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KBS-3H

BIPS and radar in borehole K08028F01

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Malå Geoscience AB

Keywords: BIPS, RAMAC, Radar, TV.

This report concerns a study which was conducted for Svensk Kärnbränslehantering AB (SKB). The conclusions and viewpoints presented in the report are those of the author. SKB may draw modified conclusions, based on additional literature sources and/or expert opinions.

Data in SKB's database can be changed for different reasons. Minor changes in SKB's database will not necessarily result in a revised report. Data revisions may also be presented as supplements, available at www.skb.se.

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Abstract

This report presents the data collected in geophysical logging operations, which were performed within the framework of the KBS-3H project System Design, subproject KBS-3H Sub-system demonstration on the −410 m level in the Äspö Hard Rock Laboratory (Äspö HRL). The logging operations presented here include borehole radar (RAMAC) and BIPS performed in the KBS-3H borehole K08028F01.

All measurements were conducted by Malå Geoscience AB in June 2014.

The objective of the radar and BIPS surveys is to obtain information on the borehole conditions (as seen in borehole wall) as well as of the rock mass around the borehole. Borehole radar is employed to investigate the nature and the structure of the rock mass surrounding the borehole, and borehole TV is performed in order to scan the borehole wall to survey the borehole rock surface as well as for determination of rock types and fracture distribution and orientations in the borehole wall.

This report describes the equipment used as well as the measurement procedures and data obtained. For the BIPS surveys, the results are presented as images. Radar data are presented in radargrams and the identified reflectors are indicated and listed.

The borehole radar data quality from K08028F01 is relatively good. It is mainly the conductive formation water that attenuates the radar wave, which limits the penetration and reduces the ability of the radar to identify structures.

The borehole radar measurements in K08028F01 resulted in 10 identified radar reflectors.

The basic conditions of the BIPS logging for geological mapping and orientation of structures were very good for the borehole logged in this project.

The KBS-3H design has been developed jointly by SKB and Posiva since 2002. This report has been prepared within the project phase "KBS-3H – System Design 2011–2016".

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom som genomförts inom KBS-3H projektet, System, delprojekt, KBS-3H Sub-system demonstration på −410 m nivån vid Äspölaboratoriet (Äspö HRL). De geofysiska loggningarna som presenteras här omfattar borrhålsradar (RAMAC) och BIPS genomförda I KBS-3H:s borrhål K08028F01.

Alla mätningar är utförda av Malå Geoscience AB under Juni 2014.

Syftet med radar och BIPS-undersökningar är att erhålla information om borrhålets kondition och bergets egenskaper i omgivningen av borrhålet. Borrhålsradar används för att karakterisera bergets egenskaper och strukturer i bergmassan närmast borrhålet

Syftet med BIPS-loggningen är att scanna borrhålsväggen för att undersöka bergväggens egenskaper och för att undersöka förekommande bergarter och dess sprickor med avseende på sprickfördelning och sprickorientering. Rapporten beskriver utrustningen som använts liksom mätprocedurer och en beskrivning av data och tolkningen av dessa. För BIPS-loggningen presenteras data som plottar längs med borrhålet. Radardata presenteras i radargram och i en tabell med tolkade radarreflektorer och deras respektive skärningsdjup i borrhålet och vinkel mellan borrhålsaxeln och reflektorns plan.

Borrhålsradardata från K08028F01 är av relativt bra kvalitet. Det är främst det konduktiva formationsvattnet som reducerar penetrationen av radarvågen och därmed minskar möjligheterna att identifiera strukturer. Totalt har 10 radarreflektorer identifierats i K08028F01.

BIPS-bilderna visar att förutsättningarna för geologisk kartering och sprickorientering är mycket goda i borrhålet.

KBS-3H är en variant av KBS-3 metoden som utvecklas gemensamt av SKB och Posiva. Denna rapport har utarbetats under projektfasen ”KBS-3H – System Design 2011–2016”.

Contents

1 Introduction

This report presents the data collected in geophysical logging operations, which are performed within the framework of the KBS-3H project System Design, subproject KBS-3H Sub-system demonstration on the −410 m level in the Äspö Hard Rock Laboratory (Äspö HRL). The logging operations presented here include borehole radar (RAMAC) and BIPS performed in the KBS-3H borehole K08028F01.

In Table 1-1 the controlling documents for performing this activity are listed. Both the activity plan and method descriptions are SKB's internal controlling documents.

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.

Table 1-1. Controlling documents for the performance of the activity (SKB's internal controlling documents).

Activity plan	**Number**	**Version**
BIPS och radar i K08028F01	AP TD 3HDEMO-14-041	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för TV-loggning med BIPS	SKB MD 222.006	2.0
Metodbeskrivning för borrhålsradar	SKB MD 252.020	4.0

The new KBS-3H borehole, K08028F01, is c. 95 m long, of c. 76 mm diameter and is collared at the far end of the TAS08 tunnel, Table 1-2. This report describes the Radar and BIPS loggings performed in the KBS-3H borehole K08028F01. The objective of the activity is to provide a geophysical platform for subsequent single hole interpretation (SHI) and also constitutes a basis for planning, performance and integrated interpretation of subsequent cross-hole surveys carried out by the DETUM-1 project with the objective of identifying and quantifying large structures/fractures and overall geoscientific modelling of the sampled rock volume. Collar coordinates for the borehole and other relevant specifications are provided in Table 1-2.

Table 1-2. Coordinates, bearing, inclination and length of K08028F01 in tunnel TAS08. Coordinates are given in accordance with the RT90 2,5 gon V system and the RHB70 elevation system.

Borehole	K08028F01 (Rock surface)
Location	Äspö Hard Rock Laboratory, TAS08
Coordinate system	RT90, elevation RHB70
Coordinates for starting point	Northing: 6368033.714 m Easting: 1551637.131 m Elevation: –396.584 m.a.s.l.
Bearing (°)	308.5431°
Inclination (°)	2.18° (directed upwards)
Borehole diameter (mm)	75.8
Length (m)	94.39 m
TOC-reference level	0.347 m

All measurements were conducted by Malå Geoscience AB between June 24 and 25 2014. The investigation site and location of the borehole are shown in Figure 1-1.

The delivered raw data have been delivered to SKB and entered in the database (SICADA) traceable by the activity plan number. The performed surveys are listed in Table 1-3.

Table 1-3. Performed surveys in borehole K08028F01.

Performed surveys	K08028F01
BIPS	X
Radar directional	X
Radar 20MHz dipol	X
Radar 100MHz dipol	X
Radar 250MHz dipol	X
Borehole parameter	
Inclination at TOC	2.18° (upward inclined)
Bearing at TOC, RT90 2,5 gon V	308.5431°
Bearing at TOC, Äspö 96	320.370°
Length (m)	94.39
Casing (m)	2.55
Borehole diameter (mm)	75.8

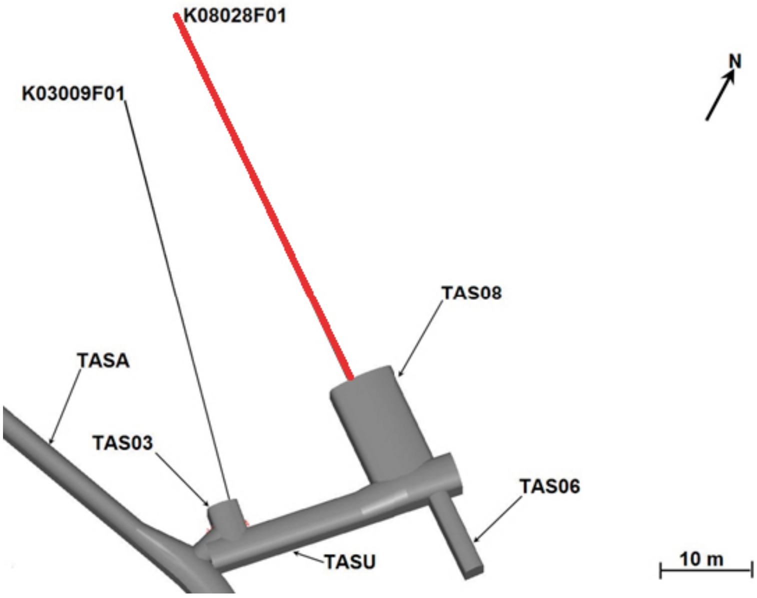


Figure 1-1. *Map of the location of borehole K08028F01 at Äspö HRL.*

2 Objective and scope

The objective of the radar and BIPS surveys is to obtain information on the borehole conditions (as seen in borehole wall) as well as of the rock mass around the borehole. Borehole radar is employed to investigate the nature and the structure of the rock mass surrounding the borehole, and borehole TV is performed in order to scan the borehole wall to survey the borehole rock surface as well as for determination of rock types and fracture distribution and orientations in the borehole wall.

This report describes the equipment used for the radar and BIPS surveys as well as the measurement procedures and data collected. For the BIPS survey, the result is presented as images. Radar data is presented in radargrams where the identified reflectors are indicated.

3 Equipment

3.1 Radar measurements RAMAC

The RAMAC GPR system owned by SKB is a fully digital GPR system where emphasis has been put 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 a 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.

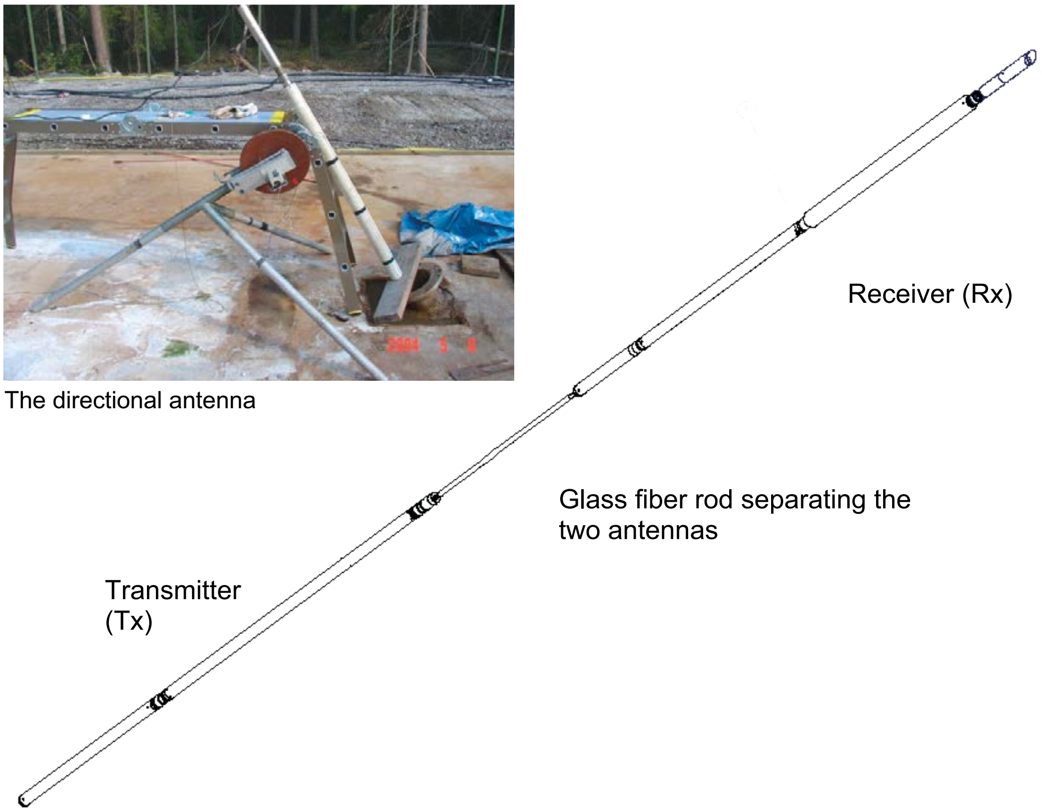


Figure 3-1. *Example of a borehole radar antenna.*

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 transparent 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 borehole) or using a gravity sensor (inclined borehole).

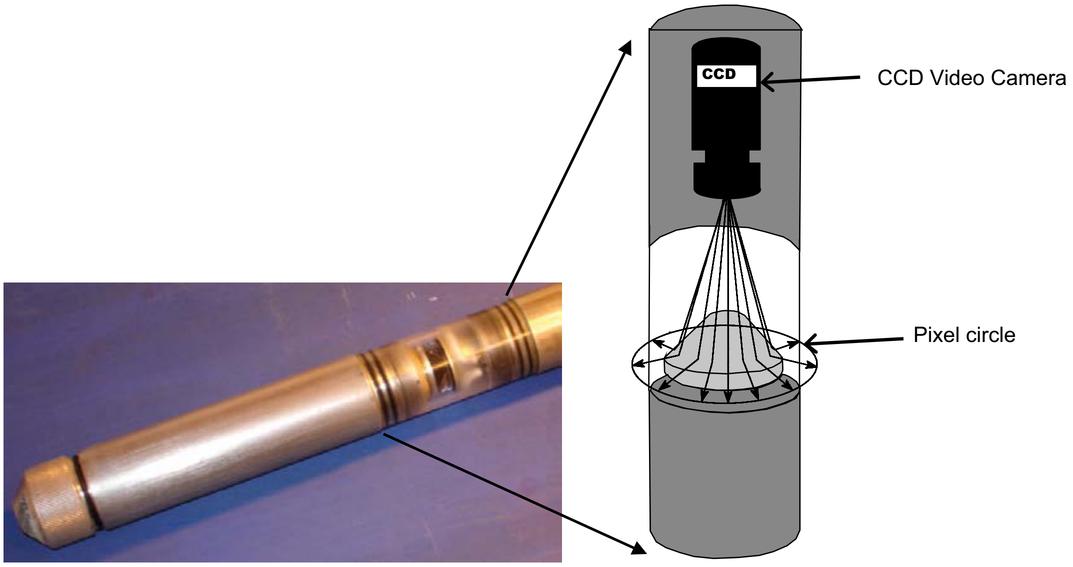


Figure 3-2. *The BIP-system. Illustration of the conical mirror scanning.*

4 Execution

4.1 General

4.1.1 RAMAC Radar

The measurements in K08028F01were carried out with dipole radar antennas, with a centre frequency of 20 MHz, 100 MHz and 250 MHz, respectively. Measurements were also carried out with a directional antenna, with a central frequency of 60 MHz.

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

All measurements were performed in accordance with the instructions and guidelines from SKB, cf. Table 1-1. All cleaning of the antennas and cable was performed according to the internal document SKB MD 600.004 before the logging operation.

Table 4-1. Radar logging information from K08028F01.

Site:	**Äspö HRL**	**Logging company:**	**MALÅ GeoScience**
BH:	**K08028F01**	**Equipment:**	**SKB RAMAC**
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ GeoScience**
Operator:	**CG**		

Antenna type:	**Directional**	**20 MHz**	**100 MHz**	**250 MHz**
Logging date:	2014-06-25	2014-06-24	2014-06-24	2014-01-24
Reference:	Rock surface	Rock surface	Rock surface	Rock surface
Sampling freq. (MHz):	693	238	890	2 424
Number of samples:	313	232	518	416
Number of stacks:	32	32	32	32
Logging from (m):	3.40	6.25	2.6	1.5
Logging to (m)[1)]:	87.4	85.5	90.6	90.1
Trace interval (m)[2)]:	0.5	0.2	0.1	0.1

[1)] Different lengths of the probes and measurement points result in the difference. The shortest probe is the 250 MHz, were we also get the best coverage along the borehole.

[2)] Distance between the measurement points along the borehole.

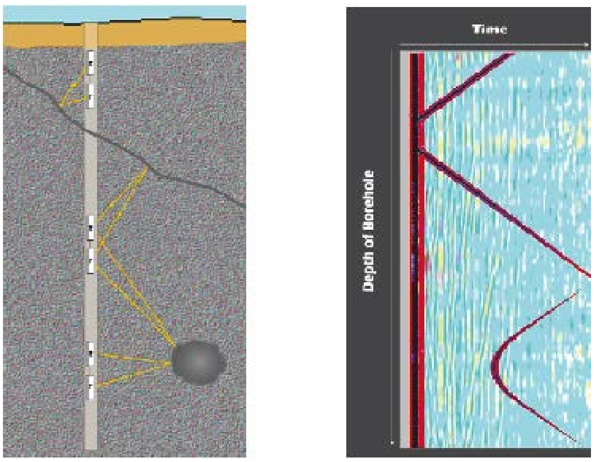


Figure 4-1. *The principle of radar borehole reflection survey and an example result.*

The functionality of the directional antenna was tested before start of the survey in K08028F01. This was performed by measurements in air, where the receiver antenna and the transmitter antenna were placed apart. During the function test the two antennas are separated about 10 m. While transmitting a radar pulses from the transmitter antenna the receiver antenna is rotated by 10 degree angular increments in the 0–360 degree interval thereby giving the orientation of the receiver antenna relative to the transmitter antenna. The difference in direction is measured by compass. The resulting difference in the angle measured with the receiver antenna compared with the compass reading was approximately 5 degrees. This can be considered to be good due to the disturbed environment, with metallic objects etc. at the test site.

For more information on system settings used in for the surveyed borehole see Table 4-1.

4.1.2 BIPS

All measurements were performed in accordance with the instructions and guidelines from SKB, cf. Table 1-1. 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, corresponding to the length resolution. The maximum speed during data collection was 1.5 m/minute.

A gravity sensor based on an air bubble in an alcohol was used to measure the orientation of the images in the logged borehole.

In order to control the quality of the system, calibration measurements were performed in a test pipe before logging and after logging. Figure 4-2 shows the results of the test logging performed before and after the logging campaign. The results show no differences regarding the colours and focus of the images. The results of the test loggings were included in the delivery of the raw data.

The BIPS logging information is found in the header presented in Appendix 2 in this report.

4.1.1 Length measurements

During logging using the RAMAC and BIPS systems the length measuring wheel on the push rig was used for length control of the survey. For an depth control the length recording was checked calculating the number of the 2 metre long aluminium rods used for pushing the probes into the borehole.

4.2 Analyses and Interpretation

4.2.1 Radar

The results from radar measurements are usually presented in the form of a radargram where the position of the probe, cf. Figure 3-1, is shown along one axis and the radar wave propagation and reflection is shown along the other axis. The radar transmitter antenna (Tx) sends out a pulse that is a sinus wave of positive and negative polarity. The strength of reflected waves (in terms of amplitude) is recorded by the receiver (Rx) and displayed in a grey scale in an amplitude map (so-called radargram where black and white colour, respectively, correspond to positive and negative signals. Grey colour corresponds to absence of reflected signals.

The presented data in this report are 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 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.).

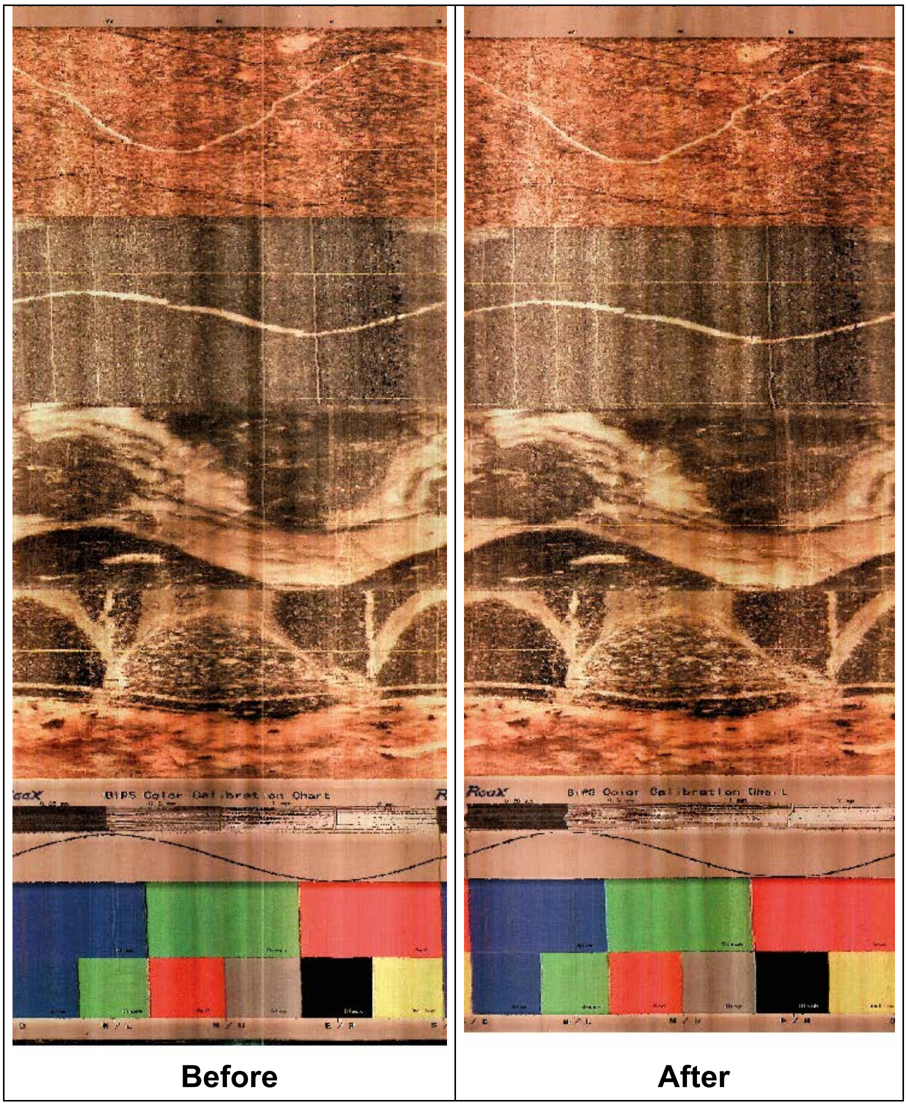


Figure 4-2. *Results from logging in the test pipe before and after the logging campaign in June, 2014.*

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 of the radar pulse is the same everywhere in the rock.

There are several ways to determine the radar wave propagation velocity. Each of them has its advantages and its disadvantages. For this logging campaign the velocity determined earlier between KLX07A and KLX07B as performed during the Oskarshamn site investigation is used. The velocity measurement was performed by keeping the transmitter fixed in one borehole while moving the receiver downwards in the second borehole. The velocity measurement was performed with the 20 MHz antennas in borehole KLX07A and KLX07B (Gustafsson and Gustafsson 2005).

The result of the velocity determination of the radar wave is plotted in Figure 4-3 and the calculation shows a radar wave velocity varying between 110 and 117 m/micro seconds. The lower velocities most probably represent a fracture zone in the length interval 40 to 60 m.

The visualization of data is made with ReflexWin, a Windows-based processing software for filtering and analysis of borehole radar data. The processing steps are shown in Table 4-3. The filters applied affect the whole borehole length and are not always suitable in all parts, depending on the geological conditions and conductivity of the borehole fluid. During interpretation further processing can be done, most often in form of bandpass filtering. This filtering can be applied to selected parts of the borehole, where needed.

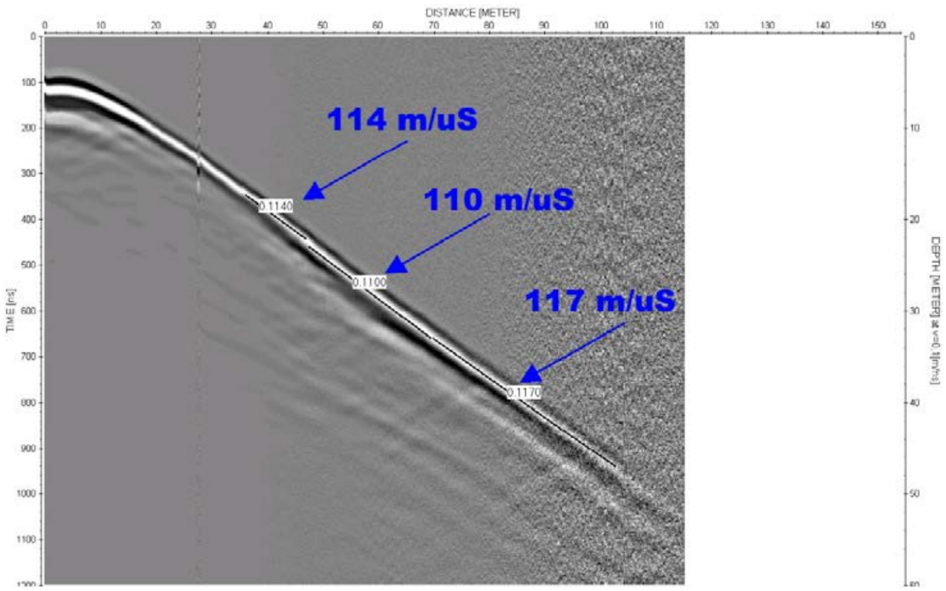


Figure 4-3. *Results from velocity measurements (Gustafsson and Gustafsson 2005).*

Table 4-3. Processing steps for borehole radar data.

Site:	**Äspö HRL**	**Logging company:**	**MALÅ GeoScience AB**
BH:	**K08028F01**	**Equipment:**	**SKB RAMAC**
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ GeoScience**
Interpret:	**CG**		

	Directional	20 MHz	100 MHz	250 MHz
Processing:	Move start time (–44 samples)	Move start time (–32)	Move start time (–38)	Move start time (–27)
	DC shift (300–511)	DC shift (300–500)	DC shift (300–500)	DC shift (300–500)
	Time gain (start 37 lin 122exp 1)	Gain (start 69 lin 44 exp 0.1)	Gain (start 33 lin 78 exp 0.1)	Gain (start 25 lin 125 exp 0.1)
	Background removal	Background removal	Background removal	Background removal

For the interpretation of the intersection angle between the borehole axis and the planes visible on the radargrams the RadinterSKB software, version 1.3 has been used. The interpreted intersection points and intersection angles of the detected structures are presented in Table 5-1 and 5-2 and are also visible on the radargrams in Appendix 1.

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 was performed, the raw data was delivered to SKB 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. For printing of the BIPS images the printing software BIPP from RaaX was used.

4.3 Nonconformities

No nonconformities occurred during the logging in June 2014.

5 Results

The results from the BIPS measurements were delivered as raw data (*.bip-files) on CD-ROM disks and MO-disks to SKB together with printable BIPS pictures in *.pdf format before the field crew left the investigation site. The information on the measurements was entered in the database of SKB (SICADA), and the digital data on CD and MO disks were stored by SKB.

The RAMAC radar data were delivered as raw data file format *.rd3 (dipole antennas) or *.rd5 (directional antenna) for with corresponding information files (file format *.rad) whereas the data processing steps and results are presented in this report. Relevant information, including the interpretation presented in this report, was entered into the database SICADA.

The delivered raw and processed data have been entered in the database SICADA and data are traceable by the activity plan number.

5.1 RAMAC logging

The results of the interpretation of the radar measurements are presented in Tables 5-1 to 5-2. Radar data are also visualized in Appendix 1. It should be remembered that the radar images in Appendix 1 are only composite pictures of all events 360 degrees around the borehole axis, 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 but are not interpreted as indicated in Appendix 1. Often a number of structures can be noticed, but they are most probably lying so close to each other that it is impossible to distinguish one reflector from the other. It should also be pointed out that reflections interpreted will always obtain an intersection point with the borehole path, but being located further away. They may in some cases not even reach the borehole.

The data quality from K08028F01 as seen in Appendix 1 is good. The borehole intersects several structures but the absence of large decreases in the amplitude values for the first arrival, e.g. attenuation of the radar wave, indicate a relatively homogenous rock mass without any major deformation zones carrying water. The conductive environment due to the high salinity of the water makes the radar wave to attenuate, which decreases the penetration. This conductive environment of course also reduces the possibility to distinguish and interpret possible structures in the rock which otherwise could give rise to a reflection.

The effect of a conductive environment is also seen in the directional antenna results which makes it more difficult to interpret the geometry to the identified structures.

Table 5-1 summarises the interpretation of radar data from K08028F01. In the table the borehole intersection length and angle to the identified reflectors are listed.

For structures or reflectors where it was possible to determine the direction to the reflector (object), the dip and strike is given. As seen some radar reflectors in Table 5-1 are marked with ±, which indicates an uncertainty in the interpretation of direction to the reflector. The direction can in these cases be ±180 degrees. The definition for direction to the reflector (object) is defined in Figure 5-2.

As the borehole inclination is less than 85° the direction to the object is calculated using gravity roll. The direction to the object and the intersection angle are recalculated to strike and dip, also given in the tables. The interpreted plane strike is the angle between line of the plane's cross-section with ground 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 interpreted plane dip is the angle between the plane and the ground surface (seen as a horizontal plane). It can vary between 0 and 90 degrees.

Table 5-1. Interpretation of radar reflectors from the dipole antennas and the directional antenna 60 MHz in borehole K08028F01.

RADINTER MODEL INFORMATION
(Directional and dipole antennas)

Site: Äspö HRL
Borehole name: K08028F01
Nominal velocity (m/μs): 117.0

Name	Intersection depth	Intersection angle	RadInter direction to object (gravity roll)	Dip 1	Strike 1	Dip 2	Strike 2
1	12.74	40	78 ±	83	245	90	29
2	26.48	35	66 ±	78	241	84	21
3	37.32	33					
4	42.90	58					
5	49.76	31					
6	66.48	44					
7	74.84	61	60 ±	64	234	77	30
8	80.25	63					
9	89.02	42					
10	93.10	55	30 ±	71	253	72	1

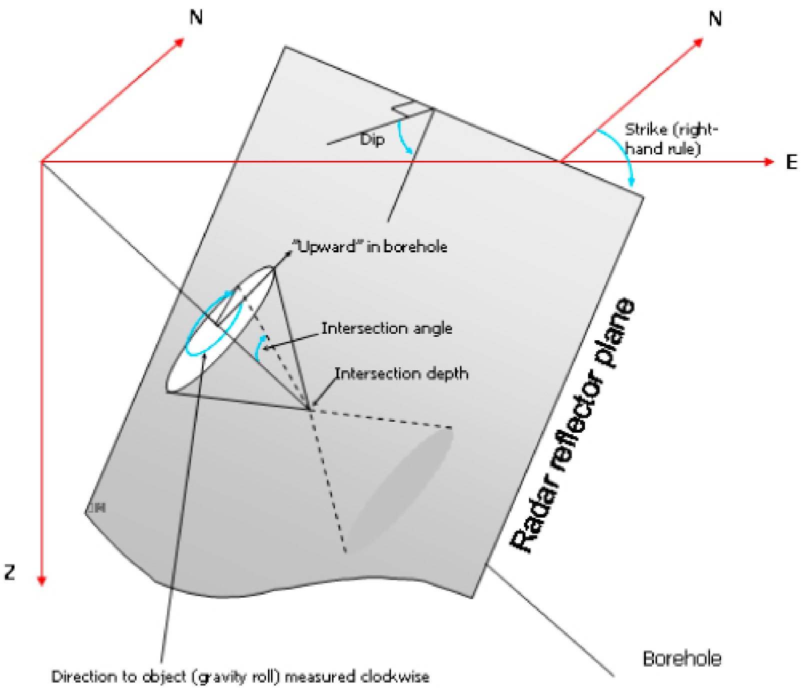


__Figure 5-2.__ Definition of intersection angle, direction to object using gravity roll, dip and strike using the right hand rule as presented in Table 5-1.

Finally, the reflectors considered as the most important (clearly distinguished in the radargram, identified with several antenna frequencies, extending far from the borehole wall etc.) are listed in Table 5-2 below.

Table 5-2. Some important reflectors observed in the borehole.

Borehole	K08028F01
Reflectors	5, 6, 7 and 10

Please note that it can be very difficult to classify different reflectors along a borehole in an objective manner. Factors that may affect the interpretation of the radar logging data is variable water quality (electrical conductivity) along the borehole and increased fracture frequency in conjunction with the structure of interest that both may result in variable degree of radar signal attenuation. Also the intersection angle of the identified structures affects the amplitude in the resulting radargram. Small intersection angles will mostly give an increased amplitude compared to larger intersection angles, and by that a more clearer interpretation of structure geometry. Another factor to be considered for the 20 MHz antenna survey is the long distance (10.05 m) between the 20 MHz transmitter (Tx) and receiver (Rx) antenna. Small structures intersecting the borehole associated with high attenuation will result in a wide anomaly over a distance that is equal to the distance between Tx and Rx components, of the probe, cf. Figure 4-1.

5.2 BIPS logging

The BIPS pictures from K08028F01are presented in Appendix 2.

In order to control the quality of the logging system, calibration measurements were performed in a test pipe before and after the logging, cf. Section 4.1.2.

The error in the length recording depends mainly on the tension of the cable and error of the length readings from the measuring wheel.

The BIPS images in the borehole shows very good quality along the borehole. Only small amount of discoloring effect of the borehole walls make the geological mapping easy.

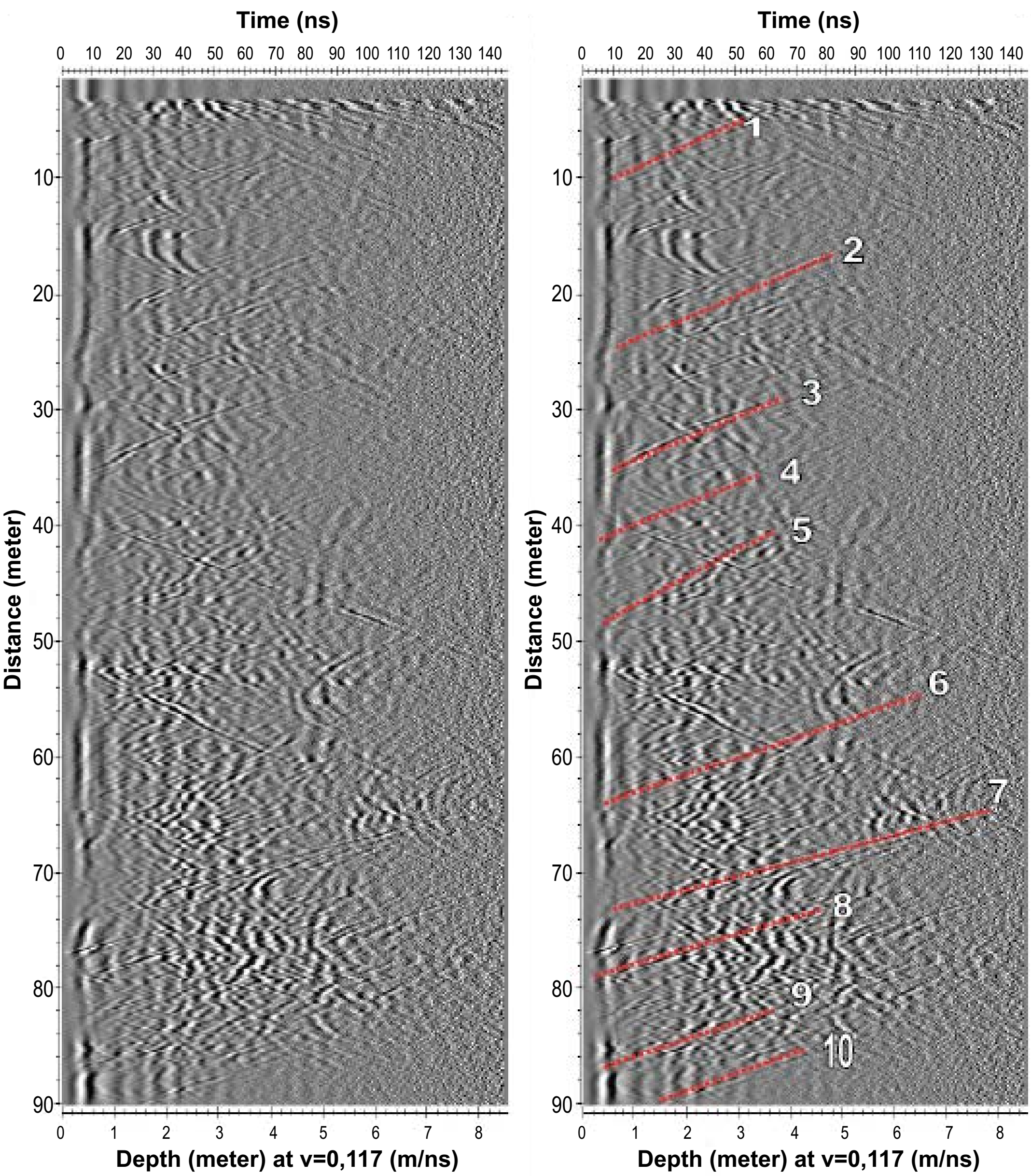
References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.com/publications.

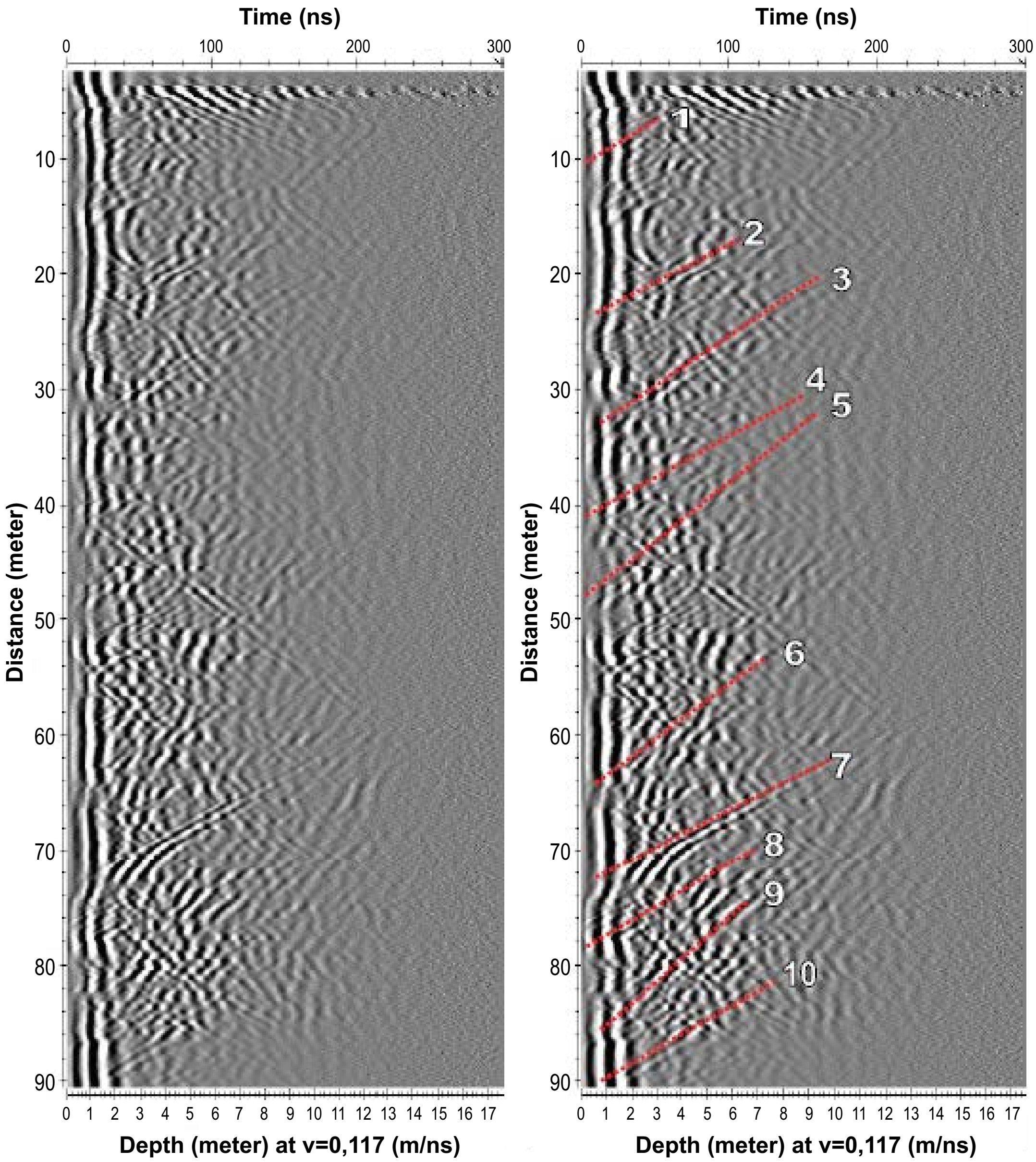
Gustafsson J, Gustafsson C, 2005. Oskarshamn site investigation. RAMAC and BIPS logging in borehole KLX07A, KLX07B, HLX34 and HLX35 and deviation logging in borehole KLX07B, HLX34 and HLX35. SKB P-05-231, Svensk Kärnbränslehantering AB.

Radar logging in K08028F01, dipole antenna 250, 100 and 20 MHz

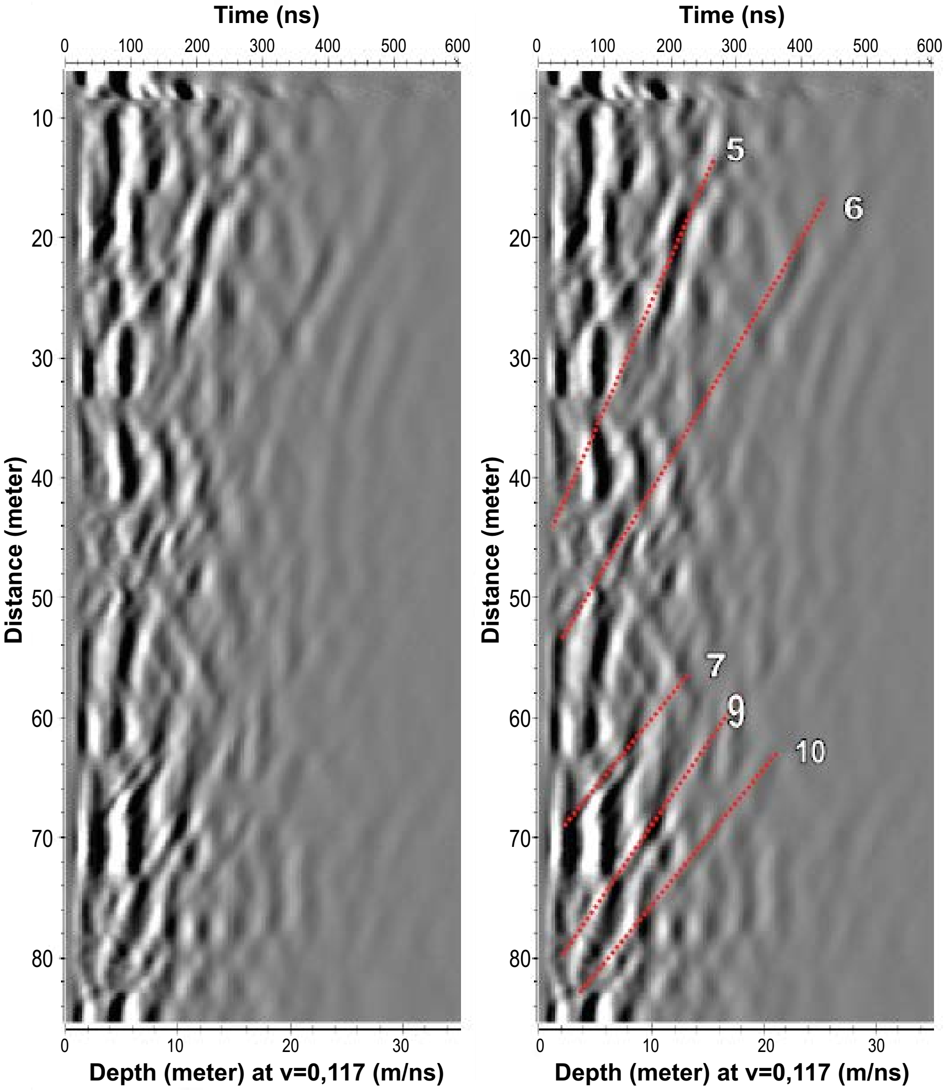
Äspö K08028F01 250 MHz data



Äspö K08028F01 100 MHz data



Äspö K08028F01 20 MHz data



Appendix 2

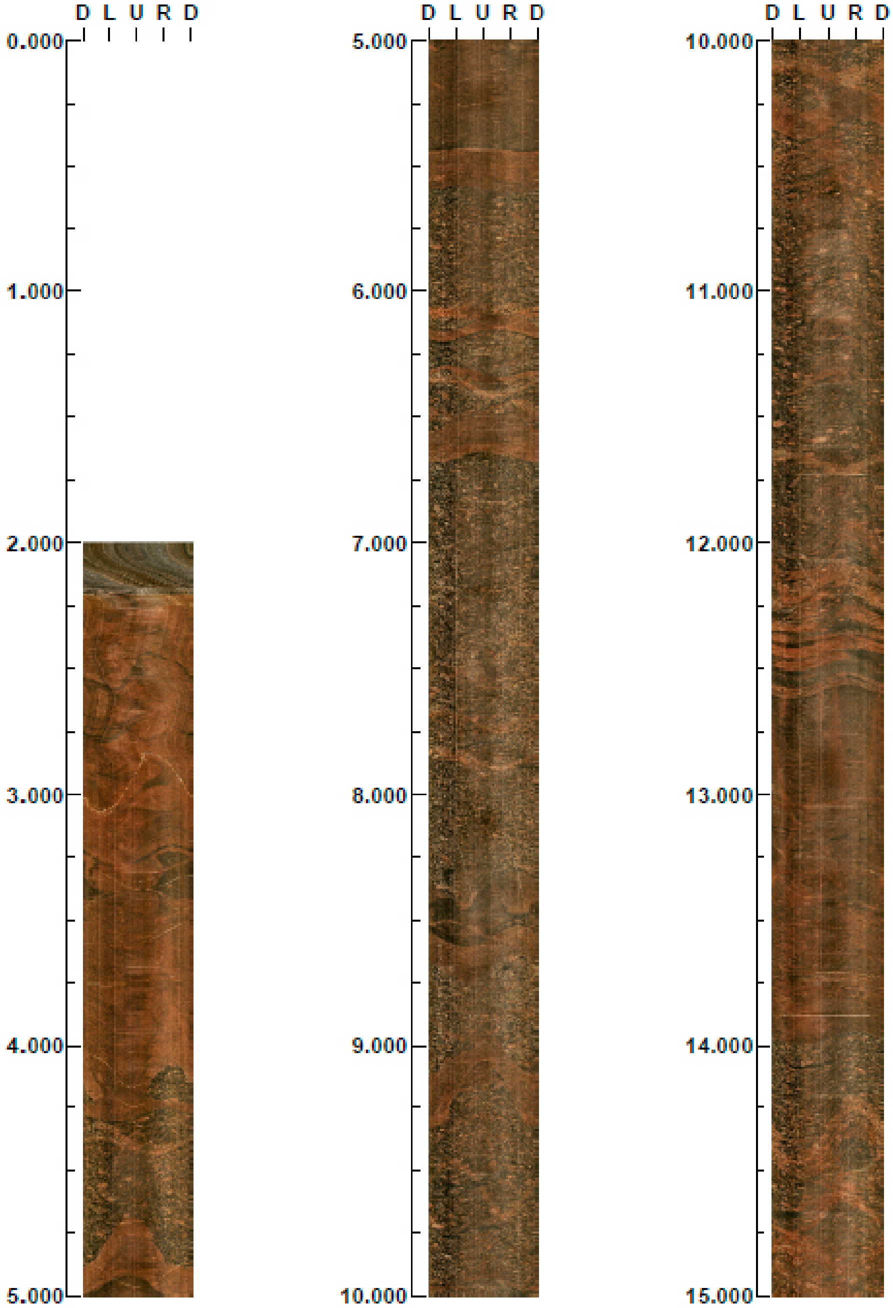
BIPS logging in K08028F01

Project name: ÄSPÖ HRL

Image file	: d:\work\sphrl~1\aptd3h~1\bips\k08028~1.bip
BDT file	:
Locality	: ASPO
Bore hole number	: K08028F1
Date	: 14/06/24
Time	: 09:51:00
Depth range	: 2.000 - 93.431 m
Azimuth	: 0
Inclination	: -90
Diameter	: 76.0 mm
Magnetic declination	: 0.0
Span	: 4
Scan interval	: 0.25
Scan direction	: To bottom
Scale	: 1/25
Aspect ratio	: 180 %
Pages	: 7
Color	: +0 +0 +0

Project name: ÄSPÖ HRL
Bore hole No.: K08028F1 Azimuth: 0 Inclination: -90

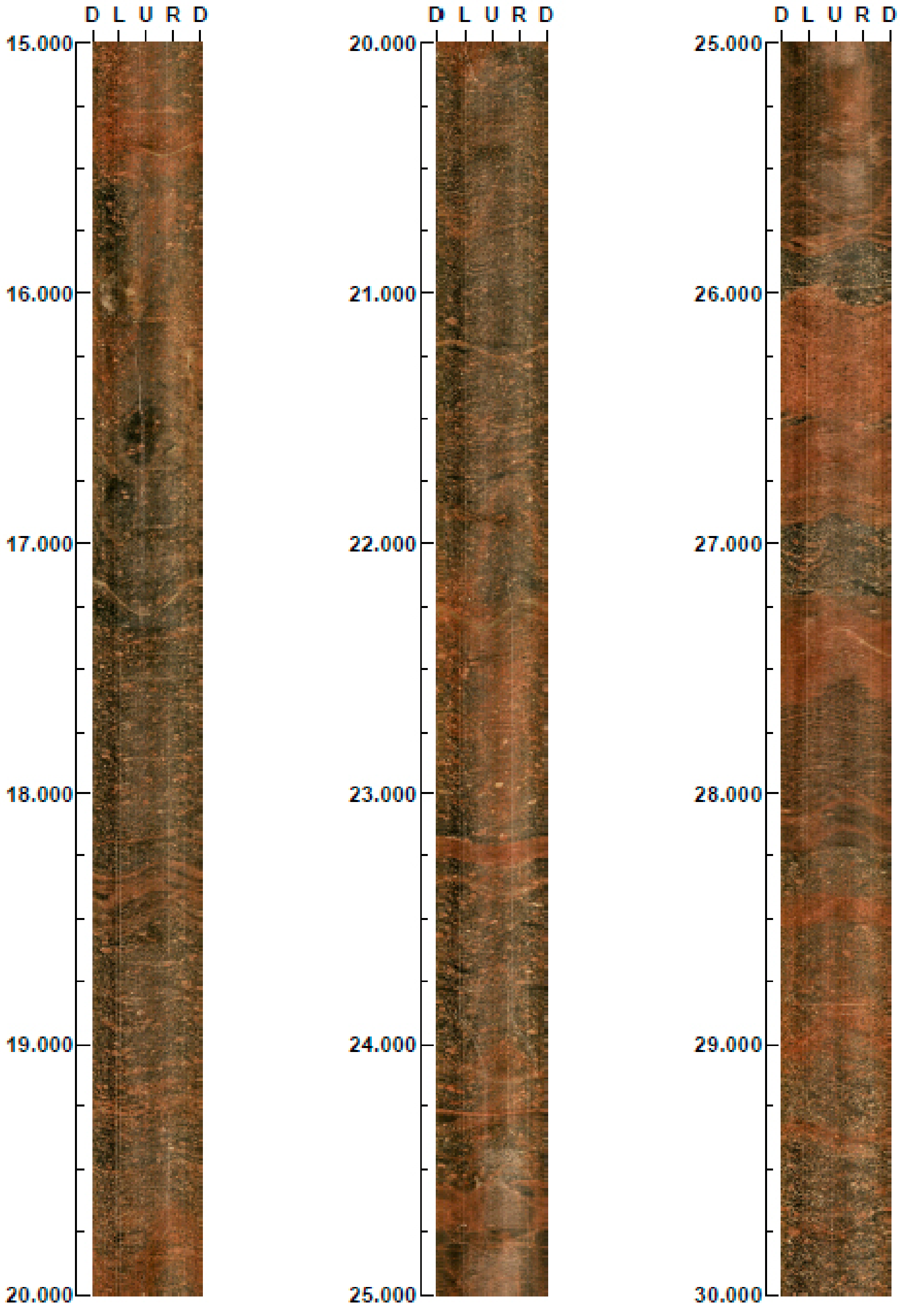
Depth range: 0.000 - 15.000 m



(1 / 7) Scale: 1/25 Aspect ratio: 180 %

Project name: ÄSPÖ HRL
Bore hole No.: K08028F1 **Azimuth: 0** **Inclination: -90**

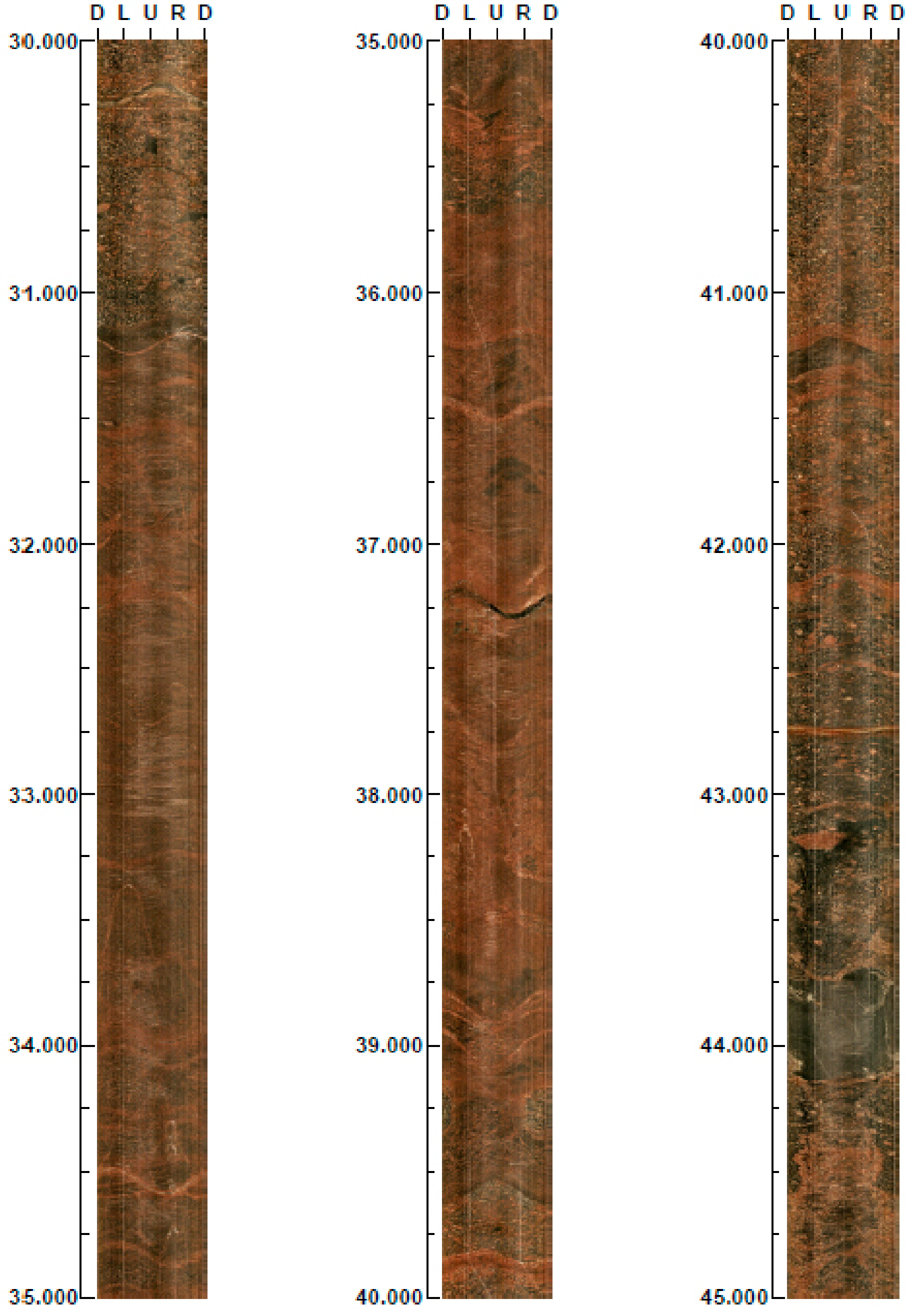
Depth range: 15.000 - 30.000 m



(2 / 7) **Scale: 1/25** **Aspect ratio: 180 %**

Project name: ÄSPÖ HRL
Bore hole No.: K08028F1 Azimuth: 0 Inclination: -90

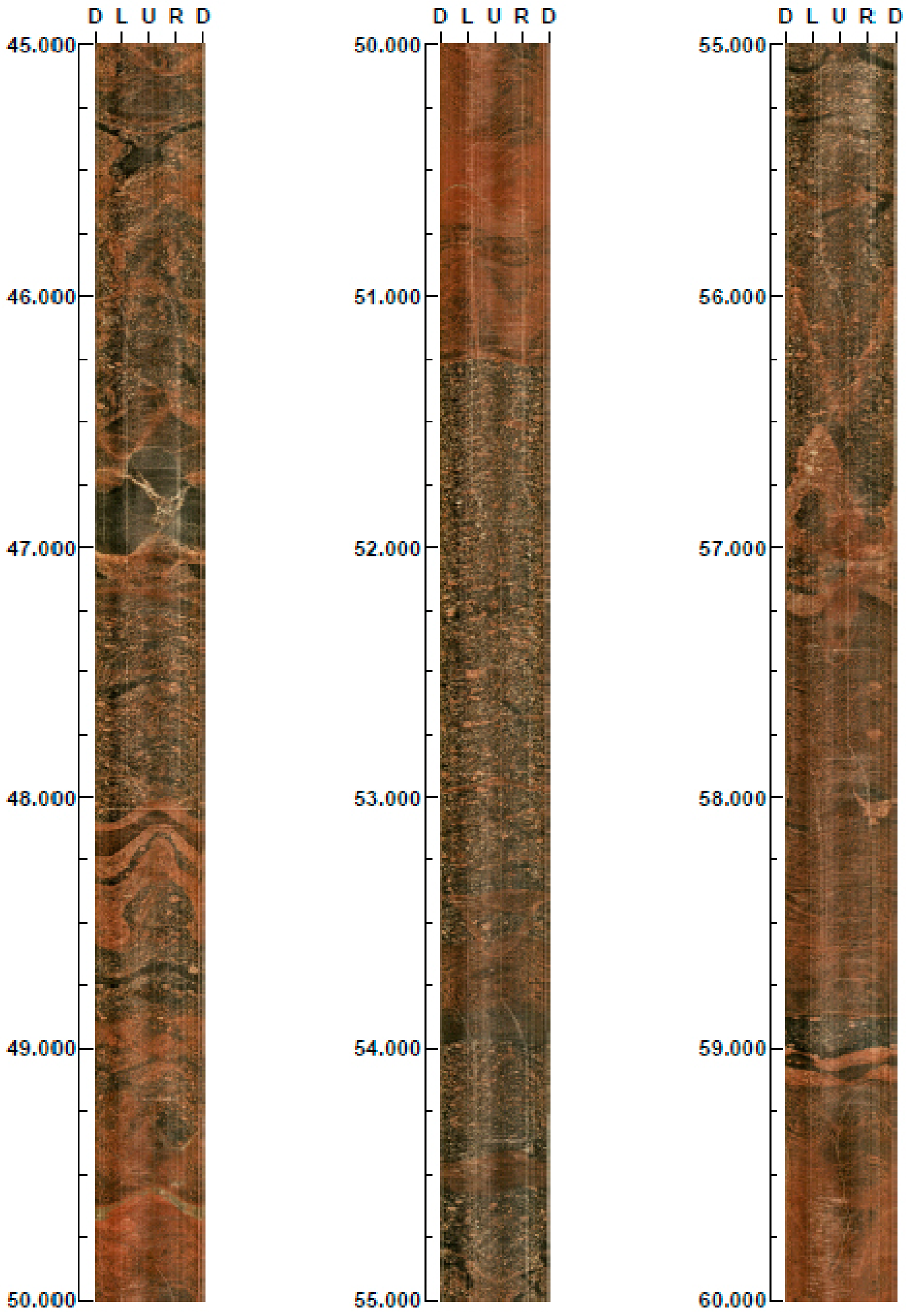
Depth range: 30.000 - 45.000 m



(3 / 7) Scale: 1/25 Aspect ratio: 180 %

Project name: ÄSPÖ HRL
Bore hole No.: K08028F1 **Azimuth: 0** **Inclination: -90**

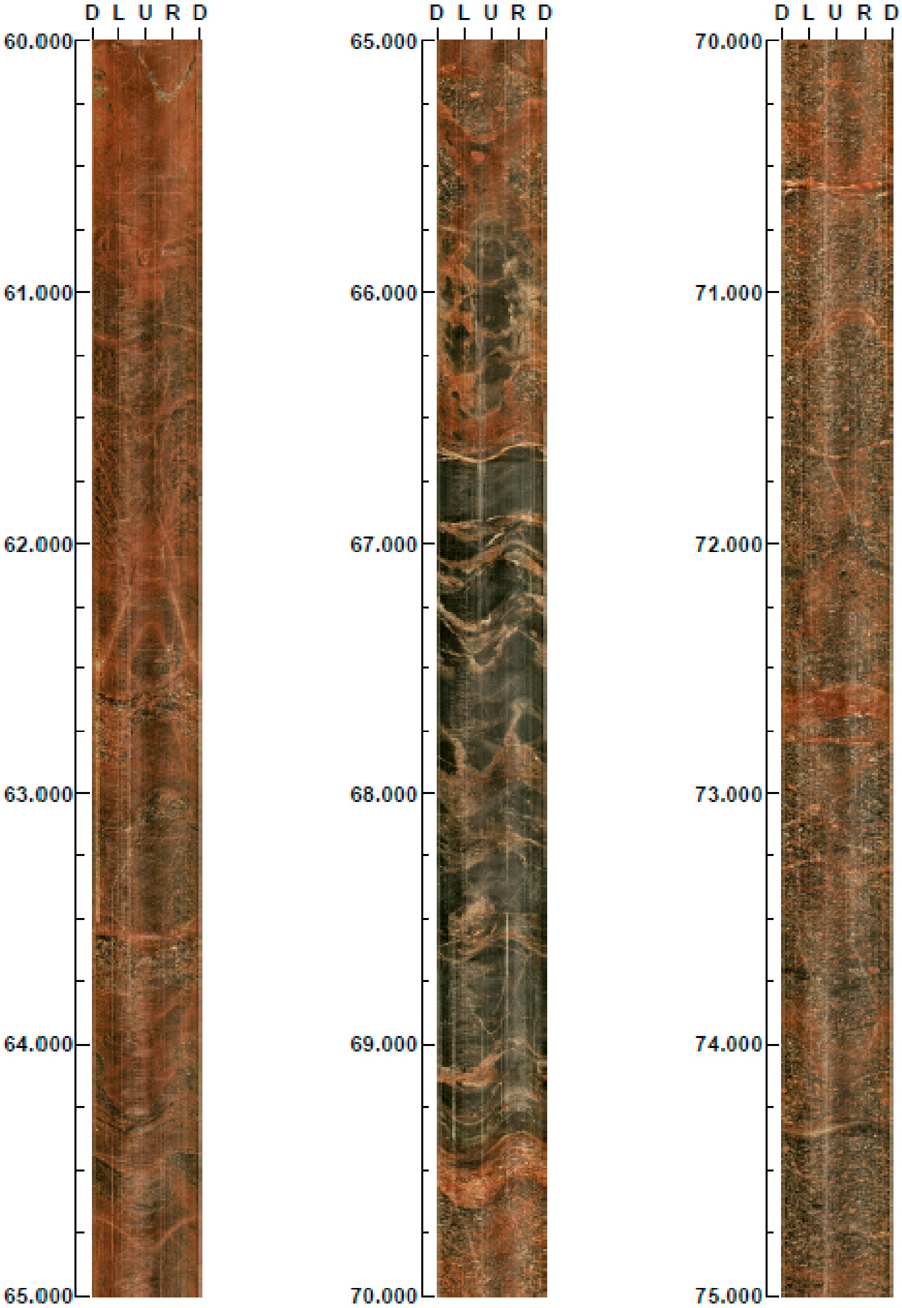
Depth range: 45.000 - 60.000 m



(4 / 7) **Scale: 1/25** **Aspect ratio: 180 %**

Project name: ÄSPÖ HRL
Bore hole No.: K08028F1 **Azimuth: 0** **Inclination: -90**

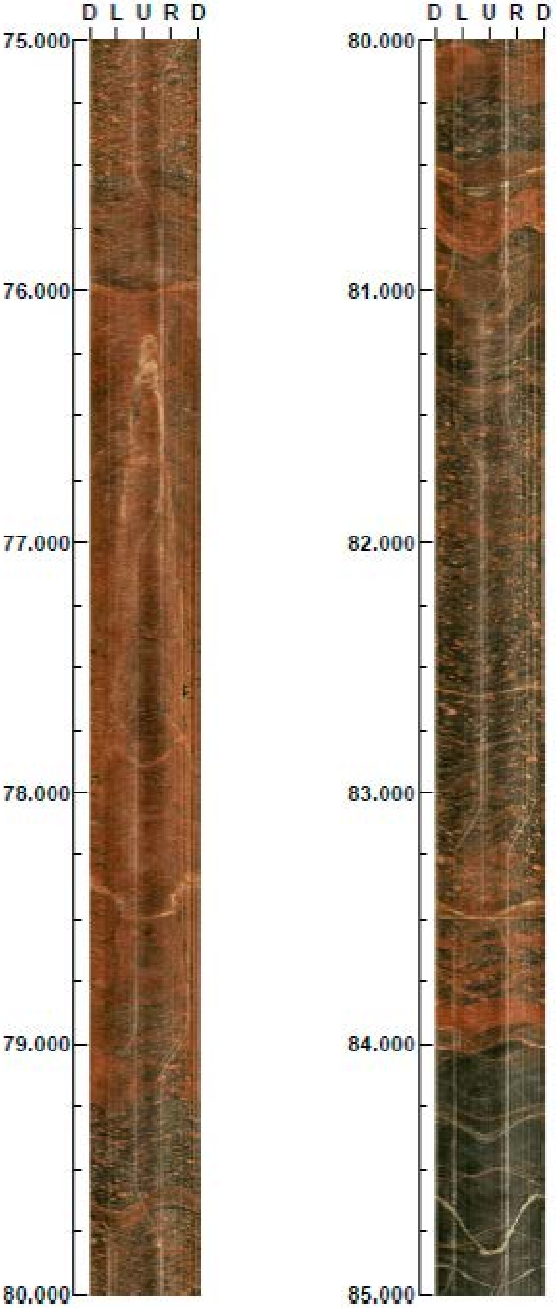
Depth range: 60.000 - 75.000 m



(5 / 7) **Scale: 1/25** **Aspect ratio: 180 %**

Project name: ÄSPÖ HRL
Bore hole No.: K08028F1 **Azimuth: 0** **Inclination: -90**

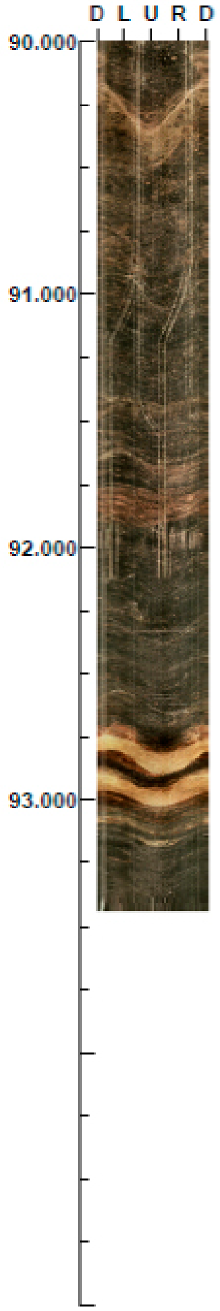
Depth range: 75.000 - 90.000 m



(6 / 7) **Scale: 1/25** **Aspect ratio: 180 %**

Project name: ÄSPÖ HRL
Bore hole No.: K08028F1 **Azimuth: 0** **Inclination: -90**

Depth range: 90.000 - 93.431 m



(7 / 7) **Scale: 1/25** **Aspect ratio: 180 %**

Arkitektkopia AB, Bromma, 2017

SKB is responsible for managing spent nuclear fuel and radioactive waste produced by the Swedish nuclear power plants such that man and the environment are protected in the near and distant future.

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