P-05-194

Oskarshamn site investigation

Percussion drilling of boreholes HSH04, HSH05, HSH06, HAV11, HAV12, HAV13 and HAV14

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August 2005

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ISSN 1651-4416
SKB P-05-194

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Keywords: Percussion drilling, Lineament investigation, Hydraulic responses.

Abstract

Drilling of percussion holes is required as a supplement to the drilling of deep cored holes. In general, the percussion holes serve two principal purposes: water supply for core drilling and as investigation boreholes to shallow depth.

Drilling of percussion boreholes HSH04, HSH05, HSH06, HAV11, HAV12, HAV13 and HAV14 was done to investigate previously interpreted lineaments in the Simpevarp subarea.

The encountered geology in the boreholes corresponds well with expectations based on surface geological mapping.

The water yields varied from 2.5 to over 200 litres per minute.

Indications of deformational zones could be seen in boreholes HAV11, HAV12, HAV13 and HAV14 as high water yields, reduced magnetic susceptibility and variable penetration rates.

No definite indication of a deformation zone could be established from the drilling results in boreholes HSH04, HSH05 or HSH06.

Sammanfattning

Hammarborrhål borras i allmänhet för två olika ändamål: dels för vattenförsörjning vid kärnborrning och dels för att möjliggöra undersökningar i ytligare berggrund.

Borrningen av hammarborrhålen HSH04, HSH05, HSH06, HAV11, HAV12, HAV13 och HAV14 utfördes för undersökning av tidigare tolkade lineament i delområdet Simpevarp inom platsundersökningen i Oskarshamn.

Den geologi som påträffades i borrhålen överrensstämmer väl med det som kunde förväntas från den geologiska karteringen på ytan.

Vatteninflödet i borrhålen varierade från 2,5 till över 200 minutliter.

Borrningsresultaten från hammarborrhålen HAV11, HAV12, HAV13 och HAV14 gav indikationer på deformationszoner genom hög vattenföring, reducerad magnetisk susceptibilitet och varierande borrsjunkhastighet.

Borrningsresultaten från hammarborrhålen HSH04, HSH05 eller HSH06 däremot, visade inga tydliga indikationer på någon deformationszon.

Contents

1 Introduction

SKB performs site investigations in order to evaluate the feasibility of locating a deep repository for high level radioactive waste /1/ in two Swedish municipalities: Östhammar and Oskarshamn /2/.

A number of linear features, lineaments, covering the site investigation area were identified by airborne geophysical methods or by remote sensing, primarily of topography /3/.

Follow-up ground geophysics by refraction seismic were done over selected lineaments /4/, see Figure 1-1.

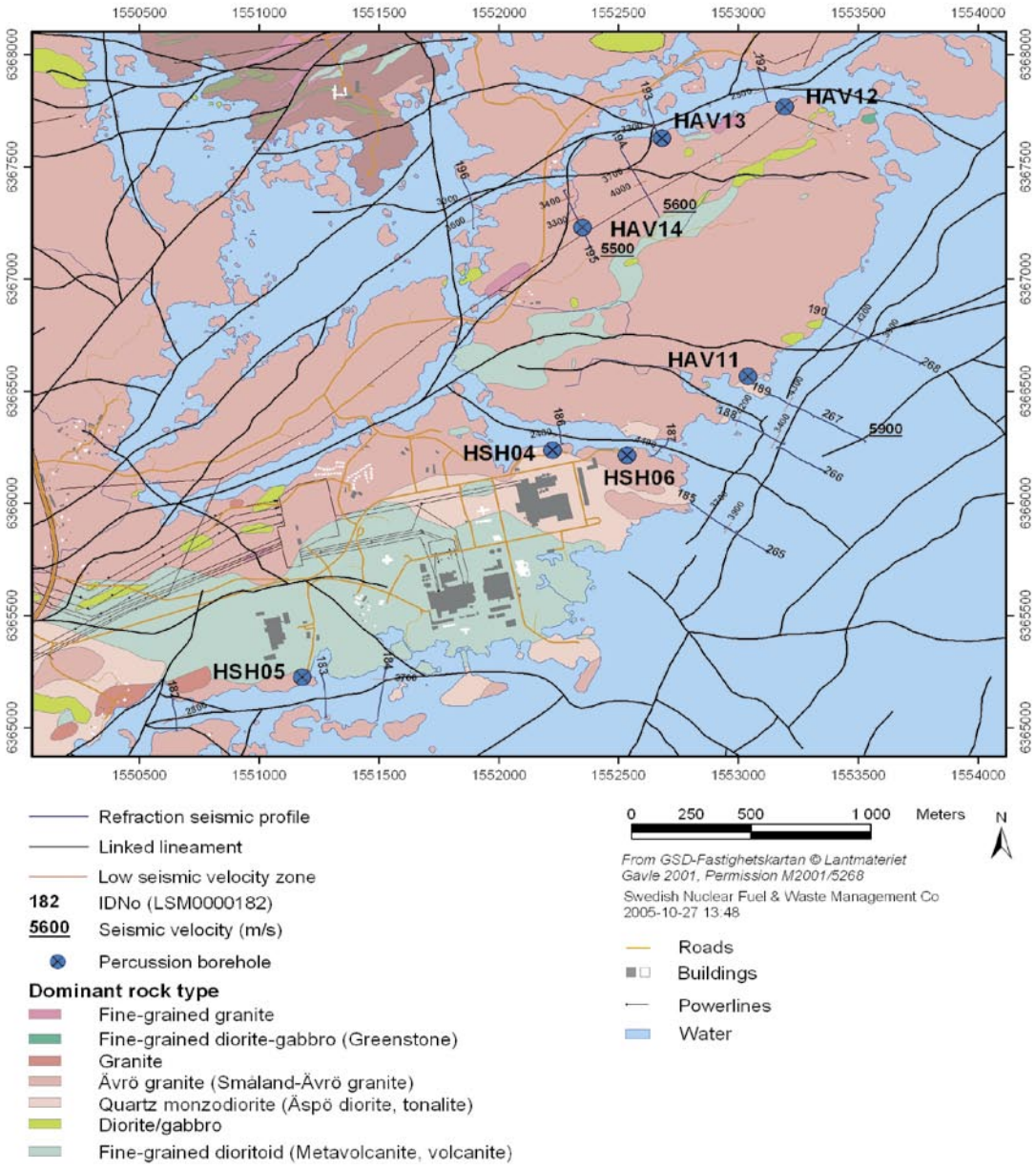


Figure 1-1. *Location of boreholes HSH04, HSH05, HSH06, HAV11, HAV12, HAV13 and HAV14 in the Simpevarp subarea. The map shows the bedrock geology, lineaments, refraction seismic lines, as well as houses, roads and power lines.*

The percussion drilling to depths of 142–236 m was done to investigate the interpreted lineaments and related geophysical anomalies.

This report will describe the drilling of percussion boreholes HSH04, HSH05, HSH06, HAV11, HAV12, HAV13 and HAV14 that were drilled to investigate interpreted lineaments. Measurements performed during the drilling phase will also be described in the report.

The holes were drilled in the Simpevarp subarea of the Oskarshamn site investigation, see Figure 1-1.

The decision to perform the drilling of boreholes HSH04, HSH05, HSH06, HAV11, HAV12, HAV13 and HAV14 is given in SKB id 1022342, date: 2004-03-09, internal document.

The regional authorities were informed by letter on 2003-10-14, SKB id 1017877, internal document and their respond is from 2003-10-28, dnr 525-13633-03, SKB id 1018498, internal document.

The drilling and all related on-site operations were performed according to a specific Activity Plan (AP PS 400-03-096). Reference is given in the activity plan to procedures in the SKB Method Description for Percussion Drilling (SKB MD 610.003, Version 1.0) and relevant method instructions for handling of chemicals, surveying and evaluation of cuttings, see Table 1-1.

The activity plans and method descriptions are SKB internal documents.
All data were stored in the SICADA database for Oskarshamn.

Table 1-1. Controlling documents for the performance of the activity.

Activity plan	**Number**	**Version**
Hammarborrning av HAV11-HAV14 och HSH04-HSH06 för lineamentsundersökningar	AP PS 400-03-096	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för hammarborrning	SKB MD 610.003	1.0
Metodbeskrivning för undersökning av borrkax	SKB MD 142.001	1.0
Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning	SKB MD 600.004	1.0
Instruktion för användning av kemiska produkter och material vid borrning och undersökningar	SKB MD 600.006	1.0
Instruktion för borrplatsanläggning	SKB MD 600.005	1.0
Instruktion för spolvattenhantering	SKB MD 620.007	1.0
Instruktion för utsättning och inmätning av borrhål	SKB MD 600.002	1.0

2 Objective and scope

This report will describe the drilling of the seven percussion holes HSH04, HSH05, HSH06, HAV11, HAV12, HAV13 and HAV14 as well as the measurements performed during drilling i.e. logging of preliminary geology and measurements of water inflow.

The objectives for the boreholes, prior to drilling, are summarised in Table 2-1.

All boreholes except for HSH06 and HAV14 were drilled parallel to seismic profiles /4/ to test anomalies and interpreted lineaments, see Figure 1-1. Borehole HSH06 was drilled to test the interpreted lineament to the north, it is situated west of a seismic profile, see Figure 1-1 and Figure 6-2. HAV14 was drilled to test interpreted lineament on the western part of the island Ävrö, at almost right angles to the seismic profile, see Figure 1-1 and Figure 6-4.

Table 2-1. Borehole objectives before drilling.

Borehole	Drilling objective
HSH04	Borehole should intercept a possible fracture zone/low velocity zone at approximately 100 m.
HSH05	Borehole should intercept a possible fracture zone/low velocity zone at approximately 150–200 m.
HSH06	Drilled close to HSH01 with a dip of 60 degrees which gives a good angle towards a possibly steeply dipping fracture zone.
HAV11	The aim is to drill to a length of 300 m to verify a possibly steeply dipping fracture zone. The borehole should intercept a reflector from reflector seismic at ca 80 m.
HAV12	Borehole should intercept a possible fracture zone/low velocity zone at approximately 150 m.
HAV13	Borehole should intercept a possible fracture zone/low velocity zone at approximately 150 m.
HAV14	Drilled towards the west and not along a geophysical profile. The interpreted lineament aimed for has a northerly direction.

3 Equipment

In this chapter the drilling equipment and the equipment used for measurements and sampling is briefly described.

Drilling and completion were made by contractor Sven Andersson, Uppsala AB.

3.1 Drilling equipment

Drilling of the boreholes HSH04, HSH05 and HSH06 was made with a Nemek 407 RTS percussion drilling machine supplied with accessories. The drilling machine was equipped with separate engines for transportation and power supplies. For the raising of water and drill cuttings from the borehole, a 27 bar diesel air-compressor, type Atlas-Copco XRVS 455 Md was used. The DTH drillhammer was of type Secoroc 5", lowered into the borehole by a Driconeq 114 mm pipe string.

The drilling of boreholes HAV11, HAV12, HAV13 and HAV14 was made with a Puntel drilling rig supplied with accessories. For the raising of water and drill cuttings from the borehole, a 27 bar diesel air-compressor, type Atlas-Copco XRVS 455 Md was used. The DTH drillhammer was of type Secoroc 5", lowered into the borehole by a Driconeq 114 mm pipe string.

3.2 Equipment for measurements and sampling

Flow measurements during drilling were performed using a graded vessel and a stop watch. Measurement of the drilling penetration time was done manually with readings for every 20 cm.

Samples of soil and drill cuttings were collected in sampling pots.

4 Execution

The work was performed in accordance with SKB MD 610.003, Version 1.0 (Method Description for Percussion Drilling, SKB internal document) and consisted of:

- preparations,
- drilling through overburden,
- gap injection techniques and equipment,
- percussion drilling in hard rock,
- sampling and measurements,
- borehole completion,
- data handling,
- environmental control.

4.1 Preparations

The preparation stage included the Contractor's functional control of his equipment. The machinery and chemicals used have to comply with SKB MD 600.006, Version 1.0 (Method Instruction for Chemical Products and Materials, SKB internal document).

The equipment was cleaned in accordance with SKB MD 600.004, Version 1.0 (Method Instruction for Cleaning Borehole Equipment and certain Ground-based Equipment, SKB internal document).

4.2 Drilling through overburden

For boreholes HSH04, HSH05, HSH06, HAV11, HAV12, HAV13 and HAV14 Excentric percussion drilling with 200 mm diameter ("ODEX 160") was made through the unconsolidated soil and fractured near-surface bedrock to a depth of between 9 and 15 m.

4.3 Gap injection techniques and equipment

In order to prevent surface water and shallow groundwater to infiltrate into deeper parts of the borehole, the gap between the borehole wall and the casing was grouted with cement, see Figure 4-1.

A packer was installed at the bottom of the cased section. The concrete was introduced through the packer and allowed to flow up between the casing and the bedrock wall. A reference sample of the cement paste was kept cool and dark on the surface to ensure that drilling was not resumed until the mixture had hardened.

The concrete seal was tested by blowing compressed air in the hole and measuring the amount of in-flowing water. As no water could be measured in the hole, the tightness of the gap injection was considered to be sufficient.

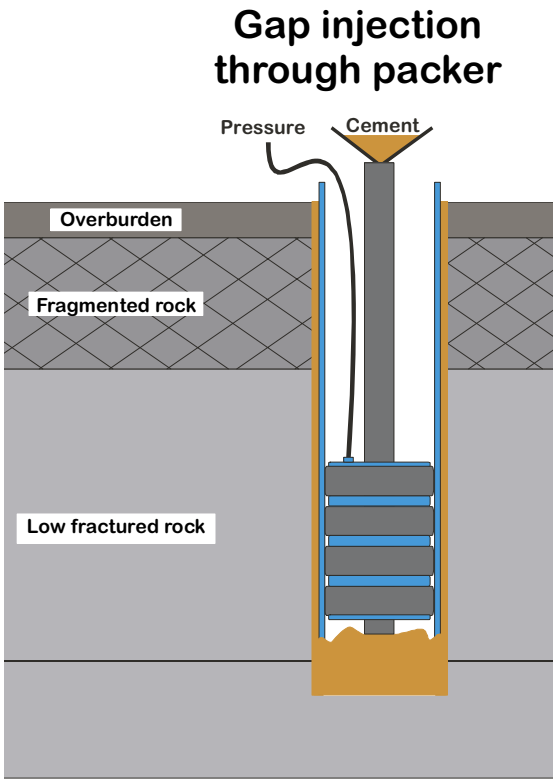


Figure 4-1. *Gap injection technique.*

Figure 4-2. *Drilling rig at the site for HAV11 on the south-eastern coastline of the island Ävrö.*

4.4 Percussion drilling in hard rock

After allowing the cement to harden, drilling could continue and was performed to the full borehole length with conventional percussion drilling with a nominal diameter of 140 mm.

4.5 Sampling and measurements

Sampling and measurements done by the drill site geologist see Figure 4-3, and the drilling crew during drilling included:

- Samples of rock chip drill cuttings were taken along the hole. One sample was taken per metre drilled. The samples were stored for subsequent logging of preliminary geology (lithology, dominant mineralogy, grain-size, roundness and, if possible, structural or textural information) and measurement of magnetic susceptibility with hand held equipment. Small cups of return water were collected during drilling, one for every metre, for determination of water colour and intensity which in turn gives an indication of clay content and level of oxidation.
- Penetration time (expressed as seconds per 20 cm) was recorded manually.
- The water yield from the hole was estimated when noticeable changes in water flow occurred during drilling, when drilling is resumed after a longer stop (overnight and/or weekend) and after the drilling phase was completed. The method employed is blowing compressed air through the drill stem and measuring the amount of return water during steady state conditions.

When the drilling was completed the hole was rinsed from drill cuttings by blowing air with the compressor at maximum capacity for 30 minutes.

Deviation measurements were not made in conjunction with drilling of the holes.

Figure 4-3. *Sampling and preliminary logging by the drill site geologist of samples of rock chip drill cuttings at the drill site for borehole HAV11 on the south-eastern coastline of the island Ävrö.*

4.6 Borehole completion

The boreholes were secured by mounting of lockable steel caps on the casing.

Removal of all equipment, cleaning of the drill sites and joint inspections were made by representatives from SKB and the Contractor to ensure that the sites had been restored to a satisfactory level.

4.7 Data handling

Data collected by the drillers and drill site personnel were reported in daily logs and other protocols and delivered to the Activity Leader. The information was entered to SICADA (SKB database) by database operators.

4.8 Environmental control

The SKB routine for environmental control (SDP-301, SKB internal document) was followed throughout the activity. A checklist was filled in and signed by the Activity Leader and filed in the SKB archive.

All waste generated during the establishment, drilling and completion phases have been removed and disposed of properly. Water effluent from drilling was allowed to infiltrate to the ground or to the Baltic Sea, in accordance with an agreement with the environmental authorities.

Recovered drill cuttings were collected in a steel container. After completion of drilling, the container was removed from the site and emptied at an approved site.

5 Results

Technical data from drilling are presented in Section 5.1.

Hydrogeological results from drilling are given in Section 5.2.

The results from the preliminary geological mapping are commented in Section 5.3

Hydrogeochemical results are presented in Section 5.4.

5.1 Borehole design

A summary of data from the borehole are presented in Tables 5-1, 5-2 and 5-3.

Technical drawings of the boreholes are given in Appendix 1.

Table 5-1. Geometric and technical data for boreholes HSH04, HSH05 and HSH06.

Parameter	HSH04		HSH05		HSH06	
Drilling period	From 2004-04-05 to 2004-04-13		From 2004-04-14 to 2004-04-19		From 2004-04-20 to 2004-04-22	
Borehole inclination (starting point) (0 to –90)	–59.000°		–57.952°		–57.772°	
Borehole azimuth (0–360)	359.774°		180.869°		2.143°	
Borehole length (m)	236.200		200.200		203.200 m	
Soil depth (m)	5.25		1.0		2.8	
Drill bit diameter (m)	0.137		0.139		0.138	
Starting point coordinates (system RT90/RHB70)	Northing: 6366237.275 m Easting: 1552223.476 m Elevation: 2.858 m a s l		Northing: 6365224.711 m Easting: 1551179.077 m Elevation: 2.718 m a s l		Northing: 6366214.627 m Easting: 1552534.621 m Elevation: 2.346 m a s l	
Water yield	12.0 l/min		3.0 l/min		2.5 l/min	
Borehole diameter (interval) (diameter mm)	0.0–9.2 m 9.2–236.2 m	190 137	0.0–6.2 m 6.2–200.2 m	190 139	0.0–9.24 m 9.24–203.2 m	190 138
Casing diameter	0.0–8.91 m	$Ø_o$ = 168 $Ø_i$ = 160	0.0–6.11 m	$Ø_o$ = 168 $Ø_i$ = 160	0.0–8.95 m	$Ø_o$ = 168 $Ø_i$ = 160
(interval) (diameter mm)	8.91–9.0 m	$Ø_o$ = 168 $Ø_i$ = 147	6.11–6.2 m	$Ø_o$ = 168 $Ø_i$ = 147	8.95–9.04 m	$Ø_o$ = 168 $Ø_i$ = 147

Table 5-2. Geometric and technical data for boreholes HAV11 and HAV12.

Parameter	HAV11		HAV12	
Drilling period	From 2004-06-07 to 2004-06-14		From 2004-05-12 to 2004-05-19	
Borehole inclination (starting point) (0 to –90)	–59.610°		–58.786°	
Borehole azimuth (0–360)	113.471°		0.274°	
Borehole length	220.500 m		157.800 m	
Soil depth	0.0 m		0.0 m	
Drill bit diameter (m)	0.140		0.140	
Starting point coordinates (system RT90/RHB70)	Northing: 6366565.254 m Easting: 1553040.898 m Elevation: 2.379 m a s l		Northing: 6367765,872 m Easting: 1553194.416 m Elevation: 9.404 m a s l	
Water yield	116 l/min		75 l/min	
Borehole diameter (interval) (diameter mm)	0.0–6.12 m 6.12–220.5 m	190 140	0.0–6.13 m 6.13–157.8 m	190 140
Casing diameter	0.0–5.94 m	$Ø_o$ = 168 $Ø_i$ = 160	0.0–5.94 m	$Ø_o$ = 168 $Ø_i$ = 160
(interval) (diameter mm)	5.94–6.03 m	$Ø_o$ = 168 $Ø_i$ = 147	5.94–6.03 m	$Ø_o$ = 168 $Ø_i$ = 147

Table 5-3. Geometric and technical data for boreholes HAV13 and HAV14.

Parameter	HAV13		HAV14	
Drilling period	From 2004-05-24 to 2004-05-27		From 2004-06-01 to 2004-06-04	
Borehole inclination (starting point) (0 to –90)	–58.809°		–60.418°	
Borehole azimuth (0–360)	0.077°		271.462°	
Borehole length	142.200 m		182.400 m	
Soil depth	0.7 m		1.05 m	
Drill bit diameter (m)	0.140		0.136	
Starting point coordinates (system RT90/RHB70)	Northing: 6367627.858 m Easting: 1552682.157 m Elevation: 2.215 m a s l		Northing: 6367227.977 m Easting: 1552350.548 m Elevation: 7.761 m a s l	
Water yield	>200 l/min		85 l/min	
Borehole diameter (interval) (diameter mm)	0.0–9.12 m 9.12–142.2 m	190 mm 140 mm	0.0–6.12 m 6.12–182.4 m	190 mm 136 mm
Casing diameter	0.0–8.95 m	$Ø_o$ = 168 $Ø_i$ = 160	0.0–5.94 m	$Ø_o$ = 168 $Ø_i$ = 160
(interval) (diameter mm)	8.95–9.04 m	$Ø_o$ = 168 $Ø_i$ = 147	5.94–6.05 m	$Ø_o$ = 168 $Ø_i$ = 147

5.2 Hydrogeological results

The water yields obtained from blowing of compressed air during drilling are given in Table 5-4 and are also shown in Appendix 2. Yields below ca 1–2 litres per minute should be regarded as very approximative estimates only, as well as flows exceeding ca 100–150 litres per minute.

The level at which the water yield was measured does not always correspond to the observed level of inflow. The observed intervals are usually given as an interval, which means that the inflow was not observed at any specific level. The observed levels of water inflow during drilling are summarised in Table 5-5, with the main inflows shown graphically in Figures 6-1 and 6-2.

The amount of effluent water that was released to the ground from the drilling activities is estimated in Table 5-6. The release of water was made within 30 m from the collar location.

No further hydrogeological tests were performed as part of the drilling activity. Further hydraulic testing of the percussion boreholes in Simpevarp and the island of Ävrö have been reported separately in SKB P-04-287 /6/.

Table 5-4. Measured water yields during drilling.

Borehole	From (m)	To (m)	Measured water yield (L/min)	Date	Time for final rinsing by air blow (local time)
HSH04	9.2	124.9	10	040407	
HSH04	9.2	209.2	10–12	040413	13:30
HSH05	6.2	121.9	5	040419	
HSH05	6.2	200.2	3	040419	16:30
HSH06	9.24	121.9	2.5	040422	
HSH06	9.24	203.2	2.5	040422	14:00
HAV11	6.12	21.9	2.5	040608	
HAV11	6.12	120.9	4	040608	
HAV11	6.12	120.9	8.5	040609	
HAV11	6.12	145.2	32	040609	
HAV11	6.12	202.2	57	040609	
HAV11	6.12	220.5	116	040609	20:30
HAV12	6.13	44.9	1.5	040517	
HAV12	6.13	81.9	2	040517	
HAV12	6.13	112.2	2.5	040517	
HAV12	6.13	148.2	37.5	040518	
HAV12	6.13	157.8	75	040518	14:00
HAV13	9.12	93.3	18	040525	
HAV13	9.12	117.3	60	040525	
HAV13	9.12	121.3	150	040526	
HAV13	9.12	135.0	>200	040526	12:00
HAV14	6.12	33.9	9	040602	
HAV14	6.12	120.9	10	040602	
HAV14	6.12	120.9	40	040603	
HAV14	6.12	165.2	66.5	040603	
HAV14	6.12	169.2	85	040603	
HAV14	6.12	182.4	85	040603	21:30

Table 5-5. Observed levels of water inflow during drilling.

Borehole	Noticeable inflow of water during drilling (metres drilled length)
HSH04	9.2–124.9 m
HSH05	6.2–121.9 m
HSH06	9.24–121.9 m
HAV11	16.9–17.9, 128–142, 168–201, 202.2–220.5 m
HAV12	44.6, 50.8–76.9, 82.6–102.8, 147–148, 148.2–157.8 m
HAV13	91.4–93.2, 108–109, 118.3–121.3, 121.3–135.0 m
HAV14	30.9–33.9, 63.9–120.9, 163.2–165.2, 165.2–169.2 m

Table 5-6. Amount of released water from drilling.

Borehole	Estimated amount of water released (m^3)
HSH04	10
HSH05	3
HSH06	2
HAV11	71
HAV12	23
HAV13	117
HAV14	70

5.3 Geological results

Lithologically boreholes HSH04, HSH05, HAV12, HAV13 and HAV14 are dominated by Ävrö granite and in borehole HSH05 granite dominates after 102.9 m. Boreholes HSH06 and HAV11 are dominated by Quartz monzodiorite, and in borehole HSH06 Ävrö granite dominates after 96.9 m. Minor intercalations of subordinate rock types occurs in all boreholes (fine-grained granite, pegmatite, quartz monzodiorite, fine-grained dioritoid, fine-grained diorite-gabbro and diorite-gabbro), see Table 5-7.

Logging results of preliminary geology together with magnetic susceptibility, penetration time and measured water flow are presented in Appendix 2.

Table 5-7. Lithology of drilled boreholes.

Borehole	Dominating rock type	Subordinate rock type
HSH04	Ävrö granite	Fine-grained dioritoid and Quartz monzodiorite
HSH05	Ävrö granite and granite	Fine-grained dioritoid and pegmatite
HSH06	Quartz monzodiorite and Ävrö granite	Pegmatite and fine-grained diorite-gabbro
HAV11	Quartz monzodiorite	Fine-grained granite and pegmatite
HAV12	Ävrö granite	Fine-grained granite and fine-grained diorite-gabbro
HAV13	Ävrö granite	Fine-grained granite and pegmatite
HAV14	Ävrö granite	Fine-grained granite, fine-grained diorite-gabbro, pegmatite and diorite/gabbro

5.4 Hydrogeochemical results

Twelve water samples were taken from six boreholes HSH04, HSH05, HAV11, HAV12, HAV13 and HAV14, two samples from each hole. They were collected during hydraulic testing /6/, and the results are given in this report in Table 5-8 and Table 5-9. The samples were only analyzed for main components (Na, K, Ca, Mg, SO_4S, Si, Fe, Mn, Li and Sr).

Table 5-8. Chemical composition in water samples from boreholes HSH04, HSH05 and HAV11.

Borehole	HSH04	HSH04	HSH05	HSH05	HAV11	HAV11
Length (m)	3.01–236.0	3.01–236.0	3.34–200.2	3.34–200.2	2.46–220.5	2.46–220.5
Date	040715	040720	040717	040718	040712	040713
Sample nr	7554	7555	7550	7548	7552	7551
Na (mg/l)	1,680	1,690	485	1,310	525	1,860
K (mg/l)	56.9	48.8	17.5	17.5	9.55	8.26
Ca (mg/l)	142	204	107	305	270	1,480
Mg (mg/l)	180	171	56.9	115	29.2	60.8
SO_4S (mg/l)	116	107	42.9	53.2	50.5	132
Si (mg/l)	7.28	7.68	4.17	5.76	3.4	4.71
Fe (mg/l)	0.575	0.626	0.164	0.499	0.121	1.01
Mn (mg/l)	0.58	0.612	0.193	0.756	0.33	0.607
Li (mg/l)	0.058	0.075	0.02	0.074	0.139	0.827
Sr (mg/l)	2.07	3	1.08	4.47	3.96	23.7

Table 5-9. Chemical composition in water samples from boreholes HAV12, HAV13 and HAV14.

Borehole	HAV12	HAV12	HAV13	HAV13	HAV14	HAV14
Length (m)	11.35–157.0	11.35–157.0	3.31–147.0	3.31–147.0	12.85–182.0	12.85–182.0
Date	040630	040702	040720	040721	040707	040708
Sample nr	7558	7556	7549	7557	7553	7559
Na (mg/l)	258	1,380	263	1,590	46.5	66.3
K (mg/l)	4.02	13.3	4.21	9.04	2.7	2.71
Ca (mg/l)	125	892	48.8	72.3	45.7	39.6
Mg (mg/l)	21.4	120	11.7	90.9	5.4	5.2
SO_4S (mg/l)	22.6	73.7	23.8	11.5	9.92	16.3
Si (mg/l)	5.11	4.82	5.26	4.64	5.95	7.16
Fe (mg/l)	0.213	1.14	0.099	0.644	0.272	0.434
Mn (mg/l)	0.307	0.8	0.111	0.591	0.254	0.245
Li (mg/l)	0.064	0.368	0.046	0.294	0.03	0.034
Sr (mg/l)	1.91	12.7	0.758	9.73	0.611	0.506

5.5 Consumption of oil and chemicals

Small amounts of hammer oil and compressor oil enter the holes during drilling but are continuously retrieved by air flushing during drilling. After the drilling is completed, only minor remainders of the products are left in the borehole.

The consumption of cement paste (low alkali cement) and oils is given in Table 5-10.

Table 5-10. Consumption of cement paste and oils.

Borehole	Cement paste used (kg)	Hammer oil -Preem Hydra 46 (L)	Compressor oil -Schuman 46 (L)
HSH04	71.4	15	None noted
HSH05	35.7	15	None noted
HSH06	54	15	None noted
HAV11	35.5	15	None noted
HAV12	36	15	None noted
HAV13	71	15	None noted
HAV14	35.5	15	None noted

5.6 Nonconformities

No formal nonconformities have been registered during the activity. Borehole HSH06 was drilled to 236.2 m (instead of 200 m) testing the possible proximity of the fracture zone. Boreholes HAV11, HAV12, HAV13 and HAV14 all had to be terminated before their full length because of the high water yield, which gave a technical limit for drilling.

6 Interpretation

Deformation zones are inferred from percussion drilling based on both geological and technical indicators, that is water yielding zones, which usually coincide with altered rock often containing joint fillings, as well as lower or highly variable penetration time and generally reduced magnetic susceptibility; see Figures 6-1 to 6-4, as well as Appendix 2.

The results from the drilling of percussion boreholes HSH04, 05 and 06 indicates no interception of deformation zones, mainly since no distinct water yielding zones were encountered, while the percussion boreholes HAV11, 12, 13 and 14 all encountered zones with high water yield, indicating deformation zones.

In borehole HSH05 the measured inflow of water indicates low water inflow before 121.9 m; see Table 5-4, which is verified in the hydraulic testing where only one very minor inflow is detected at 62–64 m /6/. The generally lower susceptibility from ca 101 m to the end of borehole seems more connected to change of rock type rather than alteration and the gradual increase of drilling penetration time seems mainly connected to the length of the borehole see Figure 6-1 and Appendix 2.

In borehole HSH06 the low penetration times between ca 45–50 m coincide with the occurrence of Ävrö granite and pegmatite in the Quartz monzodiorite. The lower susceptibility below approximately 100 m coincides with the occurrence of Ävrö granite as well, see Figure 6-2 and Appendix 2. HSH06 is drilled ca 10 m west of boreholes HSH01 and HSH03 /5/, roughly parallel with HSH01. The geological differences between the boreholes illustrate the lithological heterogeneity of the area, see Figure 6-2. Both HSH01 and HSH06 show no water yielding fracture zones, while HSH03 gave some water /5/.

The first ca 60 m of borehole HSH04 consists of altered rock with low susceptibility and relatively low penetration times which could be indicating a possible zone of deformation see Figure 6-2 and Appendix 2. Water flow during drilling indicated minor inflow before 124.9 m; see Table 5-4, verified in the hydraulic testing where only one minor inflow is detected at 28–29 m /6/.

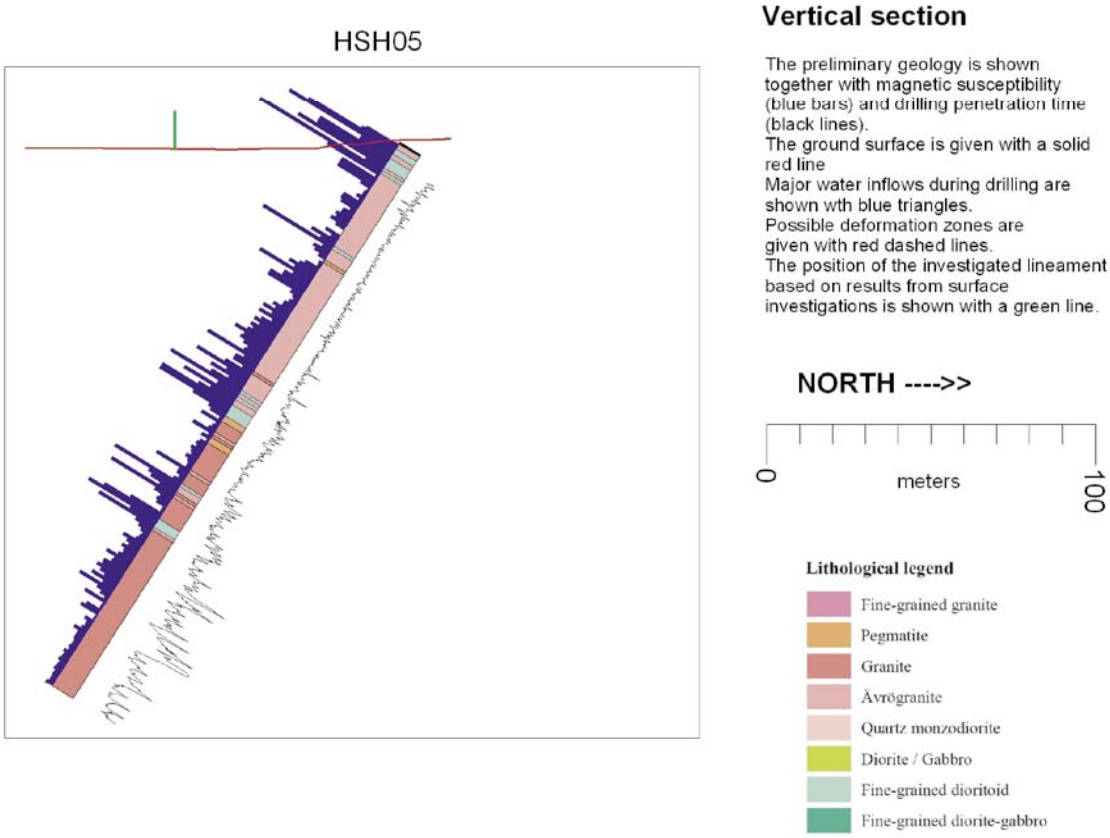
Boreholes HAV12 and HAV13 are drilled on the northern coast of the island Ävrö towards the north, parallel to refraction seismic profiles /4/. Water yielding fracture zones occurred close to the end of both boreholes, see Figure 6-3.

In HAV12 generally reduced magnetic susceptibility and relatively low or highly variable penetration times occur from ca 50 m until the end of borehole, with the main water coming in at ca 147–148 m, ca 37.5 l/min increasing to ca 75 l/min at the end of borehole, indicating deformation zone, see Table 5-4, Figure 6-3 and Appendix 2. The hydraulic testing marks three separate zones between 134.5–152 m as well as one minor zone at 32.5–36 m /6/.

In borehole HAV13 altered rocks and relatively low or highly variable penetration times occurred from ca 15 m to the end of borehole, with water inflow at the bottom of borehole exceeding ca 200 l/min. Water yielding zones indicating the deformation zone occur at 91.4–93.2 m, ca 18 l/min and at 108–109 m, but not measured until at 117.3 m, ca 60 l/min, and at 135 m the water yield exceeds 200 l/min, see Table 5-4, Figure 6-3 and Appendix 2.

Borehole HAV11 was drilled on the southern part of the island Ävrö towards the southeast, parallel to a refraction seismic profile, see Figure 1-1. Water inflow before 120.9 m was measured as 8.5 l/min, verified in the hydraulic testing where one minor inflow was detected at 57.5–61.5 m /6/. At approximately 128–142 m length a zone with ca 32 l/min of water and another one at ca 168–201 m yielding ca 57 l/min were observed, see Table 5-4. Final water flow of ca 116 l/min was measured at the end of drilling, most of which came in close to the end. The hydraulic testing confirms that the main inflow of water is below 122 m /6/. This and the overall low magnetic susceptibility below ca 110 m of the borehole indicate a deformation zone; see Figure 6-4 and Appendix 2.

Borehole HAV14 was drilled in the western part of the island of Ävrö towards the west. Low magnetic susceptibility and low or highly variable penetration times occur at approximately 50 m and occasionally between ca 100 m to ca 150 m, resulting in water flow of 85 l/min, see Table 5-4. The susceptibility is exceptionally low between ca 44–73 m, indicating an altered zone, and at 30.9–33.9 m a zone yielding ca 9 l/min occurs. One zone at ca 163.2–165.2 m gave ca 66.5 l/min and at ca 169.2 m the water yield had increased to ca 85 l/min. The assumption is therefore that the main deformation zone starts at approximately 163 m in HAV14, see Figure 6-4 and Appendix 2. The hydraulic testing shows the main inflow of water between 165–167 m, with a lower inflow at 42–45 m /6/. Available data from two boreholes in the vicinity of HAV14 are also shown in Figure 6-4, but the data is limited and gives little help in determining possible intersections with deformation zones, showing the importance of collecting all relevant information while drilling, see Figure 6-4.



Plan map of borehole locations HSH01, HSH03, HSH04, HSH05 and HSH06

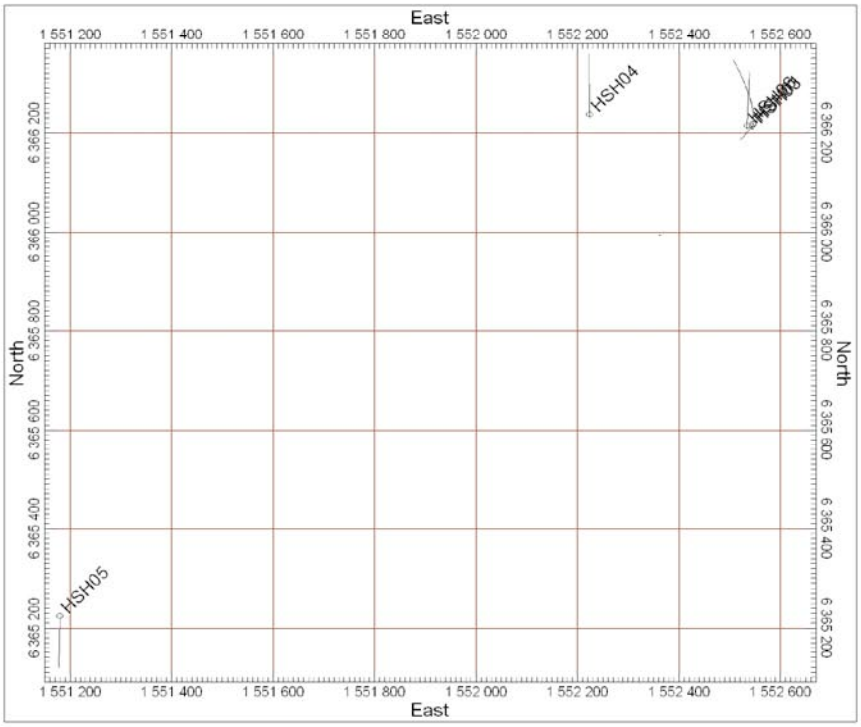


Figure 6-1. *Profile of borehole HSH05 on the southwestern coast of the Simpevarp peninsula. Shown with preliminary geological results (soil is shown in black), magnetic susceptibility (blue bars) and drilling penetration time (black line). Red line shows ground/water surface. Green line shows position of investigated lineament based on results from surface investigations. Plan map with Swedish grid coordinates (system RT90/RHB70) shows mutual positions of the boreholes in Figure 6-1 and Figure 6-2. All boreholes are assumed straight from TOC (top of casing) except for HSH01 which was surveyed, see Figure 6-2.*

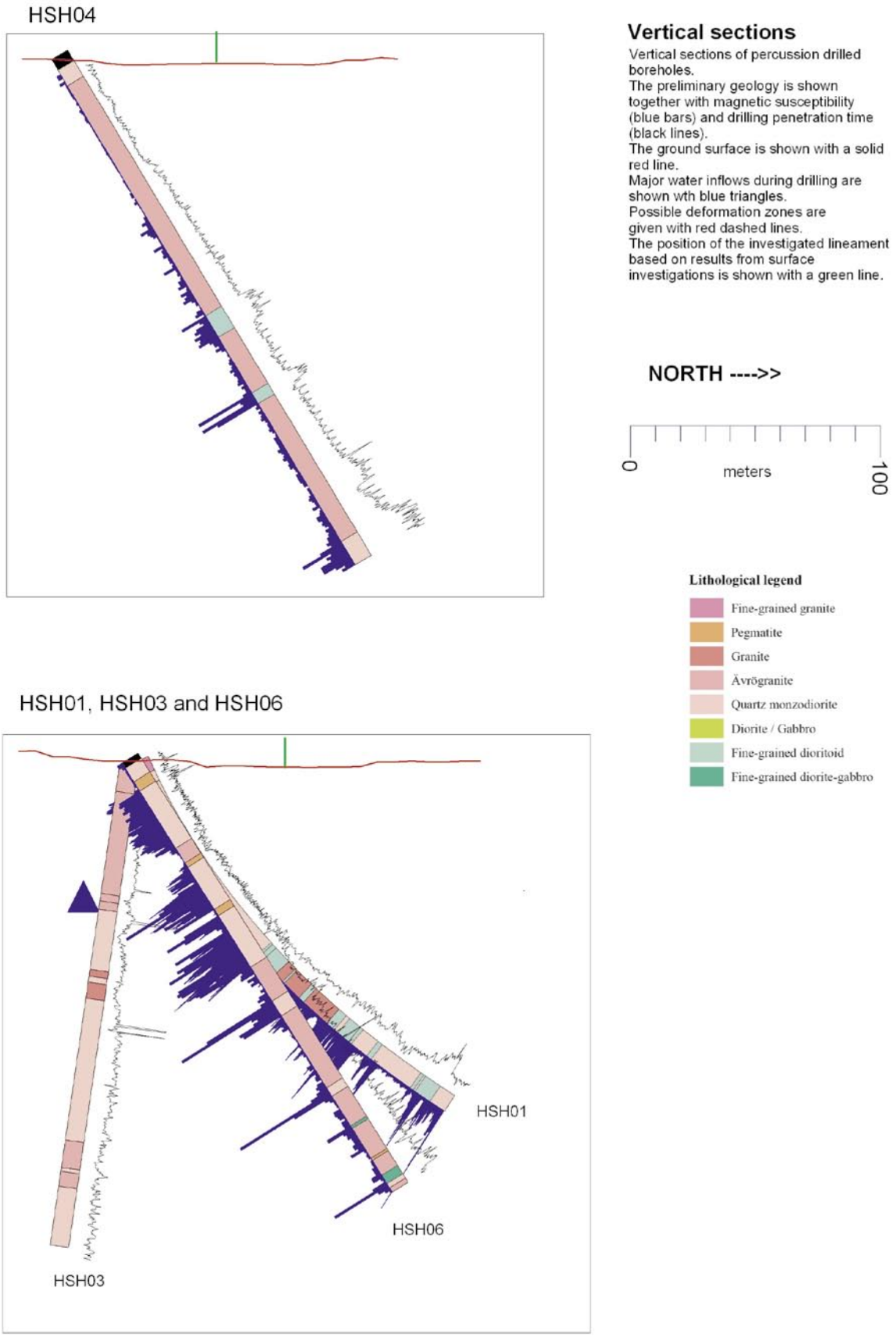


Figure 6-2. *Profile of borehole HSH04 and of boreholes HSH01, HSH03 and HSH06. HSH06 should be behind (TOC furthest to the west), but is projected to the front for clarity. Surveying data is only available for HSH01. Positions for water inflow are indicated by blue triangles. Red line shows ground/water surface. Green line shows position of investigated lineament based on results from surface investigations. For mutual positions see plan map in Figure 6-1.*

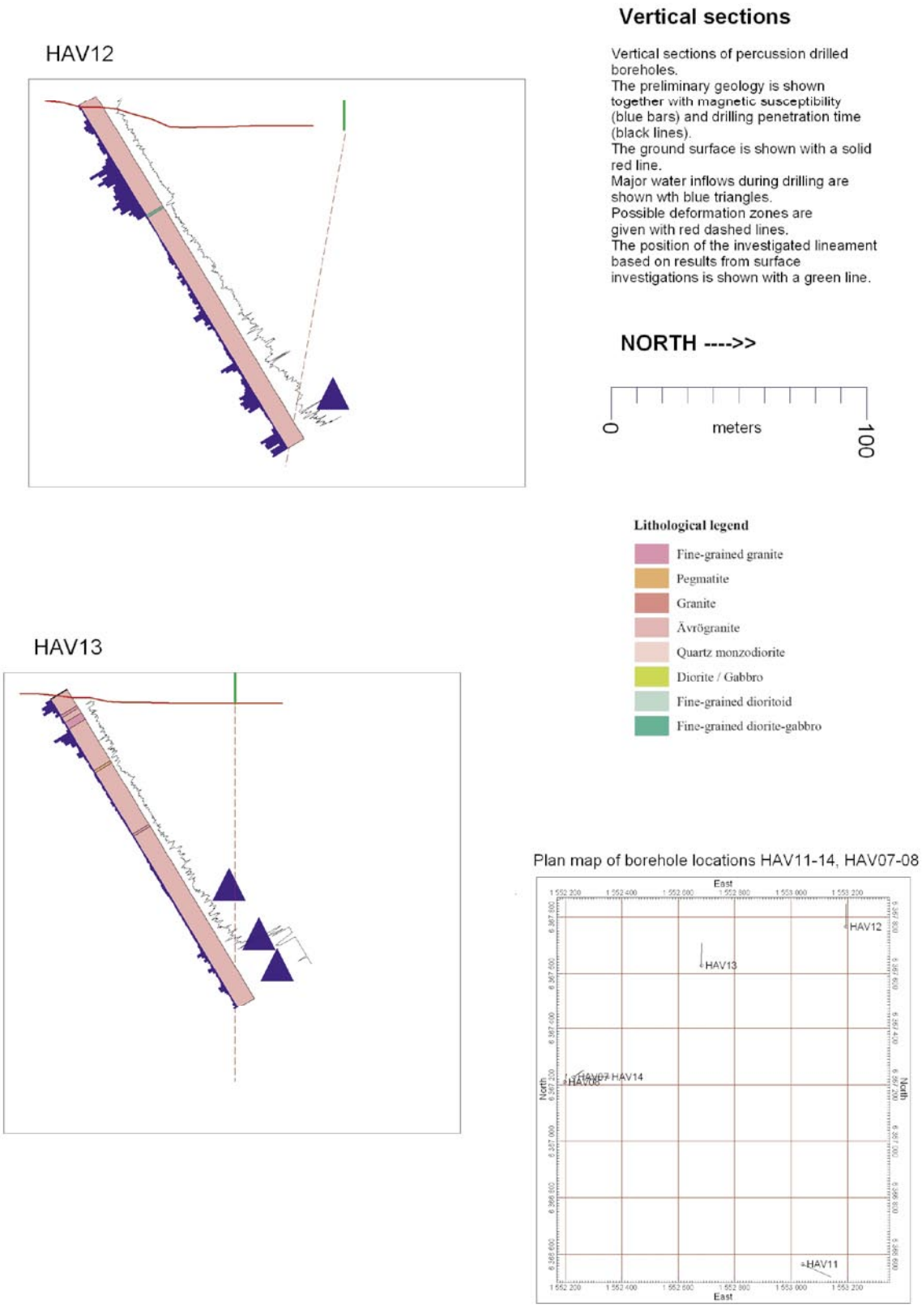


Figure 6-3. *Profiles of boreholes HAV12 and HAV13 on the northern coast of the island of Ävrö. Shown with preliminary geological results (soil is shown in black), magnetic susceptibility (blue bars) and drilling penetration time (black line). Positions for water inflow are indicated by blue triangles. Red line shows ground/water surface. Green line shows position of investigated lineament based on results from surface investigations, with dashed line indicating possible intersection with borehole. Plan map with Swedish grid coordinates (system RT90/RHB70) shows mutual positions of the boreholes inFigure 6-3 and Figure 6-4. All boreholes are assumed straight from TOC (top of casing).*

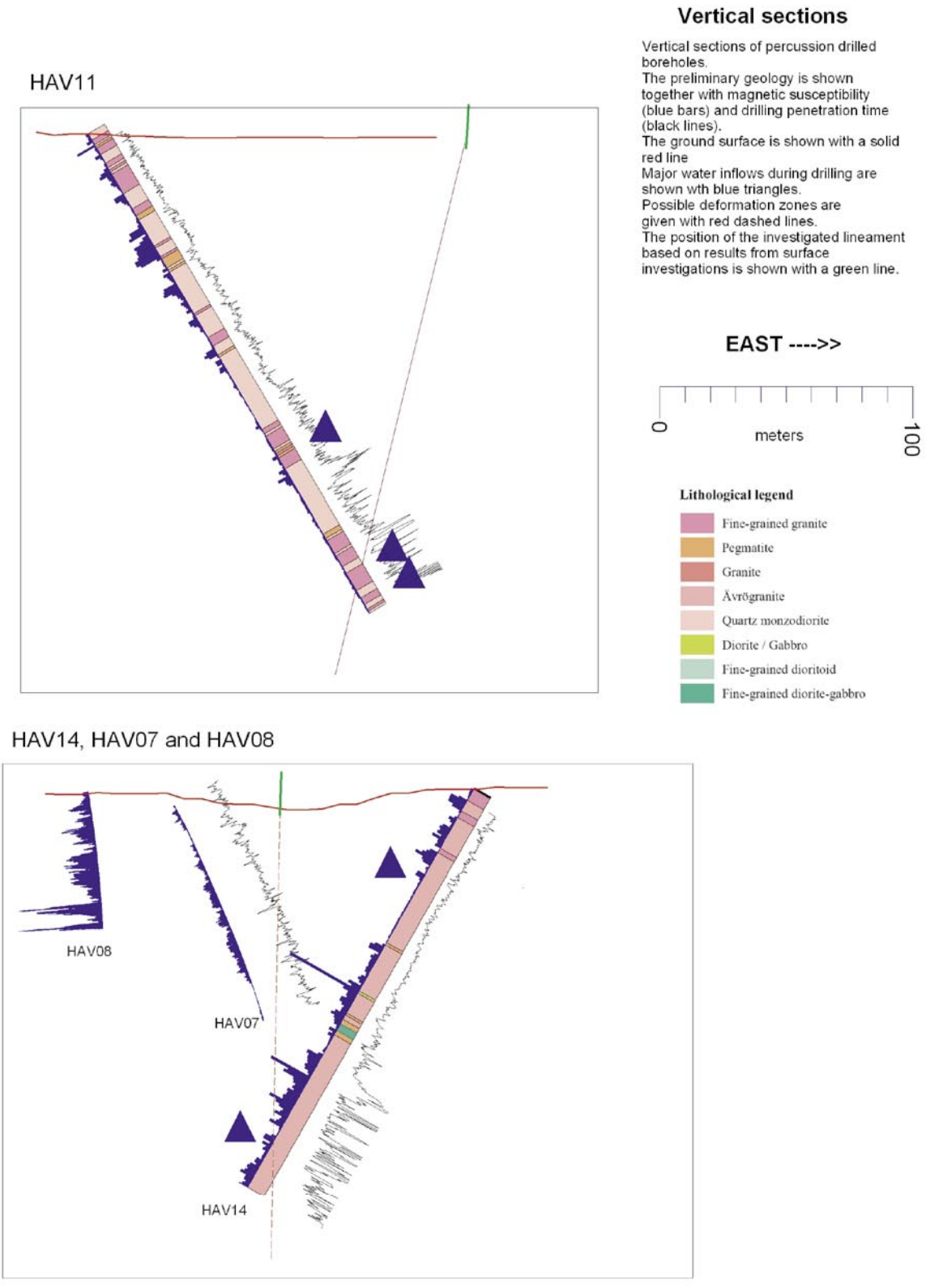


Figure 6-4. *Profile of boreholes HAV11 and HAV14. Shown with preliminary geological results (soil is shown in black), magnetic susceptibility (blue bars) and drilling penetration time (black line). Positions for water inflow are indicated by blue triangles. Red line shows ground/water surface. Green line shows position of investigated lineament based on results from surface investigations, with dashed line indicating possible intersection with borehole. Profiles of boreholes HAV07 and HAV08 are shown with HAV14, but HAV08 only shows susceptibility, while HAV07 shows both susceptibility and penetration time, but neither has any known geological data. For mutual positions see plan map in Figure 6-3.*

7 References

/1/ **SKB, 2001.** Platsundersökningar. Undersökningsmetoder och generellt genomförandeprogram SKB R-01-10, Svensk Kärnbränslehantering AB.

/2/ **SKB, 2001.** Geovetenskapligt program för platsundersökning vid Simpevarp. SKB R-01-44, Svensk Kärnbränslehantering AB.

/3/ **Triumf C-A, 2004.** Oskarshamn site investigation. Joint interpretation of lineaments. SKB P-04-49, Svensk Kärnbränslehantering AB.

/4/ **Lindqvist G, 2004.** Oskarshamn site investigation. Refraction seismic measurements in the water outside Simpevarp and Ävrö and on land on Ävrö. SKB P004-201, Svensk Kärnbränslehantering AB.

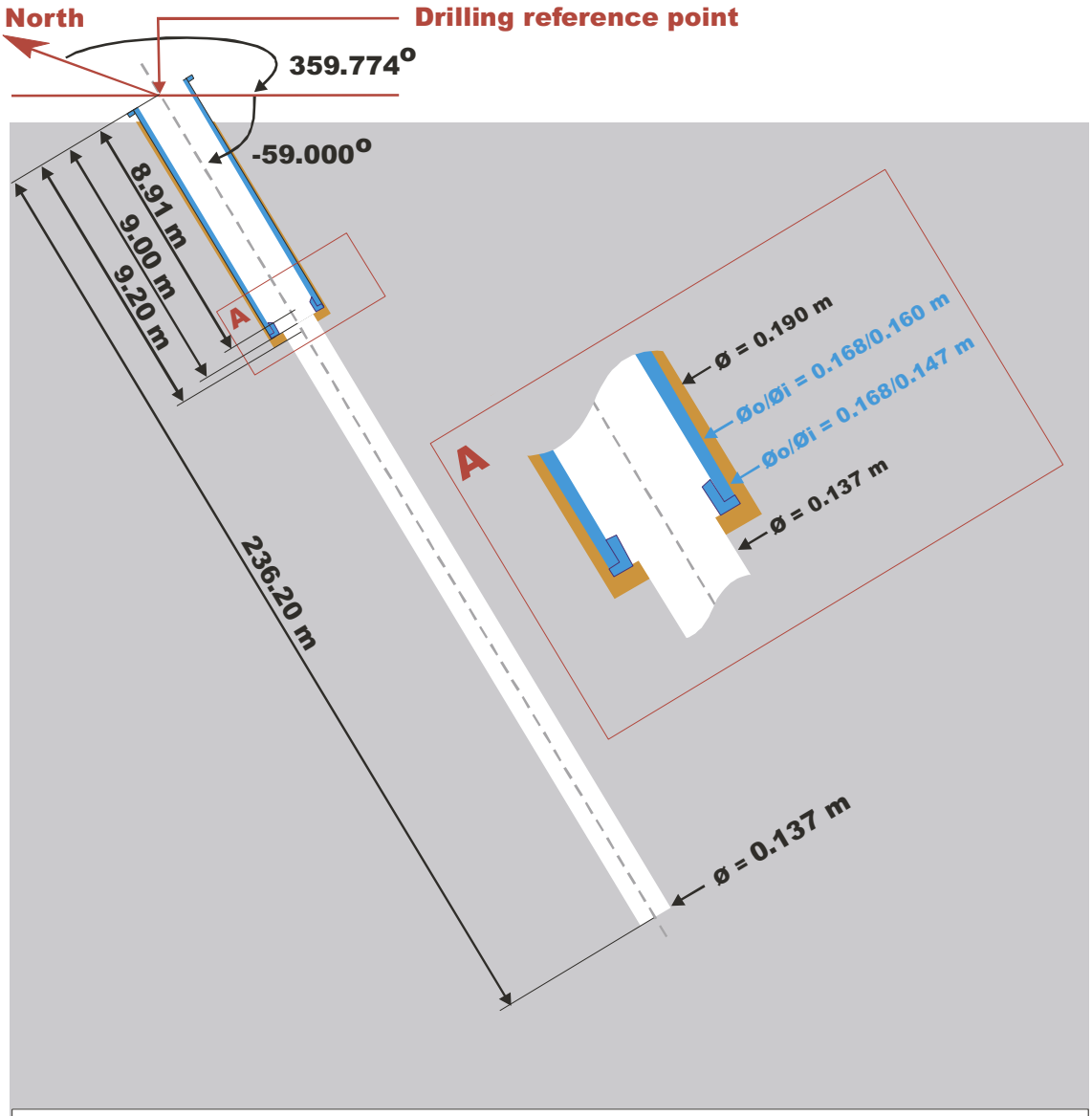
/5/ **Ask H, Samuelsson L-E, 2004.** Oskarshamn site investigation. Drilling of three flushing water wells, HSH01, HSH02 and HSH03. SKB P-03-114, Svensk Kärnbränslehantering AB.

/6/ **Rahm N, Enachescu C, 2004.** Oskarshamn site investigation. Hydraulic testing of percussion drilled lineament boreholes on Ävrö and Simpevarp, 2004. SKB P-04-287, Svensk Kärnbränslehantering AB.

Technical data for boreholes HSH04, HSH05, HSH06, HAV11, HAV12, HAV13 and HAV14

Technical data

Borehole HSH04



Drilling reference point

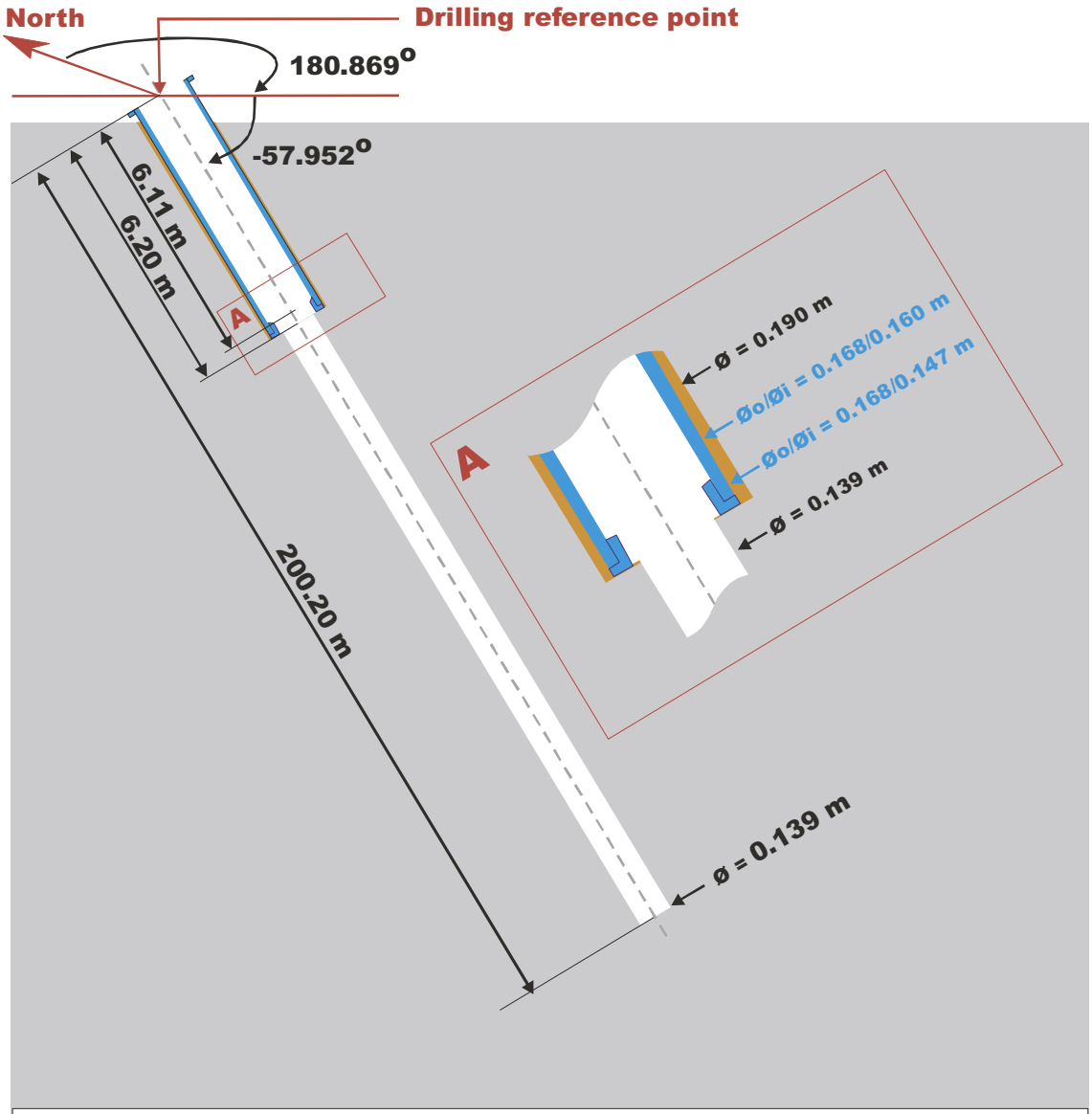
Northing:	**6366237.275 (m), RT90 2,5 gon V 0:-15**
Easting:	**1552223.476 (m), RT90 2,5 gon V 0:-15**
Elevation:	**2.858 (m), RHB 70**

Drilling period

Drilling start date:	**2004-04-05**
Drilling stop date:	**2004-04-13**

Technical data

Borehole HSH05



Drilling reference point

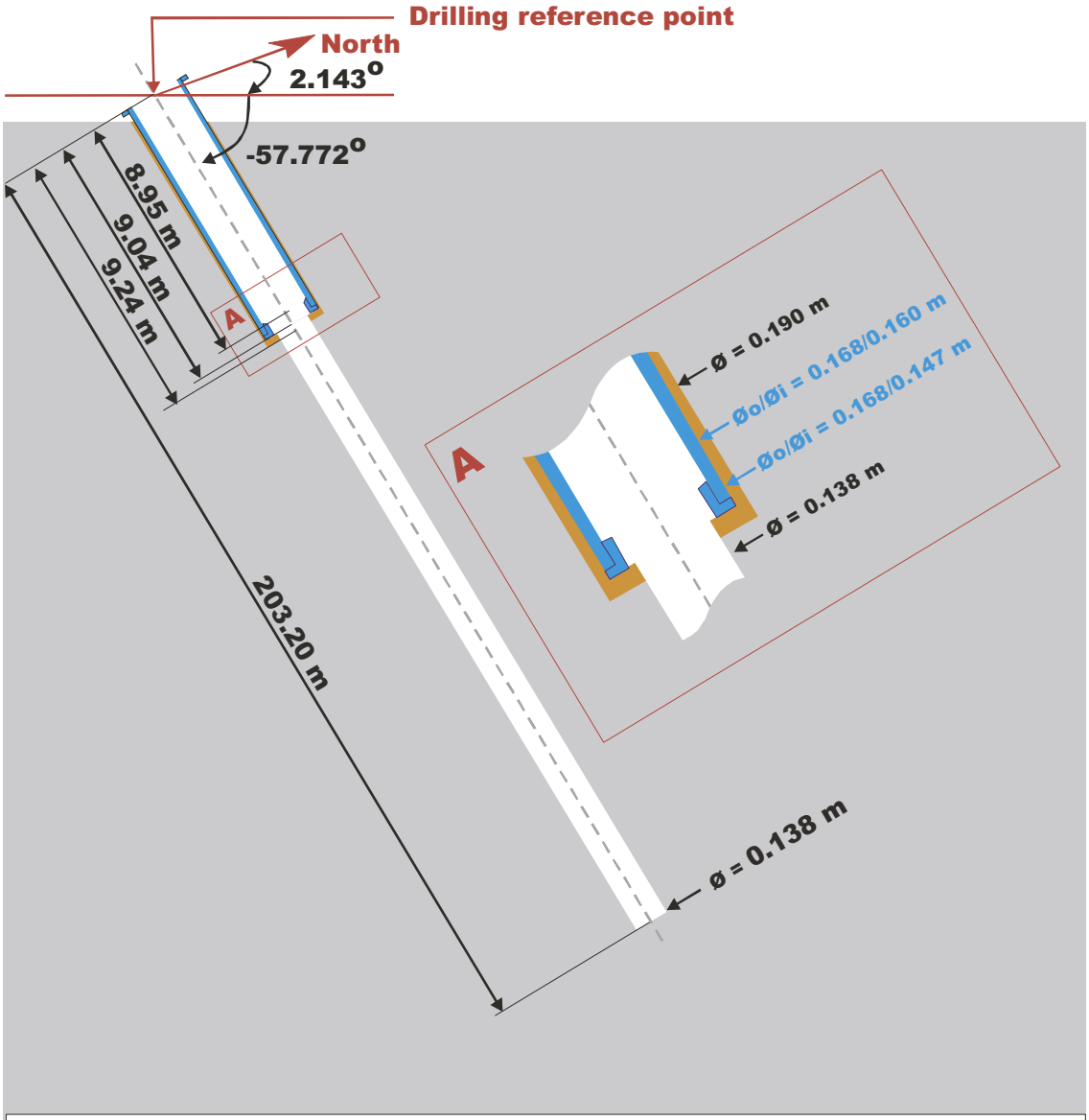
Northing:	**6365224.711 (m), RT90 2,5 gon V 0:-15**
Easting:	**1551179.077 (m), RT90 2,5 gon V 0:-15**
Elevation:	**2.718 (m), RHB 70**

Drilling period

Drilling start date: 2004-04-14
Drilling stop date: 2004-04-19

Technical data

Borehole HSH06



Drilling reference point

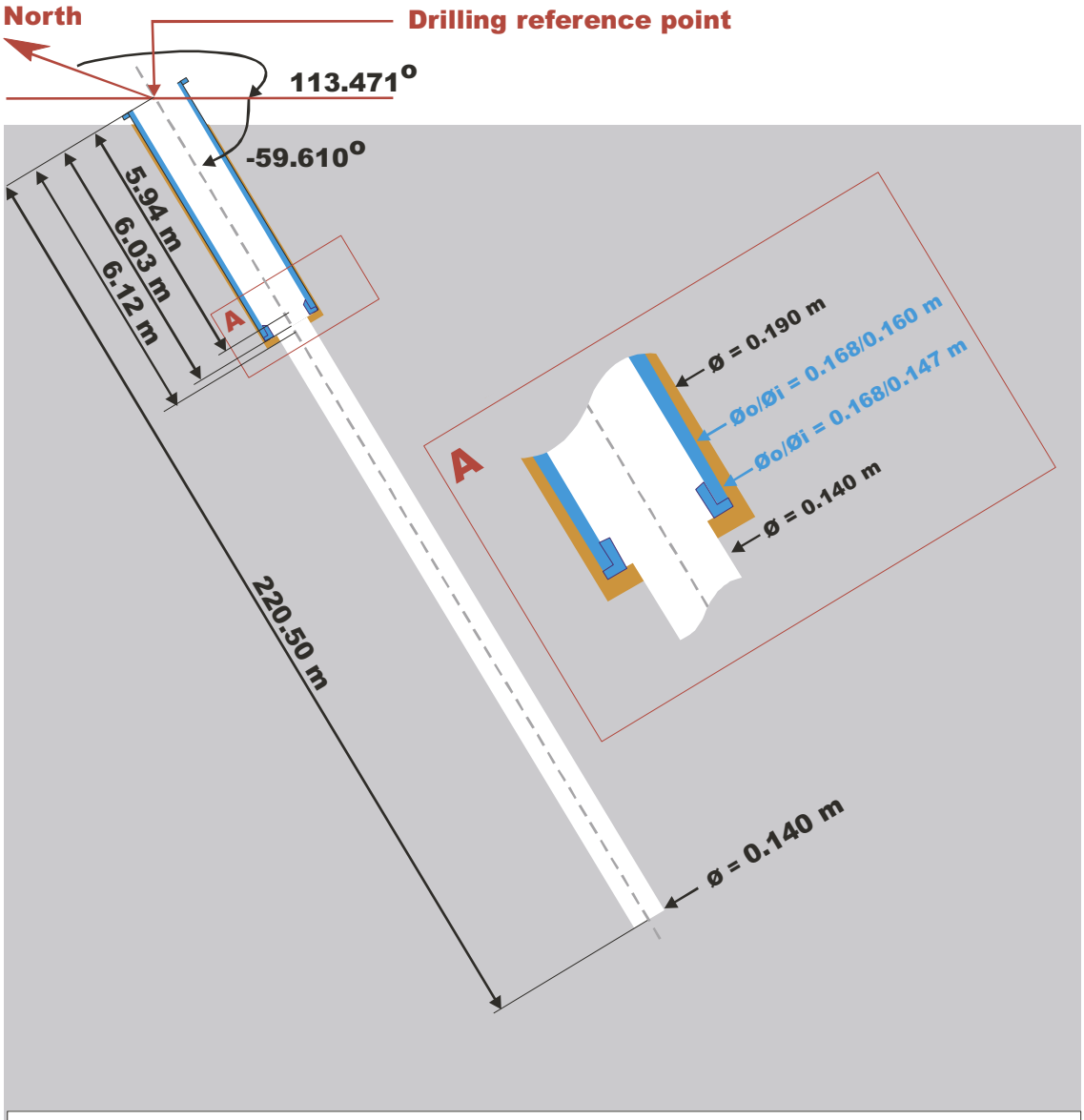
Northing: 6366214.627 (m), RT90 2,5 gon V 0:-15
Easting: 1552534.621 (m), RT90 2,5 gon V 0:-15
Elevation: 2.346 (m), RHB 70

Drilling period

Drilling start date: 2004-04-20
Drilling stop date: 2004-04-22

Technical data

Borehole HAV11



Drilling reference point

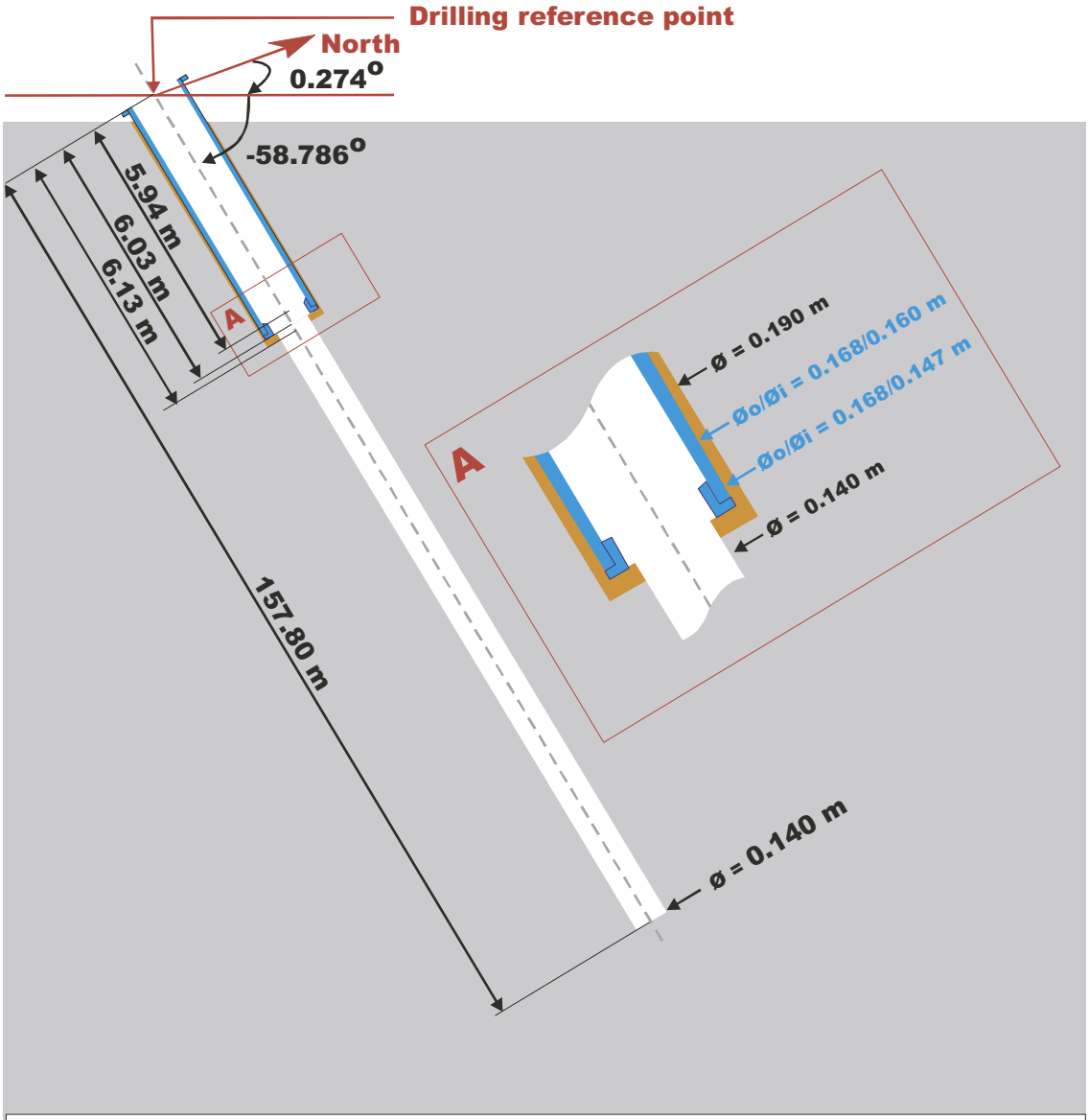
Northing: 6366565.254 (m), RT90 2,5 gon V 0:-15
Easting: 1553040.898 (m), RT90 2,5 gon V 0:-15
Elevation: 2.379 (m), RHB 70

Drilling period

Drilling start date: 2004-06-07
Drilling stop date: 2004-06-14

Technical data

Borehole HAV12



Drilling reference point

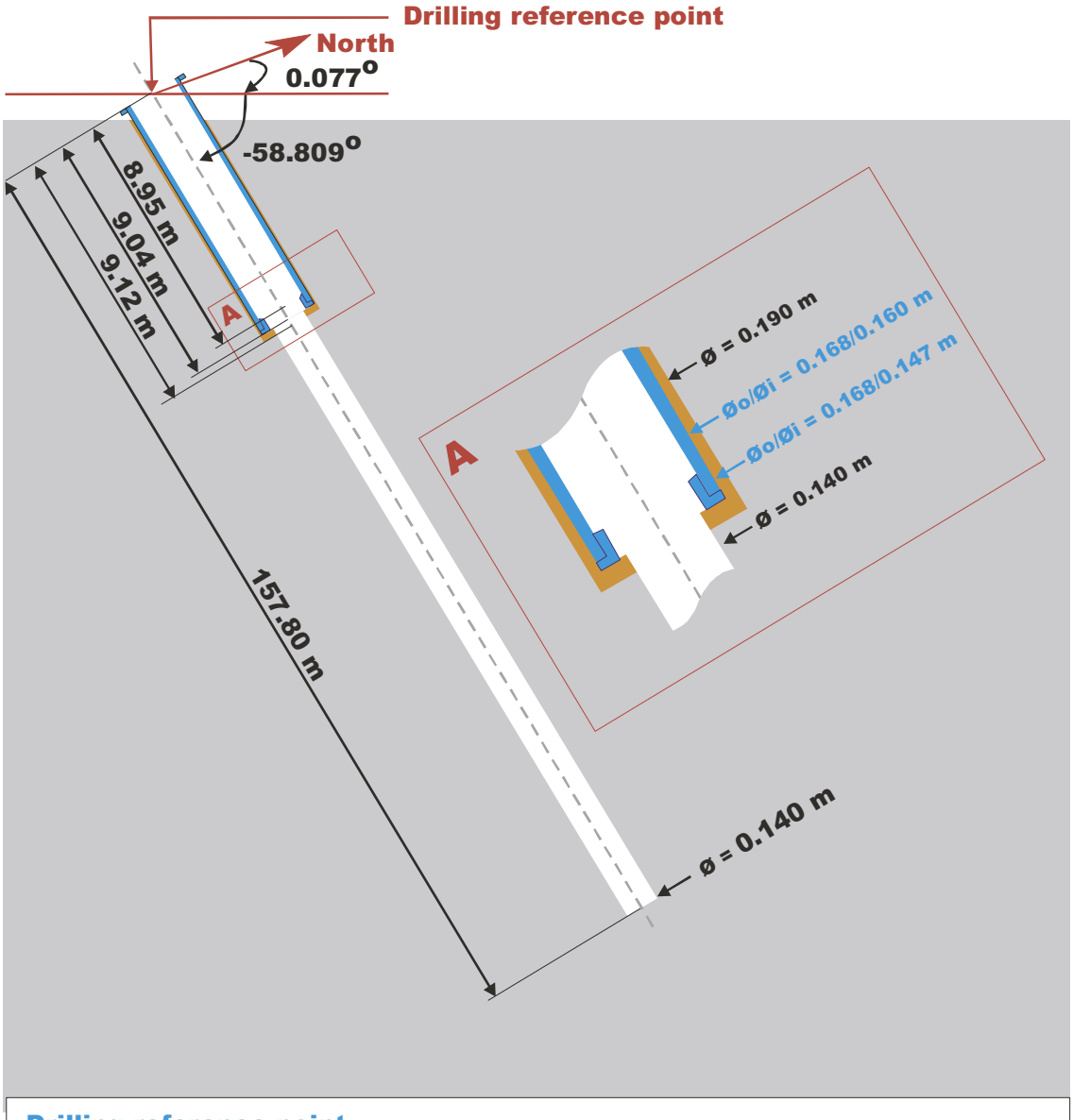
Northing: 6367765.872 (m), RT90 2,5 gon V 0:-15
Easting: 1553194.416 (m), RT90 2,5 gon V 0:-15
Elevation: 9.404 (m), RHB 70

Drilling period

Drilling start date: 2004-05-12
Drilling stop date: 2004-05-19

Technical data

Borehole HAV13



Drilling reference point

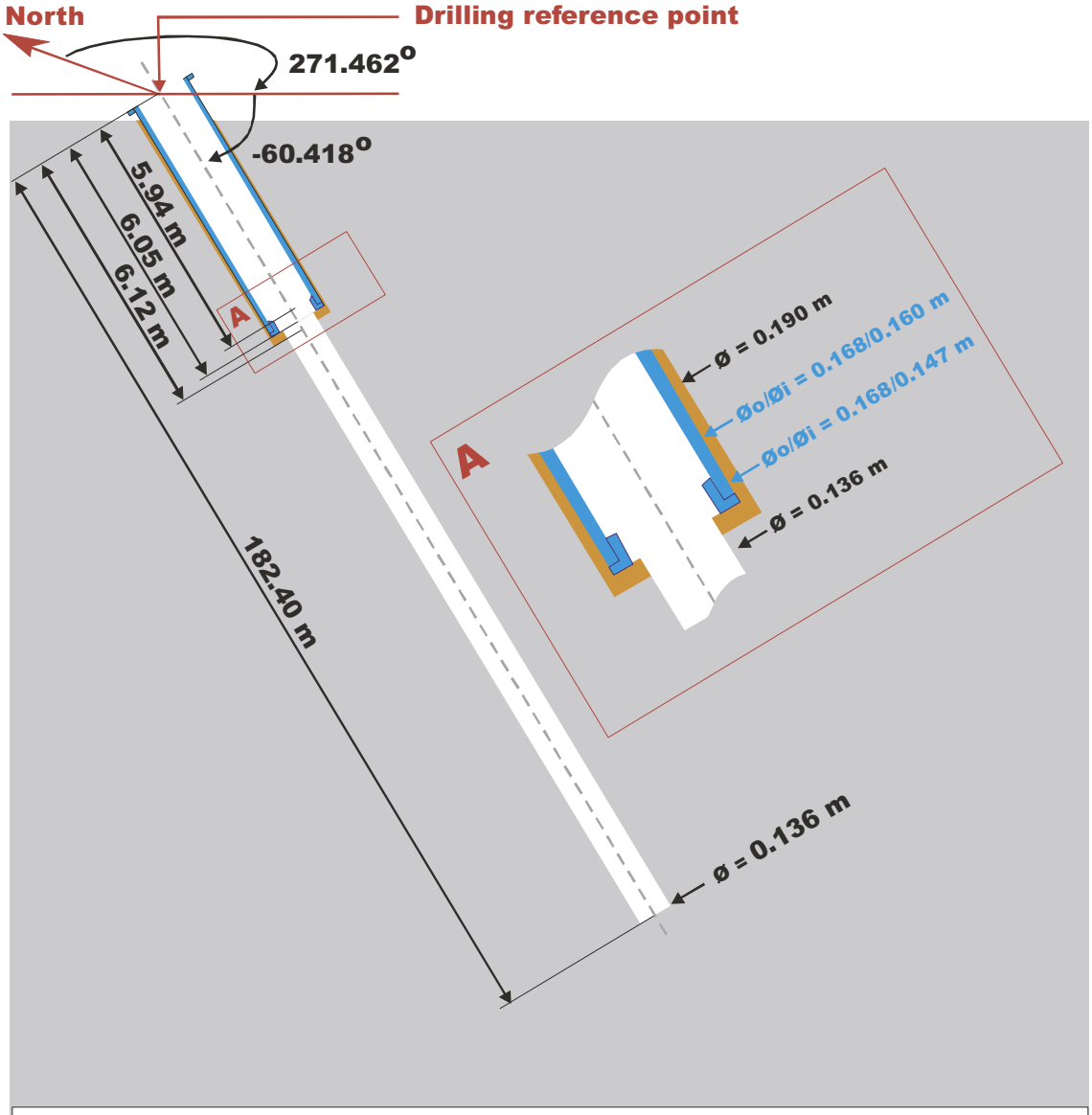
Northing: 6367627.858 (m), RT90 2,5 gon V 0:-15
Easting: 1552682.157 (m), RT90 2,5 gon V 0:-15
Elevation: 2.215 (m), RHB 70

Drilling period

Drilling start date: 2004-05-24
Drilling stop date: 2004-05-27

Technical data

Borehole HAV14



Drilling reference point

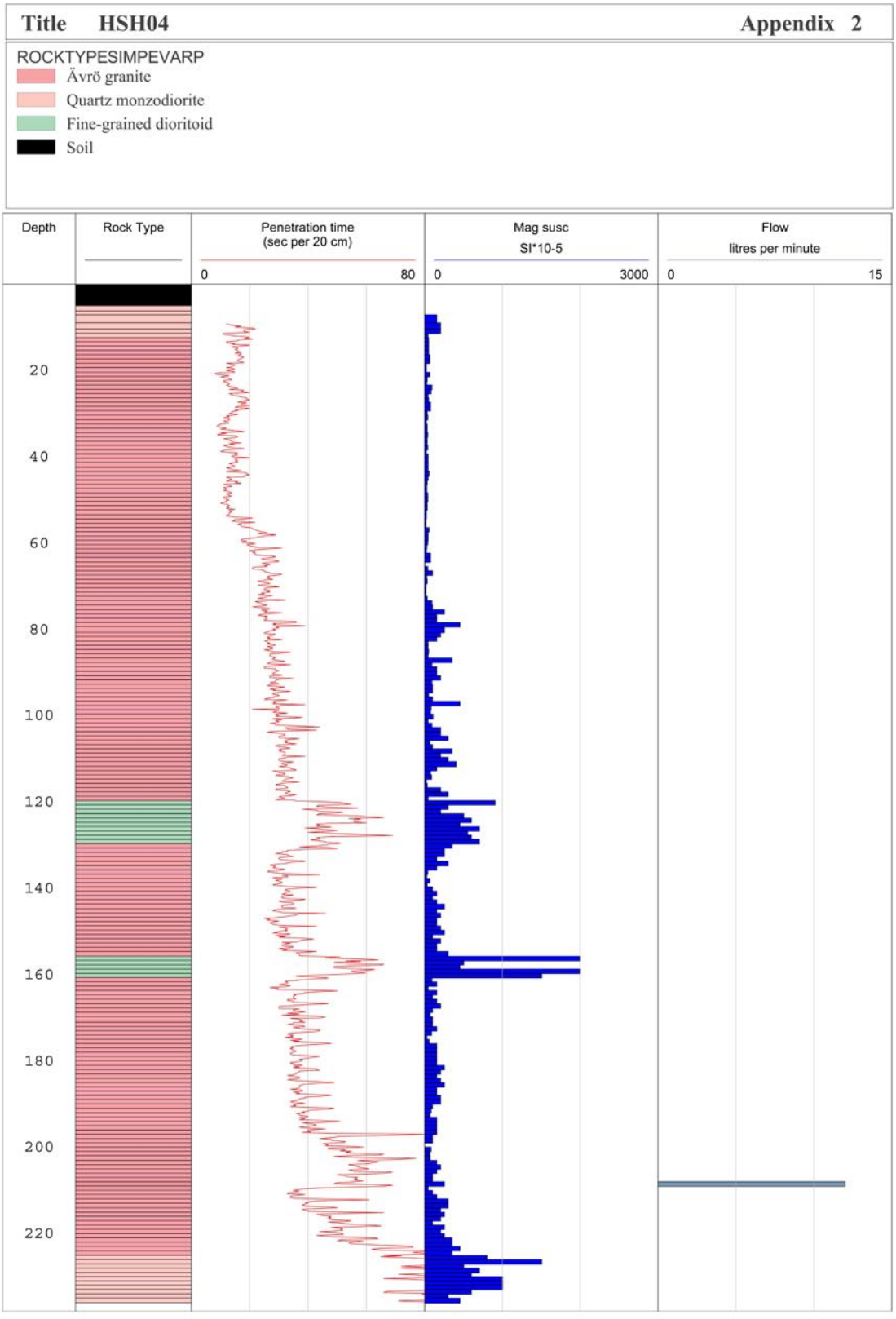
Northing:	**6367227.977 (m), RT90 2,5 gon V 0:-15**
Easting:	**1552350.548 (m), RT90 2,5 gon V 0:-15**
Elevation:	**7.761 (m), RHB 70**

Drilling period

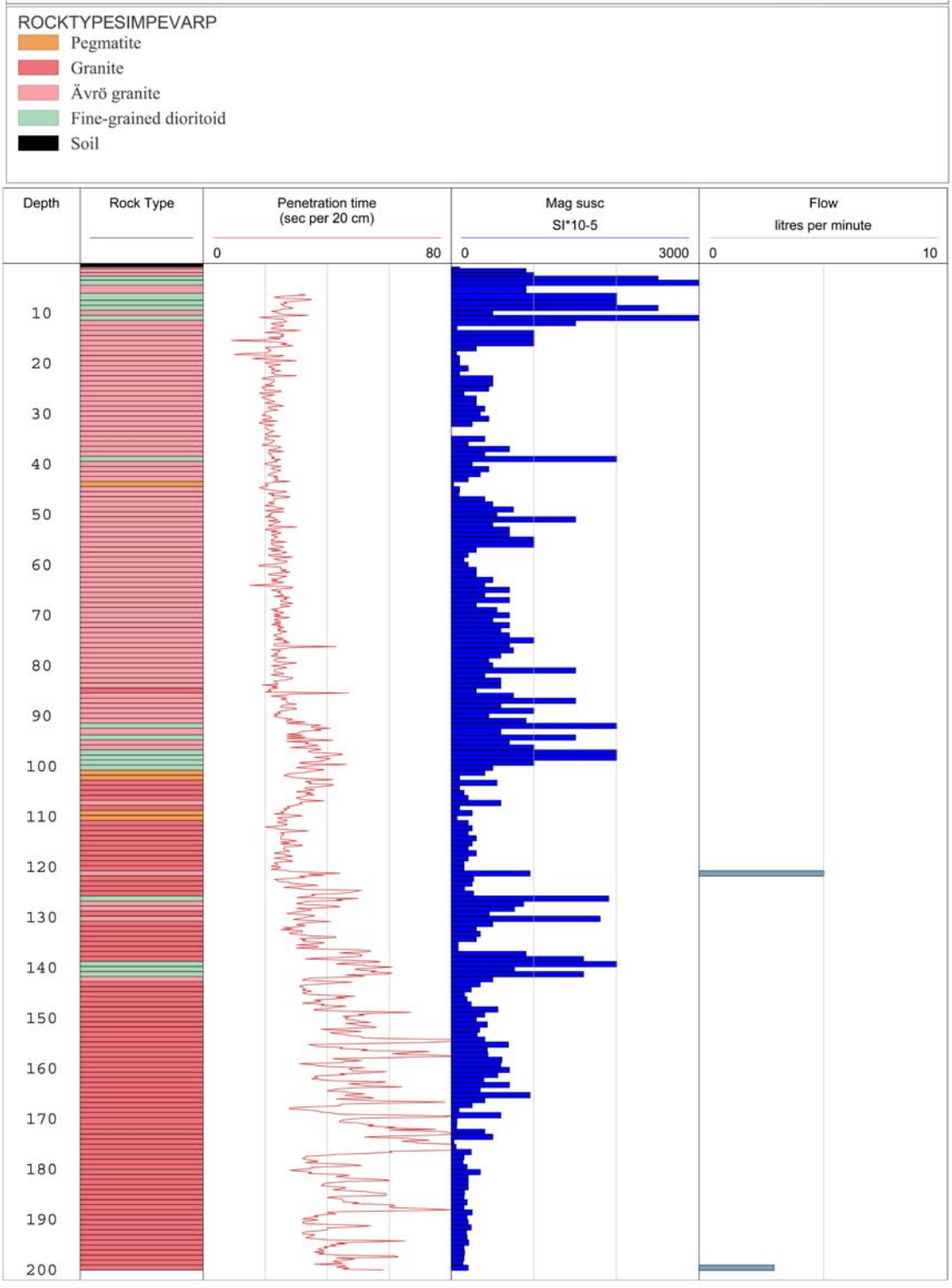
Drilling start date: 2004-06-01
Drilling stop date: 2004-06-04

Appendix 2

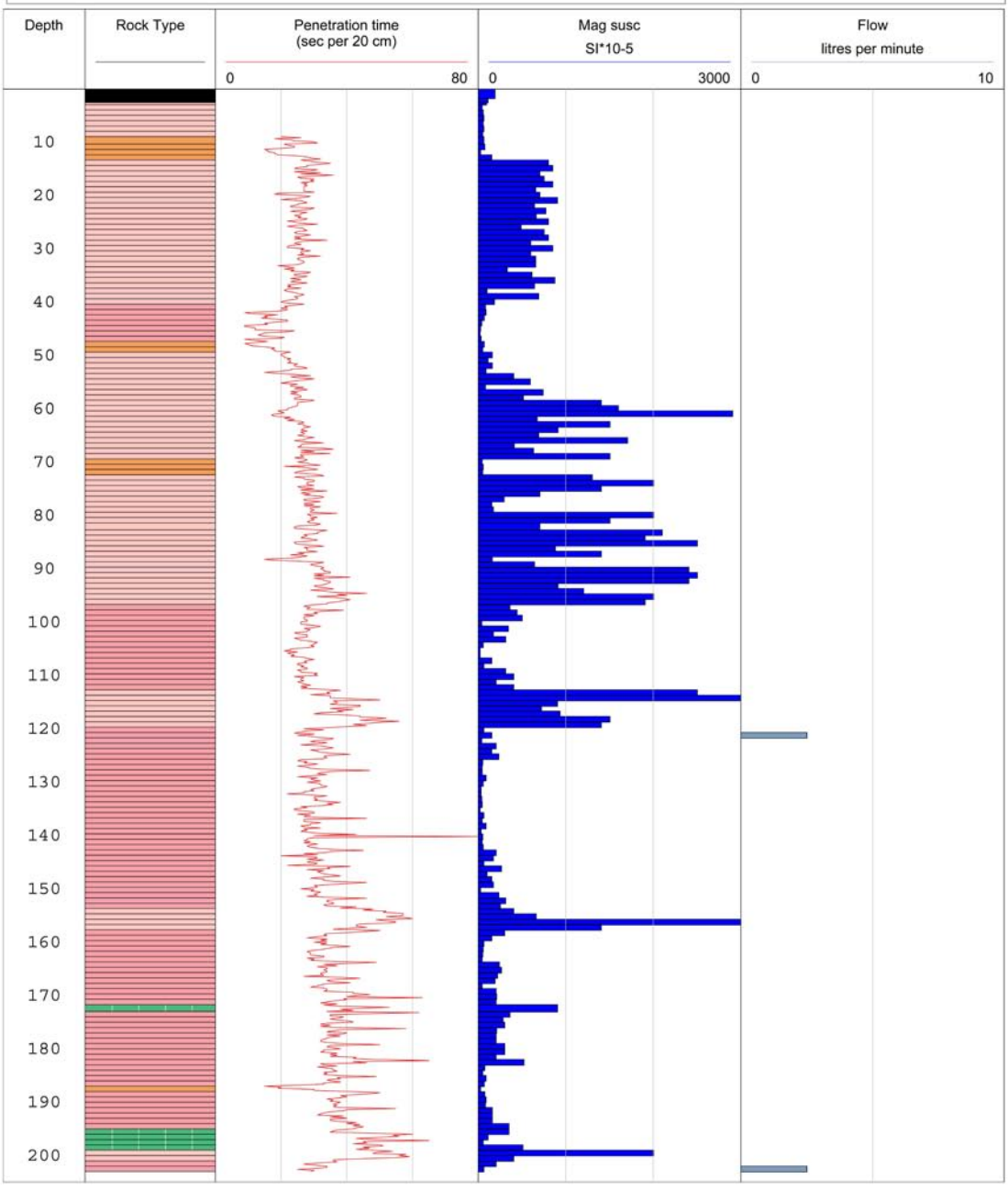
Geological summary for boreholes HSH04, HSH05, HSH06, HAV11, HAV12, HAV13 and HAV14. Preliminary geological mapping, drilling penetration time, magnetic susceptibility and measured water flow during drilling



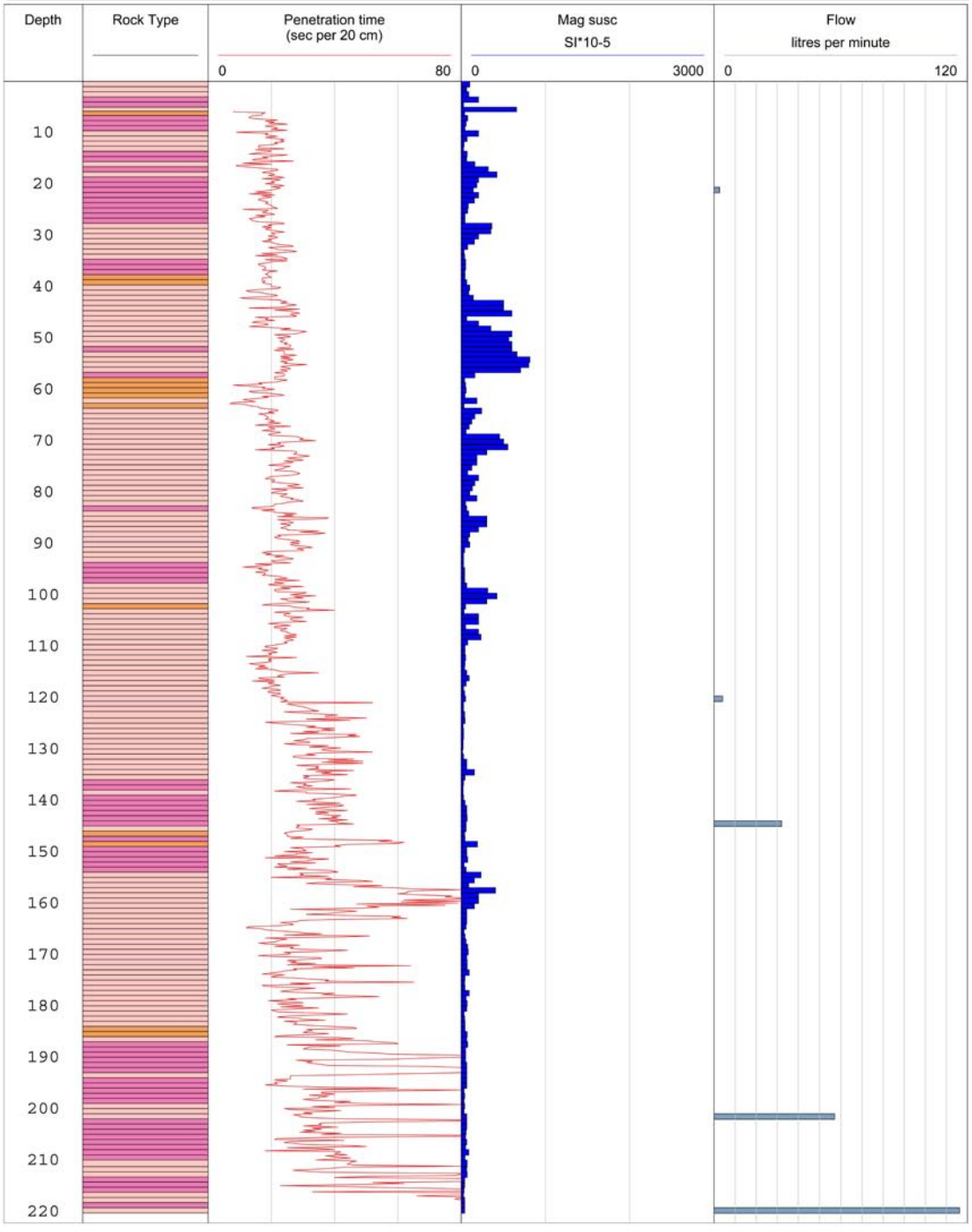
Title HSH05 **Appendix 2**



Title HSH06 **Appendix 2**

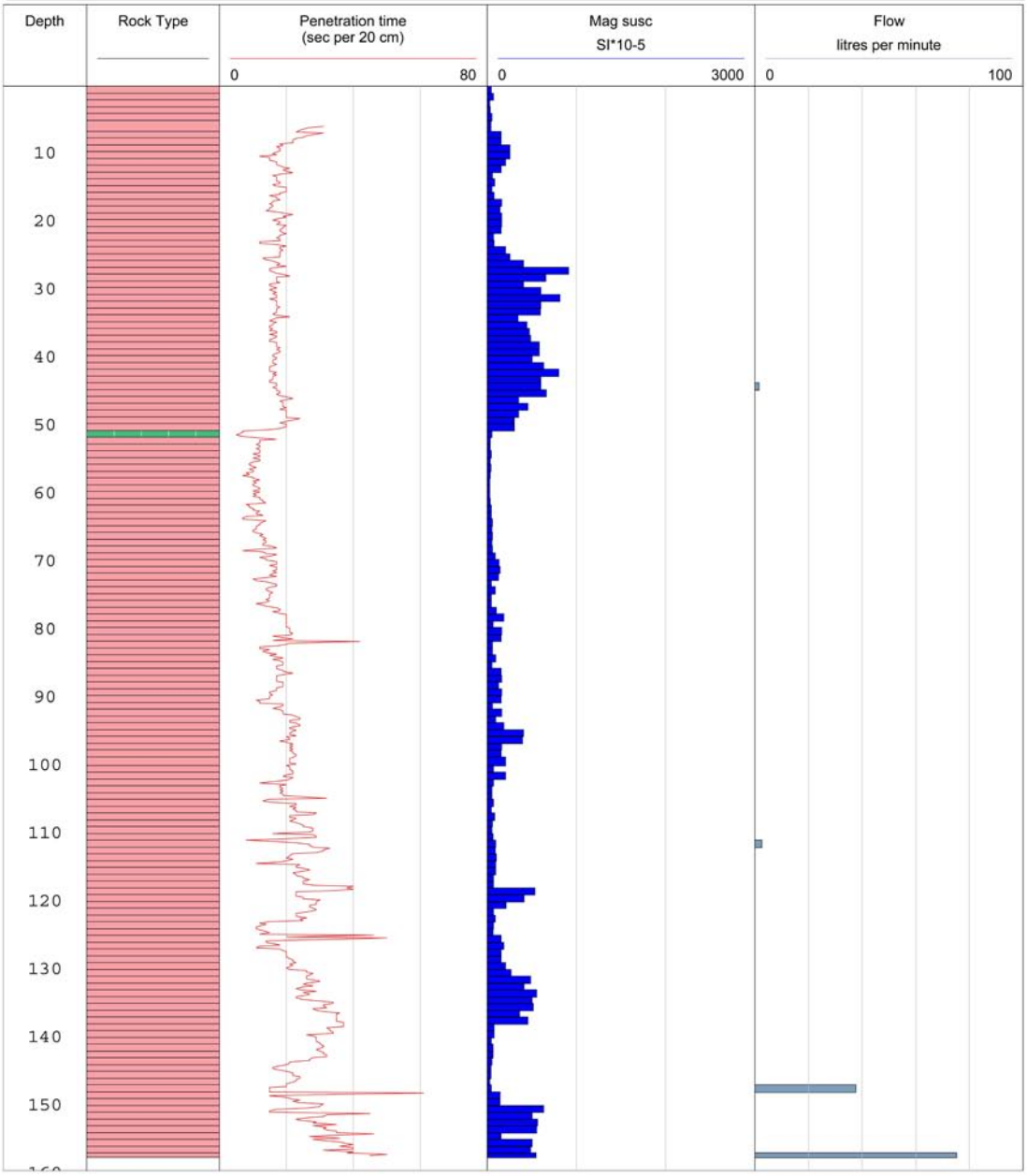


Title **HAV11** **Appendix 2**

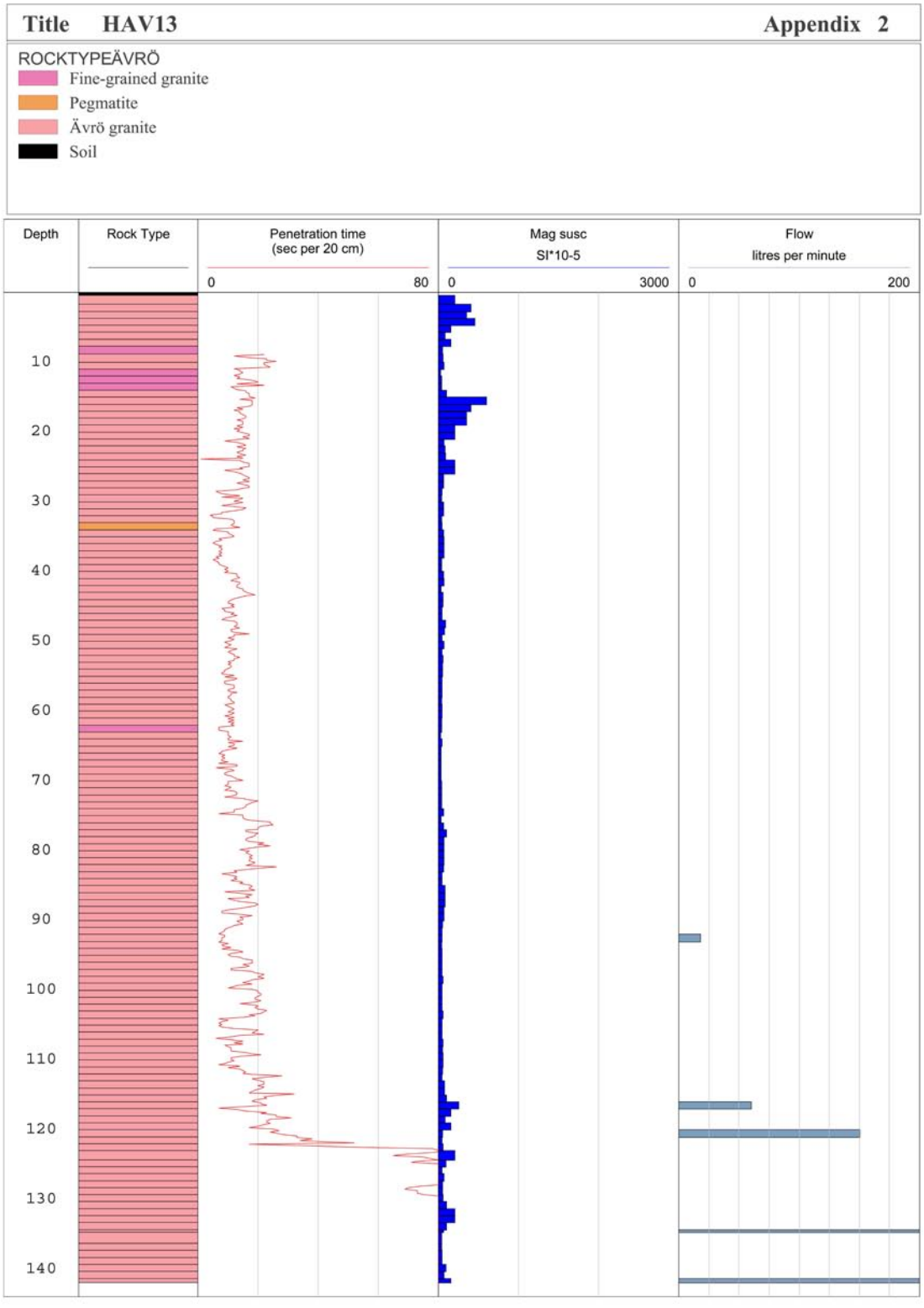


Title **HAV12** **Appendix 2**

ROCKTYPEÄVRÖ
Ävrö granite
Fine-grained diorite-gabbro



Title **HAV13** **Appendix 2**



Title HAV14 **Appendix 2**