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Forsmark site investigation

RAMAC and BIPS logging in boreholes KFM01C and KFM01D

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May 2006

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Abstract

This report includes the data gained in geophysical logging operations performed within the site investigation at Forsmark. The logging operations presented here includes BIPS and borehole radar (RAMAC) logging in the core-drilled boreholes KFM01C and KFM01D. All measurements were conducted by Malå Geoscience AB during January and March 2006.

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 surveys, the results are presented as images. Radar data is presented in radargrams and the identified reflectors are listed.

The borehole radar data quality from both KFM01C and KFM01D was satisfying, but in some parts of lower quality due to more conductive conditions. This conductive environment 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: 97 reflectors were identified in KFM01C and 182 reflectors were identified in KFM01D of which 34 were orientated (dip/strike).

The BIPS images in KFM01C and KFM01D were not perfect, mainly due to mud covering parts of the borehole wall, thus reducing the image quality.

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Forsmark. Mätningarna som presenteras här omfattar BIPS-loggning och borrhålsradarmätningar (RAMAC) i KFM01C och KFM01D. Alla mätningar är utförda av Malå Geoscience AB under januari och mars 2006.

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 loggningen 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 loggningarna presenteras data i form av plottar längs med borrhålet. Radardata presenteras i radargram, och en lista över tolkade radarreflektorer ges.

Borrhålsradardata från KFM01C och KFM01D var tillfredställande, 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 97 radarreflektorer identifierats i KFM01C. I KFM01D identifierades 182 strukturer, varav 34 är orienterade (strykning och stupning).

Förhållandena för BIPS var långt ifrån perfekta. Både i KFM01C och KFM01D var det främst borrhålsslam längs borrhålen som var orsaken till relativt dåliga bilder.

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 Forsmark. The logging operations presented here includes TV-logging (BIPS) and borehole radar (RAMAC) in the core-drilled boreholes KFM01C and KFM01D. The work was carried out in accordance with activity plans AP PF 400-05-112 and AP PF 400-06-014. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

This report includes measurements from 0 to approximately 440 m in borehole KFM01C and from 90 to approximately 800 m in KFM01D. These two core-drilled boreholes have a diameter of approximately 76 mm.

All measurements were conducted by Malå Geoscience AB during January and March 2006. Figure 1-1 shows the borehole locations.

The used investigation techniques comprised:

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

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

Activity plan	Number	Version
BIPS och RADAR loggning i KFM01C (0–450 m) och KFM09B (0–615 m) samt i HFM24, HFM26, HFM27 och HFM29	AP PF 400-05-112	1.0
BIPS- och RADAR loggning i KFM01D	AP PF 400-06-014	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	2.0

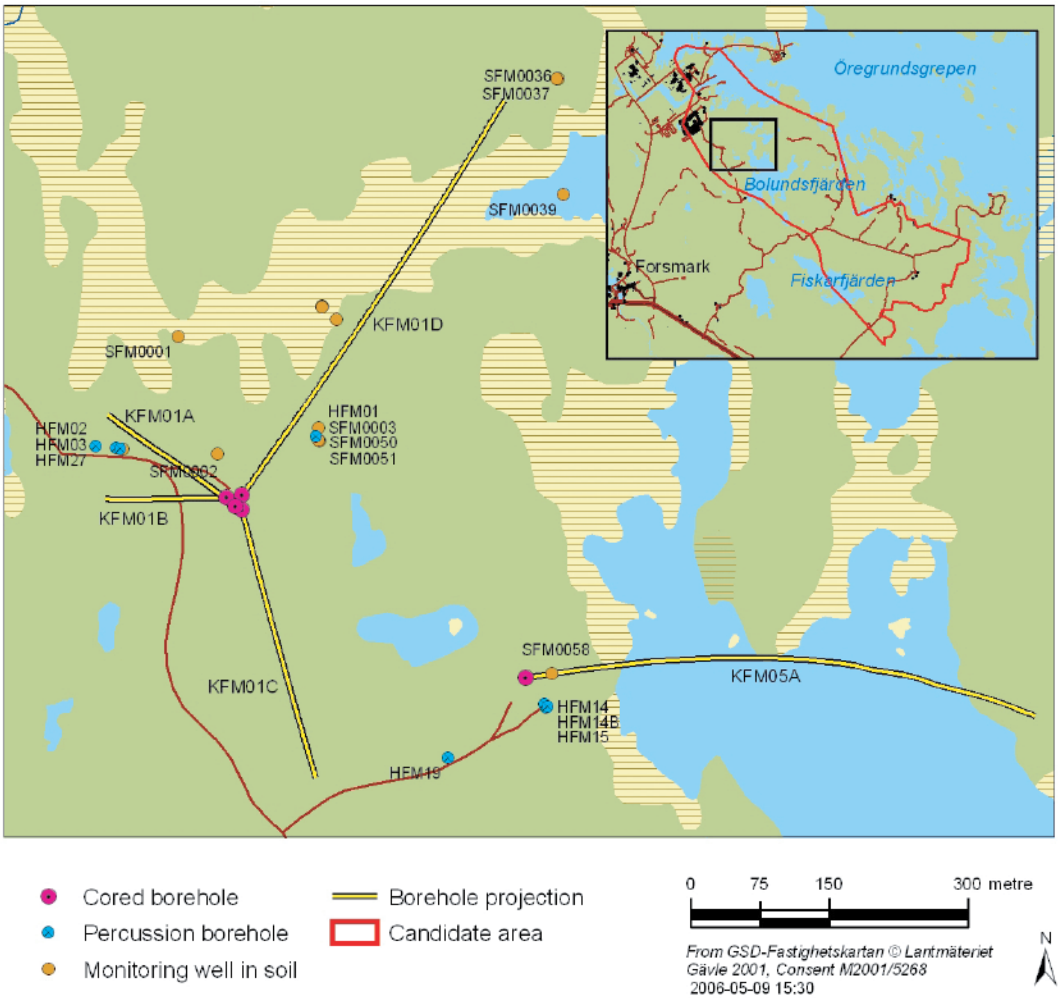


Figure 1-1. *Overview over the Forsmark investigation area and Drill Site 1, showing the location of the boreholes KFM01C and KFM01D surveyed and presented in this report.*

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 surveys, the results are presented as images. Radar data are 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.

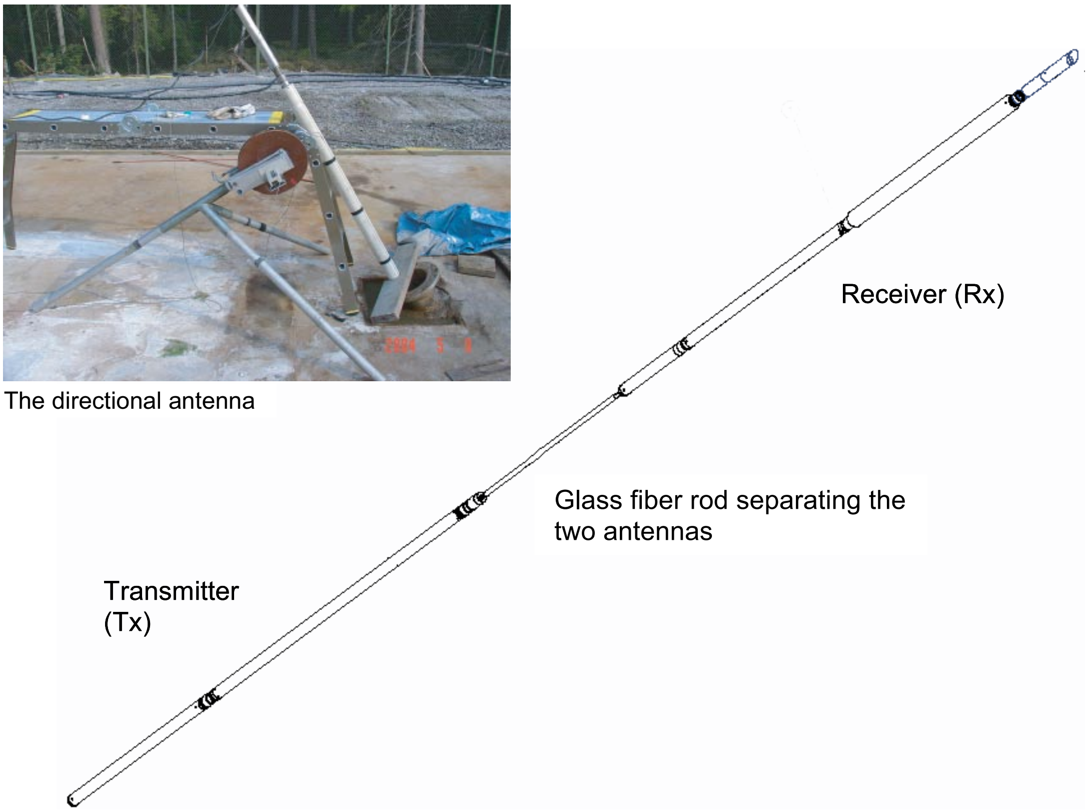


Figure 3-1. *Example of a borehole radar antenna.*

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 one pixel per degree.

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

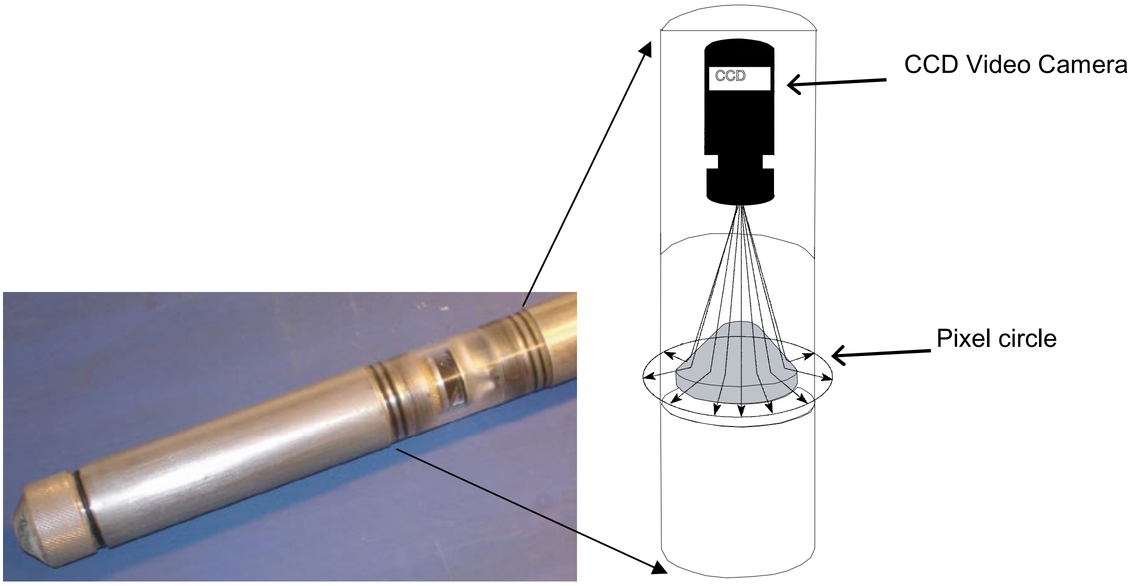


Figure 3-2. *The BIP-system. To the right a sketch showing the principles of the conical mirror.*

4 Execution

4.1 General

4.1.1 RAMAC Radar

The measurements in KFM01C and KFM01D were carried out with dipole radar antennas, with frequencies of 250, 100 and 20 MHz. In KFM01D the measurements were also carried out using the directional antenna, with a central frequency of 60 MHz. In KFM01C no measurements were conducted with the directional antenna, see Chapter 4.3 Nonconformities.

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 Tables 4-1 and 4-2. See also Figure 3-1 and 4-1.

All measurements were performed in accordance with the instructions and guidelines from SKB (internal document MD 252.020). Before the logging operation, the antennas and cable were cleaned according to the internal document SKB MD 600.004.

The functionality of the directional antenna was tested before measurements in KFM01D. This was performed 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 is measured by compass and the result difference achieved from the directional antenna was about 3 degrees. This can be considered to be very good, considering the disturbed environment with metallic objects etc at the test site.

For more information on system settings used in the investigation of KFM01C and KFM01D, see Tables 4-1 and 4-2 next page.

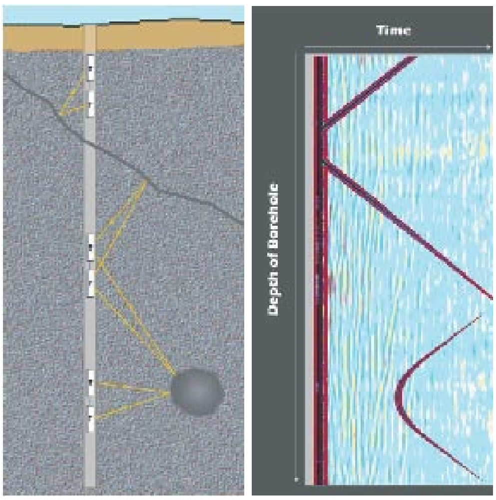


Figure 4-1. *The principle of radar borehole reflection survey (left) and an example of result (right).*

Table 4-1. Radar logging information from KFM01C.

Site:	Forsmark	Logging company:	Malå GeoScience AB	
BH:	**KFM01C**	**Equipment:**	**SKB RAMAC**	
Type:	**Dipole**	**Manufacturer:**	**MALÅ GeoScience**	
Operator:	**CG**	**Antenna**		
		250 MHz	**100 MHz**	**20 MHz**
Logging date:		2006-01-30	2006-01-30	2006-01-30
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	–1.42
Logging from (m):		1.5	2.6	6.25
Logging to (m):		443.4	440.0	439.9
Trace interval (m):		0.1	0.2	0.25
Antenna separation (m):		2.4	3.9	10.05

Table 4-2. Radar logging information from KFM01D.

Site:	Forsmark	Logging company:	Malå Geoscience AB		
BH:	**KFM01D**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Operator:	**CG**	**Antenna**			
		Directional	**250 MHz**	**100 MHz**	**20 MHz**
Logging date:		2006-03-15/16	2006-03-14	2006-03-14	2006-03-14
Reference:		T.O.C.	T.O.C.	T.O.C.	T.O.C.
Sampling frequency (MHz):		615	2,424	891	239
Number of samples:		512	619	518	518
Number of stacks:		32	Auto	Auto	Auto
Signal position:		410.5	–0.34	–0.35	–1.42
Logging from (m):		93.4	91.5	92.6	96.25
Logging to (m):		793.4	799.6	797.8	793.6
Trace interval (m):		0.5	0.1	0.2	0.25
Antenna separation (m):		5.73	2.4	3.9	10.05

4.1.2 BIPS

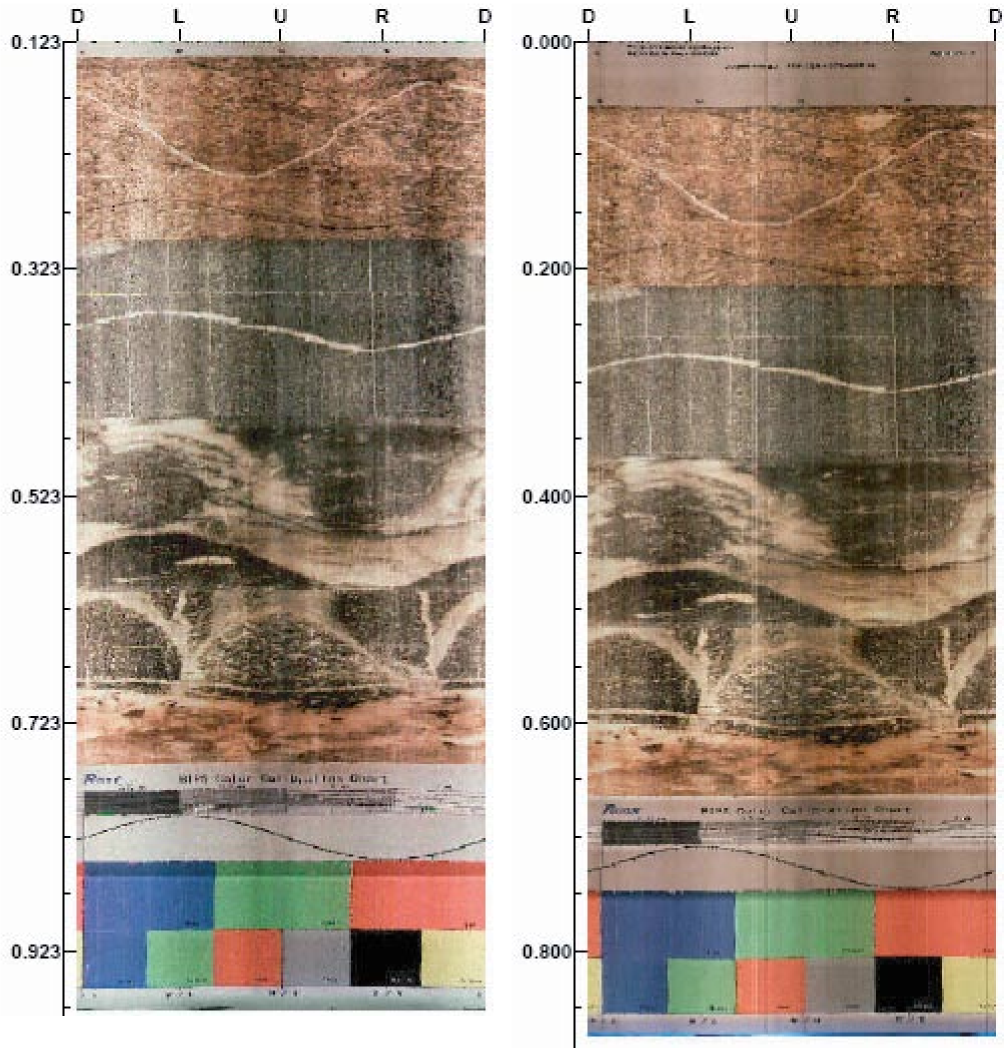
All measurements were performed in accordance with the instructions and guidelines from SKB (internal document MD 222.006). All cleaning of the probe and cable was performed according to the internal document SKB MD 600.004 before the logging operation.

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 both boreholes KFM01C and KFM01D.

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 corresponds to the test logging performed before and after the logging campaigns in March. The results showed no difference regarding the colours and focus of the images. Results of the test loggings were included in the delivery of the raw data.

The BIPS logging information is found in the header for every single borehole presented in Appendices 3 and 4 in this report.



Before logging in KFM01C

After logging in KFM01D

Figure 4-2. *Results from logging in the test pipe before and after the logging campaign in March, 8th to 16th, 2006. The length scales are not essential in the test measurements.*

4.1.3 Length measurements

During logging the length recording for the RAMAC systems is taken care of by a measuring wheel mounted on the cable winch. The logging is measured from TOC (Top of Casing). The length is adjusted to the bottom of casing when visible in the BIPS image.

During the BIPS logging in core drilled boreholes, where the reference marks in the borehole wall is visible on the image, the position where the length mark is visible is marked with scotch tape on the logging cable. During BIPS logging the measured length was adjusted to true length according to length mark visible in the BIPS image. The adjusted true length is marked with red in the image plot together with the non-adjusted measured length. The non-adjusted length is marked with black as seen in Appendices 3 and 4. The tape marks on the logging cable are then used for controlling the RAMAC measurement.

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 length divergence is less than 100 cm in the deepest parts of a 1,000 m deep borehole.

The length divergence is taken into account in the resulting tables in Chapter 5.

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 color corresponds to the large positive signals and white color to large negative signals. Grey color 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 128 m/µs (metres per microsecond) /1/. The velocity measurement was performed with the 100 MHz antenna.

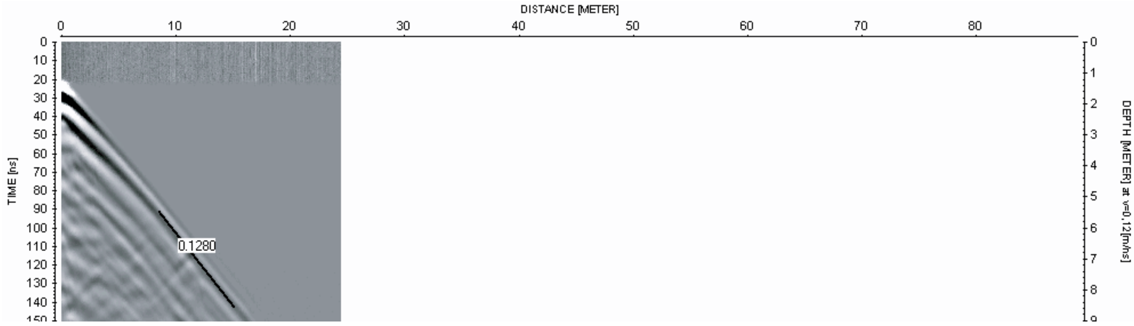


Figure 4-3. Results from velocity measurements in HFM03.

The visualization of data in Appendices 1 and 2 is made with ReflexWin, a Windows based processing software for filtering and analysis of borehole radar data. The processing steps for the data presented in Appendices 1 and 2 are given in Tables 4-3 and 4-4. 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 just in parts of the borehole, where needed.

Table 4-3. Processing steps for borehole radar data from KFM01C.

Site: Forsmark	**Logging company:**	**Malå GeoScience AB**	
BH: KFM01C	**Equipment:**	**SKB RAMAC**	
Type: Dipole	**Manufacturer:**	**MALÅ GeoScience**	
Interpret: JG	**Antenna**		
	250 MHz	**100 MHz**	**20 MHz**
Processing:	Move start time (–20.4)	Move start time (–41.5)	Move start time (–90)
	DC shift (190–230)	DC shift (460–520)	DC shift (1,800–2,100)
	Gain (start 19 lin 1.4 exp 1.4)	Gain (start 39 lin 2 exp 0.6)	Gain (start 123 lin 3.5 exp 0.2)

Table 4-4. Processing steps for borehole radar data from KFM01D.

Site: Forsmark	**Logging company:**	**Malå GeoScience AB**		
BH: KFM01D	**Equipment:**	**SKB RAMAC**		
Type: Directional/Dipole	**Manufacturer:**	**MALÅ GeoScience**		
Interpret: JG	**Antenna**			
	Directional	**250 MHz**	**100 MHz**	**20 MHz**
Processing:	Move start time (–45 samples)	Move start time (–11)	Move start time (–35.3)	Move start time (–83.1)
	DC shift (414–511)	DC shift (190–240)	DC shift (460–520)	DC shift (1,800–2,000)
	Time gain (start 76 lin 100 exp 3)	Gain (start 17 lin 3.6 exp 1)	Gain (start 43 lin 2.9 exp 0.6)	Gain (start 92 lin 3.6 exp 0.1)
	(FIR)			

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 5-3 and 5-4 and are also visible on the radargrams in Appendices 1 and 2.

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 made on the cable when logging core-drilled boreholes (where the length marks are visible in the BIPS image). For printing of the BIPS images the printing software PDPP from RaaX was used.

4.3 Nonconformities

BIPS logging in KFM01C has been carried out during three occasions, 2nd of January 2006 from 0 to 200 m length, 30th of January 2006 from 200 to 435 m length, and 9th March 2006 from 0 to 435 m length. In this report the last logging, which is the best considering the quality of the images, is presented.

The measurements with the directional antenna in KFM01C could not be carried out, due to a high risk of getting stuck with the equipment at a borehole length of 85–90 m, where the borehole wall has been stabilized with metal plates.

5 Results

The results from the BIPS measurements in KFM01C and KFM01D 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 KFM01C and KFM01D was delivered as raw data (file format *.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.

5.1 RAMAC logging

The results of the interpretation of the radar measurements are presented in Tables 5-1 to 5-7. Radar data are also visualized in Appendices 1 and 2. It should be remembered that the images in Appendices 1 and 2 is only a composite picture of all events 360 degrees around the borehole, and do not reflect the orientation of the structures.

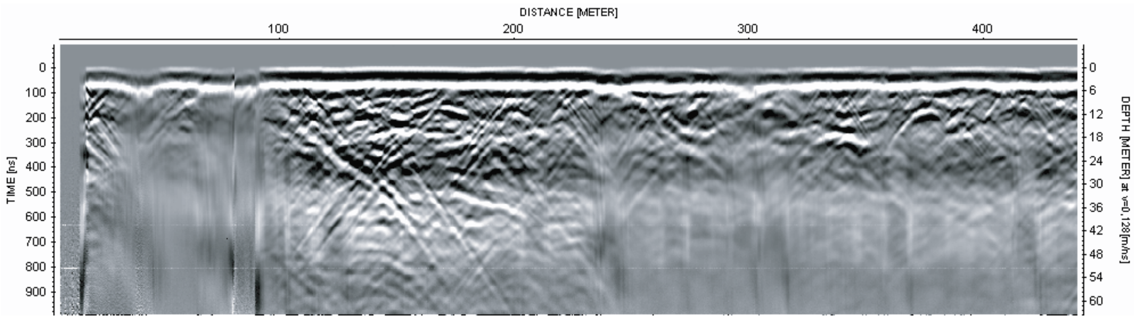
Only the larger clearly visible structures are interpreted in RadinterSKB. Overviews of the two boreholes are given in Figure 5-1 below. Large differences in data quality are observed along both boreholes. In KFM01C the data from the interval 100 m to 230 m have good penetration compared to the rest of the hole. This is either due to less conductive water, or due to more suitable rock conditions. In KFM01D a low-frequency ringing appears along the borehole from about 300 m borehole length, except for a narrow window from 338 m to 355 m. This can be due to more conductive water, less suitable for radar measurements with 20 MHz frequency.

A number of minor structures also exist, indicated in Appendices 1 and 2. Often a number of structures can be noticed, but most probably lying so close to each other that it is impossible to distinguish one from the other. Larger structures parallel to the borehole, if present, are also indicated in Appendices 1 and 2. It should also be pointed out that reflections interpreted would 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 KFM01C and KFM01D (as seen in Appendices 1 and 2) is satisfying to good, but in parts of lower quality due to more conductive conditions. This is seen in both boreholes. A conductive environment causes an attenuation of the radar wave, which in turn 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 a reflection.

This effect is also seen in the directional antenna for KFM01D, which makes it more difficult to interpret the direction to the identified structures.

KFM01C



KFM01D

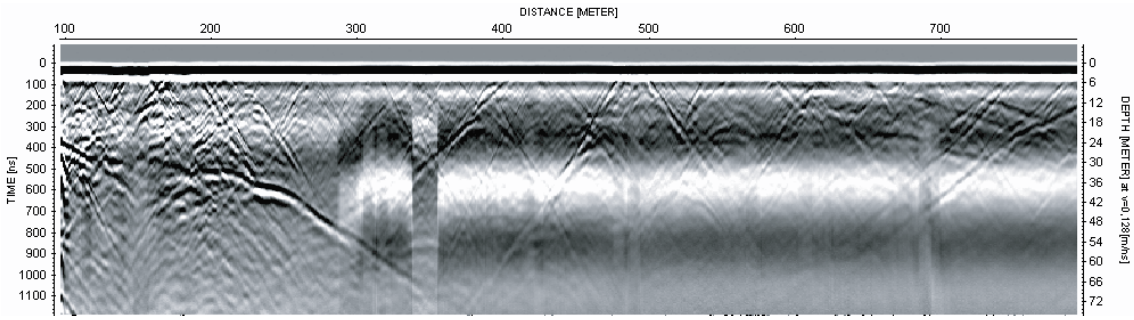


Figure 5-1. *An overview (20 MHz data) of the radar data for the two boreholes KFM01C and KFM01D. Observe that the borehole length (x-scale) and depth (y-scale) differs between the different boreholes.*

As also seen in Appendices 1 and 2 the resolution and penetration of radar waves depend on the antenna frequency used. Low antenna frequency gives less resolution but better penetration compared to a higher frequency. If structures can be identified with all three antenna frequencies, it can probably be concluded that the structure is quite significant.

In Tables 5-1 and 5-2 below the distribution of identified structures along the boreholes are listed for KFM01C and KFM01D.

Table 5-1. Identified structures as a function of borehole intersection length in KFM01C.

Length (m)	No. of structures
–100	18
100–150	12
150–200	9
200–250	12
250–300	9
300–350	11
350–400	14
400–450	9
450–	3

Table 5-2. Identified structures as a function of borehole intersection length in KFM01D.

Length (m)	No. of structures
–100	7
100–150	15
150–200	16
200–250	7
250–300	9
300–350	11
350–400	17
400–450	15
450–500	11
500–550	13
550–600	17
600–650	15
650–700	10
700–750	7
750–800	7
800–	5

Tables 5-3 and 5-4 summarises the interpretation of radar data from KFM01C and KFM01D. In the tables the borehole length and intersection angle to the identified structures are listed.

For KFM01D the direction to the object is also given. As seen some radar reflectors in Table 5-4 are marked with ±, which indicates an uncertainty in the interpretation of direction. The direction can in these cases be ±180 degrees. The direction to the object (the plane) is defined in Figure 5-2. This direction and the intersection angle are recalculated to strike and dip, also given in the tables below. The plane strike is the angle between the line of the plane's intersection with the surface and the Magnetic North direction. A strike of 0 degrees implies a dip to the east while a strike of 180 degrees implies a dip to the west (right-hand rule). The strike is measured clockwise and can vary from 0 to 359 degrees. The dip of the plane is the angle between the ground surface and the plane, and can vary from 0 to 90 degrees.

Observe that the interpretation of an undulating structure can result in several different angles and different intersection lengths. An example of this phenomenon is seen in Table 5-4 and Appendix 1: the reflectors named 100, 100x and 100xx most likely originates from the same geological structure.

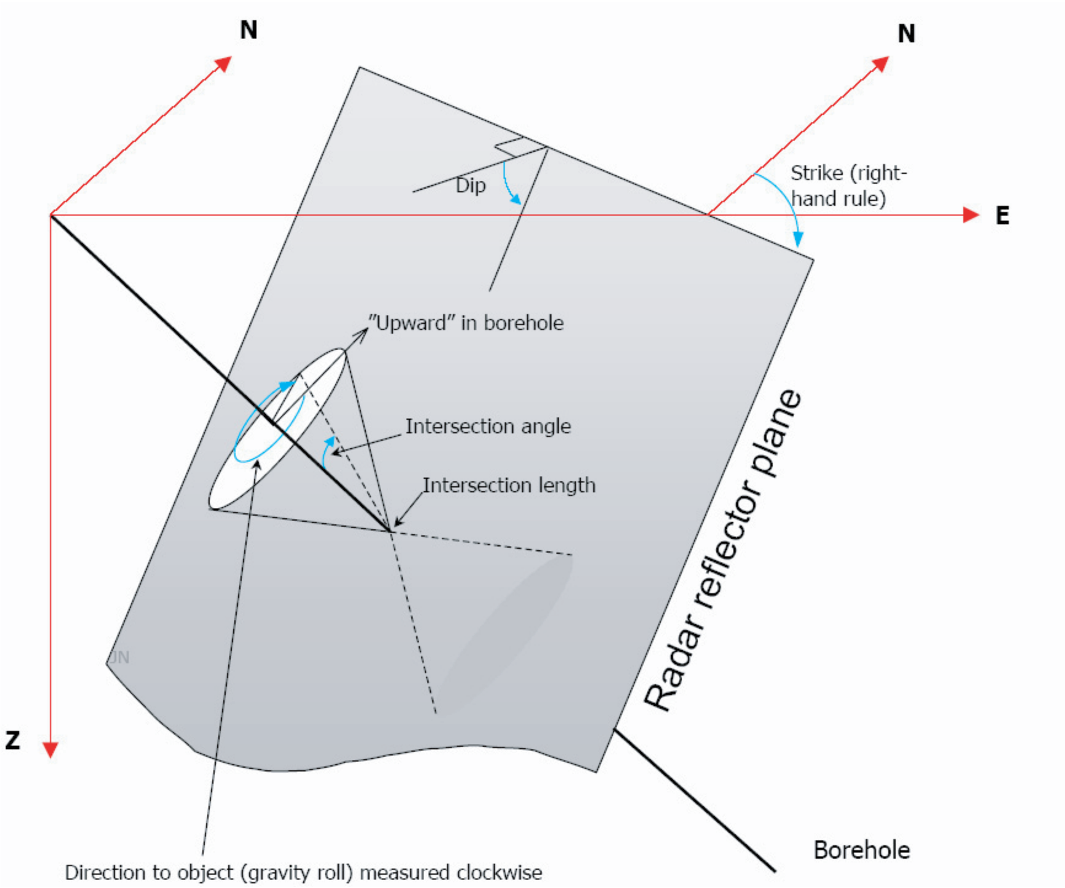


Figure 5-2. *Definition of direction to reflector (gravity roll) as presented in Table 5-4.*

Table 5-3. Interpretation of radar reflectors from the dipole antennas 250, 100 and 20 MHz in borehole KFM01C.

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas)			
Site:		**Forsmark**	
Borehole name:		**KFM01C**	
Nominal velocity (m/μs):		**128.00**	
Object type	**Name**	**Intersection length**	**Intersection angle**
PLANE	22	11.4	43
PLANE	1	18.3	47
PLANE	2	19.2	44
PLANE	3	34.0	52
PLANE	5	36.4	65
PLANE	4	42.1	47
PLANE	6	47.1	52
PLANE	7	51.9	50
PLANE	9	59.8	48
PLANE	8	66.6	50
PLANE	10	70.0	43
PLANE	93	72.3	30
PLANE	11	76.9	46
PLANE	23	78.5	56

RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas)			
Site:		**Forsmark**	
Borehole name:		**KFM01C**	
Nominal velocity (m/µs):		**128.00**	
Object type	**Name**	**Intersection length**	**Intersection angle**
PLANE	18	88.5	48
PLANE	13	91.3	48
PLANE	12	96.7	44
PLANE	14	98.2	48
PLANE	93x	100.1	51
PLANE	24	108.1	45
PLANE	15	111.7	44
PLANE	25	112.1	46
PLANE	17	121.3	53
PLANE	16	123.7	55
PLANE	94	124.5	64
PLANE	27	129.0	43
PLANE	29	134.0	43
PLANE	26	134.2	61
PLANE	19	134.6	52
PLANE	30	142.5	47
PLANE	21	152.4	48
PLANE	28	156.2	44
PLANE	31	160.6	40
PLANE	34	164.7	56
PLANE	35	167.9	56
PLANE	32	172.8	46
PLANE	33	173.4	54
PLANE	36	183.6	41
PLANE	37	189.9	40
PLANE	38	207.6	51
PLANE	40	210.3	46
PLANE	41	212.9	52
PLANE	42	216.1	48
PLANE	20	221.6	8
PLANE	43	223.9	48
PLANE	91	231.8	38
PLANE	44	236.0	49
PLANE	45	237.2	46
PLANE	46	243.7	50
PLANE	47	245.8	57
PLANE	92	246.7	70
PLANE	48	267.9	59
PLANE	90	270.9	8
PLANE	49	278.5	64
PLANE	50	283.6	56
PLANE	51	285.0	55

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

Site:	**Forsmark**
Borehole name:	**KFM01C**
Nominal velocity (m/μs):	**128.00**

Object type	Name	Intersection length	Intersection angle
PLANE	52	287.8	61
PLANE	53	290.1	51
PLANE	54	294.9	57
PLANE	55	297.6	47
PLANE	39	304.6	3
PLANE	96	305.3	62
PLANE	56	310.7	62
PLANE	57	312.6	64
PLANE	58	317.3	62
PLANE	61	322.0	51
PLANE	59	326.6	61
PLANE	60	328.4	60
PLANE	62	336.1	58
PLANE	63	338.7	70
PLANE	64	347.5	61
PLANE	69	351.4	72
PLANE	65	351.7	56
PLANE	67	357.3	55
PLANE	68	362.0	56
PLANE	70	363.7	71
PLANE	71	371.7	64
PLANE	72	373.3	60
PLANE	73	374.1	66
PLANE	74	379.2	58
PLANE	66	381.5	7
PLANE	79	389.6	46
PLANE	77	390.3	59
PLANE	75	390.8	44
PLANE	78	396.7	41
PLANE	80	404.7	57
PLANE	81	406.7	59
PLANE	82	414.7	41
PLANE	84	415.3	55
PLANE	83	418.0	54
PLANE	76	418.1	10
PLANE	89	419.6	55
PLANE	85	428.1	69
PLANE	88	433.1	44
PLANE	87	450.2	54
PLANE	86	453.7	42
PLANE	95	499.3	24

Table 5-4. Interpretation of radar reflectors from the dipole antennas 250, 100 and 20 MHz, and the directional antenna 60 MHz in borehole KFM01D.

RADINTER MODEL INFORMATION
(Directional and dipole antennas)

Site:	**Forsmark**
Borehole name:	**KFM01D**
Nominal velocity (m/μs):	**128.0**

Name	Intersection length	Inter-section angle	RadInter direc-tion to object (gravity roll)	Dip 1	Strike 1	Dip 2	Strike 2
157x	-417.3	4					
166	-16.9	15	294	88	231		
158	66.1	58					
168	68.4	74	351 ±	59	118	24	127
153	87.8	57	351 ±	72	108	5	198
2	98.3	67					
157	99.2	17					
1	106.3	65	159	15	149		
1x	105.2	58					
3	108.3	58					
4	120.8	61					
5	121.8	57					
6	123.2	56	136	25	179		
7	128.3	50	147	20	199		
8	126.7	54					
9	130.0	51					
10	132.8	51					
11	136.6	45					
12	137.9	68					
13	140.9	56					
16	146.3	59					
17	149.7	59					
14	154.1	55					
15	154.8	49					
18	168.6	50					
19	173.0	39					
20	178.0	39					
21	179.8	42					
22	182.3	56	27	71	137		
26	185.2	72					
159	187.2	55					
23	188.0	44					
24	186.9	70					
25	188.7	67					
27	193.8	60					
28	197.5	55					
29	198.0	64					
30	198.6	41					
31	206.4	44					

RADINTER MODEL INFORMATION (Directional and dipole antennas)							
Site:		**Forsmark**					
Borehole name:		**KFM01D**					
Nominal velocity (m/μs):		**128.0**					
Name	**Intersection length**	**Inter-section angle**	**RadInter direction to object (gravity roll)**	**Dip 1**	**Strike 1**	**Dip 2**	**Strike 2**
32	223.4	55					
155	227.9	3					
33	239.6	90					
34	240.6	64					
35	243.0	67					
36	247.0	54					
42	256.6	66	240 ±	34	83	55	147
37	258.0	60					
38	259.8	57					
39	264.6	65	6	63	124		
44	277.2	71					
43	279.0	68					
41	279.4	81					
40	280.1	50					
45	296.0	57					
46	307.4	63					
47	308.3	69	354 ±	62	115	11	144
48	317.0	67	342 ±	62	114	20	142
49	320.7	53					
50	332.2	74					
53	333.6	53					
51	333.7	72					
162	334.9	59					
54	335.2	71					
55	339.3	71					
56	345.0	52					
167	352.4	31	243	50	34		
58x	352.8	32					
58	353.4	36	42	88	151		
59	353.7	60					
60	355.1	60					
57	355.3	25					
61	370.0	58					
62	375.2	78					
164	375.4	5	282	85	219		
63	376.8	56	351 ±	74	112	9	152
64	379.0	58					
156	380.4	82					
66	383.3	70					
65	386.9	72	195 ±	24	106	58	123
67	392.2	49					

RADINTER MODEL INFORMATION (Directional and dipole antennas)							
Site:		**Forsmark**					
Borehole name:		**KFM01D**					
Nominal velocity (m/μs):		**128.0**					
Name	**Intersection length**	**Inter-section angle**	**RadInter direc-tion to object (gravity roll)**	**Dip 1**	**Strike 1**	**Dip 2**	**Strike 2**
68	398.6	71	93 ±	44	148	46	86
69	396.3	54					
70	402.4	76					
72	414.4	21	60	89	351		
73	416.8	45					
71x	417.6	22					
71	421.7	18					
163	421.9	77					
78	423.6	24					
161	425.7	26					
74	431.5	57					
75	432.5	59					
76	436.3	58	183 ±	10	109	72	119
77	438.9	70					
81	441.3	61					
79	443.4	71					
80	447.4	45					
82	462.4	62					
150	472.7	6					
83	476.0	66					
84	478.1	81					
85	479.9	69					
124	481.5	4					
87xx	486.5	44					
86	488.3	62					
169	488.4	45	39 ±	80	144	27	32
87	489.8	59	198	13	67		
88	493.9	62					
89	501.9	55					
90	504.3	70					
87x	507.7	37					
91	509.6	67					
97	518.4	64					
92x	522.2	50					
92	522.3	45					
93	524.6	60					
94	527.4	49					
94x	528.4	62					
95	532.1	65					
96	535.9	66					
98	537.9	80					

RADINTER MODEL INFORMATION
(Directional and dipole antennas)

Site: **Forsmark**
Borehole name: **KFM01D**
Nominal velocity (m/μs): **128.0**

Name	Intersection length	Inter-section angle	RadInter direction to object (gravity roll)	Dip 1	Strike 1	Dip 2	Strike 2
121	554.6	4					
99	561.1	66					
100	563.6	64					
101	564.8	75					
100x	565.7	41	90	59	177		
154	568.9	51					
104x	569.8	24	237 ±	48	22	88	166
103	570.1	71					
100xx	571.6	26					
102	572.3	43					
104	574.7	42					
105	574.1	79	228 ±	32	96	51	131
124x	574.2	7					
106	577.0	68					
107	580.9	78					
134	592.9	9	252	71	20		
108	593.6	64					
109	600.9	68					
116	604.4	65					
110	606.8	42					
111	607.6	57	276 ±	54	77	49	160
112	608.2	47					
113	609.6	67					
114	612.3	53					
115	614.2	59					
123	617.6	9					
117	621.9	51					
118	628.2	64					
119	630.9	75					
120	632.1	62					
122	638.7	50					
133	643.0	9	243	65	13		
170	660.4	61					
125	663.6	65					
126	676.5	72					
131	676.8	58	114	40	162		
127	683.6	70					
128	685.0	66					
129	688.1	64					
136x	690.8	6					
130	692.2	60	270 ±	52	76	52	158

RADINTER MODEL INFORMATION (Directional and dipole antennas)							
Site:		Forsmark					
Borehole name:		KFM01D					
Nominal velocity (m/μs):		128.0					
Name	**Intersection length**	**Inter-section angle**	**RadInter direction to object (gravity roll)**	**Dip 1**	**Strike 1**	**Dip 2**	**Strike 2**
132	697.6	62					
135	702.7	55					
136	708.2	10					
137	710.6	64					
138	712.3	57					
143	735.2	12					
139	737.9	47					
140	743.6	55					
144	768.9	48					
142	770.1	26	312	85	255		
141	772.0	19	126 ±	51	219	82	247
145	773.7	54					
146	776.9	59					
147	780.5	57					
149	791.5	55					
148	800.2	48	183	2	53		
165	805.9	28	159	25	244		
152	819.2	21					
151x	837.5	19					
151	856.8	14	171	33	277		

In Appendices 1 and 2, the amplitude of the first arrival is plotted against the borehole length, for the 250 MHz dipole antennas. The amplitude variation along the borehole indicates changes of the electrical conductivity of the rock volume surrounding the borehole. A decrease in this amplitude may indicate fracture zones, clay or rock volumes with increased water content. i.e. increased electric conductivity. The borehole length intervals showing decreased amplitude are listed in Tables 5-5 and 5-6.

Table 5-5. Borehole length intervals in KFM01C with decreased amplitude for the 250 MHz antenna.

Length (m)	Length (m)
30–50	270
65–80	280
80–90	295–300
120–130	305–315
205–210	360–365
235–245	415

Table 5-6. Borehole length intervals in KFM01D with decreased amplitude for the 250 MHz antenna.

Length (m)	Length (m)
105	310
130–140	480
150–155	490
180	605–625
200	685–695

Finally, the structures considered as the most important (clear in the radargram, identified with several antenna frequencies, stretching out far from the borehole wall etc) are listed in Table 5-7 below.

Table 5-7. Some important structures in KFM01C and KFM01D.

Borehole	KFM01C	KFM01D
Structures	3, 4, 8, 11, 16, 20, 38, 40, 59, 83, 90, 93, 93x and 94	1, 1x, 4, 6, 14, 15, 18, 39, 42,47, 48, 58, 72, 74, 87, 87x, 87xx, 121, 123, 124, 124x, 133, 134, 141, 145, 150, 151, 152, 152x, 155, 157, 157x, 161, 164, 165 and 166

Observe that it is can be very difficult to classify different structures in an objective manner, along a borehole. This is due to the fact that the water quality (the conductivity) amongst other parameters varies along the borehole length and by that reason affects the results of the radar logging, by for instance attenuating the radar waves differently. Also the intersection angle of the identified structures affects the amplitude on the resulting radargram. A small angle will most often cause larger amplitude than a large angle, and by that a more clear structure.

5.2 BIPS logging

The BIPS pictures are presented in Appendices 3 and 4.

To get the best possible length accuracy, the BIPS images are adjusted to the reference marks on the logging cable. Additionally the marks on the borehole wall created by the drill rig in core-drilled boreholes are visible on the BIPS screen. The recorded length is adjusted to these visible marks.

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 in the campaign. The resulting images displayed no difference regarding the colours and focus of the images. The results of the test logging were included in the delivery of the field data and are also presented in Figure 4-2 in this report.

Values for the inclination and azimuth of the boreholes, presented in this report, are only preliminary.

The BIPS logging in the core-drilled boreholes resulted in the typical discolouring effects (caused by the drilling) on the borehole wall. This is seen especially in the bottom part of the boreholes where mud covers the lowermost part of the borehole wall. The images are of low quality and the geological mapping is problematic.

Three different runs have been performed in KFM01C. The first performed 2^{nd} of January 2006 ended up at 208 m were the probe stopped due some pieces of rock that blocked the borehole. The images from that run were also of very low quality due to high content of mud on the borehole wall. After removing the rock pieces with a drilling rig a second run was performed 30^{th} of January 2006 from 200 m to a length of 435 m. At the time for this logging the mud content was still high in the borehole and an nitrogen blowing was ordered to remove the remaining mud. The third logging, 9^{th} March 2006, from 0 to 435 m length resulted in acceptable image quality. During the logging through the perforated steel plate the probe jammed and caused errors in the length recordings. This implies that the adjusted lengths in-between the length marks at 50 m and 100 m are not accurately presented in this report.

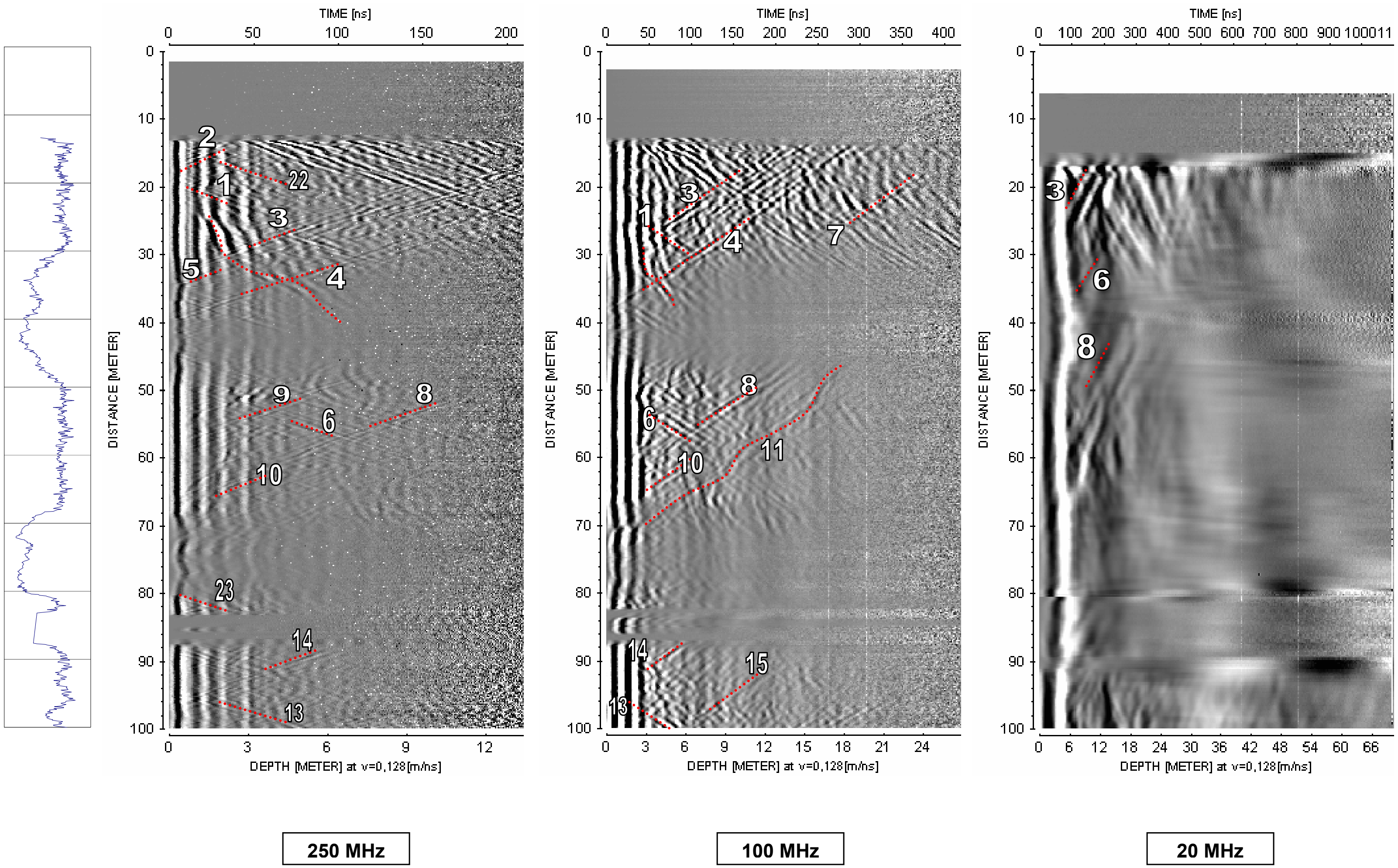
In KFM01D one run is performed and resulted in images of reasonable quality. Mud covers the lowermost part of the borehole wall and limits the visibility. One other reason for low image quality is the discoloring of the borehole wall induced from the drilling. This is very clearly seen in some sections along the borehole.

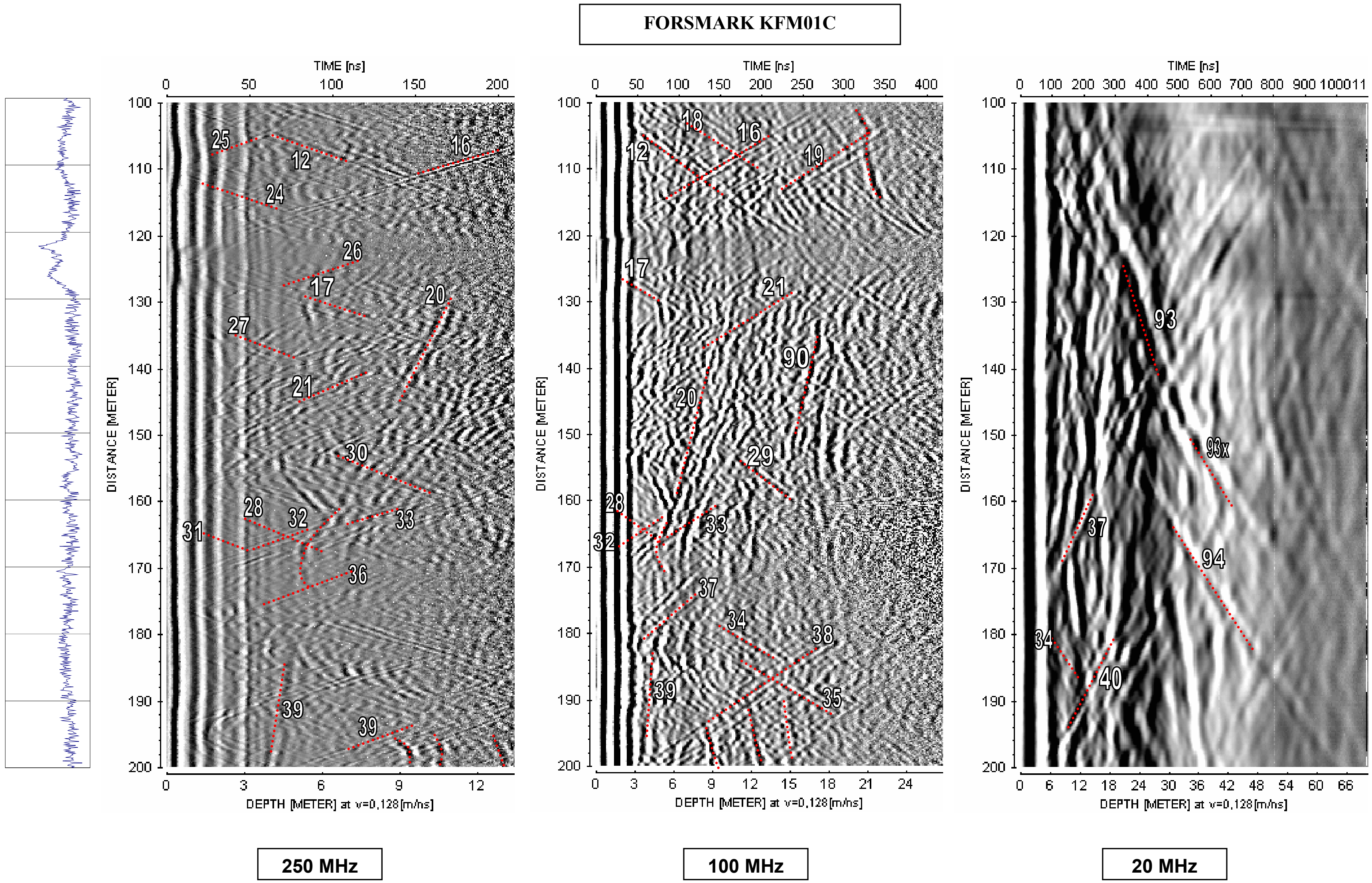
References

/1/ **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 in KFM01C, 0 to 442 m, dipole antennas 250, 100 and 20 MHz

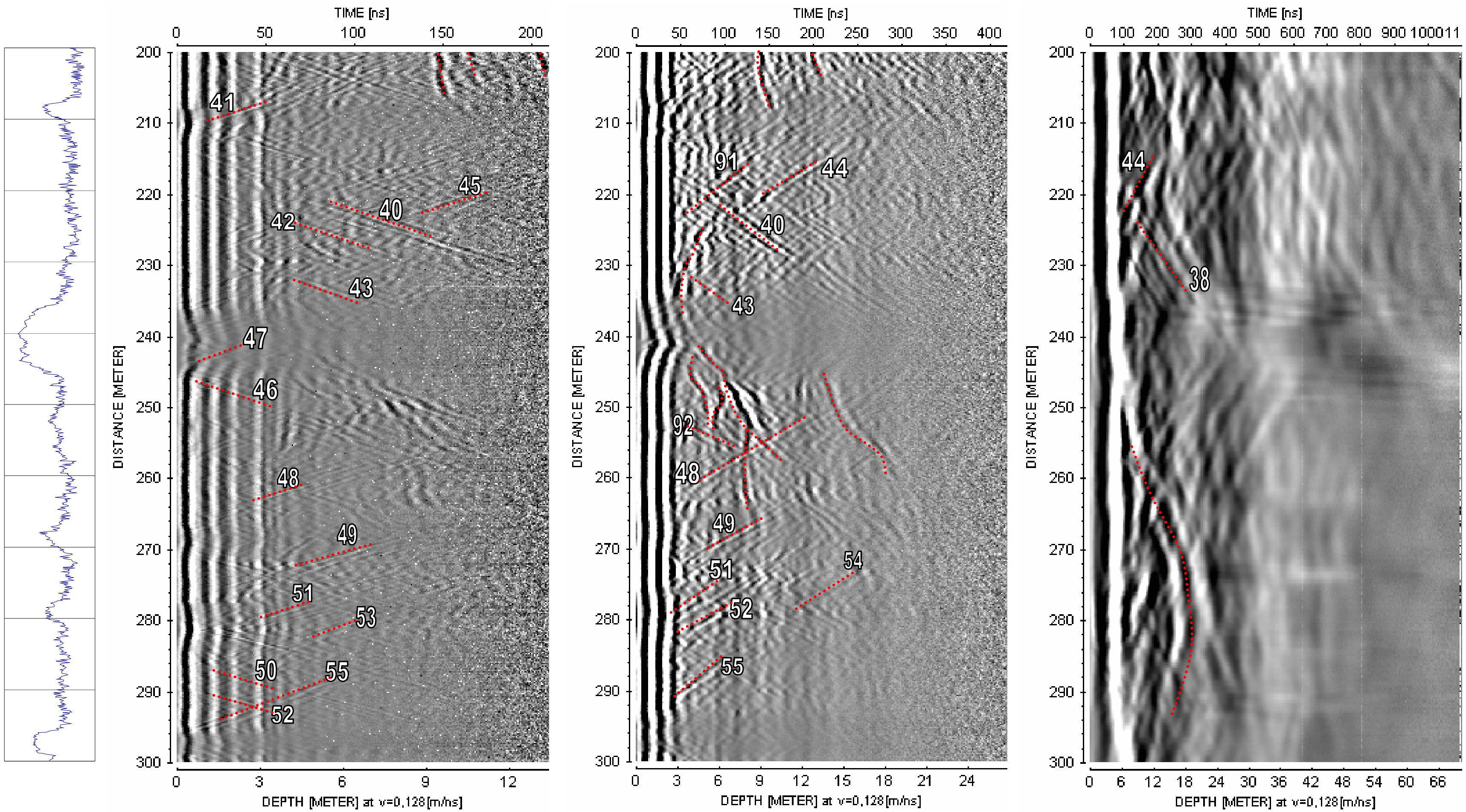
Appendix 1. FORSMARK KFM01C



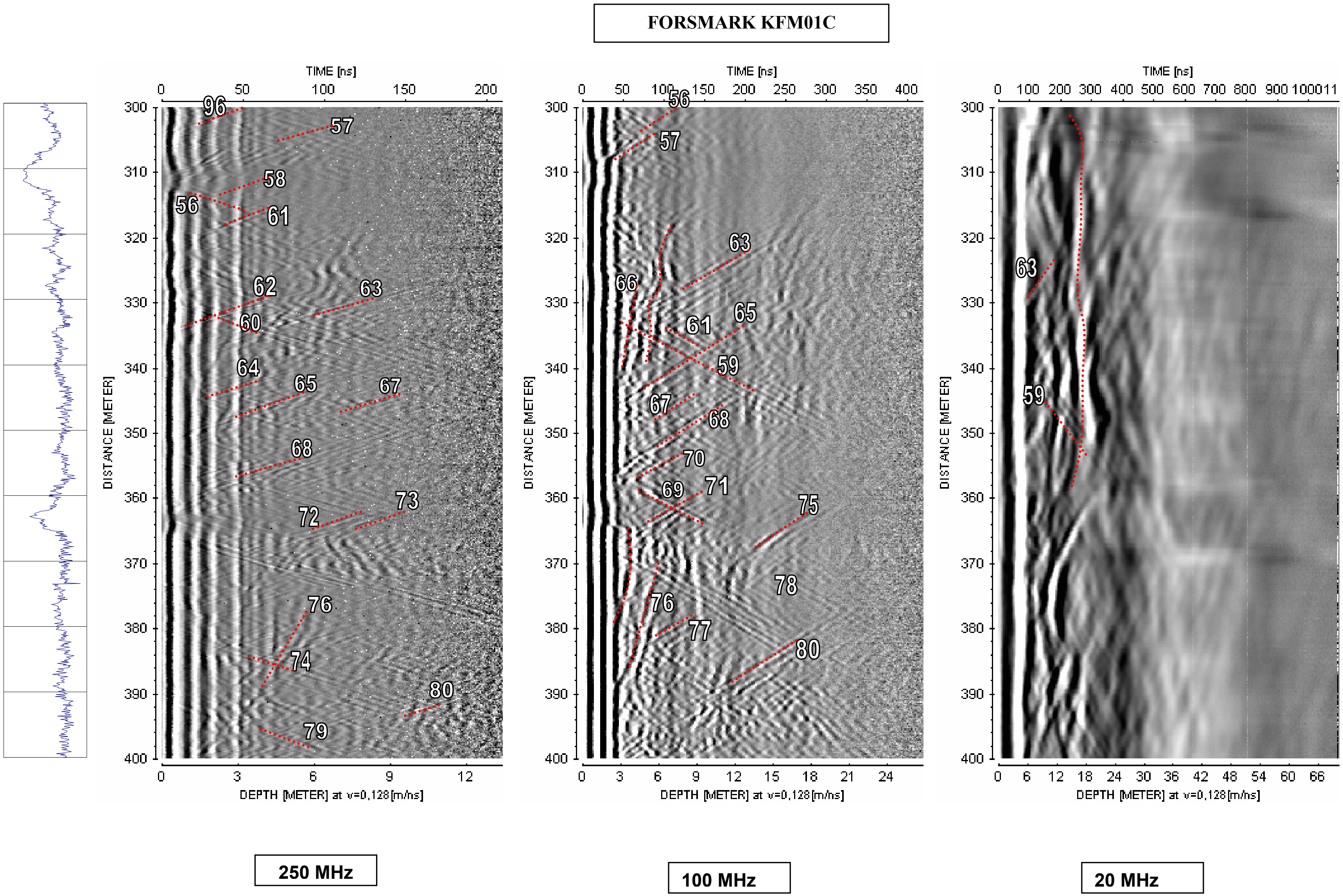


FORSMARK KFM01C
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128[m/ns]
250 MHz
100 MHz
20 MHz

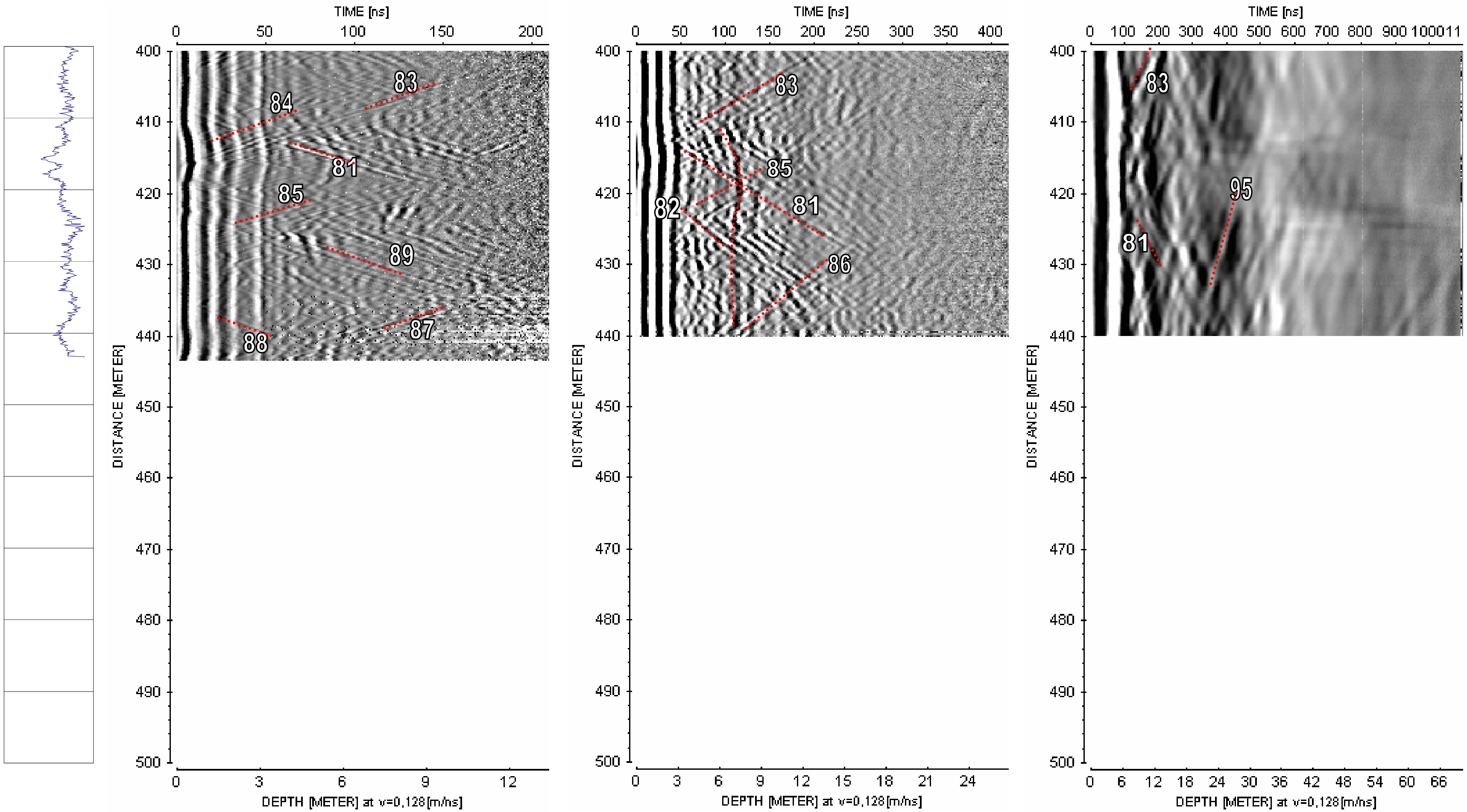
FORSMARK KFM01C



250 MHz **100 MHz** **20 MHz**


FORSMARK KFM01C
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128[m/ns]
250 MHz
100 MHz
20 MHz

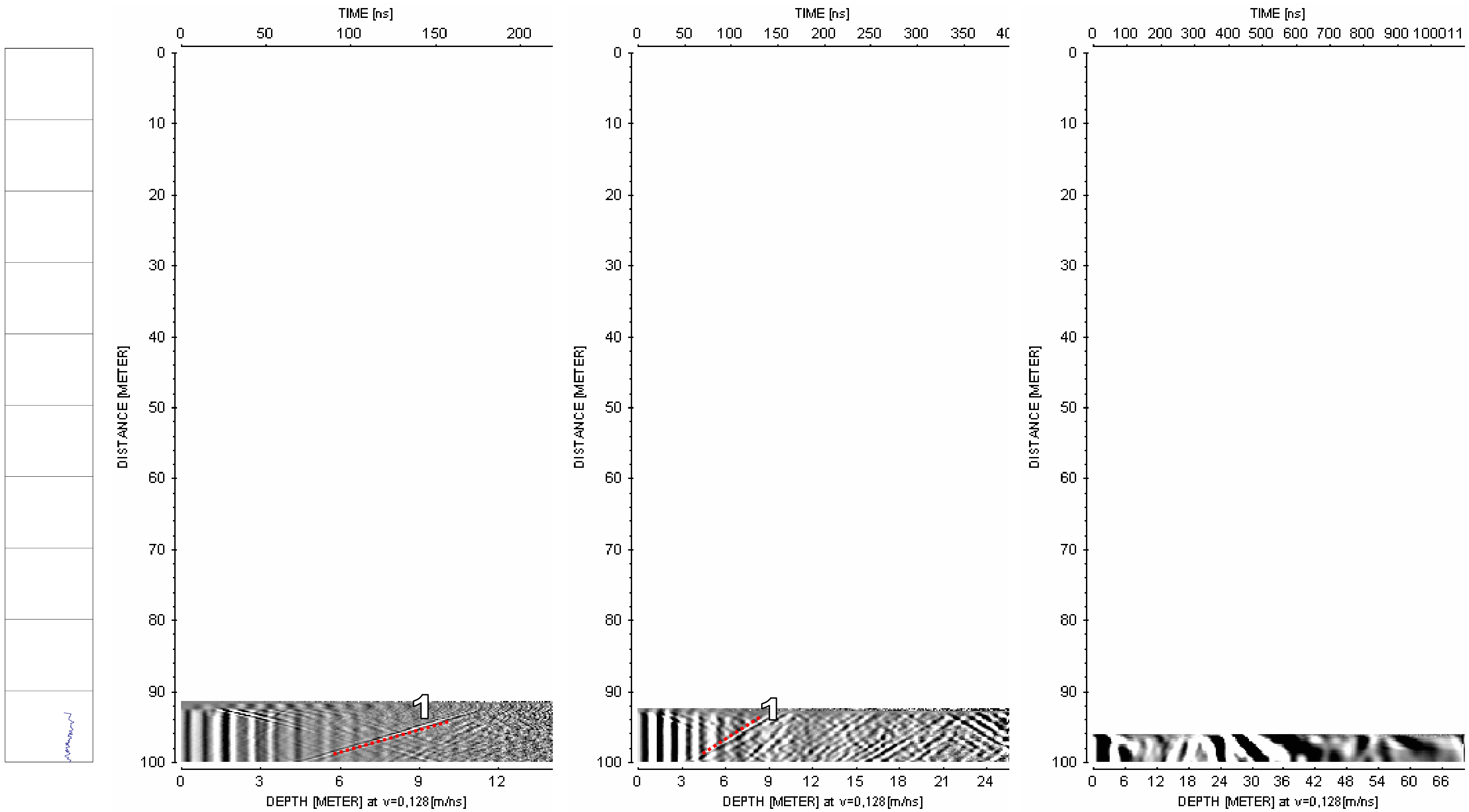
FORSMARK KFM01C



250 MHz **100 MHz** **20 MHz**

Radar logging in KFM01D, 90 to 799 m, dipole antennas 250, 100 and 20 MHz

Appendix 2. FORSMARK KFM01D

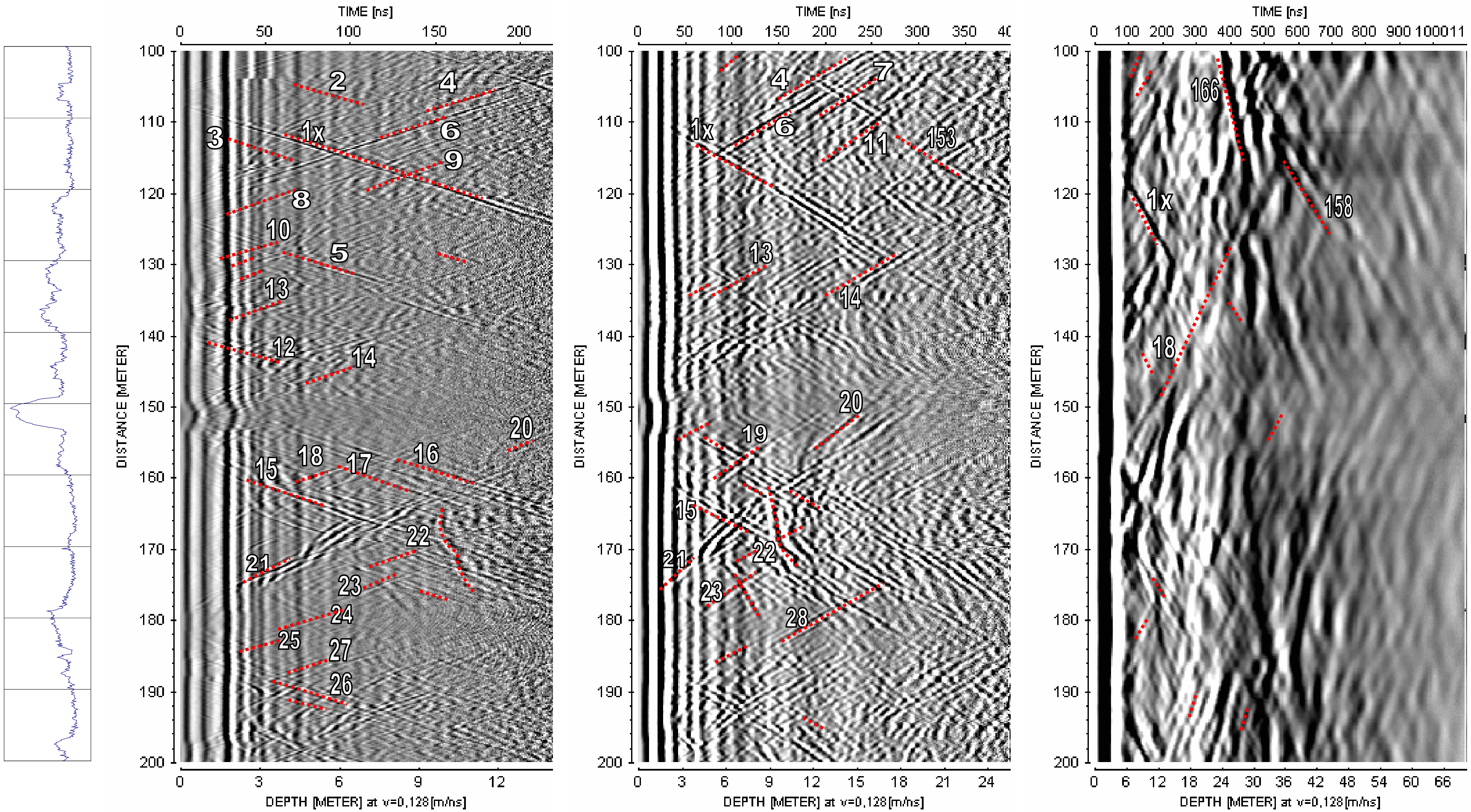


250 MHz

100 MHz

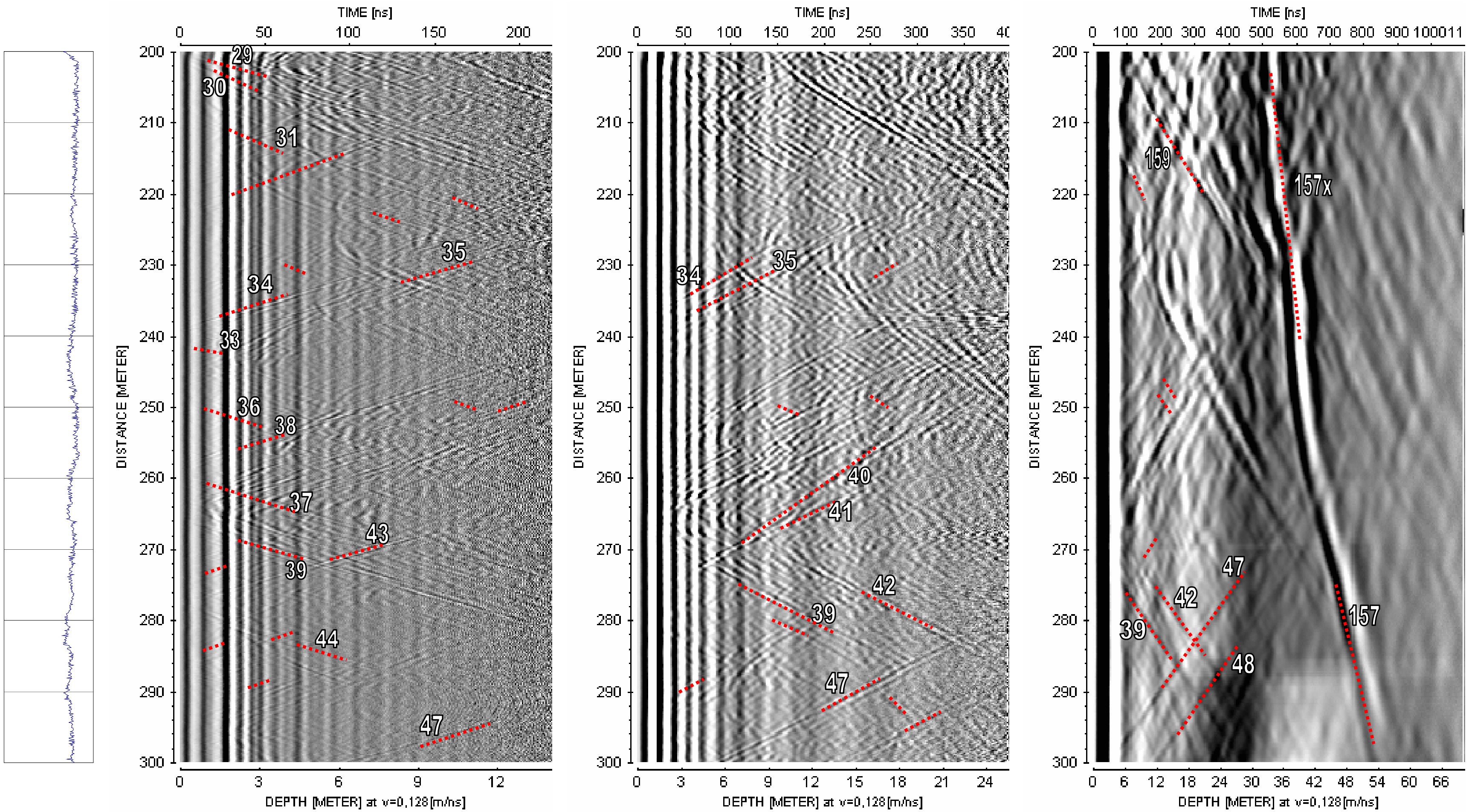
20 MHz

FORSMARK KFM01D



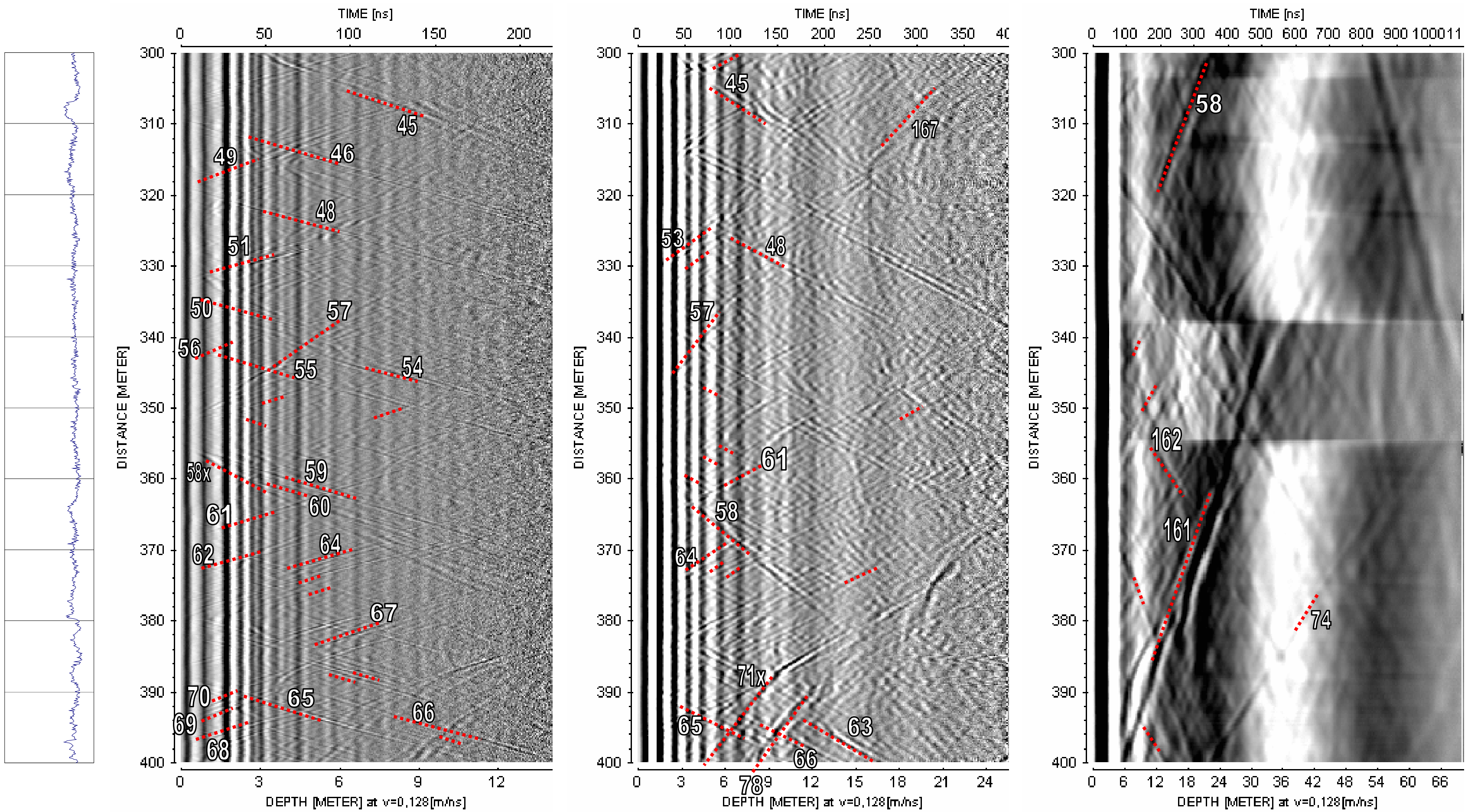
250 MHz **100 MHz** **20 MHz**

FORSMARK KFM01D



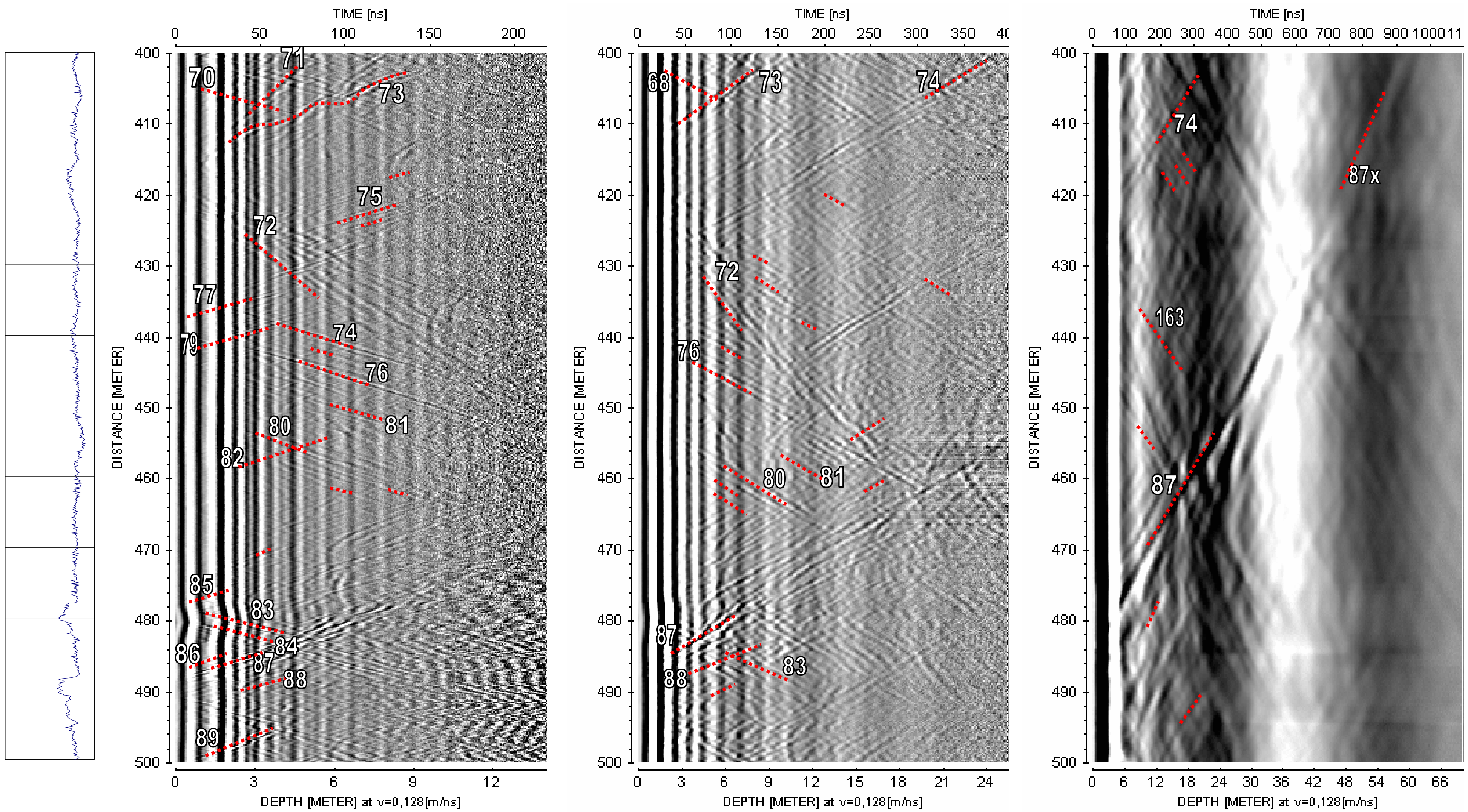
250 MHz **100 MHz** **20 MHz**

FORSMARK KFM01D



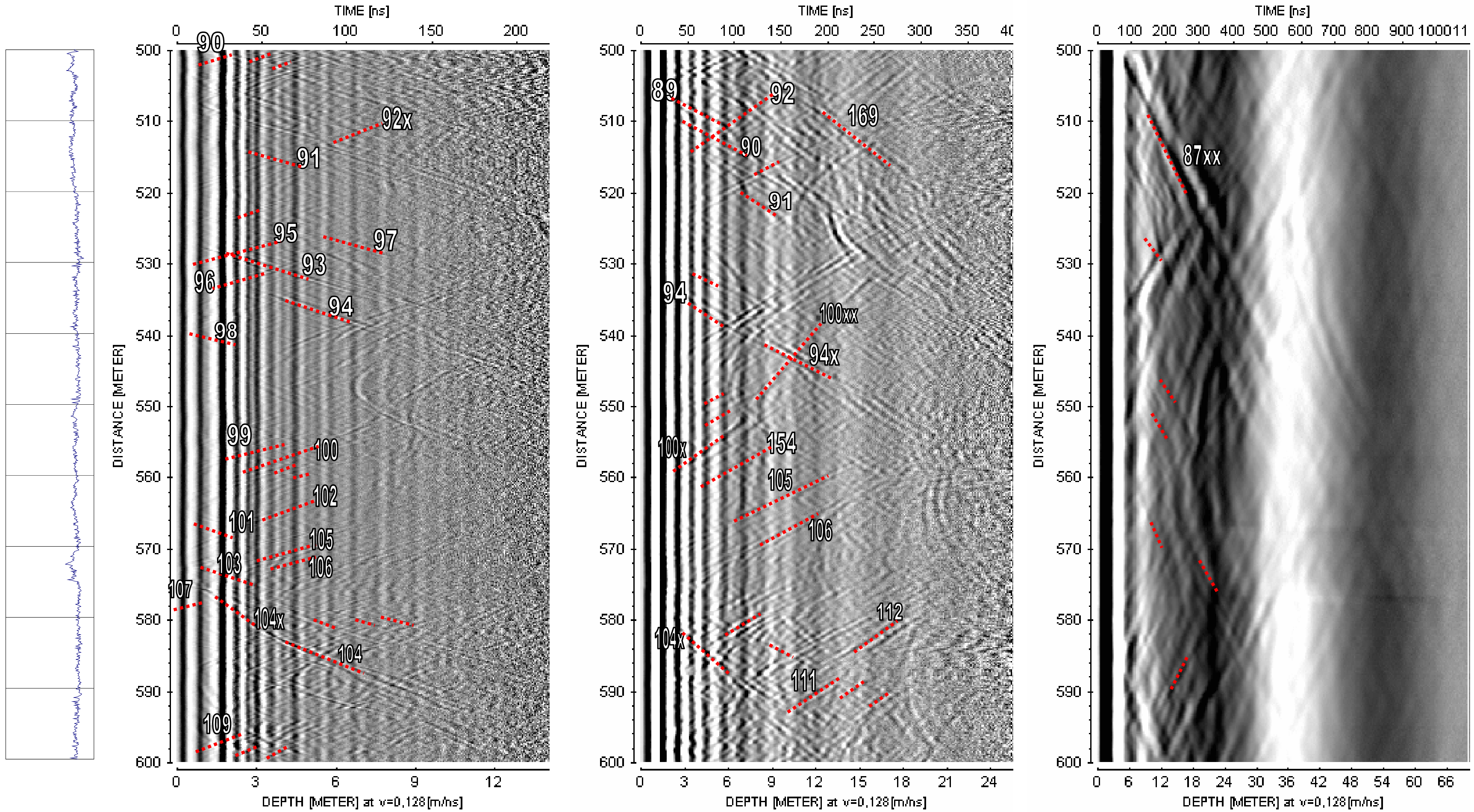
250 MHz **100 MHz** **20 MHz**

FORSMARK KFM01D



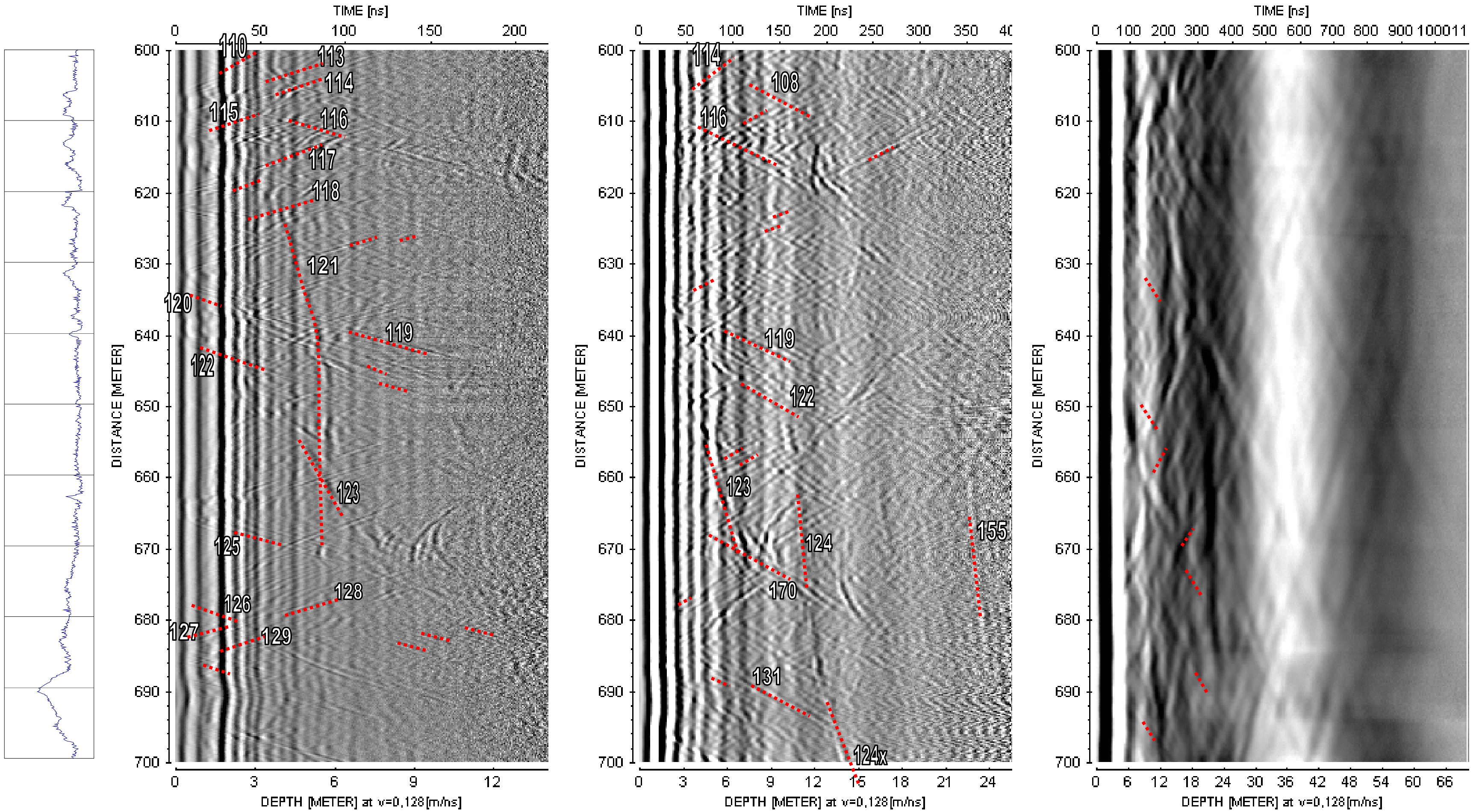
250 MHz **100 MHz** **20 MHz**

FORSMARK KFM01D



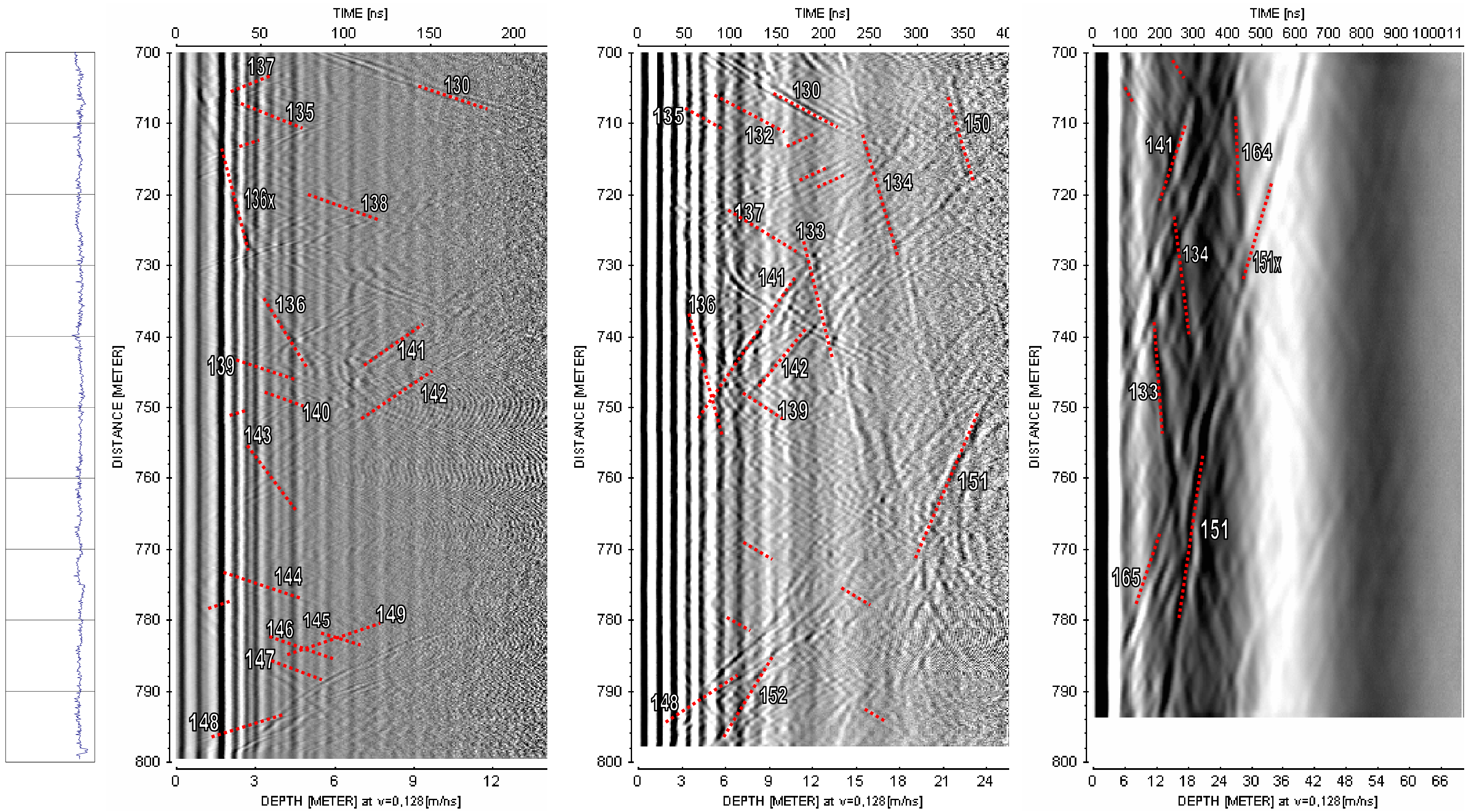
250 MHz **100 MHz** **20 MHz**

FORSMARK KFM01D



250 MHz **100 MHz** **20 MHz**

FORSMARK KFM01D



250 MHz

100 MHz

20 MHz

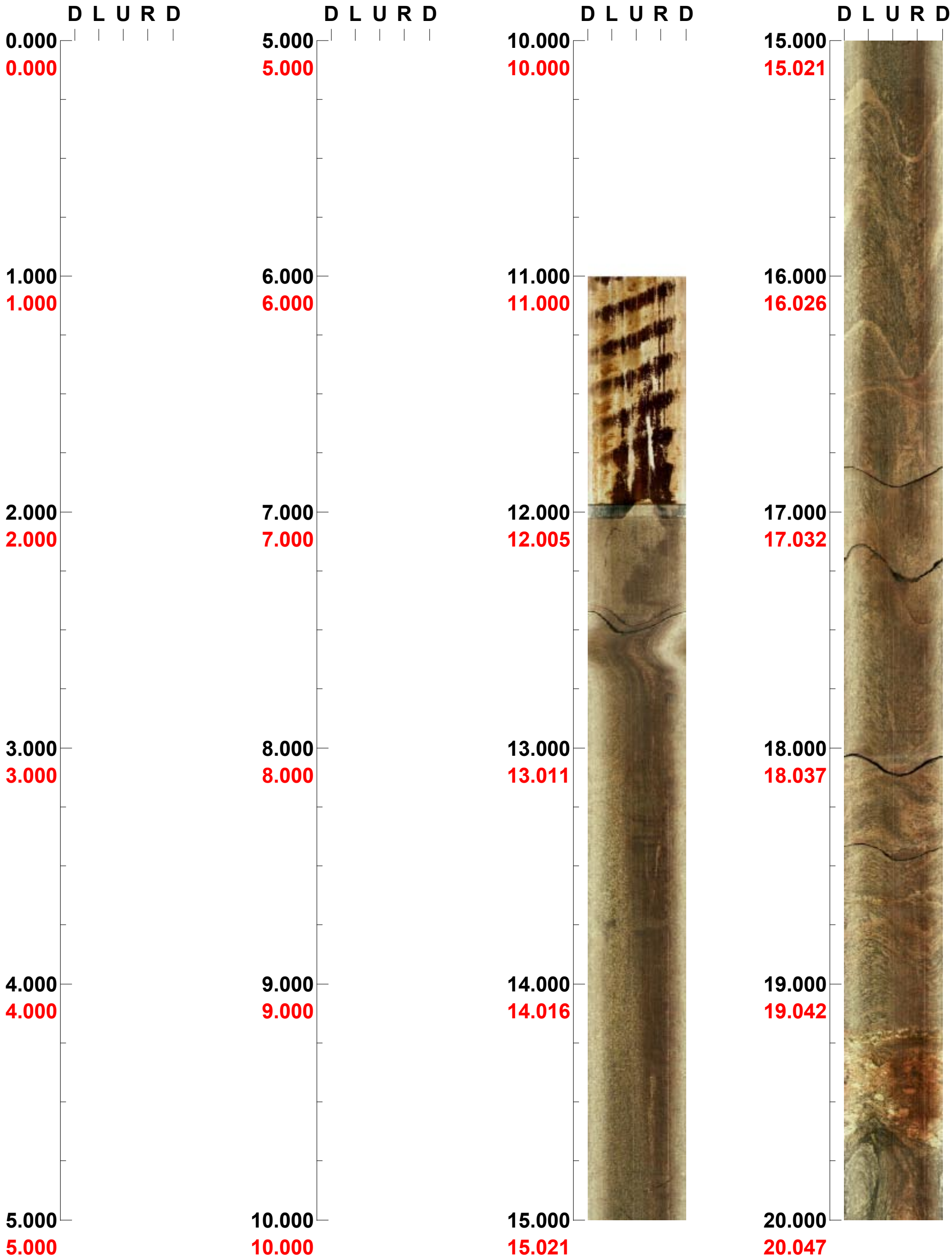
BIPS logging in KFM01C. 9 to 435 m

Project name: Forsmark

Image file	: c:\work\r5484f~1\bips\kfm01c_1.bip
BDT file	: c:\work\r5484f~1\bips\kfm01c_1.bdt
Locality	: FORSMARK
Bore hole number	: KFM01C
Date	: 06/03/08
Time	: 14:05:00
Depth range	: 11.000 - 439.665 m
Azimuth	: 165
Inclination	: -50
Diameter	: 76.0 mm
Magnetic declination	: 0.0
Span	: 4
Scan interval	: 0.25
Scan direction	: To bottom
Scale	: 1/25
Aspect ratio	: 175 %
Pages	: 14
Color	: +0 +0 +0

Project name: Forsmark
Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 0.000 - 20.000 m



(1 / 14) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01C Azimuth: 165 Inclination: -50

Depth range: 20.000 - 40.000 m

(2 / 14) Scale: 1/25 Aspect ratio: 175 %

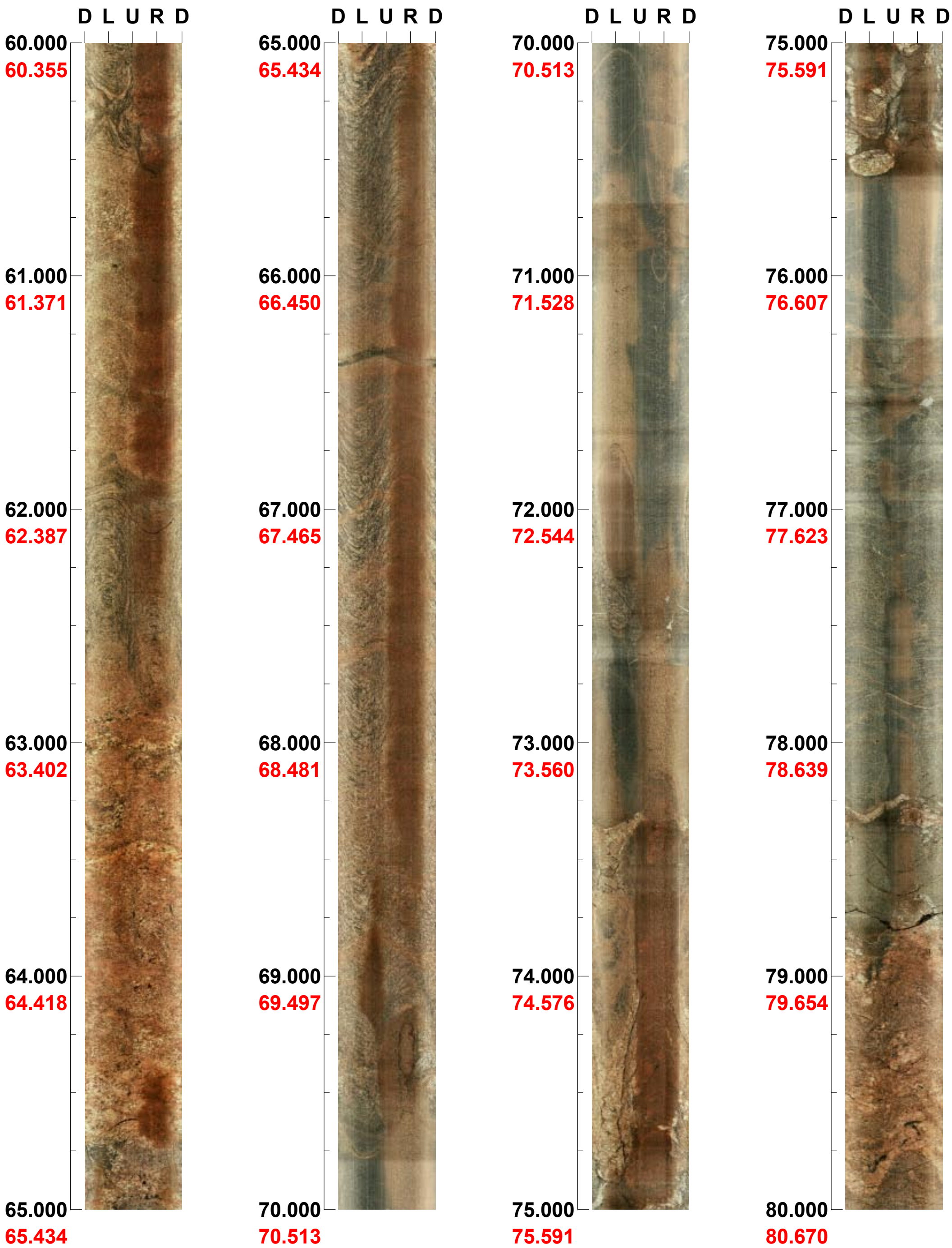
Project name: Forsmark
Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 40.000 - 60.000 m

(3 / 14) Scale: 1/25 Aspect ratio: 175 %

Project name: Forsmark
Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 60.000 - 80.000 m



(4 / 14) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 80.000 - 100.000 m

(5 / 14) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 100.000 - 120.000 m

(6 / 14) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 120.000 - 140.000 m

(7 / 14) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 140.000 - 160.000 m

(8 / 14) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 160.000 - 180.000 m

(9 / 14) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 180.000 - 200.000 m

(10 / 14) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 200.000 - 220.000 m

(11 / 14) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 220.000 - 240.000 m

(12 / 14) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

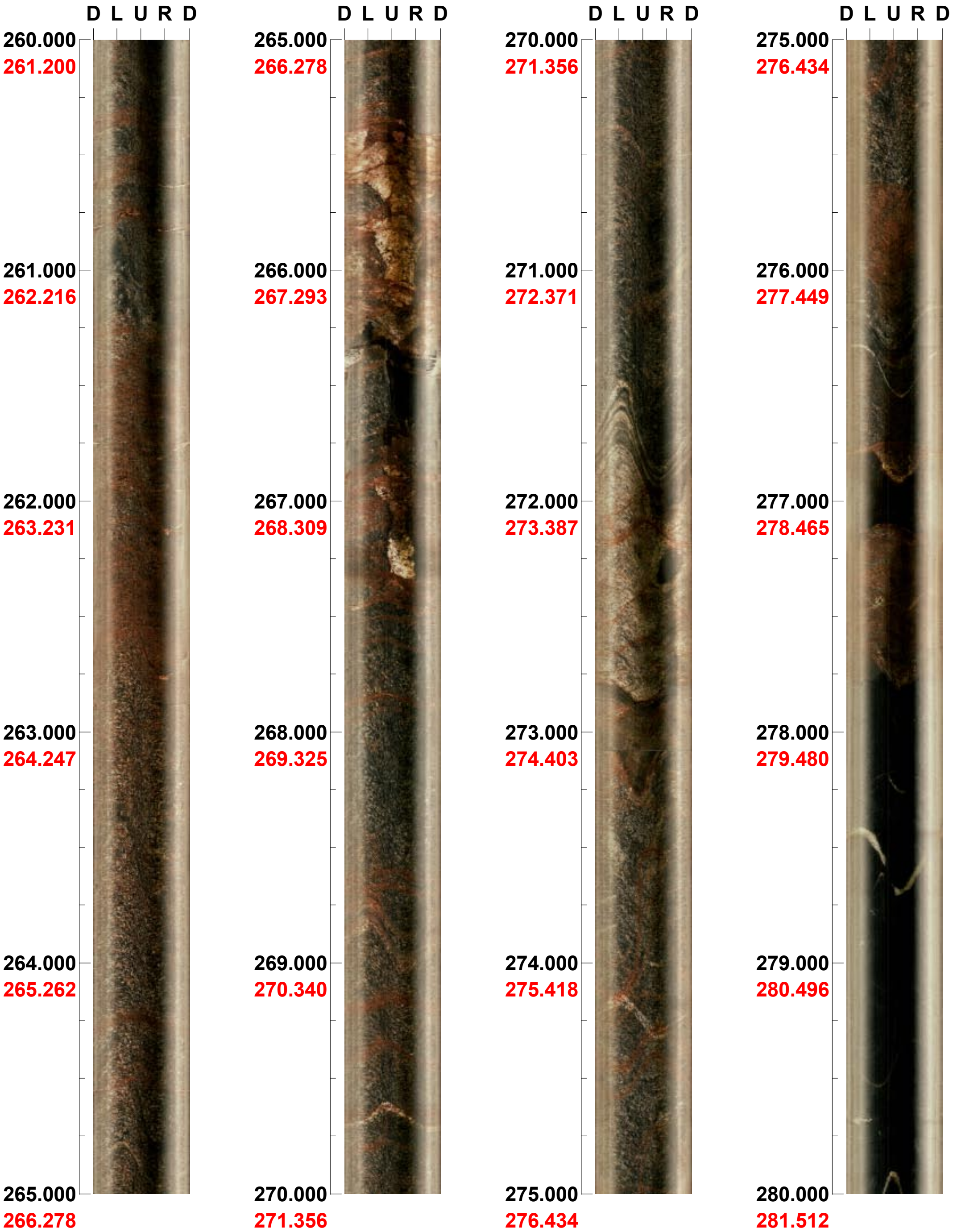
Bore hole No.: KFM01C **Azimuth: 165** **Inclination: -50**

Depth range: 240.000 - 260.000 m

(13 / 14) Scale: 1/25 Aspect ratio: 175 %

Project name: Forsmark
Bore hole No.: KFMM01C Azimuth: 165 Inclination: -50

Depth range: 260.000 - 280.000 m

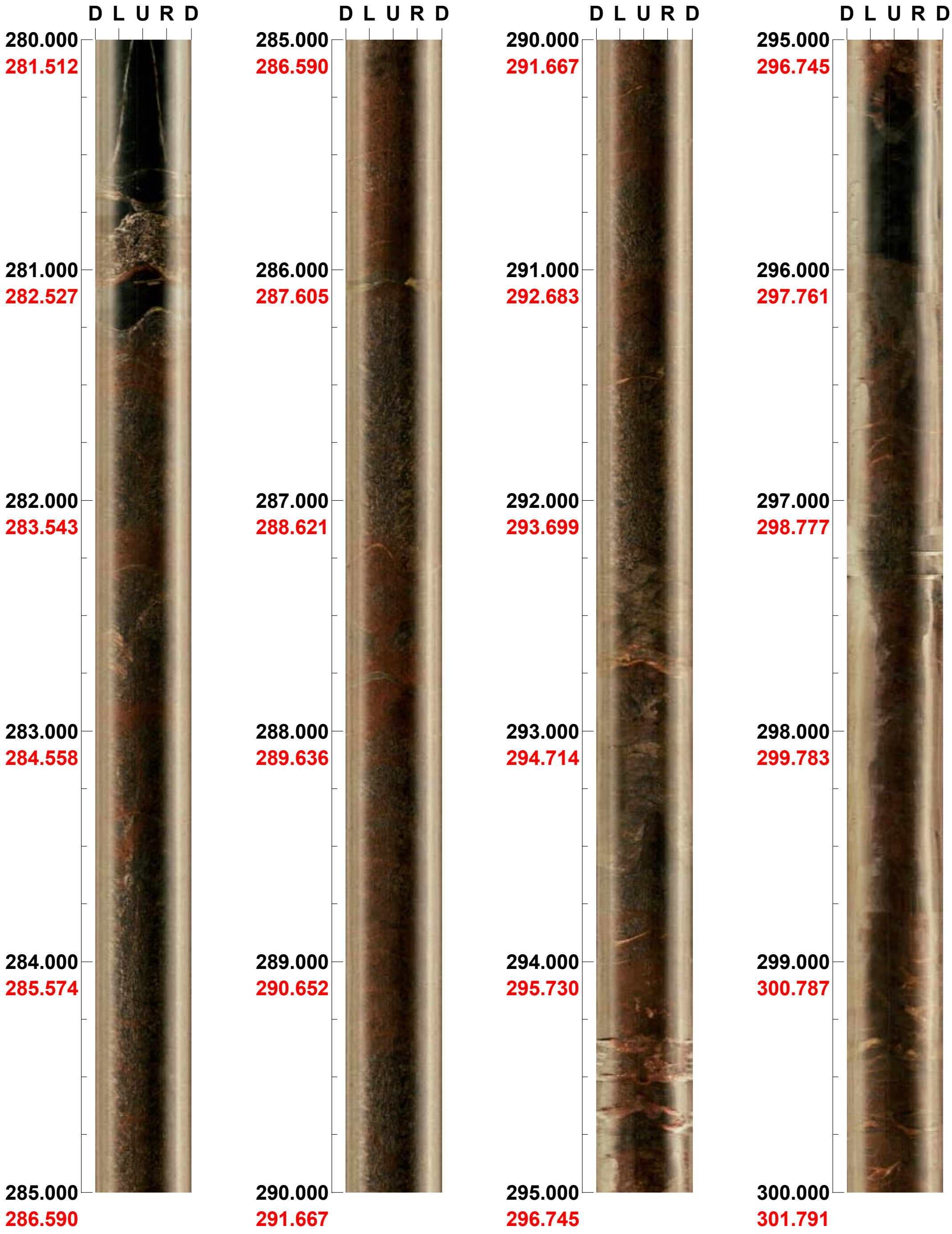


(1 / 9) Scale: 1/25 Aspect ratio: 175 %

Project name: Forsmark

Bore hole No.: KFMM01C **Azimuth: 165** **Inclination: -50**

Depth range: 280.000 - 300.000 m

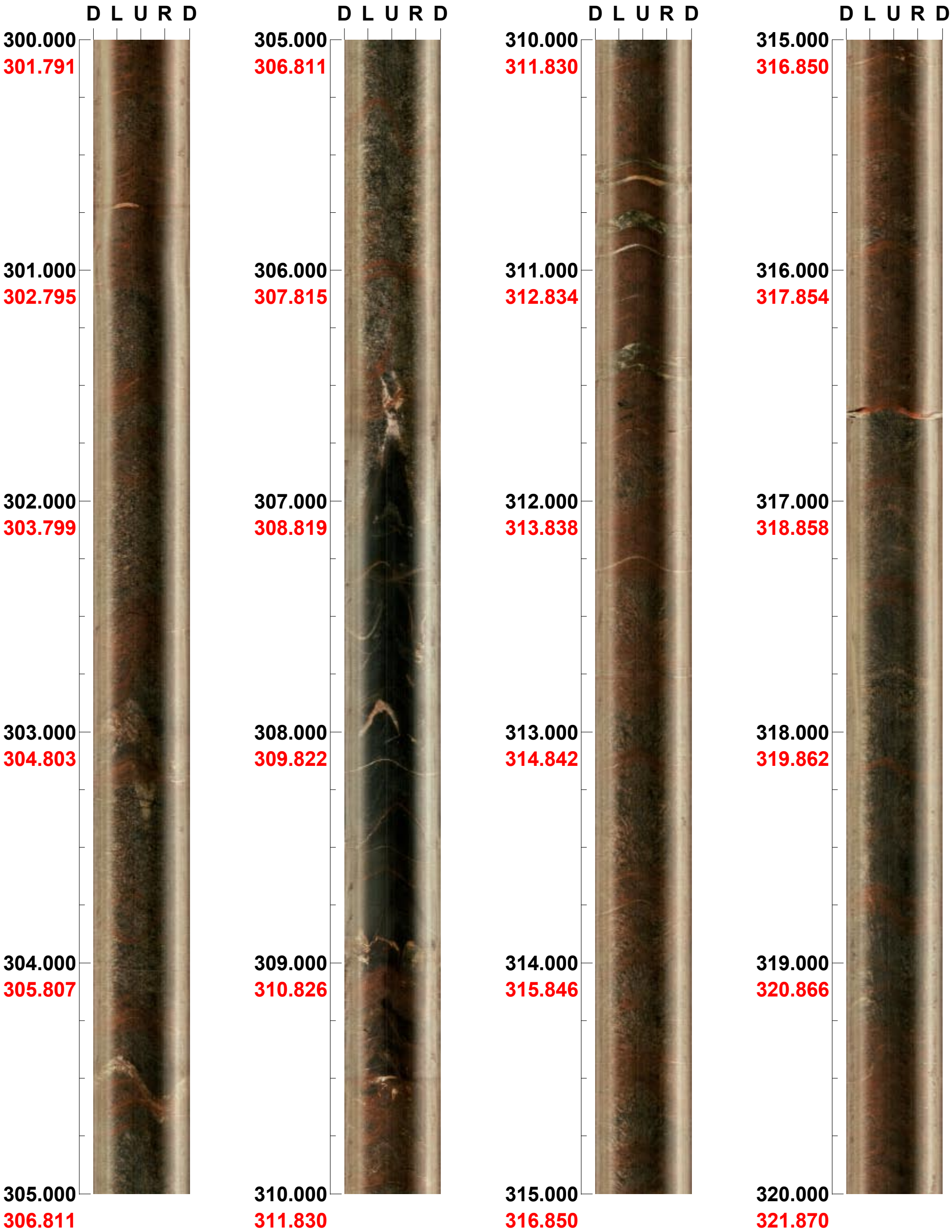


(2 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFMM01C **Azimuth: 165** **Inclination: -50**

Depth range: 300.000 - 320.000 m

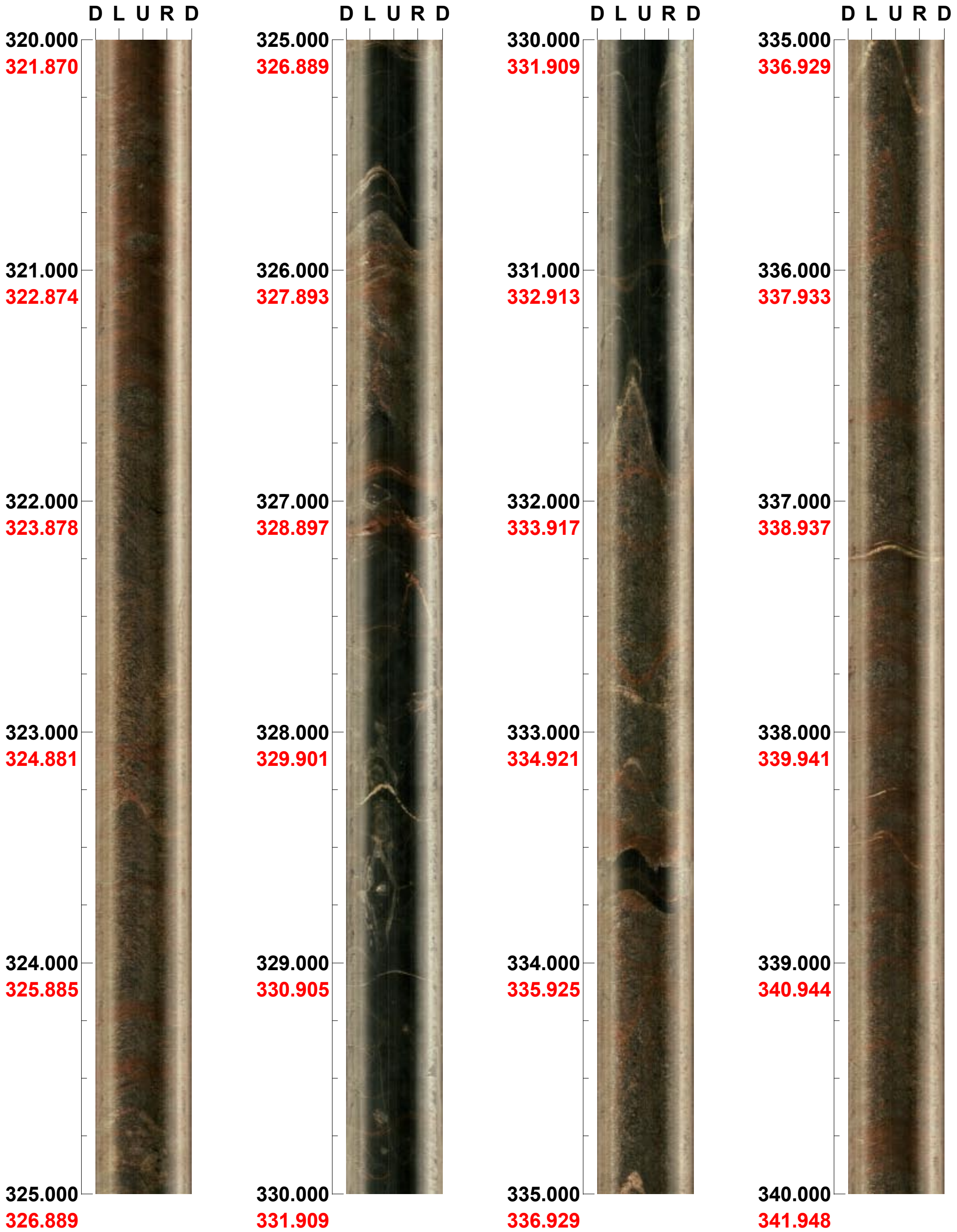


(3 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFMM01C **Azimuth: 165** **Inclination: -50**

Depth range: 320.000 - 340.000 m

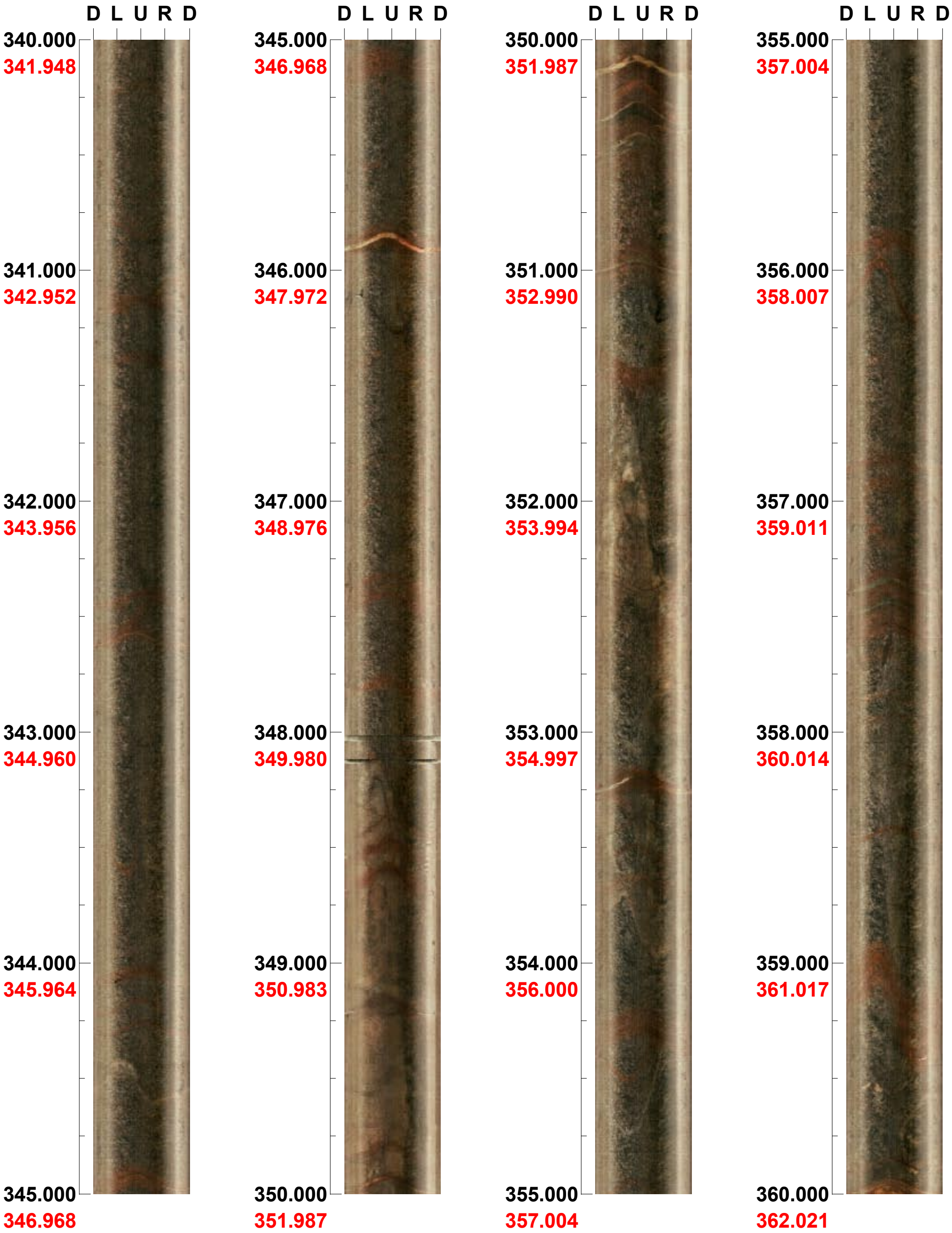


(4 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFMM01C **Azimuth: 165** **Inclination: -50**

Depth range: 340.000 - 360.000 m



(5 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFMM01C **Azimuth: 165** **Inclination: -50**

Depth range: 360.000 - 380.000 m

(6 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFMM01C **Azimuth: 165** **Inclination: -50**

Depth range: 380.000 - 400.000 m

(7 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFMM01C **Azimuth: 165** **Inclination: -50**

Depth range: 400.000 - 420.000 m

(8 / 9) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFMM01C Azimuth: 165 Inclination: -50

Depth range: 420.000 - 439.665 m

(9 / 9) Scale: 1/25 Aspect ratio: 175 %

BIPS logging in KFM01D. 91 to 796 m

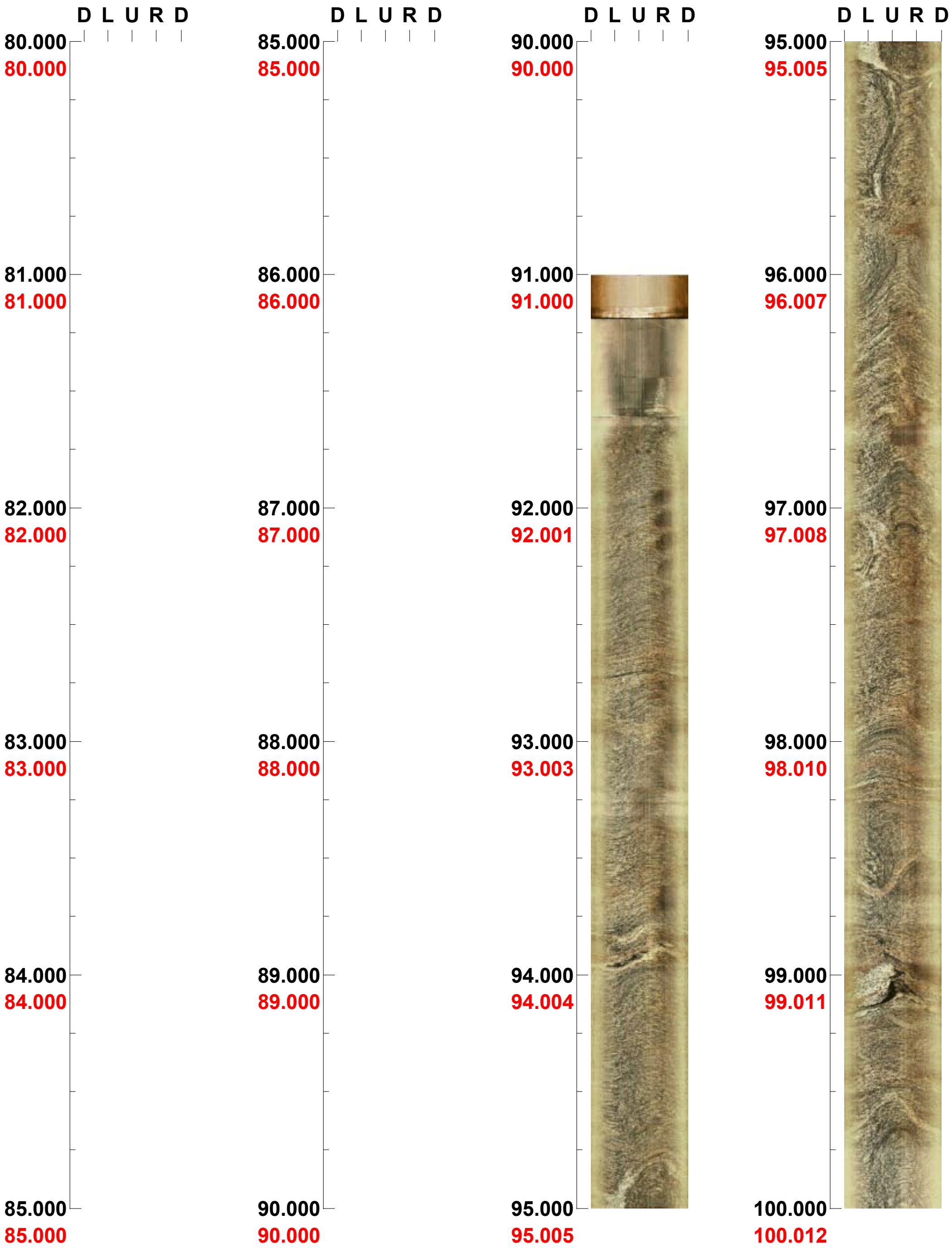
Project name: Forsmark

Image file	: c:\work\r55__k~1\bips\kfm01d_1.bip
BDT file	: c:\work\r55__k~1\bips\kfm01d_1.bdt
Locality	: FORSMARK
Bore hole number	: KFM01D
Date	: 06/03/13
Time	: 15:56:00
Depth range	: 91.000 - 796.001 m
Azimuth	: 35
Inclination	: -55
Diameter	: 76.0 mm
Magnetic declination	: 0.0
Span	: 4
Scan interval	: 0.25
Scan direction	: To bottom
Scale	: 1/25
Aspect ratio	: 175 %
Pages	: 19
Color	: +0 +0 +0

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 80.000 - 100.000 m

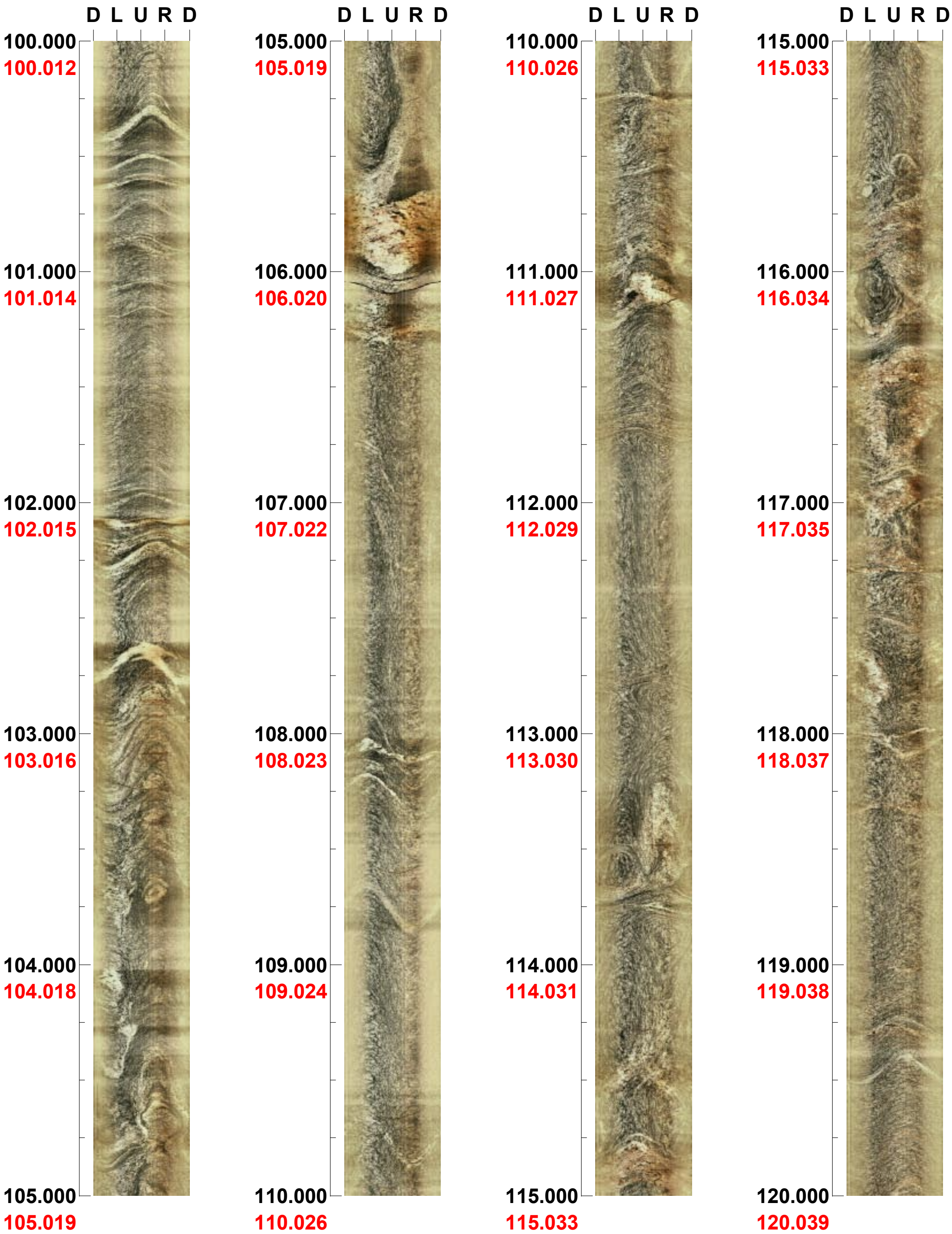


(1 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 100.000 - 120.000 m

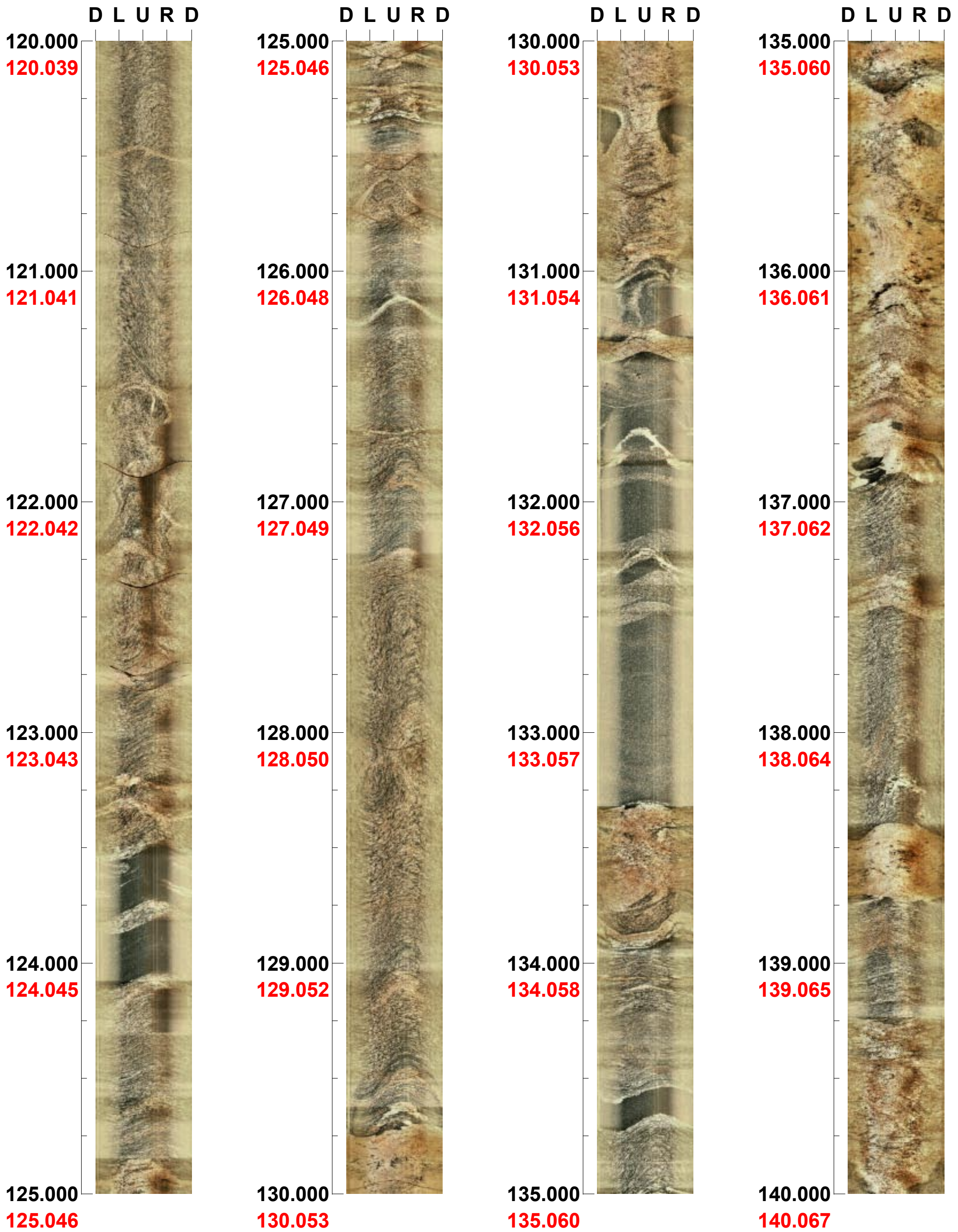


(2 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D Azimuth: 35 Inclination: -55

Depth range: 120.000 - 140.000 m

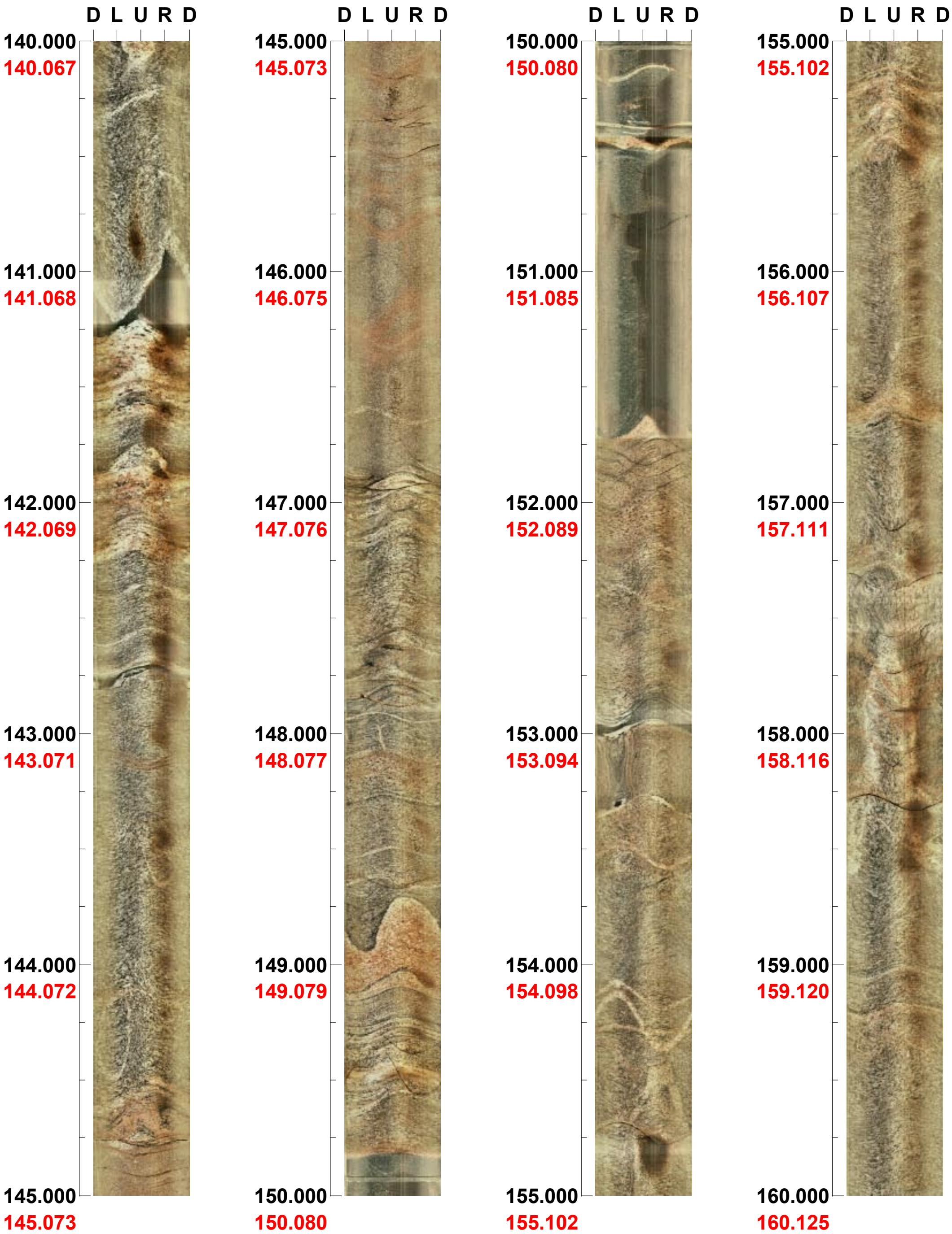


(3 / 19) Scale: 1/25 Aspect ratio: 175 %

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

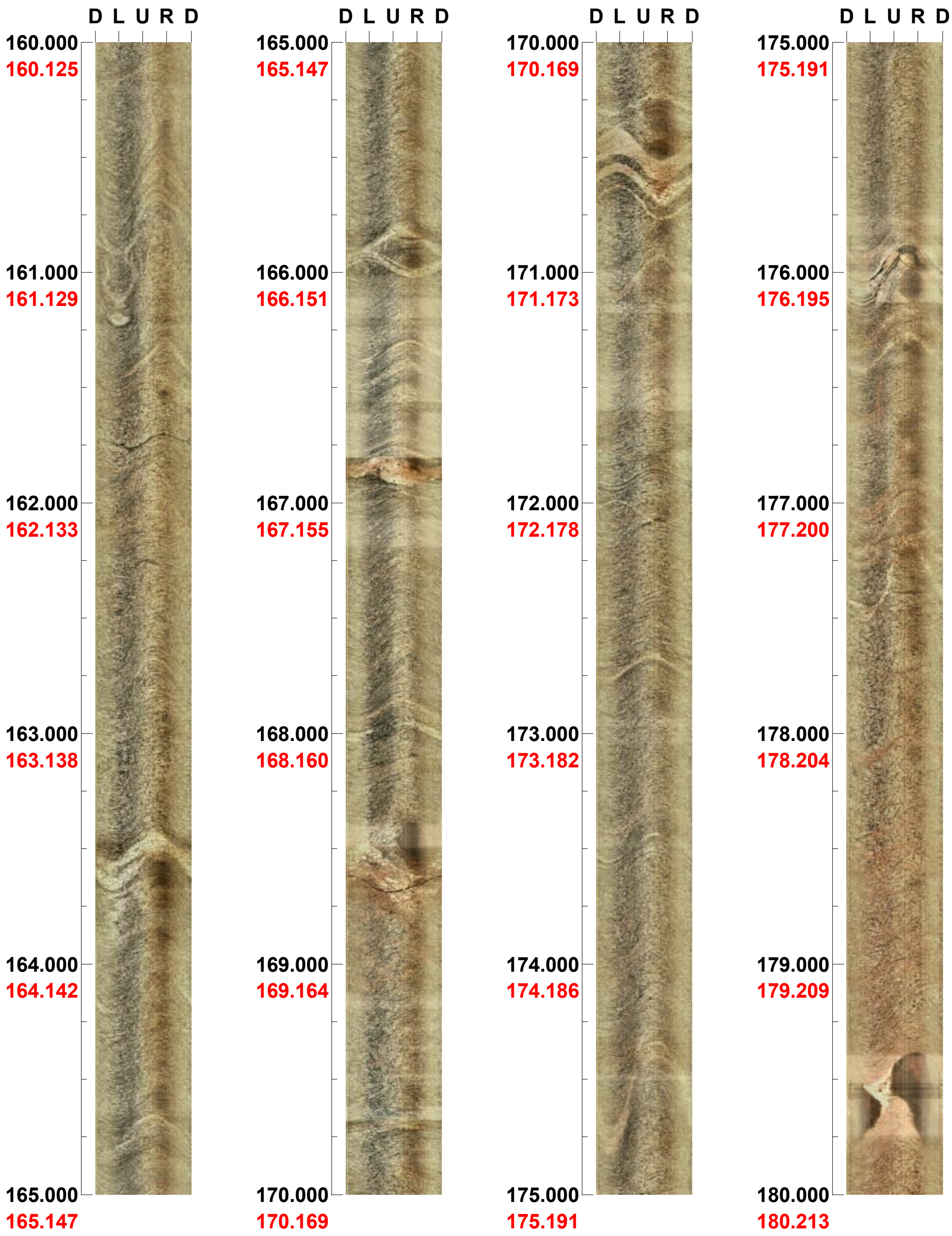
Depth range: 140.000 - 160.000 m



(4 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 160.000 - 180.000 m

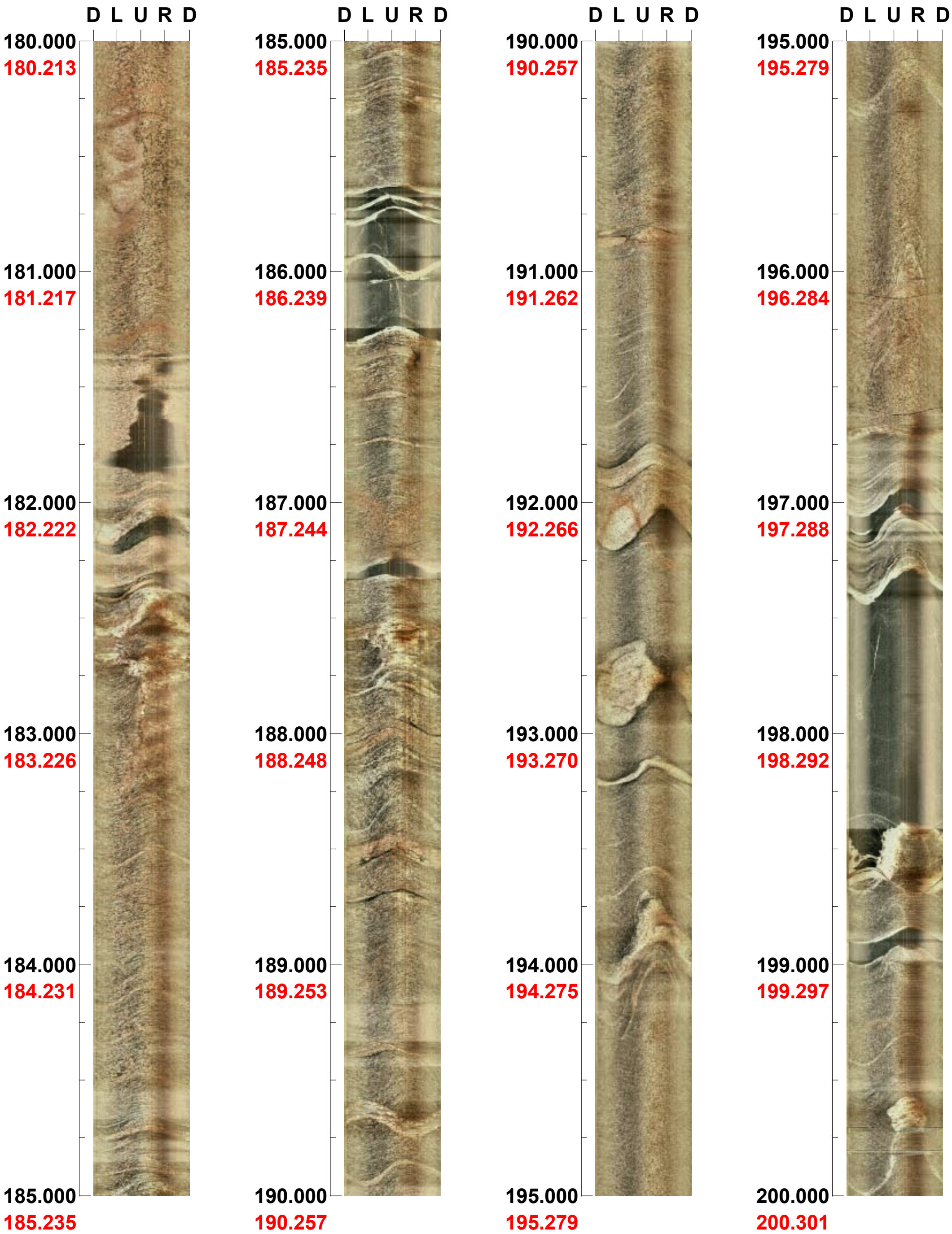


(5 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 180.000 - 200.000 m



(6 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 200.000 - 220.000 m

(7 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

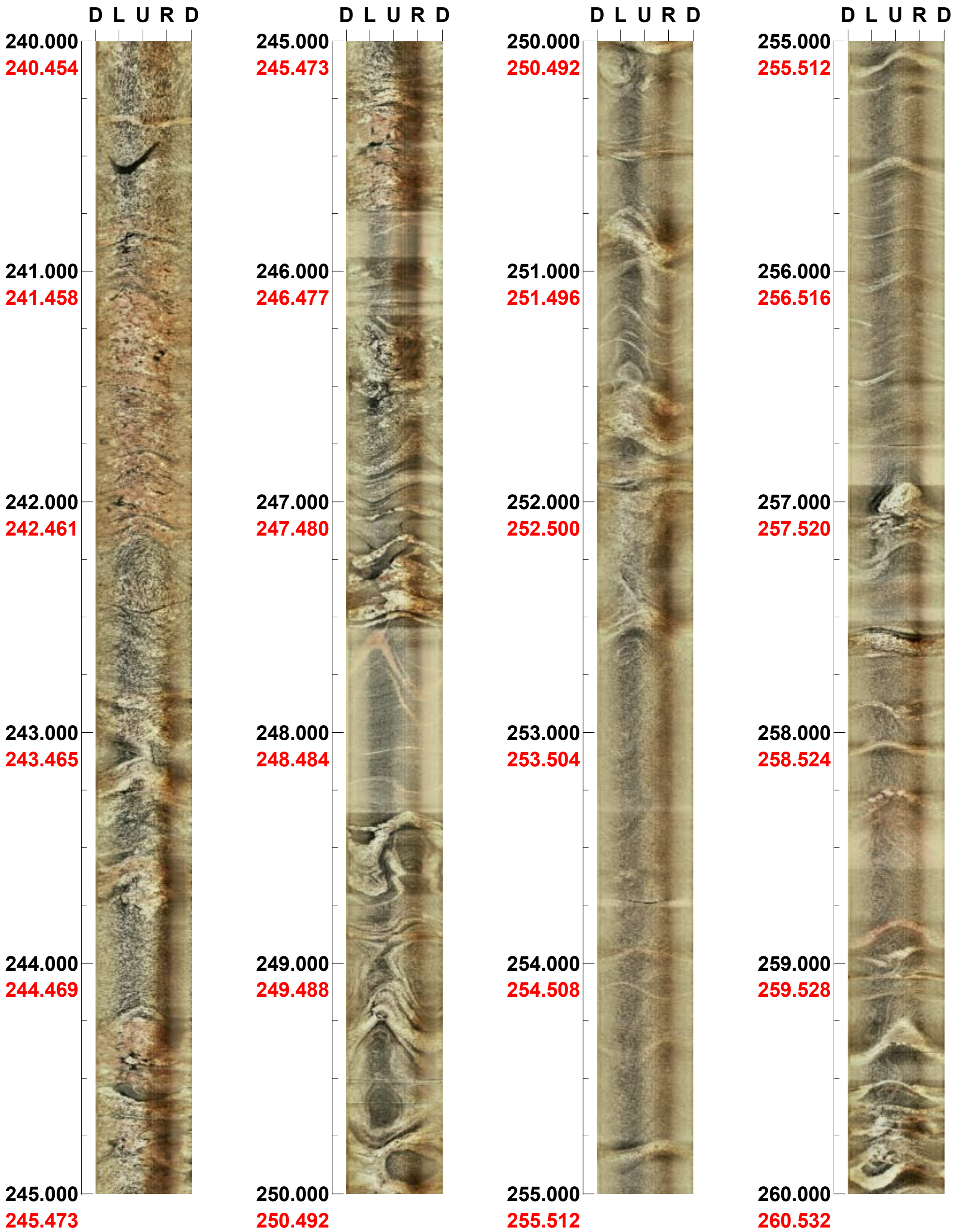
Depth range: 220.000 - 240.000 m

(8 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 240.000 - 260.000 m

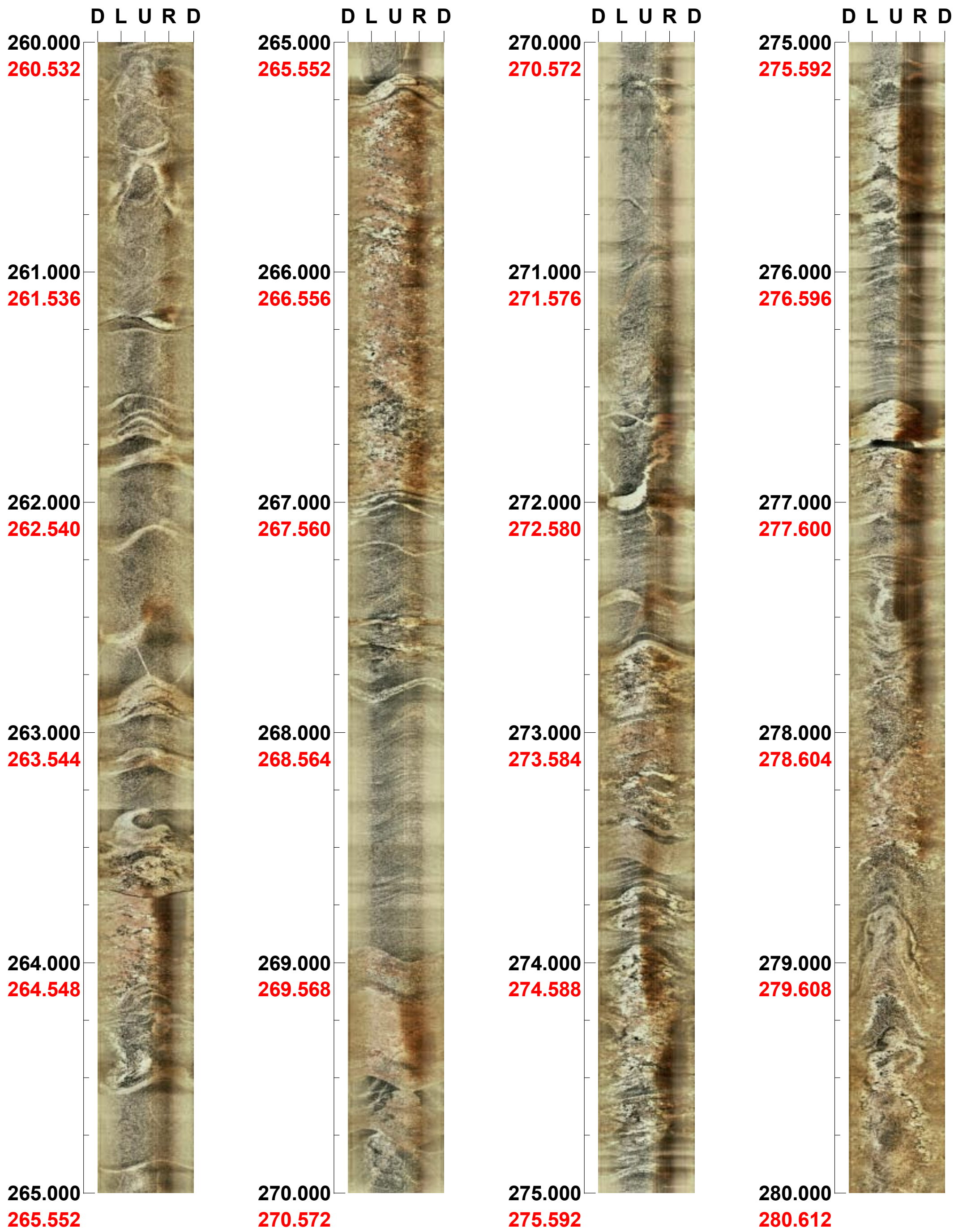


(9 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 260.000 - 280.000 m



(10 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

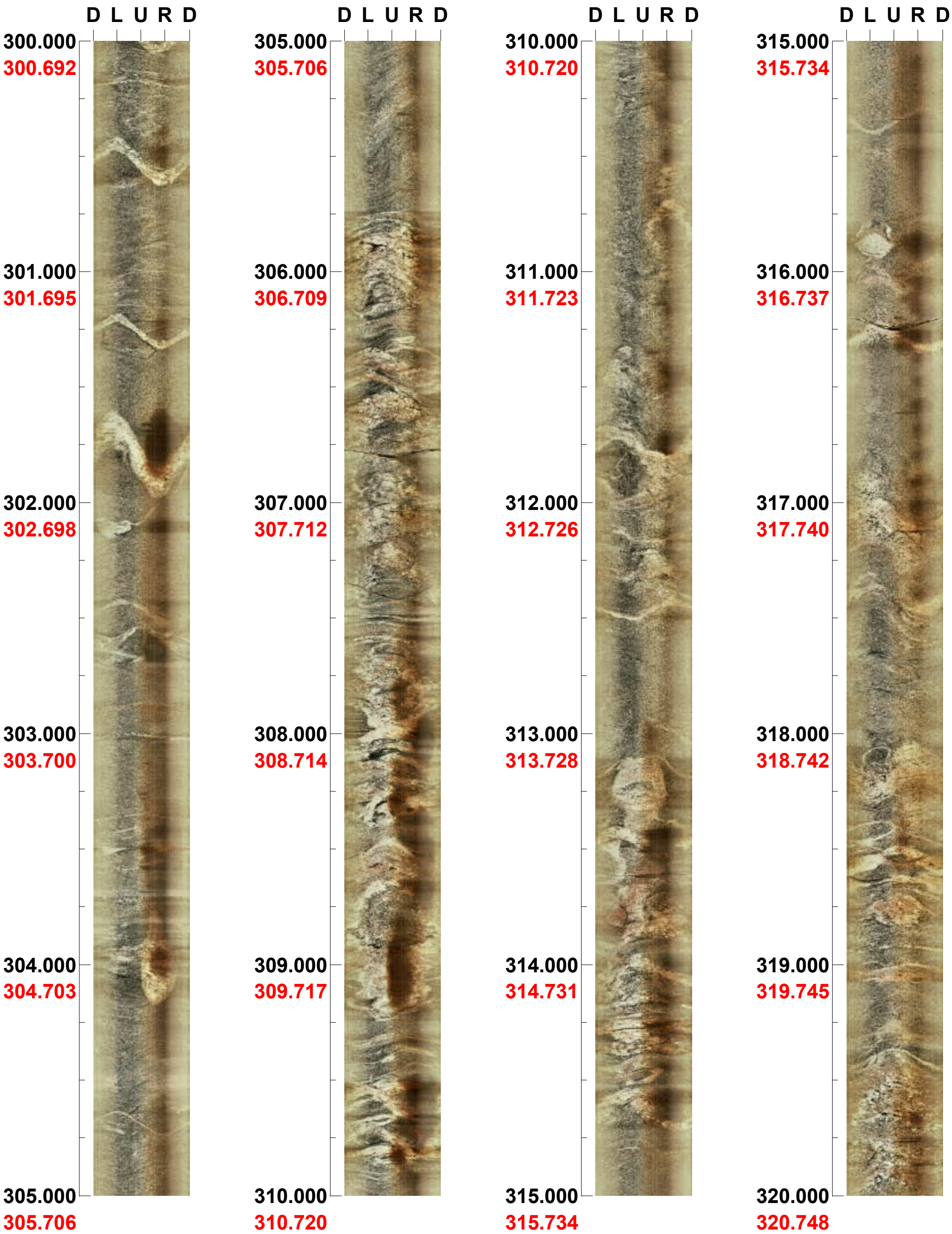
Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 280.000 - 300.000 m

(11 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 300.000 - 320.000 m



(12 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

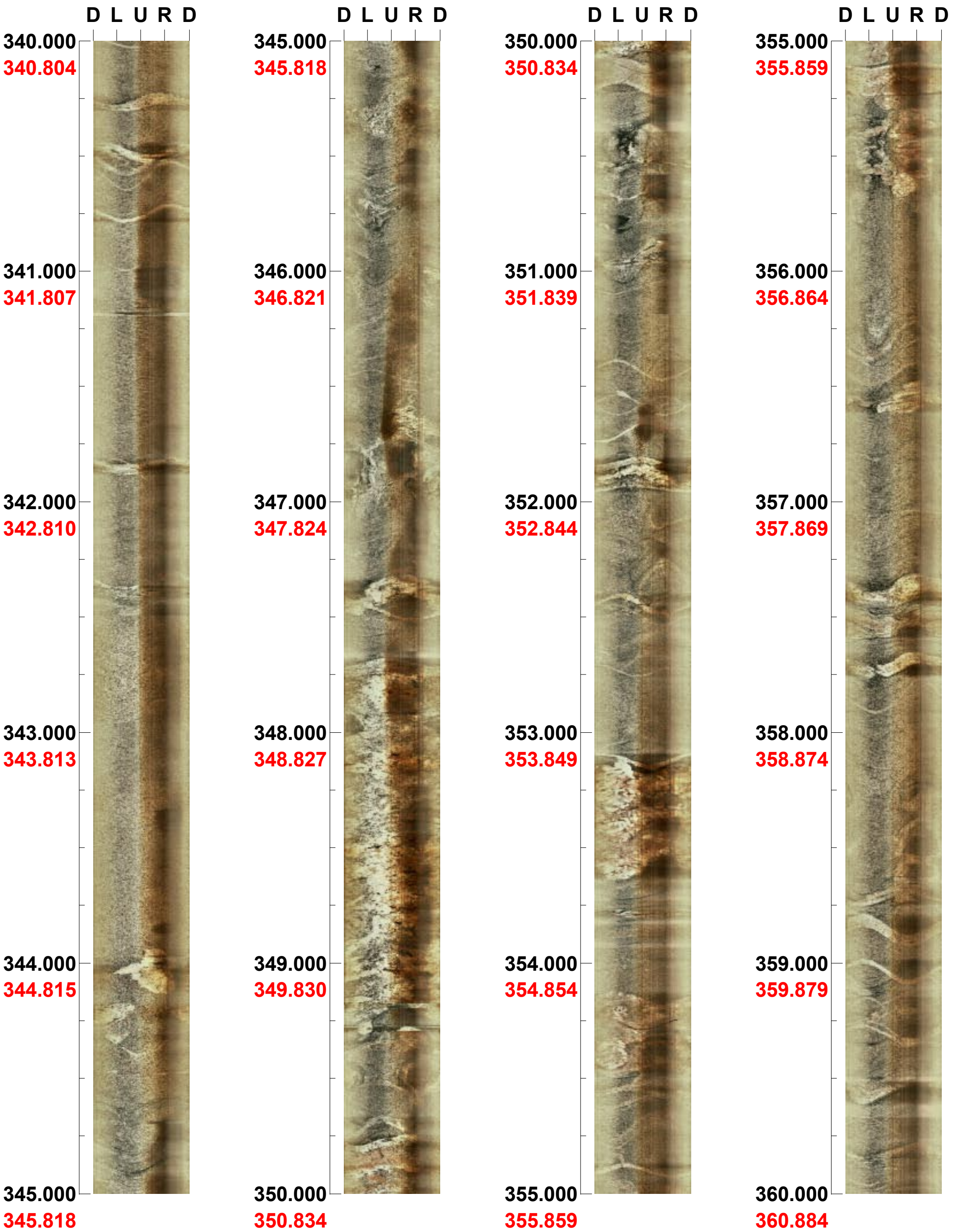
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 320.000 - 340.000 m

(13 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 340.000 - 360.000 m



(14 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 360.000 - 380.000 m

(15 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 380.000 - 400.000 m

(16 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 400.000 - 420.000 m

(17 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 420.000 - 440.000 m

(18 / 19) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 440.000 - 460.000 m

(1 / 11) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 460.000 - 480.000 m

(2 / 11) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 480.000 - 500.000 m

(3 / 11) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 500.000 - 520.000 m

(4 / 11) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 520.000 - 540.000 m

(5 / 11) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 540.000 - 560.000 m

(6 / 11) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 560.000 - 580.000 m

(7 / 11) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D Azimuth: 35 Inclination: -55

Depth range: 580.000 - 600.000 m

(8 / 11) Scale: 1/25 Aspect ratio: 175 %

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 600.000 - 620.000 m

(9 / 11) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 620.000 - 640.000 m

(10 / 11) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D Azimuth: 35 Inclination: -55

Depth range: 640.000 - 659.991 m

(11 / 11) Scale: 1/25 Aspect ratio: 175 %

Project name: Forsmark
Bore hole No.: KFM01D Azimuth: 35 Inclination: -55

Depth range: 660.000 - 680.000 m

(1 / 7) Scale: 1/25 Aspect ratio: 175 %

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 680.000 - 700.000 m

(2 / 7) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark

Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 700.000 - 720.000 m

(3 / 7) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 720.000 - 740.000 m

(4 / 7) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 740.000 - 760.000 m

(5 / 7) **Scale: 1/25** **Aspect ratio: 175 %**

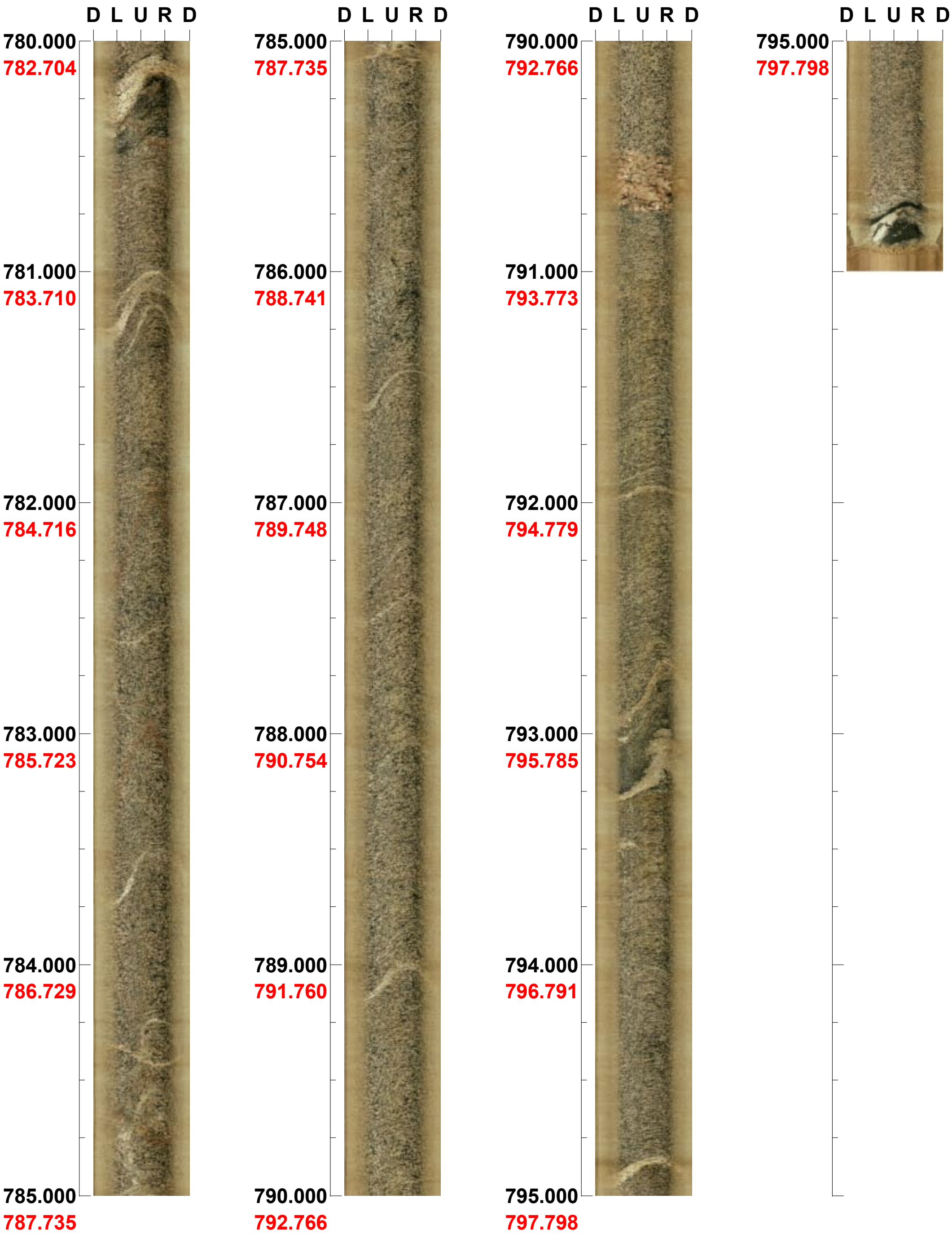
Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 760.000 - 780.000 m

(6 / 7) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01D **Azimuth: 35** **Inclination: -55**

Depth range: 780.000 - 795.996 m



(7 / 7) **Scale: 1/25** **Aspect ratio: 175 %**