587G01 and DA3575G01, hole number 1 and 3 respectively according to Figure 1-3. Measurements and sampling will be done in four vertical sections A, B, C and D according to Figure 3-3 and Figure 3-4. Direction A and C are placed in the tunnels axial direction with A headed against the end of the tunnel i.e. almost at West.

The bentonite blocks are called cylinders and rings. The cylinders are numbered C1-C4 and the rings R1-R10 respectively (Figure 3-4).

Every instrument position is described with three coordinates according to Figure 3-3. The *r*-coordinate is the horizontal distance from the center of the hole and the *z*-coordinate is the height from the bottom of the hole (the block height is set to 500mm). The α–coordinate is the angle from the vertical direction A (almost West) and anti-clockwise (when looking down in the deposition hole).

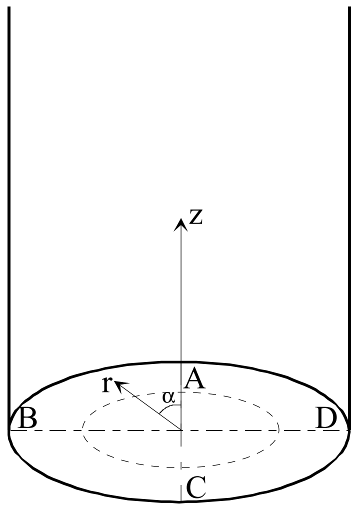

Figure 3-3. *Figure describing the coordinate system used when determining the instrument positions.*

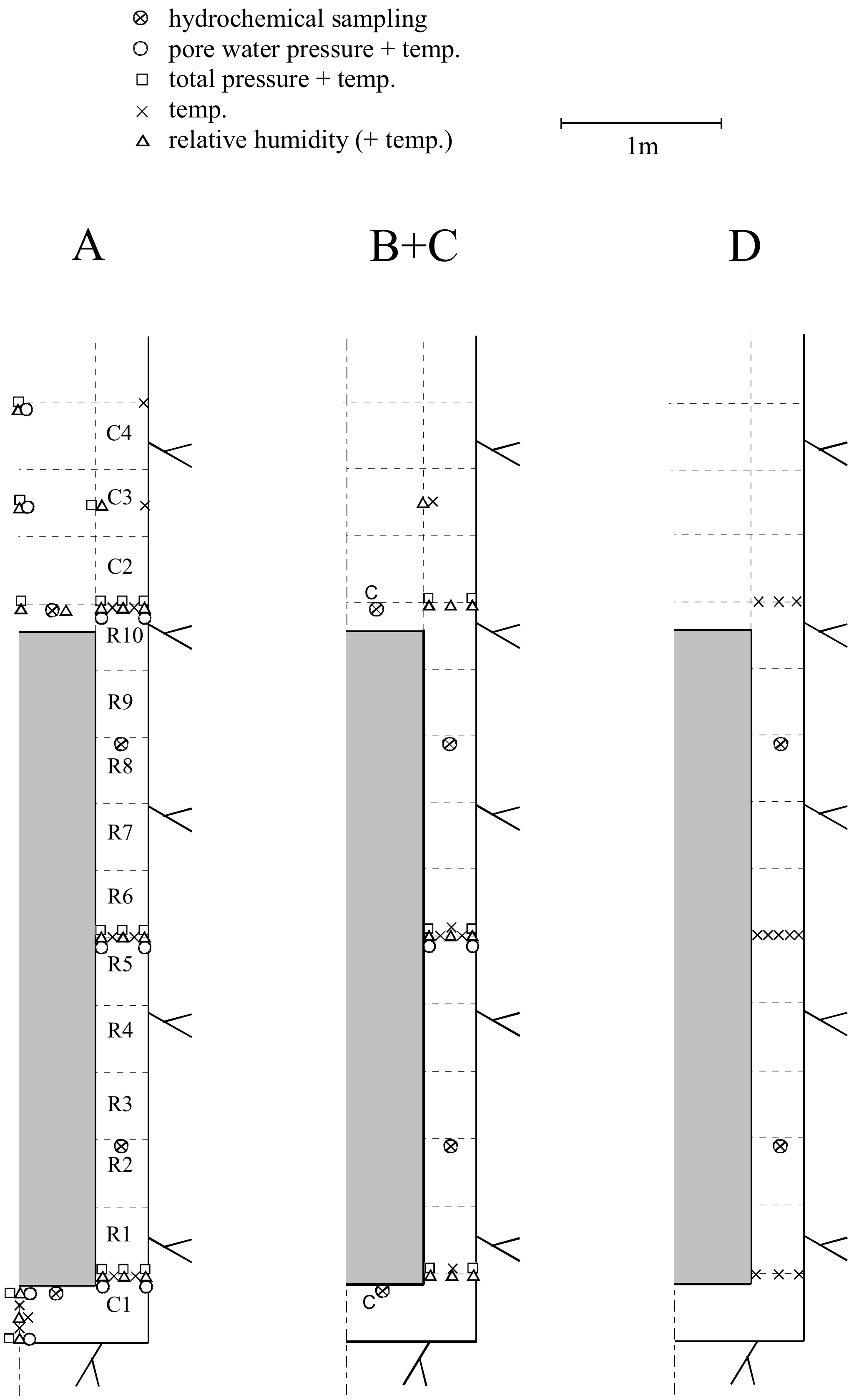

Figure 3-4. *Schematic view over the location of instruments and sampling devices in four vertical sections and designation of the bentonite blocks. The "C" beside two of the sampling points, indicates that they are only placed in section C.*

3.1.4 Position of each titanium cup in the bentonite in hole 1 (DA3587G01) and in hole 3 (DA3575G01).

The positions of each titanium cup are described in Table 3-1 and Table 3-2.

Table 3-1 Table showing the positions of the titanium cups emplaced in deposition hole DA3587G01.

Prototype Repository, Instrumentation

Instrument type	**Hydrochemical sampling**
Deposition hole, No	**1**
Lead through, No	**LT43**
Length of lead throughLT43	**44.4**
Length in G-tunnel, m	**10**

Mark	Block	Instrument position in block Direction	α	r	Z	Cable dir. α	Fabricate	Cable lengths Buffer	In test volume	Total	Remark
			degree	mm	mm	degree		m	m	m	
CUP 1	Cyl. 1	A	0	262	450	160	CT				
CUP 2	Cyl. 1	C	180	262	450	164	CT				
CUP 3	R2	A	0	685	1450	352	CT				
CUP 4	R2	B	90	685	1450	350	CT				
CUP 5	R2	C	180	685	1450	348	CT				
CUP 6	R2	D	270	685	1450	76	CT				
CUP 7	R8	A	0	685	4450	78	CT				
CUP 8	R8	B	90	685	4450	80	CT				
CUP 9	R8	C	180	685	4450	174	CT				
CUP 10	R8	D	270	685	4450	172	CT				
CUP 11	R10	A	0	262	5450	170	CT				
CUP 12	R10	C	180	262	5450	330	CT				
KBU10007	C4	A	0	875	6950	334	CT	0.5	25.0	79.4	with tube

Table 3-2 Table showing the positions of the titanium cups emplaced in deposition hole DA3575G01.

Prototype Repository, Instrumentation

Instrument type	**Hydrochemical sampling**
Deposition hole, No	**3**
Lead through, No	**LT43**
Length of lead throughLT43	**44.4**
Length in G-tunnel, m	**10**

Mark	Block	Instrument position in block Direction	α	r	Z	Cable dir. α	Fabricate	Cable lengths Buffer	In test volume	Total	Remark
			degree	mm	mm	degree		m	m	m	
KBU10008	C4	A	0	875	6950	334	CT	0.5	25.0	79.4	with tube

3.1.5 Position of each titanium cup in the backfill

Every instrument position in the backfill is described with three coordinates. The x-coordinate is the horizontal distance from the center of the tunnel and the y-coordinate is the vertical distance from the center of the tunnel. The tunnel section is the same as in the tunnel coordinate system, i.e. 3600 is the end of the tunnel. The location of the five sampling points is shown schematically in Figure 3-5, and the position of the samplers is given in Table 3-3. Initially a sixth sampler was planned (KBU10006) to be located at $x = 0$, $y = -2.4$ and 3565 m, but the tubing that would connect it to the lead-through hole was unfortunately lost in the bckfill.

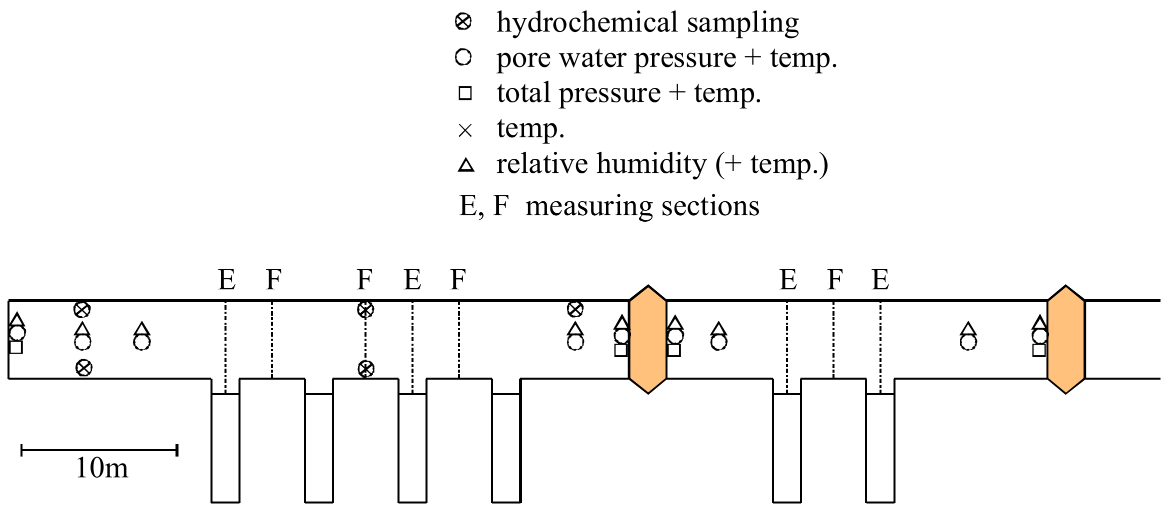

Figure 3-5. *Schematic view over the instruments and sampling points in the backfill (not to scale).*

Table 3-3 Table showing the positions of the titanium cups emplaced in the backfill.

Prototype Repository, Instrumentation
Instrument type **Hydrochemical sampling**
Backfill
Lead through, No **LT43**
Length of lead throughLT43 **44.4**
Length in G-tunnel, m **10**

Mark	Instrument position Section	x	y	z	Fabricate	Cable lengths In test volume	Total
		m	m	m		m	m
KBU10001	Inner part	0	2.4	3595	CT	25.0	79
KBU10002	Inner part	0	-2.4	3594.5	CT	25.0	79
KBU10003	Between dep.hole 2 and 3	0	2.4	3578	CT	25.0	79
KBU10004	Between dep.hole 2 and 3	0	-2.4	3578	CT	25.0	79
KBU10005	In front of plug	0	2.4	3565	CT	25.0	79

3.1.6 Installation of titanium cups in the buffer and in the backfill

Buffer

Holes with a diameter of 23 mm and with a depth of 50 mm were drilled in the bentonite blocks. The positions were taken from Table 3-1 and Table 3-2. After placing the titanium cups the holes were filled with bentonite powder.

Backfill

The positions for the titanium cups were taken from Table 3-3. The earlier installed PEEK-tubes were connected to the titanium cups, which were embedded in the backfill material. All instrumentation tubes were finally lead to lead-through holes, see Figures 3-6 and 3-7 connecting Tunnel A to Tunnel G. In the G-Tunnel the instrumentation, panels with transducer etc. are situated.

Figure 3-6. *Tubes and cables being installed in a lead-through hole.*

Figure 3-7. *Lead-through holes.*

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Svemar C, Pusch R, 2000. Äspö Hard Rock Laboratory, Prototype Repository, Project description, FIKW-CT-2000-00055, SKB, IPR-00-30