P-04-79

Forsmark site investigation

RAMAC and BIPS logging in borehole KFM01B and RAMAC directional re-logging in borehole KFM01A

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May 2004

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Contents

1 Introduction

This document reports data gained during geophysical logging, which is one of the activities performed within the site investigation at Forsmark. The logging operations presented here include borehole radar (RAMAC) and TV-logging (BIPS) and were carried out in the cored drilled part of the boreholes KFM01A and KFM01B, see Table1-1 and Figure 1-1.

Radar and TV-logging in KFM01A have been performed before, both in the upper, percussion drilled part /1/ and in the cored drilled part /2/. When the cored drilled part was logged, the directional antenna produced erroneous results, which made re-logging necessary.

In KFM01A only the RAMAC directional antenna was used. The dipole radar and BIPS logging have been carried out earlier /2/. The radar measurements with directional antenna in KFM01A were made from 100 m to a depth of approximately 990 m and radar measurements (dipole and directional antennas) and BIPS measurements were made in KFM01B from 15 to 490 m.

The borehole radar measurements were made in January and February 2004.

BIPS measurements in KFM01B have been made on several occasions. In this report the latest measurements, carried out in March 2004 and involving the total length of the borehole is reported. However, an earlier measurement, from September 2003, of the upper part (15–95 m) is also presented. This is because this part of the borehole was injected with cement in order to stabilize the borehole wall, before the drilling continued.

All measurements were conducted by Malå Geoscience AB / RAYCON according to activity plan AP PF 400-02-44 (KFM01A) and AP PF 400-03-47 (KFM01B).

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.

Table 1-1. Investigated boreholes.

Borehole ID	Azimuth (degrees from north)	Inclination (degrees from horizontal)	Length (m)	Investigated section (m)
KFM01A	318	85	1001	100–990
KFM01B	268	79	501	15–490

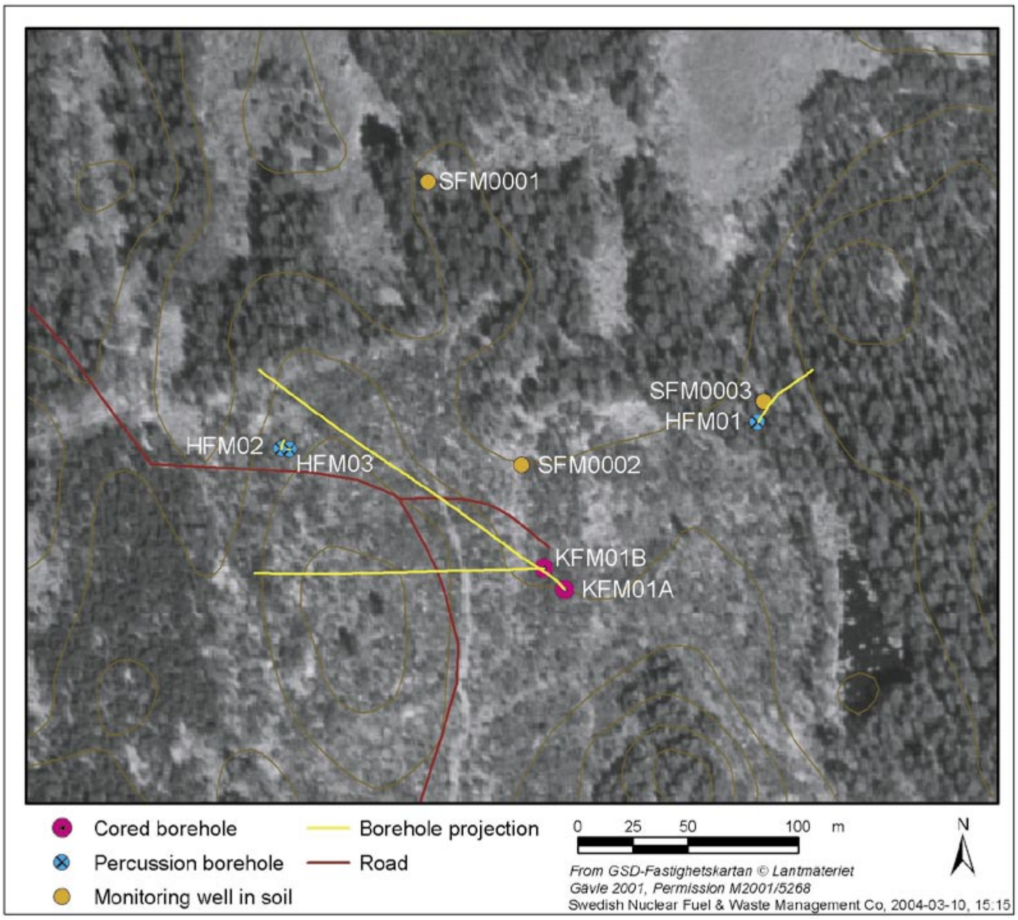


Figure 1-1. *Overview of drill site no 1 in the Forsmark area.*

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 surrounding 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 wall including determination of fracture distribution and orientation.

This report describes the equipment used as well the measurement procedures and data gained.

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 252.020, 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.

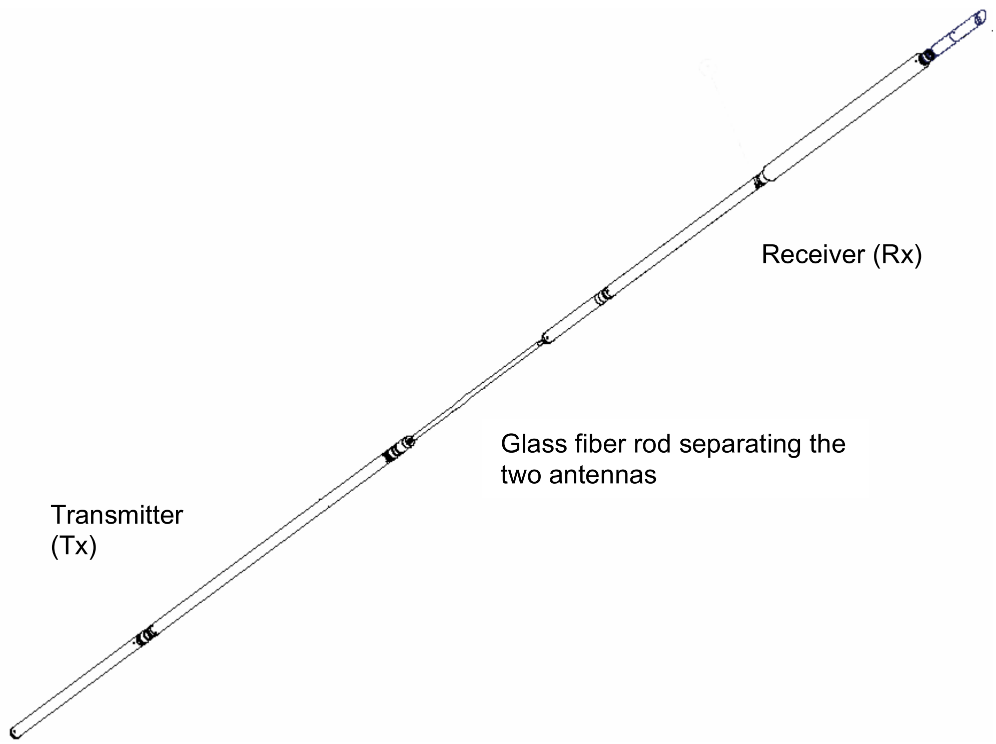


Figure 3-1. *Example of a borehole antenna.*

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 222.006, 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).

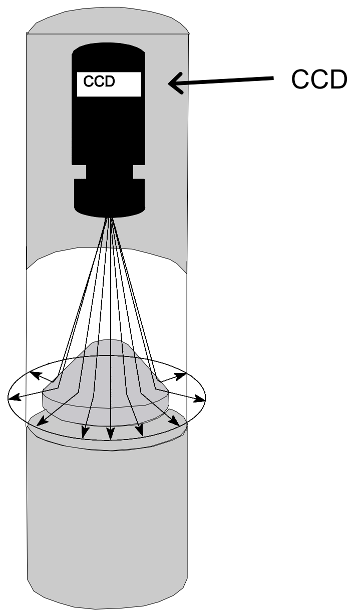


Figure 3-2. *The BIP-system. Illustration of the conical mirror scanning.*

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. In borehole KFM01A only the directional antenna were used during this logging operation. See also /2/.

During logging, the dipole antennas are 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 transmitter and receiver 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 ("Instruktion för rengöring av borrhålsutrustning och viss markbaserad utrustning") for cleaning of equipment.

Information on the system settings for the different antennas used in the investigation of KFM01A and KFM01B is presented in Table 4-1 and 4-2 below.

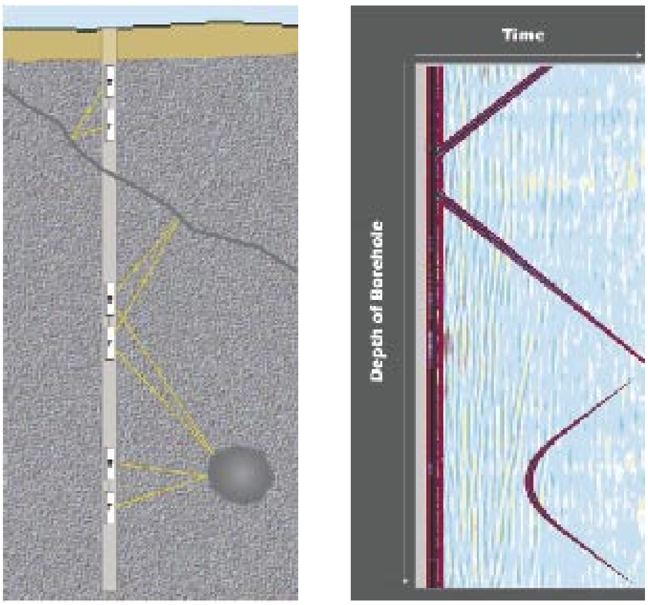


Figure 4-1. *The principle of radar borehole reflection survey (left) and a resulting radargram (right).*

Table 4-1. Radar logging information from KFM01A.

Site:	**Forsmark**	**Logging company:**	**RAYCON**
BH:	**KFM01A**	**Equipment:**	**SKB RAMAC**
Type:	**Directional**	**Manufacturer:**	**MALÅ GeoScience**
Operators:	**CG / JG**	**Antenna**	
		Directional (60 MHz)	
	Logging date:	2004-01-12 and 13	
	Reference:	T.O.C.	
	Sampling frequency (MHz):	656	
	Number of samples:	512	
	Number of stacks:	32	
	Signal position:	365.72	
	Logging from (m):	105.4	
	Logging to (m):	993	
	Trace interval (m):	0.5	
	Antenna separation (m):	5.73	

Table 4-2. Radar logging information from KFM01B.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM01A**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional / Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Operators:	**CG / JG**	**Antenna**			
		Directional (60 MHz)	**250 MHz**	**100 MHz**	**20 MHz**
	Logging date:	2004-02-10	2004-02-11	2004-02-11	2004-02-12
	Reference:	T.O.C	T.O.C	T.O.C	T.O.C
	Sampling frequency (MHz):	656	2588	951	257
	Number of samples:	512	716613	574	
	Number of stacks:	32	Auto	Auto	Auto
	Signal position:	365.72	–0.32	–0.32	–1.43
	Logging from (m):	18.4	1.5 2.6	6.25	
	Logging to (m):	493	499497	490	
	Trace interval (m):	0.5	0.1 0.2	0.25	
	Antenna separation (m):	5.73	2.4 3.9	10.05	

BIPS

BIPS measurements were only made in KFM01B. For BIPS measurements in KFM01A see /1/ and /2/.

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 measurements, 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 measure the orientation of the image.

Depth measurements

The depth recording for the RAMAC and BIP 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.

The depth divergence in KFM01A and KFM01B is less than 30 cm in the deepest parts of the boreholes.

4.2 Analyses and interpretation

The analyses and interpretation of the radar data from KFM01A (100–1000 m) include dipole data from the first logging /2/ and directional data from the re-logging.

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 large positive signals and white colour to large negative signals. Grey colour corresponds to no reflected signal.

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 4-2. The calculation shows a velocity of 128 m/micro second. The velocity measurement was performed with the 100 MHz antenna /1/.

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 4-3 and 4-4.

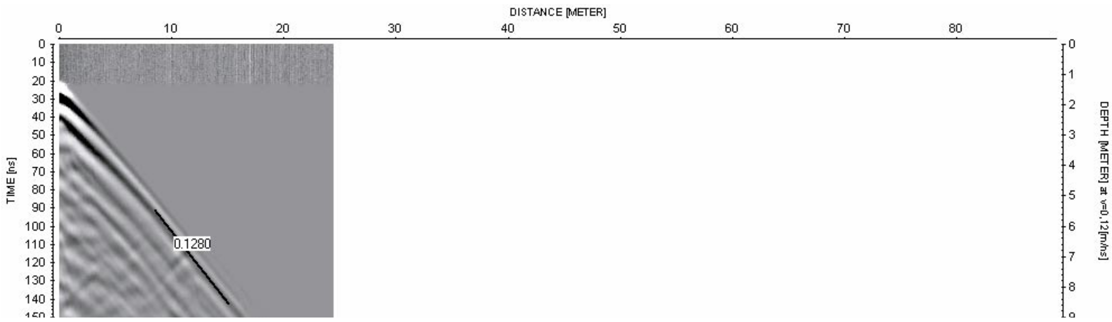


Figure 4-2. Results from velocity measurements in HFM03 /1/.

Table 4-3. Processing steps for borehole radar data from KFM01A.

Site:	**Forsmark**	**Logging company:**	**RAYCON**
BH:	**KFM01A**	**Equipment:**	**SKB RAMAC**
Type:	**Directional**	**Manufacturer:**	**MALÅ GeoScience**
Interpret:	**JG**	**Antenna**	
		Directional	
	Processing:	DC removal	
		Move start time	
		FIR	
		Gain	

Table 4-4. Processing steps for borehole radar data from KFM01B.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM01B**	**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	Gain	Gain	Gain
		Gain			

For the interpretation of the intersection angle between the borehole axis and the planes visible on the radargrams, the RadinterSKB software has been used. RadinterSKB is also used to interpret the orientation of structures identified in the directional antenna data. The interpreted intersection points and intersection angles of the detected structures are presented in Table 5-3 and 5-4 and also visible on the radargrams in Appendix 1 and 2.

BIPS

The visualization of data (see Appendix 3 and 4) is made with BDPP, a Windows based processing software for filtering, presentation and analyzing of BIPS data. No fracture mapping of the BIPS image has been performed.

5 Results and data delivery

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

RAMAC radar data has 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, has been inserted into the SKB database SICADA.

The SICADA references to the BIPS and RAMAC logging activities presented in this report are Field note Forsmark no 89 and 233 (KFM01A) and no 251 (KFM01B).

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 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 less than 20 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 to 5-4. 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. Note that the analyses and interpretation of the radar data from KFM01A include dipole data from the first logging /2/ and directional data from the re-logging.

Results from measurements with the directional antenna are only shown in tabulated form, Table 5-3 and 5-4, with the identified planes and their orientation.

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

The data quality, as seen in Appendix 1 and 2, is relatively satisfying. However, measurements in parts of the boreholes 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. This increase in conductivity of the borehole fluid is of course also reflected how well structures can be distinguished also in the data from the other antennas.

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.

Table 5-1. Identified structures as a function of depth in KFM01A.

Depth (m)	No of structures	Depth (m)	No of structures
0 – 150	5	550 – 600	5
150 – 200	9	600 – 650	2
200 – 250	6	650 – 700	4
250 – 300	3	700 – 750	4
300 – 350	8	750 – 800	2
350 – 400	4	800 – 850	5
400 – 450	5	850 – 900	6
450 – 500	4	900 – 950	2
500 – 550	2	950 –	3

Table 5-2. Identified structures as a function of depth in KFM01B.

Depth (m)	No of structures
0 – 50	9
50 – 100	6
100 – 150	8
150 – 200	8
200 – 250	10
250 – 300	3
300 – 350	6
350 – 400	5
400 – 450	10
450 –	9

Table 5-3 and 5-4 summarise the interpretation of radar data (dipole and directional antennas) from KFM01A and KFM01B. Many structures can be identified in the data from more than one antenna frequency. When an object (in this case plane) is detected by the directional antenna, the direction to the plane, as defined in Figure 5-1, is interpreted. Based on this information, the true orientation (strike and dip) of the plane can be interpreted. 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 5-3 and 5-4 then represent the most probable interpretation.

Table 5-3. Model information from dipole antennas 20, 100 and 250 MHz and the directional, 60 MHz antenna, KFM01A.

RADINTER MODEL INFORMATION									
(20, 100 and 250 MHz Dipole Antennas and Directional Antenna)									
Site: Forsmark									
Borehole name: KFM01A									
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	CC	-731.9	1						
PLANE	C	-255.4	6						
PLANE	Ax	115.6	55	342	162	154	40	338	30
PLANE	KK	141.5	29						
PLANE	II	143.7	10						
PLANE	Bxx	160	31	75		69	61		
PLANE	B	162	21	306		193	75		
PLANE	H	170.2	11	0		141	82		
PLANE	Bx	174.9	26	99		44	63		
PLANE	LL	176.0	15	96		46	76		
PLANE	LLx	183.1	44	222		275	42		
PLANE	D	186.1	12						
PLANE	LLxx	190.9	50	291	111	304	43	37	38
PLANE	O	196	11						
PLANE	HH	201.2	12						
PLANE	Dxx	213.9	47	156	336	346	38	161	48
PLANE	MM	218.2	18						
PLANE	E	225.2	23						
PLANE	Dxxx	225.9	33	168		332	51		
PLANE	Ex	241.9	48	36	216	107	48	107	48
PLANE	Exx	260.9	40						
PLANE	I	263.7	10						
PLANE	J	276.3	10	30		110	85		
PLANE	FF	304.5	19						
PLANE	K	304.8	12						
PLANE	A	308.1	2						
PLANE	Kx	308.3	53	30	210	114	43	284	31
PLANE	Kxx	323.9	50	279		211	42		
PLANE	GG	329.3	9						
PLANE	F	336.8	6						
PLANE	G	337.1	10						
PLANE	L	370.8	8						
PLANE	2	374.1	41	18	198	299	41	124	57
PLANE	Mxx	387	53	6	186	136	45	308	25
PLANE	Mx	398.6	16	198	18	304	66	126	82
PLANE	M	403.6	10						
PLANE	Px	423.9	46	351	171	150	53	333	35
PLANE	Nx	424.9	5	201	21	299	77	300	87
PLANE	N	428.8	10	204		297	69		
PLANE	Q	448.6	36	264		230	52		
PLANE	P	452.6	16						
PLANE	Rx	464.9	39	6	186	138	61	316	42
PLANE	R	469.2	17	351		151	83		
PLANE	S	490.1	25						
PLANE	Sx	503.9	54	258	78	231	35	77	39

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	3	532.9	53	276		216	39		
PLANE	Ux	557.7	47	249		244	40		
PLANE	V	557.7	12						
PLANE	T	571.4	11						
PLANE	Vx	574.4	36	261		237	53		
PLANE	Y	596.7	8						
PLANE	Vxx	641.3	47	162		349	32		
PLANE	U	648.3	4						
PLANE	X	651.9	50	27	207	125	51	292	29
PLANE	QQ	659.3	8	9		317	86		
PLANE	1	663.5	45	309		192	53		
PLANE	Xx	690.9	41	282		216	53		
PLANE	Xxx	712.9	31	330		172	70		
PLANE	Yz	731.1	29	27		120	73		
PLANE	NN	739.6	56	48		111	39		
PLANE	NNx	735.8	27	138	318	14	54	184	73
PLANE	Z	759.5	27	327		175	71		
PLANE	RR	780.1	14						
PLANE	PP	804.1	17						
PLANE	4	815.6	17	297		206	80		
PLANE	BB	831.2	33						
PLANE	6	846.5	61	39		119	42		
PLANE	AA	847.3	12	306	126	198	86	22	67
PLANE	6x	852.5	50	231		257	32		
PLANE	5	857.9	43	333		167	61		
PLANE	OO	859.5	27						
PLANE	6xx	886.5	54	93		73	38		
PLANE	7x	892.1	37	90	270	68	54	225	55
PLANE	7	899.5	52	123		42	32		
PLANE	JJ	927.1	6						
PLANE	DD	944.5	43	0		147	53		
PLANE	9	980.1	41	84	264	74	52	227	49
PLANE	EE	984.2	49	222	42	268	34	111	57
PLANE	8	1011.3	7	294		209	90		

Names in table according to Appendix 1.

Table 5-4. Model information from dipole antennas 20, 100 and 250 MHz and the directional, 60 MHz antenna, KFM01B.

RADINTER MODEL INFORMATION									
(20, 100 and 250 MHz Dipole Antennas and Directional Antenna)									
Site: Forsmark									
Borehole name: KFM01B									
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	Gx	-296	1						
PLANE	2	-126	4	39		320	85		
PLANE	A	17.9	69						
PLANE	B	20.3	64						
PLANE	C	27.7	90						
PLANE	D	29.1	64						
PLANE	E	40.8	85	126	306	147	9	199	15
PLANE	F	49.2	69	36	216	155	33	300	15
PLANE	G	49.9	9						
PLANE	H	68.5	61	306	126	219	33	78	20
PLANE	I	79.5	44						
PLANE	J	89.6	65	336	156	197	35	44	14
PLANE	K	93.2	59						
PLANE	L	95.3	56						
PLANE	M	97.6	64	354	174	184	36	12	12
PLANE	N	108.3	71						
PLANE	1	111.1	8	153		27	71		
PLANE	O	113.9	77						
PLANE	P	120.5	81						
PLANE	Q	122.4	70	327		201	33		
PLANE	3	127.3	10						
PLANE	R	131.4	59	24	204	162	43	324	22
PLANE	S	138.8	67	189	9	339	10	173	36
PLANE	Tx	151.7	21						
PLANE	T	153.7	54						
PLANE	U	166.4	65						
PLANE	V	168.9	54	243	63	275	30	129	41
PLANE	W	176.9	63	54	234	138	40	282	25
PLANE	X	185.4	65	342		191	38		
PLANE	XX	186.6	18						
PLANE	Y	195.8	60	6	186	176	41	342	13
PLANE	Z	203.8	62	183	3	364	15	178	43
PLANE	5x	210	44						
PLANE	4	220.3	52						
PLANE	6	221.4	25						
PLANE	5	222	32	153		33	41		
PLANE	7	233.8	50	102		95	39		
PLANE	Gxx	234.3	6						
PLANE	8	239.8	50						
PLANE	9	246	59						
PLANE	10	250	64						
PLANE	11	255.2	57						
PLANE	12	275.8	36						
PLANE	13	292.9	39	93	273	98	49	252	50
PLANE	15	310.9	12	339		18	88		

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	16	325.2	44						
PLANE	17	331.6	46	75	255	118	48	265	40
PLANE	18	333.7	16						
PLANE	19	339.3	51	150	330	41	29	202	56
PLANE	20	343.5	50						
PLANE	XXX	366.2	16						
PLANE	21	366.8	47	54		134	53		
PLANE	14	375.4	5						
PLANE	23	376	47	63	243	127	52	258	24
PLANE	24	394	13						
PLANE	25	404.3	12						
PLANE	27	407.8	39						
PLANE	28	408.9	51						
PLANE	29	413	49	321	141	202	54	50	29
PLANE	30	417.5	42	12	192	162	66	335	33
PLANE	31	425.3	65						
PLANE	32	429.4	42						
PLANE	26	433.3	6						
PLANE	34	436.3	50						
PLANE	35	445.7	55	27	207	152	49	302	19
PLANE	36	455.4	55	3	183	169	53	346	19
PLANE	37	464.3	43	126	306	67	33	214	52
PLANE	38	472	18						
PLANE	39	479.9	39	48		130	64		
PLANE	40	495.2	18						
PLANE	41	495.8	47	243		269	39		
PLANE	Gxxx	612	2	207		327	73		
PLANE	42	674	5						
PLANE	22	988.5	1						

Names in table according to Appendix 2.

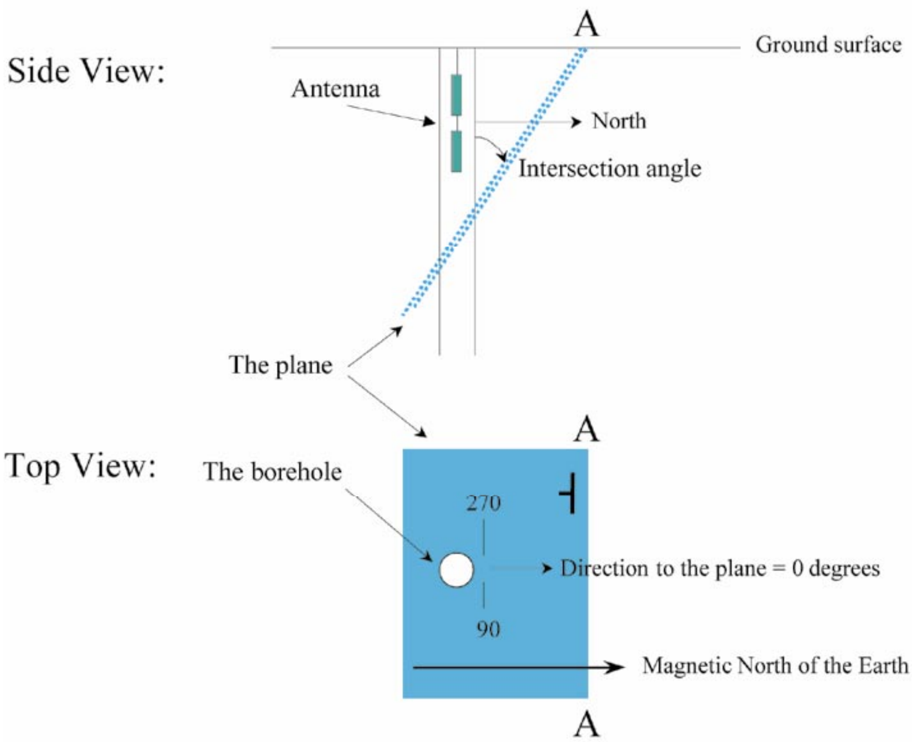


Figure 5-1. *Definition of the direction to object as presented in Table 5-3 and 5-4.*

In Appendix 1 and 2, the amplitude of the first arrival is plotted against the depth, for the 250 MHz dipole antenna. The amplitude variations along the borehole indicate 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 KFM01A:

Depth (m)	Depth (m)
125	650–655
135–140	660
145–150	670
165	730
175–180	735–740
200	775
115–125	855–860
390–400	

And for KFM01B:

Depth (m)	Depth (m)
20–25	225
30	245
40	365–375
45–50	415–420
130	420–430
185	445
195–200	

5.2 BIPS logging

The BIPS pictures for KFM01B are presented in Appendix 3. The BIPS logging of KFM01A is reported in /1/ and /2/.

To get the best possible depth accuracy, the BIPS images are adjusted to the reference marks along the borehole.

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 borehole. The resulting images displayed no difference regarding the colours and focus of the images. Results of the test loggings were included in the delivery of the raw data.

The borehole KFM01B was measured with the BIPS system during three runs. The first run, down to 202 m, was performed 03-09-01 during a temporary (planned) drilling standstill. The intention was to provide images to the core logging but unfortunately the water quality was only acceptable between 15 to c 100 m depth. The section 15–95 m is presented in Appendix 4.

A second run (04-02-12) was performed when drilling was finished. The images were again of non-acceptable quality, mainly due to bad water quality. Therefore, and based on the experience that the water quality generally improves after a couple of weeks, a third logging was carried out.

The third logging, presented in Appendix 3, was performed 04-03-10 and showed much better borehole water quality but, on the other hand, discolouring of the borehole wall is conspicuous, see Appendix 3.

6 References

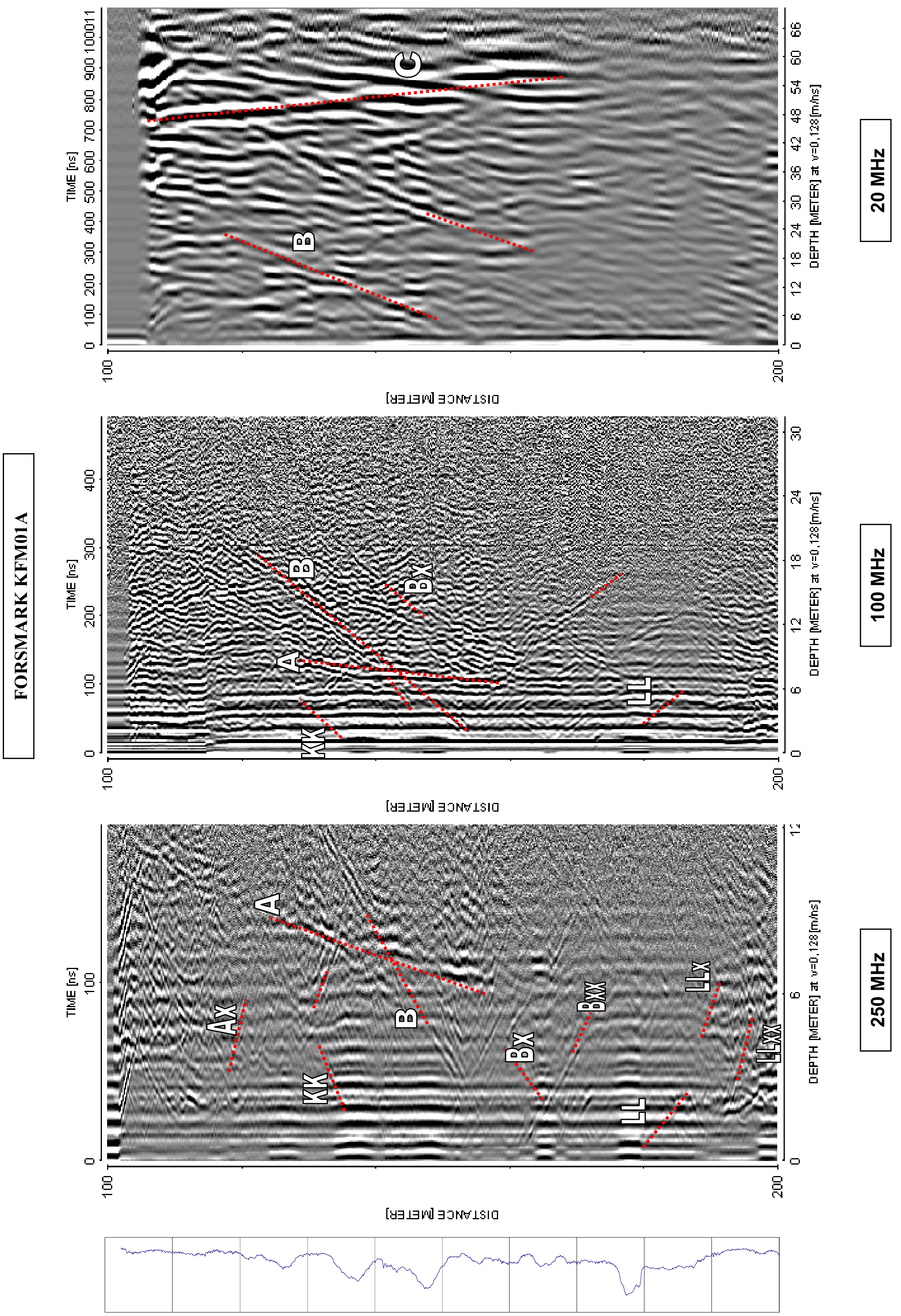
/1/ **Gustafsson C, Nilsson P, 2003.** Geophysical Radar and BIPS logging in borehole HFM01, HFM02, HFM03 and the percussion drilled part of KFM01A. SKB P-03-39. Svensk Kärnbränslehantering AB.

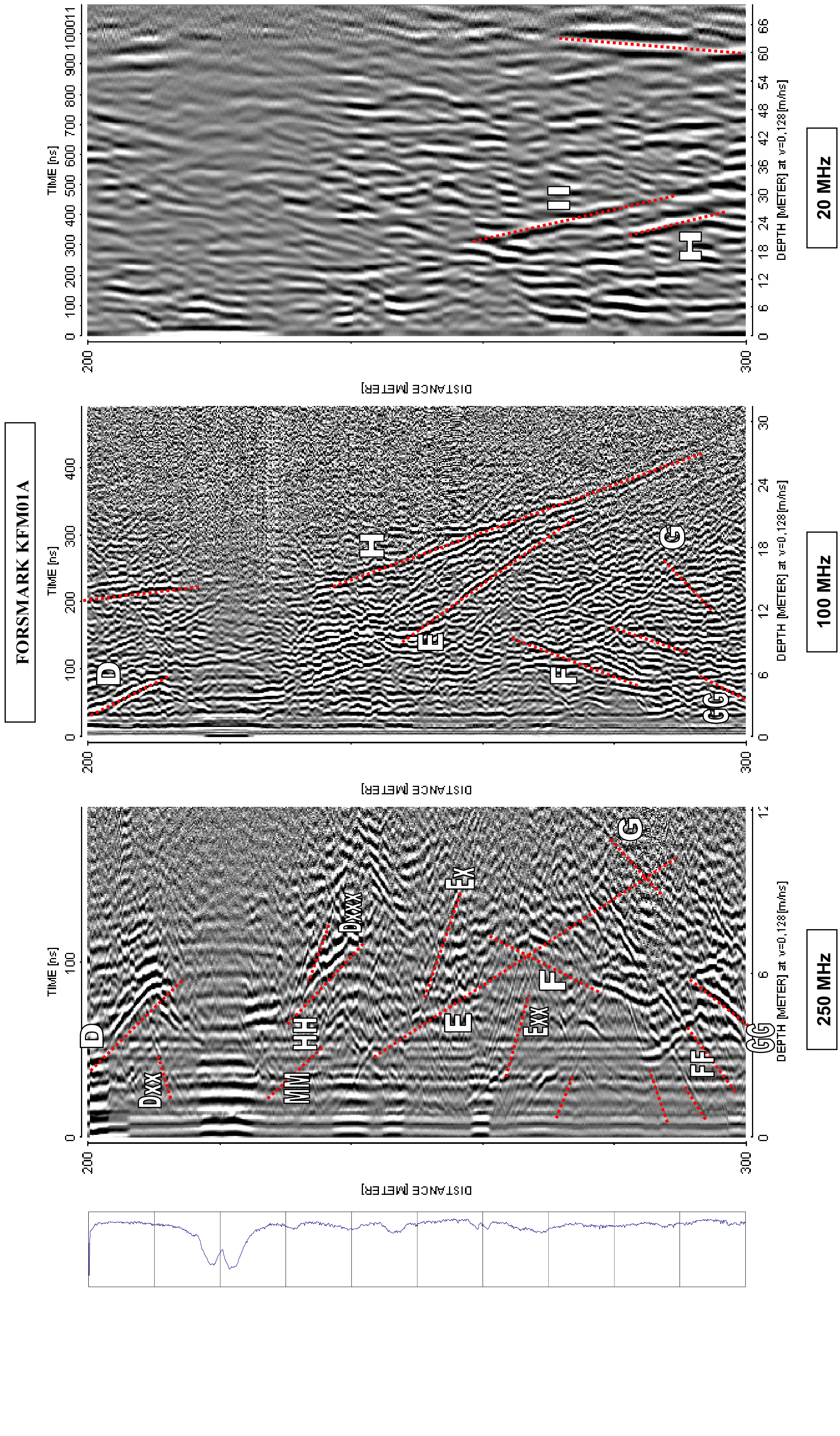
/2/ **Aaltonen J, Gustafsson C, 2003.** Forsmark site investigation. RAMAC and BIPS logging in borehole KFM01A. SKB P-03-45. Svensk Kärnbränslehantering AB.

Appendix 1

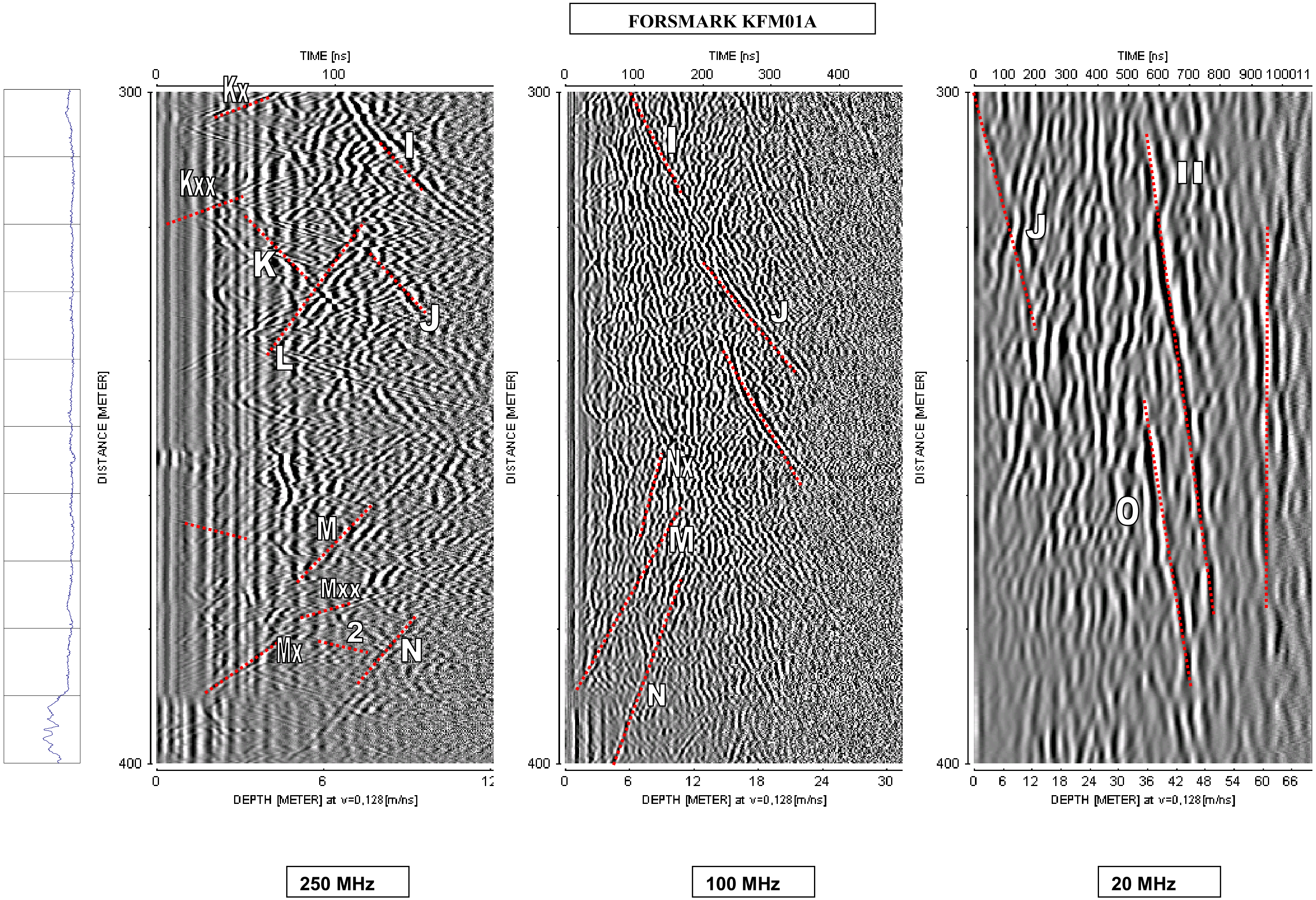
Radar logging of KFM01A, 100 to 990 m

Dipole antennas 250, 100 and 20 MHz

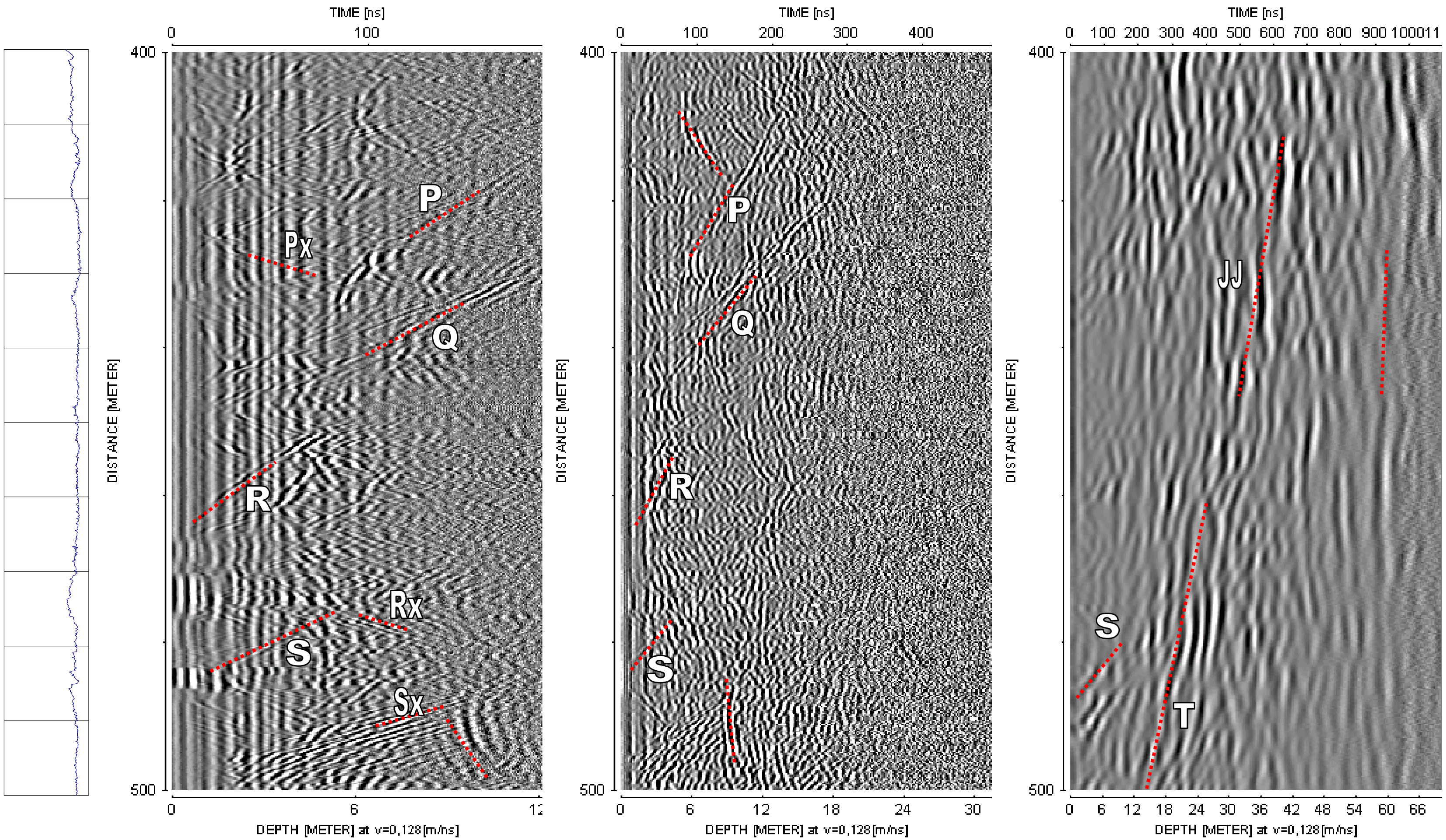




FORSMARK KFM01A
250 MHz
100 MHz
20 MHz
TIME [ns]
DEPTH [METER] at v=0,128 [m/ns]
DISTANCE [METER]


FORSMARK KFM01A
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128 [m/ns]
Kx
Kxx
I
K
J
L
M
Mxx
2
Mx
N
Nx
II
O
250 MHz
100 MHz
20 MHz

FORSMARK KFM01A

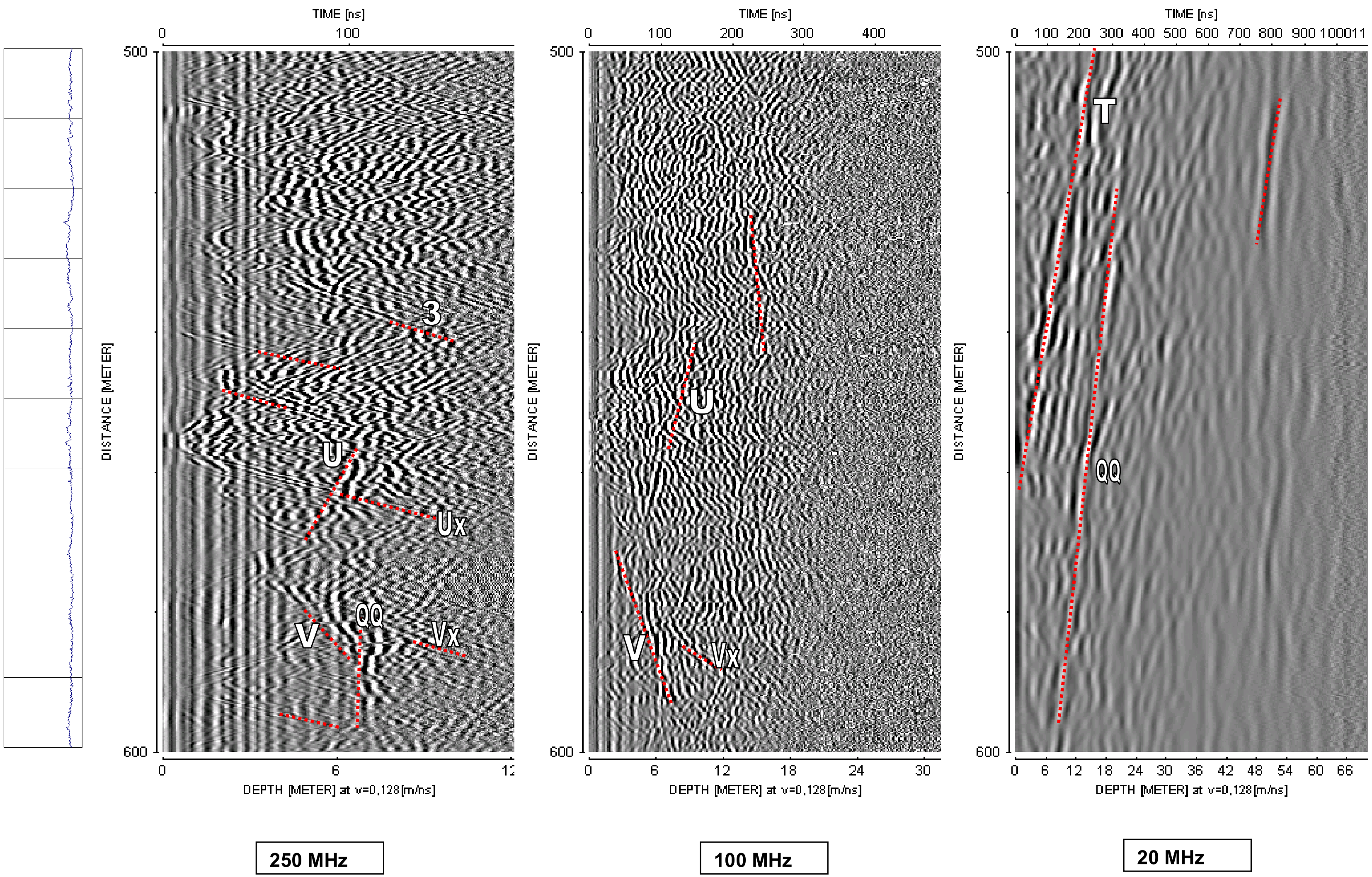


250 MHz

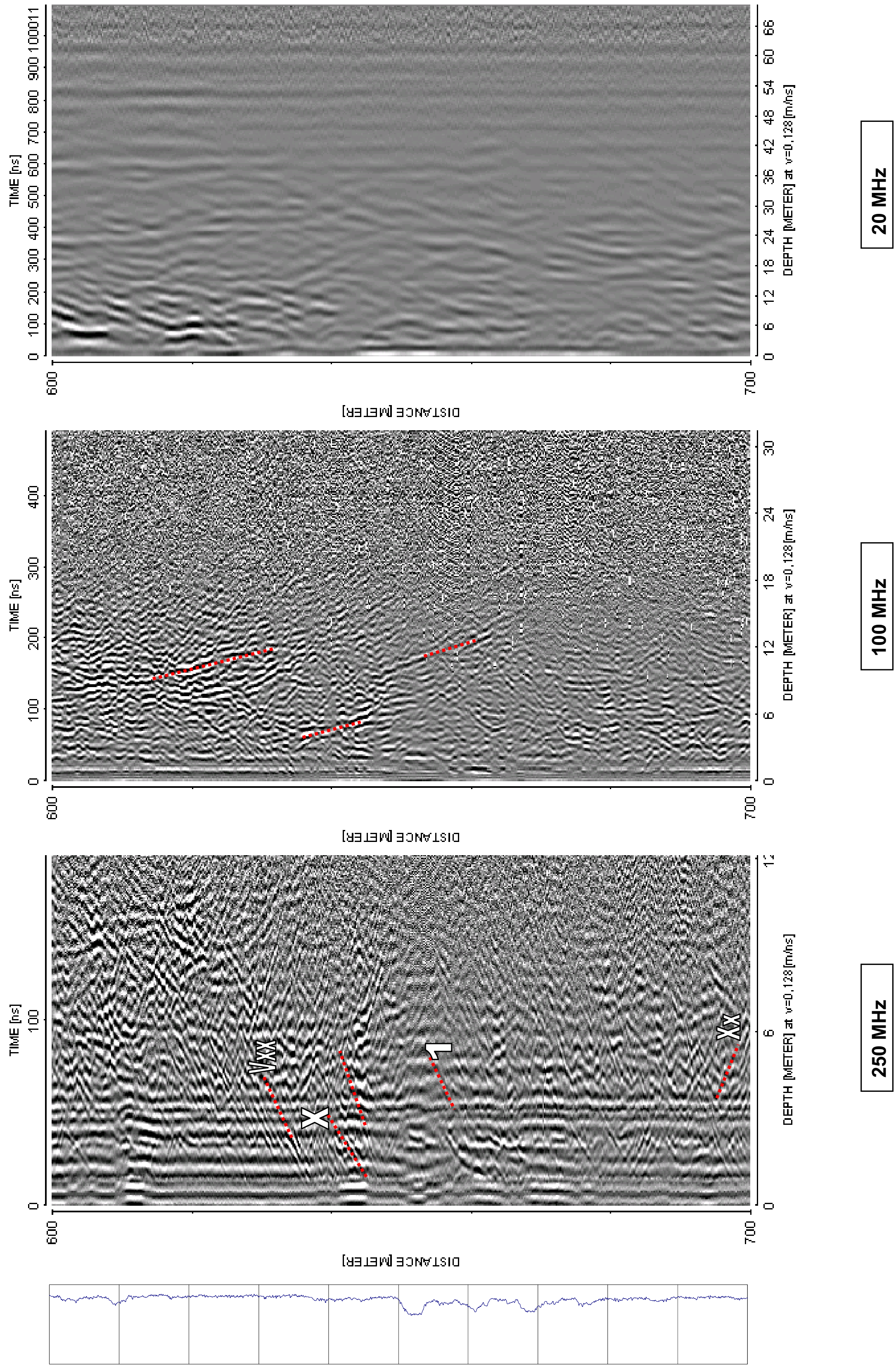
100 MHz

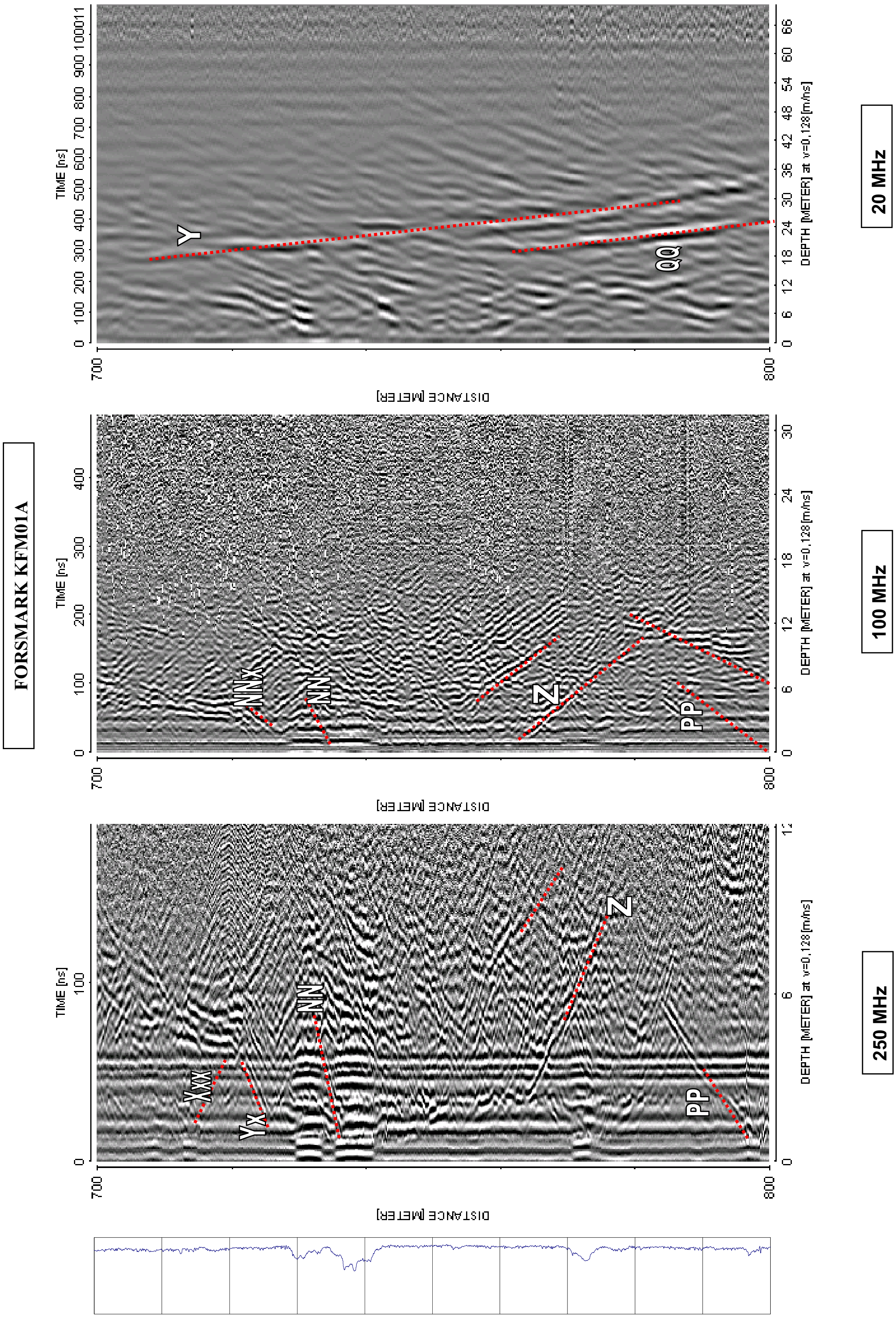
20 MHz

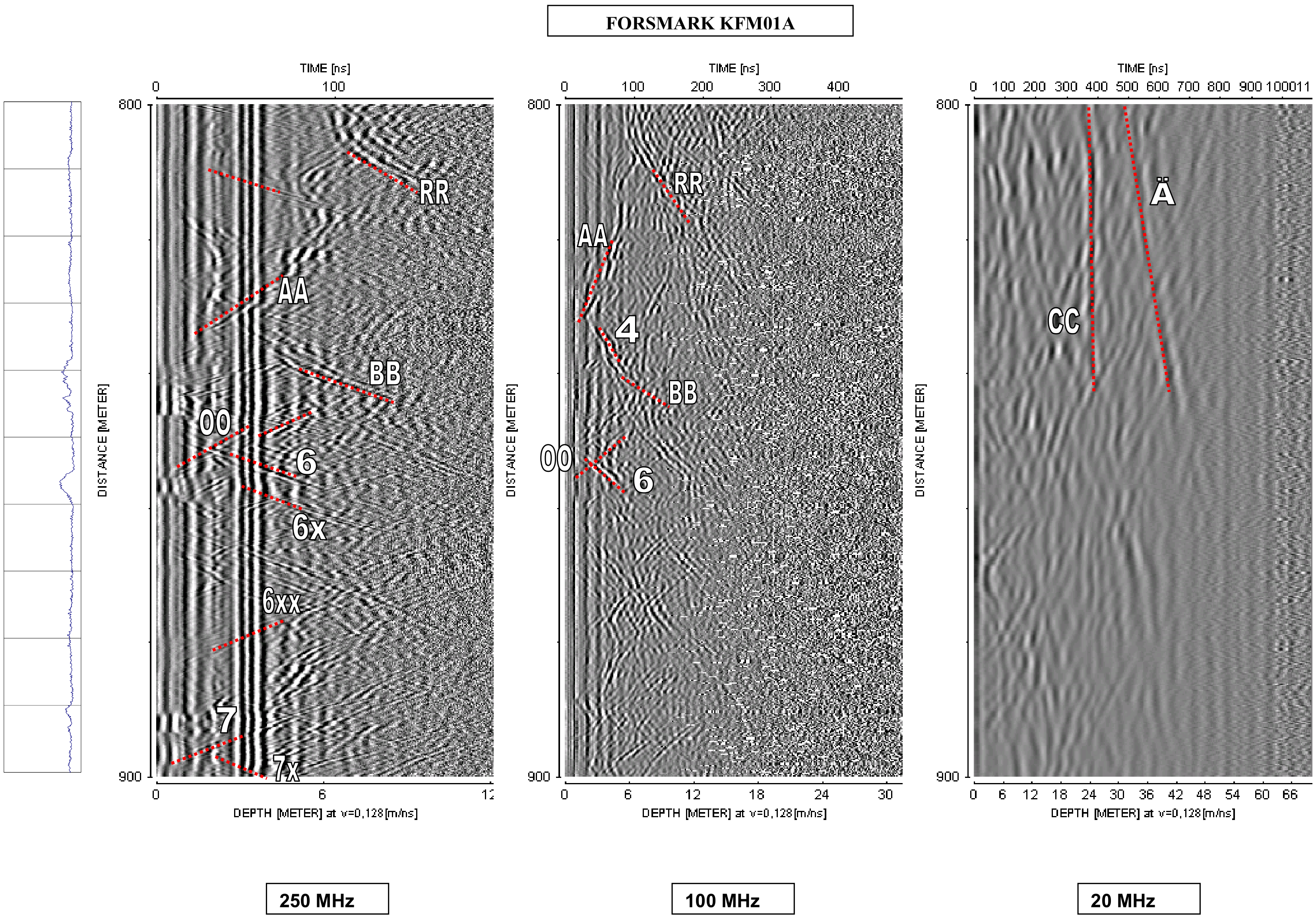
FORSMARK KFM01A

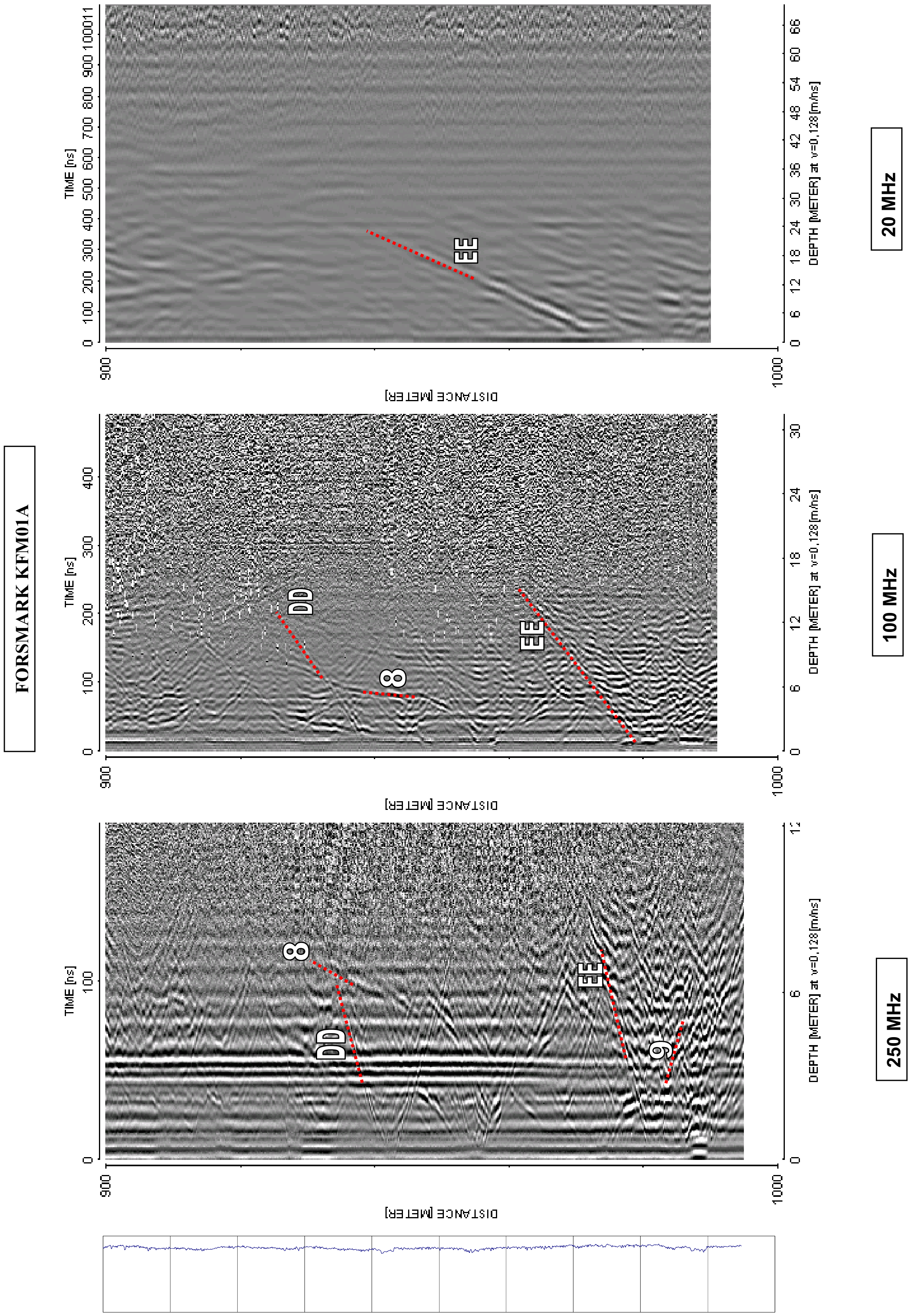


FORSMARK KFM01A



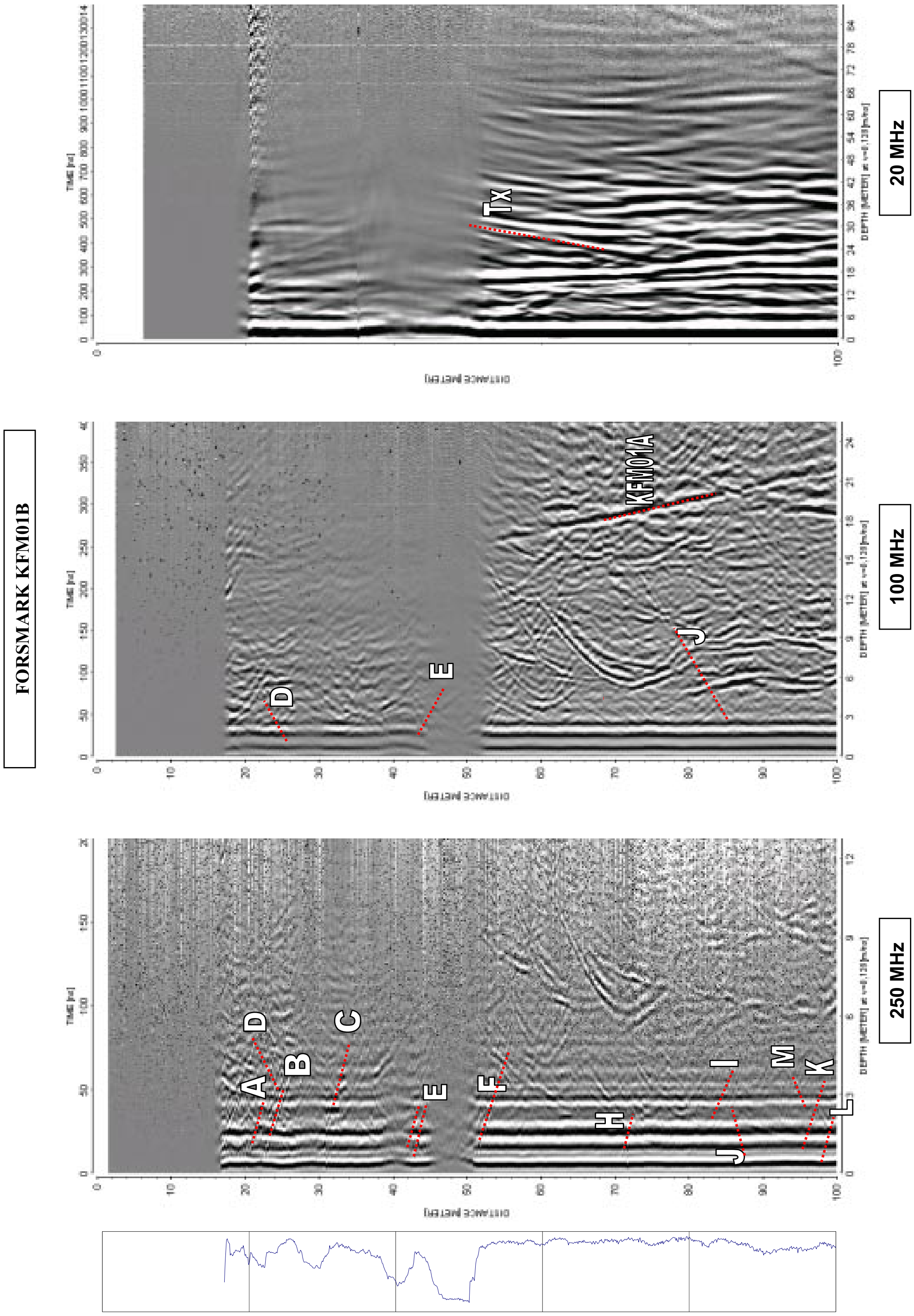

FORSMARK KFM01A
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128 [m/ns]
Xxx
Yx
NN
NNx
Z
PP
Y
QQ

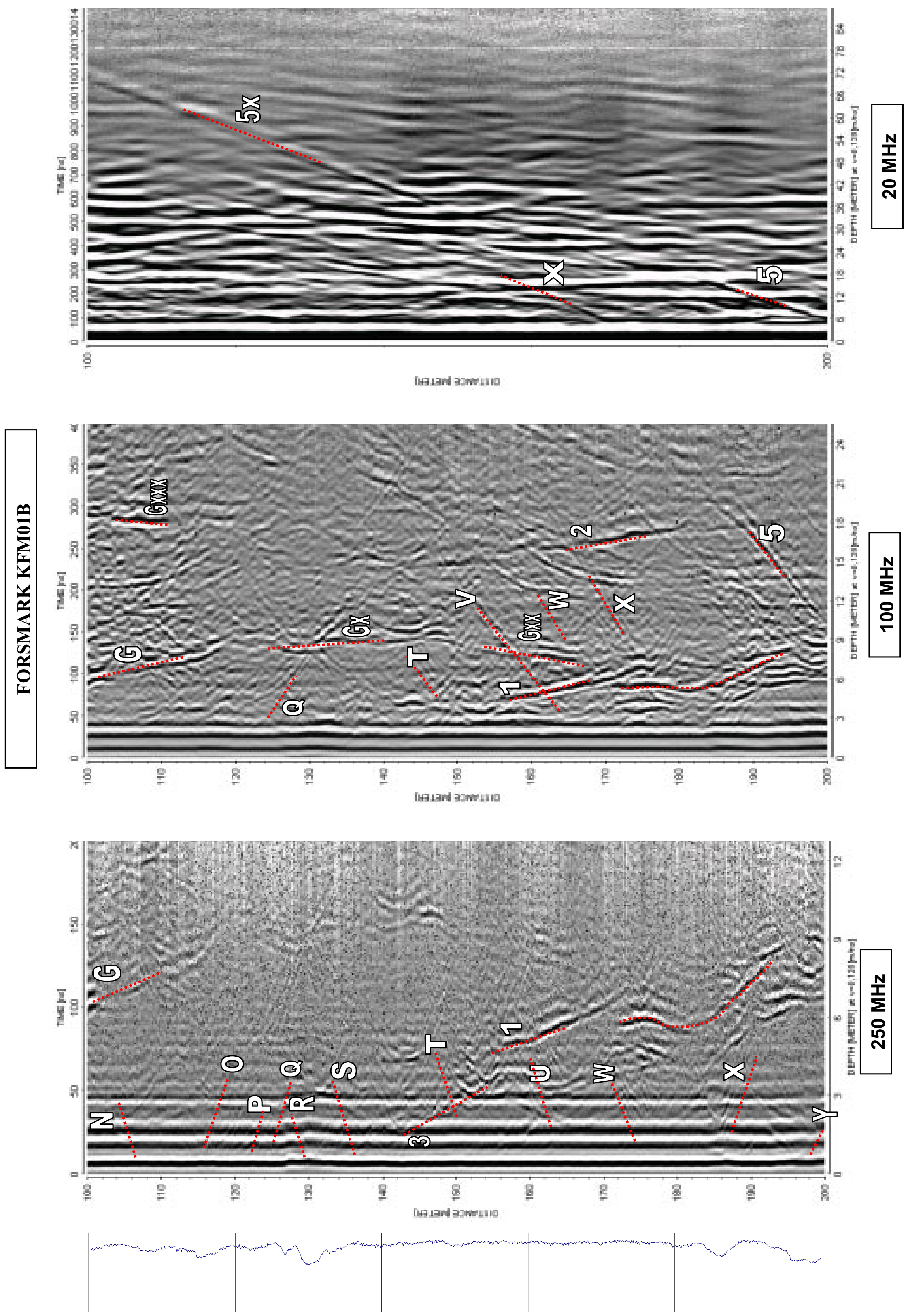

FORSMARK KFM01A
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128 [m/ns]
RR
AA
BB
OO
6
6x
6xx
7
7x
4
CC
Ä
250 MHz
100 MHz
20 MHz

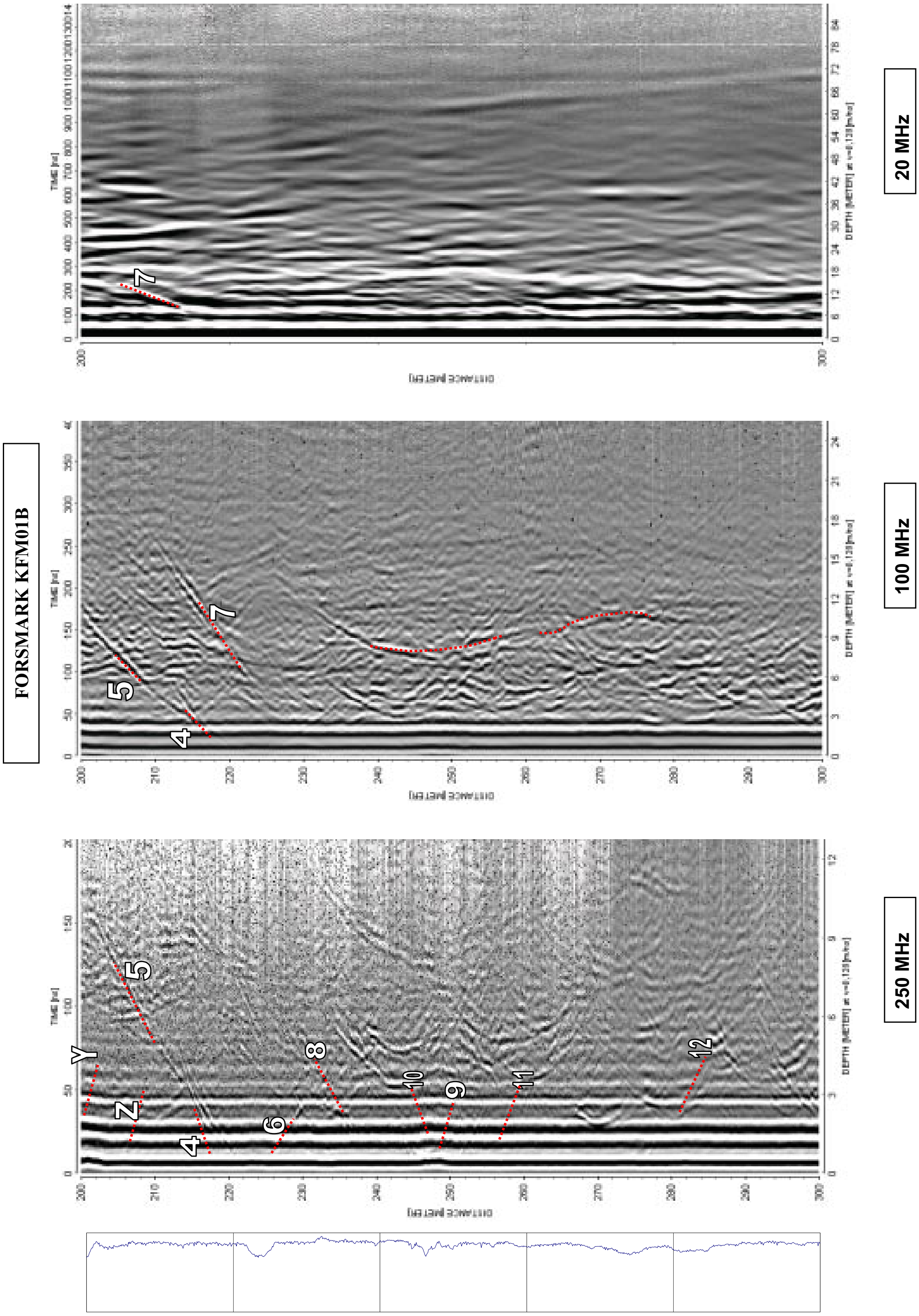

FORSMARK KFM01A
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128 [m/ns]
EE
20 MHz
DD
8
EE
100 MHz
8
DD
EE
9
250 MHz

Radar logging of KFM01B, 15 to 490 m

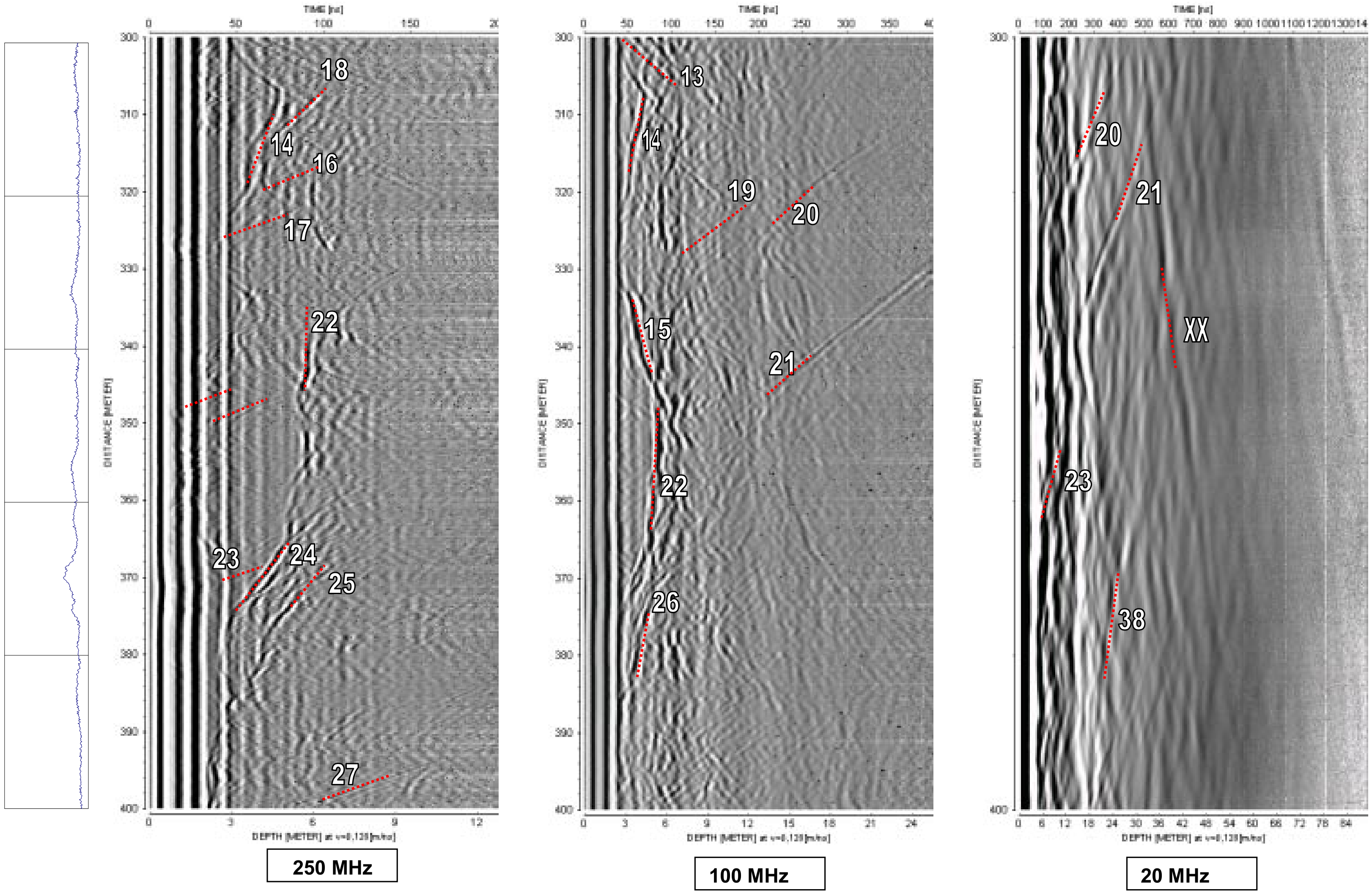
Dipole antennas 250, 100 and 20 MHz

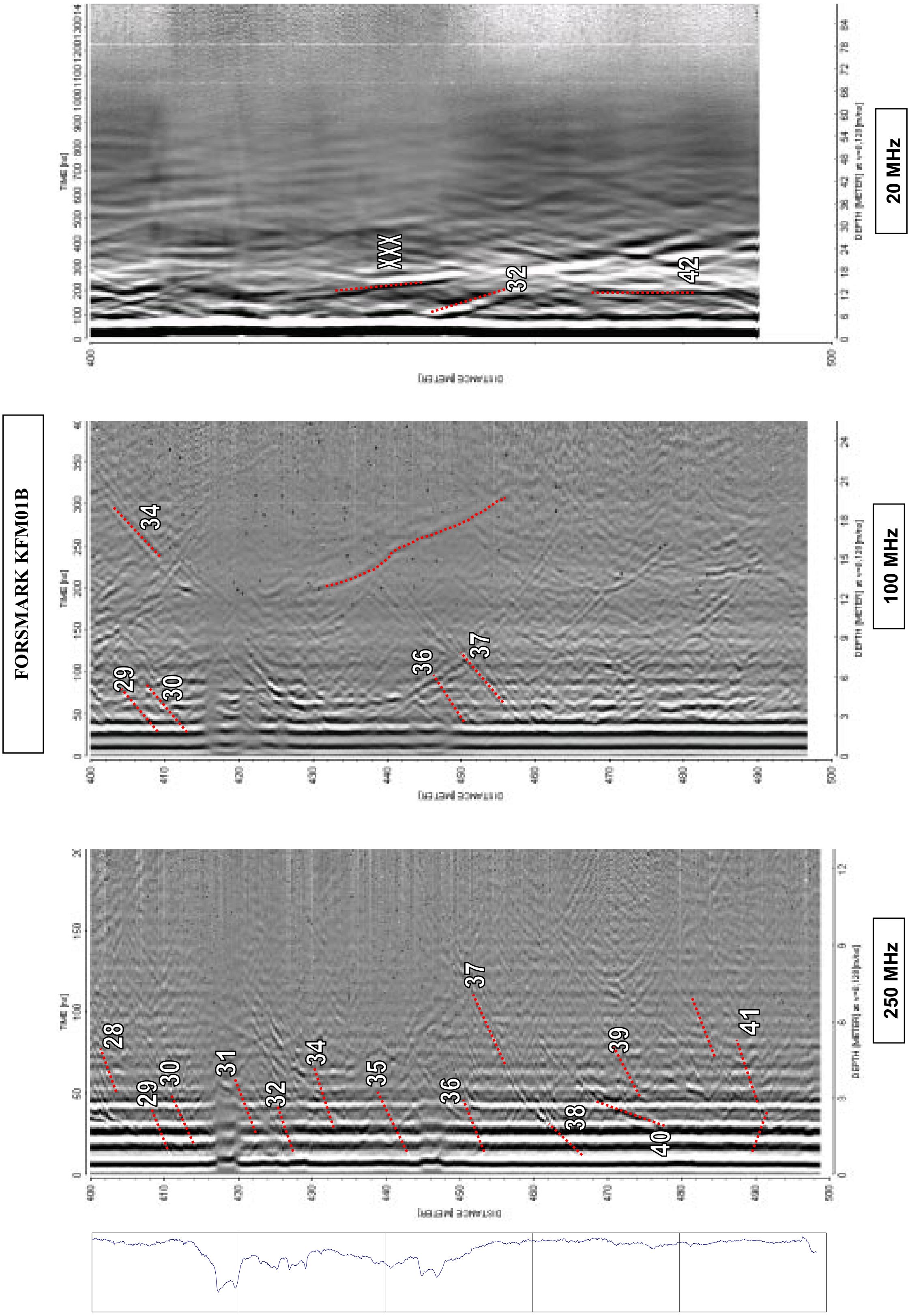



FORSMARK KFM01B
250 MHz
100 MHz
20 MHz
TIME [ns]
DISTANCE [METER]
DEPTH [METER] at v=0,128[m/ns]

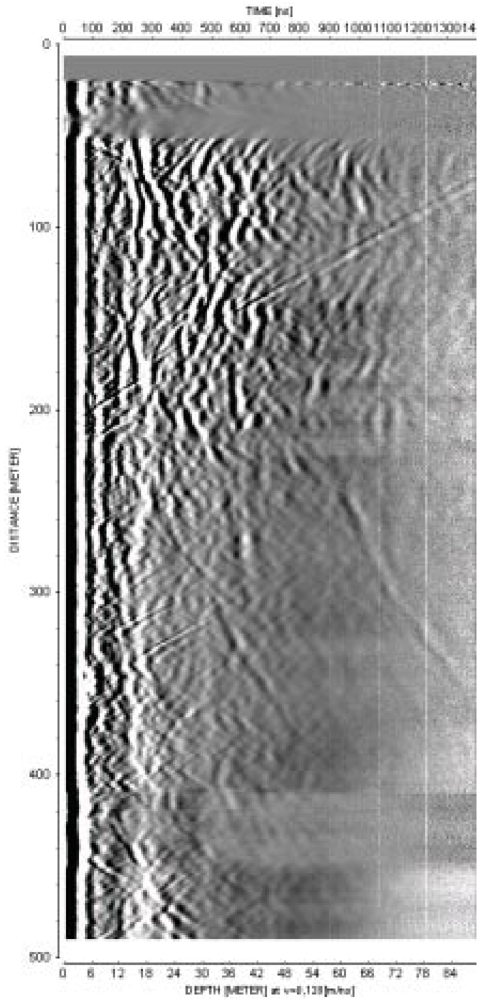

FORSMARK KFM01B
250 MHz
100 MHz
20 MHz
DISTANCE [METER]
TIME [ns]

FORSMARK KFM01B




FORSMARK KFM01B
250 MHz
100 MHz
20 MHz
28
29
30
31
32
34
35
36
37
38
39
40
41
29
30
34
36
37
XXX
32
42

FORSMARK KFM01B Overview of 20



20 MHz

Appendix 3

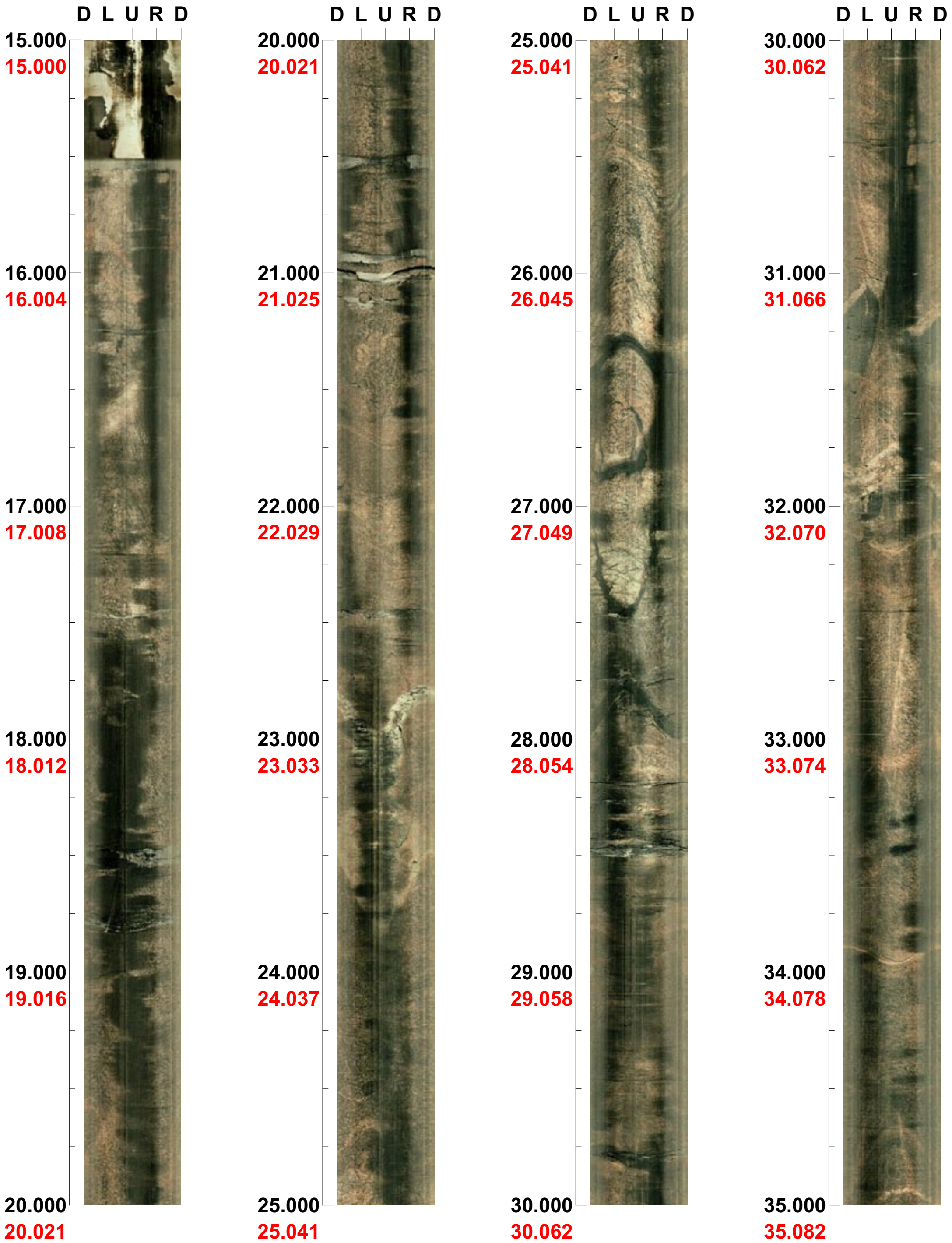
BIPS logging of KFM01B, 15 to 490 m

Project name: Forsmark

Image file	: c:\work\kfm01b\kfm01b.bip
BDT file	: c:\work\kfm01b\kfm01b.bdt
Locality	: FORSMARK
Bore hole number	: KFM01B
Date	: 04/03/10
Time	: 07:57:00
Depth range	: 15.000 - 497.265 m (red figures = corrected values)
Azimuth	: 267
Inclination	: -79
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	: 25
Color	: +0 +0 +0

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 15.000 - 35.000 m

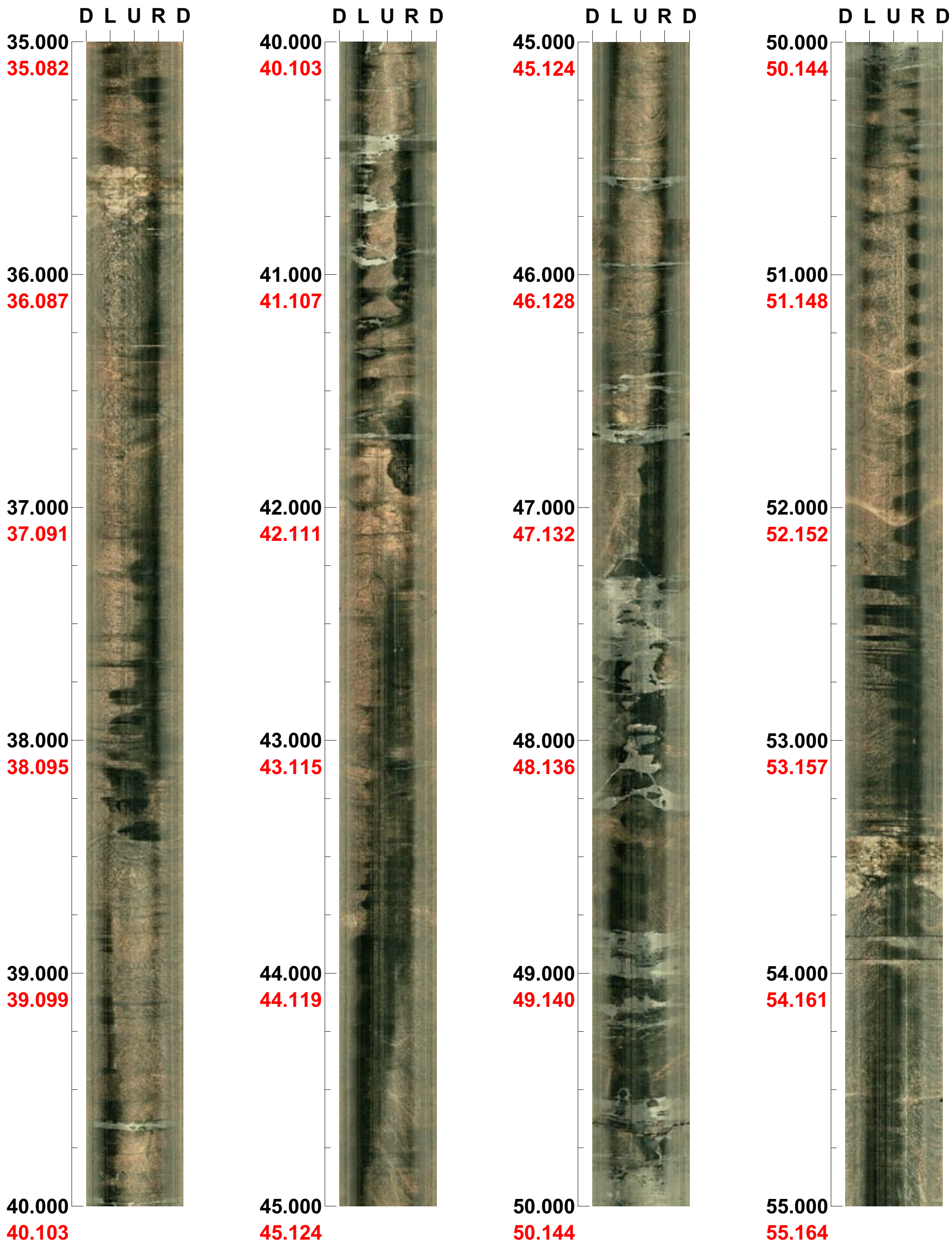


(1 / 25) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM01B

Azimuth: 267 Inclination: -79

Depth range: 35.000 - 55.000 m



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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

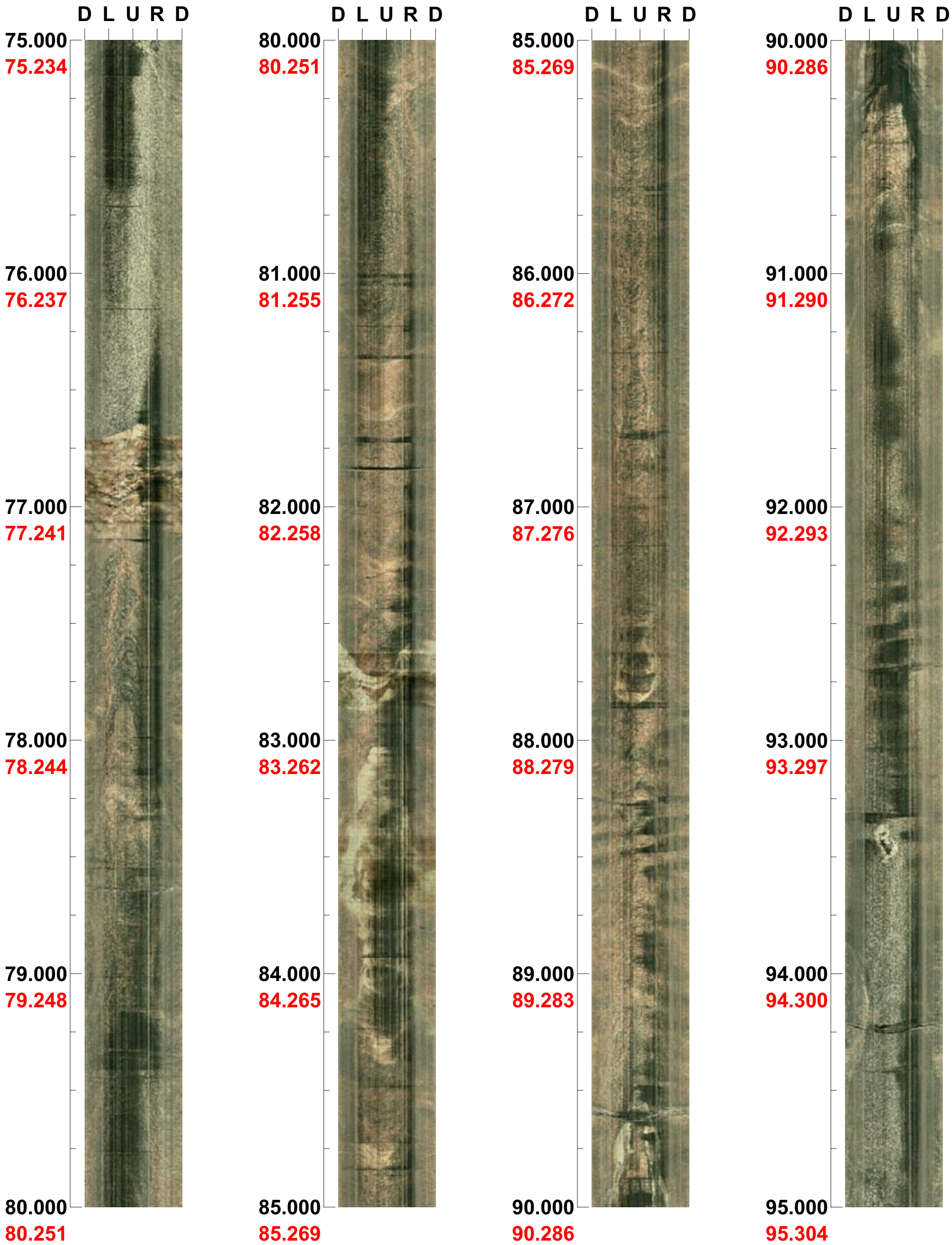
Depth range: 55.000 - 75.000 m

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

Project name: Forsmark

Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

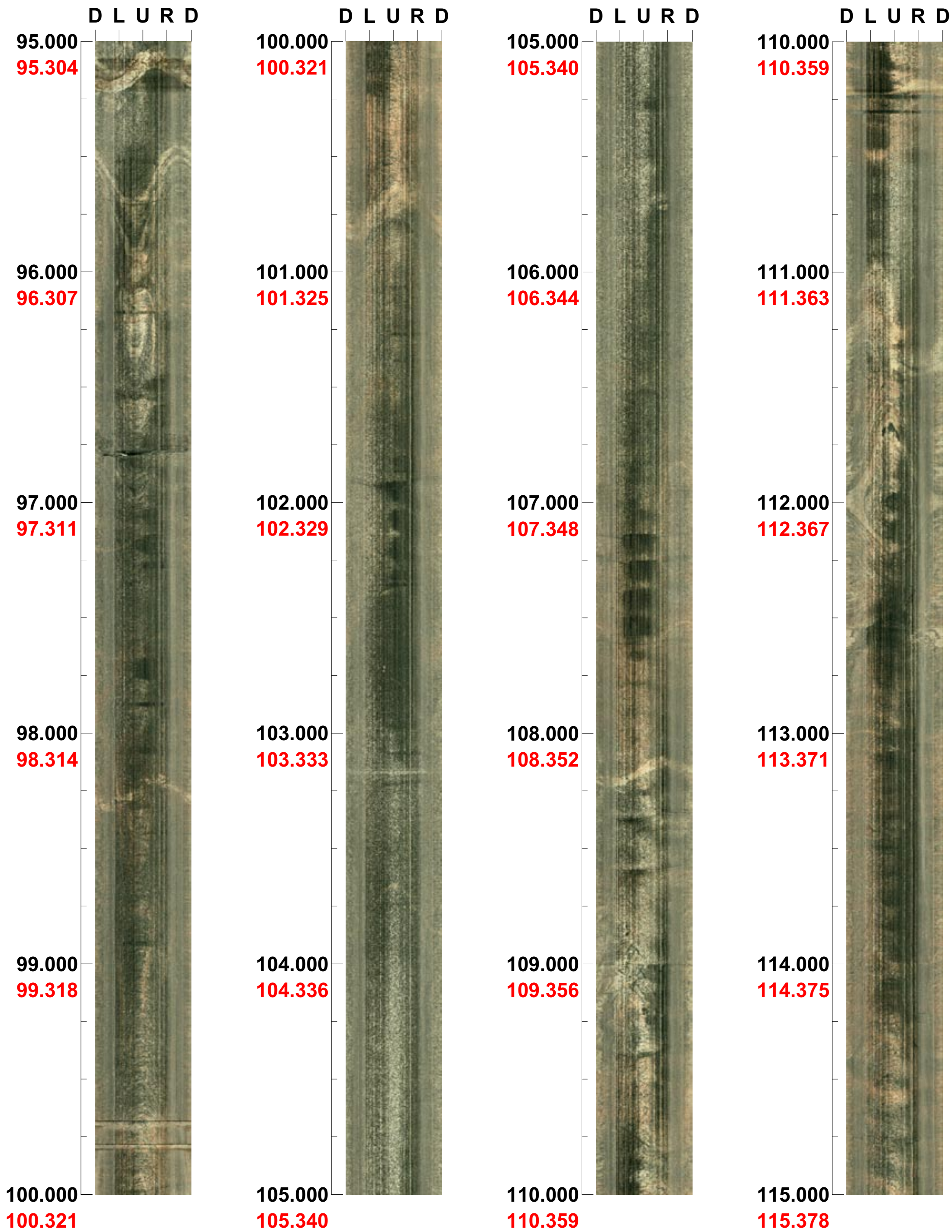
Depth range: 75.000 - 95.000 m



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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

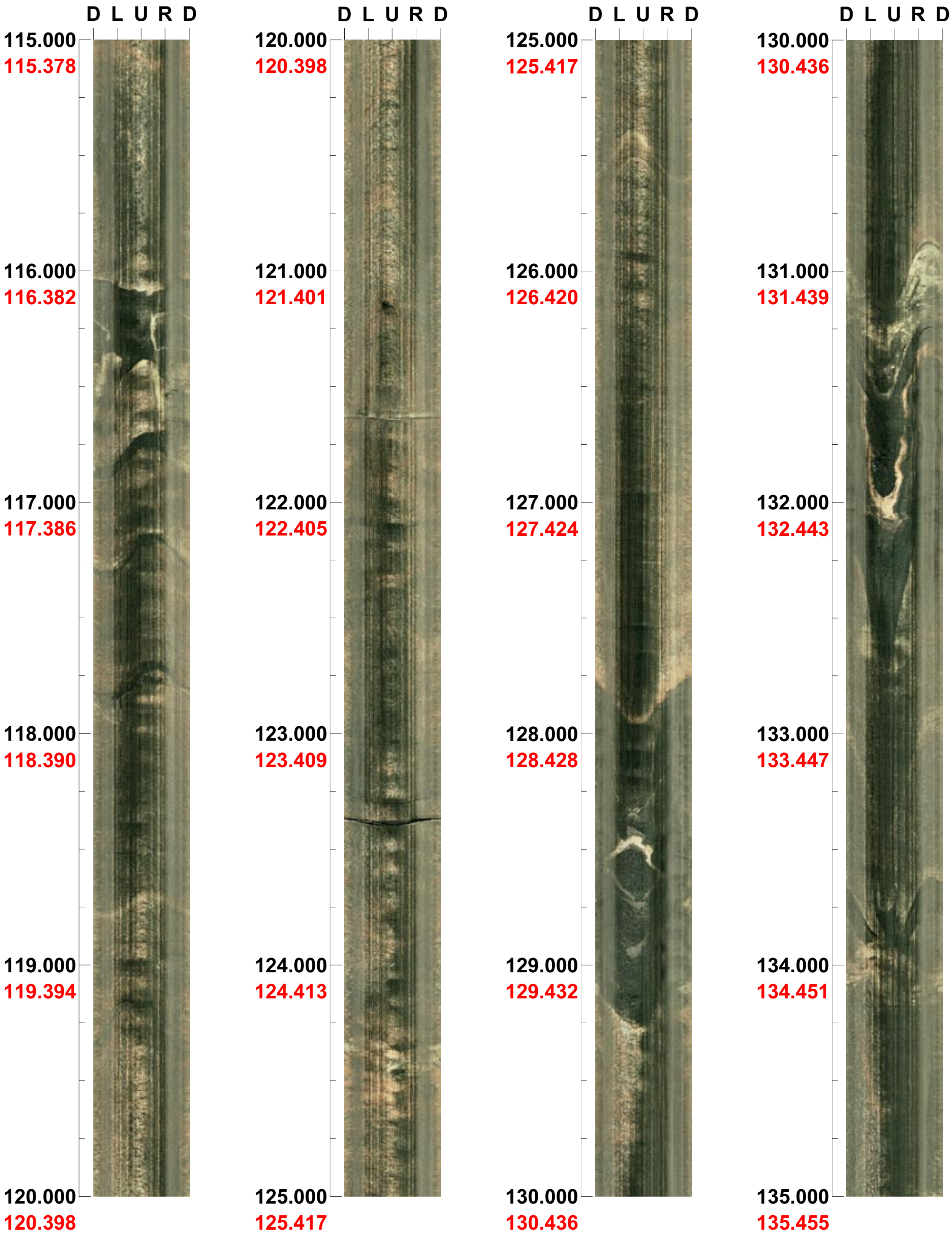
Depth range: 95.000 - 115.000 m



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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

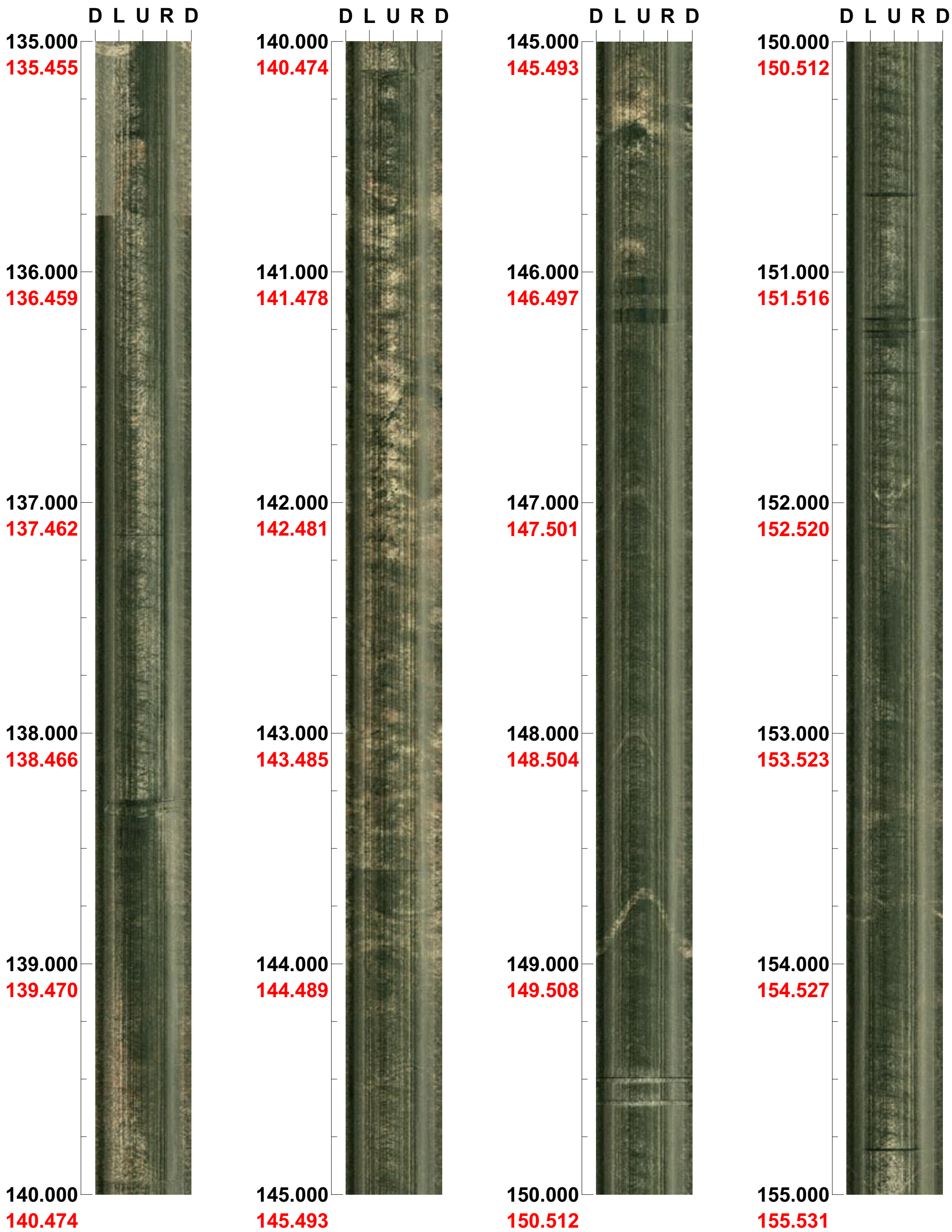
Depth range: 115.000 - 135.000 m



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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 135.000 - 155.000 m



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

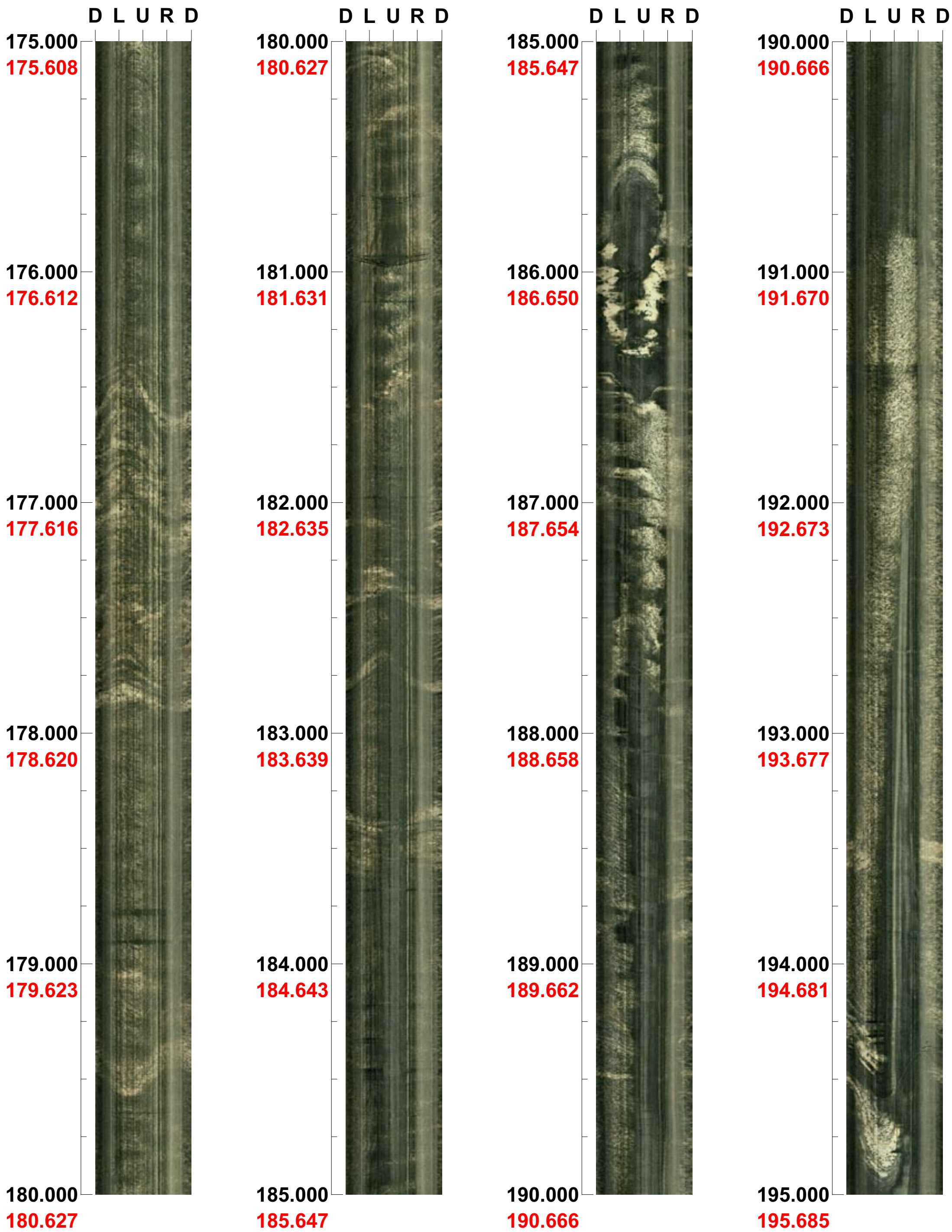
Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 155.000 - 175.000 m

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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 175.000 - 195.000 m



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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 195.000 - 215.000 m

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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 215.000 - 235.000 m

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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 235.000 - 255.000 m

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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 255.000 - 275.000 m

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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 275.000 - 295.000 m

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

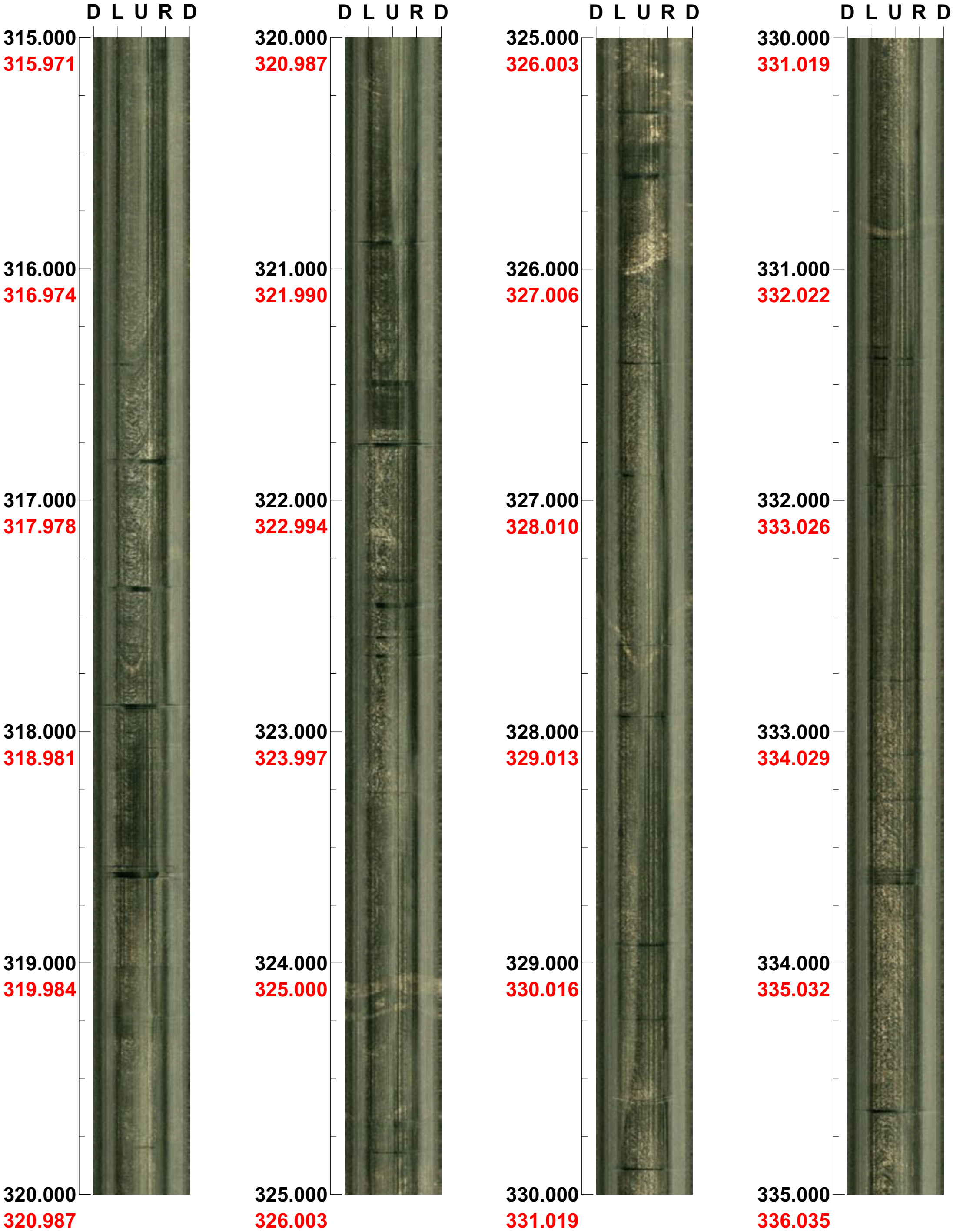
Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 295.000 - 315.000 m

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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 315.000 - 335.000 m



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

Project name: Forsmark

Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 335.000 - 355.000 m

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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

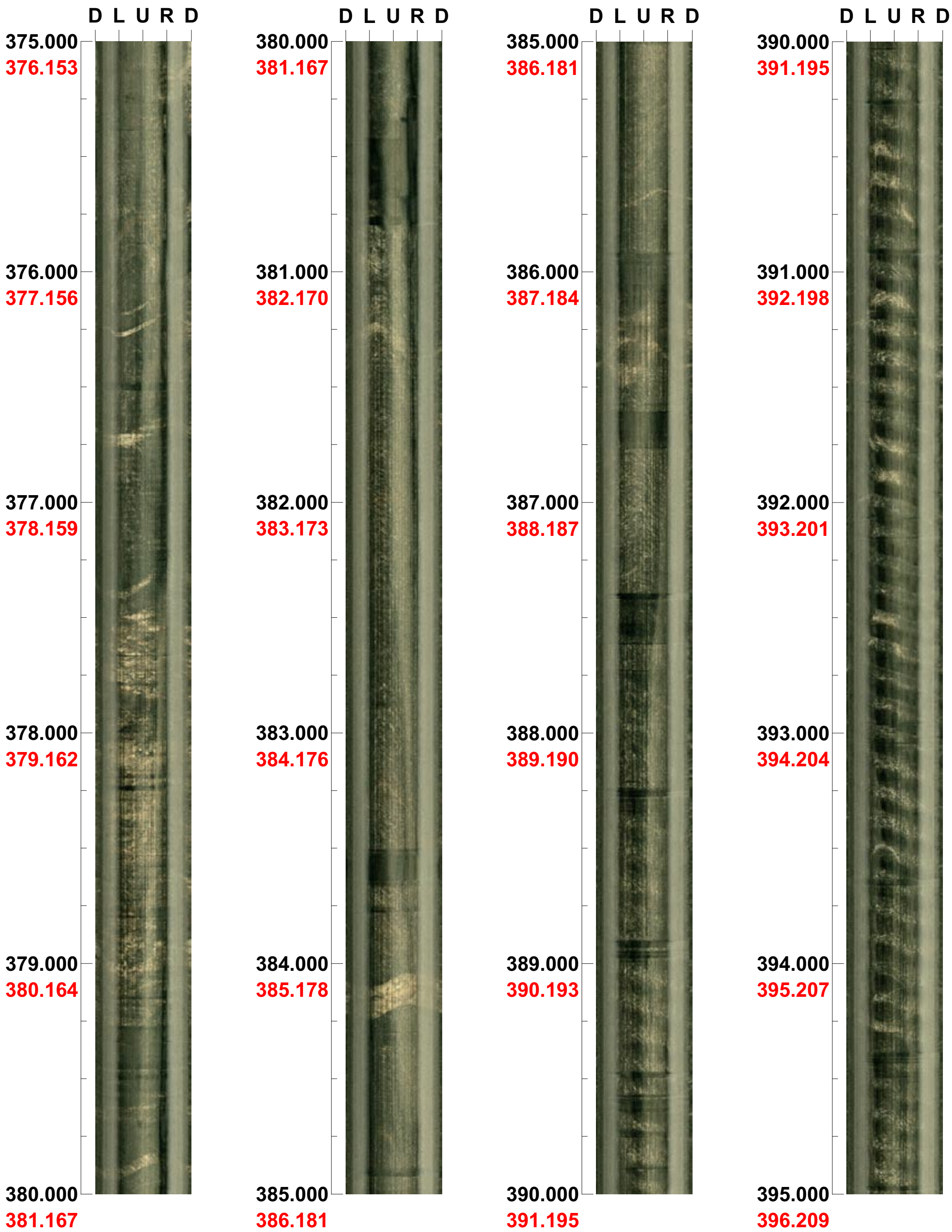
Depth range: 355.000 - 375.000 m

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

Project name: Forsmark

Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

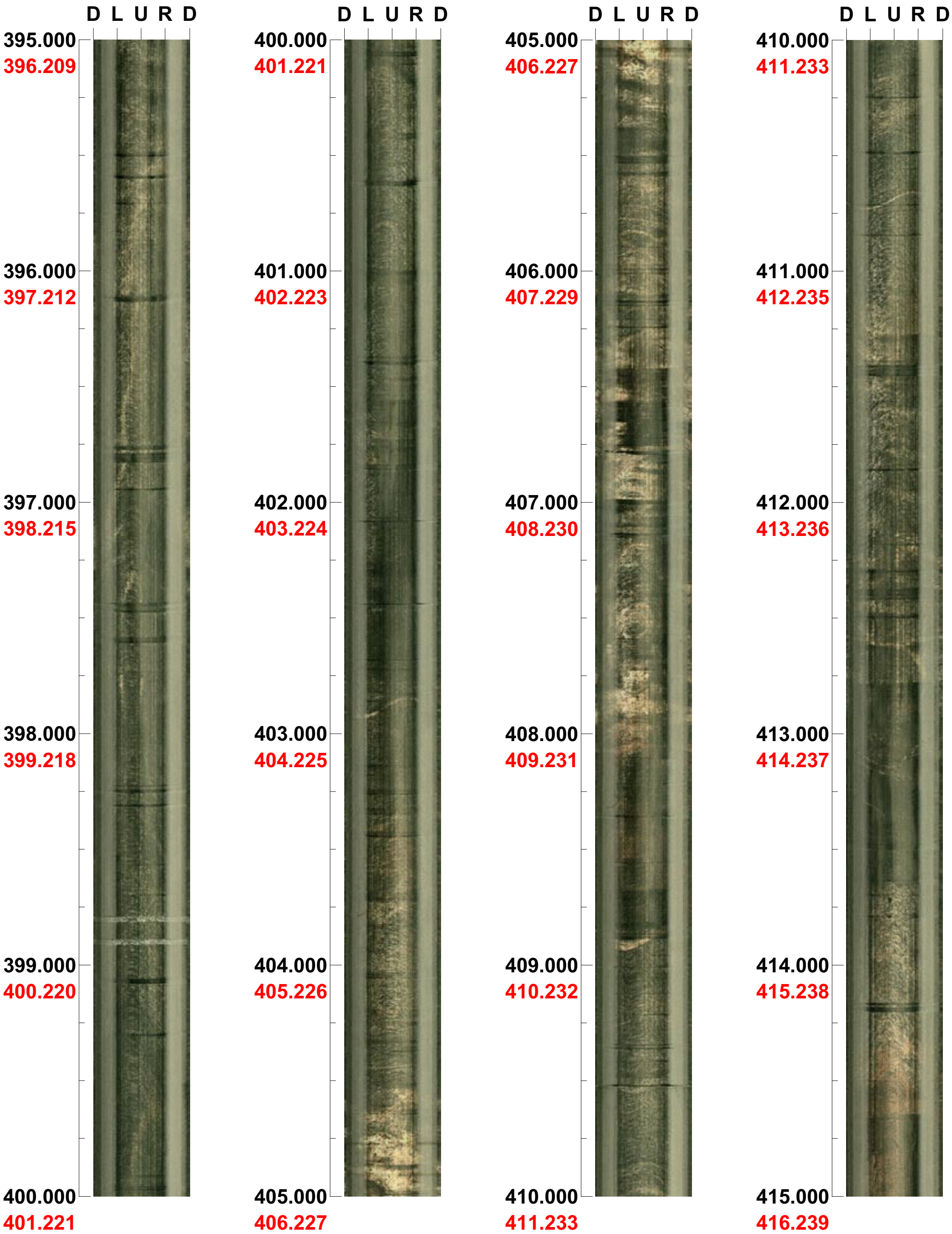
Depth range: 375.000 - 395.000 m



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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 395.000 - 415.000 m



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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 415.000 - 435.000 m

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

Project name: Forsmark

Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 435.000 - 455.000 m

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

Project name: Forsmark
Bore hole No.: KFM01B Azimuth: 267 Inclination: -79

Depth range: 455.000 - 475.000 m

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

Project name: Forsmark

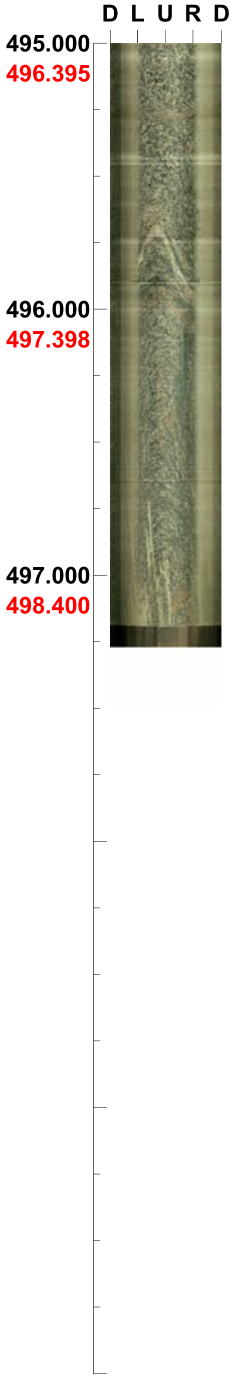
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 475.000 - 495.000 m

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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -79**

Depth range: 495.000 - 497.265 m



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

Appendix 4

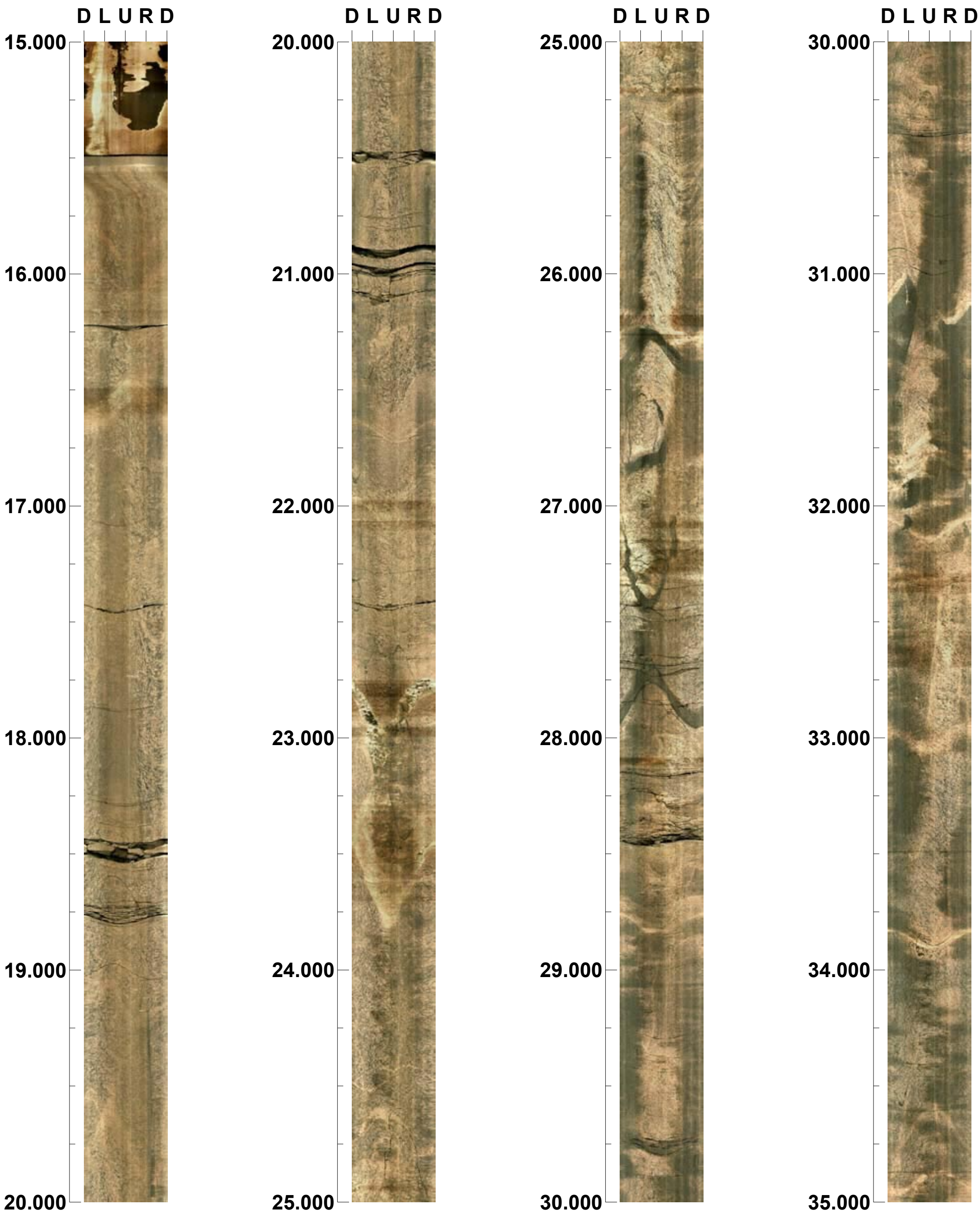
BIPS logging of KFM01B, 15 to 95 m

Project name: Forsmark

Image file	: g:\skb\bips\forsmark\kfm01b\kfm01b\20030831
BDT file	: g:\skb\bips\forsmark\kfm01b\kfm01b\20030831
Locality	: FORSMARK
Bore hole number	: KFM01B
Date	: 03/08/31
Time	: 09:30:00
Depth range	: 15.000 - 95.00 m
Azimuth	: 268
Inclination	: -78
Diameter	: 76.0 mm
Magnetic declination	: 0.0
Span	: 4
Scan interval	: 0.25
Scan direction	: To bottom
Scale	: 1/25
Aspect ratio	: 150 %
Pages	: 7
Color	: +0 +0 +0

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 268** **Inclination: -78**

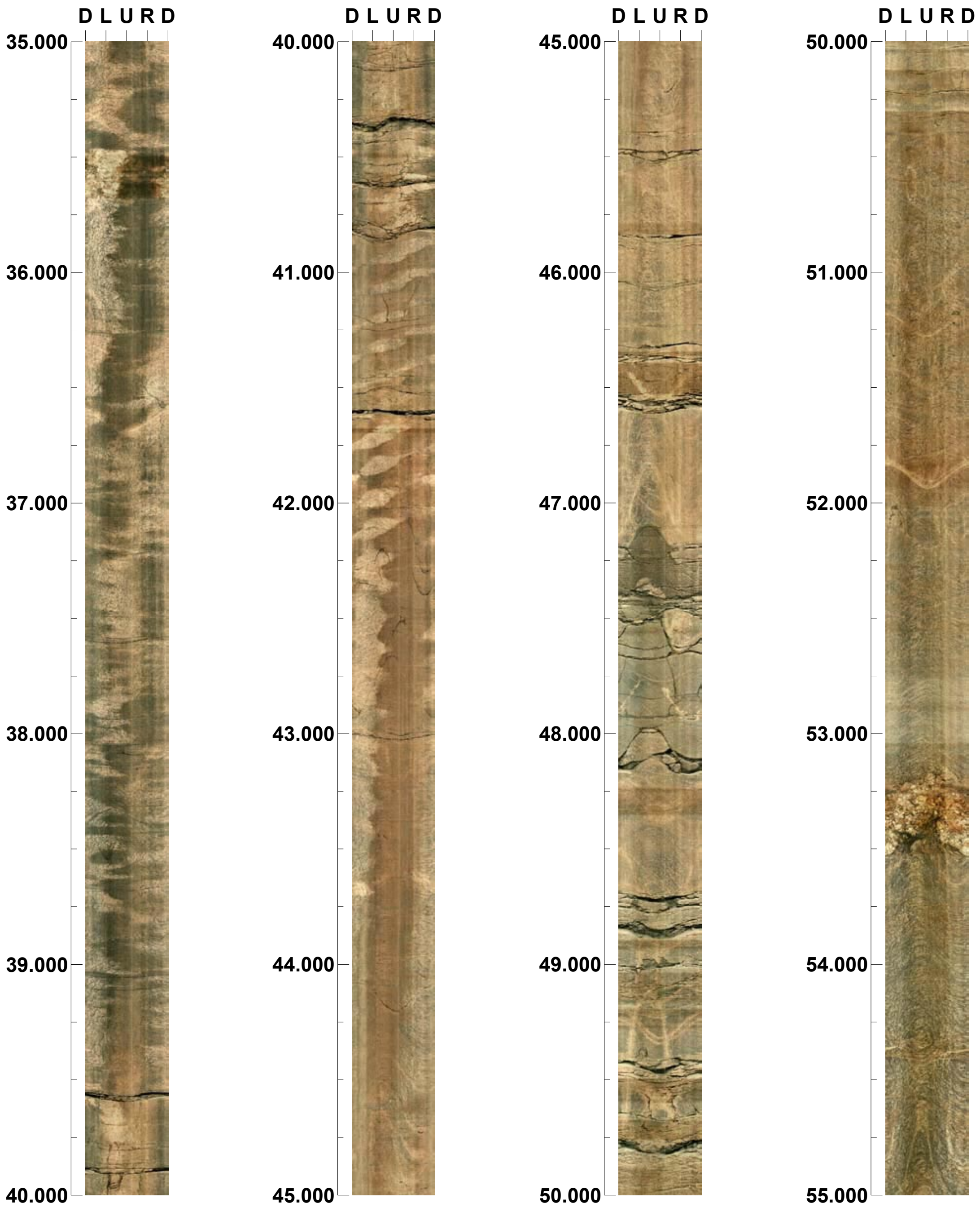
Depth range: 15.000 - 35.000 m



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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 268** **Inclination: -78**

Depth range: 35.000 - 55.000 m



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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 267** **Inclination: -78**

Depth range: 55.000 - 75.000 m

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

Project name: Forsmark
Bore hole No.: KFM01B **Azimuth: 268** **Inclination: -77**

Depth range: 75.000 - 95.000 m

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