P-03-30

Forsmark site investigation

Drilling of a flushing water well, HFM01, and two groundwater monitoring wells, HFM02 and HFM03 at drillsite DS1

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April 2003

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Keywords: AP PF 400-02-08, AP PF 400-02-18, AP PF 400-02-22, percussion drilling, flushing water well, monitoring well, soil, bedrock, DS1.

Contents

1 Introduction

SKB performs site investigations to locate a deep repository for high level radioactive waste /1/. The investigations are performed in two Swedish municipalities: Östhammar and Oskarshamn. The investigation area in Östhammar is situated close to the nuclear power plant at Forsmark /2/, see Figure 1-1.

Drilling is one important activity performed within the frame of the site investigations. Three main types of boreholes are produced: core drilled boreholes, percussion drilled boreholes in hard rock and boreholes drilled through unconsolidated soil. The initial phase of the investigations includes drilling of three, c 1000 m deep boreholes, one at each of the drillsites DS1, DS2 and DS3, see Figure 1-1. At these sites, also percussion drilled boreholes in hard rock and soil have been produced.

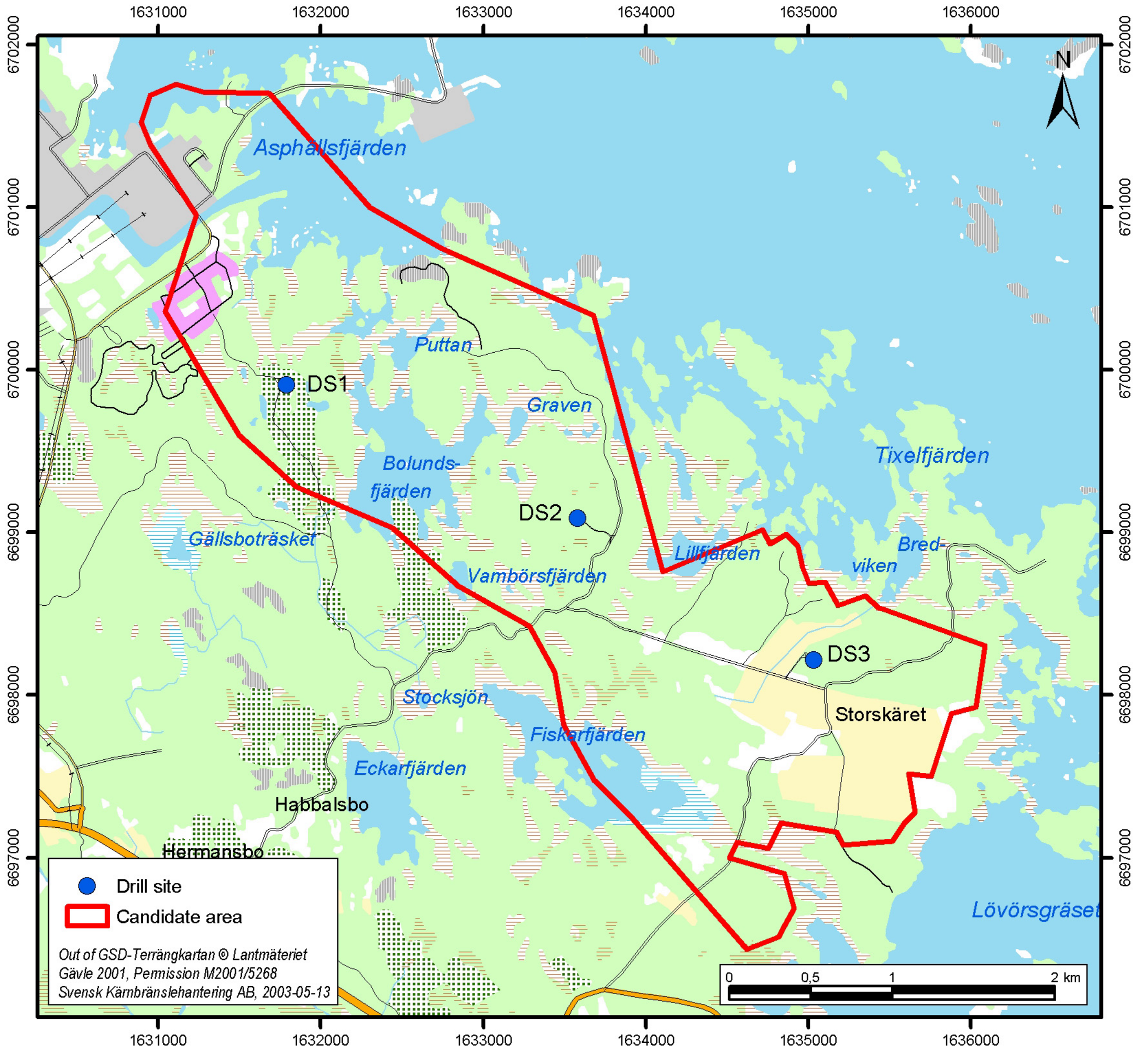


***Figure 1-1.** The investigation area at Forsmark including the candidate area selected for more detailed investigations. Drillsites DS1–3 are marked with blue dots.*

At drillsite DS1, the deep cored borehole is named KFM01A, see Figure 1-2. The results from the drilling operations of this borehole are presented in /3/. Besides the deep borehole, altogether three percussion boreholes in hard rock with depths between 26–200 metres, as well as three boreholes through the soil layer were drilled at the drillsite (Figure 1-2). Results from drilling of the three monitoring wells in soil at drillsite DS1, SFM0001, SFM0002 and SFM0003 (Figure 1-2) are presented in /4/.

In the present report performance of and results from drilling of the three percussion boreholes in hard rock, HFM01, HFM02 and HFM03 at drillsite DS1 are dealt with. The report also treats investigations made during and immediately after the drilling operations and the same of the results obtained.

Borehole HFM01 was produced for supply of the flushing water needed for drilling the deep cored borehole KFM01A, whereas boreholes HFM02 and HFM03 were drilled to serve as monitoring wells, enabling long-term study of groundwater levels and groundwater-chemical composition. The drilling operations were performed by Sven Andersson in Uppsala AB, with support from SKB-personnel regarding measurements

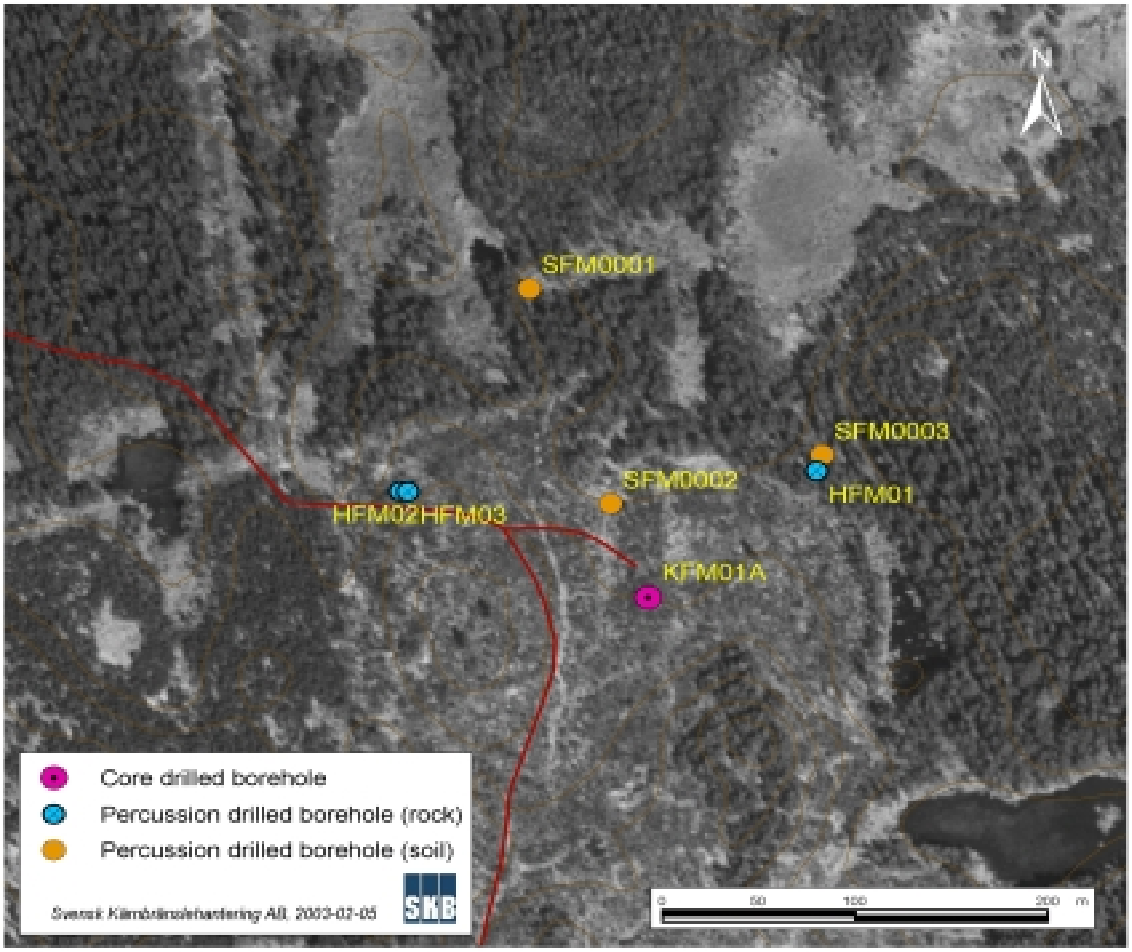


Figure 1-2. *Borehole locations at drillsite DS1. Besides the flushing water well and the monitoring wells in hard rock, also monitoring wells in unconsolidated overburden were drilled.*

and tests during drilling. A Nemek 407 RE percussion drilling machine was engaged for the commission.

The drilling and measurement operations were performed according to a specific Activity Plan (internal SKB controlling document) for each borehole: respectively AP PF 400-02-08 (HFM01), AP PF 400-02-18 (HFM02) and AP PF 400-02-22 (HFM03). All Activity Plans refer to SKB MD 610.003, Version 1.0 (Method Description for Percussion Drilling).

2 Objective and scope

Drilling of a 1000 m deep core borehole is a time consuming operation associated with extensive operations regarding e.g. water handling. At the SKB site investigations, drilling of deep cored boreholes is performed using a so called telescopic drilling technique, implying that the upper 100 m of the borehole is percussion drilled with a large diameter (≥ 200 mm), whereas the borehole section 100–1000 m is core drilled with a diameter of approximately 76–77 mm.

Core drilling demands injection of relatively large amounts of flushing water through the drill string and drill bit for the purpose of cooling down the drill bit and for transportation of drill cuttings from the borehole bottom to the ground surface. At the SKB site investigations, an air-lift pump is installed in the upper, large-diameter part of the telescopic drilled borehole in order to enhance the recovery of flushing water and drill cuttings. During the entire drilling period (comprising several months) the air-lift pumping and, to a lesser extent, the injection of flushing water, entail some impact on the groundwater levels and, possibly, on the groundwater-chemical composition in the near-surrounding of the deep borehole.

Boreholes HFM01–03 are of so called SKB chemical type. The meaning of this is that the boreholes are prioritized for hydro-geochemical investigations (also including study of microorganisms, primarily bacteria, prevailing in the groundwater). The practical consequence of this is that all DTH (Down The Hole)-equipment used during and/or after drilling must undergo severe cleaning procedures, see Section 4.1.

However, borehole HFM01 was drilled with the primary aim to, at a convenient distance (c 120 m) from the core drilled borehole KFM01A, account for the supply of relatively large amounts (c 5–50 L/min) of clean flushing water, whereas boreholes HFM02 and HFM03 were drilled to serve primarily as monitoring wells. Such wells may be used for the study of groundwater levels and groundwater-chemical conditions under undisturbed as well as disturbed conditions.

The strategy for positioning the monitoring wells was to locate them within the expected radius of influence of groundwater-level draw-down, approximately 300–400 m from borehole KFM01A, due to air-lift pumping during drilling. The location was also selected between geophysical anomalies in what was estimated to be homogeneous, low-fractured bedrock.

The location of boreholes HFM02 and HFM03, separated as they are only a few metres from each other, may require an explanation. During drilling of borehole HFM02, fracturing associated with an inflow of groundwater of approximately 30–40 L/min was observed at 16.2–16.8 m depth. Deeper down, at 43.2–43.6 m, a very large inflow of approximately 1000 l/min occurred. In this situation the borehole was cased to 25.4 m and gap injected in order to isolate the deeper parts of the hole from the fracture zone at 16.2–16.4 m. To enable the study of possible hydraulic responses in the fracture zone at 16.2–16.4 m during pumping in KFM01A (and HFM01), a new percussion borehole, HFM03, was proposed to be drilled close to borehole HFM02. The casing length in

HFM03 was limited to c 13 m in order not to isolate the fracture zone at 16.2–16.4 m. With this solution, hydraulic responses in HFM03 due to pumping in boreholes KFM01A and HFM01 could be studied. Also possible hydraulic connections between the two fracture zones could be revealed. The location of HFM03 is 4–5 m SSE of HFM02.

Drilling of monitoring wells in the vicinity of a deep core drilled borehole should normally be performed prior to the start of drilling operations at the deep borehole, since the objective of the monitoring wells is to make the study of undisturbed as well as of disturbed groundwater conditions possible . However, due to logistic reasons, drilling of borehole KFM01A was initiated shortly before drilling of the monitoring wells HFM02 and HFM03. Undisturbed conditions therefore have to be studied after completion of drilling of KFM01A. The wells may be used both for the study of groundwater levels and of groundwater-chemical conditions.

Data gained during monitoring of undisturbed conditions will be part of the basic characterization of the groundwater conditions of the shallow part of the bedrock. Monitoring during the percussion and core drilling operations in KFM01A is primarily part of the environmental control program for these drilling operations. However, also these data may be used for basic characterization purposes. After completion of drilling, the monitoring wells will be used for long-term groundwater monitoring.

3 Equipment

Drilling of the three percussion boreholes in hard rock at drillsite DS1 was performed with a Nemek 407 RE DTH percussion drilling machine (Figure 3-1) supplied with various accessory equipment. In this chapter short descriptions are given of the drilling equipment, the technique and equipment for gap injection of the borehole casings and of the instrumentation used for deviation measurements performed after completion of drilling. Also the equipment used for measurements and sampling during drilling is briefly described.

3.1 Drilling equipment

The drilling machine was equipped with separate engines for transportation and power supplies. For uplifting of water and drill cuttings from the borehole, a 27 bar diesel air-compressor, type Atlas-Copco XRVS 455 Md was usedure. The DTH drillhammer was of type Secoroc 5", lowered into the borehole by a Driconeq 76 mm pipe string.

Figure 3-1. *The Nemek 407 percussion drill machine engaged for drilling the three percussion boreholes in hard rock at drillsite DS1. Note the fluidproof cover beneath the drill rig used for protection of the ground in case of unintentional oil spillage. Photo Alf Sevastik.*

A 254 mm (external diameter) temporary steel casing was driven through the soil layer and further through fractured rock and a certain distance into solid rock, see detailed description in Section 4.3. The gap between the borehole wall and the casing was grouted with cement, see Section 3.2.

Cleaning of all DTH-equipment was performed with a high-capacity steam cleaner of type Kärcher HDS 1195.

Recovered drill cuttings and groundwater was, for environmental reasons, not allowed to spread out on the ground surface, but was conducted to and collected in a steel container. After completion of drilling, the container was removed from the site and emptied at an approved deposit.

3.2 Gap injection technics and equipment

Grouting the gap between the borehole wall and the casing pipe with cement is performed in order to prevent surface water and shallow groundwater to infiltrate into deeper parts of the borehole. The cement application may be performed using different techniques and equipment. Two variants of gap injection with cement are illustrated in Figure 3-2.

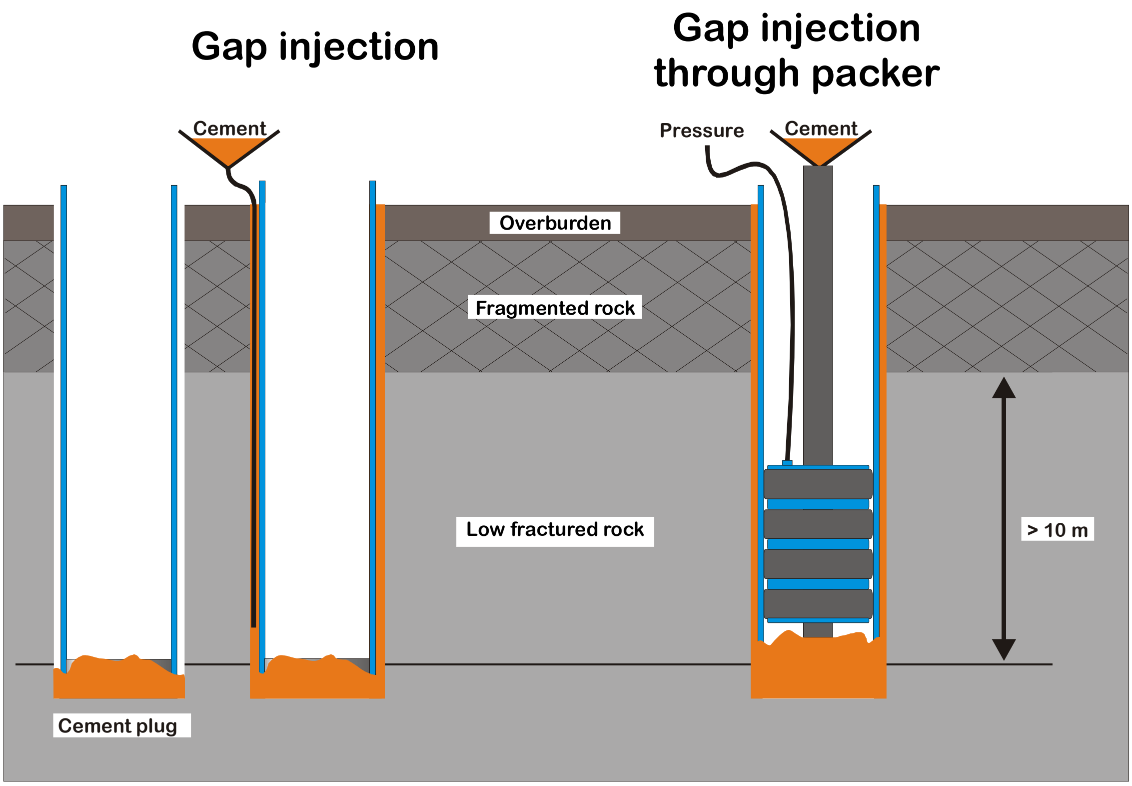


Figure 3-2. *Gap injection technique. In order to grout the gap between the borehole wall and the casing, two systems were used. To the left, filling up a cement-water mixture with a flexible hose is shown. To the right, injection is performed through a borehole packer.*

3.3 Equipment for deviation measurements

Deviation measurements were performed in all three boreholes using a Reflex **MAXIBOR™** (non magnetic) equipment. Azimuth and dip was measured every third metre. The coordinates for the starting point and the measured values were used for calculating the coordinates for every measured point.

3.4 Equipment for measurements and sampling during drilling

Flow measurements during drilling were performed using measuring vessels of different sizes and a stop watch. Measurements of drilling penetration rate were accomplished with a carpenter's rule and a stop watch.

Samples of soil and drill cuttings were collected in sampling pots and groundwater in small bottles. A field measuring devise was used for measurements of electrical conductivity of the groundwater.

4 Execution

The performance of the work followed SKB MD 610.003, Version 1.0 (Method Description for Percussion Drilling) and included the following items: preparations,

- mobilisation, including lining up the machine and measuring the position,
- drilling, measurements, and sampling during drilling,
- finishing off work,
- deviation measurements
- data handling,
- environmental control.

4.1 Preparations

The preparation stage included the Contractor's service and function control of his equipment. The machinery was obliged to be supplied with fuel, oil and grease exclusively of the types stated in SKB MD 600.006, Version 1.0 (Method Instruction for Chemical Products and Materials). Finally the equipment was cleaned (Figure 4-1) in accordance with SKB MD 600.004, Version 1.0 (Method Instruction for Cleaning Borehole Equipment and certain Ground-based Equipment) at level two used for SKB boreholes of chemical type.

4.2 Mobilisation

Mobilisation onto and at the site included first of all transport of drilling and accessory equipment to the drill site. Furthermore, the mobilisation comprised preparation of the drill site, cleaning of all in the hole-equipment at level two according to SKB MD 600.004, Version 1.0, lining up the machine, and final control of function.

4.3 Drilling, measurements, and sampling during drilling

4.3.1 Drilling through the overburden

In normal Swedish terrain, the rock surface is often covered with a more or less thick strata of unconsolidated rock material, e.g. till. The procedure of drilling a percussion borehole is in this case divided into two drill phases: 1) drilling through the overburden

Figure 4-1. *A high temperature steam cleaner is used for cleaning the stainless steel casing at level two according to SKB MD 600.004, Version 1.0, before start of Ejector-NO-X drilling. To avoid contamination from surface water and shallow groundwater, the casing is grouted. Photo by Alf Sevastik.*

and 2) drilling in hard rock. The bedrock at drillsites HFM01, HFM02 and HFM03 are all till covered, and hence drilling was performed according to these two phases. Figure 4-2 schematically illustrates the different steps carried out.

Drilling through the overburden may be accomplished using different technical approaches. In this case, so called Ejector NO-X was applied. The prefix “ejector” indicates that the discharge channels for the flushing medium, in this case compressed air, is such that the oxygen and oil contamination of the penetrated soil layers is reduced compared to conventional systems. The NO-X system represents a method for concentric drilling through the overburden with casing. A circular pilot bit, attached to a DTH-hammer shank, and with large internal flushing holes and external flushing grooves is connected to a symmetrical ring bit (reamer) with an internal bayonet coupling. The pilot bit and the ring bit are both rotating clockwise, thereby drilling a borehole with such a diameter that the casing will easily slip down into the reamed borehole. The ring bit is rotating freely against the casing shoe, which is welded to the lower end of the casing. The casing is non-rotating during drilling.

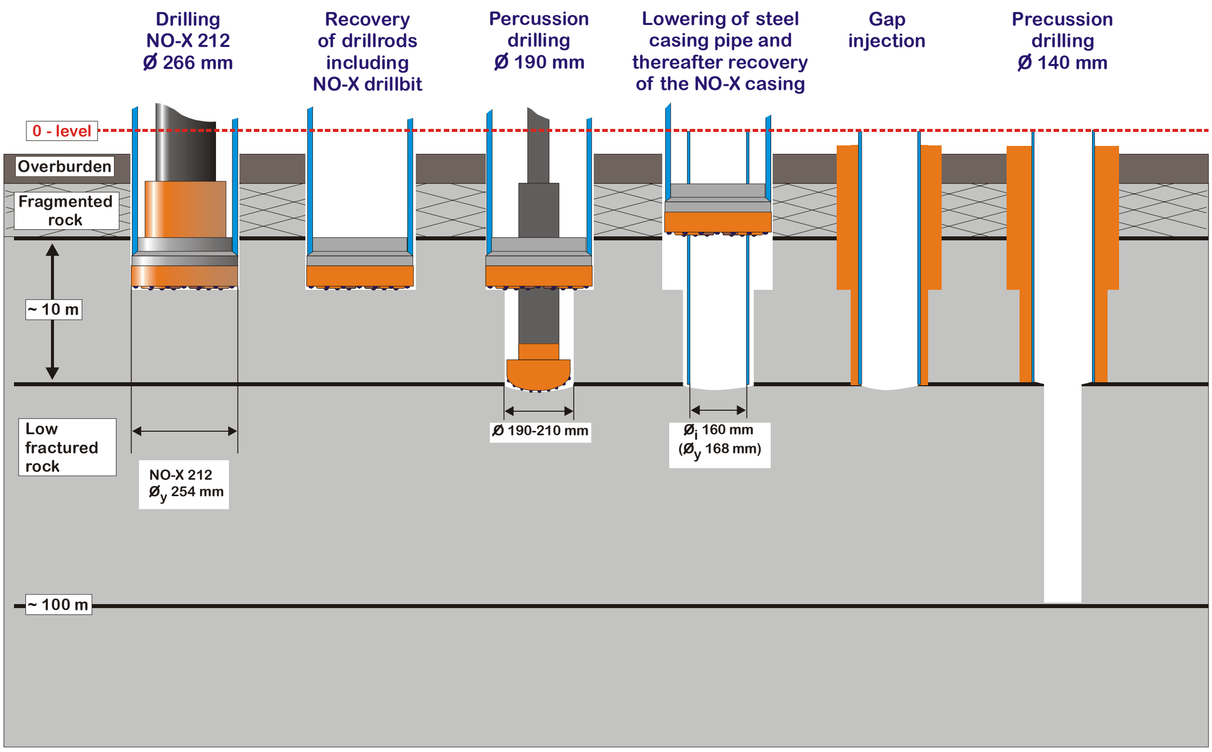


__Figure 4-2.__ The different steps included in the performance of the percussion drilled boreholes HFM01–03.

Drilling through the overburden of boreholes HFM01–03 basically followed the principles for the Ejector-NO-X system. However, the method was to some extent applied in a non-conventional manner. During drilling of a borehole with the diameter 266 mm, a temporary steel casing with an outer diameter of 254 mm was driven through the till overburden and, in some cases, through fragmented rock a short distance into fresh, low-fractured rock, see Figure 4-2. The drillrods with the drillhammer and pilot bit were then retrieved from the borehole. A percussion drill bit was lowered into the borehole inside the temporary casing, and a borehole with a diameter of 190 mm was drilled about 10 m into high-quality, low-fractured rock.

Again the drillrods, drillhammer and drill bit were retrieved, whereafter a stainless steel casing with the external/internal diameter 168/160 mm was applied. The casing was lowered into the borehole in 3 m-lengths, which were successively welded together.

4.3.2 Gap injection

When the casing string had been firmly installed in the borehole, the narrow gap between the borehole wall and the outer wall of the casing was grouted with a cement/water-mixture according to one or both of the techniques illustrated in Figure 3-2. Borehole HFM03 was, however, only grouted with a bottom plug, which after grouting was drilled through. This operation was performed in order to isolate the deeper groundwater aquifer penetrated by the borehole from contamination with shallow groundwater and surface water.

4.3.3 Percussion drilling in hard rock

After stiffening of the grout, drilling could continue and was now performed to the full borehole length with conventional percussion drilling. Before start of drilling, the diameter of the drill bit was measured. In this last drill step the borehole diameter (approximately the same as the drill bit diameter) is normally 140 mm, see Figure 4-2. However, a diameter decrease of about 1 mm/100 drill length is to be expected during drilling in the rock types prevailing in the Forsmark area. For boreholes deeper then 100 metre the drill bit had to be grinded.

4.3.4 Sampling and measurements during drilling

During drilling, a sampling and measurement program was performed, which included:

- Collecting of one soil sample per metre drill length. Analysis and results are reported in /5/.

- Collecting of one sample per 3 metre drill length of drill cuttings from the bedrock. Each sample consists of three individual samples taken at every metre borehole length, collected in one plastic box marked with a sample number. Effort is devoted to avoid mixing of the three individual samples. A first description of the material was made on-site including the mineral content and rock structure, which gave a preliminary classification of the rock type. These samples were examined and interpreted together with a BIPS-log (so called Boremap-mapping) and reported in /6/.

- Measurements of the penetration rate (one measurement per 20 cm drill length). The time needed for the drill bit to sink 20 cm was recorded manually in a paper record.

- Performing one observation of groundwater flow (if any) and water colour per 20 cm drill length and a measurement of the flow rate at each major flow change observed. The measured values were noted in a paper record.

- Measurements of one value of the electrical conductivity of the groundwater (if any) per 3 metre drill length (noted in a paper record).

The results from the third and fourth items were used as supporting data for the Boremap-mapping of the boreholes mentioned above. The last item gave on-site information about hydraulic and hydro-geochemical characteristics of the penetrated aquifers at the respective drillsites.

4.4 Finishing off work

Finishing off work included rinsing of the borehole from drill cuttings by a "blow out" with the compressor at maximum capacity during 30 minutes. The recovery of the groundwater table was recorded, enabling a preliminary evaluation of the hydraulic conditions. The drillrods were then removed from the hole, and the diameter of the drill bit was measured as well as the deviation of the borehole. The borehole was secured by a stainless steel lockable cap, mounted on the casing. Finally, the equipment was removed, the site cleaned and a joint inspection was made by representatives from SKB and the Contractor to ensure that the site had been satisfactorily restored.

4.5 Data handling

Minutes for the following items: Activities, Cleaning of the equipment, Drilling, Borehole, Percussion drilling penetration rate, Deliverance of field material, and Discrepancy report were collected by the Activity Leader, who made a control of the information, and had it stored in the SKB database SICADA /7/.

4.6 Environmental control

A programme according to SKB's routine for environmental control was followed throughout the activity. A checklist was filled in and signed by the Activity Leader and finally filed in the SKB archive.

5 Results

All data were stored in the SICADA database for Forsmark. Field Note numbers are 8, 10, 17, 31, 46 /7/.

Below, a summary of the data achieved during the drilling period is presented.

5.1 Borehole design

Administrative, geometric, and technical data for the percussion drilled boreholes HFM01–03 are presented in Table 5-1. The design of each borehole is illustrated in drawings in Figures 5-1, 5-2, and 5-3.

Table 5-1. Administrative, geometric and technical data for boreholes HFM01–03.

Parameter	HFM01	HFM02	HFM03
Drilling period	From 2002-04-18 to 2002-05-03	From 2002-05-07 to 2002-05-21	From 2002-05-27 to 2002-05-27
Borehole inclination (starting point)	–77.513° (– = downwards)	–87.7868° (– = downwards)	–87.2835° (– = downwards)
Borehole bearing	34.061°	6.5165°	264.5276°
Borehole length	200.20 m	100.00 m	26.00 m
Borehole diameter	From 0.00 m to 31.93 m: 0.204 m	From 0.00 m to 25.40 m: 0.204 m	From 0.00 m to 13.10 m: 0.204 m
	From 31.93 m to 200.2 m: decreasing from 0.140 m to 0.138 m	From 25.40 m to 100.0 m: decreasing from 0.138 m to 0.137 m	From 13.10 m to 26.00 m: decreasing from 0.137 m to 0.136 m
Casing length	31.93 m	25.40 m	13.10 m
Casing diameter	$Ø_o$ = 168 mm, $Ø_i$ = 160 mm	$Ø_o$ = 168 mm, $Ø_i$ = 160 mm	$Ø_o$ = 168 mm, $Ø_i$ = 160 mm
Drill bit diameter	Start of drilling: 0.140 m End of drilling: 0.140 m	Start of drilling: 0.140 m End of drilling: 0.137 m	Start of drilling: 0.137 m End of drilling: 0.136 m
Starting point coordinates (system RT90/RHB70)	Northing: 6699605.181 m Easting: 1631484.552 m Elevation: 1.731 m.a.s.l.	Northing: 6699593.212 m Easting: 1631268.674 m Elevation: 3.053 m.a.s.l.	Northing: 6699592.812 m Easting: 1631272.626 m Elevation: 3.148 m.a.s.l.

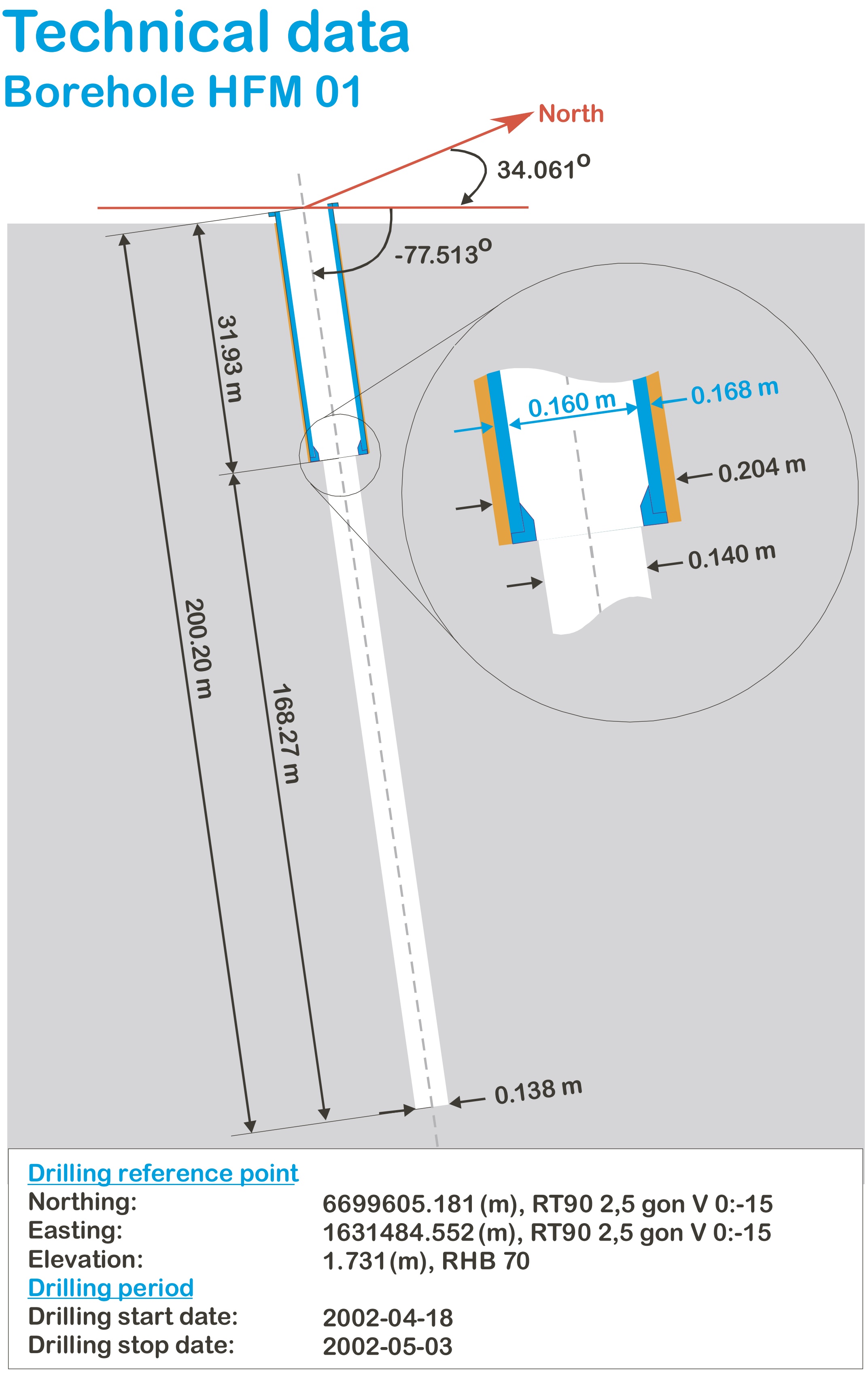
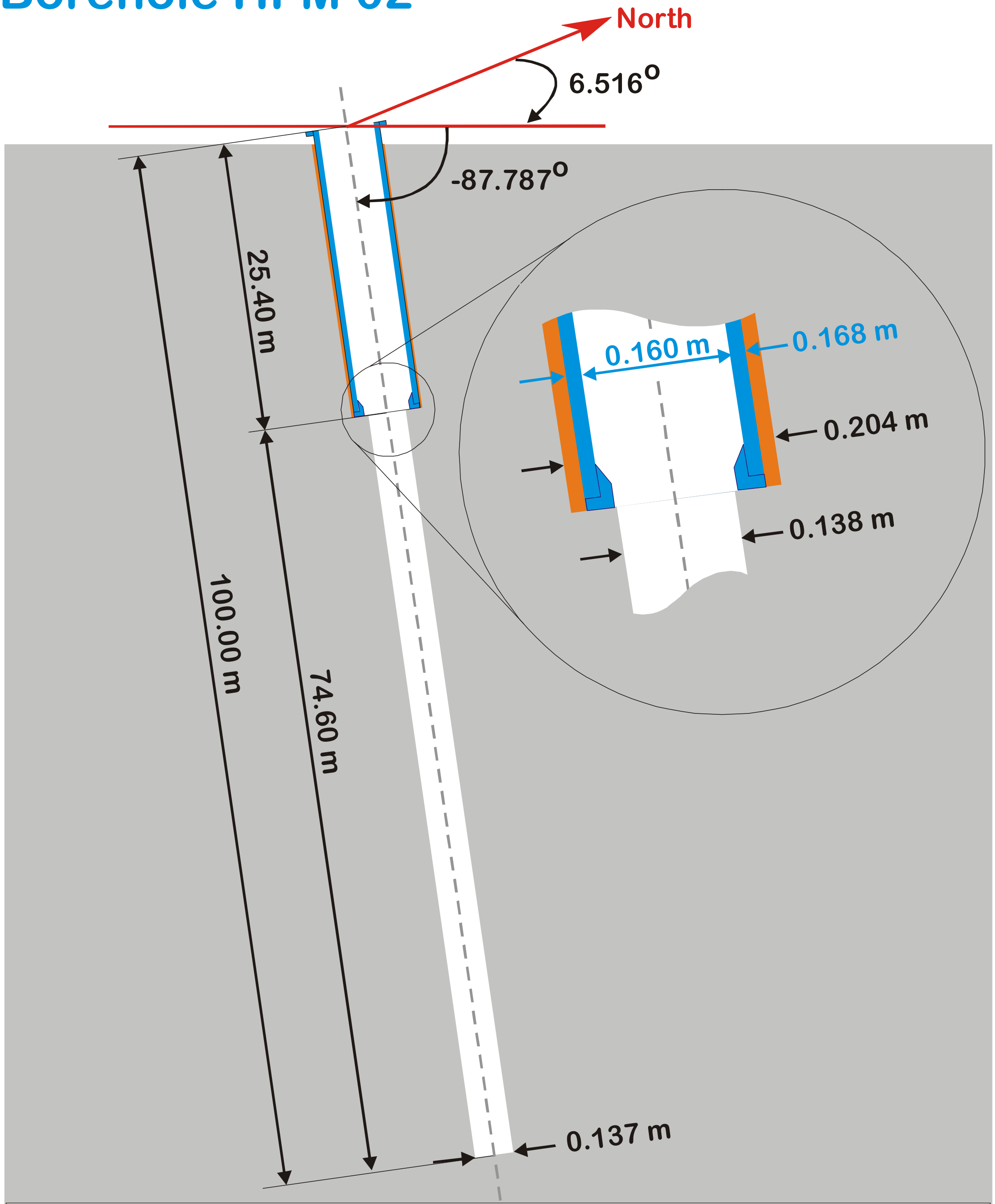


Figure 5-1. *Technical data for borehole HFM01.*

Technical data

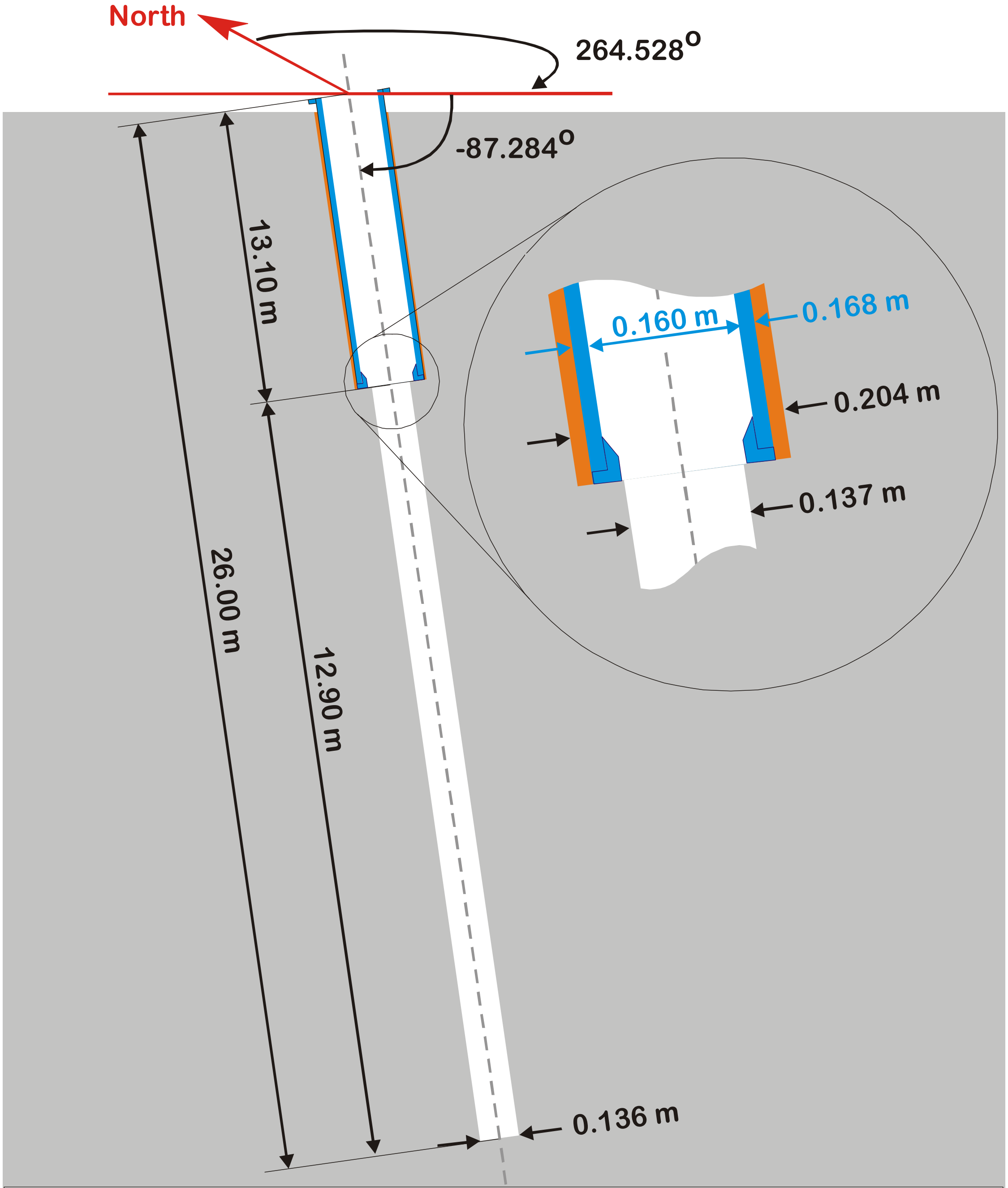
Borehole HFM 02



Drilling reference point	
Northing:	6699593.212 (m), RT90 2,5 gon V 0:-15
Easting:	1631268.674 (m), RT90 2,5 gon V 0:-15
Elevation:	3.053 (m), RHB 70
Drilling period	
Drilling start date:	2002-05-07
Drilling stop date:	2002-05-21

Figure 5-2*. Technical data for borehole HMF02.*

Technical data
Borehole HFM 03



Drilling reference point	
Northing:	**6699592.812 (m), RT90 2,5 gon V 0:-15**
Easting:	**1631272.626 (m), RT90 2,5 gon V 0:-15**
Elevation:	**3.148 (m), RHB 70**
Drilling period	
Drilling start date:	**2002-05-27**
Drilling stop date:	**2002-05-28**

***Figure 5-3**. Technical data for borehole HMF03.*

5.2 Consumables used up during drilling

The amount of oil products consumed in each borehole during drilling and grout used for gap injection of the respective casings is reported in Tables 5-2 and 5-3. Regarding hammer oil and compressor oil, these products are indeed entering the borehole but are, on the other hand, continuously retrieved from the borehole due to the permanent air flushing during drilling. After completion of drilling, only minor remainders of the products are left in the borehole.

Table 5-2. Oil consumption.

Borehole ID	Hammer oil Preem Hydra 46	Compressor oil Schuman 46
HFM01	15 L	Not detected
HFM02	5 L	Not detected
HFM03	0 L	Not detected

Table 5-3. Consumption of cement grouting.

Borehole ID	Casing length	Cement volume (Portland Standard Cement)	Grouting method	Remarks
HFM01	31.93 m	500 kg	Packer	
HFM02	25.40 m	400 kg	Hose	Highly fractured rock
HFM03	13.10 m	10 kg	Bottom plug	

5.3 Well Cad presentations

Technical as well as geoscientific results achieved during drilling are also presented in Figures 5-4, 5-5 and 5-6.

The deviation measurements made in borehole HFM01 (Figure 5-4) indicate that the end (bottom) point deviates 9.9 m downwards and 7.2 m to the right compared to an imagined straight line following the dip and strike of the borehole start point (inclination –77.513º and bearing 34.061º). The corresponding values for borehole HFM02 are 0.7 m upwards and 0.18 m to the right, compared to a straight line with the inclination –87.787º and bearing 6.516º. Regarding the short borehole HFM03, no measurable deviation was observed (dip/strike at borehole start –87.284º and 264.528º respectively).

Especially notable results are associated with a written comment in the Well Cad diagram. For example, in borehole HFM01 (Figure 5-4), decreasing penetration rate in combination with a water inflow of 10 L/min (see the Deltaqi column) is interpreted as a subhorizontal fracture zone at approximately 22–25 m, and is commented as such in the diagram. The interpretation of the zone beeing subhorizontal is, however, not based on specific measurements during or after drilling of this first borehole at drillsite DS1 (the zone was immediately after drilling cased and gap injected), but is rather an overall assessment, based on results from all boreholes at the site, of the structural conditions prevailing in the shallow part of the bedrock.

A fracture zone is also interpreted between 16 and 21 m in borehole HFM02 (Figure 5-5) and at 21–23 m depth in HFM03 (Figure 5-6). In both cases the inclination of the zone is interpreted to be subhorizontal based on hydraulic responses observed between these boreholes and approximately the same level in borehole KFM01A during drilling of the latter borehole. In HFM03 the Boremap-mapping supports this interpretation (HFM02 is cased at the actual level and, hence, not Boremap-mapped).

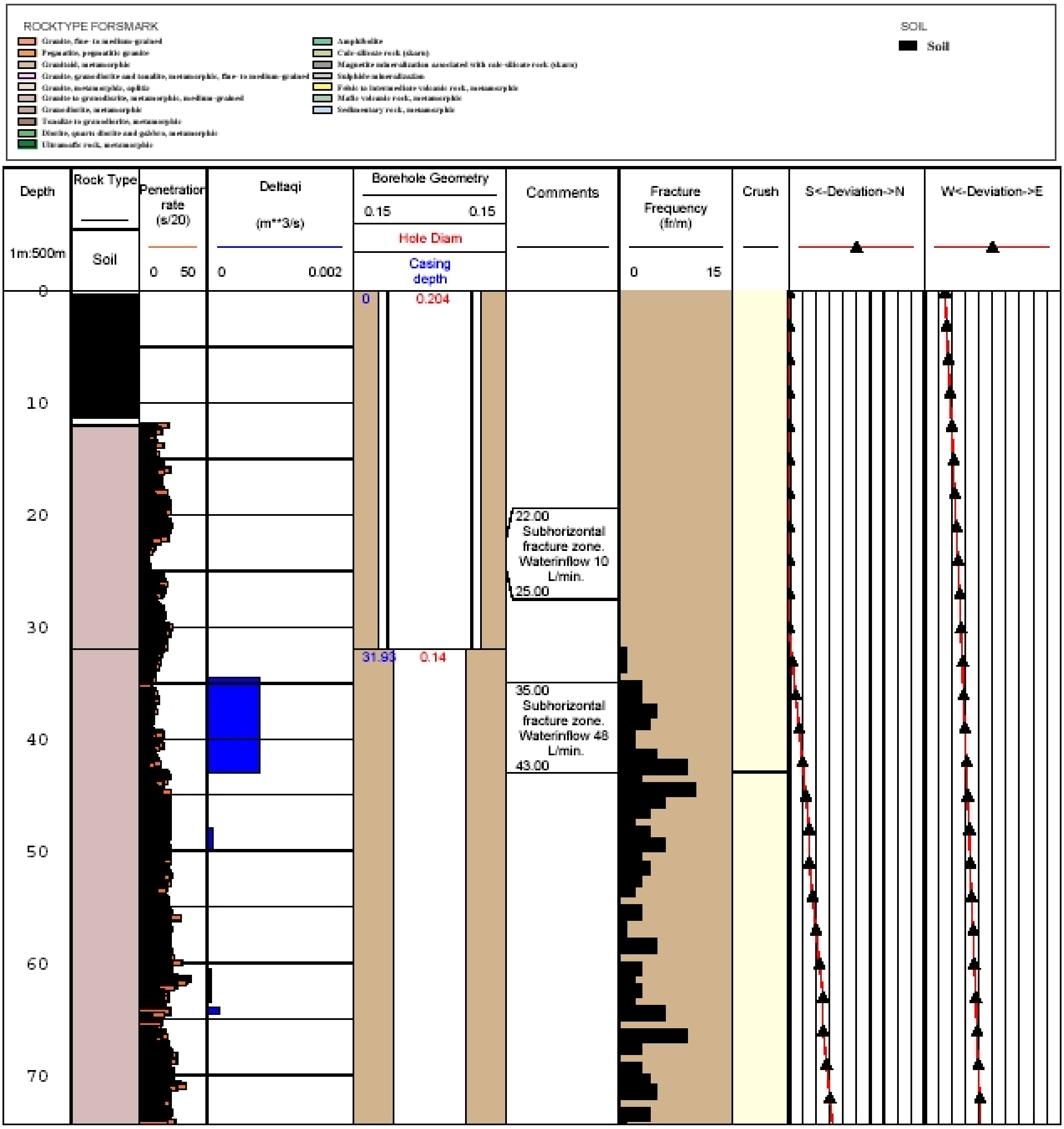
A deeper fracture zone, between 35 and 43 m, was indicated in HFM01 by a significant inflow of groundwater, estimated at 48 L/min (Figure 5-4). The Fracture Frequency column implies that the zone could be even broader. A crushed part is marked at 43 m in the Crush column. Borehole HFM01 has served as flushing water well for drilling of the core drilled part of borehole KFM01A during the period August to October 2002. The impact of the long pumping period has increased the water-yield, which today is estimated to exceed 120 L/min.

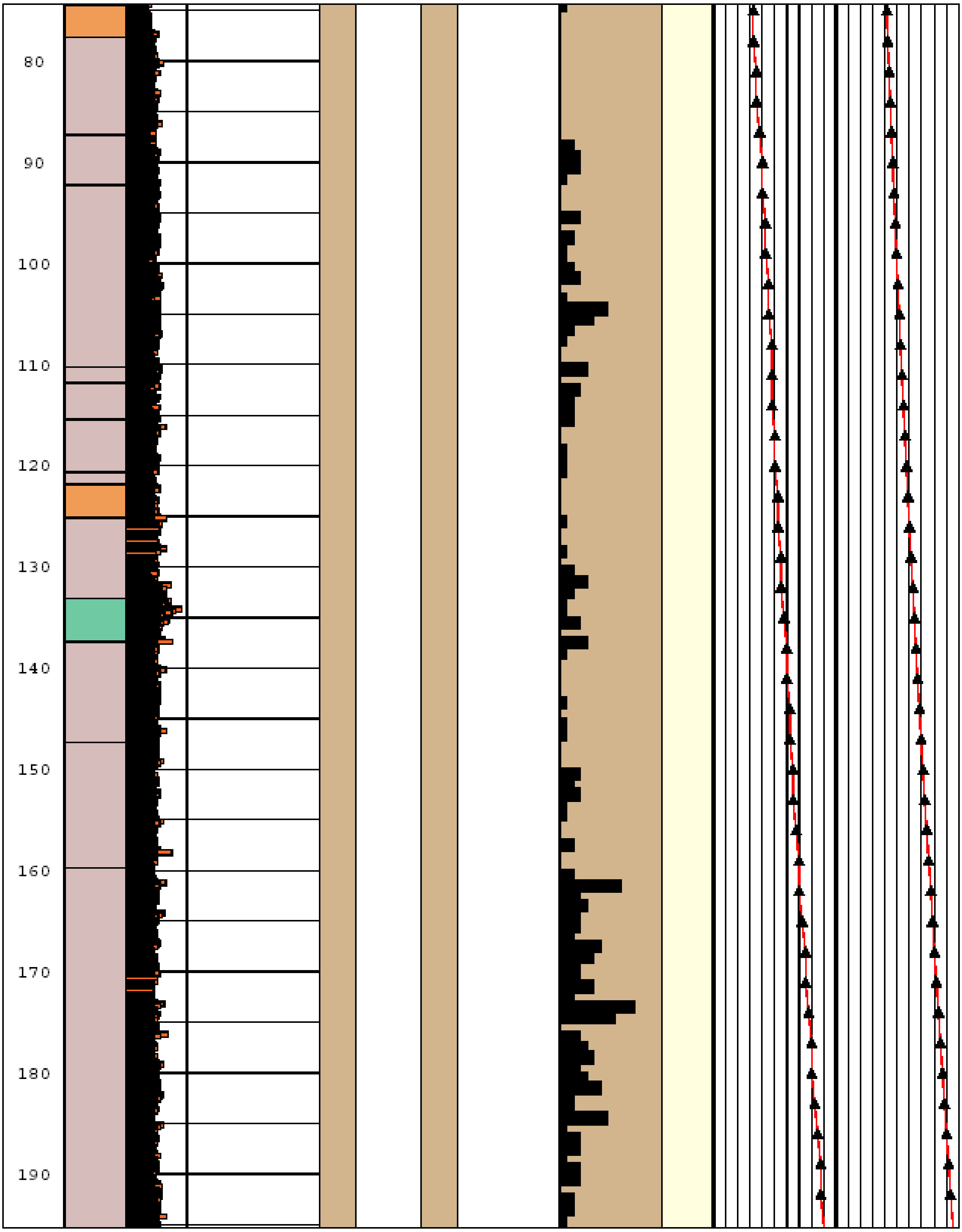
Also in borehole HFM02 a second, deeper situated (at 42–44 m) fracture zone was revealed (Figure 5-5). This zone was associated with an increased fracture frequency and a very large inflow of groundwater, c 700 L/min.

After completion of drilling, hydraulic interference tests were performed between the boreholes at drillsite DS1 /8/. Significant hydraulic responses, supported by responses observed during the drilling operations, indicate that the deeper fracture zone observed in HFM01 and HFM02 may be one and the same, and that this zone also is intersected by the telescopic borehole KFM01A. These results imply that the inclination of the fracture zone is subhorizontal. Furthermore, the results are hinting at the possibility that the more shallowly situated fracture zone observed in HFM01, HFM02 and HFM03 is connected between the boreholes and, hence, likewise subhorizontal.

Figure 5-7 illustrates a tentative, simplified interpretation of the structural conditions in the upper part of the bedrock at drillsite DS1, based on observations during drilling as well as on the Boremap-mapping of the boreholes at drillsite DS1 and on results from hydraulic interference tests. Continued investigations will either confirm or modify this interpretation.

Title	PERCUSSION BOREHOLE HFM01		
Site	FORSMARK	Coordinate System	RT90-RHB70
Borehole	HFM01	Northing [m]	6699605.181
Diameter [m]	0.14	Easting [m]	1631484.552
Length [m]	200.2	Elevation [m.a.s.l.]	1.731
Bearing [°]	34.0606	Drilling Start Date	2002-04-18 14:30:00
Inclination [°]	-77.5135	Drilling Stop Date	2002-05-03 17:22:00
Remark		Plot Date	2003-04-09 21:09:24

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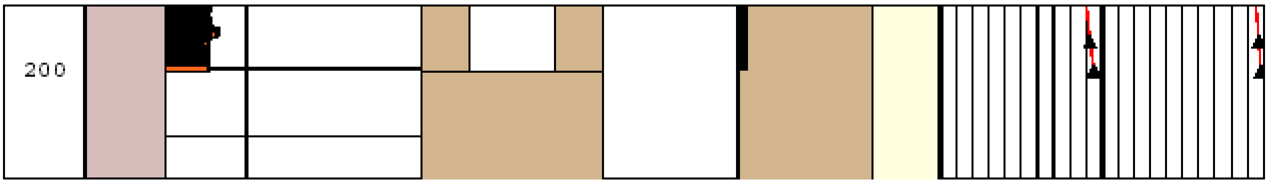


Figure 5-4. *Results achieved during drilling of borehole HMF01.*

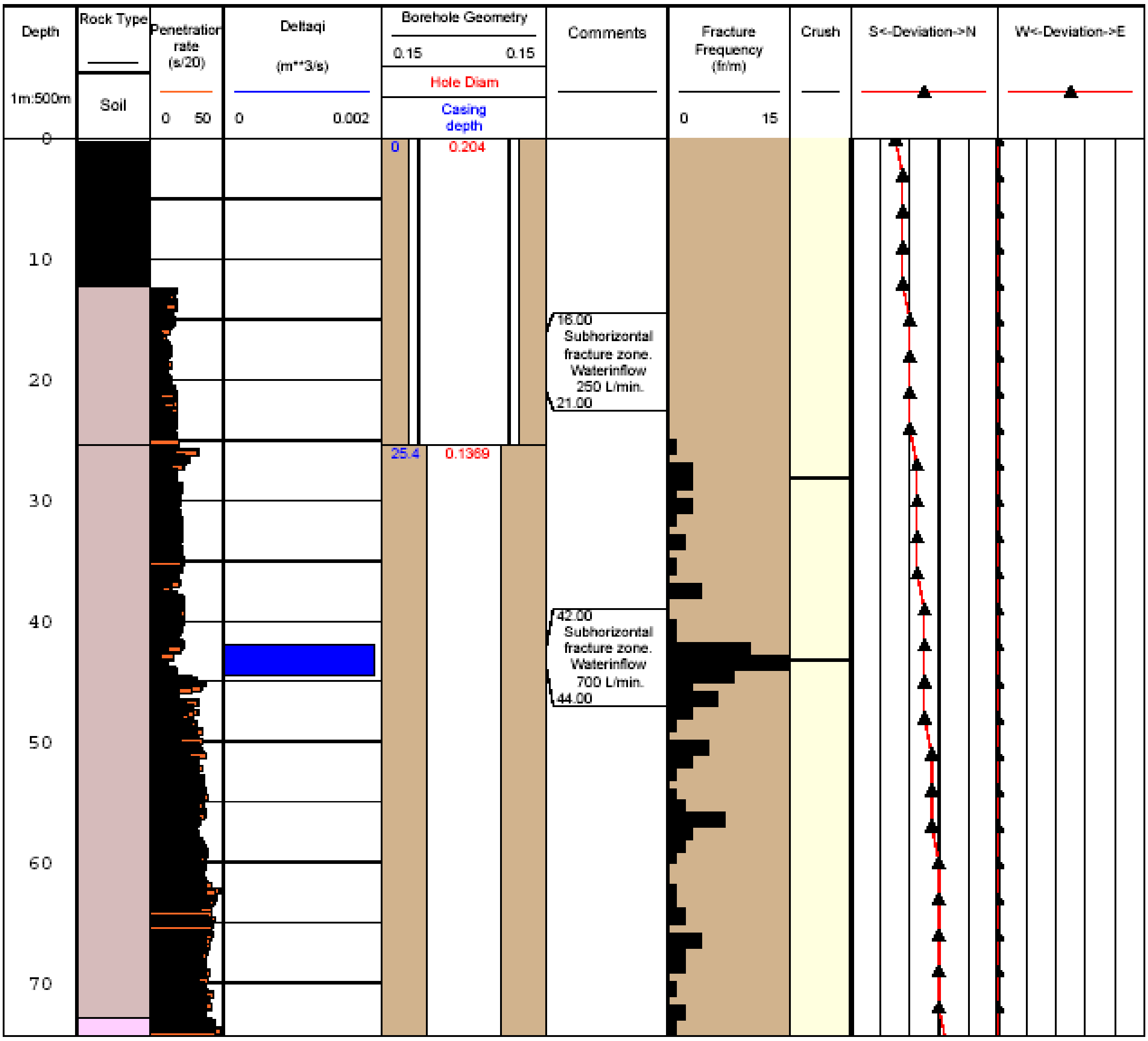
Title	PERCUSSION BOREHOLE HFM02		
Site	FORSMARK	Coordinate System	RT90-RHB70
Borehole	HFM02	Northing [m]	6699593.212
Diameter [m]	0.1369	Easting [m]	1631268.674
Length [m]	100	Elevation [m.a.s.l.]	3.053
Bearing [°]	6.5165	Drilling Start Date	2002-05-07 10:00:00
Inclination [°]	-87.7868	Drilling Stop Date	2002-05-21 12:00:00
Remark		Plot Date	2003-04-09 21:09:24

ROCKTYPE FORSMARK

- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granitoid, metamorphic
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite, metamorphic, aplitic
- Granite to granodiorite, metamorphic, medium-grained
- Granodiorite, metamorphic
- Tonalite to granodiorite, metamorphic
- Diorite, quartz diorite and gabbro, metamorphic
- Ultramafic rock, metamorphic
- Amphibolite
- Calc-silicate rock (skarn)
- Magnetite mineralization associated with calc-silicate rock (skarn)
- Sulphide mineralization
- Felsic to intermediate volcanic rock, metamorphic
- Mafic volcanic rock, metamorphic
- Sedimentary rock, metamorphic

SOIL

- Soil



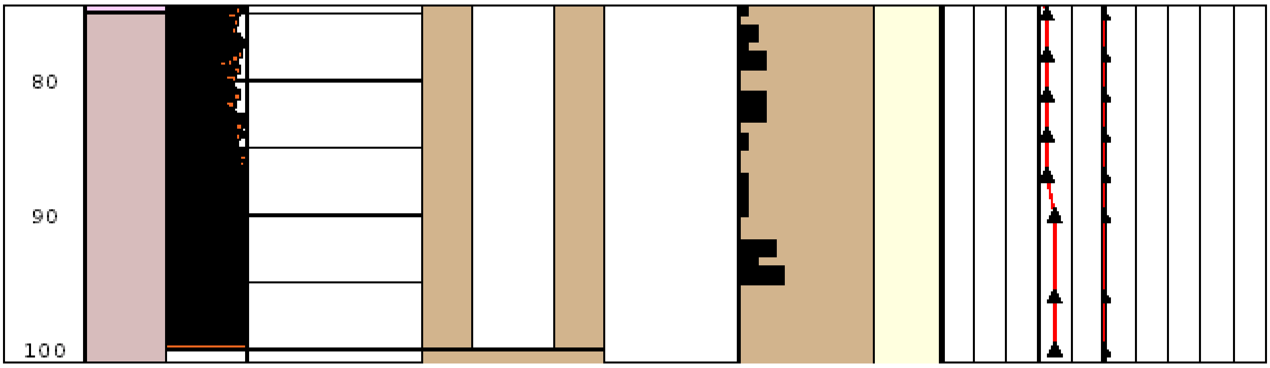


Figure 5-5. *Results achieved during drilling of borehole HMF02.*

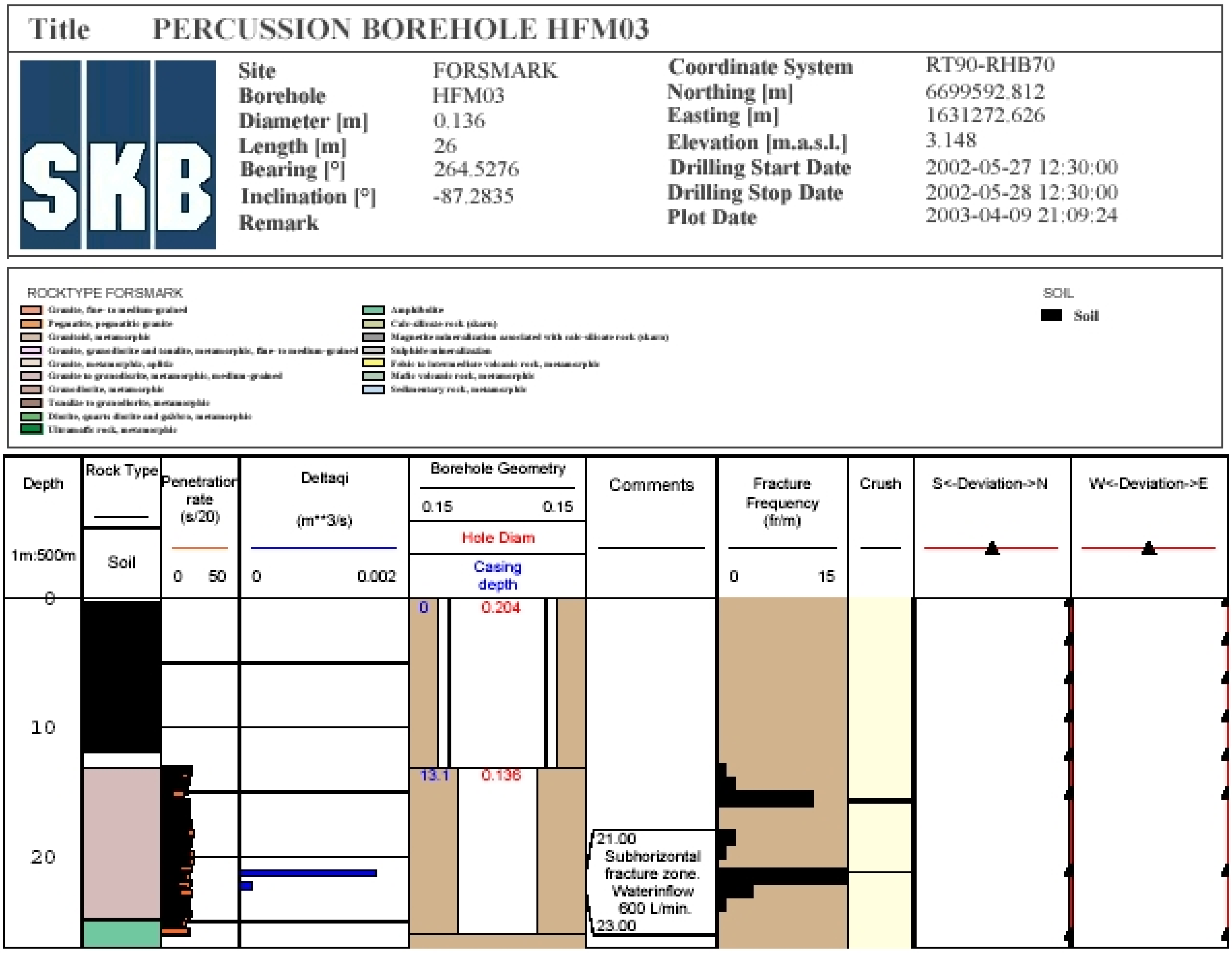


Figure 5-6. Results achieved during drilling of borehole HMF03.

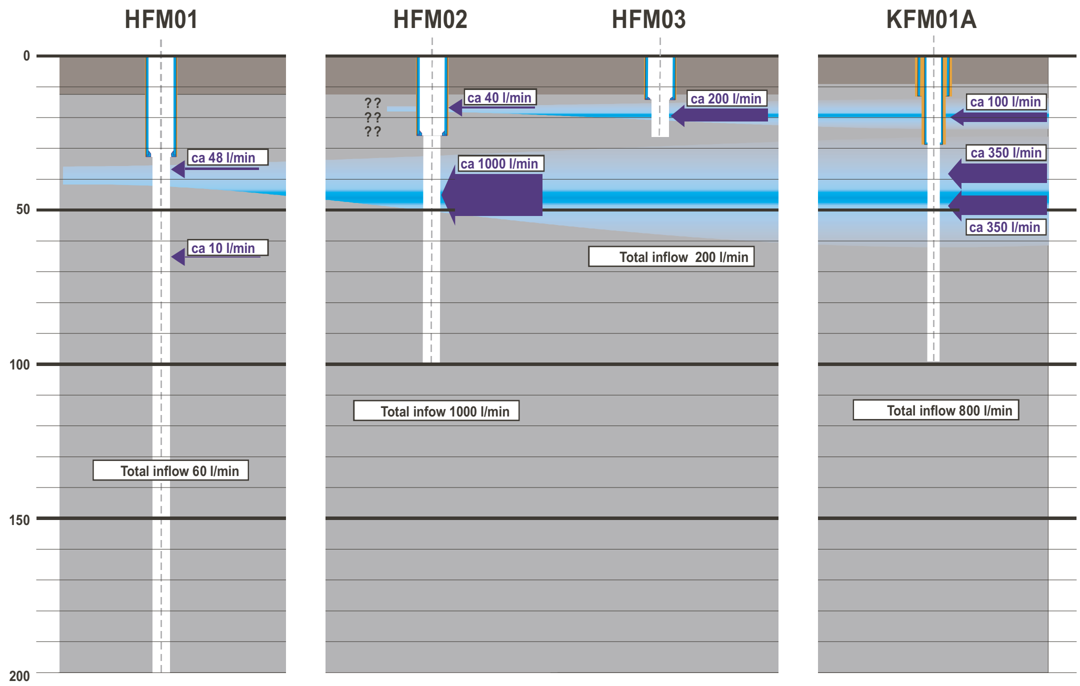


Figure 5-7. *Tentative, simplified interpretation of the structural conditions in the shallow part of the bedrock at drillsite DS1. Although evident proofs are not available, the shallow one of the two interpreted subhorizontal fracture zones may also intersect borehole HFM01.*

6 References

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