P-04-275

Revised April 2006

Oskarshamn site investigation

RAMAC and BIPS logging in boreholes KLX03, HAV11 to HAV13 and HLX21 to HLX25

Jaana Gustafsson, Christer Gustafsson
Malå Geoscience AB / RAYCON

October 2004

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1651-4416
SKB P-04-275

Revised April 2006

Oskarshamn site investigation

RAMAC and BIPS logging in boreholes KLX03, HAV11 to HAV13 and HLX21 to HLX25

Jaana Gustafsson, Christer Gustafsson
Malå Geoscience AB / RAYCON

October 2004

Keywords: BIPS, RAMAC, Radar, TV.

Reading instruction

For revision no 1 of this report a recalculation of the directional radar data has been done. The strike angle between the line of the plane's cross-section with the surface and the Magnetic North direction was earlier counted counter-clockwise but it is now recalculated as such it counts clockwise, see Figure 5-2. New values for strike and dip are therefore updated in Table 5-10.

Abstract

This report includes the data gained in geophysical logging operations performed within the site investigation at Oskarshamn. The logging operations presented here includes borehole radar (RAMAC) and BIPS logging in the core-drilled borehole KLX03 and percussion drilled boreholes HAV11 to HAV13 and HLX21 to HLX25. All measurements were conducted by Malå Geoscience AB/RAYCON during September 2004.

The objective of the radar surveys is to achieve information on the rock mass around the borehole. Borehole radar is used to investigate the nature and the structure of the rock mass enclosing the boreholes.

The objective of the BIPS logging is to achieve information of the borehole including occurrence of rock types as well as determination of fracture distribution and orientation.

This report describes the equipment used as well as the measurement procedures and data gained. For the BIPS survey, the result is presented as images. Radar data is presented in radargrams and the identified reflectors are listed.

The borehole radar data quality from KLX03, HAV11 to HAV13 and HLX21 to HLX25 was relatively satisfying, but in some parts of lower quality due to more conductive conditions. This conductive environment of course reduces the possibility to distinguish and interpret possible structures in the rock mass which otherwise could give a reflection. However, the borehole radar measurements resulted in a number of identified radar reflectors. In KLX03 approximately 200 radar reflectors were identified and about 50 of them were also orientated (strike/dip). In HAV11 19 radar reflectors were identified and the corresponding numbers for HAV12, HAV13, HLX21, HLX22, HLX23, HLX24 and HLX25 are 28, 8, 24, 27, 28, 26 and 19.

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Oskarshamn. Mätningarna som presenteras här omfattar borrhålsradarmätningar (RAMAC) och BIPS-loggningar i borrhålen KLX03, HAV11 till HAV13 samt HLX21 till HLX25. Alla mätningar är utförda av Malå Geoscience AB/RAYCON under september 2004.

Syftet med radarmätningarna är att samla information om bergmassan runt borrhålet. Borrhålsradar används till att karakterisera bergets egenskaper och strukturer i bergmassan närmast borrhålet.

Syftet med BIPS loggingen är att skaffa information om borrhålet inkluderande förekommande bergarter och bestämning av sprickors fördelning och deras orientering.

Rapporten beskriver utrustningen som använts liksom mätprocedurer och en beskrivning och tolkning av data som erhållits. För BIPS loggningen presenteras data som plottar längs med borrhålet. Radardata presenteras i radargram och en lista över tolkade radarreflektorer ges.

Borrhålsradardata från KLX03, HAV11–HAV13 samt HLX21–HLX25 var relativt tillfredsställande, men tidvis av sämre kvalité troligen till stor del beroende på en konduktiv miljö. En konduktiv miljö minskar möjligheterna att identifiera strukturer från borrhålsradardata. Dock har runt 200 radarreflektorer identifierats i KLX03, varav cirka 50 har kunnat orienteras (strykning/stupning). Motsvarande antal för HAV11, HAV12, HAV13, HLX21, HLX22, HLX23, HLX24 och HLX25 är 19, 28, 8, 24, 27, 28, 26 och 19.

Contents

1 Introduction

This document reports the data gained in geophysical logging operations, which is one of the activities performed within the site investigation at Oskarshamn. The logging operations presented here includes borehole radar (RAMAC) and TV-logging (BIPS) in the core-drilled borehole KLX03 and in the percussion-drilled boreholes HAV11 to HAV13 and HLX21 to HLX25. The work was carried out in accordance with activity plan AP PS 400-04-080. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

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

Activity plan	Number	Version
Borrhålsradar och BIPS i KLX03 och i HAV11, HAV12, HAV13 samt i HLX21, HLX22, HLX23, HLX24 och HLX25	AP PS 400-04-080	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för TV- loggning med BIPS	SKB MD 222.006	1.0
Metodbeskrivning för borrhålsradar	SKB MD 252.020	1.0

This report includes measurements from 0 to 1,000 m in KLX03. In HAV11 the loggings were performed to approximately 220 m depth, to 150 m in HAV12, to 140 in HAV13, to 150 m in HLX21, to 160 m in HLX22 and HLX23, to 170 m in HLX24 and to 195 m in HLX25.

The boreholes HAV11 to HAV13 and HLX21 to HLX25 are drilled with a diameter of approximately 140 mm and KLX03 with a diameter of 76 mm.

All measurements were conducted by Malå Geoscience AB/RAYCON during September 2004. The location of the boreholes is shown in Figure 1-1.

The used investigation techniques comprised:

- Borehole radar measurements (Malå Geoscience AB's RAMAC system) with dipole and directional radar antennas.
- Borehole TV logging with the so-called BIP-system (Borehole Image Processing System), which is a high resolution, side viewing, colour borehole TV system.

The delivered raw and processed data have been inserted in the database of SKB (SICADA). The SICADA Field Note reference to the present activity is presented in Table 1-2.

Table 1-2. Data references.

Subactivity	Database	Identity number
BIPS/radar KLX03, HLX21, HLX22, HLX23, HLX24, HLX25	SICADA	Field note 490
BIPS/radar loggning HAV11, HAV12, HAV13	SICADA	Field note 491

Figure 1-1. *General overview over the Simpevarp and Laxemar subareas in Oskarshamn with the location of the borehole KLX03, HAV 11 to 13 and HLX21 to HLX25.*

2 Objective and scope

The objective of the radar and BIPS surveys is to achieve information on the borehole conditions (borehole wall) as well as on the rock mass around the borehole. Borehole radar is engaged to investigate the nature and the structure of the rock mass enclosing the boreholes, and borehole TV for geological surveying of the borehole including determination of fracture distribution and orientation.

This report describes the equipment used as well the measurement procedures and data gained. For the BIPS survey, the result is presented as images. Radar data is presented in radargrams and the identified reflectors are listed.

3 Equipment

3.1 Radar measurements RAMAC

The RAMAC GPR system owned by SKB is a fully digital GPR system where emphasis has been laid on fast survey speed and easy field operation. The system operates dipole and directional antennas (see Figure 3-1). A system description is given in the SKB internal controlling document MD 252.021.

The borehole radar system consists of a transmitter and a receiver antenna. During operation an electromagnetic pulse, within the frequency range of 20 MHz up to 250 MHz, is emitted into the bedrock. Once a feature, e.g. a water-filled fracture, with sufficiently different electrical properties is encountered, the pulse is reflected back to the receiver and recorded.

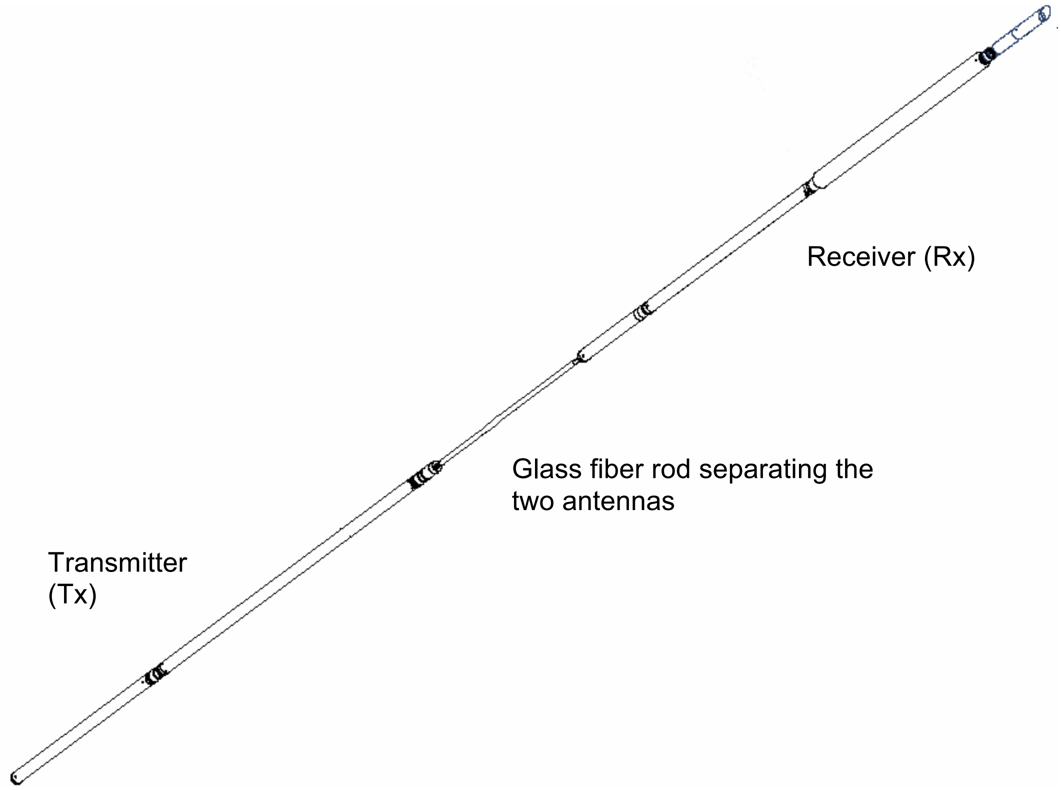

Figure 3-1. *Example of a borehole radar antenna.*

3.2 TV-Camera, BIPS

The BIPS 1500 system used is owned by SKB and described in SKB internal controlling document MD 222.005. The BIPS method for borehole logging produces a digital scan of the borehole wall. In principle, a standard CCD video camera is installed in the probe in front of a conical mirror (see Figure 3-2). An acrylic window covers the mirror part and the borehole image is reflected through the window and displayed on the cone, from where it is recorded. During the measuring operation, pixel circles are grabbed with a resolution of 360 pixels/circle.

The system orientates the BIPS images according to two alternative methods, either using a compass (vertical boreholes) or with a gravity sensor (inclined boreholes).

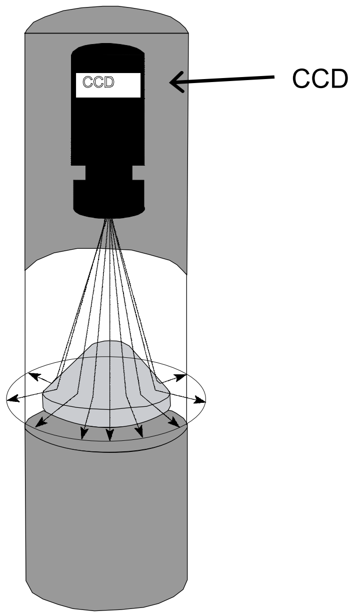

Figure 3-2. *The BIP-system. Illustration of the conical mirror scanning.*

4 Execution

4.1 General

4.1.1 RAMAC Radar

The measurements in KLX03, HAV11 to HAV13 and HLX21 to HLX25, were carried out with dipole radar antennas, with frequencies of 250, 100 and 20 MHz. In KLX03 measurements were also made using the directional antenna, with a central frequency of 60 MHz.

During logging the dipole antennas (transmitter and receiver) were lowered continuously into the borehole and data were recorded on a field PC along the measured interval. The measurement with the directional antenna is made step wise, with a short pause for each measurement occasion. The antennas (transmitter and receiver, both for dipole and directional) are kept at a fixed separation by glass fiber rods according to Table 4-1 to 4-9. See also Figures 3-1 and 4-1.

All measurements were performed in accordance with the instructions and guidelines from SKB (internal document MD 252.020). All cleaning of the antennas and cable was performed according to the internal document SKB MD 600.004 before the logging operation.

The functionality of the directional antenna was tested before measurements in KLX03. This is done by measurements in the air, where the receiver antenna and the transmitter antenna are placed apart. While transmitting and measuring the receiver antenna is turned around and by that giving the direction from the receiver antenna to the transmitter antenna. The difference in direction measured by compass and the result achieved from the directional antenna was about 5 degrees. This can be considered as good due to the disturbed environment, with metallic objects etc at the test site.

For more information on system settings used in the investigation of KLX03, HAV11 to HAV13 and HLX21 to HLX25, see Table 4-1 to 4-9 below.

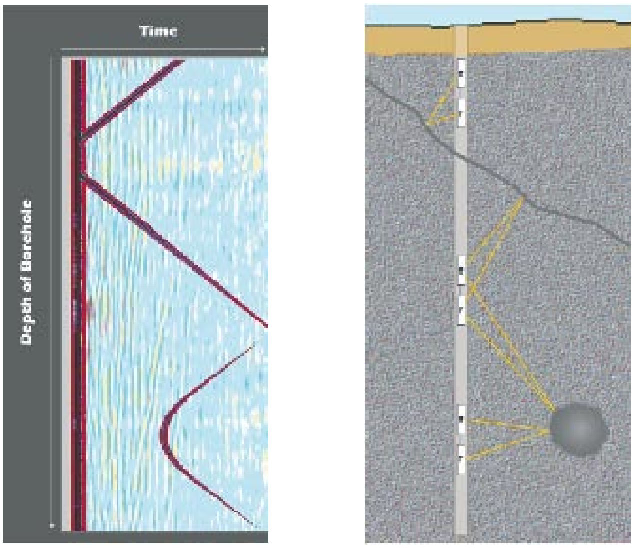

Figure 4-1. *The principle of radar borehole reflection survey and an example of result.*

Table 4-1. Radar logging information from KLX03.

Site:	**Oskarshamn**	**Logging company:**		**RAYCON**	
BH:	**KLX03**	**Equipment:**		**SKB RAMAC**	
Type:	**Directional/Dipole**	**Manufacturer:**		**MALÅ GeoScience**	
Operators:	**CG**	**Antenna**			
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
	Sampling frequency (MHz):	615	2,588	951	247
	Number of samples:	512	619	518	518
	Number of stacks:	32	Auto	Auto	Auto
	Signal position:	390.5	–0.32	–032	1.35
	Logging from (m):	103.4	101.5	102.6	106.25
	Logging to (m):	988.4	992	997.6	991.1
	Trace interval (m):	0.5	0.25	0.2	0.1
	Antenna separation (m):	5.73	2.4	3.9	10.05

Table 4-2. Radar logging information from HAV11.

Site:	**Oskarshamn**	**Logging company:**		**RAYCON**
BH:	**HAV11**	**Equipment:**		**SKB RAMAC**
Type:	**Dipole**	**Manufacturer:**		**MALÅ GeoScience**
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	04-09-23	04-09-23	04-09-23
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2,424	891	239
	Number of samples:	619	518	518
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.34	–0.34	–1.54
	Logging from (m):	1.5	2.6	6.25
	Logging to (m):	218.7	217.9	214.2
	Trace interval (m):	0.1	0.2	0.25
	Antenna separation (m):	2.4	3.9	10.05

Table 4-3. Radar logging information from HAV12.

Site:	**Oskarshamn**	**Logging company:**		**RAYCON**
BH:	**HAV12**	**Equipment:**		**SKB RAMAC**
Type:	**Dipole**	**Manufacturer:**		**MALÅ GeoScience**
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	04-09-23	04-09-23	04-09-23
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2,424	891	239
	Number of samples:	619	518	518
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.34	–0.34	–1.54
	Logging from (m):	1.5	2.6	6.25
	Logging to (m):	156	155.1	150.8
	Trace interval (m):	0.1	0.2	0.25
	Antenna separation (m):	2.4	3.9	10.05

Table 4-4. Radar logging information from HAV13.

Site:	**Oskarshamn**	**Logging company:**		**RAYCON**
BH:	**HAV13**	**Equipment:**		**SKB RAMAC**
Type:	**Dipole**	**Manufacturer:**		**MALÅ GeoScience**
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	04-09-24	04-09-24	04-09-24
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2,424	891	239
	Number of samples:	619	518	518
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.34	–0.35	–1.54
	Logging from (m):	1.5	2.6	6.25
	Logging to (m):	139	137.3	134
	Trace interval (m):	0.1	0.2	0.25
	Antenna separation (m):	2.4	3.9	10.05

Table 4-5. Radar logging information from HLX21.

Site:	**Oskarshamn**	**Logging company:**		**RAYCON**
BH:	**HLX21**	**Equipment:**		**SKB RAMAC**
Type:	**Dipole**	**Manufacturer:**		**MALÅ GeoScience**
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	04-09-28	04-09-28	04-09-28
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2,424	891	239
	Number of samples:	619	518	518
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.34	–0.35	–1.54
	Logging from (m):	1.5	2.6	6.25
	Logging to (m):	148.7	148	143.6

Table 4-6. Radar logging information from HLX22.

Site:	**Oskarshamn**	**Logging company:**		**RAYCON**
BH:	**HLX22**	**Equipment:**		**SKB RAMAC**
Type:	**Dipole**	**Manufacturer:**		**MALÅ GeoScience**
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	04-09-29	04-09-29	04-09-29
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2,424	891	239
	Number of samples:	619	518	518
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.34	–0.35	–1.54
	Logging from (m):	1.5	2.6	6.25

Table 4-7. Radar logging information from HLX23.

Site:	**Oskarshamn**	**Logging company:**		**RAYCON**
BH:	**HLX23**	**Equipment:**		**SKB RAMAC**
Type:	**Dipole**	**Manufacturer:**		**MALÅ GeoScience**
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	04-09-29	04-09-29	04-09-29
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2,424	891	239
	Number of samples:	619	518	518
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.34	–0.35	–1.53
	Logging from (m):	1.5	2.6	6.25
	Logging to (m):	158.6	157.7	153.8
	Trace interval (m):	0.1	0.2	0.25
	Antenna separation (m):	2.4	3.9	10.05

Table 4-8. Radar logging information from HLX24.

Site:	**Oskarshamn**	**Logging company:**		**RAYCON**
BH:	**HLX24**	**Equipment:**		**SKB RAMAC**
Type:	**Dipole**	**Manufacturer:**		**MALÅ GeoScience**
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	04-09-30	04-09-30	04-09-30
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2,424	891	239
	Number of samples:	619	518	518
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.34	–0.35	–1.54
	Logging from (m):	1.5	2.6	6.25
	Logging to (m):	173.4	172.4	168.5
	Trace interval (m):	0.1	0.2	0.25
	Antenna separation (m):	2.4	3.9	10.05

Table 4-9. Radar logging information from HLX25.

Site:	**Oskarshamn**	**Logging company:**		**RAYCON**
BH:	**HLX25**	**Equipment:**		**SKB RAMAC**
Type:	**Dipole**	**Manufacturer:**		**MALÅ GeoScience**
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	04-09-28	04-09-28	09-04-28
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2,424	891	239
	Number of samples:	619	518	518
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.34	–0.35	–1.54
	Logging from (m):	1.5	2.6	6.25
	Logging to (m):	196.5	196.6	197.1
	Trace interval (m):	0.1	0.2	0.25
	Antenna separation (m):	2.4	3.9	10.05

4.1.2 BIPS

All measurements were performed in accordance with the instructions and guidelines from SKB (internal document MD 222.006). All cleaning of the probe and cable was performed according to the internal document SKB MD 600.004 before the logging operation.

During the measurement, a pixel circle with a resolution of 360 pixels/circle was used and the digital circles were stored at every 1 mm on a MO-disc in the surface unit. The maximum speed during data collection was 1.5 m/minute.

A gravity sensor was used to measure the orientation of the images in the boreholes KLX03, HAV11 to HAV13 and HLX21 to HLX25.

In order to control the quality of the system, calibration measurements were performed in a test pipe before logging the first borehole and after logging the last one, Figure 4-2. The results showed no difference regarding the colours and focus of the images. Results of the test loggings were also included in the delivery of the raw data.

The BIPS logging information is found in the header for every single borehole presented in Appendix 10 to 18 in this report.

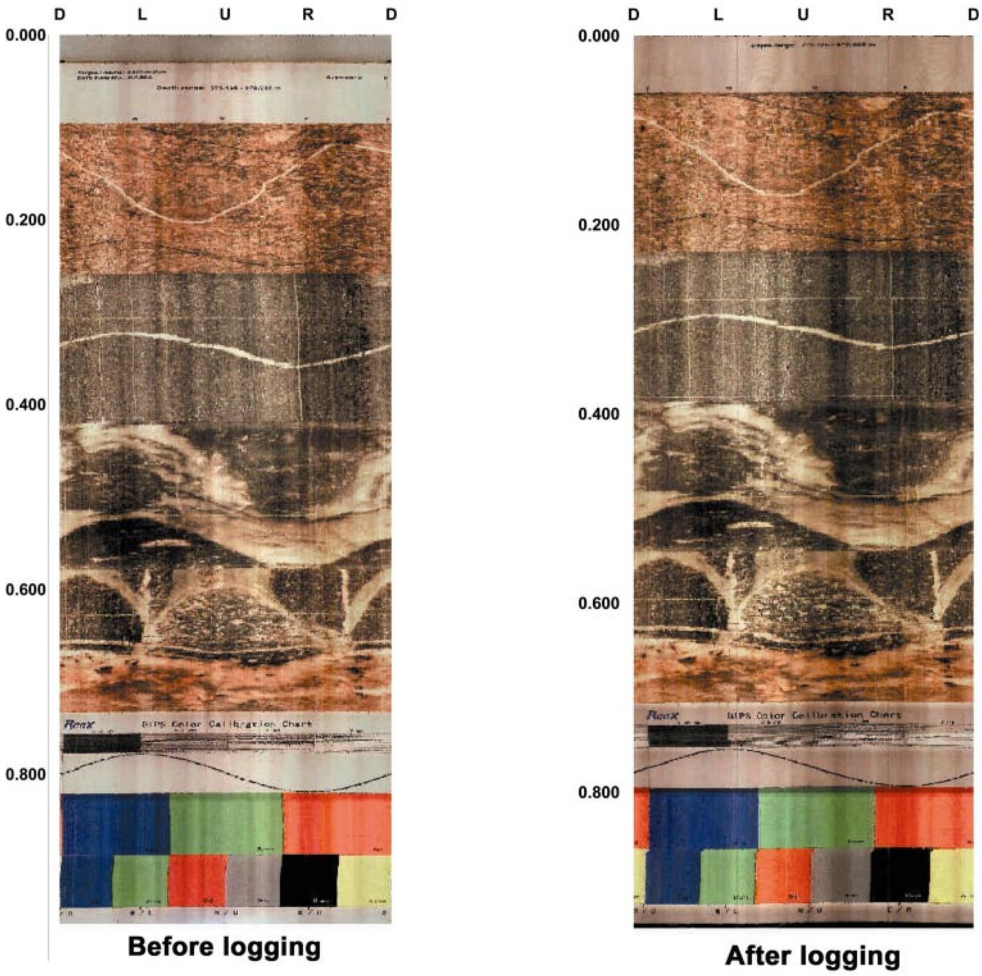

Figure 4-2. *Results from logging in the test pipe before and after the logging campaign.*

4.1.3 Length measurements

During logging the depth recording for the RAMAC and BIPS systems is taken care of by a measuring wheel mounted on the cable winch. During the BIPS logging in the core-drilled borehole, were the reference marks in the borehole is visible on the image, the logging cable is marked with scotch tape. These tape marks are then used for controlling the RAMAC radar measurements. The depth marks (presented in the Appendix 10 to 18) in the BIPS images represent the recorded depth (in black) and adjusted depth (in red) was also used for adjusting the depth of the radar measurements.

The experience we have from earlier measurements with dipole antennas in the core-drilled boreholes in Forsmark and Oskarshamn for the radar logging is that the depth divergence is less than 50 cm in the deepest parts of the boreholes after the depth adjustment performed above.

For the measurements with the directional antenna in KLX03 the depth divergence was at most 0.95 m. This divergence is taken into account in the results below, Table 5-5. For the measurements with the dipole antennas in KLX03 the depth divergence was less than 50 cm and no adjustment has been done on the results.

In percussion-drilled boreholes the BIPS results is adjusted according to experience from the marking procedure in core-drilled boreholes. The adjusted depth reported for HAV11 to HAV13 and HLX21 to HLX25 is 30 cm for each 100 m.

4.2 Analyses and interpretation

4.2.1 Radar

The result from radar measurements is most often presented in the form of a radargram where the position of the probes is shown along one axis and the propagation is shown along the other axis. The amplitude of the received signal is shown in the radargram with a grey scale where black colour corresponds to large positive signals and white colour to large negative signals. Grey colour corresponds to no reflected signals.

The presented data in this report is adjusted for the measurement point of the antennas. The measurement point is defined to be the central point between the transmitter and the receiver antenna.

The two basic patterns to interpret in borehole measurements are point and plane reflectors. In the reflection mode, borehole radar essentially gives a high-resolution image of the rock mass, showing the geometry of plane structures which may or may not, intersect the borehole (contact between layers, thin marker beds, fractures) or showing the presence of local features around the borehole (cavities, lenses etc.).

The distance to a reflecting object or plane is determined by measuring the difference in arrival time between the direct and the reflected pulse. The basic assumption is that the speed of propagation is the same everywhere.

There are several ways to determine the radar wave propagation velocity. Each of them has its advantages and its disadvantages. In this project the velocity determination was performed by keeping the transmitter fixed in the borehole while moving the receiver downwards in the borehole. The result is plotted in Figure 4-3 and the calculation shows a velocity of 120 m/micro seconds. The velocity measurement was performed in borehole KSH01B with the 100 MHz antennas /1/.

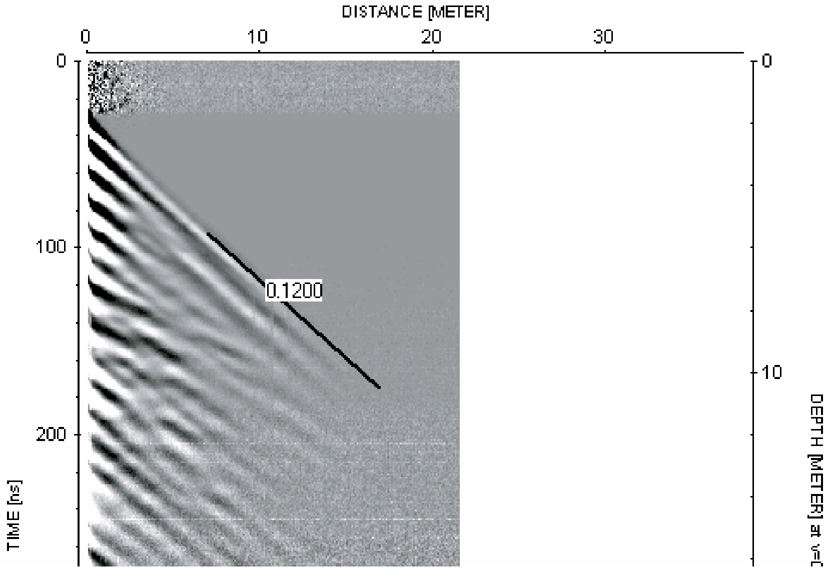

***Figure 4-3.** Results from velocity measurements in KSH01B with 100 MHz dipole antennas /1/.*

The visualization of data in Appendix 1 to 9 is made with ReflexWin, a Windows based processing software for filtering and analysis of borehole radar data. The processing steps are shown in Tables 4-10 to 4-19.

For the interpretation of the intersection angle between the borehole axis and the planes visible on the radargrams the RadinterSKB software has been used. The interpreted intersection points and intersection angles of the detected structures are presented in the Tables 5-1 to 5-18 and are also visible on the radargrams in Appendix 1 to 9.

Table 4-10. Processing steps for borehole radar data from KLX03.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**		
BH:	**KLX03**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Interpret:	**JA**	**Antenna**			
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal	DC removal
		Time gain	Move start time	Move start time	Move start time
		FIR	Gain	Gain	Gain

Table 4-11. Processing steps for borehole radar data from HAV11.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HAV11**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time
		Gain	Gain	Gain

Table 4-12. Processing steps for borehole radar data from HAV12.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HAV12**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time
		Gain	Gain	Gain

Table 4-13. Processing steps for borehole radar data from HAV13.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HAV13**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time
		Gain	Gain	Gain

Table 4-14. Processing steps for borehole radar data from HLX21.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX21**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time
		Gain	Gain	Gain

Table 4-15. Processing steps for borehole radar data from HLX22.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX22**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time
		Gain	Gain	Gain

Table 4-16. Processing steps for borehole radar data from HLX23.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX23**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time
		Gain	Gain	Gain

Table 4-17. Processing steps for borehole radar data from HLX24.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX24**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time
		Gain	Gain	Gain

Table 4-18. Processing steps for borehole radar data from HLX25.

Site:	**Oskarshamn**	**Logging company:**	**RAYCON**	
BH:	**HLX25**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Interpret:	**JA**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time
		Gain	Gain	Gain

4.2.2 BIPS

The visualization of data is made with BDPP, a Windows based processing software for filtering, presentation and analysis of BIPS data. As no fracture mapping of the BIPS image is performed, the raw data was delivered on a CD-ROM together with printable pictures in *.pdf format before the field crew left the investigation site.

The printed results were delivered with measured length, together with adjusted length according to the length marks visible in the BIPS image. For printing of the BIPS images the printing software PDPP from RaaX was used.

4.3 Nonconformities

For revision no 1 of this report a recalculation of the directional radar data has been done. The strike angle between the line of the plane’s cross-section with the surface and the Magnetic North direction was earlier counted counter-clockwise but it is now recalculated as such it counts clockwise, see Figure 5-2. New values for strike and dip are therefore updated in Table 5-10.

5 Results

The results from the BIPS measurements in KLX03, HAV11 to HAV13 and HLX21 to HLX25 were delivered as raw data (*.bip-files) together with printable BIPS pictures in *.pdf format before the field crew left the investigation site. The information of the measurements was registered in SICADA, and the CD-ROM's stored by SKB.

The RAMAC radar data for KLX03, HAV11 to HAV13 and HLX21 to HLX25 was delivered as raw data (fileformat *.rd3 or *.rd5) with corresponding information files (file format *.rad) on CD-ROM's to SKB before the field crew left the investigation site, whereas the data processing steps and results are presented in this report. Relevant information, including the interpretation presented in this report, was inserted into the SKB database SICADA.

The delivered raw and processed data have been inserted in the database of SKB (SICADA). The SICADA reference to the present activity is field notes 490 and 491 respectively.

5.1 RAMAC logging

The results of the interpretation of the radar measurements are presented in Tables 5-1 to 5-27. Radar data is also visualized in Appendix 1 to 9. It should be remembered that the images in Appendix 1 to 9 is only a composite picture of all events 360 degrees around the borehole, and do not reflect the orientation of the structures.

Only the larger clearly visible structures are interpreted in RadinterSKB. A number of minor structures also exist, indicated in Appendix 1 to 9. It should also be pointed out that reflections interpreted will always get an intersection point with the borehole, but being located further away. They may in some cases not reach the borehole.

The data quality from KLX03, HAV11 to HAV13 and HLX21 to HLX25, (as seen in Appendix 1 to 9) is quite varying. In the percussion-drilled boreholes the data quality is rather bad, most likely due to more conductive conditions (salt water in the borehole). A conductive environment (close to sea as in Figure 5-1) makes the radar wave to attenuate, which decreases the penetration of the radar wave. This is for instance seen very clearly in the data from HAV11 from a depth of 100 m (Appendix 2). This conductive environment of course also reduces the possibility to distinguish and interpret possibly structures in the rock which otherwise could give a reflection.

When the radar wave is strongly attenuated most of the structures seen in the measured data (see Appendix 1 to 9 and tables below) is resulting in a dip of 90 degrees, which indicates that it is only the edges of the structures that are identified, and no information is gained further away from the borehole wall.

As also seen in Appendix 1 to 9 the resolution and penetration of radar waves depend on the antenna frequency used. Low antenna frequency gives less resolution but higher penetration rate compared to a higher frequency.

In Tables 5-1 to 5-9 below the distribution of identified structures along the borehole are listed for KLX03, HAV11 to HAV13 and HLX21 to HLX25.

Figure 5-1. *Example of a borehole location, in this case HAV11. The location close to the shore-line gives most certainly a conductive environment due to salt-water intrusion.*

Table 5-1. Identified structures as a function of depth in KLX03.

Depth (m)	No of structures
–150	13
150–200	11
200–250	12
250–300	16
300–350	18
350–400	14
400–450	10
450–500	10
500–550	10
550–600	11
600–650	15
650–700	13
700–750	7
750–800	8
800–850	11
850–900	10
900–950	8
950–	5

Table 5-2. Identified structures as a function of depth in HAV11.

Depth (m)	No of structures
–20	2
20–40	3
40–60	4
60–80	2
80–100	4
100–120	4

Table 5-3. Identified structures as a function of depth in HAV12.

Depth (m)	No of structures
–20	1
20–40	1
40–60	2
60–80	5
80–100	3
100–120	6
120–140	6
140–160	4

Table 5-4. Identified structures as a function of depth in HAV13.

Depth (m)	No of structures
–20	1
20–40	2
40–60	1
60–80	1
80–100	–
100–120	2
120–140	1

Table 5-5. Identified structures as a function of depth in HLX21.

Depth (m)	No of structures
–20	–
20–40	4
40–60	4
60–80	3
80–100	5
100–120	1
120–140	4
140–160	3

Table 5-6. Identified structures as a function of depth in HLX22.

Depth (m)	No of structures
–20	5
20–40	1
40–60	2
60–80	4
80–100	4
100–120	3
120–140	5
140–160	2
160–180	–
180–	1

Table 5-7. Identified structures as a function of depth in HLX23.

Depth (m)	No of structures
–20	2
20–40	1
40–60	4
60–80	3
80–100	4
100–120	5
120–140	3
140–160	2
160–180	2
180–200	2

Table 5-8. Identified structures as a function of depth in HLX24.

Depth (m)	No of structures
–20	2
20–40	2
40–60	2
60–80	4
80–100	3
100–120	1
120–140	4
140–160	3
160–180	2
180–200	–
200–	3

Table 5-9. Identified structures as a function of depth in HLX25.

Depth (m)	No of structures
–20	2
20–40	1
40–60	2
60–80	3
80–100	1
100–120	2
120–140	4
140–160	1
160–180	1
180–200	1
200–	1

Tables 5-10 to 5-18 summarises the interpretation of radar data from KLX03, HAV11 to HAV11 and HLX21 to HLX25. As seen some radar reflectors are marked with ± (for the data from KLX03), which indicates an uncertainty in the interpretation of the direction to the reflector. The direction can in these cases be ±180 degrees. The direction to the reflector (the plane) is defined in Figure 5-2. As the borehole inclination for KLX03 is less than 85° the direction to object is calculated using gravity roll. This direction and the intersection angle are also recalculated to strike and dip, also given in Table 5-10 below. The plane strike is the angle between line of the plane's cross-section with the surface and the Magnetic North direction. It counts clockwise and can be between 0 and 359 degrees. A strike of 0 degrees implies a dip to the east while a strike of 180 degrees implies a dip to the west. The plane dip is the angle between the plane and the surface. It can vary between 0 and 90 degrees.

Table 5-10. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz and the directional antenna in borehole KLX03.

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas and directional antenna)							
Site:			Oskarshamn				
Borehole name:			KLX03				
Nominal velocity (m/μs):			120.0				
Name	Intersection depth	Intersection angle	Direction to object (gravity roll)	Interpreted Dip 1	Interpreted Strike 1	Interpreted Dip 2	Interpreted Strike 2
21	18.50	2	279	89	212		
1	116.00	28					
2	117.10	64					
4	122.90	52					
5	124.10	19					
3	124.30	21					
7	127.30	30					
9	128.30	52	348	55	280		
6	130.80	19					
8	135.40	55					

RADINTER MODEL INFORMATION
(20, 100 and 250 MHz Dipole Antennas and directional antenna)

Site:	**Oskarshamn**
Borehole name:	**KLX03**
Nominal velocity (m/μs):	**120.0**

Name	Intersection depth	Intersection angle	Direction to object (gravity roll)	Interpreted Dip 1	Interpreted Strike 1	Interpreted Dip 2	Interpreted Strike 2
10	137.90	39	198	35	135		
11	142.40	84					
14	143.20	31					
12	159.90	17					
13	160.50	23					
17	164.90	61					
26x	165.20	8	354	83	106		
16	166.90	27					
15	167.30	21					
18	167.70	64 ±	198	13	147	41	300
19	168.90	57					
20	198.10	17					
22	195.90	64					
23	198.20	57	315	33	264		
24	210.50	50 ±	147	30	69	53	267
26	214.20	32					
25	214.70	47 ±	351	60	286	32	101
27	219.30	44					
28	224.80	51					
29	231.20	48					
31	231.20	69					
30	234.10	49 ±	6	59	302	31	123
32	241.70	64					
33	244.80	55					
34	246.10	46					
35	247.90	64					
34x	250.40	67	177	9	108		
36	256.50	39					
37	258.60	52					
38	266.90	64	198	9	164		
39	267.20	55					
41	277.40	76					
42	279.70	60					
43	279.90	66 ±	141	15	44	35	273
40	282.50	13	267	77	207		
40x	292.00	11 ±	306	86	248	70	63
44	284.90	63					
45	288.70	60 ±	105	32	21	39	241
46	292.30	61					

RADINTER MODEL INFORMATION
(20, 100 and 250 MHz Dipole Antennas and directional antenna)

Site:			**Oskarshamn**				
Borehole name:			**KLX03**				
Nominal velocity (m/µs):			**120.0**				
Name	**Intersection depth**	**Intersection angle**	**Direction to object (gravity roll)**	**Interpreted Dip 1**	**Interpreted Strike 1**	**Interpreted Dip 2**	**Interpreted Strike 2**
47	294.60	64 ±	192	15	142	42	307
50	296.70	41					
48	297.70	80					
49	301.70	64					
49x	302.30	57					
51	304.90	52					
52	305.20	65					
53	306.80	62					
54	315.70	58					
55	316.70	53					
56	320.00	65					
57	323.40	65	120	18	25		
58	325.90	54					
59	327.50	60					
60	332.80	61	345	47	294		
61	339.80	53					
63	337.80	51					
62x	341.10	59					
62	341.40	68					
64	342.30	46	336	51	286		
65	348.30	50					
66	353.50	48					
68	358.50	49					
67	364.20	26					
69	367.90	49					
77	368.80	13					
71	368.90	74					
72	372.30	46					
70	376.40	22	234	60	187		
74	378.50	57					
74x	378.60	45					
73	382.20	72					
75	380.60	60					
76	385.80	71					
82	399.00	9	306	89	249		
78	406.80	60					
79	411.90	73					
80	416.00	57 ±	318	38	278	19	61

RADINTER MODEL INFORMATION
(20, 100 and 250 MHz Dipole Antennas and directional antenna)

Site:			**Oskarshamn**				
Borehole name:			**KLX03**				
Nominal velocity (m/μs):			**120.0**				
Name	**Intersection depth**	**Intersection angle**	**Direction to object (gravity roll)**	**Interpreted Dip 1**	**Interpreted Strike 1**	**Interpreted Dip 2**	**Interpreted Strike 2**
81	419.50	49					
83	426.90	55					
84	428.50	69					
85	435.60	54					
86	441.50	51 ±	135	22	59	39	274
88	444.70	76					
87	448.60	52					
89	456.50	70					
90	458.60	74	0	27	310		
91	467.10	55					
92	471.80	70 ±	354	35	306	9	116
93	482.00	53					
94	485.60	50					
95	489.70	64					
96	492.70	73					
97	493.50	46					
98	496.40	62	165	21	109		
99	500.10	62 ±	123	21	43	34	270
101	505.60	78					
100	506.60	55					
104	516.90	61 ±	168	14	100	39	295
190	522.10	6					
102	529.40	24					
106	533.40	65					
103	534.40	50					
105	543.70	71					
113	545.41	22					
107	556.80	64					
108	560.20	35 ±	330	62	276	39	85
109	565.50	33					
111	569.40	32					
110	569.80	54					
114	576.00	84					
112	578.20	52					
116	583.60	58					
115	586.70	63					
117	588.30	72					
118	596.70	56					
119	600.50	59	186	15	138		

RADINTER MODEL INFORMATION
(20, 100 and 250 MHz Dipole Antennas and directional antenna)

Site:			**Oskarshamn**				
Borehole name:			**KLX03**				
Nominal velocity (m/μs):			**120.0**				
Name	**Intersection depth**	**Intersection angle**	**Direction to object (gravity roll)**	**Interpreted Dip 1**	**Interpreted Strike 1**	**Interpreted Dip 2**	**Interpreted Strike 2**
120	606.70	70					
121	609.10	90					
122x	612.90	44 ±	99	45	34	49	239
122	616.60	70					
123	618.70	77					
124	620.00	80					
125	622.70	54					
126	624.90	74					
192	626.90	39					
127	630.80	60					
132xx	634.50	19					
128	637.90	58					
129	641.50	56					
130	643.50	63					
131	652.10	55					
133	661.20	62					
132x	662.30	31	213	45	168		
132	664.30	18	27	85	335		
134	668.10	63					
135	671.90	58					
136	676.50	52					
137	677.00	81					
138	685.10	69 ±	315	27	285	11	33
139	689.60	51					
140	690.30	70					
141	699.60	62					
142	699.80	79					
143	704.40	71	0	28	314		
144	707.70	66 ±	327	11	62	31	295
145	719.90	52					
146	729.50	51 ±	162	19	108	44	304
147	731.50	55					
148	733.70	59	120	29	57		
149	738.00	68					
150	757.40	71					
189	759.50	6	51	87	191		
151	768.00	56	117	29	53		
152	774.30	73					
153	781.60	61					

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas and directional antenna)							
Site:			**Oskarshamn**				
Borehole name:			**KLX03**				
Nominal velocity (m/μs):			**120.0**				
Name	**Intersection depth**	**Intersection angle**	**Direction to object (gravity roll)**	**Interpreted Dip 1**	**Interpreted Strike 1**	**Interpreted Dip 2**	**Interpreted Strike 2**
154	784.70	61					
155	791.10	52					
156	796.00	77					
157	806.30	51					
158	807.70	49					
159	811.40	56					
160	811.90	71					
161	815.60	42 ±	57	57	14	43	214
162	825.20	36					
163	823.20	53					
167	821.90	48					
164	824.90	74					
165	830.30	72					
175	842.90	27	129	54	87		
166	855.20	21	93	68	55		
170	855.40	76					
168	857.50	58	183	14	151		
169	860.90	61					
171	864.30	68					
172	870.90	57					
173	881.10	61 ±	246	34	230	45	17
174	887.30	73					
176	895.80	24	105	63	69		
177	899.00	70					
176x	901.80	15					
179	907.50	79					
178	909.60	27					
180	914.30	50					
181	920.50	82					
182	921.40	59					
183	929.30	54					
184	950.10	90					
185	951.50	90					
186	967.20	90					
187	970.40	90					
188	976.40	90					
191	1,009.50	64					

Table 5-11. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz and the directional antenna in borehole HAV11.

RADINTER MODEL INFORMATION			
(20, 100 and 250 MHz Dipole Antennas and Directional antenna)			
Site:		**Oskarshamn**	
Borehole name:		**HAV11**	
Nominal velocity (m/μs):		**120.0**	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	A	13.60	90
PLANE	B	17.50	90
PLANE	C	25.30	70
PLANE	D	29.10	82
PLANE	E	33.40	54
PLANE	F	46.80	63
PLANE	G	48.30	34
PLANE	H	56.40	85
PLANE	I	59.50	66
PLANE	J	64.00	77
PLANE	K	67.00	85
PLANE	L	82.80	67
PLANE	M	84.30	85
PLANE	N	93.70	90
PLANE	O	98.20	78
PLANE	P	100.00	77
PLANE	Q	106.40	62
PLANE	R	108.90	69
PLANE	S	112.60	90

Table 5-12. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz and the directional antenna in borehole HAV12.

RADINTER MODEL INFORMATION			
(20, 100 and 250 MHz Dipole Antennas and Directional antenna)			
Site:		**Oskarshamn**	
Borehole name:		**HAV12**	
Nominal velocity (m/μs):		**120.0**	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	1	26.30	13
PLANE	A	16.30	32
PLANE	B	50.40	36
PLANE	C	52.20	81
PLANE	D	64.80	64
PLANE	E	67.90	74
PLANE	F	69.40	71
PLANE	G	76.30	61
PLANE	H	78.20	84
PLANE	I	95.70	62

RADINTER MODEL INFORMATION			
(20, 100 and 250 MHz Dipole Antennas and Directional antenna)			
Site:		Oskarshamn	
Borehole name:		HAV12	
Nominal velocity (m/µs):		120.0	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	J	91.70	34
PLANE	K	93.40	53
PLANE	L	103.10	55
PLANE	P	108.50	53
PLANE	M	112.30	61
PLANE	N	115.30	56
PLANE	Q	117.00	56
PLANE	O	118.20	55
PLANE	R	122.30	71
PLANE	S	125.20	61
PLANE	T	126.40	53
PLANE	U	131.90	57
PLANE	W	135.80	65
PLANE	V	136.90	49
PLANE	Z	144.20	24
PLANE	X	144.70	58
PLANE	Y	148.90	80
PLANE	2	150.90	78

Table 5-13. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz and the directional antenna in borehole HAV13.

RADINTER MODEL INFORMATION			
(20, 100 and 250 MHz Dipole Antennas and Directional antenna)			
Site:		Oskarshamn	
Borehole name:		HAV13	
Nominal velocity (m/µs):		120.0	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	A	9.60	47
PLANE	B	32.00	55
PLANE	C	35.20	63
PLANE	E	57.10	59
PLANE	D	63.50	65
PLANE	F	102.50	64
PLANE	G	121.90	25
PLANE	H	136.80	27

Table 5-14. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz in borehole HLX21.

RADINTER MODEL INFORMATION			
(20, 100 and 250 MHz Dipole Antennas)			
Site:		**Oskarshamn**	
Borehole name:		**HLX21**	
Nominal velocity (m/μs):		**120.00**	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	A	22.60	67
PLANE	B	24.90	59
PLANE	C	26.50	58
PLANE	U	39.40	58
PLANE	D	42.80	48
PLANE	E	49.50	44
PLANE	F	51.90	39
PLANE	G	54.00	51
PLANE	I	61.80	82
PLANE	H	70.80	35
PLANE	Mx	77.20	18
PLANE	V	81.40	42
PLANE	J	88.20	47
PLANE	K	94.70	42
PLANE	M	97.30	40
PLANE	L	98.90	85
PLANE	N	109.80	40
PLANE	O	122.20	52
PLANE	T	129.40	50
PLANE	P	132.60	34
PLANE	Q	138.10	39
PLANE	R	147.30	37
PLANE	Px	153.50	30
PLANE	S	160.80	39

Table 5-15. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz in borehole HLX22.

RADINTER MODEL INFORMATION			
(20, 100 and 250 MHz Dipole Antennas)			
Site:		**Oskarshamn**	
Borehole name:		**HLX22**	
Nominal velocity (m/μs):		**120.00**	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	Z	–704.00	3
PLANE	B	8.70	57
PLANE	X	12.30	45
PLANE	A	16.40	58
PLANE	C	19.50	71
PLANE	D	34.00	45
PLANE	F	45.00	46
PLANE	E	54.30	53
PLANE	G	61.80	47
PLANE	1	72.00	60
PLANE	H	72.70	43
PLANE	J	79.60	40
PLANE	I	80.40	54
PLANE	K	82.70	37
PLANE	L	98.60	35
PLANE	M	99.70	50
PLANE	O	102.00	33
PLANE	P	106.00	37
PLANE	R	118.80	60
PLANE	Q	124.40	27
PLANE	U	131.30	45
PLANE	V	134.00	41
PLANE	N	137.20	12
PLANE	W	138.20	33
PLANE	S	150.00	38
PLANE	T	152.30	45
PLANE	Y	212.40	54

Table 5-16. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz in borehole HLX23.

RADINTER MODEL INFORMATION

(20, 100 and 250 MHz Dipole Antennas)

Site: Oskarshamn

Borehole name: HLX23

Nominal velocity (m/μs): 120.00

Object type	Name	Intersection depth	Intersection angle
PLANE	Ax	11.10	38
PLANE	A	11.30	31
PLANE	B	25.10	80
PLANE	C	49.00	41
PLANE	E	47.80	28
PLANE	D	48.00	73
PLANE	Cx	52.90	28
PLANE	F	61.00	60
PLANE	Gx	66.30	38
PLANE	G	66.70	60
PLANE	H	80.40	46
PLANE	Hx	80.80	55
PLANE	Hxx	81.00	39
PLANE	M	88.90	40
PLANE	I	100.10	55
PLANE	J	104.50	50
PLANE	K	112.50	62
PLANE	R	115.20	47
PLANE	L	116.60	36
PLANE	Nx	128.80	43
PLANE	N	129.10	60
PLANE	O	135.10	56
PLANE	P	141.00	51
PLANE	Q	148.20	48
PLANE	U	161.70	29
PLANE	S	164.50	59
PLANE	V	186.50	58
PLANE	T	189.50	27

Table 5-17. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz in borehole HLX24.

RADINTER MODEL INFORMATION			
(20, 100 and 250 MHz Dipole Antennas)			
Site:		**Oskarshamn**	
Borehole name:		**HLX24**	
Nominal velocity (m/µs):		**120.00**	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	A	6.50	65
PLANE	B	16.40	40
PLANE	C	31.20	59
PLANE	D	35.90	53
PLANE	E	57.00	64
PLANE	F	59.10	63
PLANE	G	61.50	56
PLANE	I	71.00	43
PLANE	Ix	73.20	52
PLANE	H	77.70	30
PLANE	L	83.90	38
PLANE	J	86.20	71
PLANE	K	99.20	68
PLANE	S	107.30	42
PLANE	V	124.10	46
PLANE	T	130.10	38
PLANE	P	134.30	55
PLANE	Mx	139.00	49
PLANE	M	141.30	55
PLANE	N	143.60	56
PLANE	O	145.80	61
PLANE	U	161.00	42
PLANE	R	175.30	47
PLANE	X	213.80	55
PLANE	W	253.10	12
PLANE	Q	376.00	3

Table 5-18. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz in borehole HLX25.

RADINTER MODEL INFORMATION			
(20, 100 and 250 MHz Dipole Antennas)			
Site:		**Oskarshamn**	
Borehole name:		**HLX25**	
Nominal velocity (m/μs):		**120.00**	
Object type	**Name**	**Intersection depth**	**Intersection angle**
PLANE	A	7.00	70
PLANE	B	11.40	63
PLANE	C	25.30	51
PLANE	D	41.70	53
PLANE	E	50.60	73
PLANE	F	72.20	53
PLANE	G	71.00	39
PLANE	Gx	71.10	70
PLANE	H	96.00	67
PLANE	I	112.80	84
PLANE	J	116.30	63
PLANE	K	124.00	50
PLANE	L	127.70	58
PLANE	M	134.80	69
PLANE	N	136.70	74
PLANE	O	149.00	67
PLANE	P	177.10	59
PLANE	Q	181.20	65
PLANE	R	208.40	50

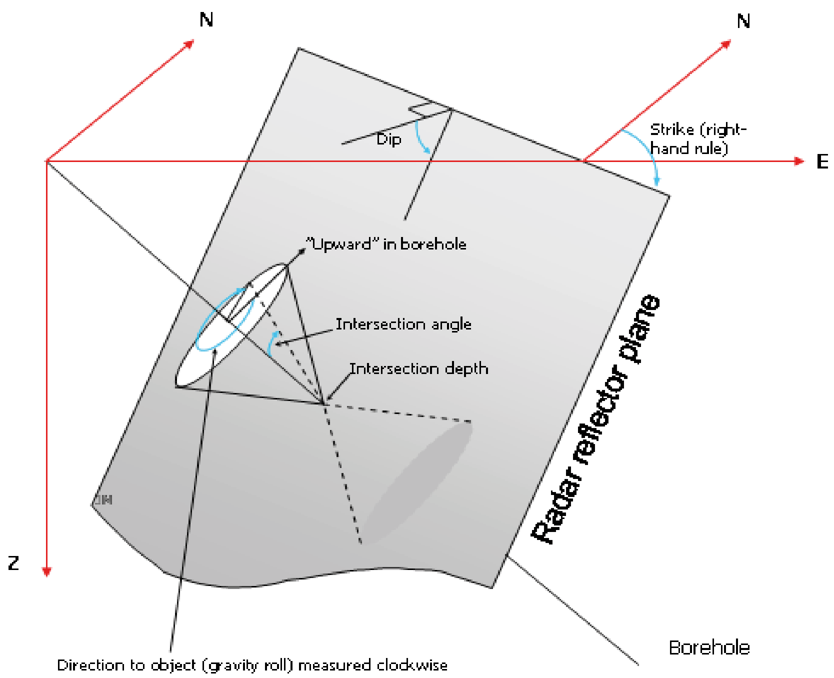

Figure 5-2. Definition of intersection angle, direction to object using gravity roll, dip and strike using the right hand rule as presented in Table 5-10.

In Appendix 1 to 9, the amplitude of the first arrival is plotted against the depth, for the 250 MHz dipole antennas. The amplitude variation along the borehole indicates changes of the electrical conductivity of the volume of rock surrounding the borehole. A decrease in this amplitude may indicate fracture zones, clay or rock volumes with increases in water content, i.e. increases in electric conductivity. The decrease in amplitude is shown in Tables 5-19 to 5-27.

Table 5-19. Decrease in amplitude for the 250 MHz antenna for borehole KLX03.

Depth (m)						
115–125	265–270	445	555–560	655–670	730–735	810–815
135–140	285–295	460	575–585	675	735–740	825
190	305–310	475	595–600	685	740–780	855
210–215	315	525	620	705	785	920
235	335	545	630	725–730	790–805	965–975
250	435					

Table 5-20. Decrease in amplitude for the 250 MHz antenna for borehole HAV11.

Depth (m)	
15	60–85
25–35	95
40	110–140
45–50	145–220

Table 5-21. Decrease in amplitude for the 250 MHz antenna for borehole HAV12.

Depth (m)
50–90
100–105
115–125
135–150

Table 5-22. Decrease in amplitude for the 250 MHz antenna for borehole HAV13.

Depth (m)	
35–40	90–95
60–70	105–110
85	115–125

Table 5-23. Decrease in amplitude for the 250 MHz antenna for borehole HLX21.

Depth (m)	
20–25	85
60	95–100
65	105–110

Table 5-24. Decrease in amplitude for the 250 MHz antenna for borehole HLX22.

Depth (m)
15–20
40–50
105
120

Table 5-25. Decrease in amplitude for the 250 MHz antenna for borehole HLX23.

Depth (m)	
15–20	80
35	115
45–50	135
65	

Table 5-26. Decrease in amplitude for the 250 MHz antenna for borehole HLX24.

Depth (m)	
25–40	105
55–65	135
75	140
85	145

Table 5-27. Decrease in amplitude for the 250 MHz antenna for borehole HLX25.

Depth (m)	
20	110
35–50	120–135
65–70	170–185
75	

5.2 BIPS logging

The BIPS pictures are presented in Appendix 10 to 18.

To get the best possible depth accuracy, the BIPS images are adjusted to the reference marks on the logging cable. Additionally the marks on the core-drilled borehole wall created by the drill rig are visible on the BIPS screen. The recorded length is adjusted to these visible marks. In percussion drilled boreholes we use these marks on the cable as reference for the depth adjustment. The experience from one year of logging is that the marks on the logging cable is very good and differs very little compared with the results from core-drilled boreholes. At present we have marks at 110, 150 and 200 metre on the logging cable that are used for depth adjustments of the BIPS results in percussion drilled boreholes.

In order to control the quality of the system, calibration measurements were performed in a test pipe before logging the first borehole and after logging of the last borehole. The resulting images displayed no difference regarding the colours and focus of the images. Results of the test loggings were included in the delivery of the field data and are also presented in Figure 4-2 in this report.

5.2.1 KLX03

The BIPS logging shows reasonable good images for geological and fracture mapping. The main defect is that mud covers the lowermost part of the borehole. This effect is visible along the borehole except in-between 200 and 320 m where the effect is much less. The effect of induced discolouring of the borehole wall from the drilling is in this borehole very small compared to other boreholes in the site investigation program. Also the common unsynchronised speed between the probe and the measuring wheel is in this borehole very limited.

5.2.2 HAV11

The BIPS image shows a dark discolouring of the borehole wall between the casing shoe and down to approximately 30 m. This effect is also visible at the end of the borehole. The water is of good quality along the borehole. The only remarks are that mud covers the lowermost part of the borehole. This effect is visible from around 150 m down to the bottom of the borehole.

5.2.3 HAV12

No unwanted effects on the data and a good water quality along the borehole. This gives almost perfect images easy for the core loggers to perform geological mapping.

5.2.4 HAV13

Heavily affected images. From the casing shoe down to the big open fracture at 62 m the images is affected by mud. The mud that is whiter than the surrounding, covering the lowermost part of the borehole wall, has a bad effect on the automatic gain control in the camera. This combination gives that the uppermost part of the borehole wall gets too dark. This may cause difficulties to perform the geological mapping on the data but still the fracture mapping can be done. Below the fracture at 62 m depth the water quality is bad and in some parts the borehole wall is not visible at all and spoils most of the intentions for mapping. The logging is divided in to tree sections due to problem with the battery supply in the camera and problem with the depth recording. Overlapping measurements were made in the parts with the equipment problems.

5.2.5 HLX21

The worst quality problem is in the upper part of the borehole. This is likely depending on water with bad quality enters in to the borehole in the fracture zone in-between 22 and 23 m depth. Below that section the water is of good quality. Further down in the borehole there is an increasing effect on mud covering the lowermost part of the borehole wall that limits the visibility of the borehole wall.

5.2.6 HLX22

Very good quality along the borehole except for the last 20 m that shows an increasing effect on mud covering the lowermost part of the borehole wall.

5.2.7 HLX23

Between the casing shoe down to 13.5 m the water quality is so bad that there is impossible to observe the borehole wall. This is due to water that enters in to the borehole or flow out from the borehole at that point. Most likely it is clean water that enters or flow out at that position.

The BIPS logging was divided in to two parts due to a jammed probe. This was in connection with the big open fracture at 65.5 metres in the borehole. The effect of mud covering the lowermost part of the borehole wall is also visible in the bottom parts in the borehole.

5.2.8 HLX24

The logging in HLX24 shows a very good quality along the borehole except for a section around 70 to 140 m that have a slightly increasing effect on mud covering the lowermost part of the borehole wall. After 140 m the effect is less but start again to increase at 160 m down to the bottom of the borehole.

5.2.9 HLX25

The quality problem in HLX25 relates from the water table. During the percussion drilled moment small amount of oil from the air-compressor is injected in to the borehole. This oil is not water-soluble and for that reason the remaining oil floats on top of the water table. In HLX25 the water table is at 10.5 metres and therefore the cleaning procedure done by the drilling rig is difficult. Figure 5-3 shows the 20 cm thick oil layer on top of the water table. Some effect from the oil is obvious on the images direct after entering in to the oil. The effect from the oil remains down to a depth of approximate 40 m. After that the results of the images are very good. The BIPS logging was divided in to two parts due to a jammed probe. This was in connection with fractures at 50 m.

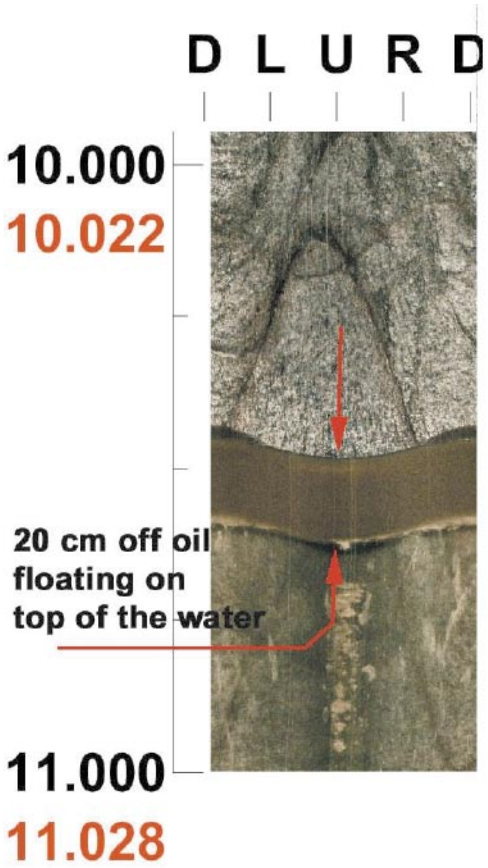

Figure 5-3. *Oil floating on top of the water table in HLX25.*

References

/1/ **Aaltonen J, Gustafsson C, Nilsson P, 2003.** Oskarshamn site investigation. RAMAC and BIPS logging and deviation measurements in boreholes KSH01A, KSH01B and the upper part of KSH02. SKB P-03-73, Svensk Kärnbränslehantering AB.