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Oskarshamn site investigation

Percussion drilling of boreholes HLX36 and HLX37 for investigation of lineament NS001

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January 2006

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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, typically 150 to 200 m.

Boreholes HLX36 and HLX37 were drilled for investigation of lineament NS001 in the southwestern part of the Laxemar subarea. The boreholes were drilled in opposite directions, straddling the north-south trending lineament.

No clear indications of a deformation zone could be seen in the boreholes and the geophysical anomaly (low velocity zone) in profile LSM000539 is therefore unexplained by the results from drilling.

The water yield in HLX36 was nil and in HLX37 it was a moderate 40 L/min.

No wider sections with significantly reduced magnetic susceptibility have been noted. The drilling penetration times were, with a few smaller exceptions, stable.

Monitoring of hydraulic responses was made in 13 surrounding boreholes. A logger was also emplaced in HLX36 during the drilling of HLX37. Only two, very questionable, responses during drilling of HLX36 and HLX37 were noted in HLX28 and HLX36.

Sammanfattning

Hammarborrhål borras i allmänhet för två olika ändamål: dels vattenförsörjning inför kärnborrrning dels för att möjliggöra undersökningar i ytligare berggrund.

Borrhålen HLX36 och HLX37 utfördes för undersökning av lineament NS001 i den sydvästra delen av Laxemarsområdet. Hålen borrades mot varandra på ömse sidor om det nord-sydliga lineamentet.

Inga tydliga indikationer på en deformationszon kunde ses i borrhålen och den geofysiska anomalin (låghastighetszon) i profil LSM000539 kan därmed inte förklaras utifrån resultaten från borrning.

Vattenföringen var noll i HLX36 och i HLX37 var den på måttliga 40 L/min.

Inga större partier med signifikant minskad magnetisk susceptibilitet kunde noteras. Borrsjunktiderna var, med några få undantag, stabila.

Övervakning av hydrauliska responser gjordes i 13 omgivande borrhål. En logger placerades även i HLX36 inför borrning av HLX37. Endast två, mycket tveksamma, responser under borrning av HLX36 och HLX37 kunde ses i HLX28 och HLX36.

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 were identified by air-borne geophysical methods or by remote sensing, primarily of topography /3/.

Follow-up ground geophysics over lineament NS001, as shown in Figure 1-1, was done /4/.

Percussion drilling to a length of ca 200 m was done to investigate the interpreted lineament, NS001, and a geophysical anomaly along the refraction seismic profile LSM000539.

This report will describe the drilling of the two percussion holes, HLX36 and HLX37 and the measurements performed during the drilling phase. The holes were drilled on lineament NS001 in the south-western part of the Laxemar subarea of the Oskarshamn site investigation, see Figure 1-1.

The decision to drill boreholes HLX36 and HLX37 is given in SKB id 1043712, internal document.

The regional authorities were informed by letters on 2005-09-07, SKB id 1043713.

The drilling and all related on-site operations were performed according to a specific activity plans (AP PS 400-05-064). 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.

Method descriptions and activity plans 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 HLX36 och HLX37	AP PS 400-05-064	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

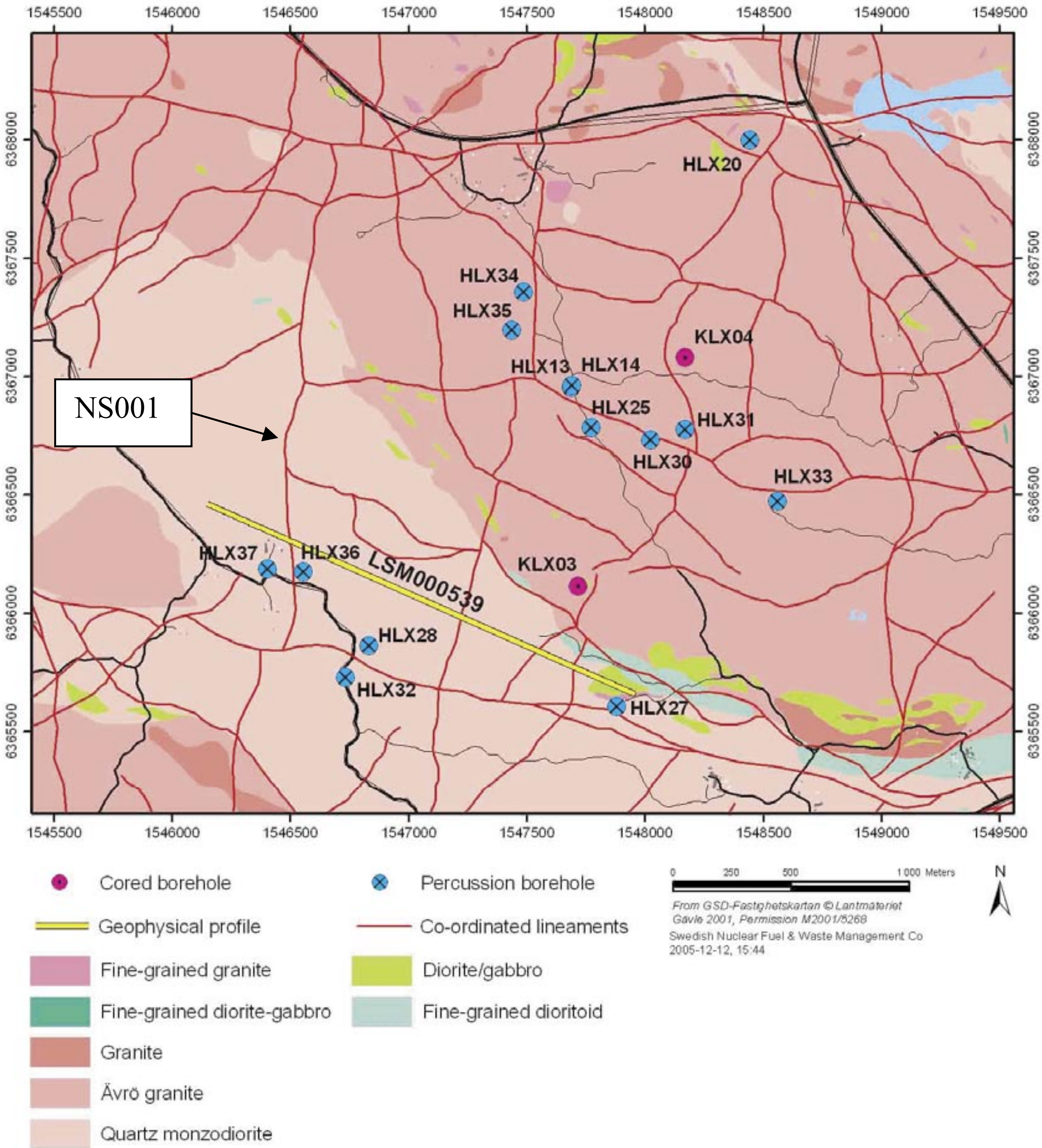


Figure 1-1. *Location of boreholes HLX36 and HLX37 in the Laxemar subarea. The map shows the bedrock geology, main lineaments and surface geophysical profile LSM000539 and surrounding boreholes.*

2 Objective and scope

This report will describe the drilling of two percussion boreholes, HLX36 and 37, and the measurements performed during drilling ie logging of preliminary geology, pumping tests and measurements of hydraulic responses.

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

Table 2-1. Borehole objectives before drilling.

Borehole	Drilling objective
HLX36	The borehole would intercept a possible subvertical deformation zone related to the low-velocity zone in the refraction seismic profile LSM000539 at 100–120 m drilled length. The low-velocity zone is thought to correspond to lineament NS001.
HLX37	The borehole would intercept a possible subvertical deformation zone, corresponding to lineament NS001 on the surface, at 180–200 m drilled length ie a deformation zone dipping to the west would be intercepted earlier in the borehole.

3 Equipment

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

3.1 Drilling equipment

Drilling of boreholes HLX36 and HLX37, performed by Sven Andersson AB, was made with a Nemek 710 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" (140 mm), lowered into the borehole by a Driconeq 114 mm pipe string.

***Figure 3-1**. Drill site HLX36, the drill rig and equipment for preliminary geological mapping.*

3.2 Equipment for measurements and sampling during drilling

Flow measurements during drilling were performed using measuring a graded vessel and a stop watch.

Measurement of the drilling penetration time was done automatically with MWD equipment, see also Section 4.5. The lengths recorded by manual observations (flow measurements and preliminary geology) can differ a few centimeters from the lengths recorded automatically with the MWD equipment (drilling penetration time). This should, however, not be regarded as an inconsistency but as a reflection of the inherent uncertainty in length measurements.

Samples of soil and drill cuttings were collected in sampling pots and a preliminary geological logging was done. Magnetic susceptibility in the samples was measured with a hand-held meter, JH-8 from Geoinstruments, Finland. The electrical conductivity of the return water was measured with a hand-held Waterproof TDScan WP Pocket Conductivity tester from Eutech Instruments.

Hydraulic responses in surrounding boreholes were measured with Mini-Troll pressure loggers.

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,
- pumping tests and hydraulic responses,
- 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

Excentric percussion drilling with 190 mm diameter ("Tubex 140") was made through the unconsolidated soil and fractured near-surface bedrock to a depth of between 6 m (HLX36) and 12 m (HLX37). A casing rests on top of the excentric drill bit and is lowered into the borehole as drilling progresses.

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 from the excentric drilling was grouted with low-alkali cement, see Figure 4-1.

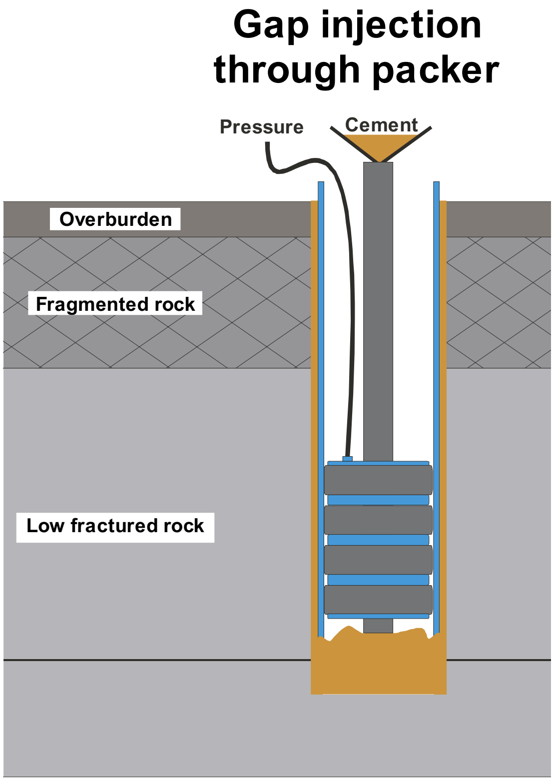


Figure 4-1. *Gap injection technique.*

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 holes and measuring the amount of in-flowing water. As no water could be measured in the holes, the tightness of the gap injection was considered to be sufficient.

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 drillsite geologist and the drilling crew included the following items:

- 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 estimation of water colour and intensity which in turn gives an indication of clay content and level of oxidation. The electrical conductivity was measured in the cups.
- Penetration time (expressed as seconds per 20 cm) was logged automatically.
- The water yield from the hole was estimated when noticeable changes in water flow occurred and after the drilling phase was completed. The method employed was to blow compressed air through the drill stem and to measure the amount of return water during steady state conditions. The method employed gives an indication of the actual yield. The lower detection limit is estimated at 1–2 L/min. At higher flow rates (over 100 L/min) the uncertainty of the method increases.

***Figure 4-2**. Return water from drilling (HLX37) is led to a settling container. The cyclone for collecting the cuttings can be seen fastened on top of the container. Equipment for the preliminary geological logging can be seen in the foreground.*

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

Borehole deviation measurements were made with a magnetometer/accelerometer instruments; FLEXIT SmartTool, in conjunction with drilling.

4.6 Borehole completion

All equipment was removed, the sites cleaned and joint inspections were made by representatives from SKB and the Contractor to ensure that the sites had been restored to a satisfactory level. Lockable steel caps on the casing will be installed in January 2006.

4.7 Hydraulic responses

The water levels in selected neighbouring boreholes were monitored for hydraulic responses with MiniTroll pressure loggers. The logger settings were:

Scan time: 1 s
Log time: 10 s
Event: 0.1 kPa

The scan time is the interval for the pressure readings. With an event function of 0.1 kPa, the logger saves any data that has changed more than 0.1 kPa since the previous scanning. The log time is the interval between data savings regardless of pressure changes.

4.8 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.

4.9 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 in accordance with an agreement with the environmental authorities. The water amounted to very small quantities.

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

Boreholes HLX36 and HLX37 were drilled for investigation of lineament NS001 in the southwestern part of the Laxemar subarea.

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

The water yield was nil in HLX36 and 40 L/min in HLX37.

No clear hydraulic responses in surrounding boreholes could be established.

5.1 Borehole design

A summary of data from the borehole are presented in Tables 5-1. Technical data of the boreholes are illustrated in Appendix 1.

The results from measurement of borehole deviation with the Flexit tool in HLX36 and HLX37 are given in Table 5-2 and presented graphically in a vertical section in Figure 6-1.

Table 5-1. Geometric and technical data for borehole HLX36 and HLX37.

Parameter	HLX36		HLX37	
Drilling period	From 2005-09-20 to 2005-09-22		From 2005-09-26 to 2005-09-28	
Borehole inclination (starting point) (0 to –90)	–59.30°		–59.25°	
Borehole azimuth (0–360)	270.6°		86.2°	
Borehole length	199.80 m		199.80 m	
Soil depth	0 m		6.0 m	
Drill bit diameter	0.140 m		0.139 m	
Starting point coordinates (system RT90/RHB70)	Northing: 6366172.94 m Easting: 1546558.45 m Elevation: 15.558 m a s l		Northing: 6366183.66 m Easting: 1546406.21 m Elevation: 15.188 m a s l	
Water yield (interval)	0 L/min (0–199.8 m)		40 L/min (0–199.8 m)	
Borehole diameter (interval) (diameter)	0–6.10 m	190 mm	0–12.10 m	190 mm
	6.10–121.5 m	139.8 mm	12.10–121.5 m	140.0 mm
	121.5–199.8 m	139.6 mm	121.5–199.8 m	139.4 mm
Casing diameter (interval) (diameter)	0–5.94 m	$Ø_o$ = 168	0–11.94 m	$Ø_o$ = 168
	5.94–6.03 m	$Ø_i$ = 160	11.94–12.03 m	$Ø_i$ = 160
		$Ø_o$ = 168		$Ø_o$ = 168
		$Ø_i$ = 142		$Ø_i$ = 142

Table 5-2. Results from deviation measurements in HLX36 and HLX37.

Bhlen (m)	HLX36		HLX37	
	Magnetic Bearing (degrees)	Dip (degrees)	Magnetic Bearing (degrees)	Dip (degrees)
0.00				
10.00	269.09	–58.14		
20.00	268.99	–57.45	83.55	–59.33
30.00	269.34	–56.34	84.20	–59.33
40.00	269.56	–55.71	84.45	–59.14
50.00	269.66	–55.06	84.76	–58.86
60.00	269.83	–54.59	85.54	–58.80
70.00	269.86	–54.11	86.03	–58.44
80.00	271.12	–53.26	87.20	–57.89
90.00	270.94	–52.89	85.39	–56.91
100.00	271.24	–52.62	87.99	–56.46
110.00	271.74	–52.39	89.14	–55.97
120.00	271.83	–52.13	90.40	–55.35
130.00	270.92	–51.76	86.54	–54.96
140.00	272.02	–51.36	89.16	–54.62
150.00	273.16	–51.01	89.01	–54.13
160.00	273.13	–50.67	89.00	–54.04
170.00	269.78	–50.48	90.44	–53.81
180.00	271.62	–49.81	90.52	–53.53

5.2 Hydrogeological results

The water yields obtained from blowing of compressed air during drilling are given in Table 5-3.

Table 5-3. Water yields from drilling.

Borehole	From (m)	To (m)	Water yield (L/min)	Date and time (local)	
HLX36	6.03	199.8	0	050922	17:00*
HLX37	12.03	103.5	9	050927	18:08
HLX37	12.03	121.5	10	050927	19:10
HLX37	12.03	121.5	42	050928	12:20
HLX37	12.03	148.5	42	050928	13:50
HLX37	12.03	199.8	40	050928	18:00*

NB. In the geoscientific summary given in Appendix 2 only the lowest of two measurements from the same length in the borehole is presented. Measurements at the same length in a hole typically occur because one measurement is done at the end of the working day and another is done the following day. The latter measurement normally gives a significantly higher value due to recovery and storage.

* Time at final rinsing by air blow.

The level at which the water yield was measured does not always correspond to the observed level of inflow.

The observed levels of water inflow during drilling are summarised in Table 5-4 and shown graphically in Figure 6-1.

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

Table 5-4. Observed levels of water inflow during drilling.

Borehole	Noticeable inflow of water during drillling (meters drilled length)
HLX36	N/A
HLX37	5, 100, 148.5 m

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

Borehole	Amount of water released (m^3)
HLX36	0
HLX37	18

Water conductivity

Measurements of the electrical conductivity in the return water show that, apart from a slight increase in the initial stage of drilling, the values are low and stable around 50–60 mS/m.

Hydraulic responses

Monitoring of hydraulic responses through evaluation of the changes in water table levels was done in the following boreholes during drilling of HLX36 and HLX37:

- HLX13, 14, 25, 30, 31 and 33 in lineament EW007.
- HLX34 and 35 in linement NS059.
- HLX20 in lineament EW002.
- HLX27, 28 and 32 in lineament NW042.
- Cored borehole KLX04.

A logger was also emplaced in HLX36 before drilling in HLX37 was started. No instrumentation for monitoring was installed in KLX03.

The locations of boreholes not previously mentioned in this report are given in Figure 1-1.

No clear hydraulic responses in surrounding boreholes during drilling of boreholes HLX36 and HLX37 could be established, see Table 5-6. However, a slight decrease in the water level in HLX28 could be noted during September 28 and 29, see Figure 5-1. This could be related to drilling of HLX37.

The response in HLX36 during drilling of HLX37 is unclear and shows mainly a slow recovery of the water table in HLX36, see Figure 5-2.

Table 5-6. Summary of hydraulic response observations.

Drilling in borehole	Hydraulic response in borehole													
	HLX13	HLX14	HLX25	HLX30	HLX31	HLX33	HLX34	HLX35	HLX20	HLX27	HLX28	HLX32	HLX36	KLX04
HLX36	n	n	n	n	n	n		n	n	n	n	n		n
HLX37	n	n	n	n	n	n	n	n	n	n	?	n	?	n

Legend:

- n =no
- ? =unclear response
- blank=no data available

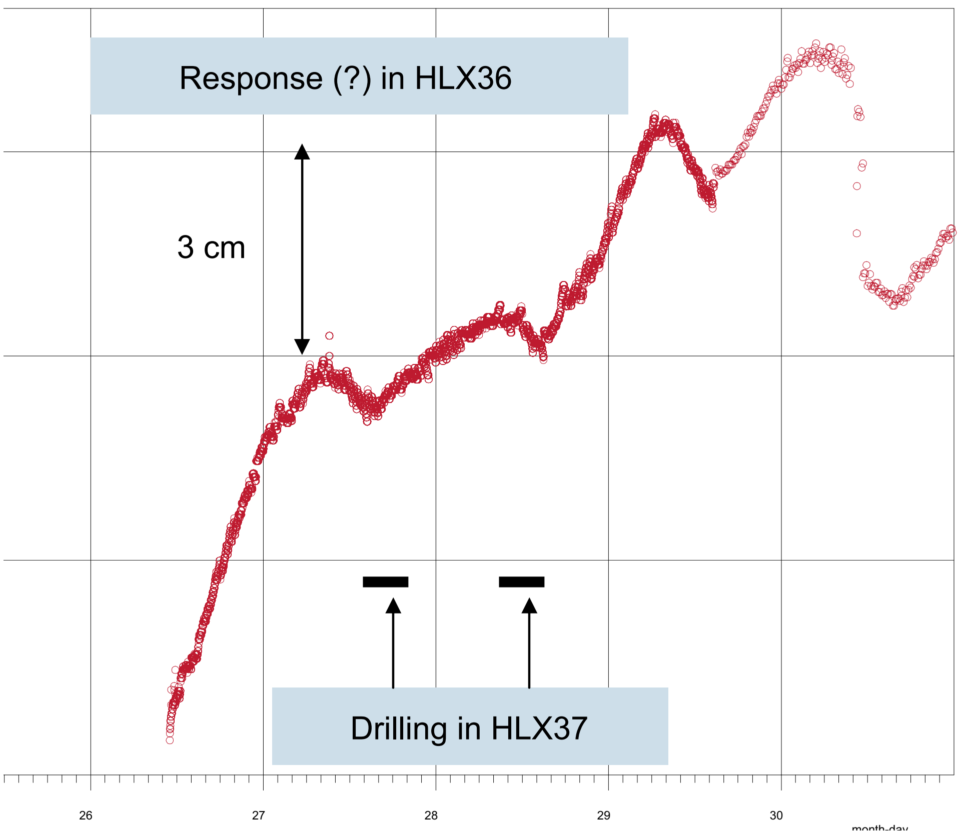


Figure 5-1. *The water table in borehole HLX36 during drilling in HLX37. The water table in HLX36 is interpreted here as being in a state of recovery after drilling. No clear hydraulic response can be seen, however a reduced rate of recovery could be interpreted during the times when drilling is performed in borehole HLX37.*

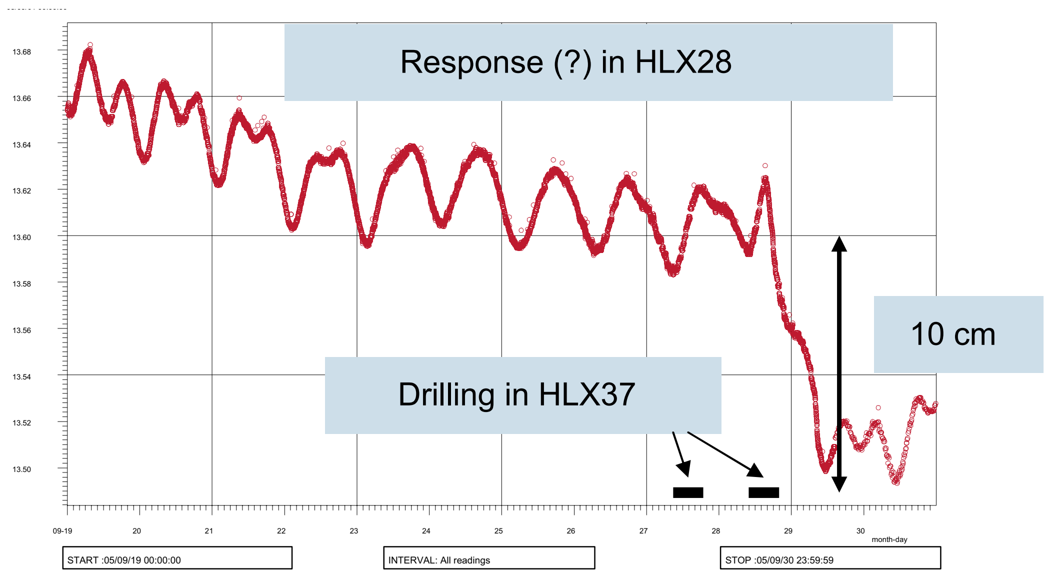


Figure 5-2. Possible hydraulic response in HLX28 during drilling of HLX37. A slight drawdown of some 10 cm can be seen during the later stages and after drilling in HLX37.

5.3 Geological results

Lithologically the holes were dominated by Quartzmonzodiorite. This corresponds well with expectations based on results from surface geological mapping.

However, a substantial part of HLX36 (110–190 m) and HLX37 (120–145 m) consisted of a mafic rock that was somewhat difficult to classify. The mafic rock in boreholes HLX36 and HLX37 is fine- to medium grained, with similar magnetic susceptibility as in the surrounding Quartz monzodiorite and contains the minerals talc and serpentine. It was here called Diorite/Gabbro because it seemed more appropriate than the optional classification as “fine-grained diorite-gabbro” or “fine-grained dioritoide”. Fine-grained diorite-gabbro usually occurs as fragments or enclaves with low magnetic susceptibility in Ävrö granite and fine-grained dioritoide contains feldspar and/or amphibole megacrysts.

Minor intercalations of fine-grained granite have also been noted.

The geological results from drilling are presented in Appendix 2.

5.4 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 low alkali cement paste and oils are given in Table 5-7.

Table 5-7. Consumption of cement paste and oils.

Borehole	Cement paste used (low-alkali White Cement) litres/kg	Hammer oil (Preem Hydra 46) litres	Compressor oil (Schuman 46) litres
HLX36	60/71	30	None noted
HLX37	60/71	30	None noted

5.5 Nonconformities

No instrumentation for monitoring was installed in KLX03. Measurements of hydraulic responses was not made in this borehole.

6 Interpretation

The results from drilling are summarised in Figure 6-1.

No clear indication of a deformation zone that could be related to the low-velocity zone in the refraction seismic profile LSM000539 was seen in either borehole. HLX36 was not water bearing and did not show any other signs of deformation zones. HLX37 was moderately water bearing with a yield of 40 L/min, but did otherwise not demonstrate any clear signs of deformation zones. The penetration rate and magnetic susceptibility were reasonably consistent throughout both boreholes and did not display any clear indication of any deformation zones such as highly variable penetration rate or wider sections with highly reduced magnetic susceptibility.

Monitoring of hydraulic responses was made in 13 surrounding boreholes. A logger was also emplaced in HLX36 during the drilling of HLX37. Only two, very questionable, responses during drilling of HLX36 and HLX37 were noted in HLX28 and HLX36. The absence of clear hydraulic responses should also be seen as an indication that the boreholes do not penetrate a deformation zone.

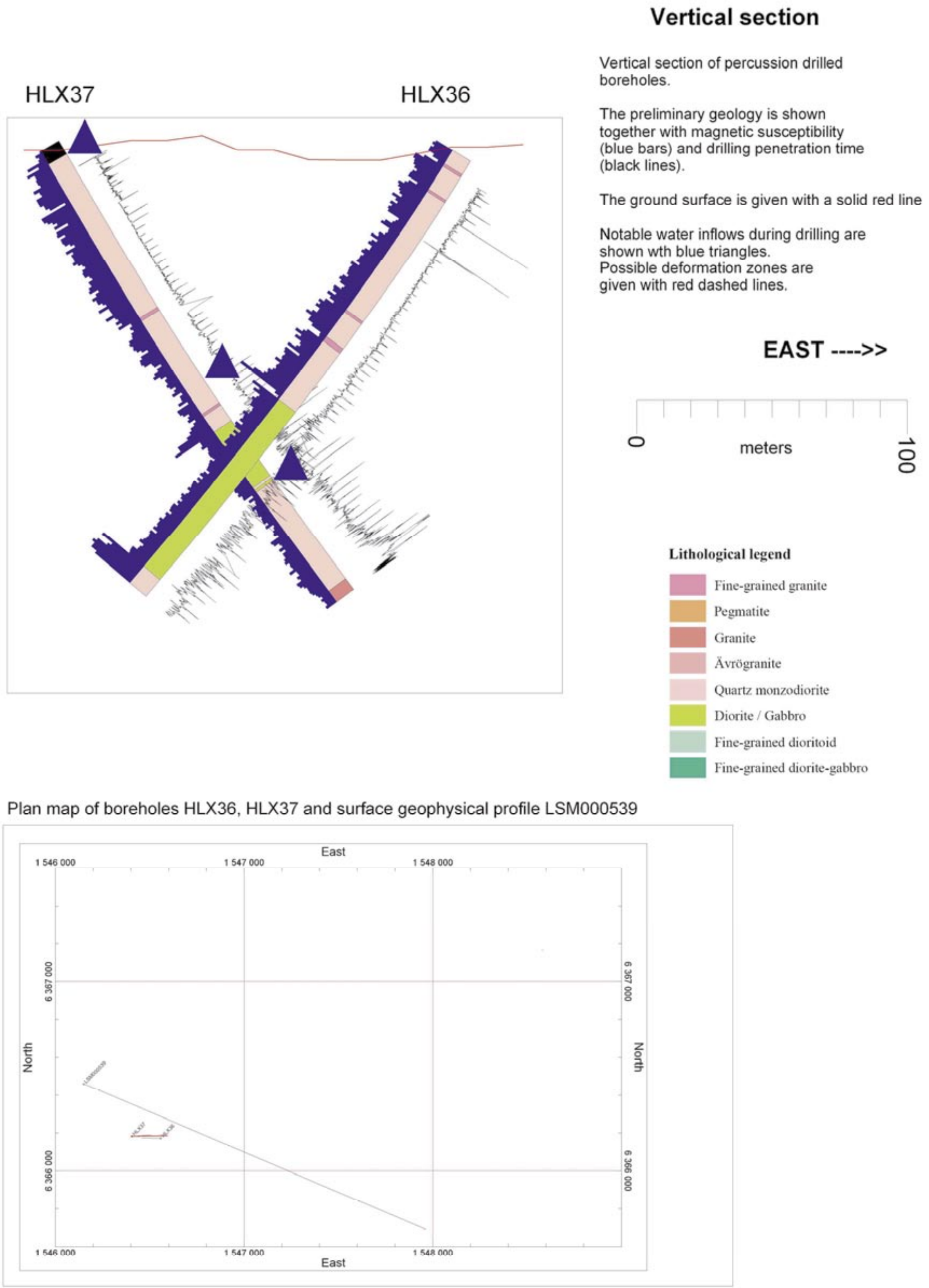


***Figure 6-1**. Boreholes HLX36 and HLX37 in the southwestern part of the investigated lineament are shown with preliminary geological results, magnetic susceptibility (blue bars) and drilling penetration time (black line). Positions for water inflow are indicated by blue triangles. Soil is shown with black colour in the borehole.*

7 References

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

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

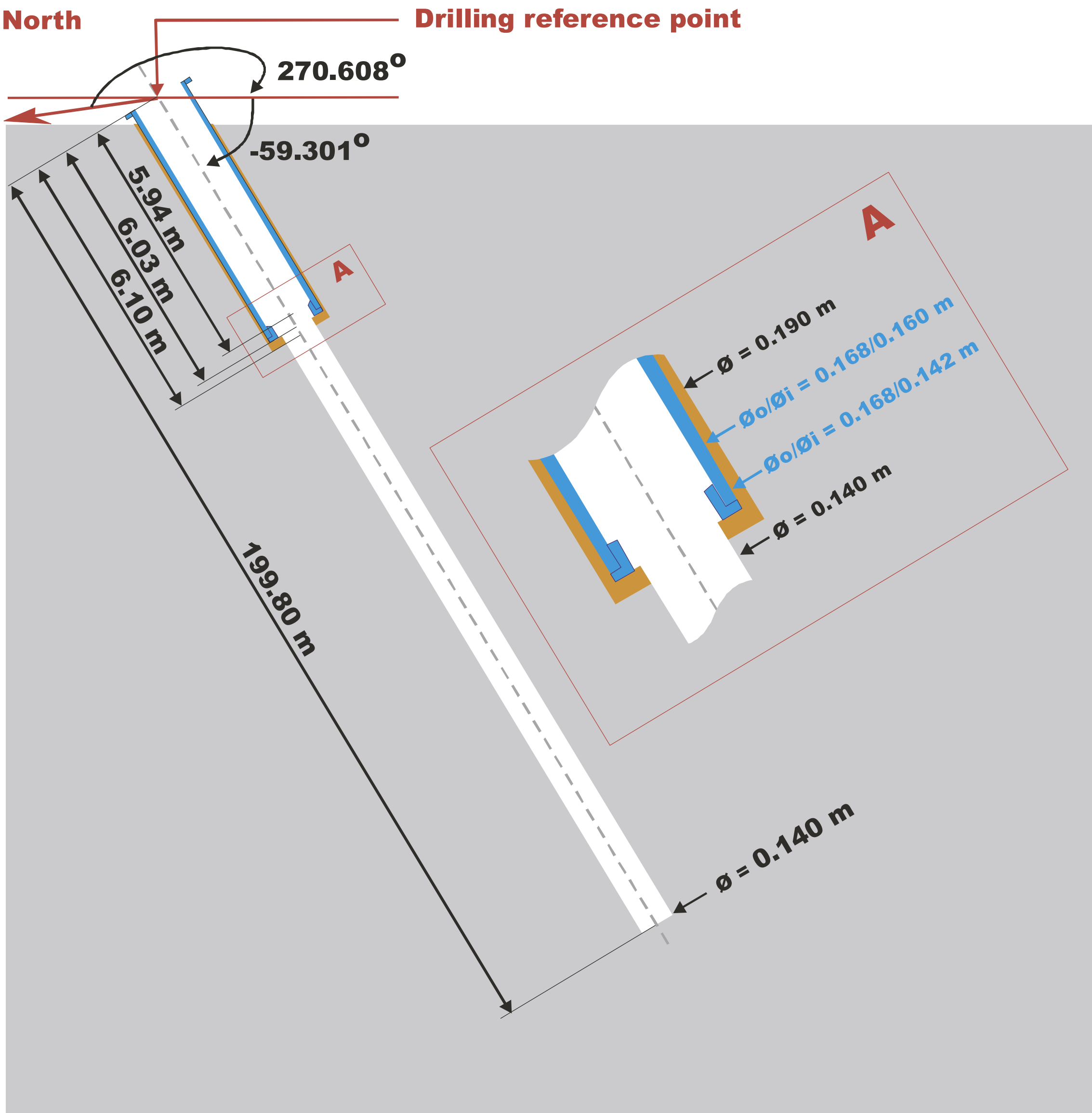
/3/ **Triumf C-A, 2004.** Oskarshamn site investigation. Joint interpretation of lineaments. SKB P-04-49, Svensk Kärnbränslehantering AB.

/4/ **Lindqvist G, 2004.** Oskarshamn site investigation. Refraction seismic measurements in Laxemar spring 2005. SKB P-05-155, Svensk Kärnbränslehantering AB.

Technical data boreholes HLX36 and HLX37

Technical data

Borehole HLX36



Drilling reference point

Northing: 6366172.935 (m), RT90 2,5 gon V 0:-15

Easting: 1546558.452 (m), RT90 2,5 gon V 0:-15

Elevation: 15.558 (m), RHB 70

Drilling period

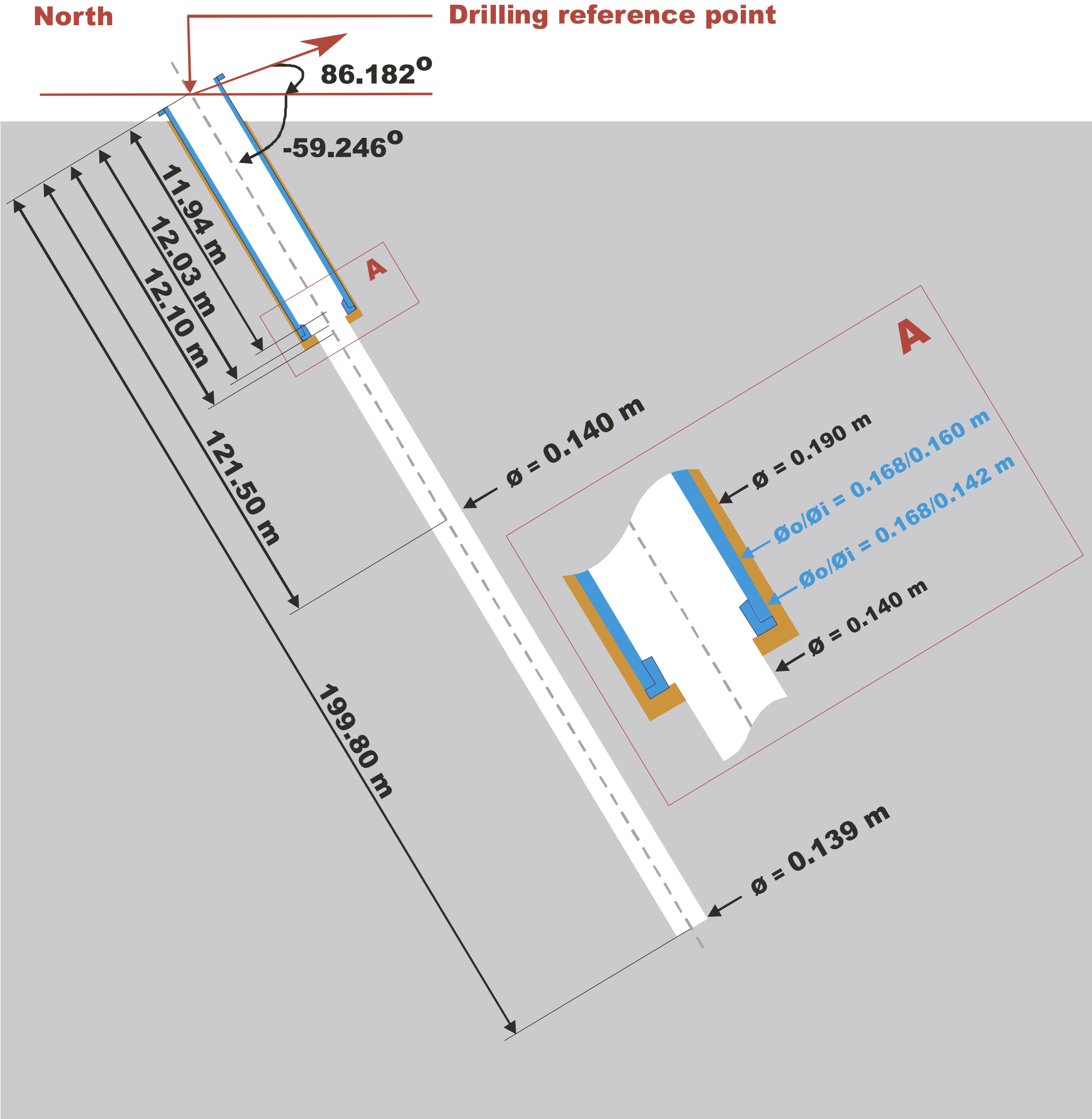
Drilling start date: 2005-09-20

Drilling stop date: 2005-09-22

Rev 2005-11-24

Technical data

Borehole HLX37



Drilling reference point

Northing: 6366183.660 (m), RT90 2,5 gon V 0:-15

Easting: 1546406.214 (m), RT90 2,5 gon V 0:-15

Elevation: 15.188 (m), RHB 70

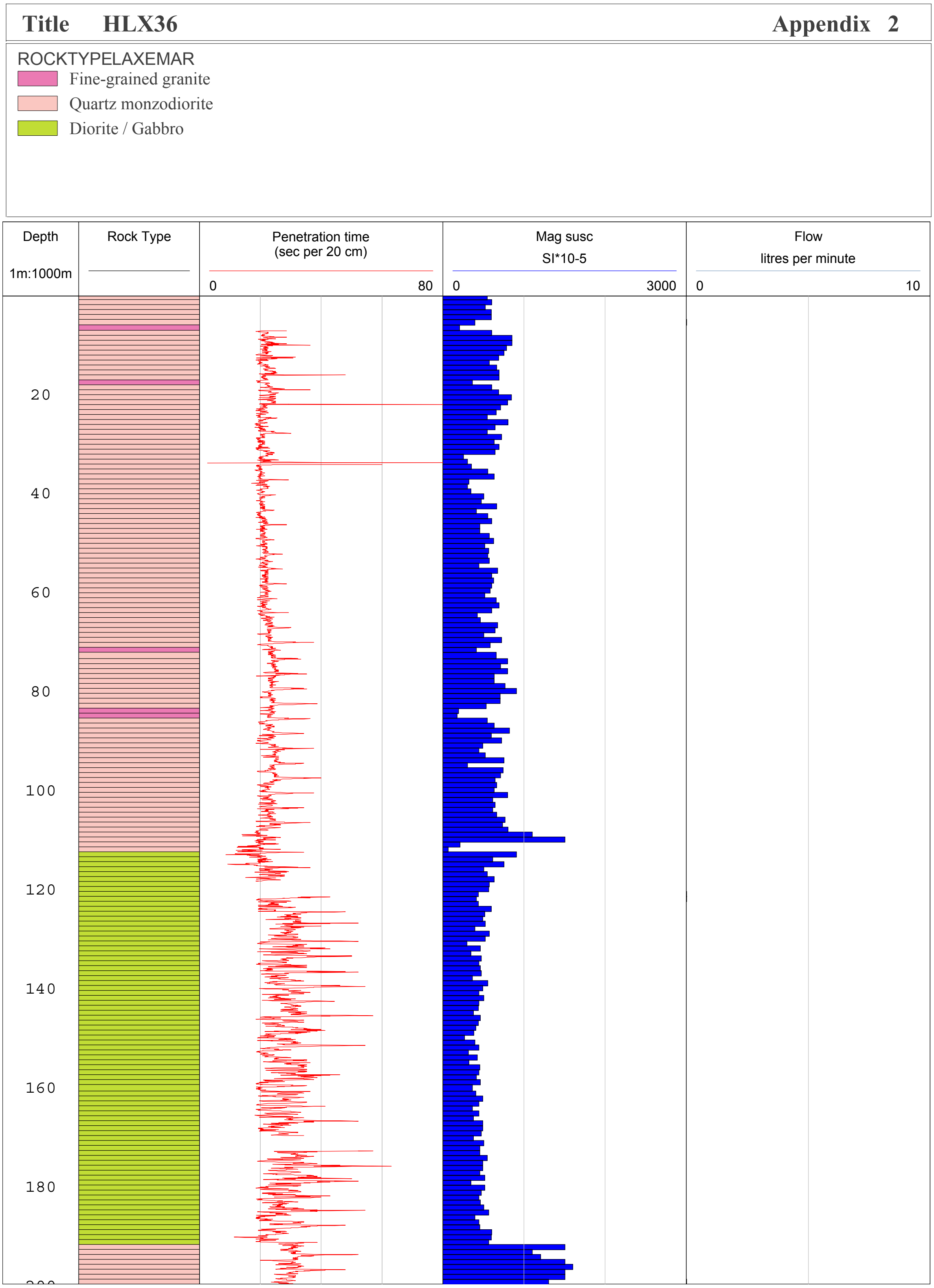
Drilling period

Drilling start date: 2005-09-26

Drilling stop date: 2005-09-28

Rev 2005-11-24

Geoscientific summary for boreholes HLX36 and HLX37



Title HLX37 **Appendix 2**

ROCKTYPELAXEMAR
- Fine-grained granite
- Granite
- Quartz monzodiorite
- Diorite / Gabbro
- Soil