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Forsmark site investigation

RAMAC and BIPS logging in borehole KFM02A

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Malå Geoscience AB / RAYCON

March 2004

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Keywords: BIPS, RAMAC, Radar, TV, Geophysical logging.

Contents

1 Introduction

This document reports data gained during geophysical logging operations, which is one of the activities performed within the site investigation at Forsmark. The logging operations here include borehole radar (RAMAC) and TV-logging (BIPS) and was carried out in the core drilled part of borehole KFM02A (see Figure 1-1). Both the radar and BIPS measurements have been made from 100 m to approximately 1000 m. The borehole is drilled near vertical (85 degrees from horizontal) and has a diameter of 76 mm and a length of 1002.44 m. Previous investigations in KFM02A are presented in /1/.

The borehole radar measurements were conducted by Malå Geoscience AB / RAYCON during February 2003 (100–600 m), May 2003 (600–1000 m), and January 2004 (directional antenna 100–1000 m) while the BIPS measurements were made in February 2003 (100–635 m, not presented in this report) and April 2004 (100–1000 m). The work was conducted according to activity plan AP PF 400-03-02 (SKB internal controlling document).

The applied investigation techniques comprised:

- Borehole radar with both 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.

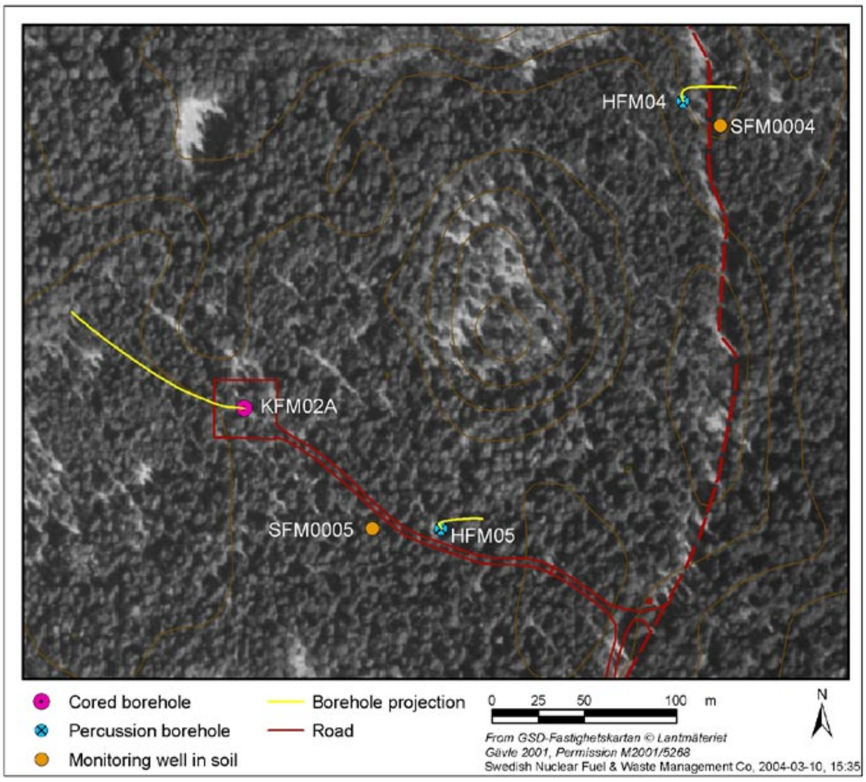


Figure 1-1. *Overview of drill site no 2 in the Forsmark area.*

2 Objective and scope

The objective of the radar- and BIPS-surveys was to achieve information on the borehole conditions (borehole wall) as well as on the rock mass around the borehole. Borehole radar was 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 Borehole radar – RAMAC

The RAMAC GPR system owned by SKB is fully digital, and emphasis has been laid on high survey speed and smooth field operation. The system operates dipole and directional antennas (see Figure 3-1). A system description is given in the method description "Metodbeskrivning för borrhålsradar" (SKB MD 252.21, Version 1.0).

The borehole radar system consists of a transmitter and a receiver antenna. During operation, an electromagnetic pulse, within the frequency range 20 to 250 MHz is emitted and penetrates the bedrock. The resolution and penetration of the radar waves depend on the antenna frequency used. A low antenna frequency results in lower resolution but higher penetration rate compared to a higher frequency. If a feature, e.g. a water-filled fracture, with anomalous electrical properties compared to the surrounding is encountered; the pulse is reflected back to the receiver and recorded.

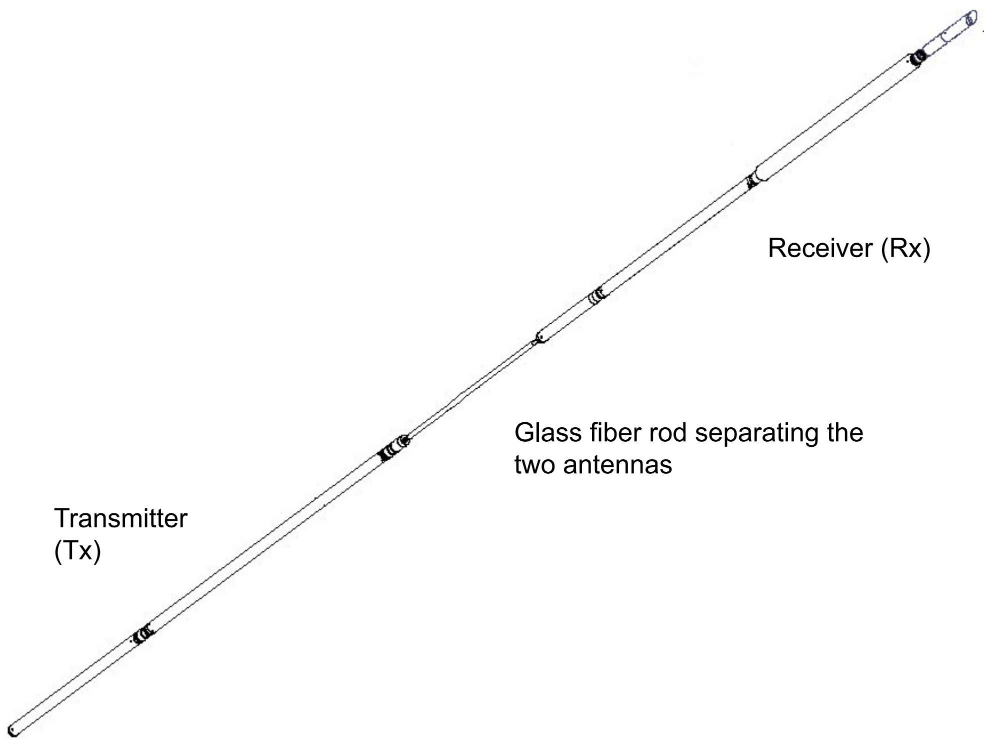


Figure 3-1. *Example of a borehole antenna.*

3.2 TV-Camera – BIPS

The BIPS 1500 system used is owned by SKB and described in the method description "Metodbeskrivning för TV-loggning med BIPS" (SKB MD 222.005, Version 1.0). 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 BIPS images can be orientated by means of to two alternative methods, either with a compass (vertical and sub-vertical boreholes) or with a gravity sensor (inclined boreholes).

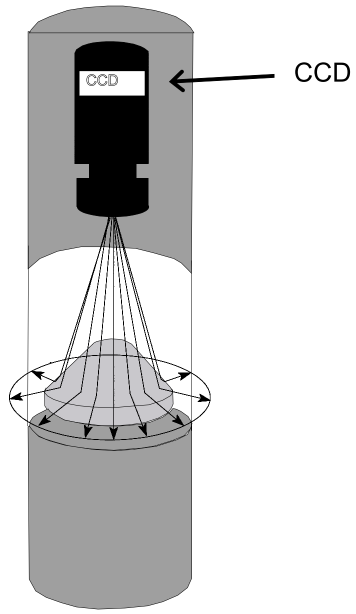


Figure 3-2. *The BIP-system. Illustration of the conical mirror scanning.*

4 Execution

4.1 Data aquisition

RAMAC

For the borehole radar measurements, both dipole and directional antennas were engaged. The dipole antennas used have central frequencies of 20 MHz, 100 MHz and 250 MHz, respectively, whereas the directional antenna has a central frequency of 60 MHz.

During logging, the dipole antennas (transmitter and receiver) were lowered continuously into the borehole and the data recorded on a field PC. The measurements with the directional antenna were made step-wise, with a short pause for each measurement. The antennas (both dipole and directional) are kept at a fixed separation by glass fibre rods according to Table 4-1 and 4-2. See also Figure 3-1 and 4-1.

For detailed information see the SKB MD 252.020 for method description and MD 600.004 for cleaning of equipment.

Information on the system settings for the different antennas used in the investigation of KFM02A is presented in Table 4-1 to 4-3 below.

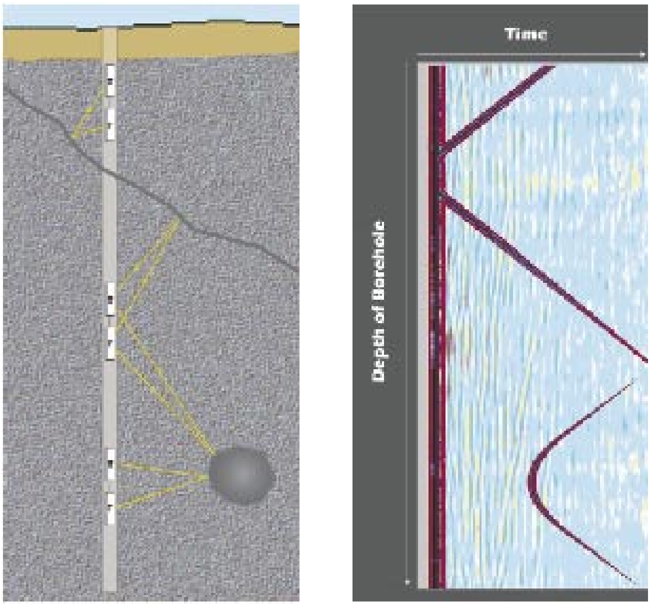


Figure 4-1. *The principle of radar borehole reflection survey (left) and a resulting radargram (right).*

Table 4-1. Radar logging information from KFM02A from 100 to 600 m (February 2003).

Site:	**Forsmark**	**Logging company:**	**RAYCON**	
BH:	**KFM02A**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operators:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	02-02-14	02-02-14	02-02-14
	Reference:	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	2588	951	247
	Number of samples:	619	518	512
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.32	–0.32	–1.36
	Logging from (m):	101.5	102.6	103.3
	Logging to (m):	640.5	634.8	633.8
	Trace interval (m):	0.10	0.20	0.25
	Antenna separation (m):	2.4	3.9	10.05

Table 4-2. Radar logging information from KFM02A from 600 to 1000 (May 2003).

Site:	**Forsmark**	**Logging company:**	**RAYCON**	
BH:	**KFM02A**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operators:	**CG / JG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
	Logging date:	03-05-23	03-05-22	03-05-23
	Reference:	T.O.C	T.O.C	T.O.C
	Sampling frequency (MHz):	2588	951	257
	Number of samples:	619	518	518
	Number of stacks:	Auto	Auto	Auto
	Signal position:	–0.32	–0.32	–1.36
	Logging from (m):	601.5	602.6	106.25
	Logging to (m):	1000.5	949.7	995.65
	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 KFM02A from 100 to 1000 (January 2004).

Site:	**Forsmark**	**Logging company:**	**RAYCON**
BH:	**KFM02A**	**Equipment:**	**SKB RAMAC**
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**
Operators:	**JG / JN**	**Antenna**	
		Directional (60 MHz)	
	Logging date:	2004-01-22	
	Reference:	T.O.C.	
	Sampling frequency (MHz):	656	
	Number of samples:	512	
	Number of stacks:	32	
	Signal position:	365.72	
	Logging from (m):	103.4	
	Logging to (m):	994	
	Trace interval (m):	0.5	
	Antenna separation (m):	5.73	

BIPS

For detailed information on BIPS measurements see the SKB MD 222.006 for a method description and MD 600.004 for cleaning of equipment.

During the measurement, pixel circles with a resolution of 360 pixels/circle were recorded 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 orientate the BIPS images.

Depth measurements

The depth recording for the RAMAC and BIPS systems is taken care of by a measuring wheel mounted on the cable winch. Whenever reference marks in the borehole are visible on the image displayed by the ground unit during the BIPS logging, the logging cable is marked with a piece of scotch tape. These marks are then used for controlling the depth registration during the RAMAC measurements.

In Figure 4-2, the divergence between the individual dipole measurements and the difference compared to the reference marks is plotted. For the directional antenna the depth divergence was approximately 50 cm to a depth of 350 m, and then a bit lager due to icing of the measuring wheel. The length recordings of the radar measurements were adjusted before the final data delivery.

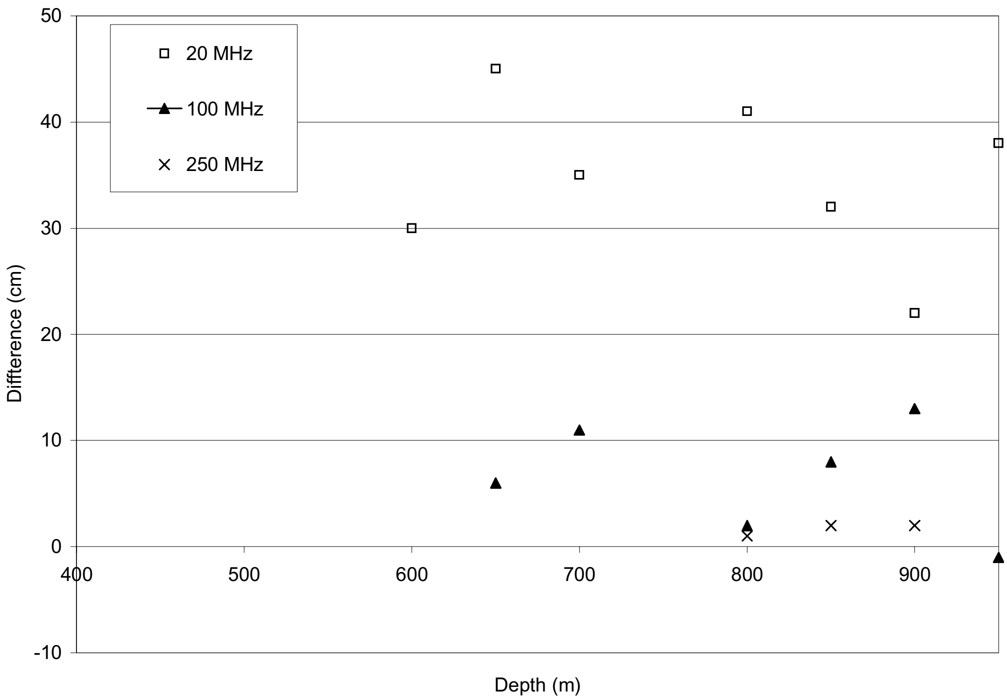


Figure 4-2. *Illustration of the divergence in depth measurements for the different radar antennas used and compared to the borehole reference marks.*

4.2 Analyses and Interpretation

Radar

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

The data presented in this report is related to the "measurement point", which is defined to be the central point between the transmitter and the receiver antenna.

In the reflection mode, borehole radar primarily offer a high-resolution image of the rock mass, visualizing the geometry of plane structures (contacts between rock units of different lithology, thin marker beds, fractures, fracture zones etc), which may or may not intersect the borehole, or showing the presence of local features (cavities, lenses etc) around the borehole.

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 consistent in the rock volume investigated.

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 a borehole at drill site no 1 (the percussion drilled borehole HFM03) while moving the receiver downwards in the borehole. The result is plotted in Figure 4-3. The calculation shows a velocity of 128 m/micro seconds. The velocity measurement was performed with the 100 MHz antenna /2/.

The visualization of data in Appendix 1 and 2 is made with REFLEX, a Windows based processing software for filtering and analysis of radar data. The processing steps are shown in Table 4-4 and 4-5.

For the interpretation of the intersection angle between the borehole axis and the planes visible on the radargrams the RadinterSKB software has been applied. RadinterSKB is also used to interpret the orientation of structures identified in the data obtained with the directional antenna. The interpreted intersection points and intersection angles of the detected structures are presented in the Table 5-1 and also visible on the radargrams in Appendix 1 and 2.

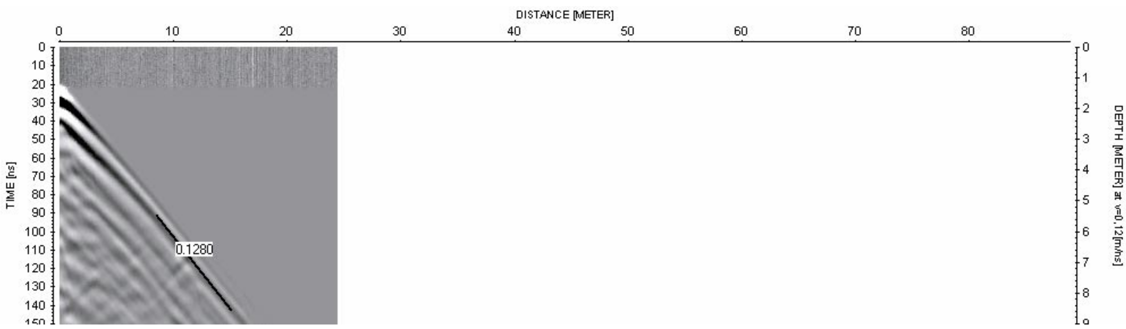


Figure 4-3. *Results from velocity measurements in HFM03 /2/.*

Table 4-4. Processing steps for borehole radar data from KFM02A 100 to 600 m.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM02A**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional / Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Interpret:	**JG**	**Antenna**			
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time	Move start time
		FIR	Energy decay	Energy decay	Bandpass
		Time gain	Dewow	Dewow	Gain

Table 4-5. Processing steps for borehole radar data from KFM02A 600 to 1000 m.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM02A**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional / Dipole**	**Manufacturer:**	**wMALÅ GeoScience**		
Interpret:	**JG**	**Antenna**			
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
	Processing:	DC removal	DC removal	DC removal	DC removal
		Move start time	Move start time	Move start time	Move start time
		FIR	Energy decay	Energy decay	Gain
		Time gain	Dewow	Dewow	

BIPS

The visualization of data (see Appendix 3) is made with BDPP, a Windows based processing software for filtering, presentation and analyzing of BIPS data. No fracture mapping of the BIPS image was performed.

5 Results and data delivery

The results from the radar and BIPS measurements were delivered to SKB as raw data (*.bip-files) on CD-ROMs together with printable BIPS pictures in *.pdf format before the field crew left the investigation site. The information of the measurements is registered in SICADA, and the CD-ROMs stored by SKB.

RAMAC radar data have been delivered as raw data (fileformat *.rd3 or *.rd5) 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 inserted into the SKB database SICADA.

The SICADA reference to the BIPS and RAMAC logging activity in KFM02A is Field note Forsmark no 88, 131 and 240.

5.1 RAMAC logging

The functionality of the directional antenna was tested before the measurements were carried out. This was done by measuring in the air. While measuring, the position of the receiver antenna is turned and by this way the direction to the transmitter antenna is determined. The difference in direction measured by compass and the result achieved from the directional antenna was about 10 degrees. This is considered to be satisfying, taking into account the somewhat disturbed environment at the site.

The results of the interpretation of the radar measurements are presented in Table 5-1 and 5-2. Radar data for the dipole antennas are also visualized in Appendix 1 and 2. It should be remembered that the images in Appendix 1 and 2 are only composite pictures of all events, 360 degrees around the borehole, and do not reflect the true orientation of the structures. Results from measurements with the directional antenna are only shown in tabulated form, Table 5-2, with the identified planes and their orientation.

Only the major, clearly visible structures are interpreted in RadinterSKB. A number of minor structures were also encountered as indicated in Appendix 1 and 2.

The data quality, as seen in Appendix 1 and 2, is relatively satisfying. However, the measurements in part of the borehole suffer from deteriorated quality due to increased electrical conductivity in the rock or borehole fluid. A conductive environment entails attenuation of the radar waves, resulting in decreased penetration.

As also seen in Appendix 1 and 2, the resolution and penetration of the radar waves depend of the antenna frequency used. A high frequency will result in a high resolution but a lower penetration rate compared to a lower frequency.

The identified structures intersecting the borehole are quite evenly distributed, see Table 5-1.

Table 5-1. Identified structures as a function of depth in KFM02A.

Depth (m)	no of structures	Depth (m)	no of structures
100–150	9	550–600	9
150–200	8	600–650	5
200–250	8	650–700	2
250–300	4	700–750	4
300–350	4	750–800	2
350–400		800–850	4
400–450	6	850–900	5
450–500	5	900–950	8
500–550	4	950–	6

Table 5-2 summarises the interpretation of radar data from KFM02A. Many structures can be identified in the data from more than one antenna frequency. When an object (in this case a plane) is detected by the directional antenna the direction to the plane, as defined in Figure 5-1, is interpreted. Based in this information, the true orientation (strike and dip) of the plane can be interpreted, see Table 5-2. In some cases, however, there is an uncertainty (± 180 degrees) in the interpretation of the direction to the plane. Object direction 1, strike 1 and dip 1 in Table 5-2 then represent the most probable interpretation.

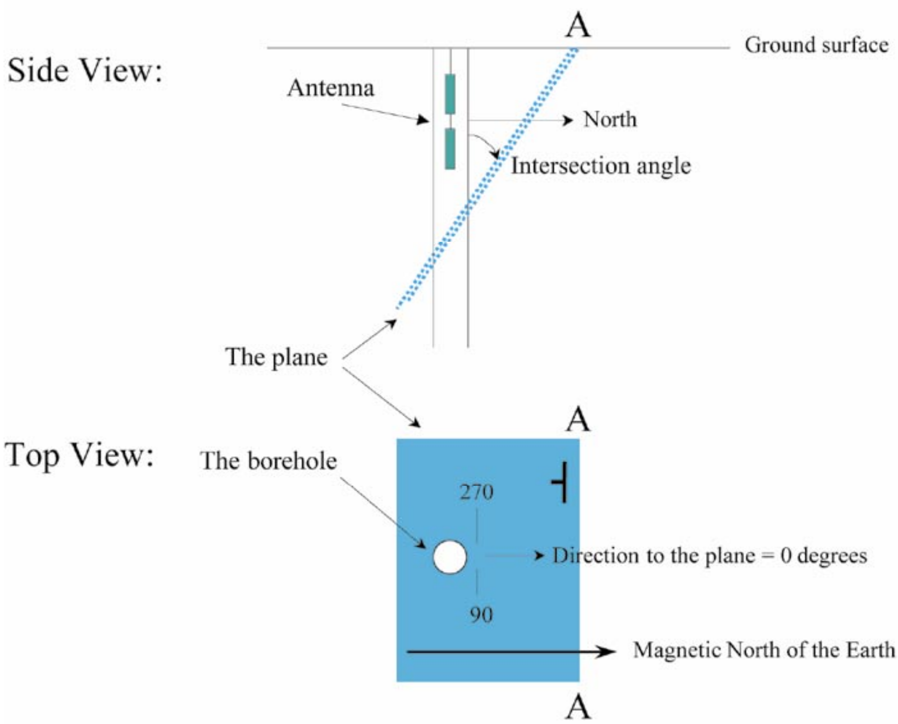


Figure 5-1. Definition of the direction to object as presented in Table 5-2.

Table 5-2. Model information from dipole antennas 20, 100 and 250 MHz and the directional, 60 MHz antenna. See Figure 5-1 for definitions of properties.

RADINTER MODEL INFORMATION
(20, 100 and 250 MHz Dipole Antennas and Directional Antenna)

Site: Forsmark
Borehole name: KFM02A
Nominal velocity (m/μs): 128.00

Object type	Name	Intersection depth (m)	Intersection angle (deg)	Object direction 1 (deg)	Object direction 2 (deg)	Interpreted true orientation Strike 1 (deg)	Dip 1 (deg)	Strike 2 (deg)	Dip 2 (deg)
PLANE	1	106.9	90						
PLANE	2	112.5	49	252		90	41		
PLANE	4	113.7	85	165		90	5		
PLANE	3	121.6	38	177	357	90	52	90	46
PLANE	5	125.6	90						
PLANE	6	133.7	90						
PLANE	7	139.3	80	309		90	10		
PLANE	8a	147.2	57	123		90	33		
PLANE	8	147.5	83						
PLANE	8b	164.4	72	108	288	75	17	226	20
PLANE	10	169.3	90						
PLANE	10a	173.9	76	42	222	137	18	289	11
PLANE	10b	176.3	51	27		142	44		
PLANE	9	185.6	15						
PLANE	11	186.9	90						
PLANE	12	197.3	90						
PLANE	11a	199.4	46	21		144	49		
PLANE	13	207.2	47	27	207	142	48	317	40
PLANE	39	209.9	18						
PLANE	15	214.1	90						
PLANE	14	215.3	44						
PLANE	15b	219.8	51	288	108	229	41	61	38
PLANE	15a	219.9	53	138		32	33		
PLANE	17	233.1	61						
PLANE	17a	240.3	50	24		144	45		
PLANE	18	251.1	90						
PLANE	18a	256.6	48	351		173	47		
PLANE	18b	262.5	67	354	174	169	28	351	18
PLANE	16	280.2	16	282	102	90	74	62	73
PLANE	19	300.9	70						
PLANE	20	308.9	54						
PLANE	21	336.6	81						
PLANE	22	343.2	72						
PLANE	24	419.6	75	237	57	265	12	119	17
PLANE	23	419.9	18	81	261	81	73	257	71
PLANE	25	425.9	16	210		308	71		
PLANE	25a	426.7	63	192		323	22		
PLANE	26	437.2	90	252		159	5		
PLANE	25b	443.9	77	351		167	18		

Object type	Name	Intersection depth (m)	Intersection angle (deg)	Object direction 1 (deg)	Object direction 2 (deg)	Interpreted true orientation Strike 1 (deg)	Dip 1 (deg)	Strike 2 (deg)	Dip 2 (deg)
PLANE	26a	456.0	49	12		147	46		
PLANE	27	468.4	42						
PLANE	28	474.9	53	228		279	34		
PLANE	29	484.6	90	57	237	152	5	175	4
PLANE	30	492.0	90	261		203	6		
PLANE	38	503.1	49						
PLANE	31	512.1	90	18		136	32		
PLANE	32	532.9	57	54		105	36		
PLANE	33	549.8	63	168		347	22		
PLANE	40	553.6	15						
PLANE	34a	560.8	66	321	141	185	29	22	20
PLANE	34	562.1	90						
PLANE	35	564.0	70						
PLANE	BB	566.2	28	345	165	167	68	349	56
PLANE	36	576.9	63						
PLANE	A	580.8	13						
PLANE	B	580.9	38						
PLANE	36a	596.9	36	18	198	135	60	312	48
PLANE	CC	614.3	43	354		157	53		
PLANE	37	621.5	83						
PLANE	C	621.6	42	234		271	45		
PLANE	D	624.7	36						
PLANE	E	648.8	41						
PLANE	FF	664.7	36						
PLANE	F	676.5	38	183		326	39		
PLANE	G	722.6	40	264	84	240	50	72	51
PLANE	HH	726.8	52						
PLANE	H	737.4	57						
PLANE	I	741.5	57	258		240	32		
PLANE	GG	751.6	8						
PLANE	J	799.4	50	255		245	39		
PLANE	K	806.4	50	270		235	41		
PLANE	KK	816.4	51	93		63	39		
PLANE	LL	828.9	51	231	51	268	35	102	44
PLANE	L	843.0	35	48		102	61		
PLANE	M	853.4	53						
PLANE	N	856.4	49	249	69	250	39	86	45
PLANE	O	866.7	52	246	46	252	35	91	40
PLANE	P	872.8	51						
PLANE	PP	895.7	61						
PLANE	R	903.7	55						
PLANE	Q	914.7	57	264		231	33		
PLANE	QQ	917.4	34						
PLANE	QQQ	917.3	73	87		82	19		
PLANE	RR	924.4	69						
PLANE	RRR	930.5	60						

Object type	Name	Intersection depth (m)	Intersection angle (deg)	Object direction 1 (deg)	Object direction 2 (deg)	Interpreted true orientation Strike 1 (deg)	Dip 1 (deg)	Strike 2 (deg)	Dip 2 (deg)
PLANE	S	939.2	74	228	48	252	12	116	22
PLANE	T	949.6	58						
PLANE	U	960.2	54						
PLANE	V	967.8	64						
PLANE	W	971.9	54						
PLANE	X	980.2	57						
PLANE	Y	992.6	62						
PLANE	Z	1025.5	46						

Names in table according to Appendix 1 and 2.

In Appendix 1 and 2, 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 material. A decrease in this amplitude may indicate fracture zones, clay or rock volumes with increased water content. The decrease in amplitude is seen for the following sections in KFM02A:

Depth (m)	Depth (m)
110–125	565
165–185	575
Around 200	675
240–320	725
345	805
425	845
455	855
480	895
490	905
Around 500	915–925
515	935
535	960–980

At a depth of approximately 260 to 290 m the radar signal was completely attenuated (see Appendix 1 and Figure 5-2 and 5-3 below). This attenuation is due to a very porous granite formation. In an attempt to characterize this formation, two different measurement where carried out with the 20 MHz dipole antennas and varying distances between the transmitter and receiver antenna. The results from these measurements are shown in Figure 5-2 and 5-3 below.

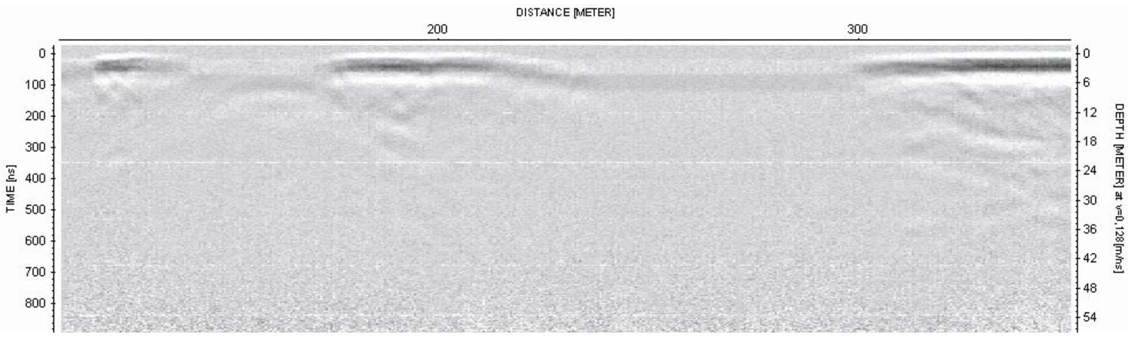


Figure 5-2. *Measurements along the conductive structure with 34,05 m between the transmitter and receiver antennas.*

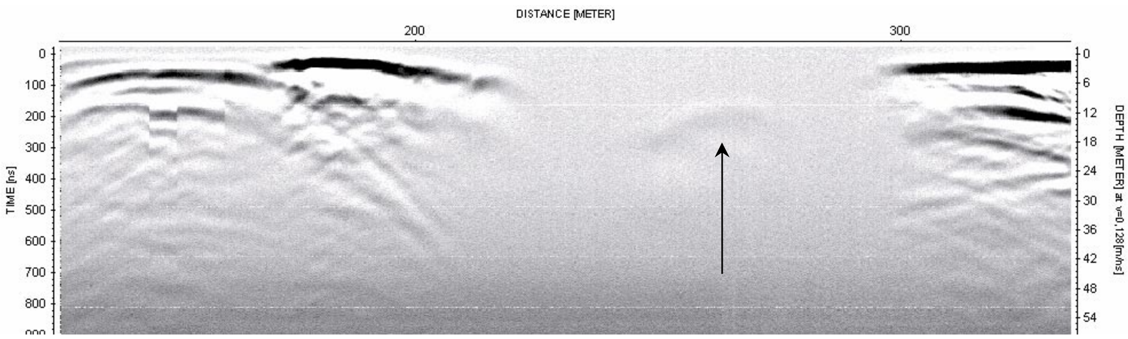


Figure 5-3. *Measurements along the conductive structure with 54,05 m between the transmitter and receiver antennas.*

As seen in Figure 5-3, where the distance between the transmitter and receiver antennas is 54 m, a minor reflection is identified in the mid part of the conductive formation. A possible explanation to this feature is that some energy (direct wave) has been transmitted from the transmitter to the receiver antenna (see Figure 5-4). This is possible when both the transmitter and receiver antenna are located outside the conductive formation and the formation is limited in its horizontal extension.

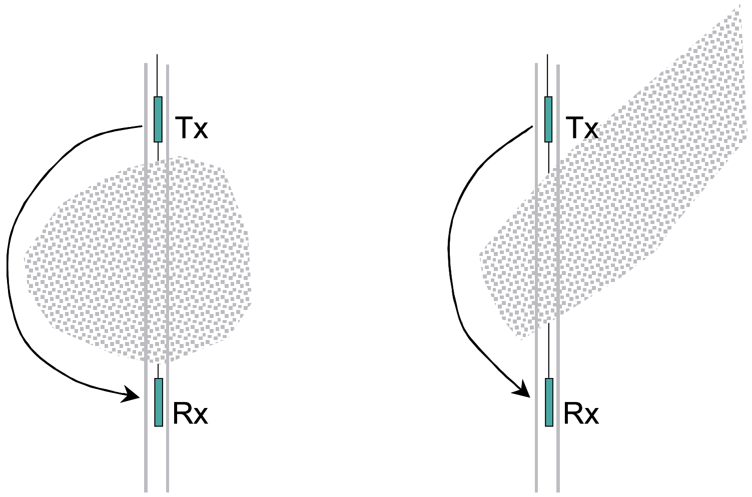


Figure 5-4. A possible explanation to the reflector seen in Figure 5-3 is that energy be transmitted from the transmitter antenna to the receiver antenna when these are both located outside the conductive body. This indicates that the body of porous granite is limited in at least one direction.

5.2 BIPS logging

In order to control the quality of the BIP system, calibration measurements were performed in a test pipe before logging the first borehole and after logging of the borehole. The resulting images displayed no difference regarding the colours and focus of the images. Results of the test loggings were included in the raw data delivery.

To get the best possible depth accuracy, the BIPS images are adjusted (red figures in Appendix 3 to 6) to the reference marks along the borehole.

Two runs with the BIPS were performed in the borehole. The first run (101–635 m) was carried out 2003-02-13 in connection with a break of the drilling operations. The results indicated that the water quality in some parts was not good enough for logging. The second logging in the complete borehole performed 2003-04-14/15 (101–999 m) showed a much better water quality. The experience so far is that the water quality is much better 1 or 2 weeks after drilling.

The BIPS images are presented in this report, both from the percussion drilled part (0–100 m, Appendix 3) and the cored drilled part (Appendix 4 to 6).

The images are impaired by some quality problems related to a discolouring of parts of the borehole wall induced during drilling, see Figure 5-5. In the parts of the borehole that are heavily defected, there are problems to map thin structures and single fractures.

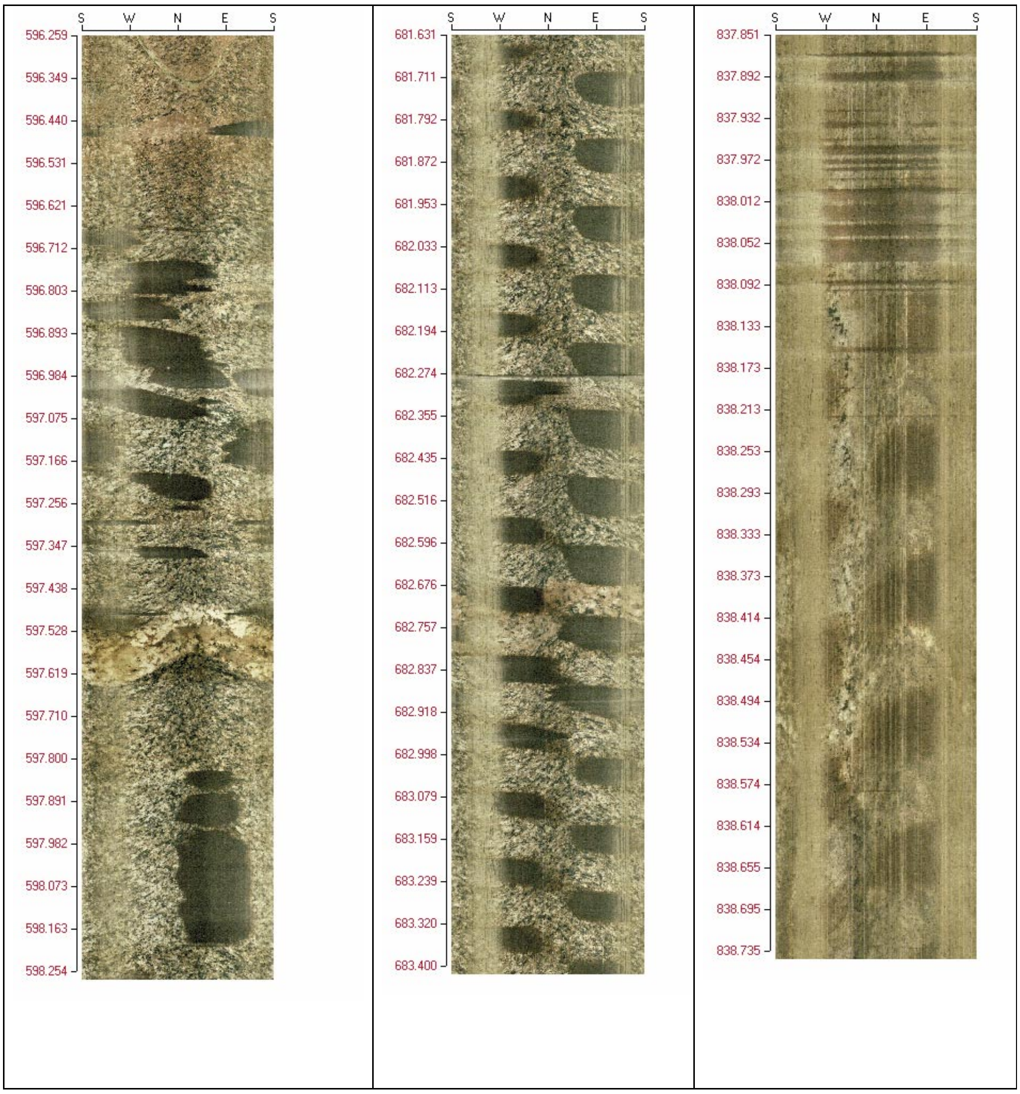


Figure 5-5. *Example of discolouring of the borehole wall.*

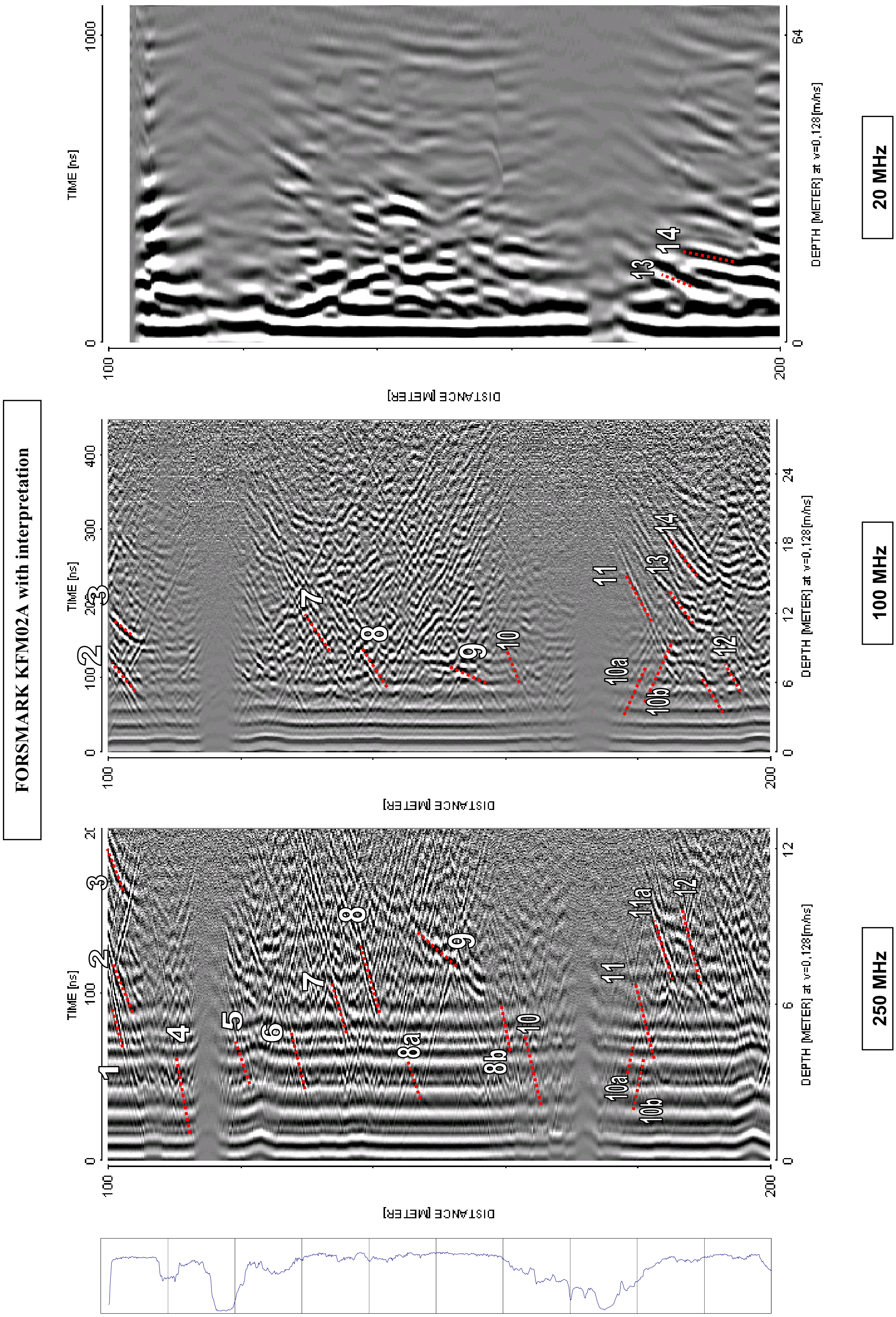
6 References

/1/ **Gustafsson C, Nilsson P, 2003.** Geophysical, radar and BIPS logging in boreholes HFM04, HFM05, and the percussion drilled part of KFM02A. SKB P-03-53. Svensk Kärnbränslehantering AB.

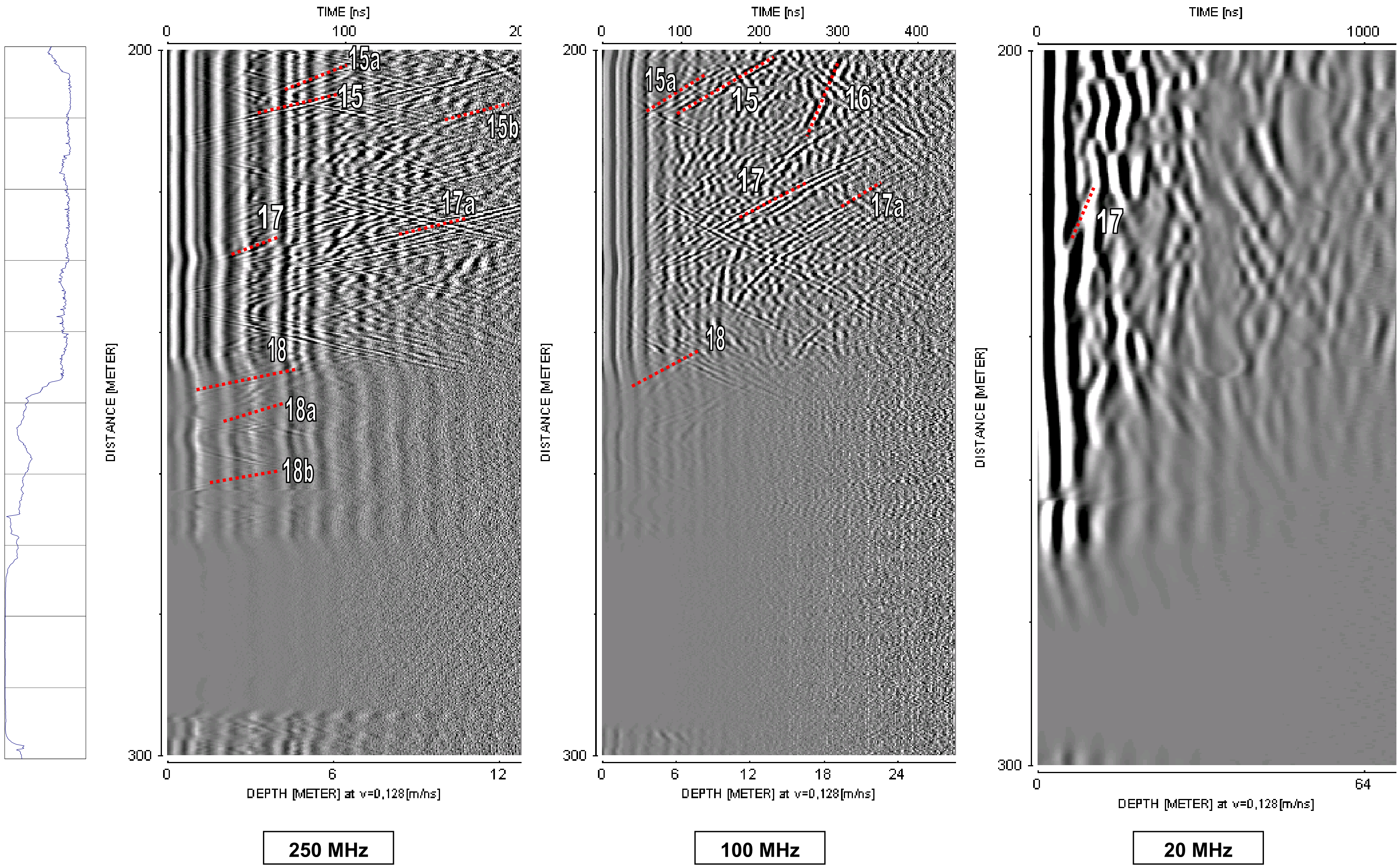
/2/ **Gustafsson C, Nilsson P, 2003.** Geophysical Radar and BIPS logging in borehole HFM01, HFM02, HFM03 and the percussion drilled part of KFM01A. SKB P-03-39. Svensk Kärnbränslehantering AB.

Radar logging of KFM02A, 100 to 600 m

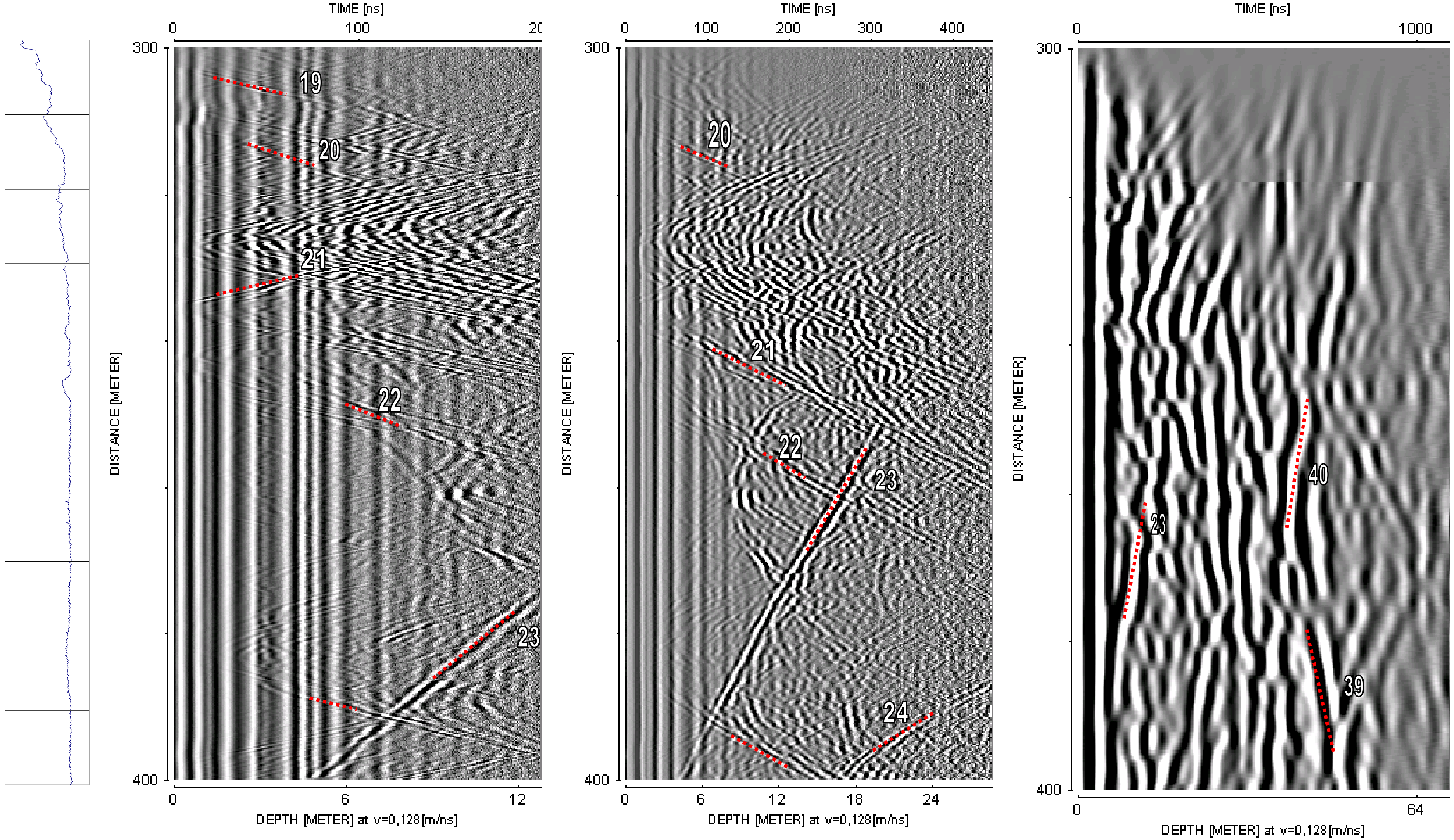
Dipole antennas 250, 100 and 20 MHz



FORSMARK KFM02 with interpretation



FORSMARK KFM02 with interpretation

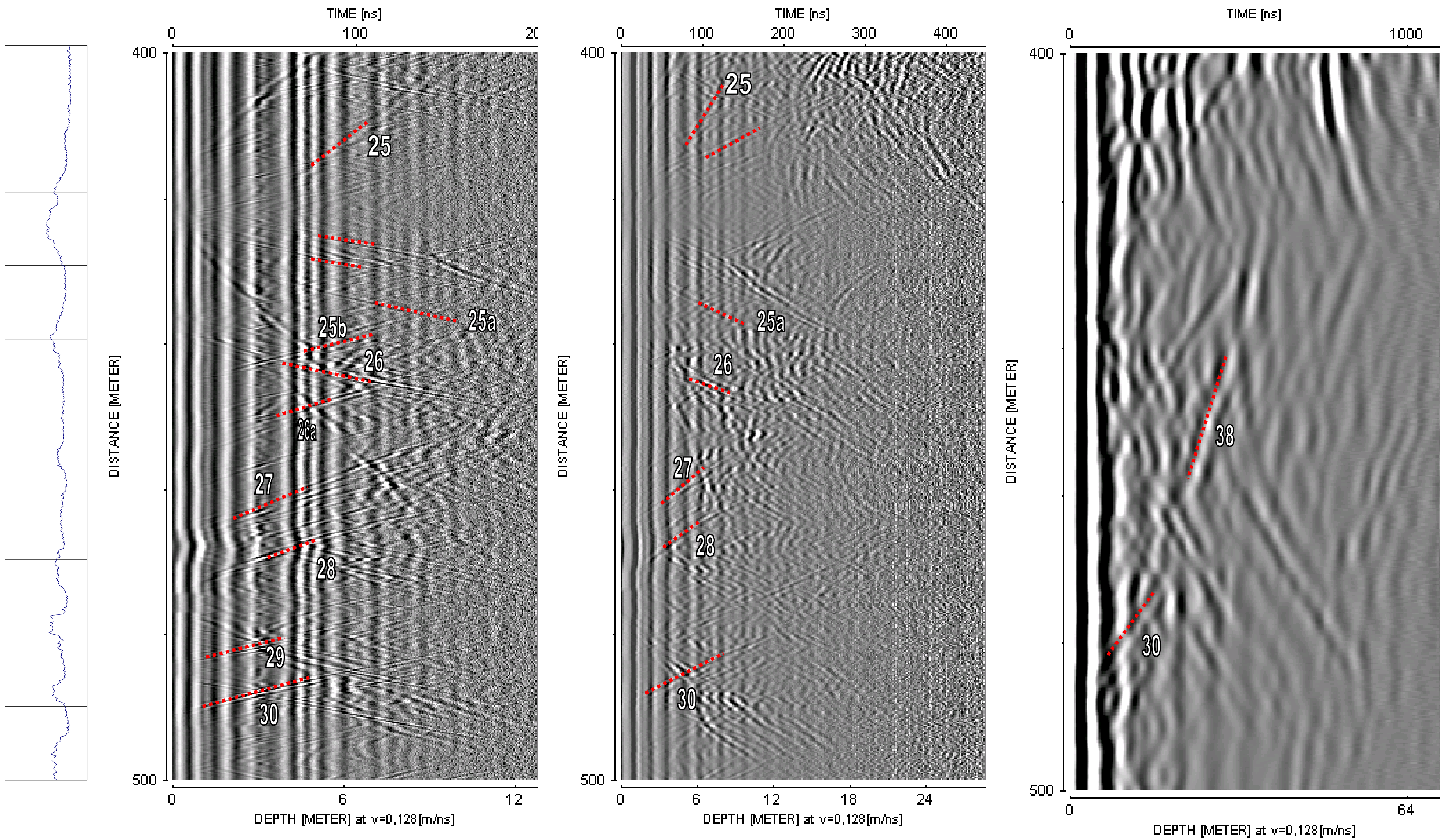


250 MHz

100 MHz

20 MHz

FORSMARK KFM02 with interpretation

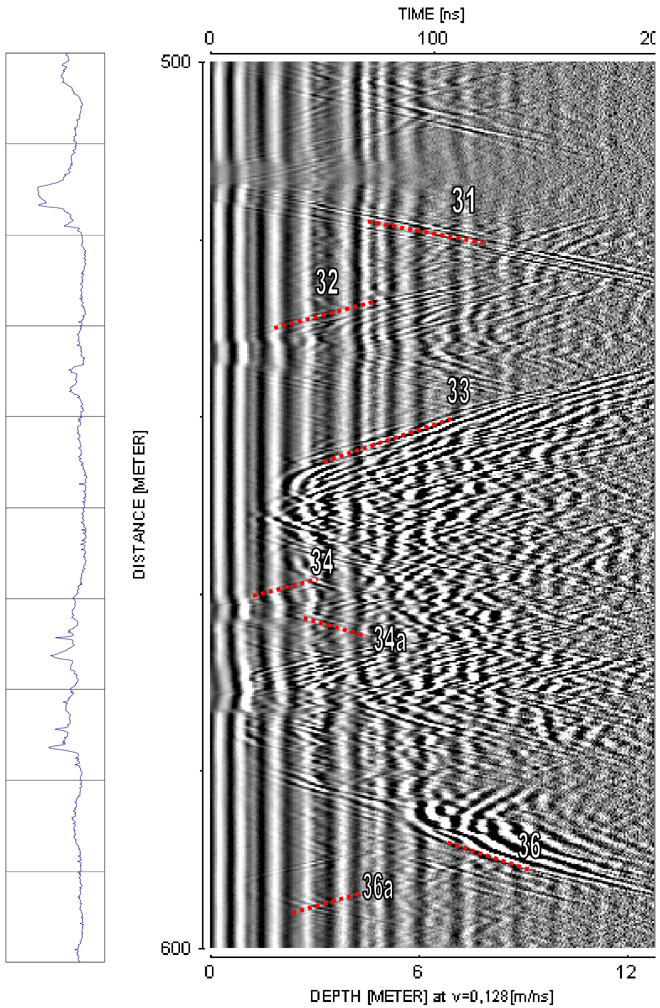


250 MHz

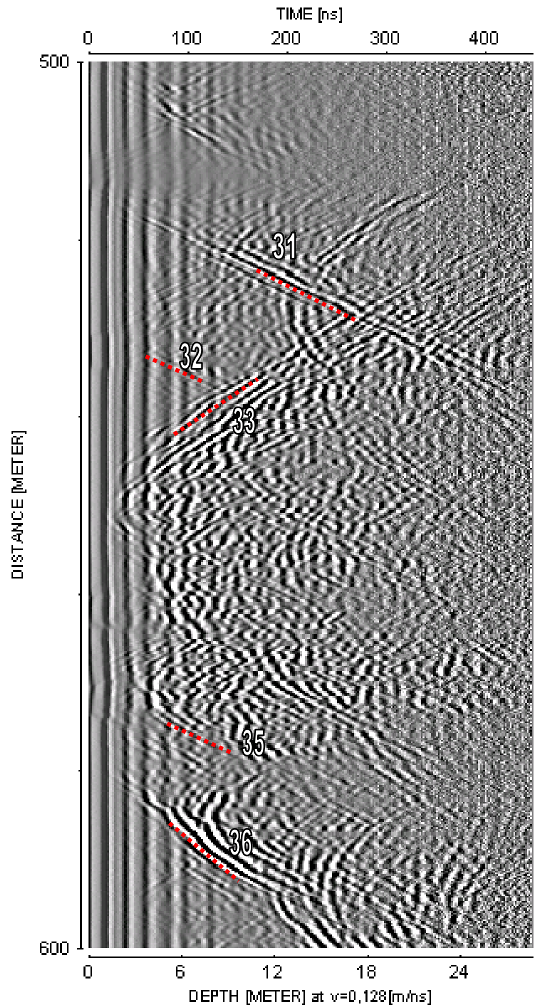
100 MHz

20 MHz

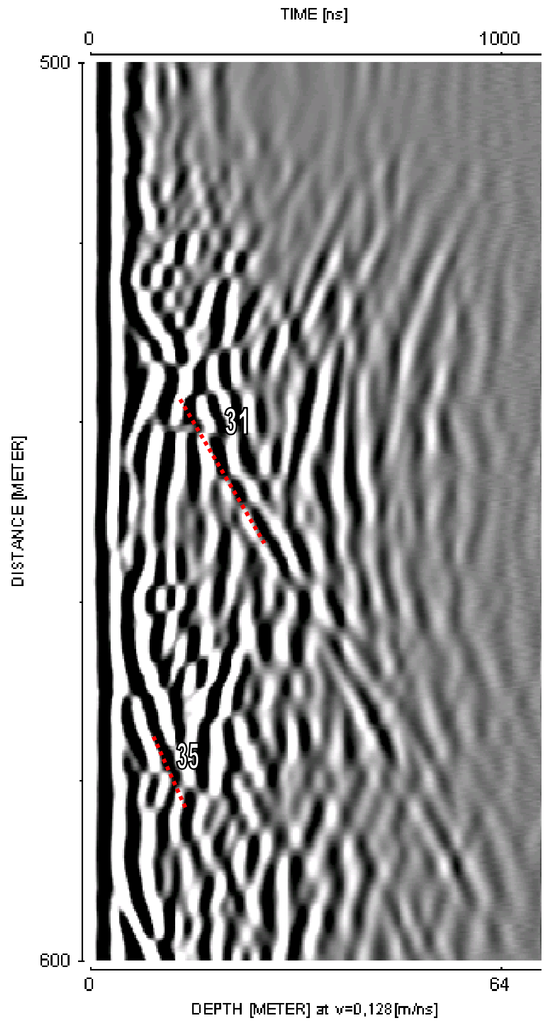
FORSMARK KFM02A with interpretation



250 MHz

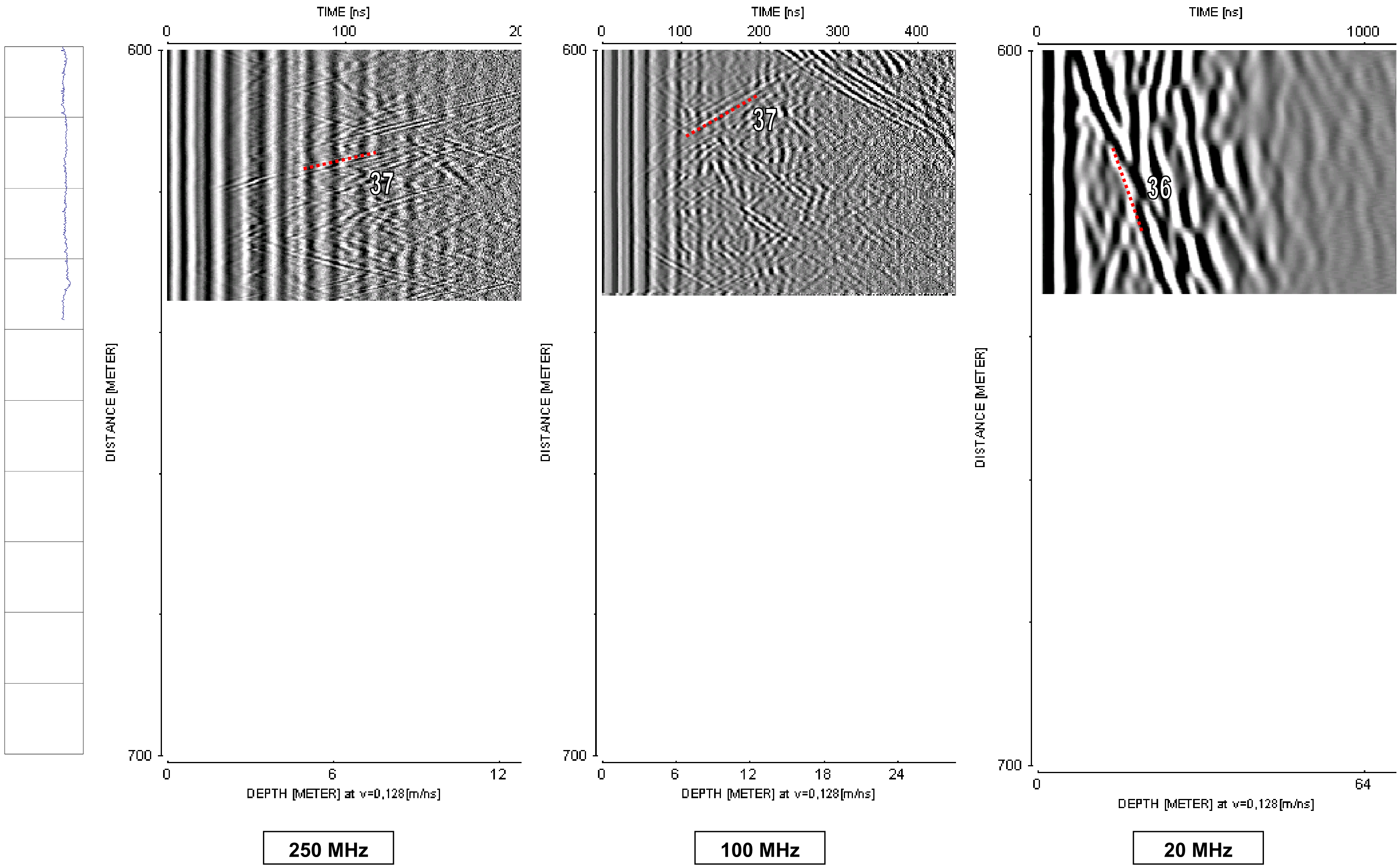


100 MHz



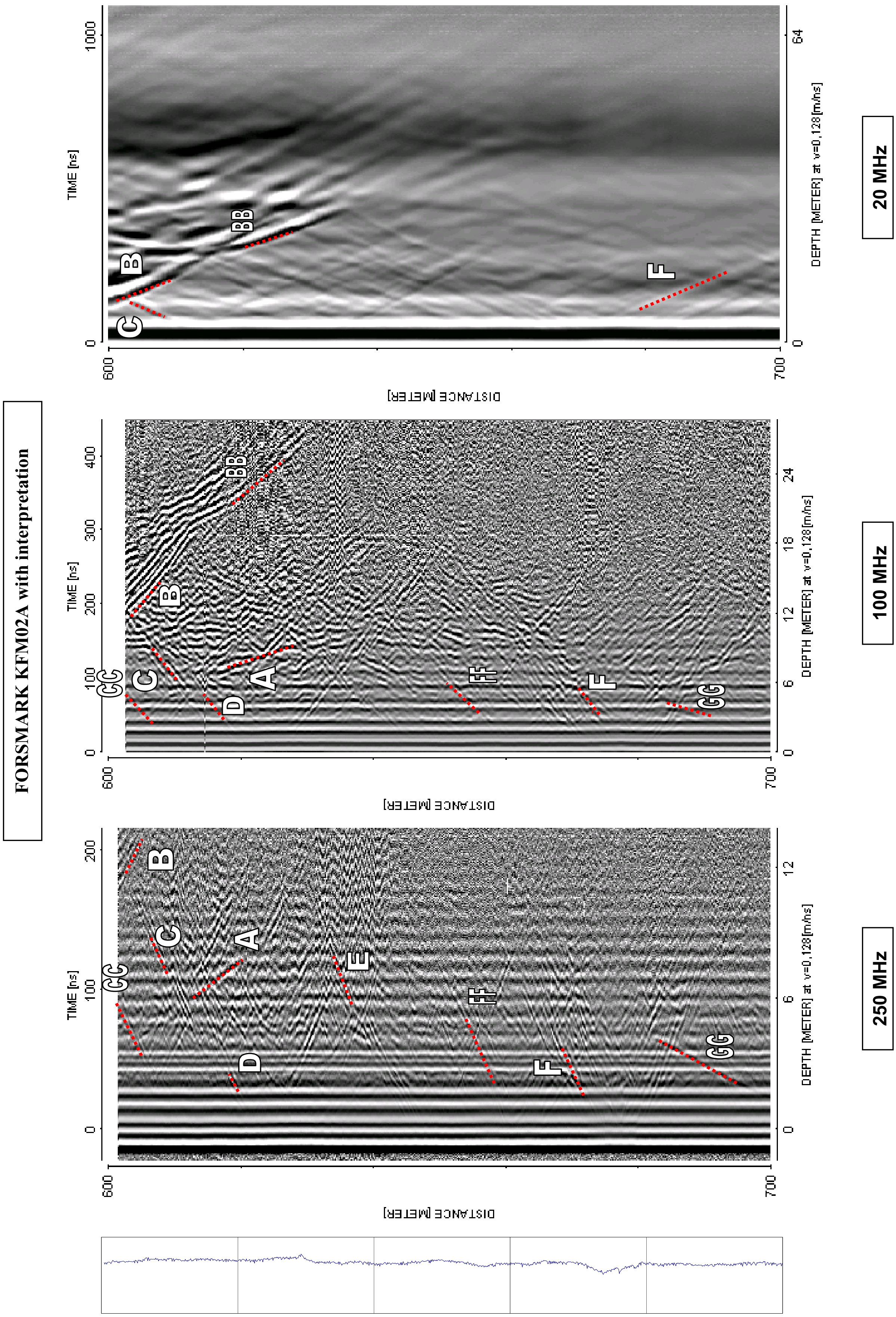
20 MHz

FORSMARK KFM02 with interpretation

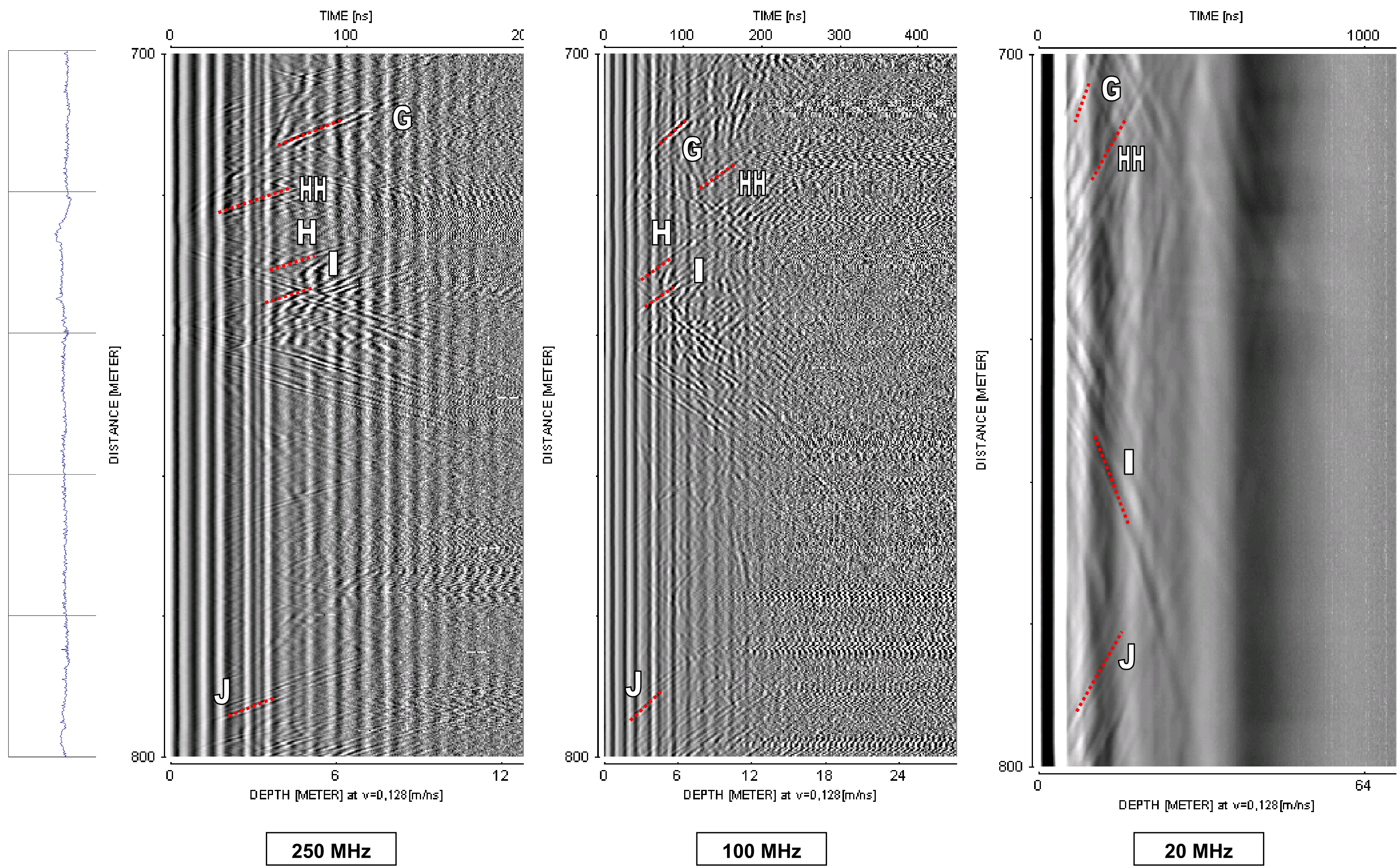


Radar logging of KFM02A, 600 to 1000 m

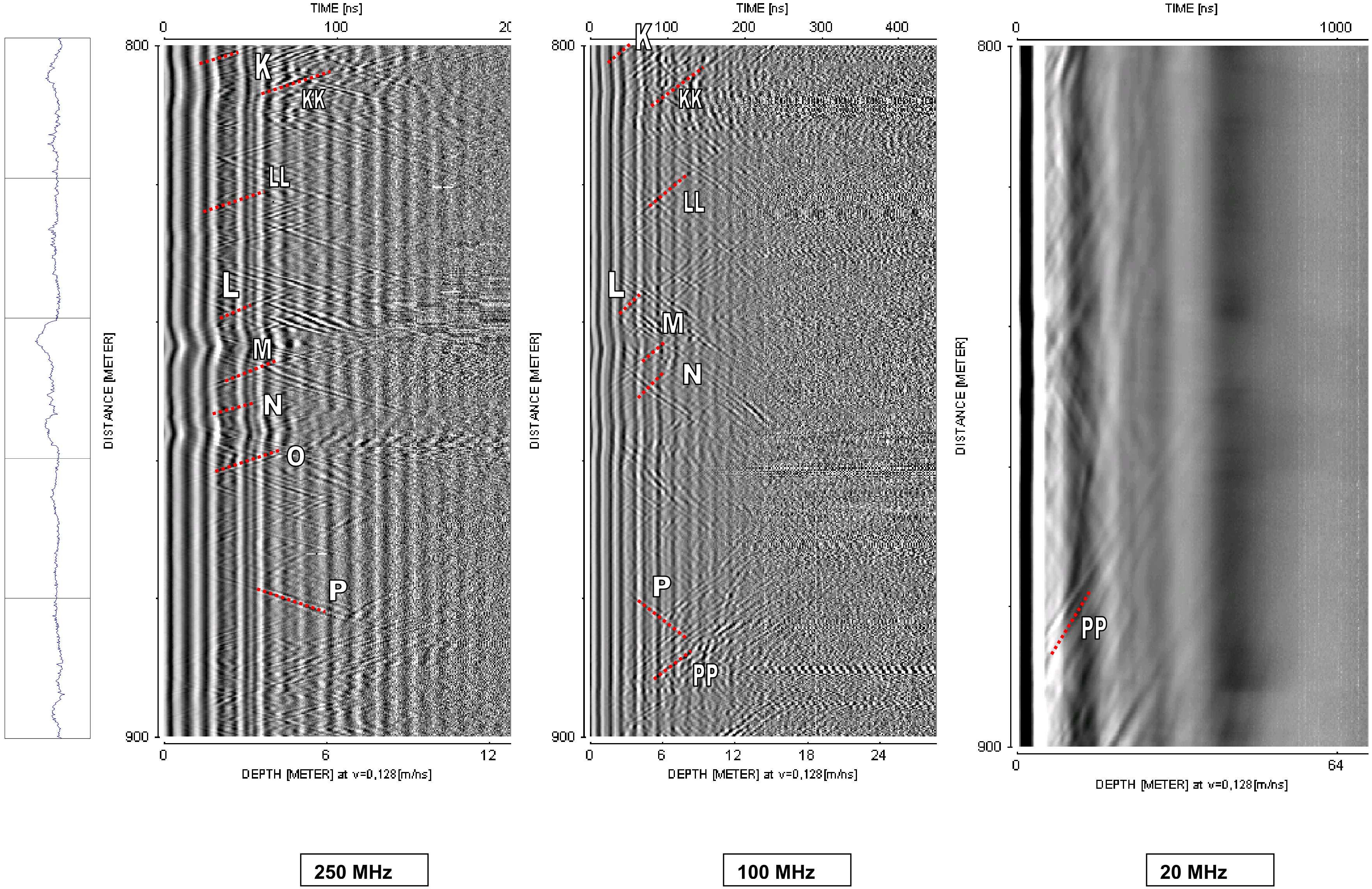
Dipole antennas 250, 100 and 20 MHz



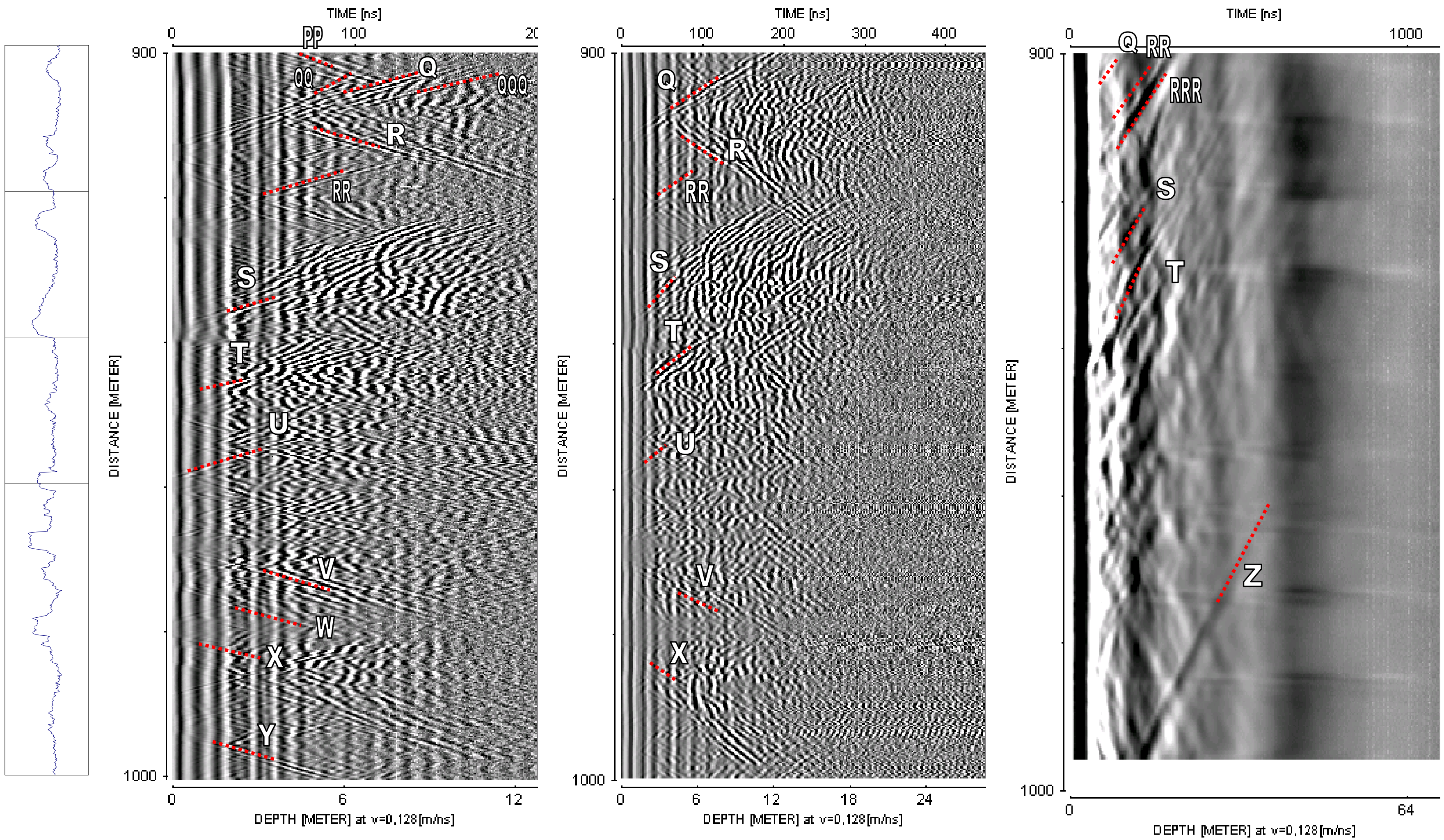
FORSMARK KFM02 with interpretation



FORSMARK KFM02 with interpretation



FORSMARK KFM02 with interpretation



250 MHz

100 MHz

20 MHz

Appendix 3

BIPS logging of KFM02A, 10 to 100 m

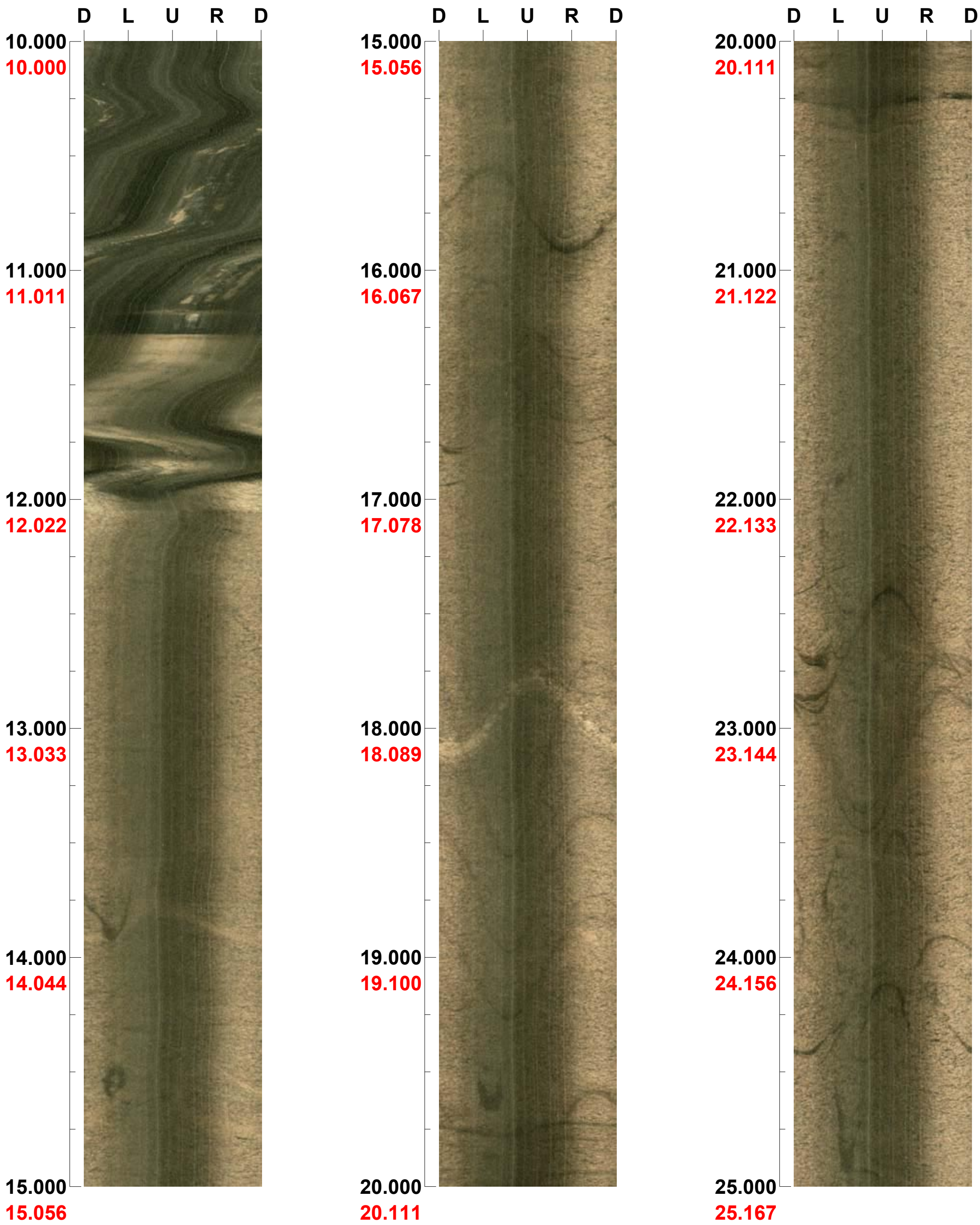
Project name: Forsmark

Image file	: g:\skb\bips\forsmark\kfm02a\bips_~rl\kfm02a_0.bip
BDT file	: g:\skb\bips\forsmark\kfm02a\bips_~rl\kfm02a_0.bdt
Locality	: FORSMARK
Bore hole number	: KFM02A
Date	: 02/12/02
Time	: 21:39:00
Depth range	: 10.000 - 99.728 m (red figures = corrected values)
Azimuth	: 276
Inclination	: -85
Diameter	: 164.0 mm
Magnetic declination	: 0.0
Span	: 4
Scan interval	: 0.25
Scan direction	: To bottom
Scale	: 1/25
Aspect ratio	: 150 %
Pages	: 6
Color	: +0 +0 +0

Project name: Forsmark
Bore hole No.: KFM02A

Azimuth: 276 Inclination: -85

Depth range: 10.000 - 25.000 m



(1 / 6) Scale: 1/25 Aspect ratio: 150 %

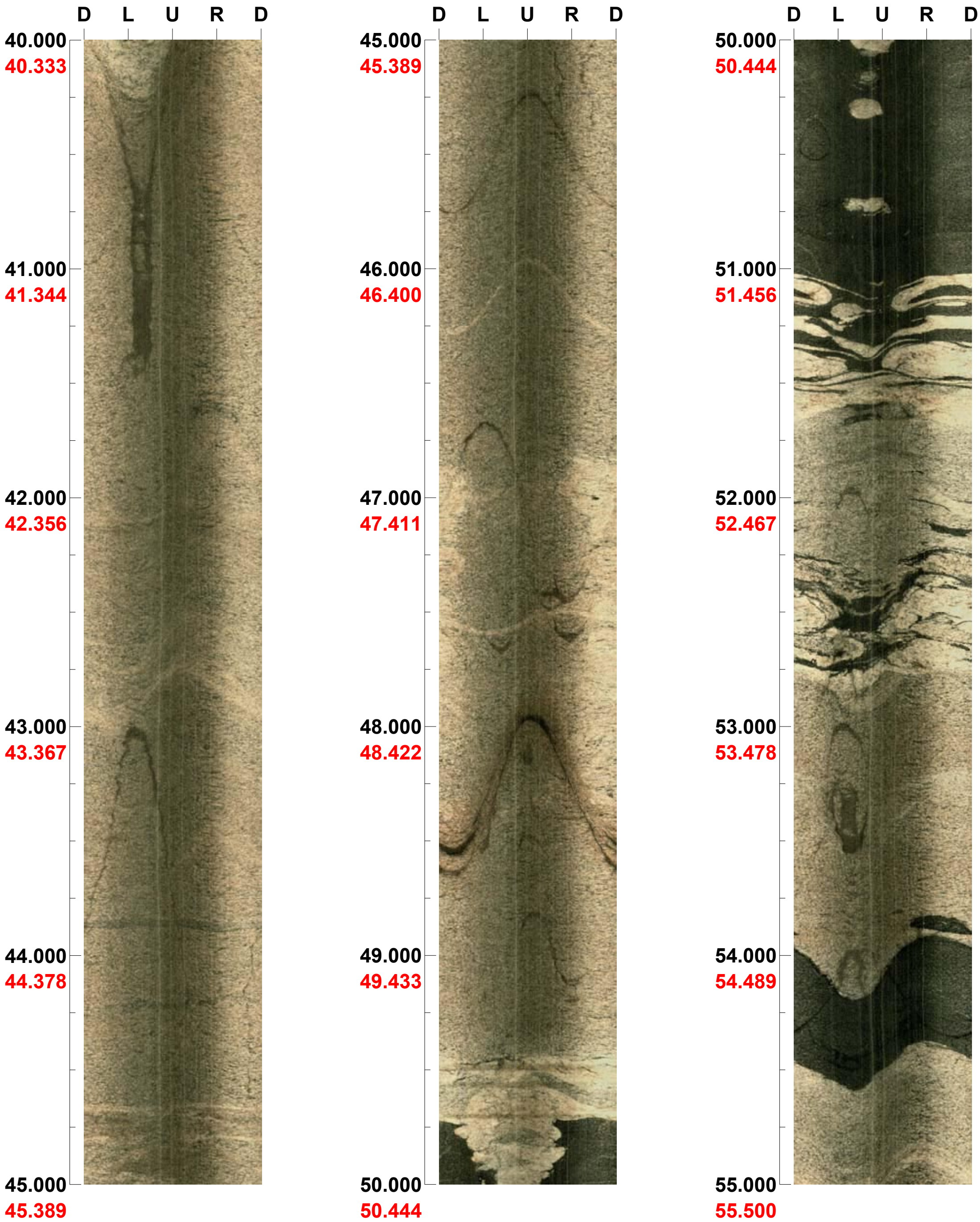
Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 276** **Inclination: -85**

Depth range: 25.000 - 40.000 m

(2 / 6) **Scale: 1/25** **Aspect ratio: 150 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 276** **Inclination: -85**

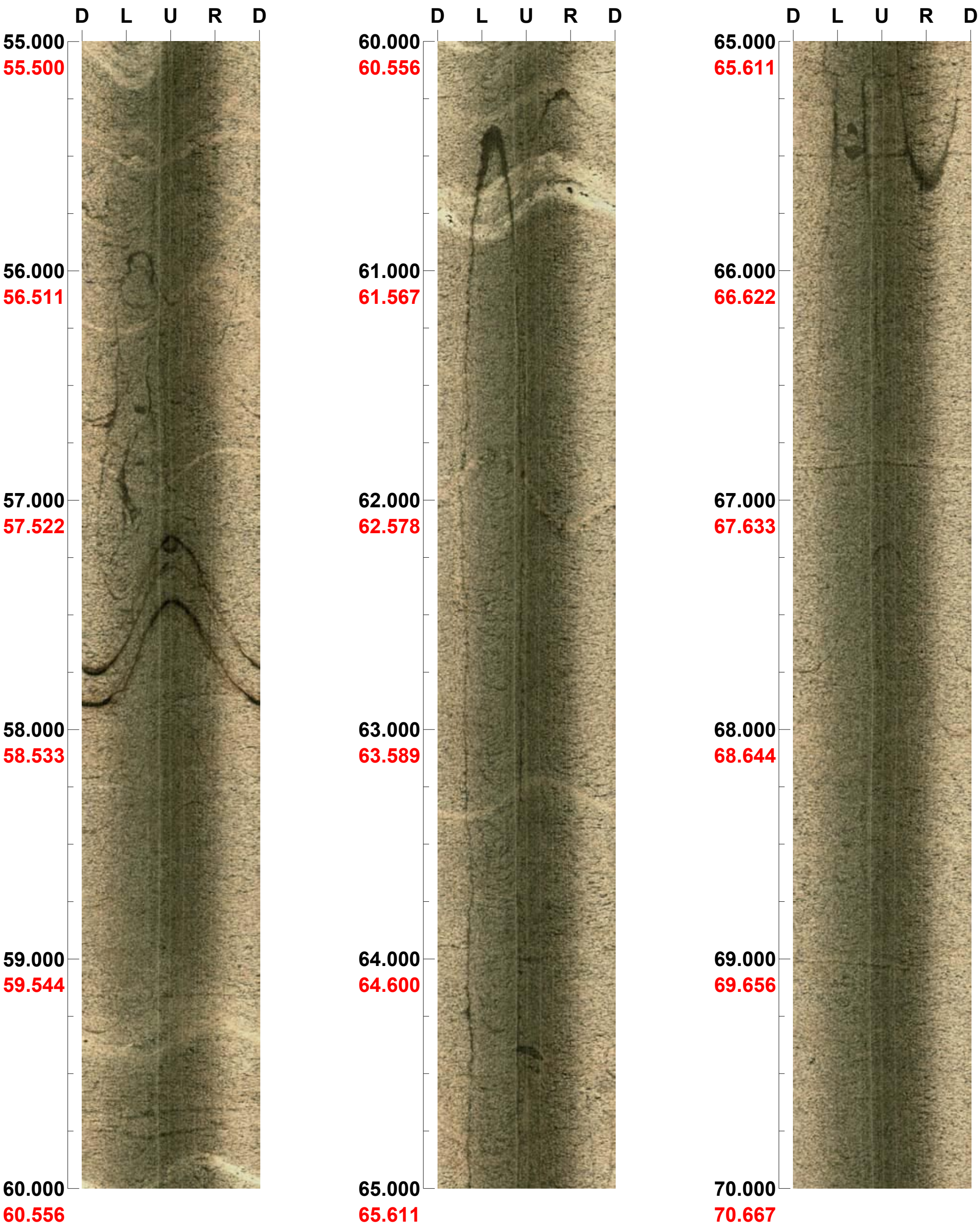
Depth range: 40.000 - 55.000 m



(3 / 6) **Scale: 1/25** **Aspect ratio: 150 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 274** **Inclination: -86**

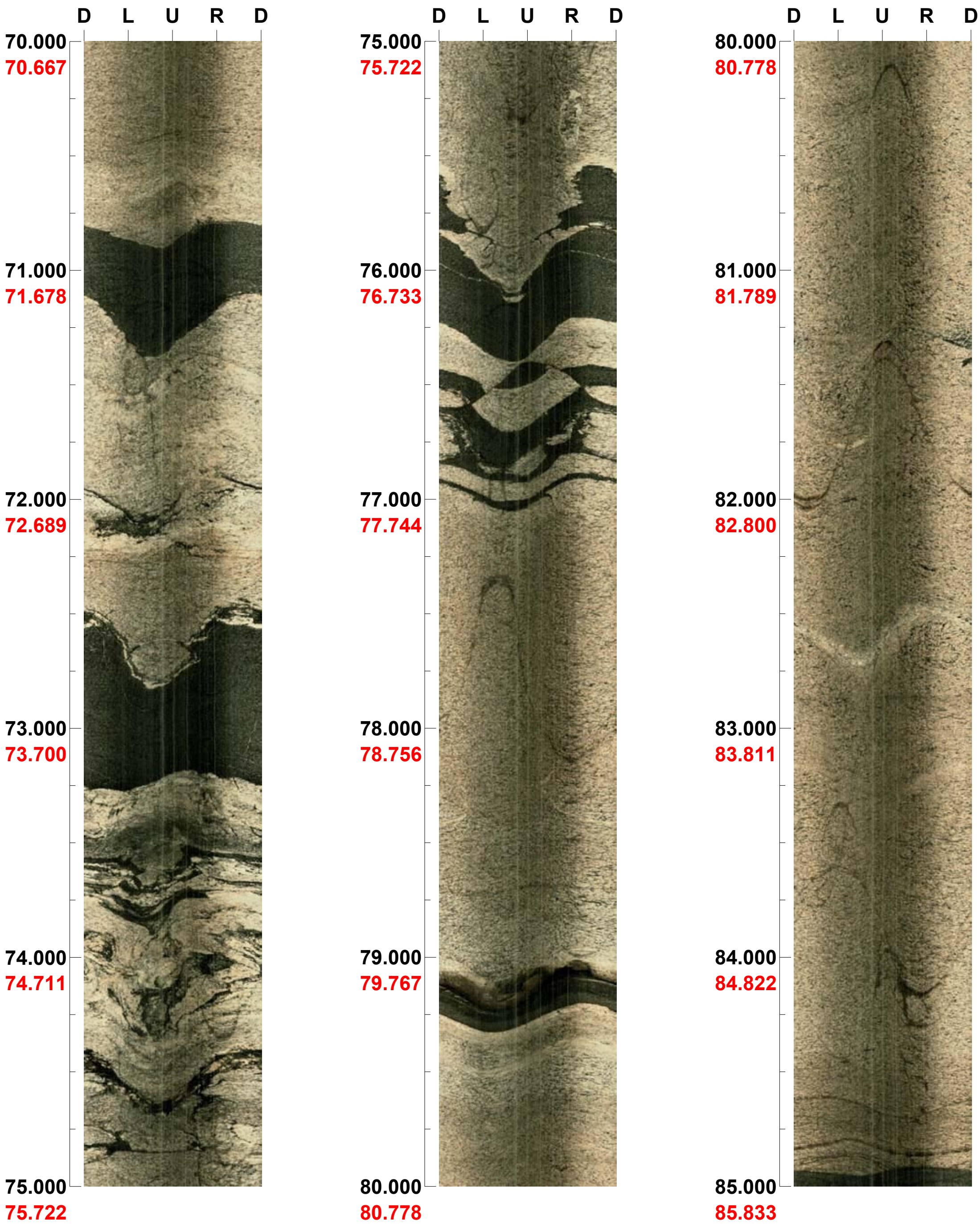
Depth range: 55.000 - 70.000 m



(4 / 6) **Scale: 1/25** **Aspect ratio: 150 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 273** **Inclination: -86**

Depth range: 70.000 - 85.000 m

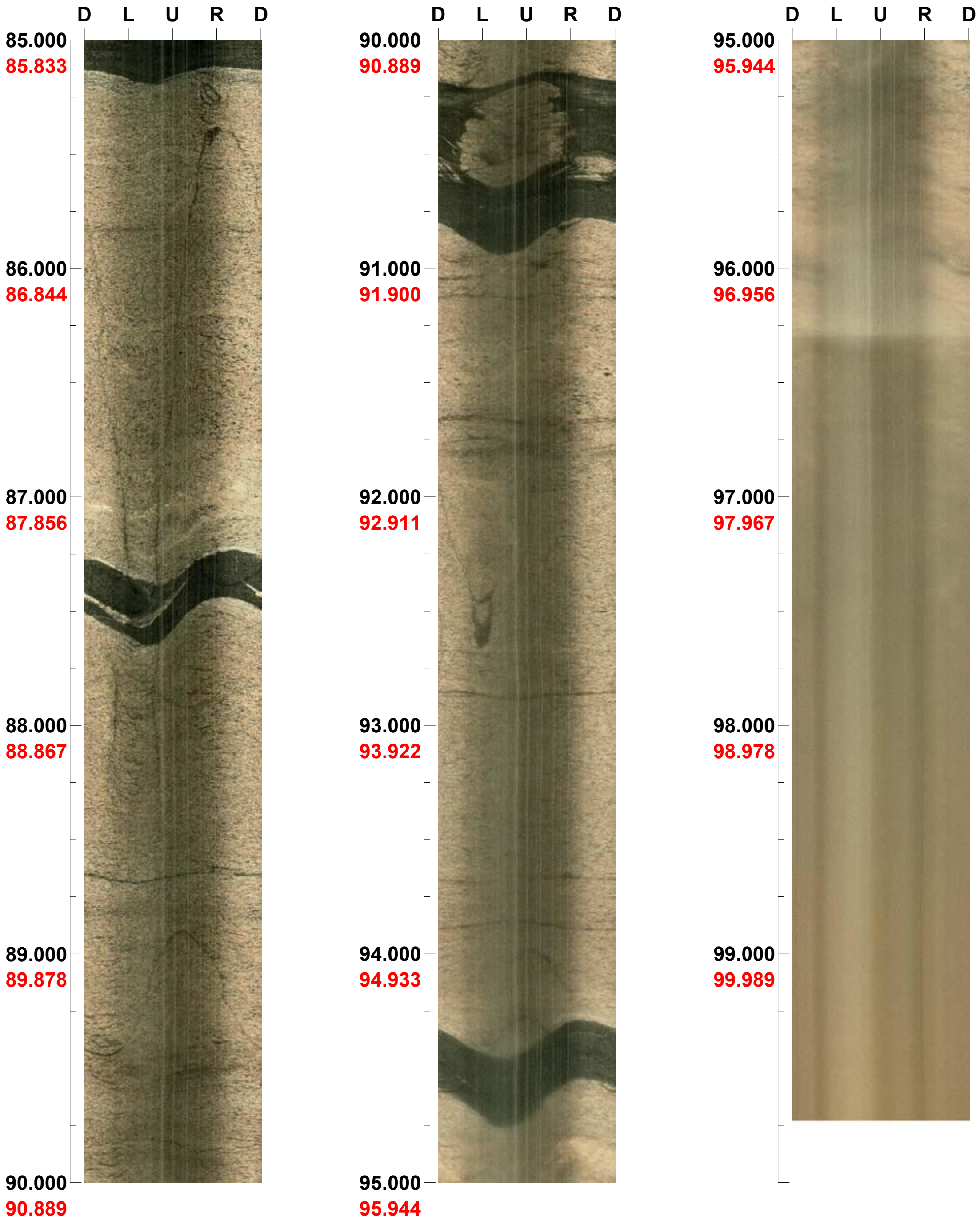


(5 / 6) **Scale: 1/25** **Aspect ratio: 150 %**

Project name: Forsmark

Bore hole No.: KFM02A **Azimuth: 274** **Inclination: -86**

Depth range: 85.000 - 99.728 m



(6 / 6) **Scale: 1/25** **Aspect ratio: 150 %**

Appendix 4

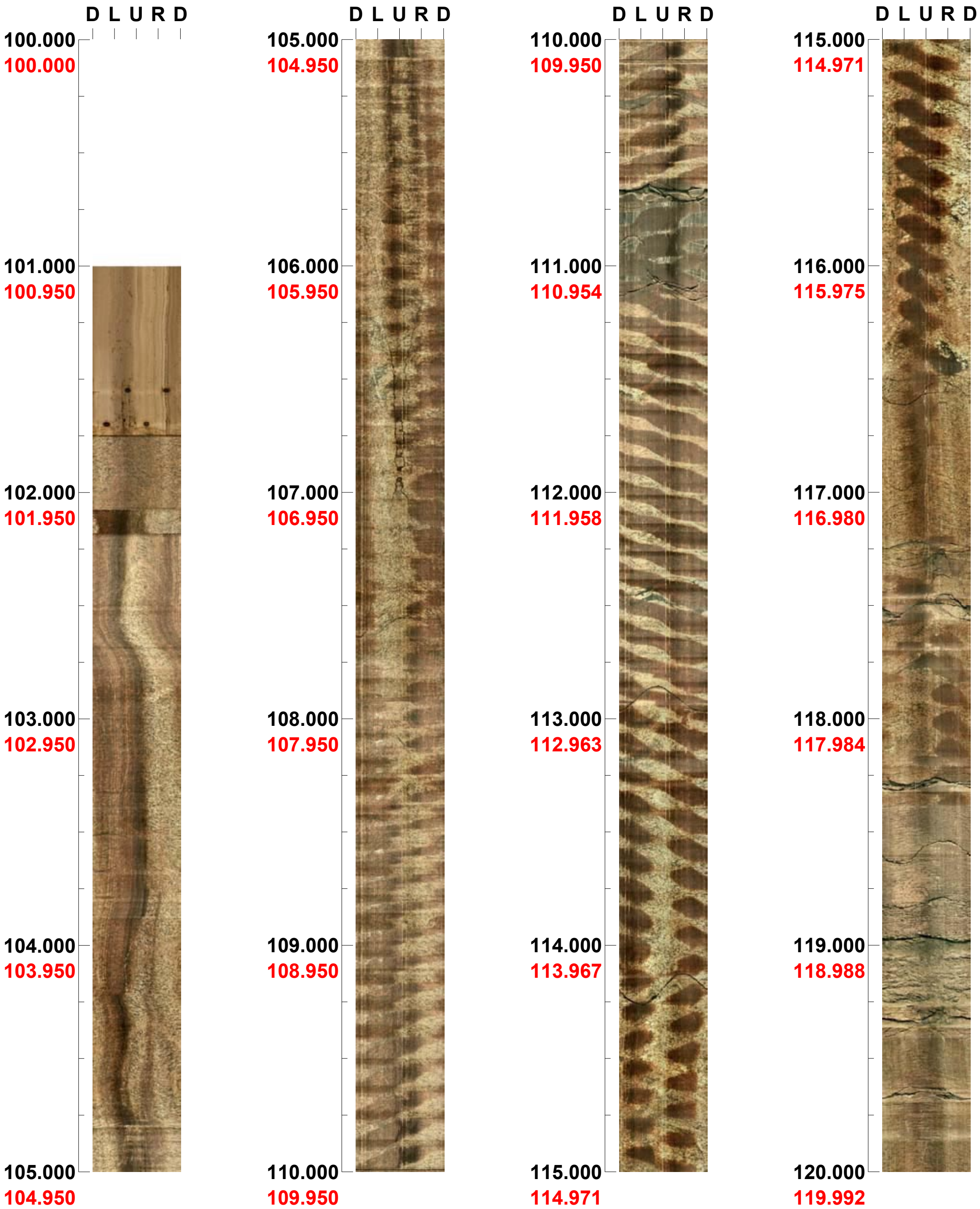
BIPS logging of KFM02A, 100 to 380 m

Project name: Forsmark

Image file	: g:\skb\bips\forsmark\kfm02a\bips_~c5\kfm02a_1.bip
BDT file	: g:\skb\bips\forsmark\kfm02a\bips_~c5\kfm02a_1.bdt
Locality	: FORSMARK
Bore hole number	: KFM02A
Date	: 03/04/14
Time	: 20:46:00
Depth range	: 101.000 - 380.000 m (red figures = corrected values)
Azimuth	: 270
Inclination	: -86
Diameter	: 77.0 mm
Magnetic declination	: 0.0
Span	: 4
Scan interval	: 0.25
Scan direction	: To bottom
Scale	: 1/25
Aspect ratio	: 160 %
Pages	: 14
Color	: +0 +0 +0

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 270** **Inclination: -86**

Depth range: 100.000 - 120.000 m



(1 / 14) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 277** **Inclination: -86**

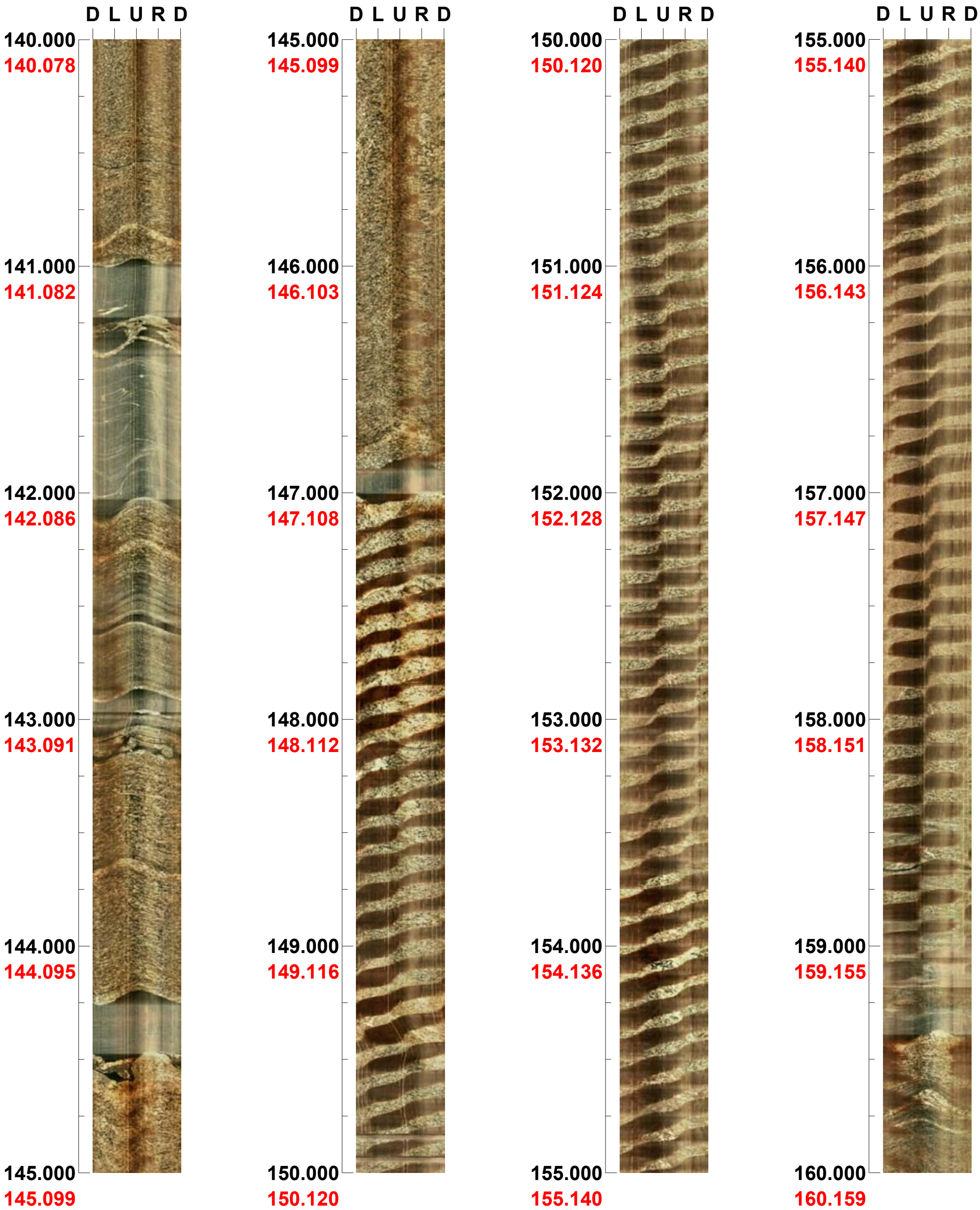
Depth range: 120.000 - 140.000 m

(2 / 14) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A

Azimuth: 280 Inclination: -85

Depth range: 140.000 - 160.000 m



(3 / 14) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark

Bore hole No.: KFM02A **Azimuth: 282** **Inclination: -85**

Depth range: 160.000 - 180.000 m

(4 / 14) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 284** **Inclination: -85**

Depth range: 180.000 - 200.000 m

(5 / 14) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark

Bore hole No.: KFM02A **Azimuth: 288** **Inclination: -85**

Depth range: 200.000 - 220.000 m

(6 / 14) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A   Azimuth: 289   Inclination: -85

Depth range: 220.000 - 240.000 m

(7 / 14)   Scale: 1/25   Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 291** **Inclination: -85**

Depth range: 240.000 - 260.000 m

(8 / 14) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 291** **Inclination: -84**

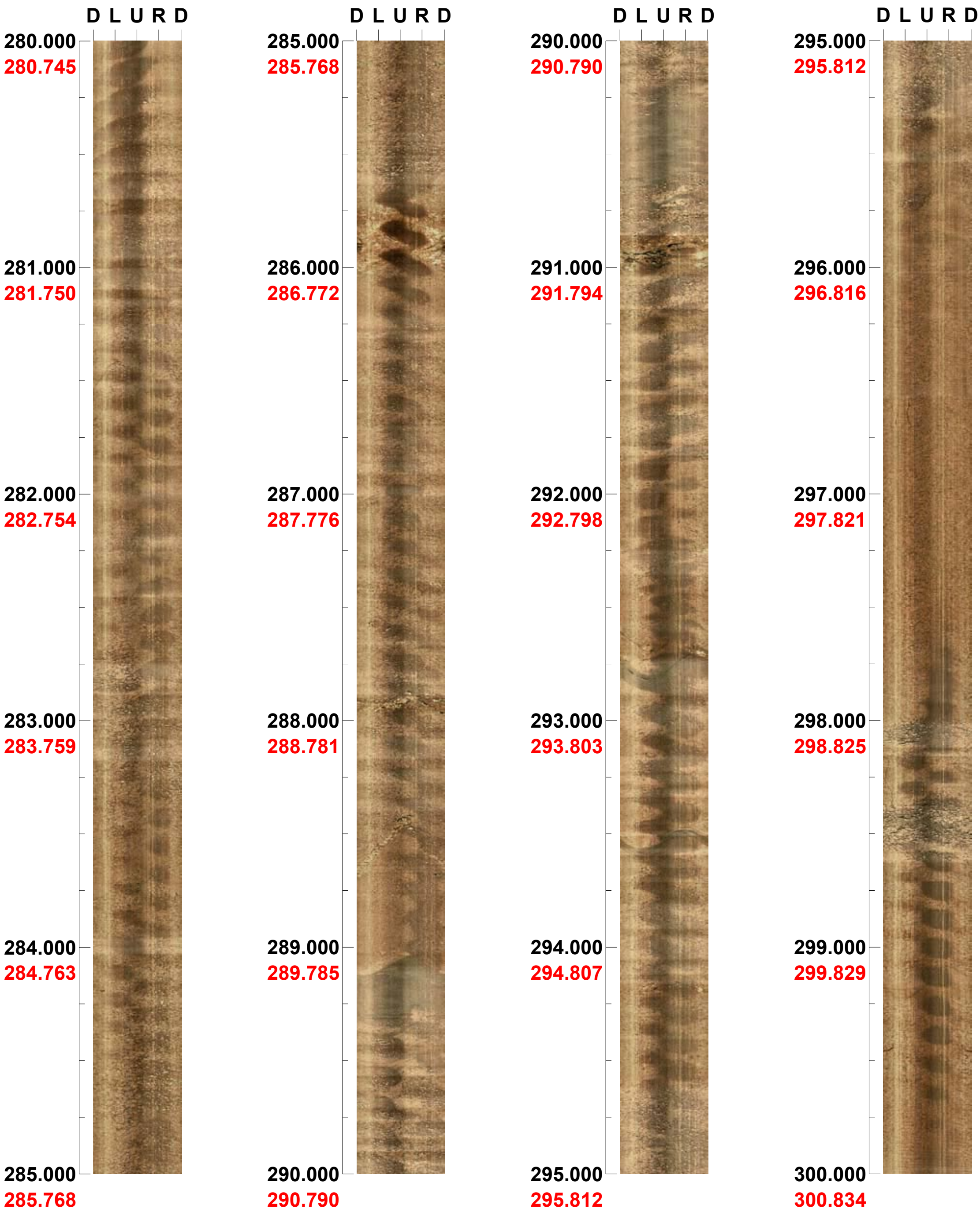
Depth range: 260.000 - 280.000 m

(9 / 14) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark

Bore hole No.: KFM02A **Azimuth: 292** **Inclination: -85**

Depth range: 280.000 - 300.000 m



(10 / 14) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 291** **Inclination: -85**

Depth range: 300.000 - 320.000 m

(11 / 14) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A Azimuth: 291 Inclination: -85

Depth range: 320.000 - 340.000 m

(12 / 14) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A Azimuth: 291 Inclination: -84

Depth range: 340.000 - 360.000 m

(13 / 14) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark

Bore hole No.: KFM02A **Azimuth: 292** **Inclination: -84**

Depth range: 360.000 - 380.000 m

(14 / 14) **Scale: 1/25** **Aspect ratio: 160 %**

Appendix 5

BIPS logging of KFM02A, 380 to 590 m

Project name: Forsmark

Image file	: g:\skb\bips\forsmark\kfm02a\bips_~c5\kfm02a_2.bip
BDT file	: g:\skb\bips\forsmark\kfm02a\bips_~c5\kfm02a_2.bdt
Locality	: FORSMARK
Bore hole number	: KFM02A
Date	: 03/04/15
Time	: 09:25:00
Depth range	: 380.000 - 590.012 m (red figures = corrected values)
Azimuth	: 293
Inclination	: -84
Diameter	: 77.0 mm
Magnetic declination	: 0.0
Span	: 4
Scan interval	: 0.25
Scan direction	: To bottom
Scale	: 1/25
Aspect ratio	: 160 %
Pages	: 11
Color	: +0 +0 +0

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 293** **Inclination: -84**

Depth range: 380.000 - 400.000 m

(1 / 11) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A Azimuth: 293 Inclination: -84

Depth range: 400.000 - 420.000 m

(2 / 11) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A   Azimuth: 294   Inclination: -84

Depth range: 420.000 - 440.000 m

(3 / 11)   Scale: 1/25   Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 296** **Inclination: -84**

Depth range: 440.000 - 460.000 m

(4 / 11) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 296** **Inclination: -84**

Depth range: 460.000 - 480.000 m

(5 / 11) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark

Bore hole No.: KFM02A **Azimuth: 299** **Inclination: -84**

Depth range: 480.000 - 500.000 m

(6 / 11) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A Azimuth: 300 Inclination: -84

Depth range: 500.000 - 520.000 m

(7 / 11) Scale: 1/25 Aspect ratio: 160 %

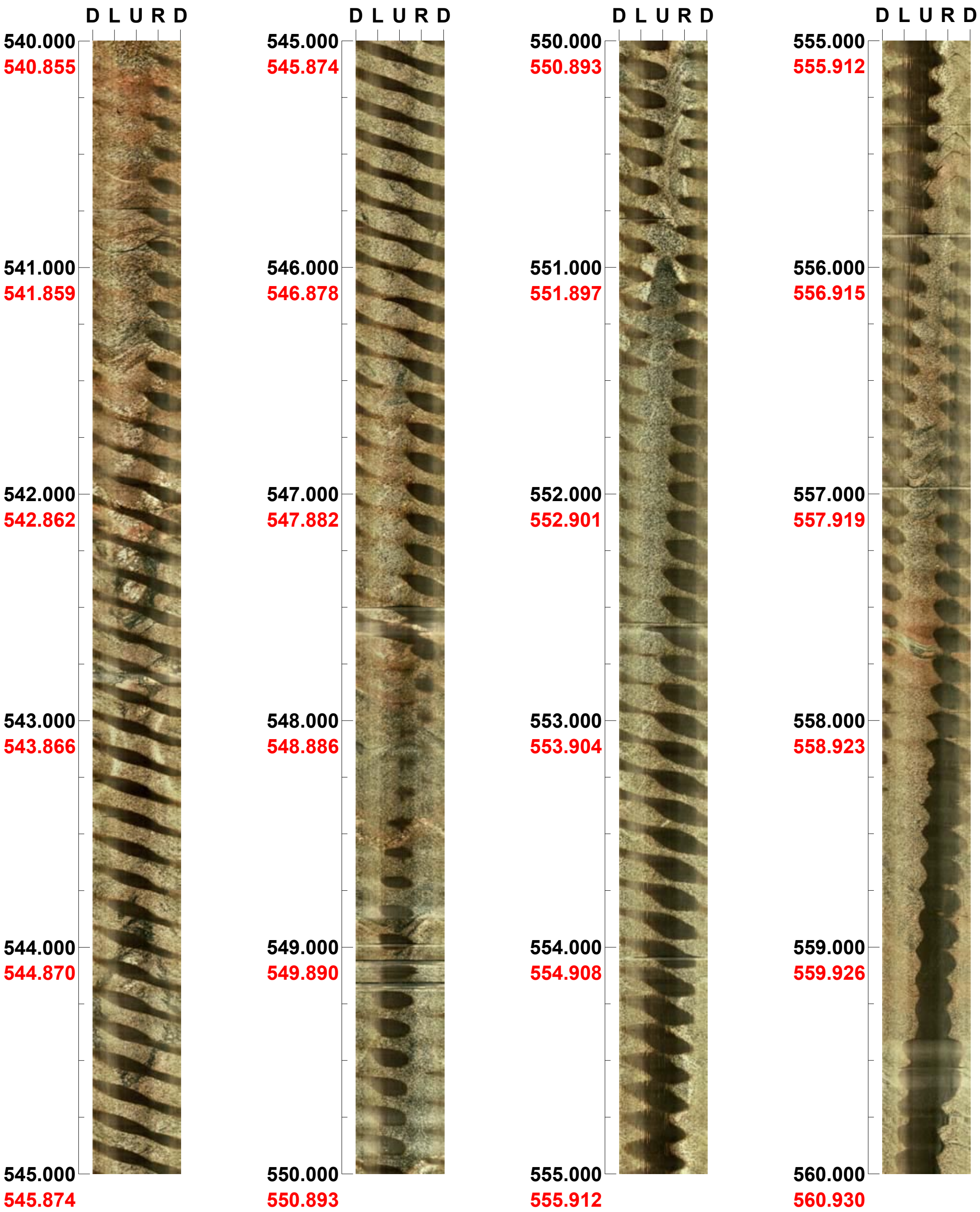
Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 301** **Inclination: -84**

Depth range: 520.000 - 540.000 m

(8 / 11) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A Azimuth: 300 Inclination: -83

Depth range: 540.000 - 560.000 m



(9 / 11) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 299** **Inclination: -83**

Depth range: 560.000 - 580.000 m

(10 / 11) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 300** **Inclination: -83**

Depth range: 580.000 - 590.000 m

(11 / 11) **Scale: 1/25** **Aspect ratio: 160 %**

Appendix 6

BIPS logging of KFM02A, 590 to 999 m

Project name: Forsmark

Image file	: g:\skb\bips\forsmark\kfm02a\bips_~c5\kfm02a_3.bip
BDT file	: g:\skb\bips\forsmark\kfm02a\bips_~c5\kfm02a_3.bdt
Locality	: FORSMARK
Bore hole number	: KFM02A
Date	: 03/04/15
Time	: 11:49:00
Depth range	: 590.000 - 999.191 m (red figures = corrected values)
Azimuth	: 303
Inclination	: -82
Diameter	: 77.0 mm
Magnetic declination	: 0.0
Span	: 4
Scan interval	: 0.25
Scan direction	: To bottom
Scale	: 1/25
Aspect ratio	: 160 %
Pages	: 21
Color	: +0 +0 +0

Project name: Forsmark

Bore hole No.: KFM02A **Azimuth: 303** **Inclination: -82**

Depth range: 590.000 - 610.000 m

(1 / 21) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark

Bore hole No.: KFM02A **Azimuth: 303** **Inclination: -82**

Depth range: 610.000 - 630.000 m

D L U R D

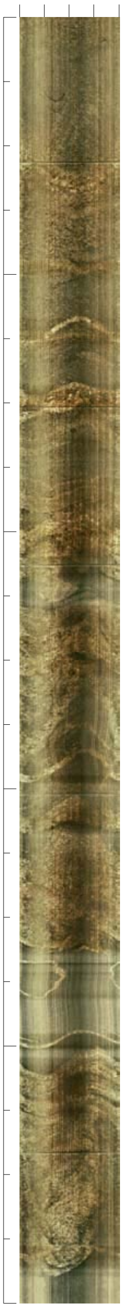
610.000
611.162
611.000
612.166
612.000
613.170
613.000
614.174
614.000
615.178
615.000
616.181

D L U R D

615.000
616.181
616.000
617.185
617.000
618.189
618.000
619.193
619.000
620.197
620.000
621.201

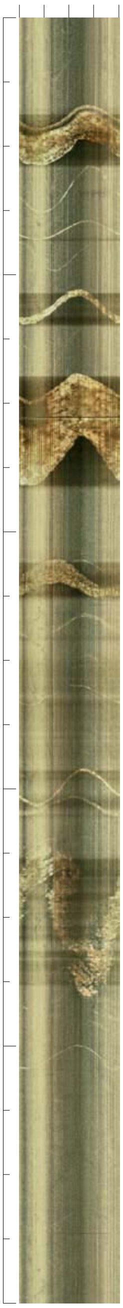
D L U R D

620.000
621.201
621.000
622.204
622.000
623.208
623.000
624.212
624.000
625.216
625.000
626.220



D L U R D

625.000
626.220
626.000
627.223
627.000
628.227
628.000
629.231
629.000
630.235
630.000
631.239



(2 / 21) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A   Azimuth: 304   Inclination: -82

Depth range: 630.000 - 650.000 m

(3 / 21)   Scale: 1/25   Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 303** **Inclination: -82**

Depth range: 650.000 - 670.000 m

(4 / 21) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 303** **Inclination: -82**

Depth range: 670.000 - 690.000 m

(5 / 21) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 304** **Inclination: -82**

Depth range: 690.000 - 710.000 m

(6 / 21) **Scale: 1/25** **Aspect ratio: 160 %**

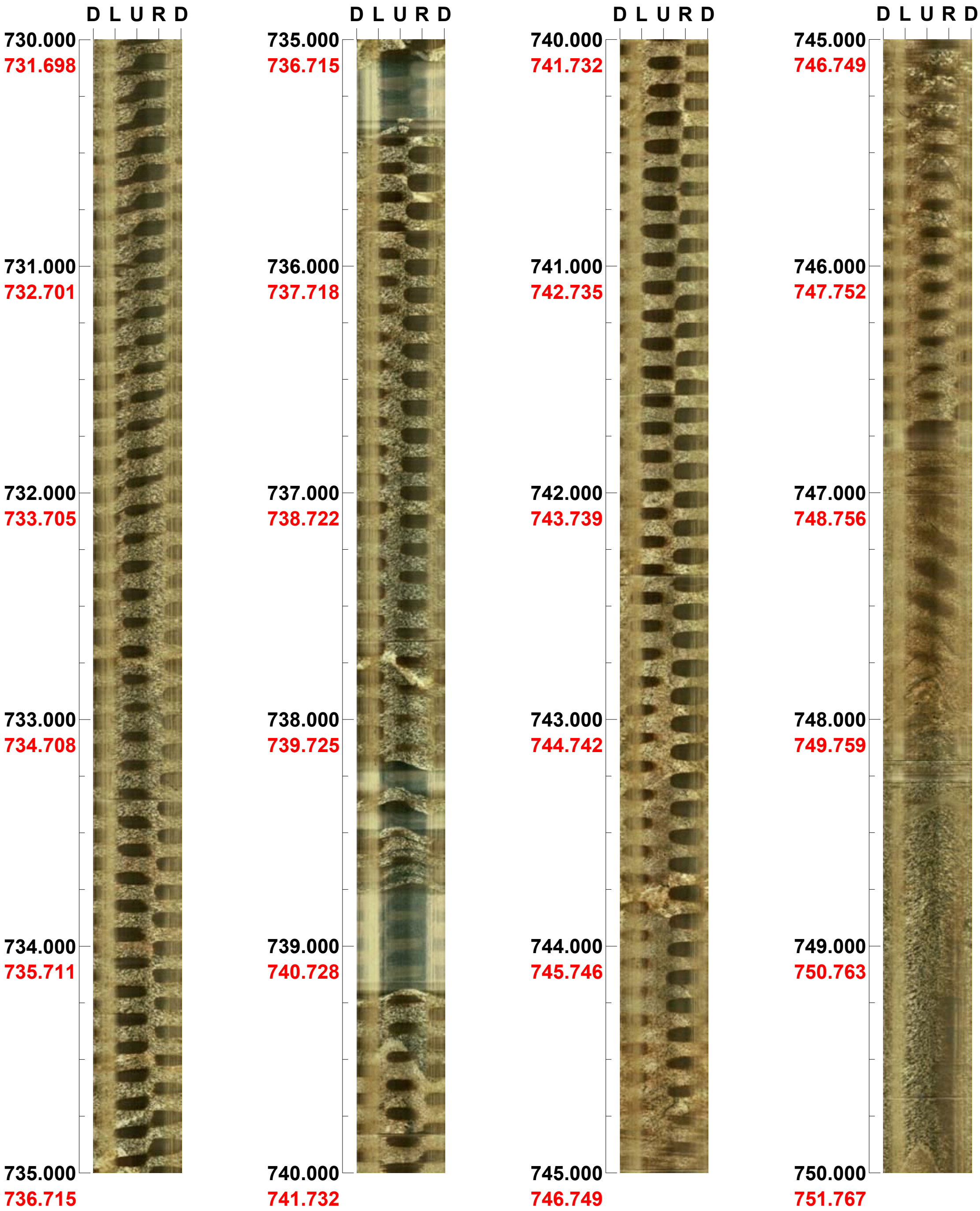
Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 304** **Inclination: -82**

Depth range: 710.000 - 730.000 m

(7 / 21) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 305** **Inclination: -82**

Depth range: 730.000 - 750.000 m



(8 / 21) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 305** **Inclination: -82**

Depth range: 750.000 - 770.000 m

(9 / 21) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A Azimuth: 305 Inclination: -82

Depth range: 770.000 - 790.000 m

(10 / 21) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A   Azimuth: 305   Inclination: -82

Depth range: 790.000 - 810.000 m

(11 / 21)   Scale: 1/25   Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A

Azimuth: 306 Inclination: -81

Depth range: 810.000 - 830.000 m

(12 / 21) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 306** **Inclination: -81**

Depth range: 830.000 - 850.000 m

(13 / 21) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A Azimuth: 306 Inclination: -81

Depth range: 850.000 - 870.000 m

(14 / 21) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark

Bore hole No.: KFM02A **Azimuth: 307** **Inclination: -81**

Depth range: 870.000 - 890.000 m

(15 / 21) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A Azimuth: 307 Inclination: -81

Depth range: 890.000 - 910.000 m

(16 / 21) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A Azimuth: 308 Inclination: -81

Depth range: 910.000 - 930.000 m

(17 / 21) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A Azimuth: 309 Inclination: -81

Depth range: 930.000 - 950.000 m

(18 / 21) Scale: 1/25 Aspect ratio: 160 %

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 309** **Inclination: -81**

Depth range: 950.000 - 970.000 m

(19 / 21) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 310** **Inclination: -80**

Depth range: 970.000 - 990.000 m

(20 / 21) **Scale: 1/25** **Aspect ratio: 160 %**

Project name: Forsmark
Bore hole No.: KFM02A **Azimuth: 310** **Inclination: -80**

Depth range: 990.000 - 999.191 m

(21 / 21) **Scale: 1/25** **Aspect ratio: 160 %**