P-04-41

Forsmark site investigation

RAMAC and BIPS logging in borehole KFM03A and KFM03B

Jaana Gustafsson, Christer Gustafsson
Malå Geoscience AB/RAYCON

April 2004

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

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

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 boreholes KFM03A (core drilled part) and KFM03B, see Table 1-1 and Figure 1-1. In the uppermost 11–100 m section of KFM03A, BIPS logging has been carried out but the results were not positive due to bad water quality in the borehole. These results are not further discussed in this report.

The borehole dipole radar measurements and BIPS measurements were conducted by Malå Geoscience AB/RAYCON during August 2003, while the directional radar antenna measurements were conducted in January 2004. The measurements were carried out according to activity plan AP-400-03-02 (SKB internal controlling document).

The applied investigation techniques comprised:

- Borehole radar with both dipole and directional radar antennas.
- Borehole TV logging with the so-called BIP-system (Borehole Image Processing System), which is a high resolution, side viewing, colour borehole TV system.

Table 1-1. Investigated boreholes.

Borehole ID	Azimuth (degrees from north)	Inclination (degrees from horizontal)	Length (metres)	Investigated section (metres)
KFM03A	272	86	1001	(11)100–1000
KFM03B	264	85	102	0–100

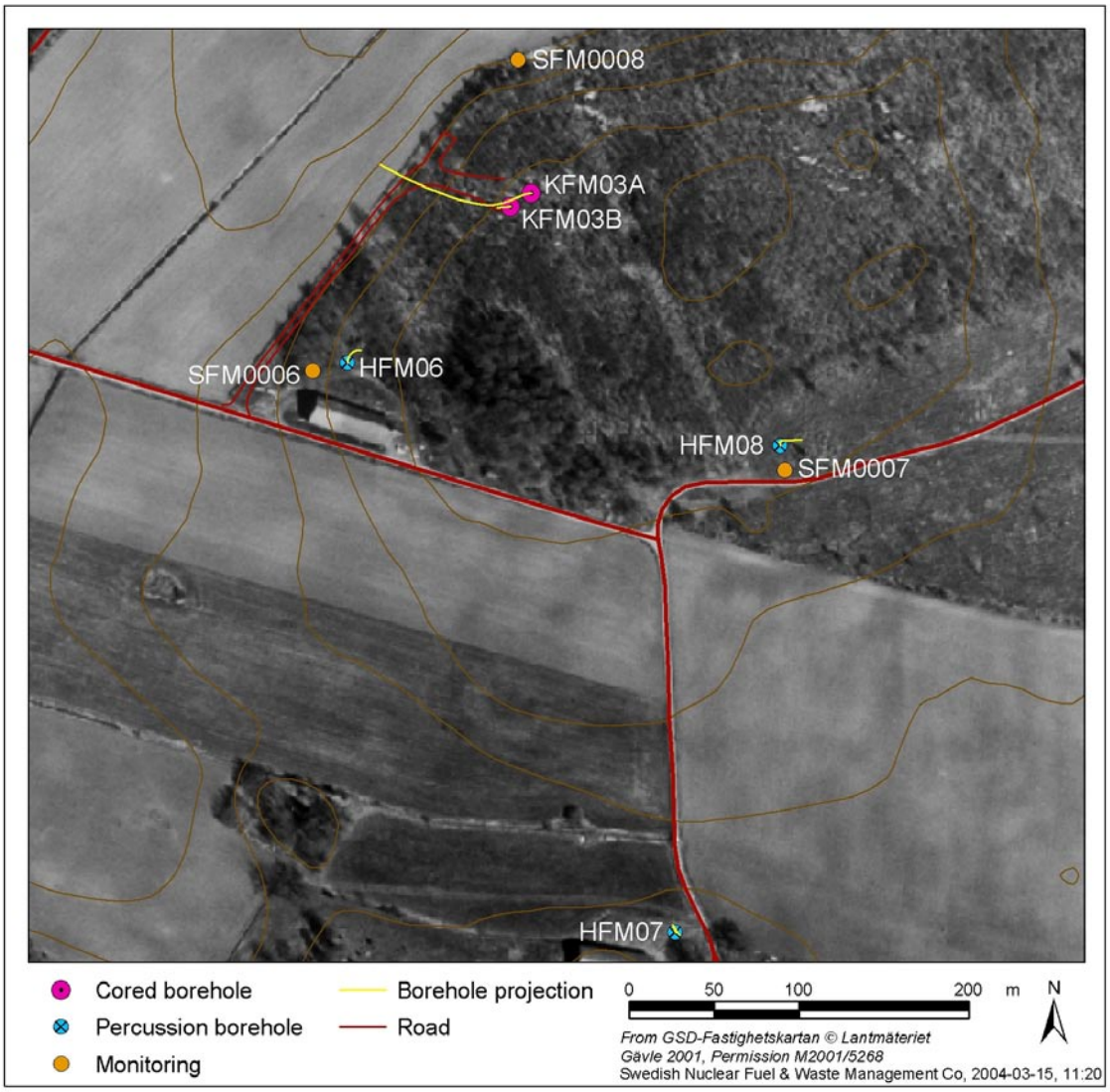


Figure 1-1. *Overview of drill site No. 3 in the Forsmark area.*

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. 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.

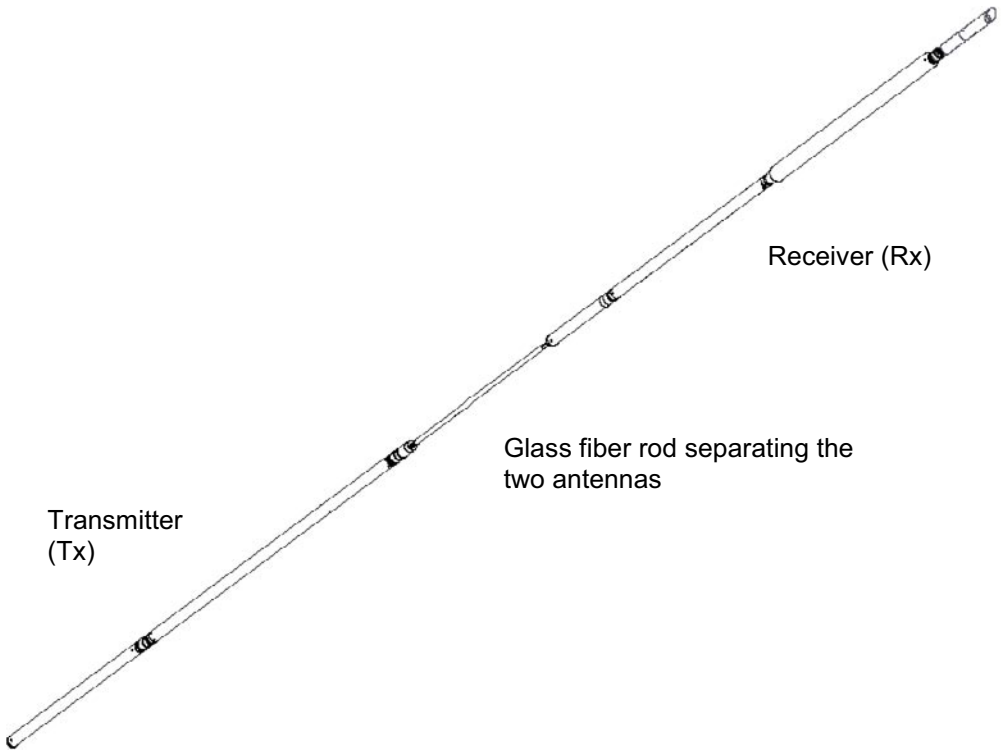


Figure 3-1. *Example of a borehole antenna.*

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).

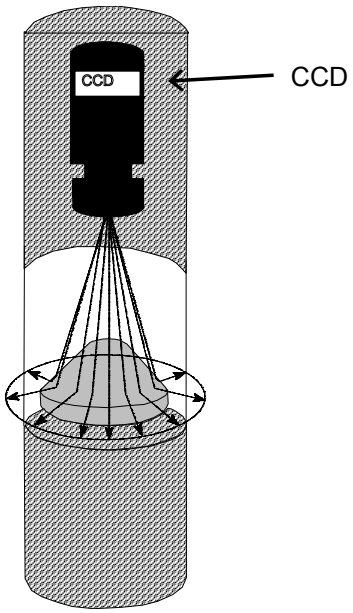


Figure 3-2. *The BIP-system. Illustration of the conical mirror scanning.*

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.

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 KFM03A and KFM03B is presented in Table 4-1 and 4-2 below.

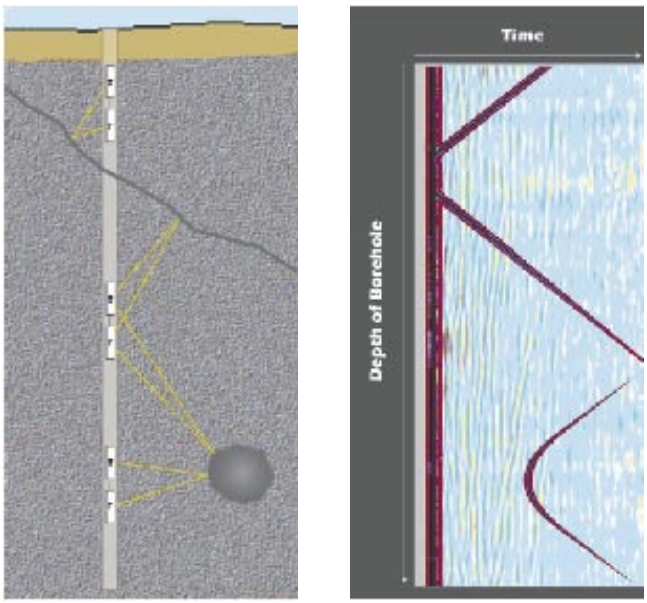


Figure 4-1. *The principle of radar borehole reflection survey (left) and a resulting radargram (right).*

Table 4-1. Radar logging information from KFM03A.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM03A**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Operators:	**CG/JG**	**Antenna**			
		Directional (60 MHz)	**250 MHz**	**100 MHz**	**20 MHz**
	Logging date:	04-01-14	03-08-04	03-08-05	03-08-05
	Reference:	T.O.C	T.O.C	T.O.C	T.O.C
	Sampling frequency (MHz):	656	2588	951	257
	Number of samples:	512	619	518	703
	Number of stacks:	32	Auto	Auto	Auto
	Signal position:	365.72	–0.32	–0.32	–1.43
	Logging from (m):	105.4	101.5	102.6	106.25
	Logging to (m):	993	996.5	995.2	993.0
	Trace interval (m):	0.5	0.1	0.2	0.25
	Antenna separation (m):	5.73	2.4	3.9	10.05

Table 4-2. Radar logging information from KFM03B.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM03B**	**Equipment:**	**SKB RAMAC**		
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ GeoScience**		
Operators:	**CG**	**Antenna**			
		Directional (60 MHz)	**250 MHz**	**100 MHz**	**20 MHz**
	Logging date:	04-01-14	030-08-04	03-08-05	03-08-05
	Reference:	T.O.C	T.O.C	T.O.C	T.O.C
	Sampling frequency (MHz):	656	2588	951	257
	Number of samples:	512	619	518	703
	Number of stacks:	32	Auto	Auto	Auto
	Signal position:	365.72	–0.32	–0.32	–1.43
	Logging from (m):	9.4	1.5	2.6	6.25
	Logging to (m):	93.4	98.3	97.5	93.4
	Trace interval (m):	0.5	0.1	0.2	0.25
	Antenna separation (m):	5.73	2.4	3.9	10.05

BIPS

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

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

Both boreholes presented in this report are inclined (c. 85 degrees from horizontal) and, therefore, the gravity sensor was used to orientate the BIPS camera.

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 KFM03A varies from 10 cm at a depth of 450 m to 50 cm at a depth of 900 metres for the three different dipole antennas. In the short borehole KFM03B, the divergences are assumed to be very limited.

4.2 Analyses and Interpretation

Radar

The results from radar measurements are commonly presented in the form of a radargram, where the position of the probes is displayed along one axis and the propagation along the other. The amplitude of the received signal is shown with a grey scale where black colour corresponds to 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.

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.

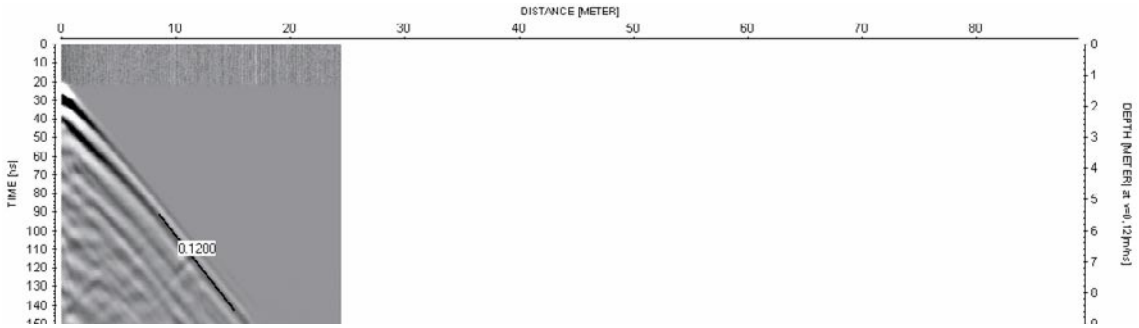


Figure 4-2. *Results from velocity measurements in HFM03 /1/.*

Table 4-3. Processing steps for borehole radar data from KFM03A.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM03A**	**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	Background removal	Bandpass	

Table 4-4. Processing steps for borehole radar data from KFM03B.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM03B**	**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			

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 reference to the BIPS and RAMAC logging activities in KFM03A and KFM03B is Field note Forsmark No. 88, 164 and 234.

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 about 10 degrees. This is considered to be satisfying, taking into account the somewhat disturbed environment at the site.

The results of the interpretation of the radar measurements are presented in Table 5-1 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.

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, above all in KFM03A, suffer from deteriorated quality due to increased electrical conductivity in the bedrock or in the borehole fluid. A conductive environment entails attenuation of the radar waves, resulting in decreased penetration. The deteriorated quality is especially seen for the 20 MHz data below 520 m (KFM03A), which therefore is not displayed in Appendix 1.

The data quality from the directional antenna measurements in KFM03A was in large parts quite low, most probably due to a conductive environment, which in combination with a frequency of 60 MHz gave a pronounced ringing in the data, see Figure 5-1. This has resulted in a high uncertainty of the interpretation of the directions listed in Table 5-3.

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 5-3 and 5-4 summarise the interpretation of radar data from KFM03A and KFM03B. 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 5-2, 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.

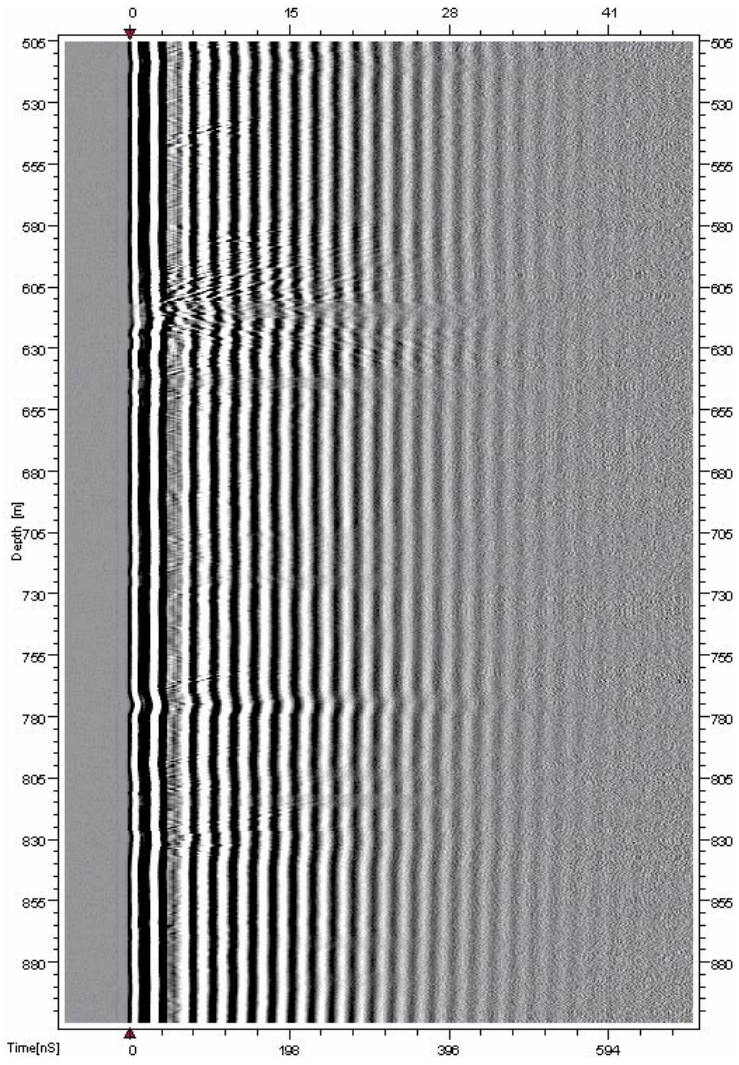


Figure 5-1. *Example of the dipole component of the directional antenna.*

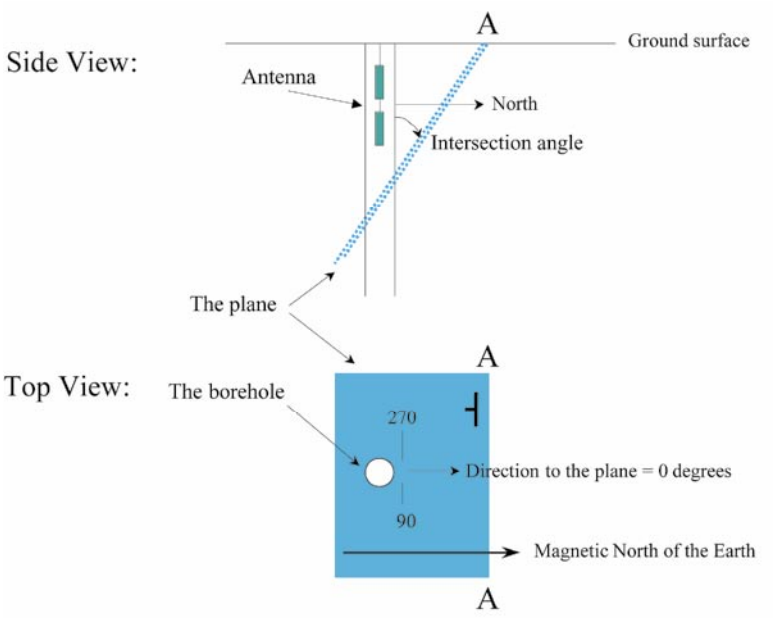


Figure 5-2. *Definition of the direction to object as presented in Table 5-3 and 5-4.*

Table 5-1. Identified structures as a function of depth in KFM03A.

Depth (m)	No. of structures	Depth (m)	No. of structures
0–150	10	550–600	4
150–200	6	600–650	6
200–250	5	650–700	6
250–300	5	700–750	5
300–350	3	750–800	4
350–400	9	800–850	5
400–450	6	850–900	3
450–500	9	900–950	3
500–550	6	950–1000	5

Table 5-2. Identified structures as a function of depth in KFM03B.

Depth (m)	No. of structures
0–50	8
50–100	8

Table 5-3. Model information from dipole antennas 20, 100 and 250 MHz and the directional, 60 MHz antenna, KFM03A.

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

Site: Forsmark
Borehole name: KFM03A
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	Hx	69	12	270	90	262	78	84	78
PLANE	H	102	14	42	222	170	80	348	72
PLANE	A	106	73						
PLANE	B	110	50	330	150	236	42	62	34
PLANE	G	113	13	57	237	151	79	329	73
PLANE	C	114	50	309	129	254	41	84	35
PLANE	Ox	114	17						
PLANE	D	127	62	102		113	25		
PLANE	E	132	56	321	141	240	39	69	31
PLANE	F	140	57	270		288	33		
PLANE	I	177	62	333		240	29		
PLANE	Ix	179	24	78		129	67		
PLANE	J	184	54	51	231	159	36	327	30
PLANE	Dx	186	25						
PLANE	Kx	187	70	276	96	276	21	123	20
PLANE	K	190	53	204	24	354	32	182	42
PLANE	L	228	60						

Object type	Name	Intersection depth (m)	Intersection angle (deg)	Object direction 1 (deg)	Object direction 2 (deg)	Interpreted true orientation			
						Strike 1 (deg)	Dip 1 (deg)	Strike 2 (deg)	Dip 2 (deg)
PLANE	Lx	239	17	246	66	312	71	135	75
PLANE	Mx	240	42	9	189	193	53	11	43
PLANE	2x	244	16						
PLANE	O	246	64						
PLANE	M	256	71						
PLANE	P	259	48						
PLANE	Q	262	58	162		38	32		
PLANE	N	266	32	144		56	53		
PLANE	Qx	267	43	348	168	209	52	31	42
PLANE	R	280	70						
PLANE	S	317	21	78	258	115	69	291	67
PLANE	T	330	55						
PLANE	V	337	53						
PLANE	W	351	52						
PLANE	Y	359	61	354	174	187	36	9	26
PLANE	X	365	73	132	312	64	14	219	21
PLANE	U	367	16	42	222	140	78	318	70
PLANE	Z	373	79						
PLANE	Zx	375	62	192	12	346	23	170	33
PLANE	1	382	62						
PLANE	2	389	71	264	84	263	22	107	23
PLANE	3	399	66	90		98	24		
PLANE	4	403	73						
PLANE	5	413	68	213	33	316	23	147	31
PLANE	6	419	72	222	42	299	15	140	22
PLANE	7	423	69	255	75	268	21	111	24
PLANE	8	431	69						
PLANE	9	436	67						
PLANE	10	452	58	39	219	137	36	305	27
PLANE	3x	462	20						
PLANE	11	463	62	219	39	306	23	138	31
PLANE	12	471	56	192	12	338	32	161	44
PLANE	13	478	60						
PLANE	14	482	65						
PLANE	15	486	57	39	219	136	42	306	33
PLANE	16	489	23						
PLANE	17	495	55						
PLANE	18	501	60						
PLANE	20	511	63	63		117	29		
PLANE	19	515	61	39	219	138	33	303	24
PLANE	21	529	63	219	33	301	21	138	38
PLANE	22	535	61	57	237	121	31	280	23
PLANE	23	550	59	183		344	22		
PLANE	24	570	55	297	117	224	37	60	32
PLANE	25	579	60	228		292	27		
PLANE	26	592	55						

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	27	596	52	279		243	39		
PLANE	28	603	57	204	24	320	32	147	43
PLANE	29	614	80						
PLANE	30	619	71						
PLANE	31	626	62						
PLANE	32	640	63	171	351	357	20	172	34
PLANE	33	644	69	39		135	30		
PLANE	34	654	63	219	39	291	19	131	29
PLANE	35	661	70						
PLANE	36	668	57	234	54	276	21	122	29
PLANE	37	687	58						
PLANE	38x	698	56	249	69	266	32	105	37
PLANE	38	699	53	75	255	99	37	266	34
PLANE	39	709	63						
PLANE	40x	721	58	84	264	91	33	249	32
PLANE	40	725	60						
PLANE	41	738	67						
PLANE	42	750	73	78	258	106	20	243	17
PLANE	43	772	63	48		121	32		
PLANE	44	779	60	237	57	271	27	112	34
PLANE	45	794	64	75	255	98	28	249	23
PLANE	46	797	49						
PLANE	47	804	58	237		272	27		
PLANE	47x	811	68	87		88	23		
PLANE	48	815	81	291	111	212	21	71	17
PLANE	49	829	82	183	3	336	8	160	22
PLANE	50	835	65						
PLANE	51	865	65						
PLANE	52	871	80	171	351	358	6	165	20
PLANE	53	895	86						
PLANE	54	918	72	15	195	147	26	316	12
PLANE	55	923	65						
PLANE	56	944	76	12	192	149	26	317	10
PLANE	59	958	68						
PLANE	58	969	60	168	348	354	23	168	39
PLANE	60	985	64	357	177	159	32	341	15
PLANE	57	990	12						
PLANE	61	993	83						

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, KFM03B.

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

Site: Forsmark
Borehole name: KFM03B
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	Ax	–81	9	288		162	81		
PLANE	A	–73	6	288		162	83		
PLANE	B	14	48	303	123	189	47	327	42
PLANE	C	27	62	186	6	264	25	84	25
PLANE	Cx	29	46	6		84	44		
PLANE	E	34	59						
PLANE	D	37	59	90	270	0	33	180	33
PLANE	F	45	58						
PLANE	G	54	71	306	126	165	28	324	23
PLANE	H	66	59	294		181	36		
PLANE	HH	69	69						
PLANE	I	82	63						
PLANE	Ix	85	51	354		181	44		
PLANE	K	91	62						
PLANE	J	93	59	174		185	35		
PLANE	L	167	8	120		181	87		

Names in table according to Appendix 2.

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 KFM03A:

Depth (m)	Depth (m)
125–130	550
140	575
175	600–605
225	610–620
255	625
265	635–645
315	675
325	710
355	725
365	745
370	770–780
390	795
415	800–820
420	825–835
430	855
455	865–875
465	915
515	940–950
530–535	985–1000

And for KFM03B:

Depth (m)	Depth (m)
25–30	80–85
45	Around 90
65–70	

5.2 BIPS logging

The BIPS pictures for KFM03A and KFM03B are presented in Appendix 3 and 4, respectively.

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

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.

Two individual runs with the BIPS have been performed in KFM03A. The first one, 2003-08-03/04, showed very poor results due to dirty borehole water. Between 450 and 850 metres depth, it was almost impossible to distinguish any structures. When the second run was carried out, 2003-09-01, the water quality had improved significantly, and data of good quality was recorded. Still there are the some quality problems related to the drilling induced discolouring of parts of the borehole wall. These quality problems are clearly visible on the data presented in Appendix 3. In the parts of the borehole which are heavily defected, there will likely be difficult to map thin structures and single fractures.

The water quality is in KFM03B was considered to be fairly good and only one run has been performed, 2003-08-05. The BIPS images are shown in Appendix 4.

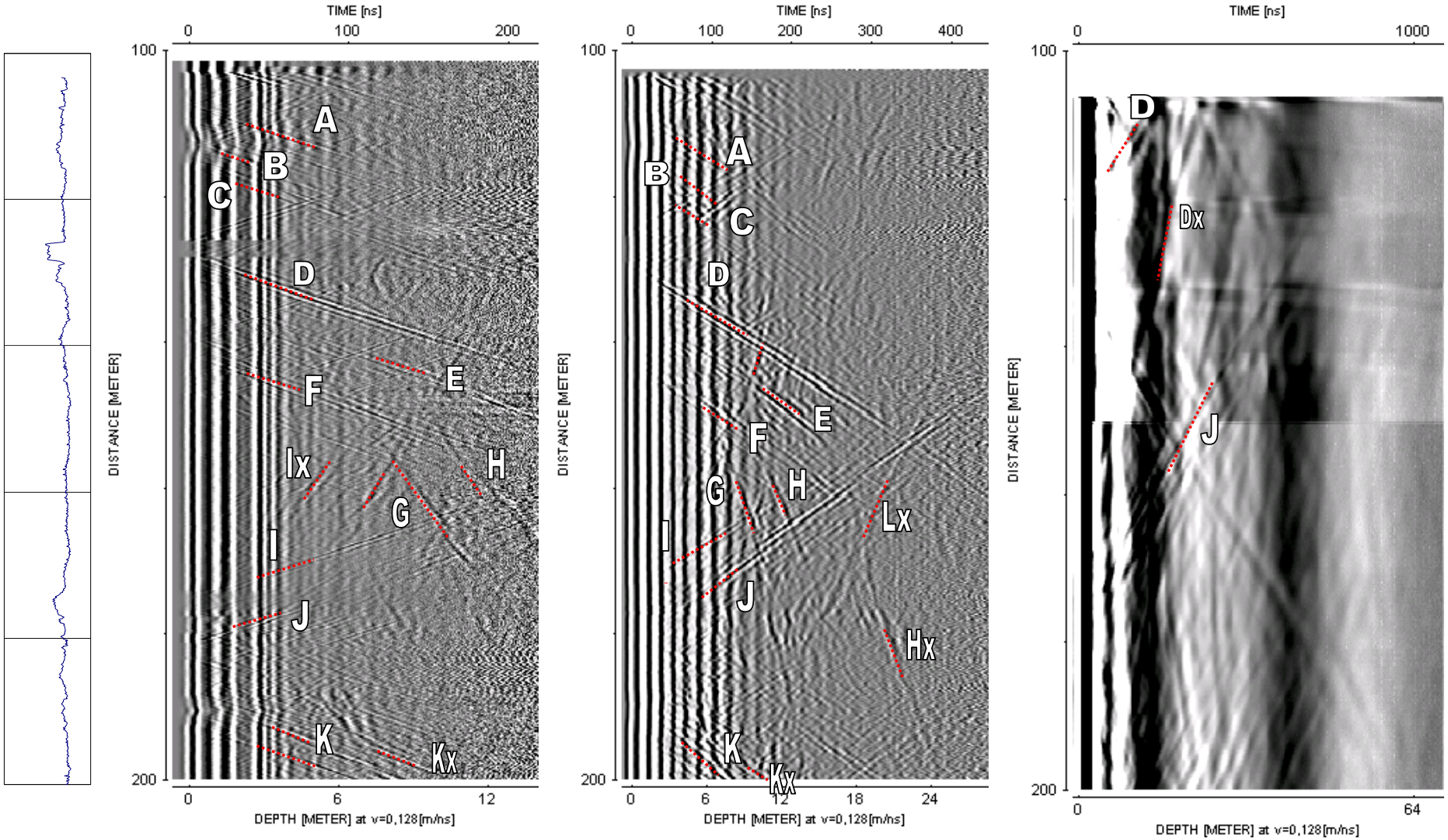
6 References

/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.

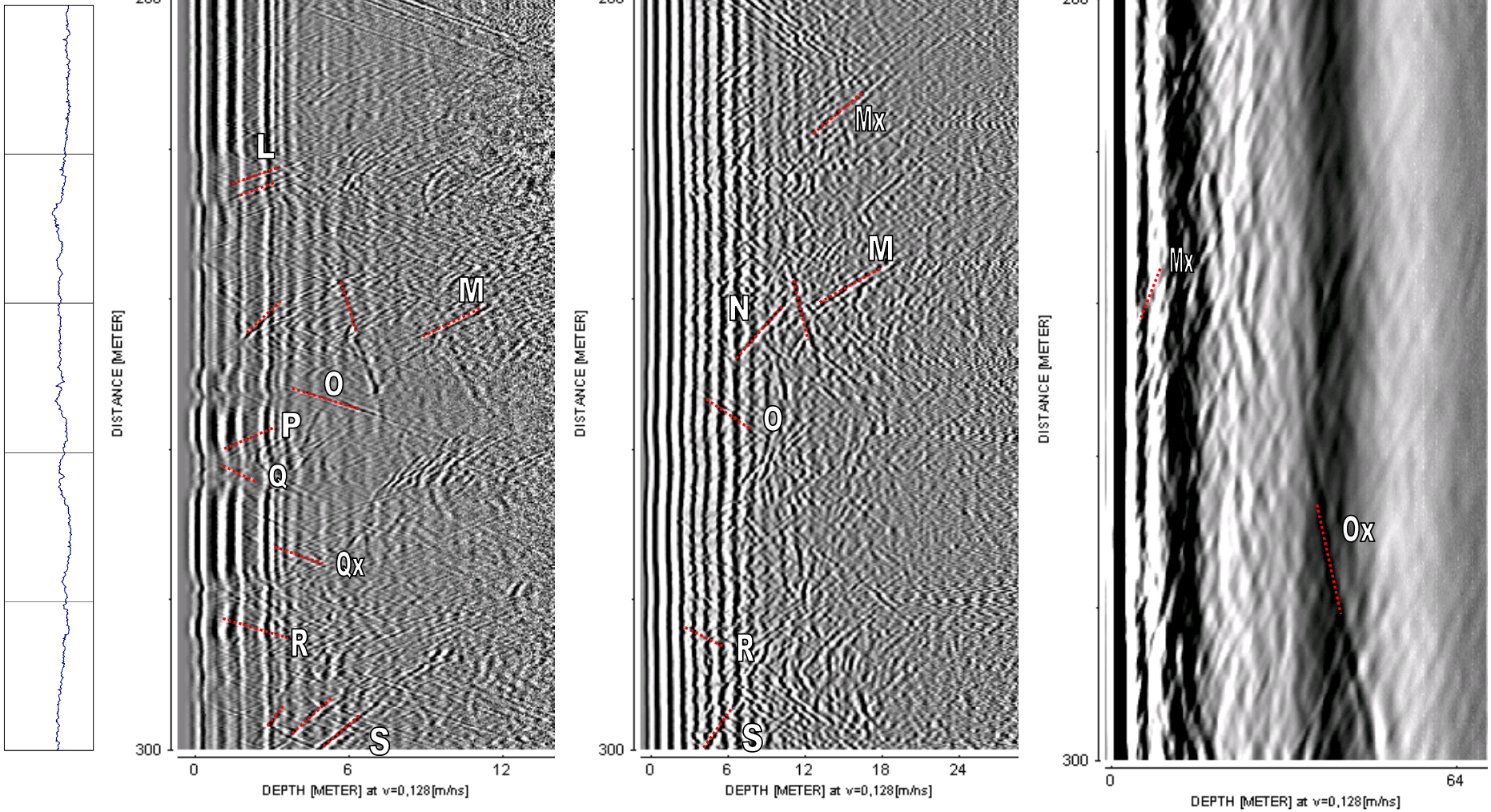
Appendix 1

Radar logging of KFM03A, 100 to 1000 m
Dipole antennas 250, 100 and 20 MHz

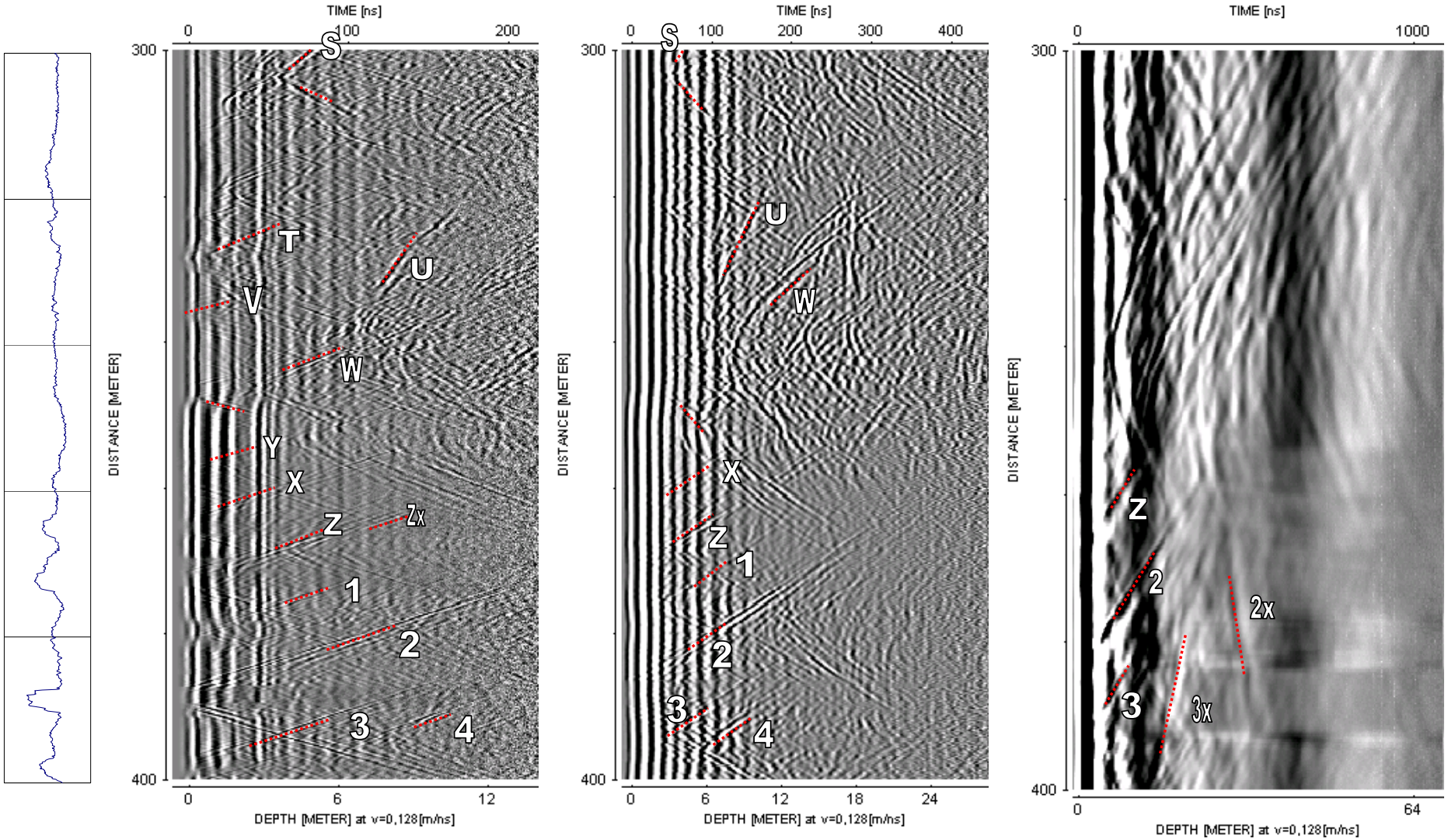
FORSMARK KFM03A with interpretation



FORSMARK KFM03A with interpretation

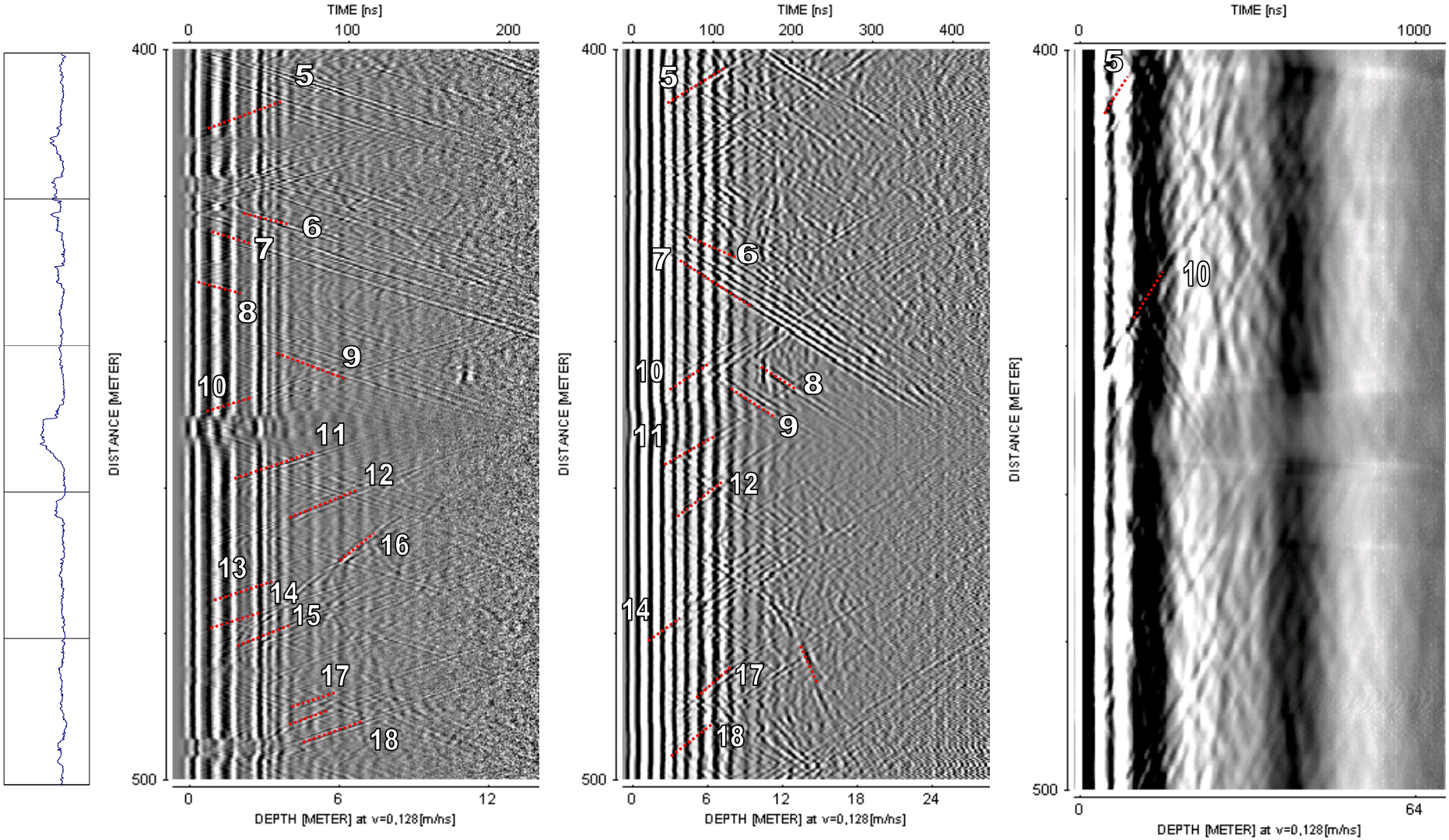


FORSMARK KFM03A with interpretation



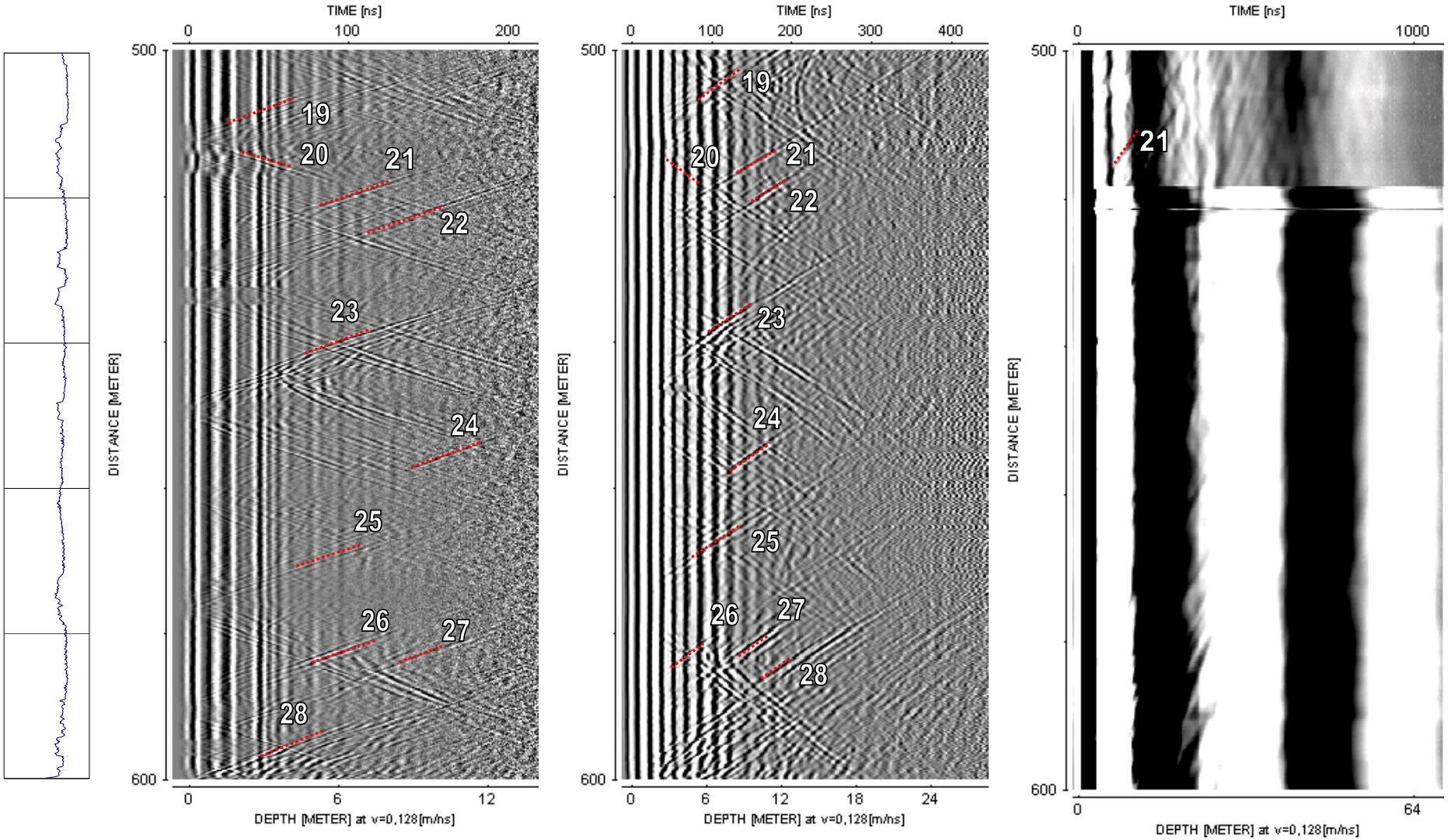
250 MHz | **100 MHz** | **20 MHz**

FORSMARK KFM03A with interpretation



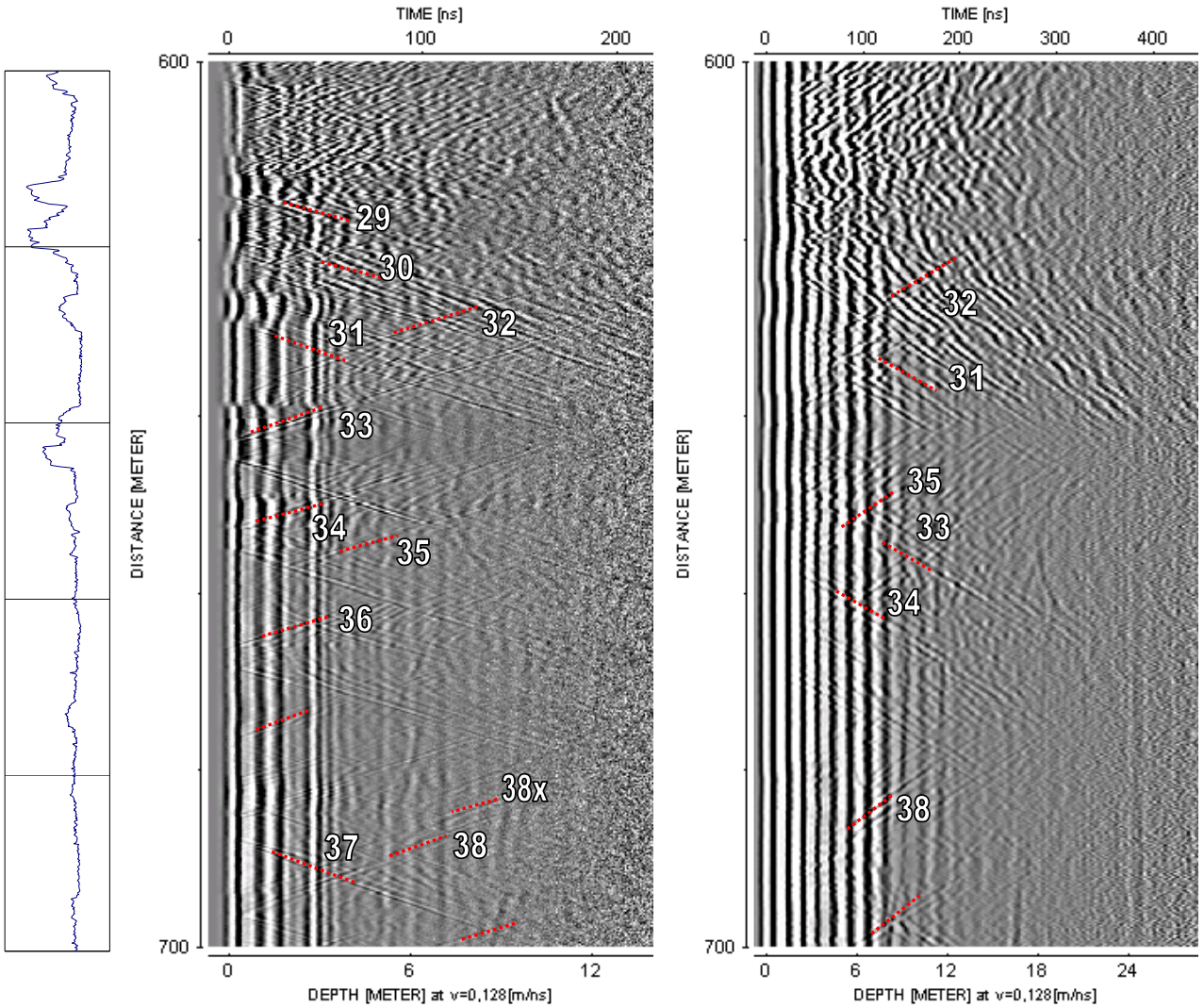
250 MHz **100 MHz** **20 MHz**

FORSMARK KFM03A with interpretation



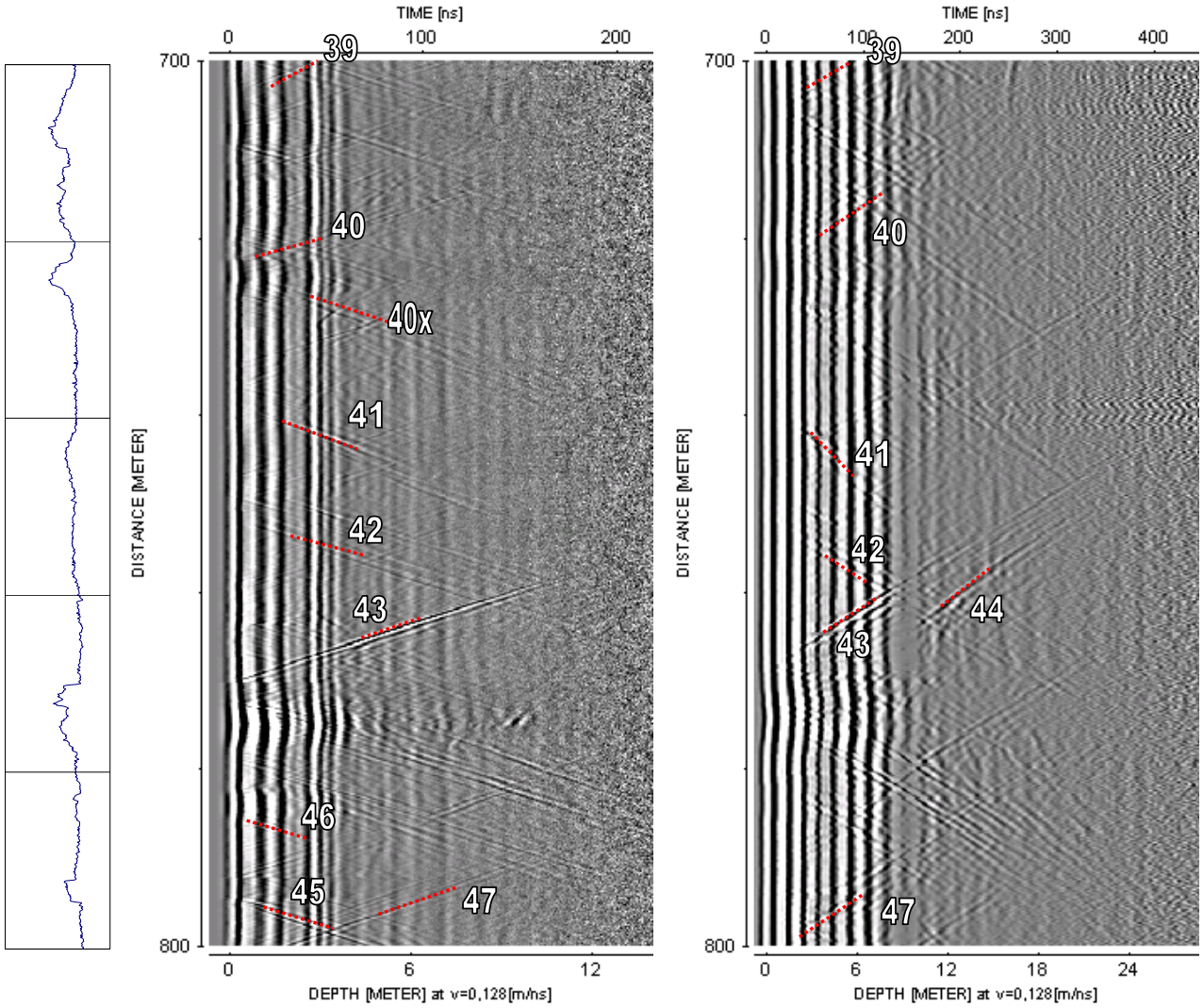
250 MHz **100 MHz** **20 MHz**

FORSMARK KFM03A with interpretation



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

FORSMARK KFM03A with interpretation

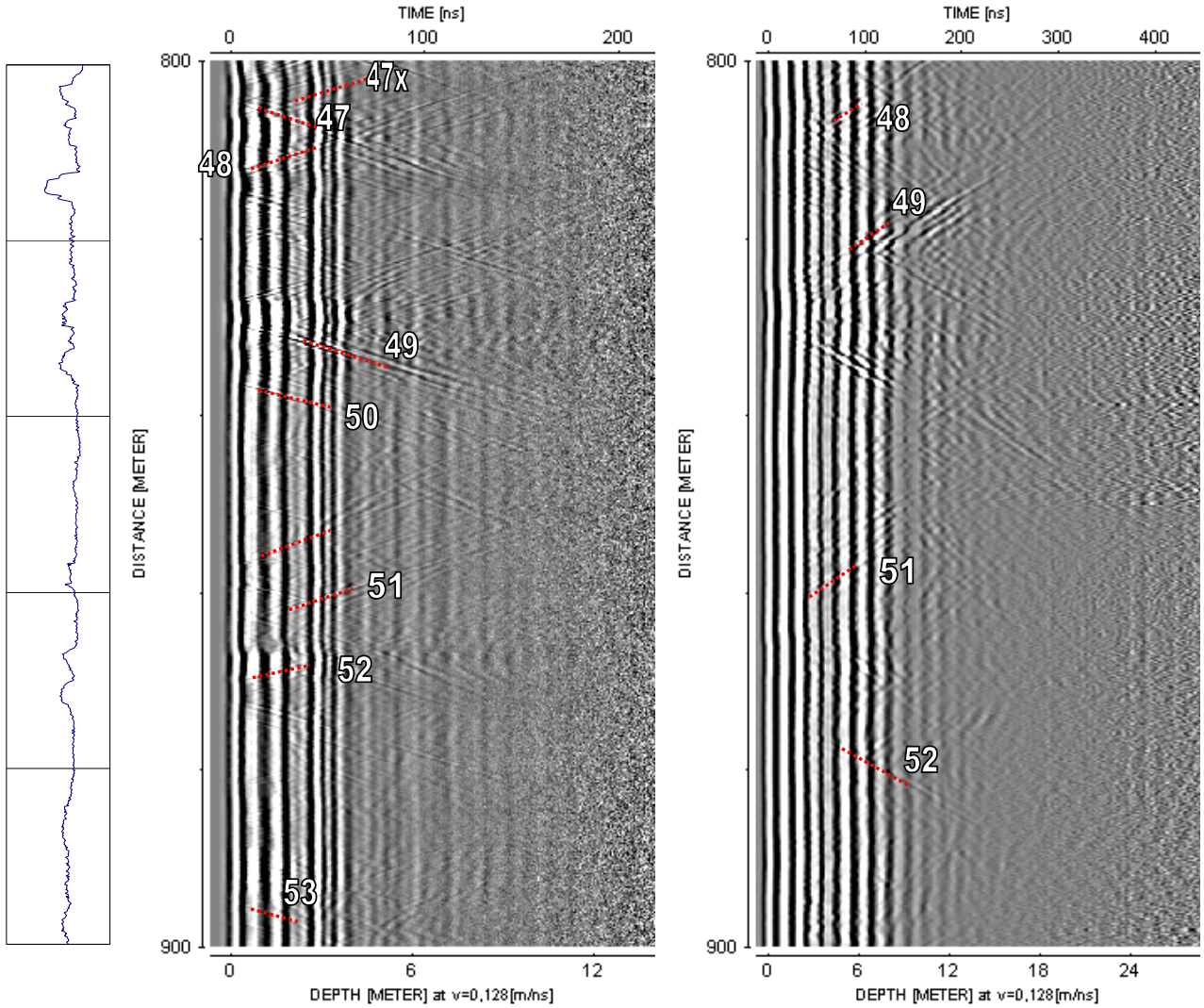


250 MHz

100 MHz

20 MHz

FORSMARK KFM03A with interpretation

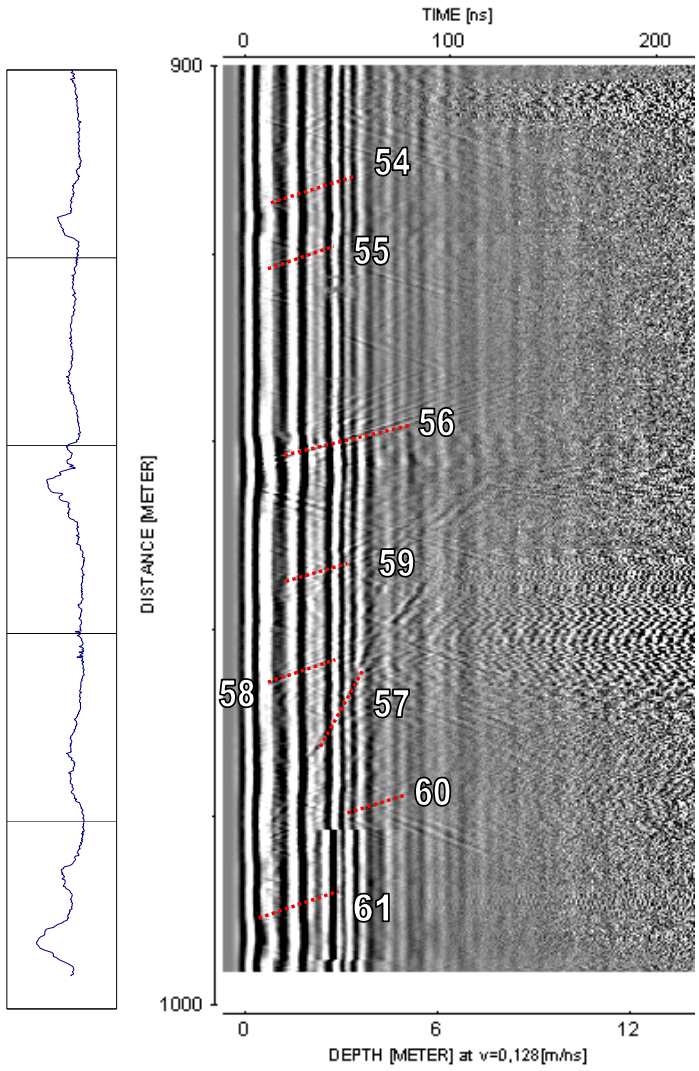


250 MHz

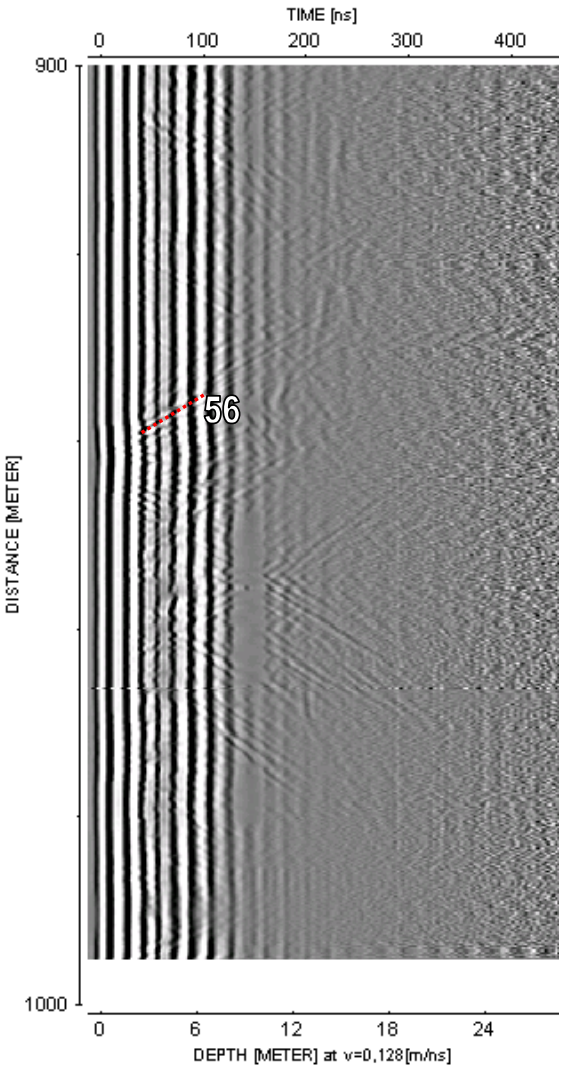
100 MHz

20 MHz

FORSMARK KFM03A with interpretation



250 MHz



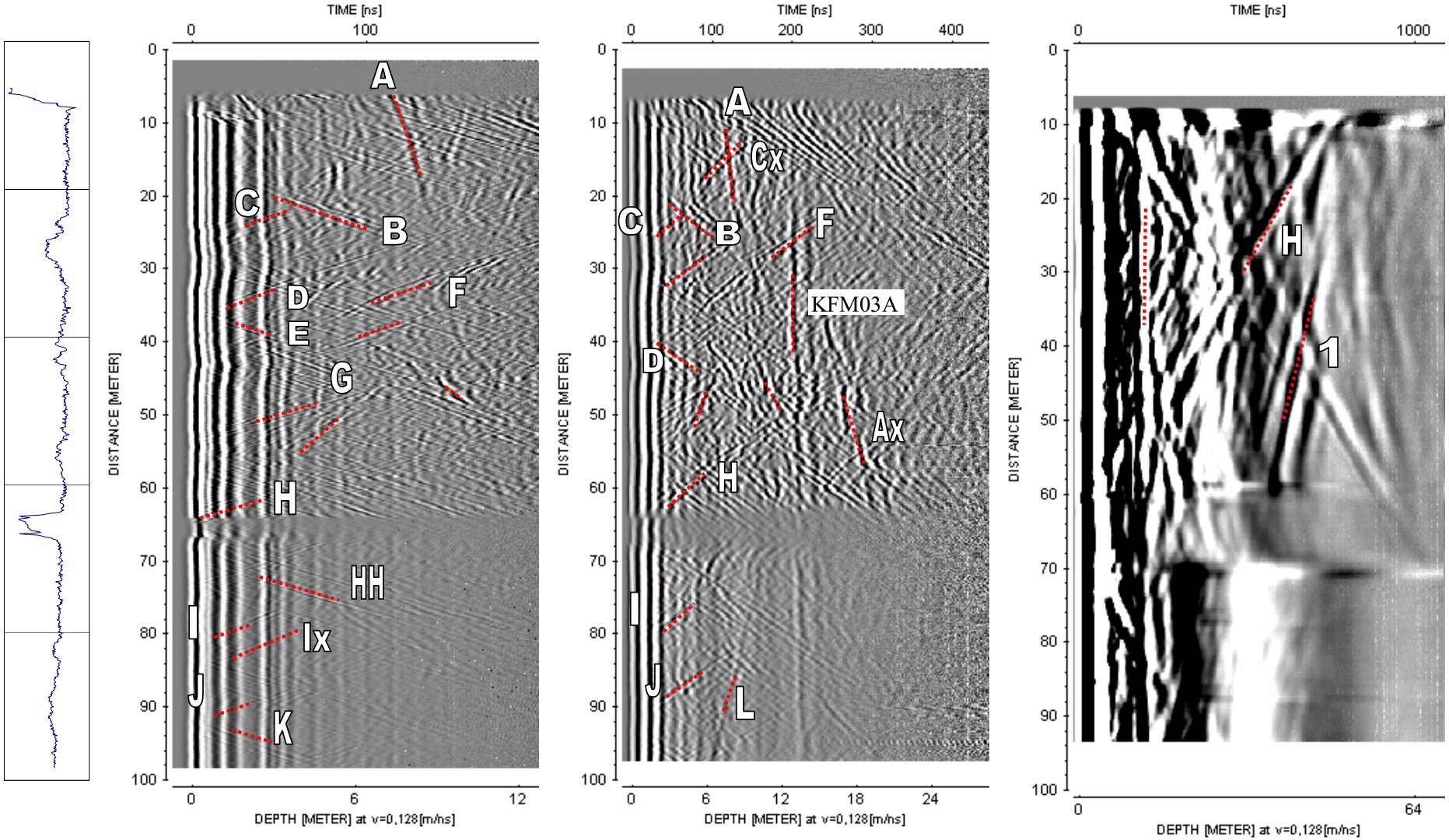
100 MHz

20 MHz

Appendix 2

Radar logging of KFM03B, 0 to 100 m
Dipole antennas 250, 100 and 20 MHz

FORSMARK KFM03B with interpretation



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

Appendix 3

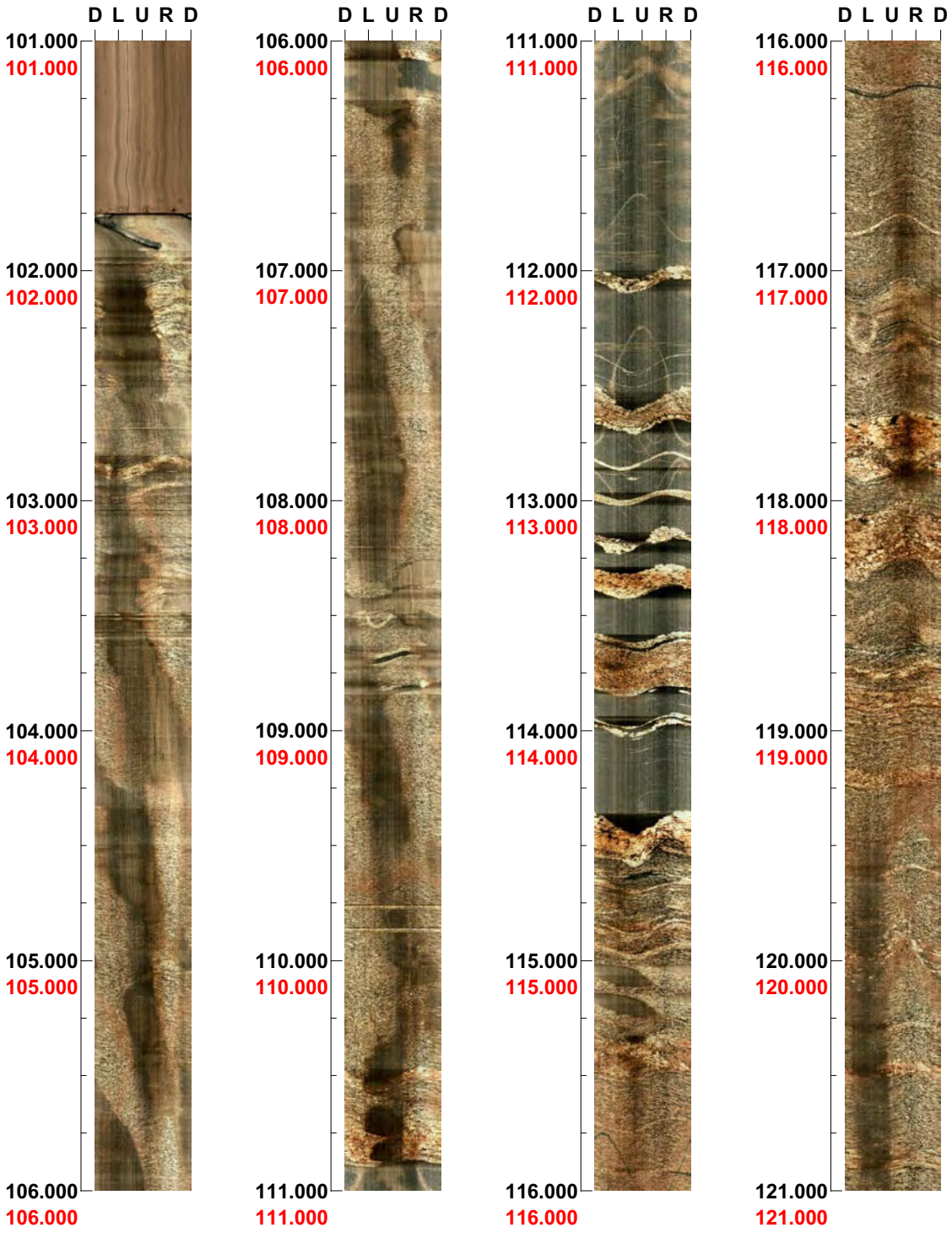
BIPS logging of KFM03A, 101 to 997.1 m

Project name: Forsmark

Image file	**: h:\work\kfm03a\bips10~1\septem~1\kfm03a~2.bip**
BDT file	**: h:\work\kfm03a\bips10~1\septem~1\kfm03a~2.bdt**
Locality	**: FORSMARK**
Bore hole number	**: KFM03A**
Date	**: 03/08/31**
Time	**: 17:15:00**
Depth range	**: 101.000 - 451.067 m (red figures = corrected values)**
Azimuth	**: 271**
Inclination	**: -85**
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	**: 18**
Color	**: +0 +0 +0**

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

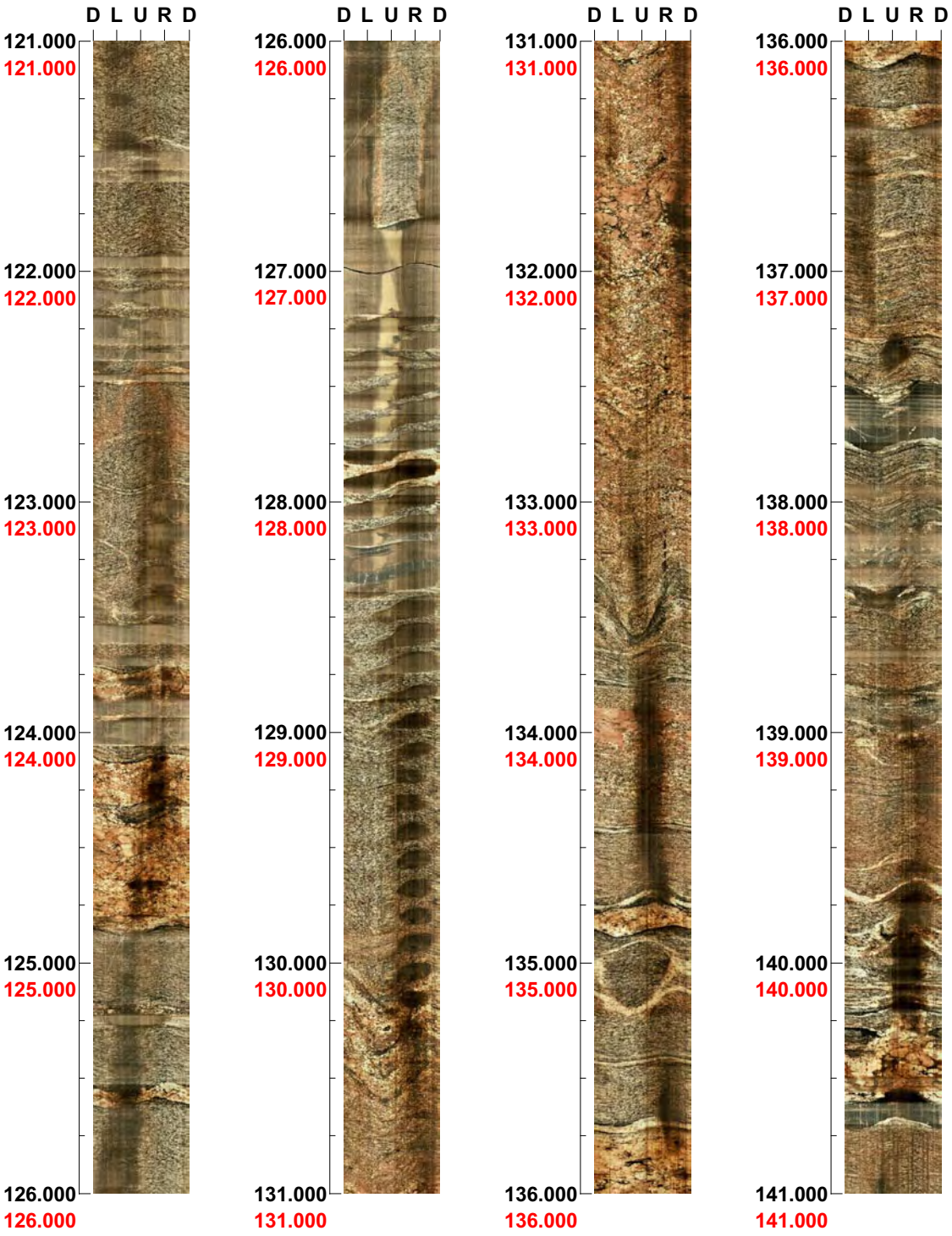
Depth range: 101.000 - 121.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

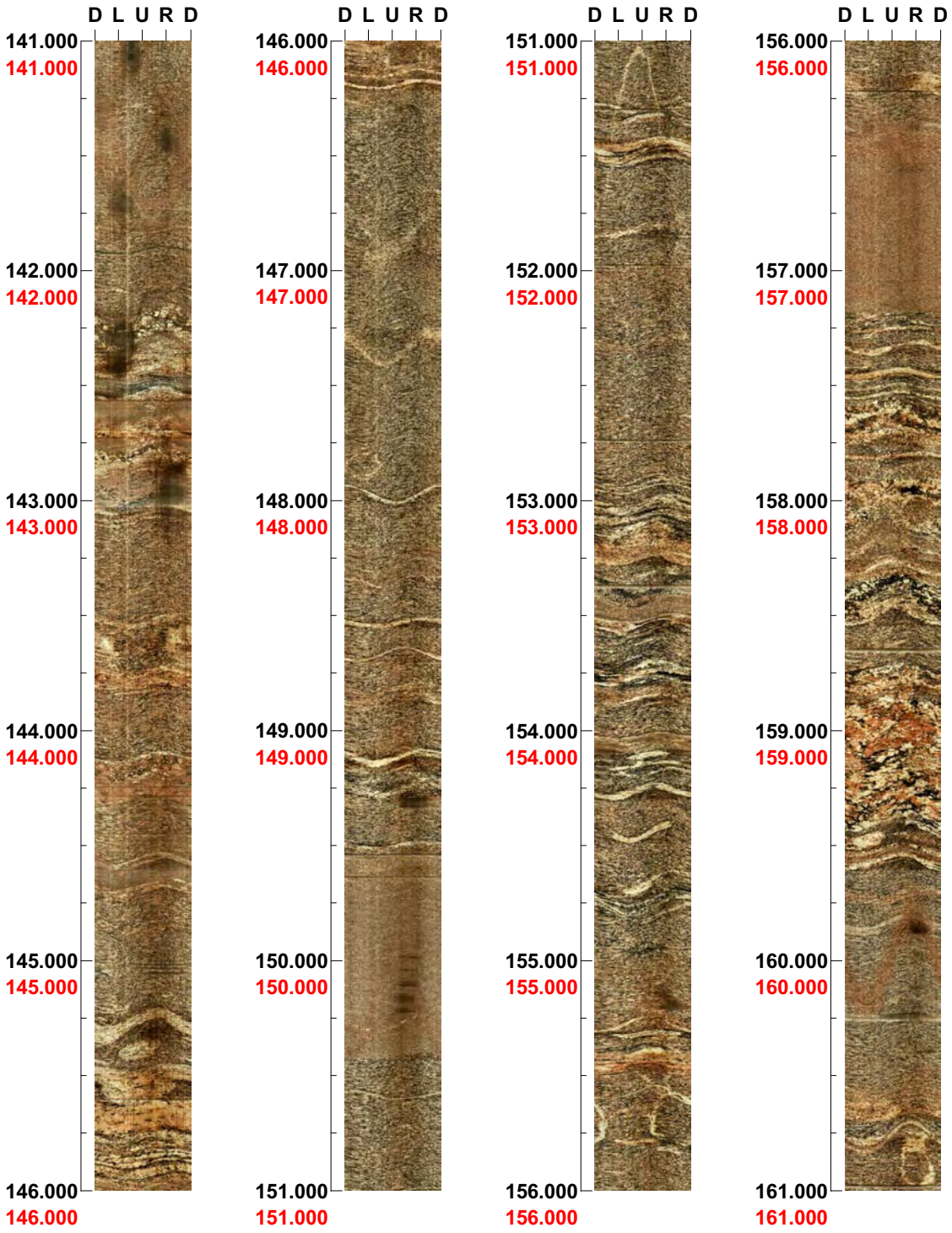
Depth range: 121.000 - 141.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

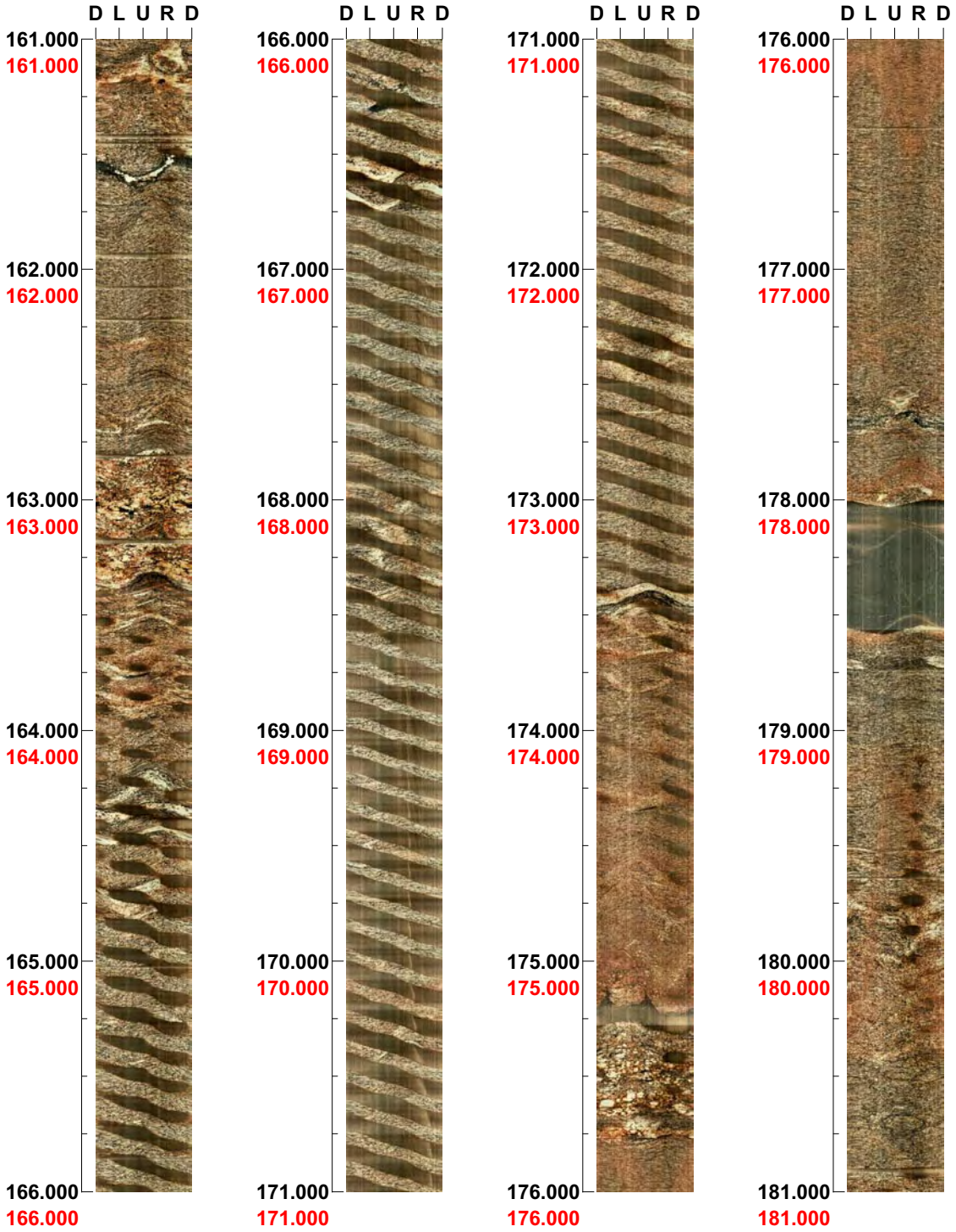
Depth range: 141.000 - 161.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

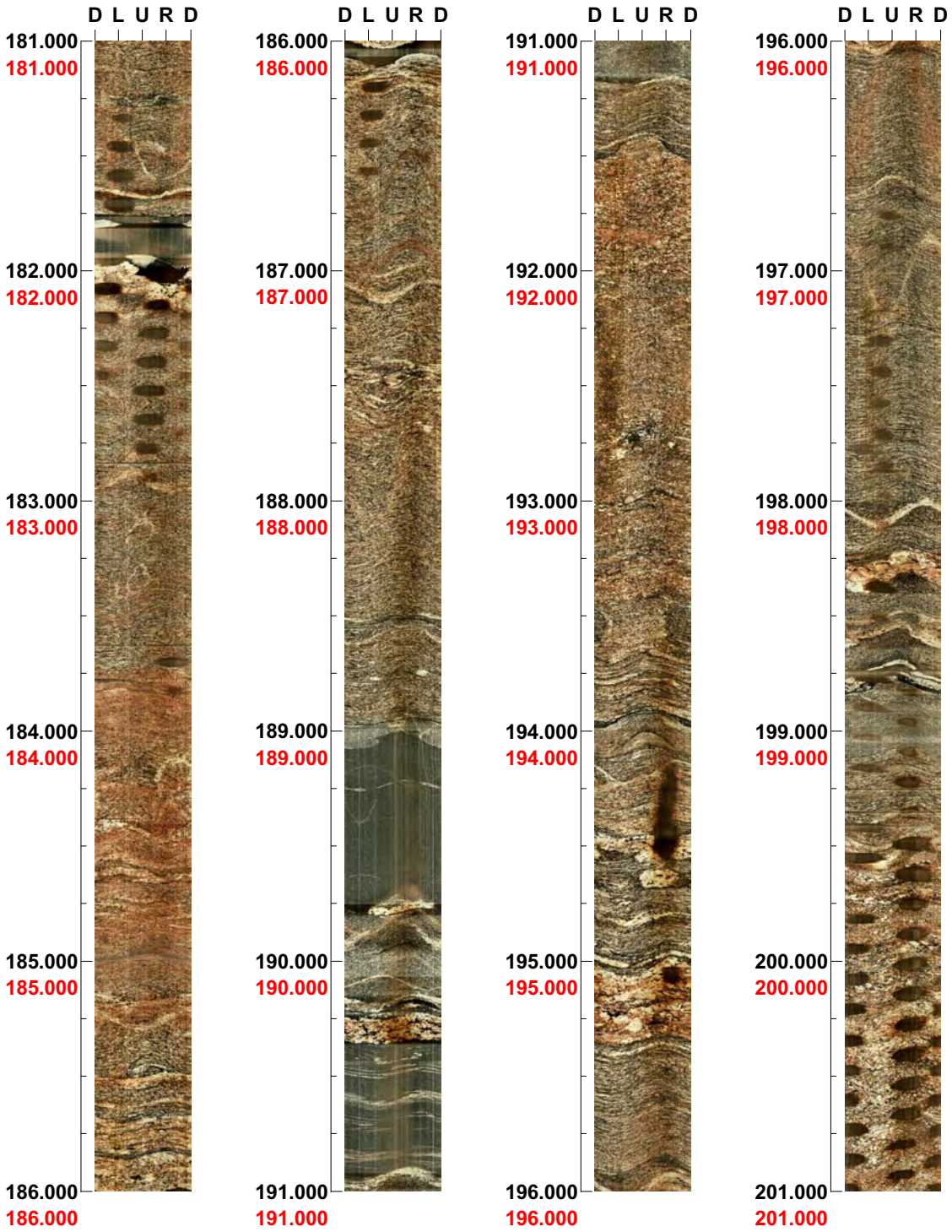
Depth range: 161.000 - 181.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

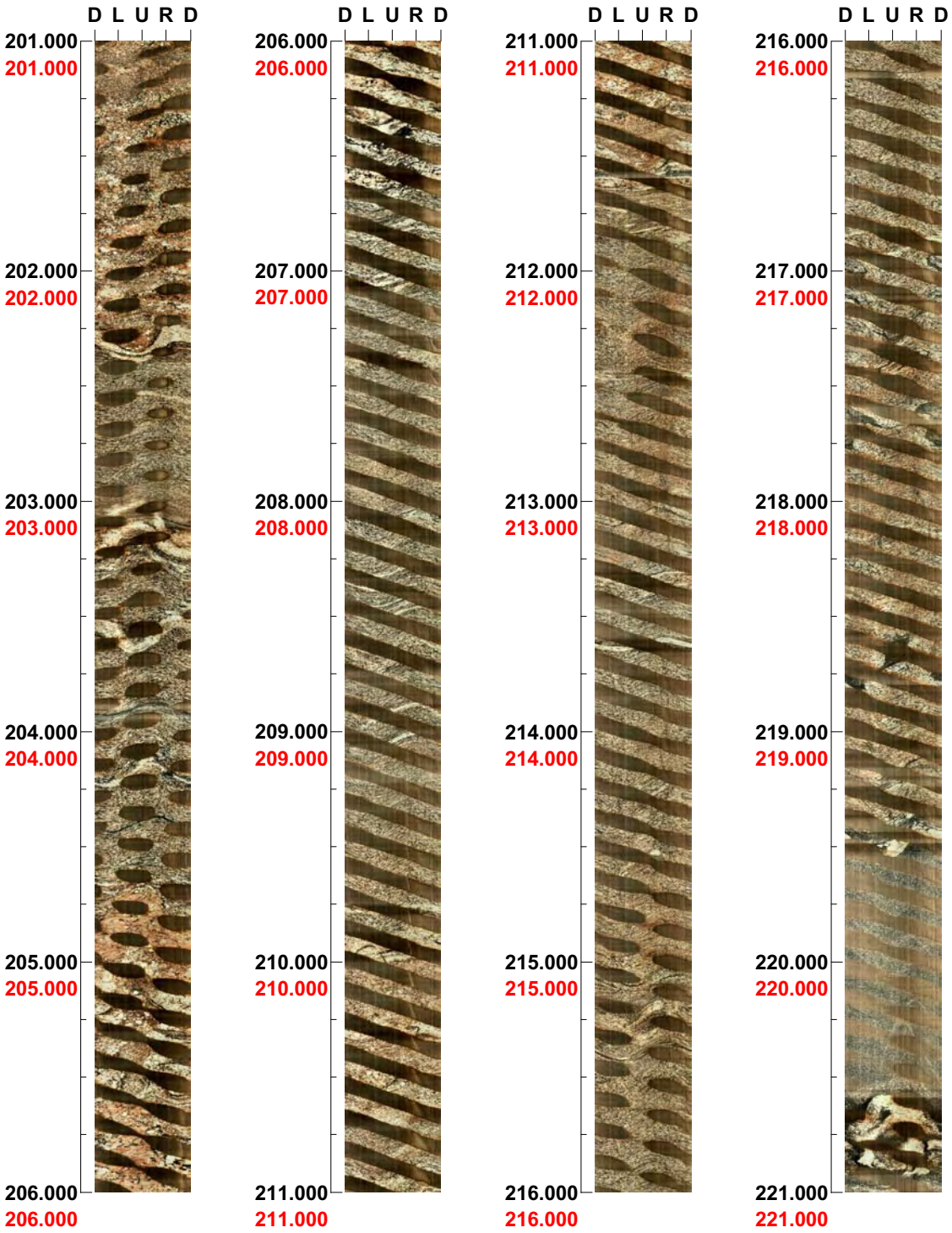
Depth range: 181.000 - 201.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 201.000 - 221.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 221.000 - 241.000 m

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

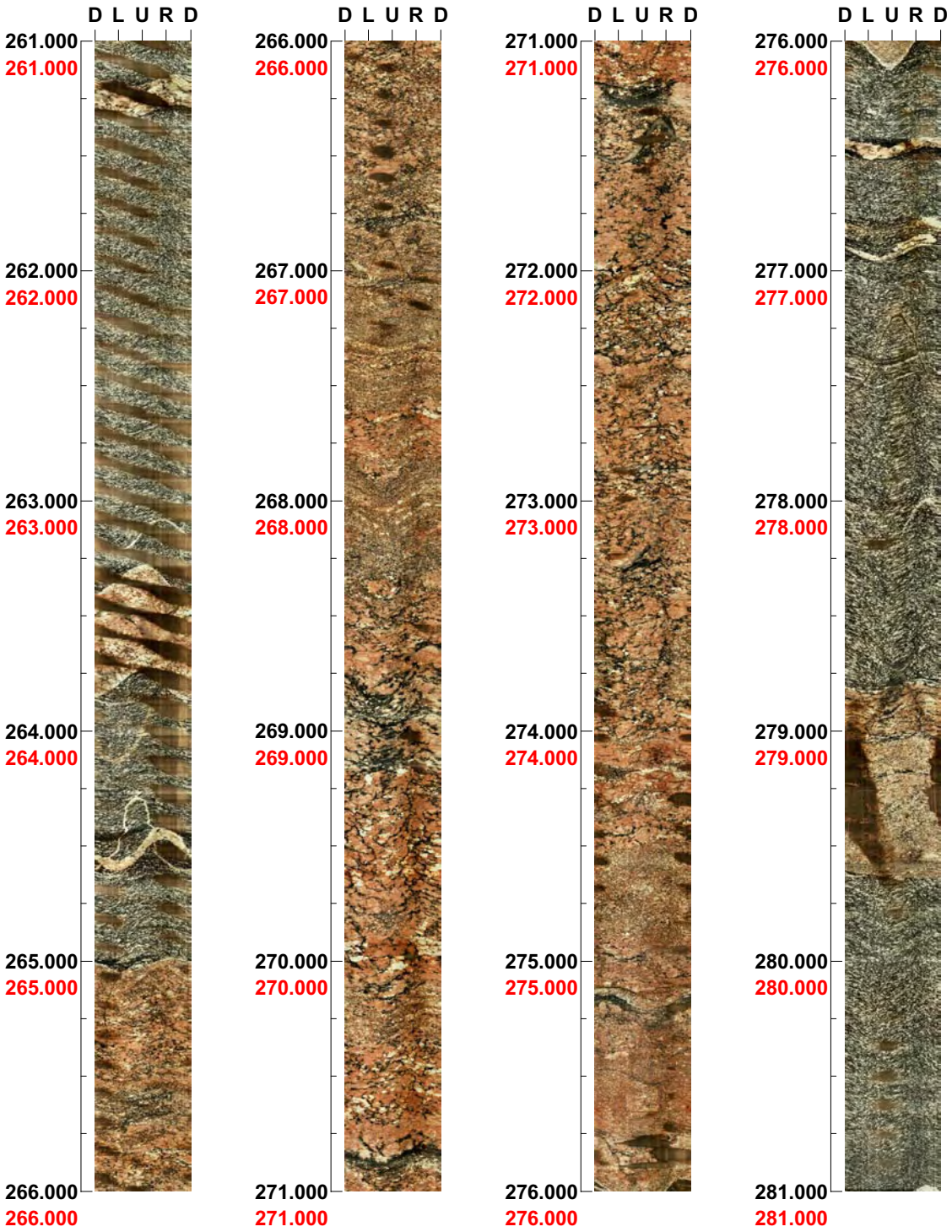
Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 241.000 - 261.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

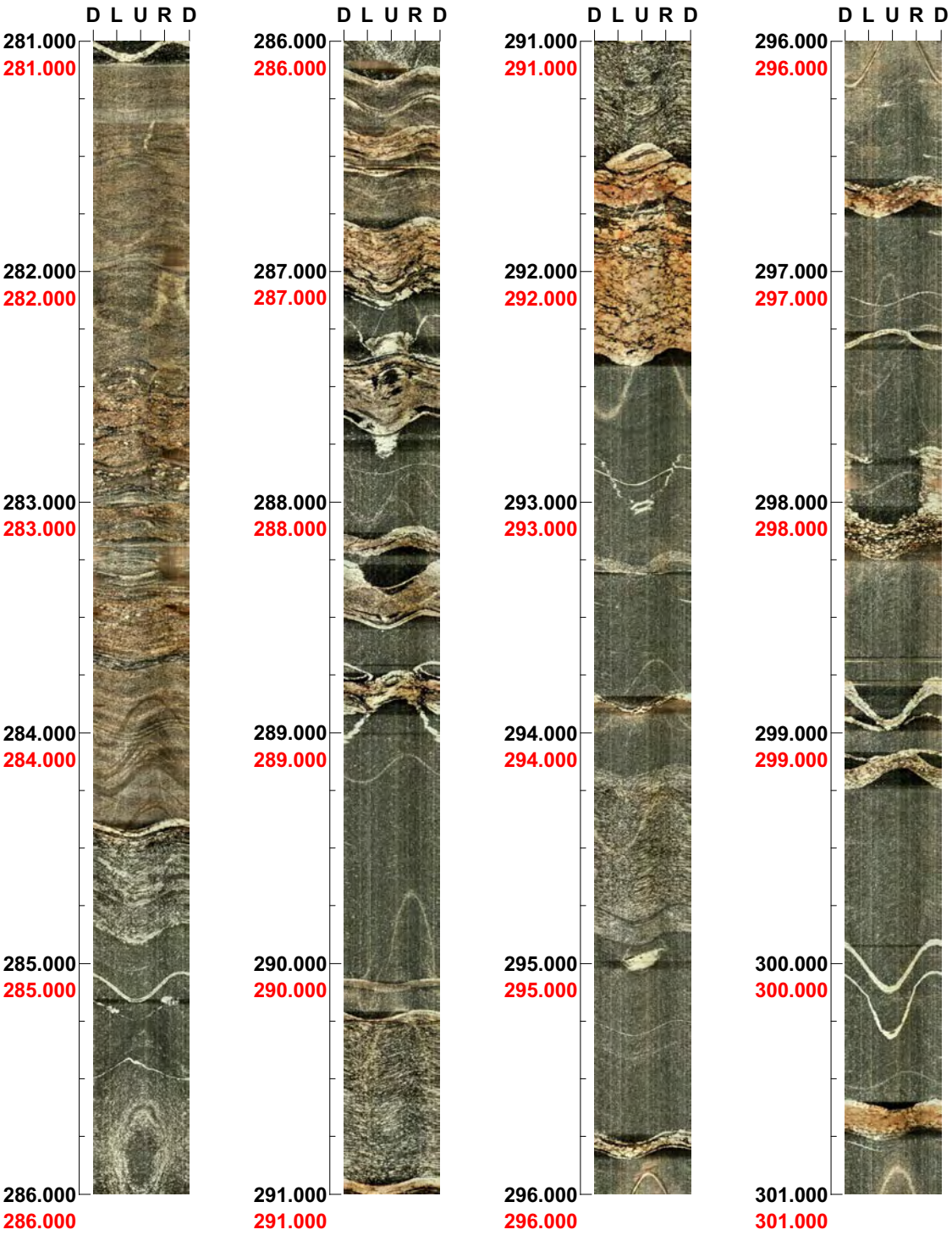
Depth range: 261.000 - 281.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

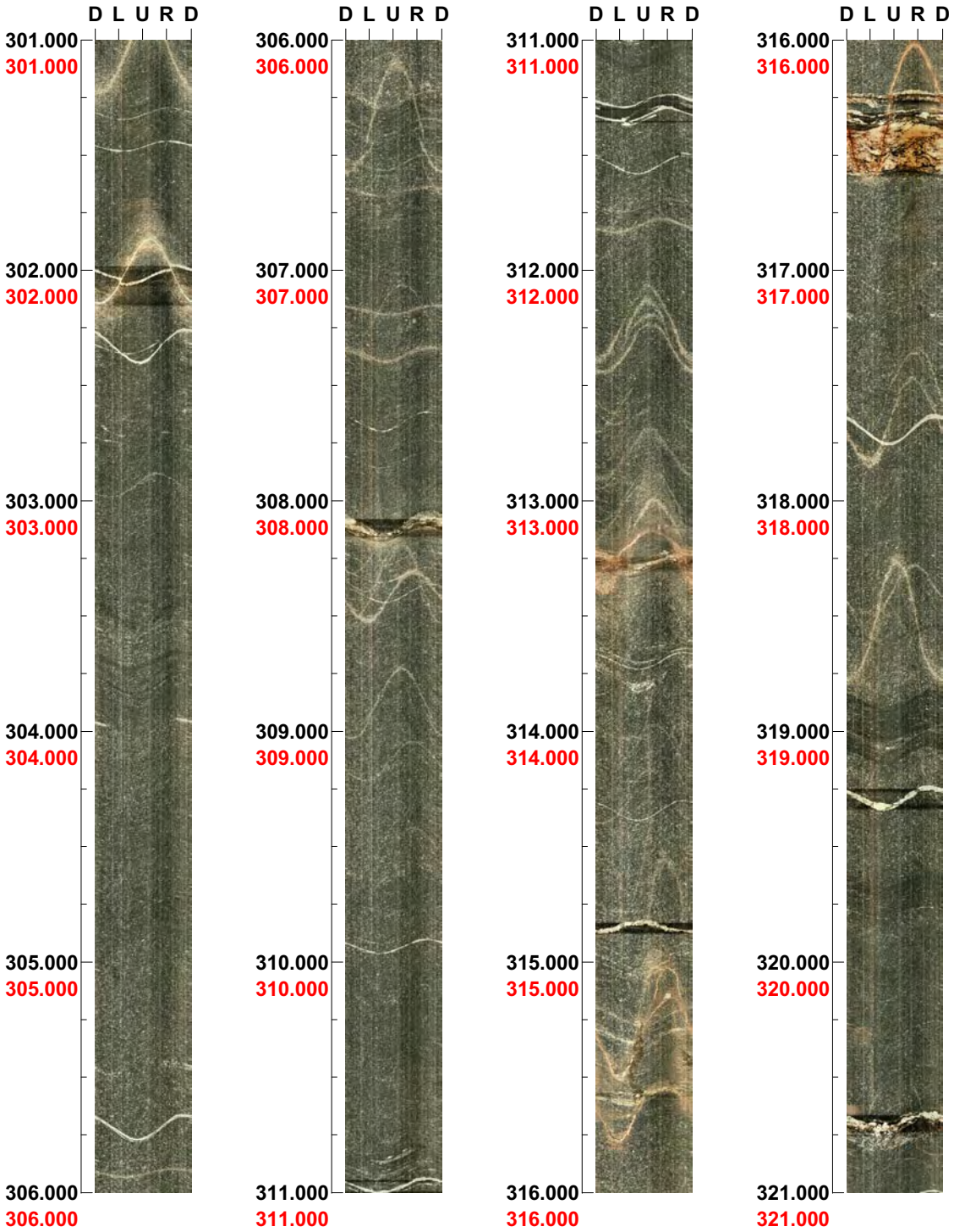
Depth range: 281.000 - 301.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

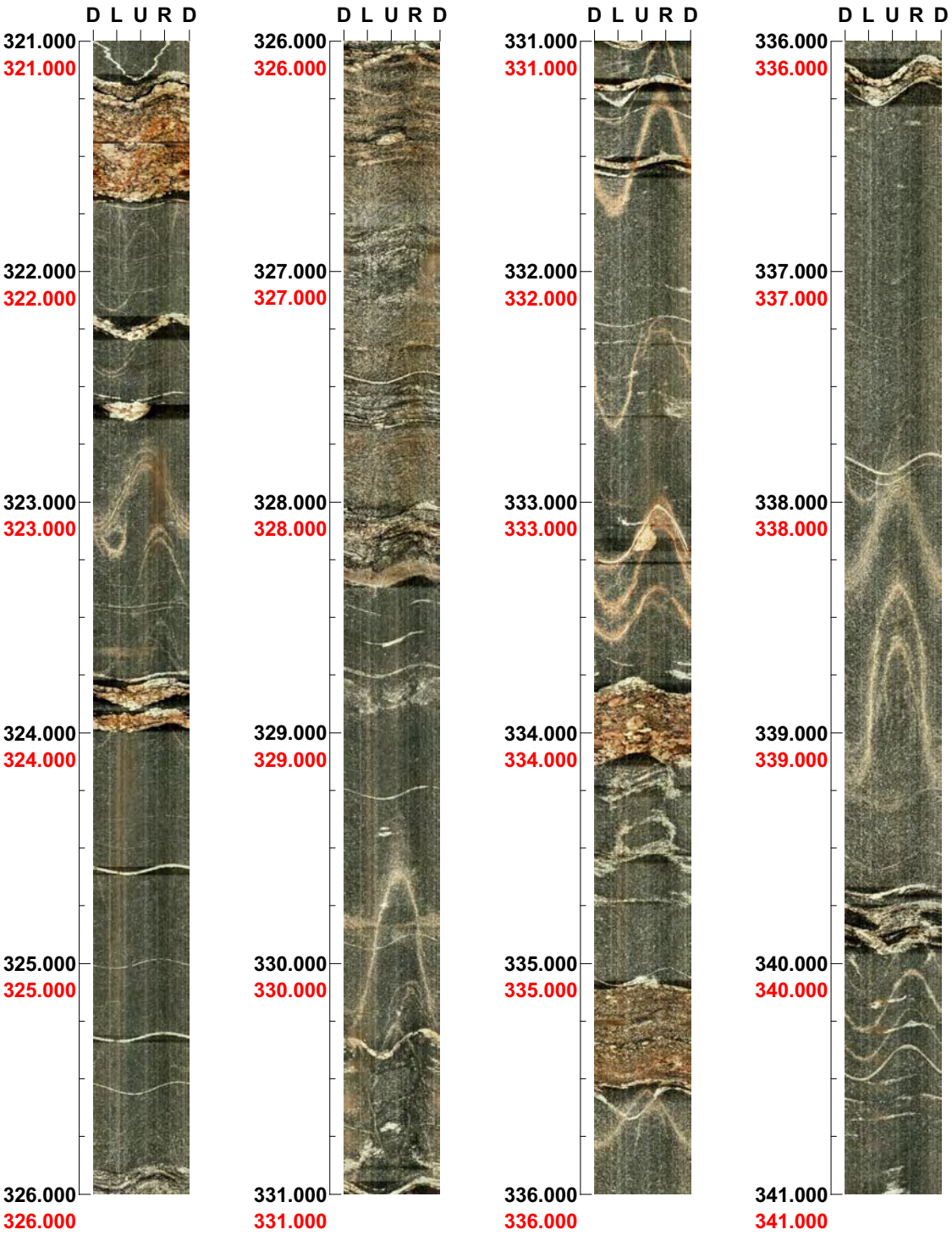
Depth range: 301.000 - 321.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

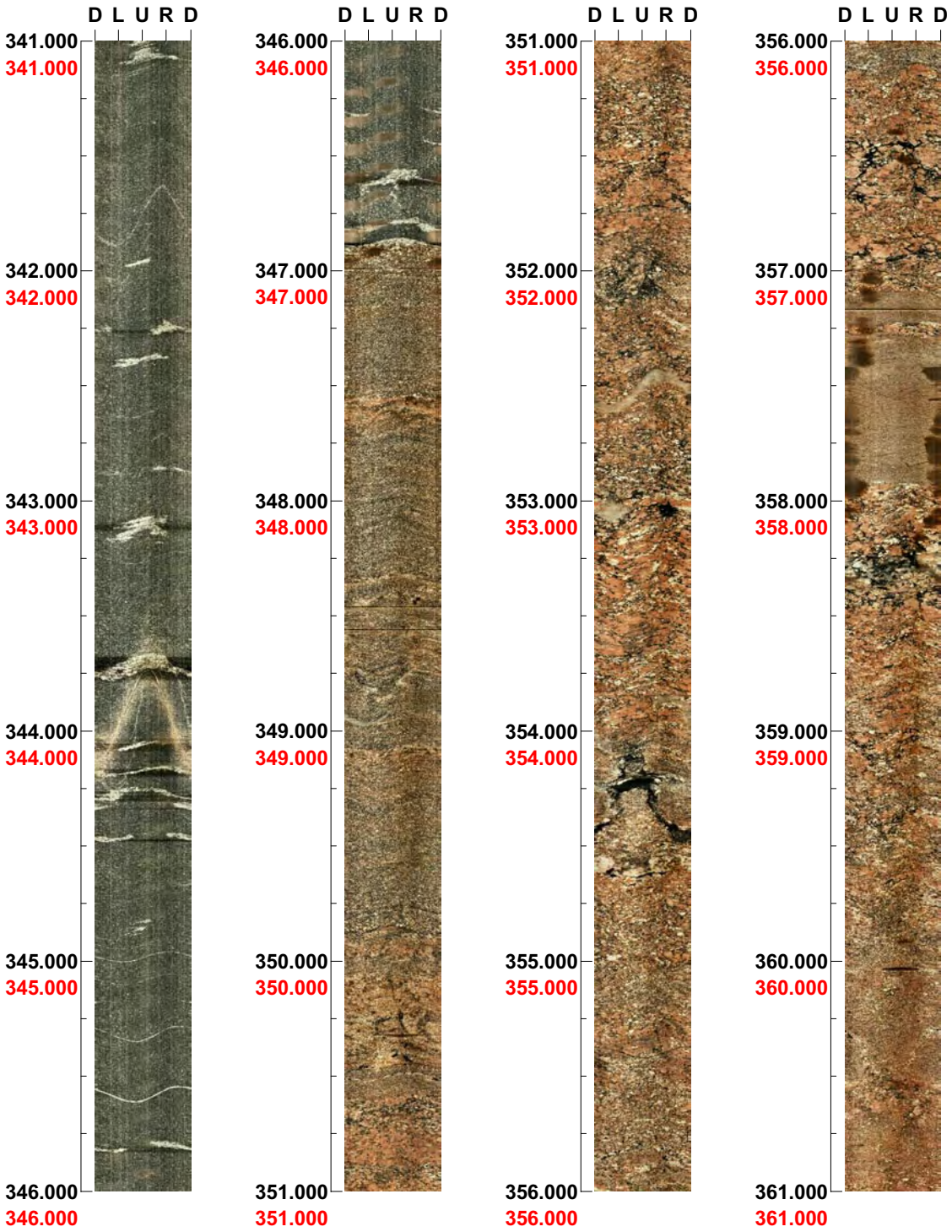
Depth range: 321.000 - 341.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

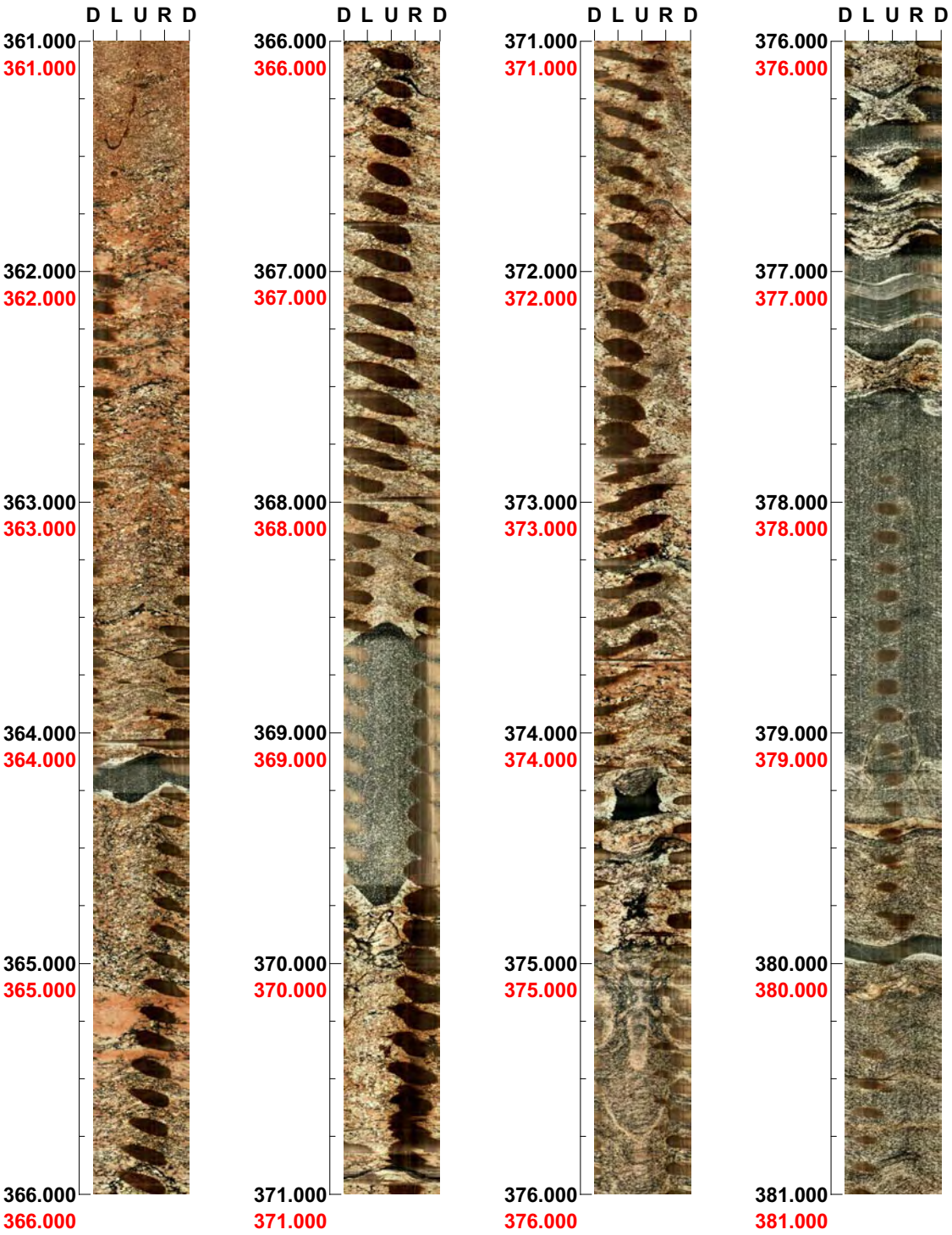
Depth range: 341.000 - 361.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

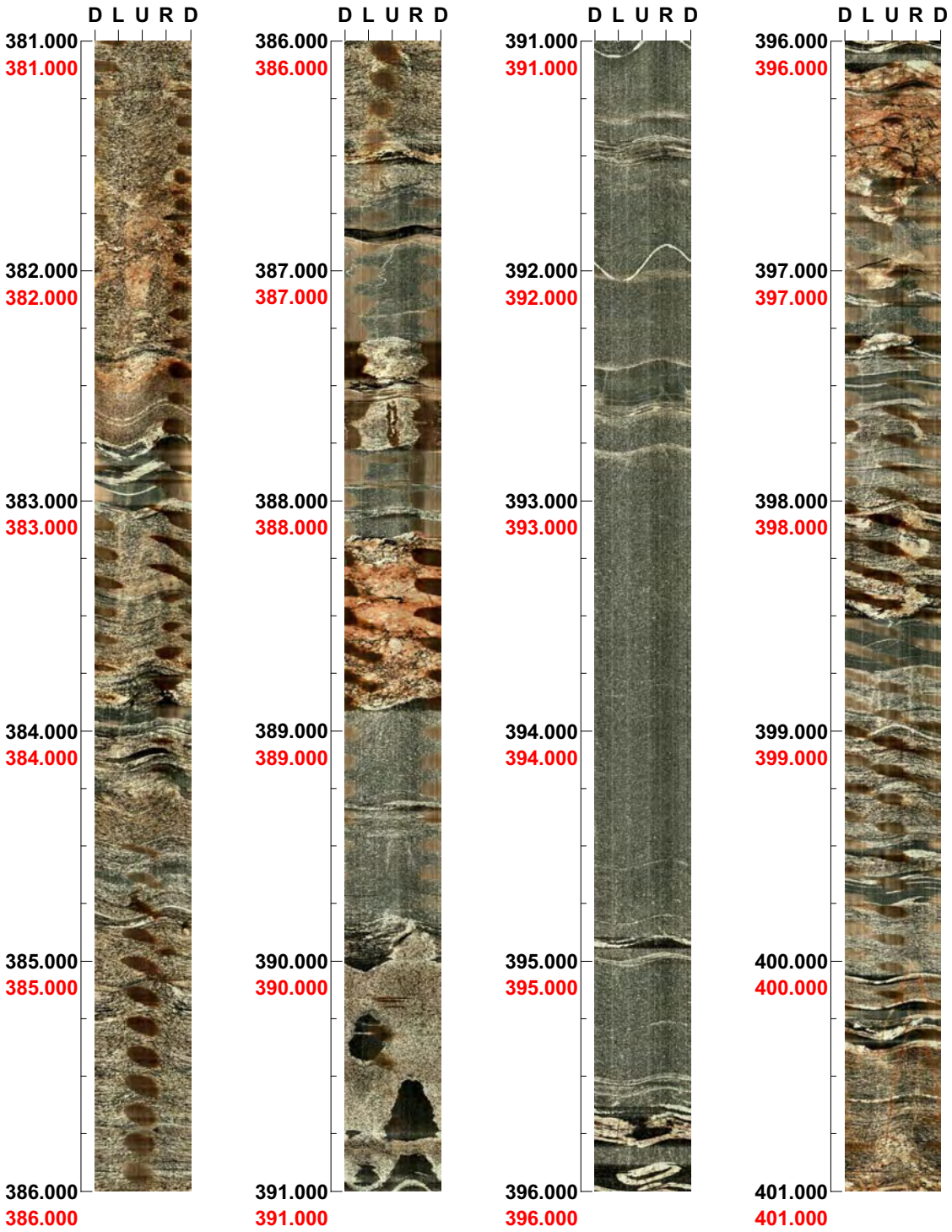
Depth range: 361.000 - 381.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 381.000 - 401.000 m



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

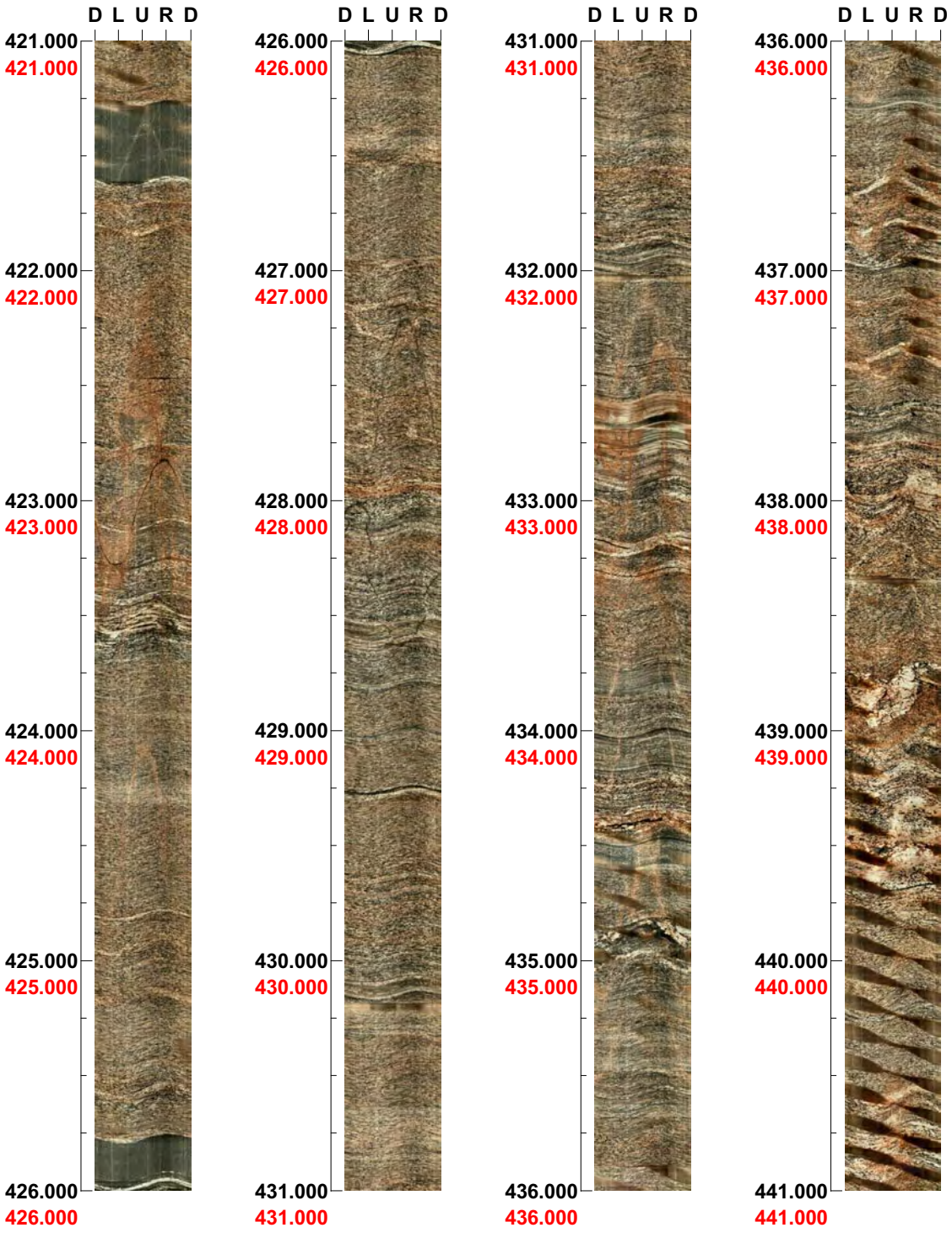
Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 401.000 - 421.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

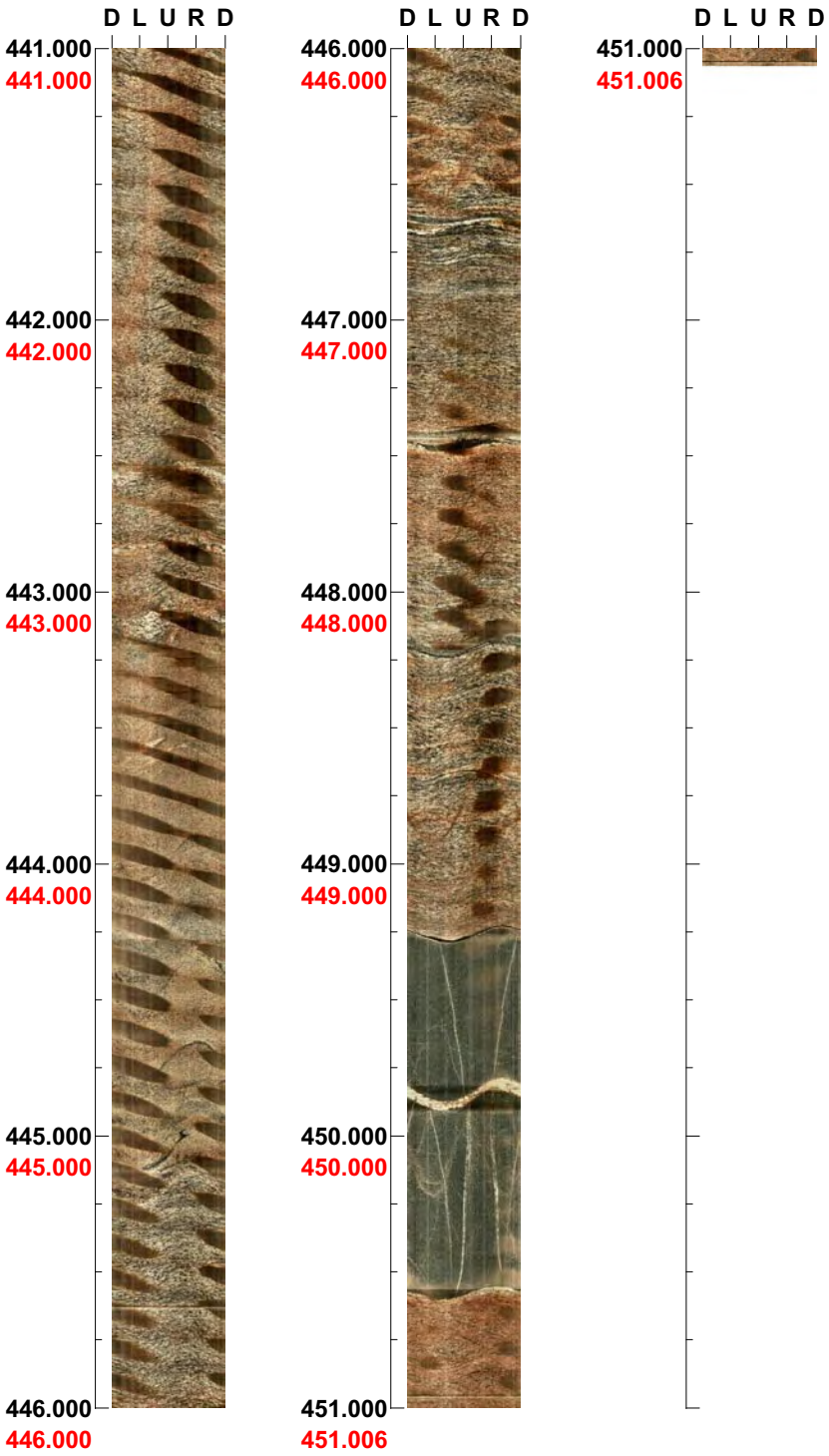
Depth range: 421.000 - 441.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

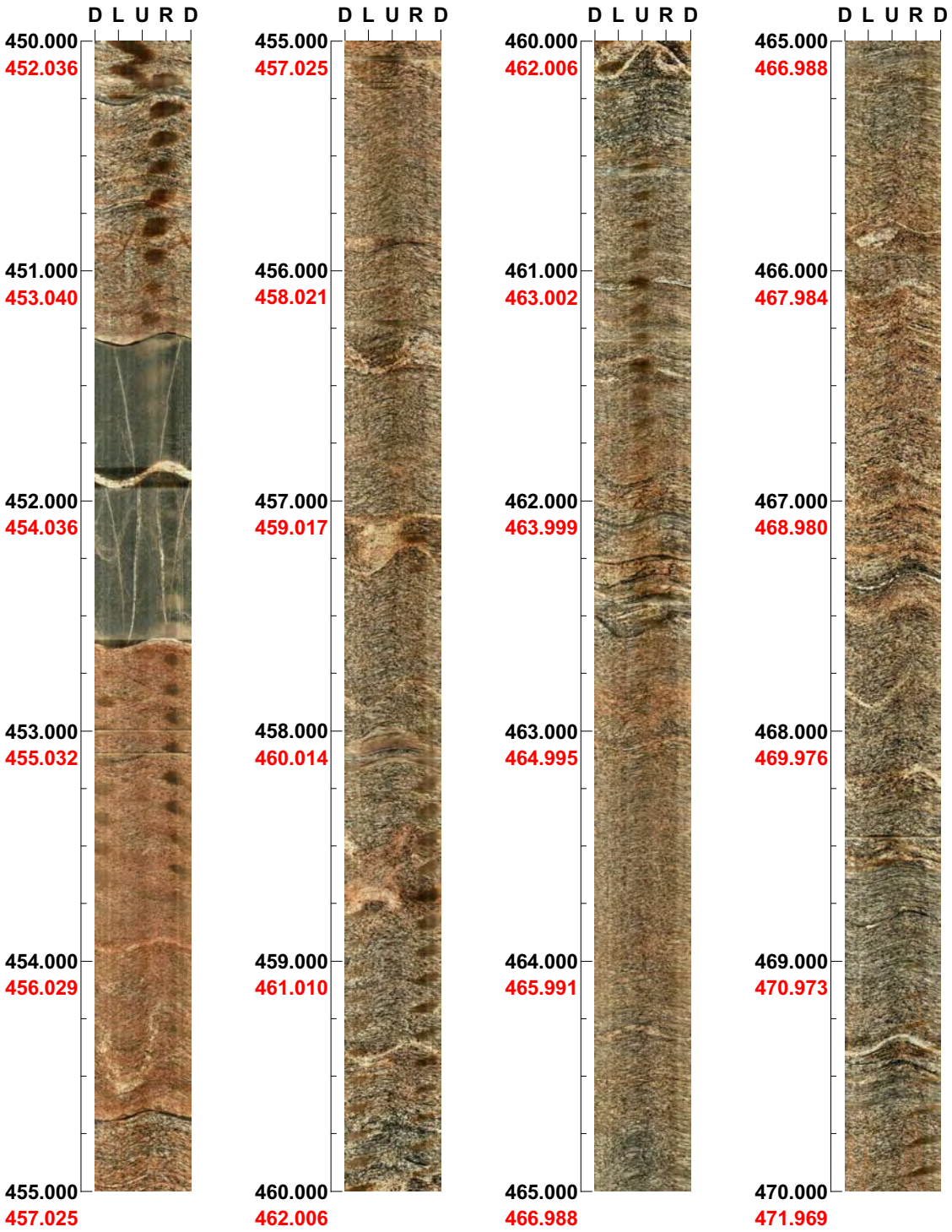
Depth range: 441.000 - 451.067 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 450.000 - 470.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 470.000 - 490.000 m

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

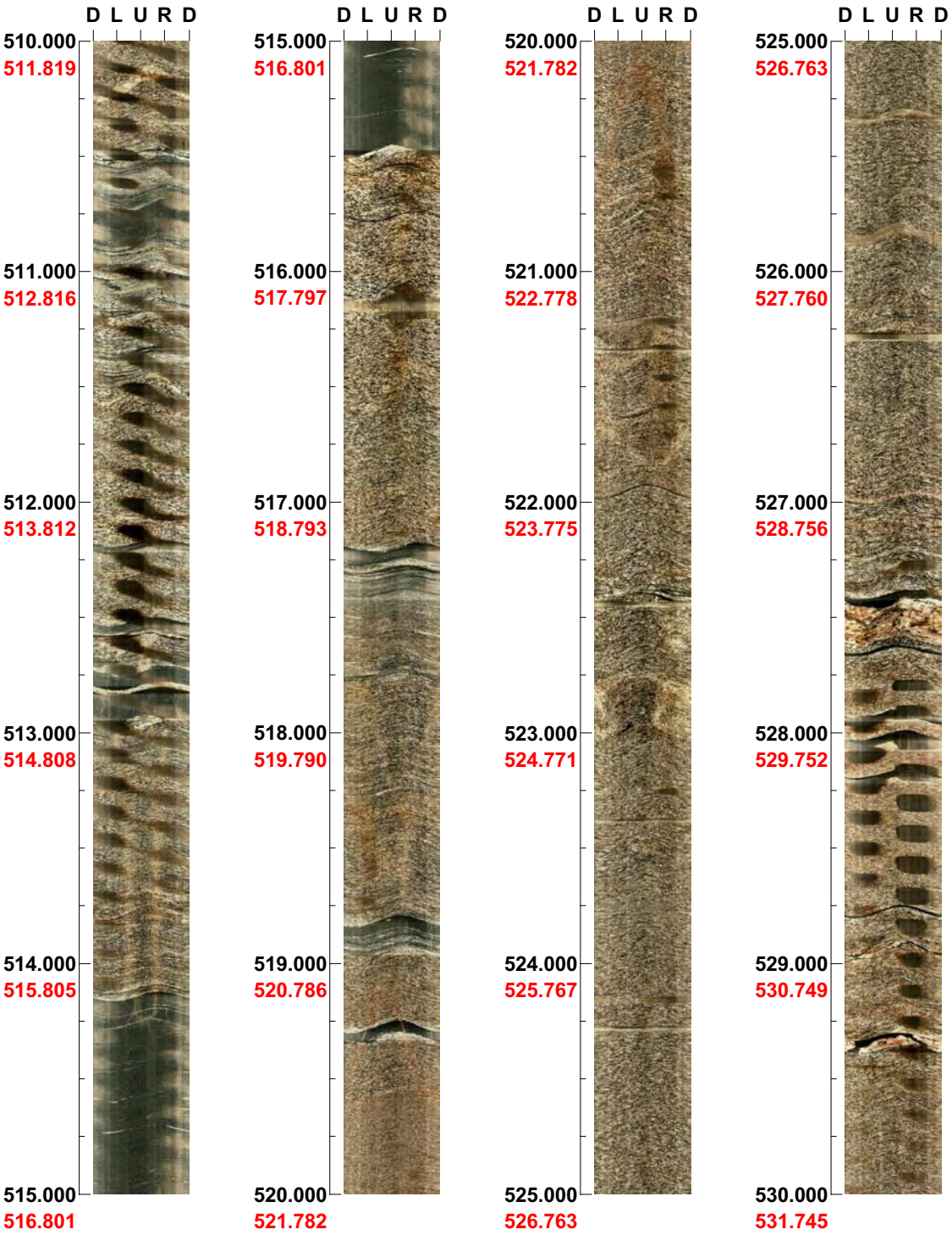
Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 490.000 - 510.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

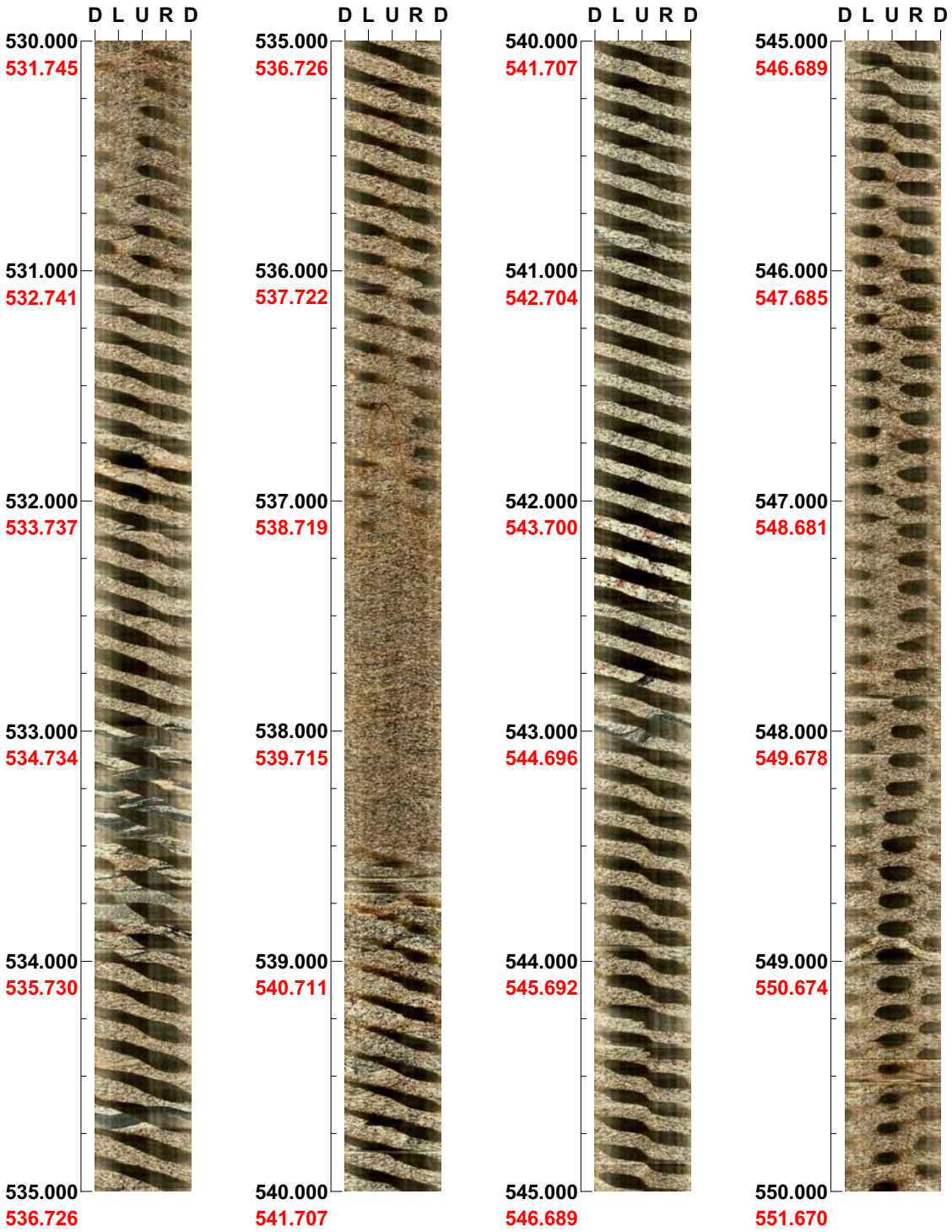
Depth range: 510.000 - 530.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 530.000 - 550.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 550.000 - 570.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 570.000 - 590.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 590.000 - 610.000 m

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

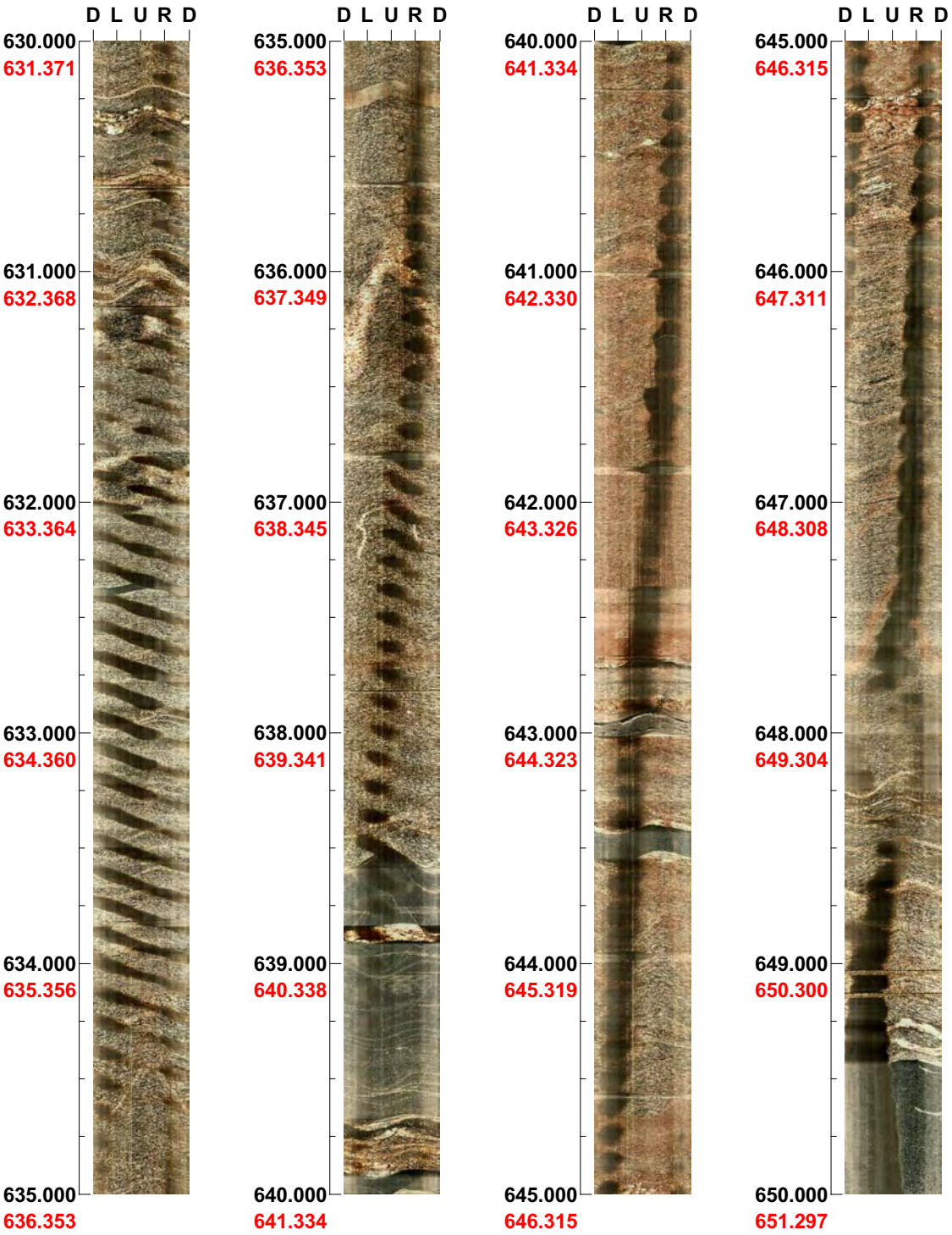
Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 610.000 - 630.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

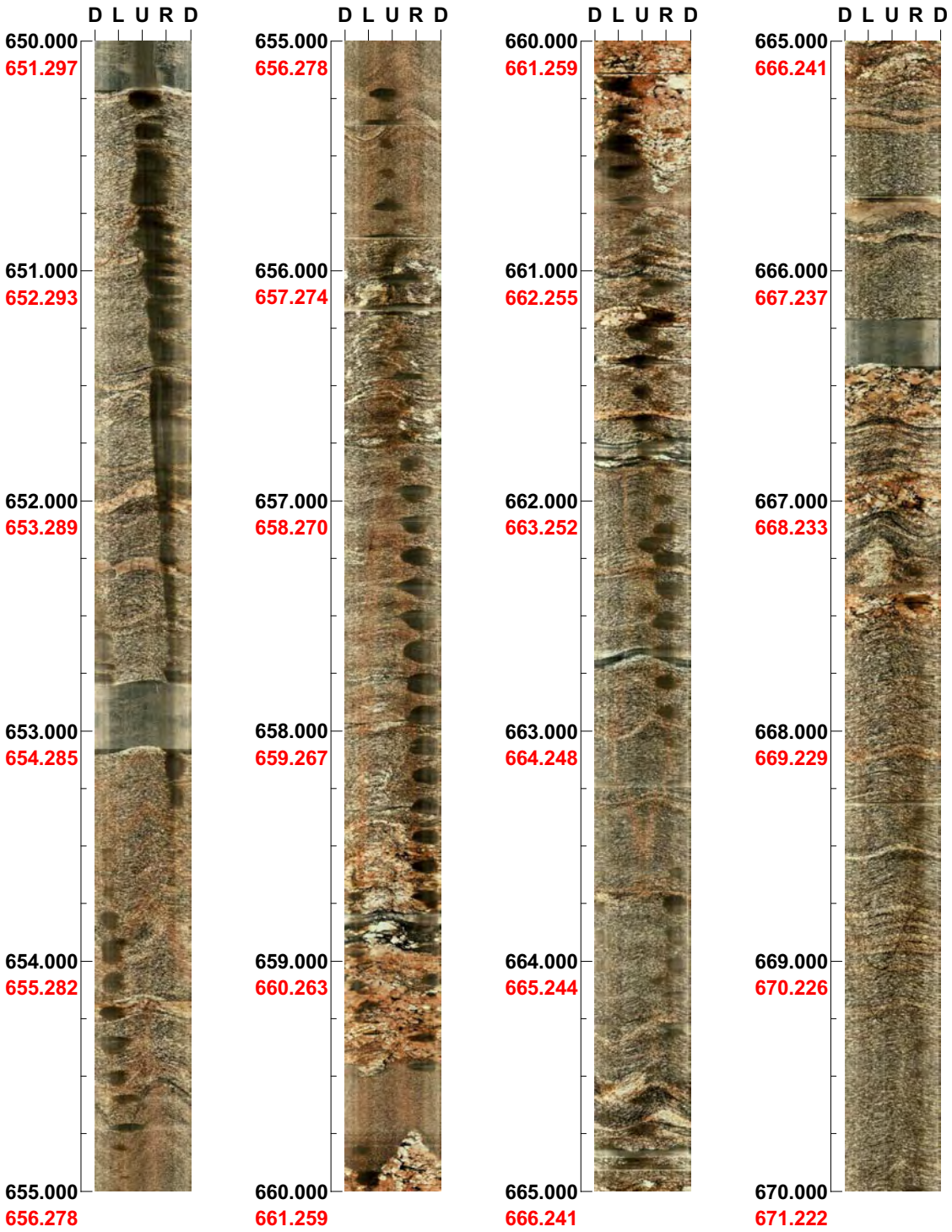
Depth range: 630.000 - 650.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 650.000 - 670.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 670.000 - 690.000 m

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

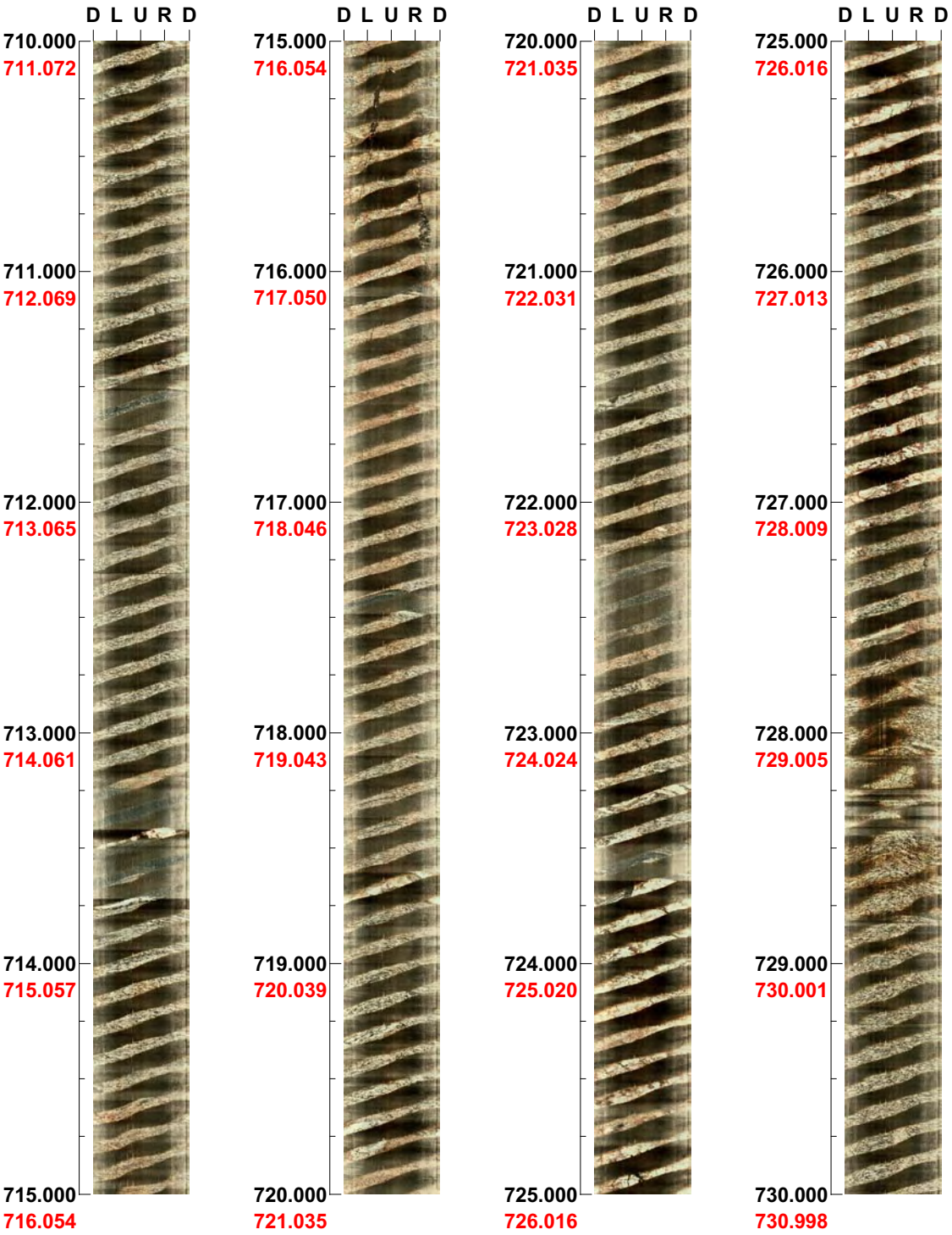
Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 690.000 - 710.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 710.000 - 730.000 m



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

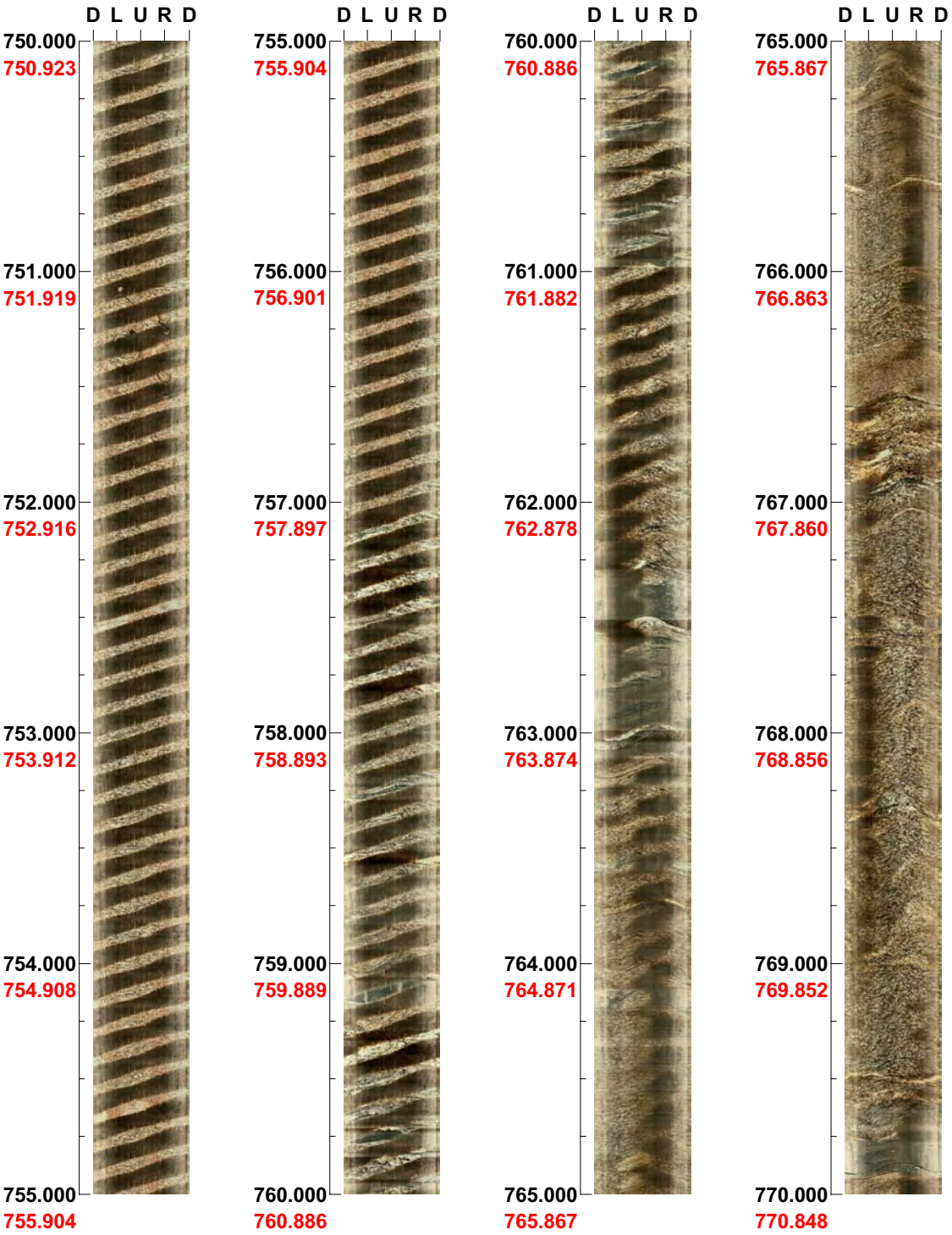
Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 730.000 - 750.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

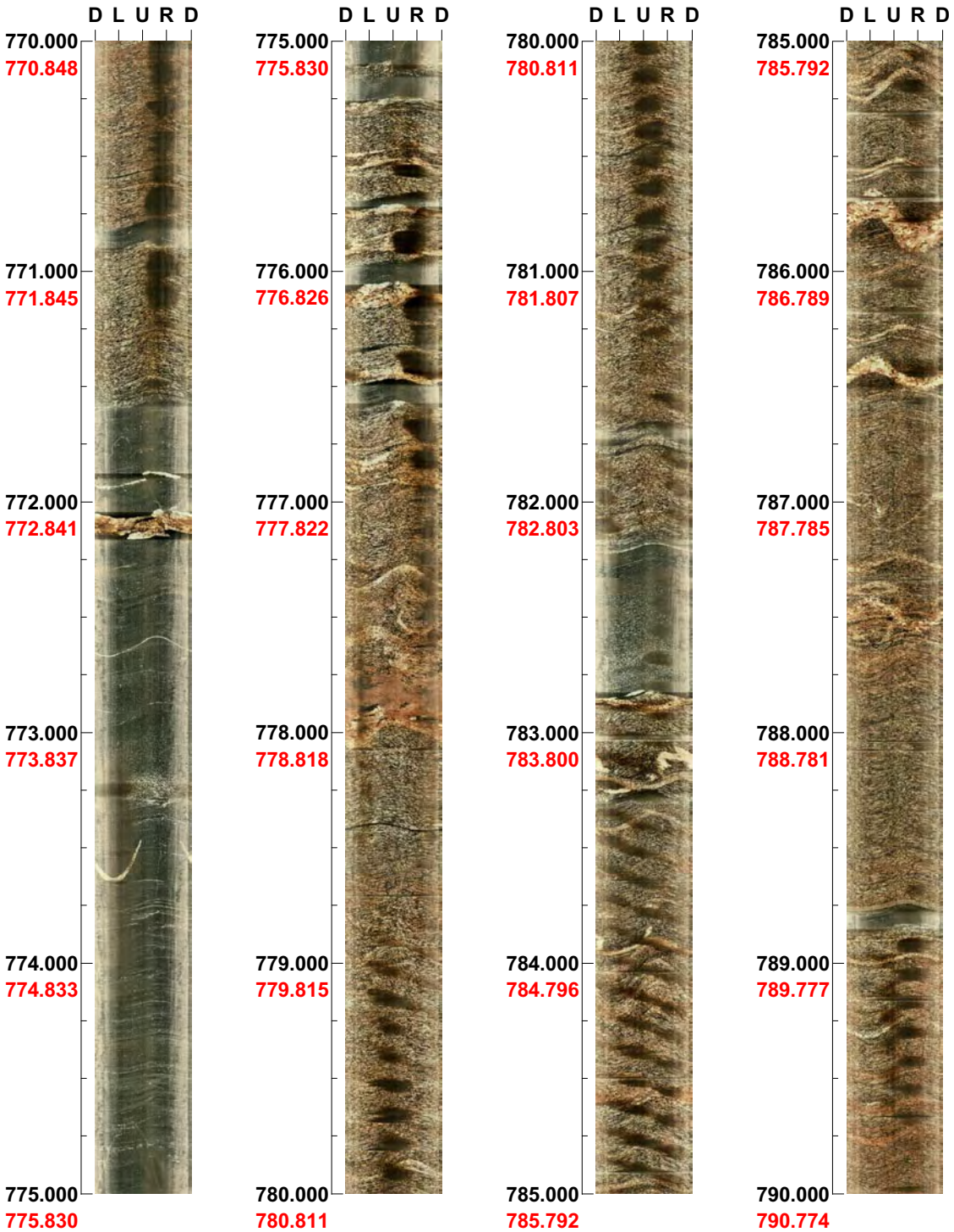
Depth range: 750.000 - 770.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 770.000 - 790.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 790.000 - 810.000 m

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

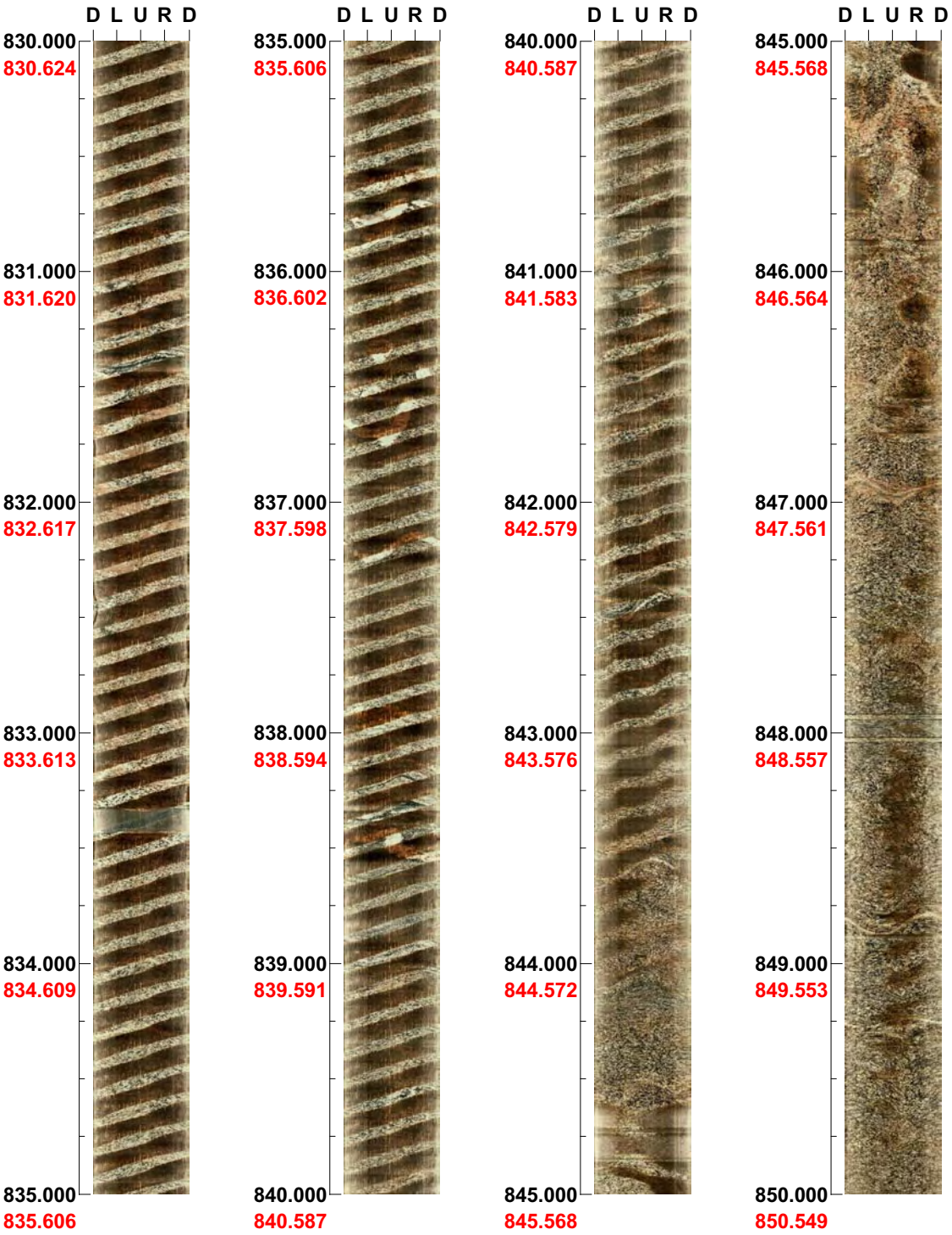
Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 810.000 - 830.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 830.000 - 850.000 m



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

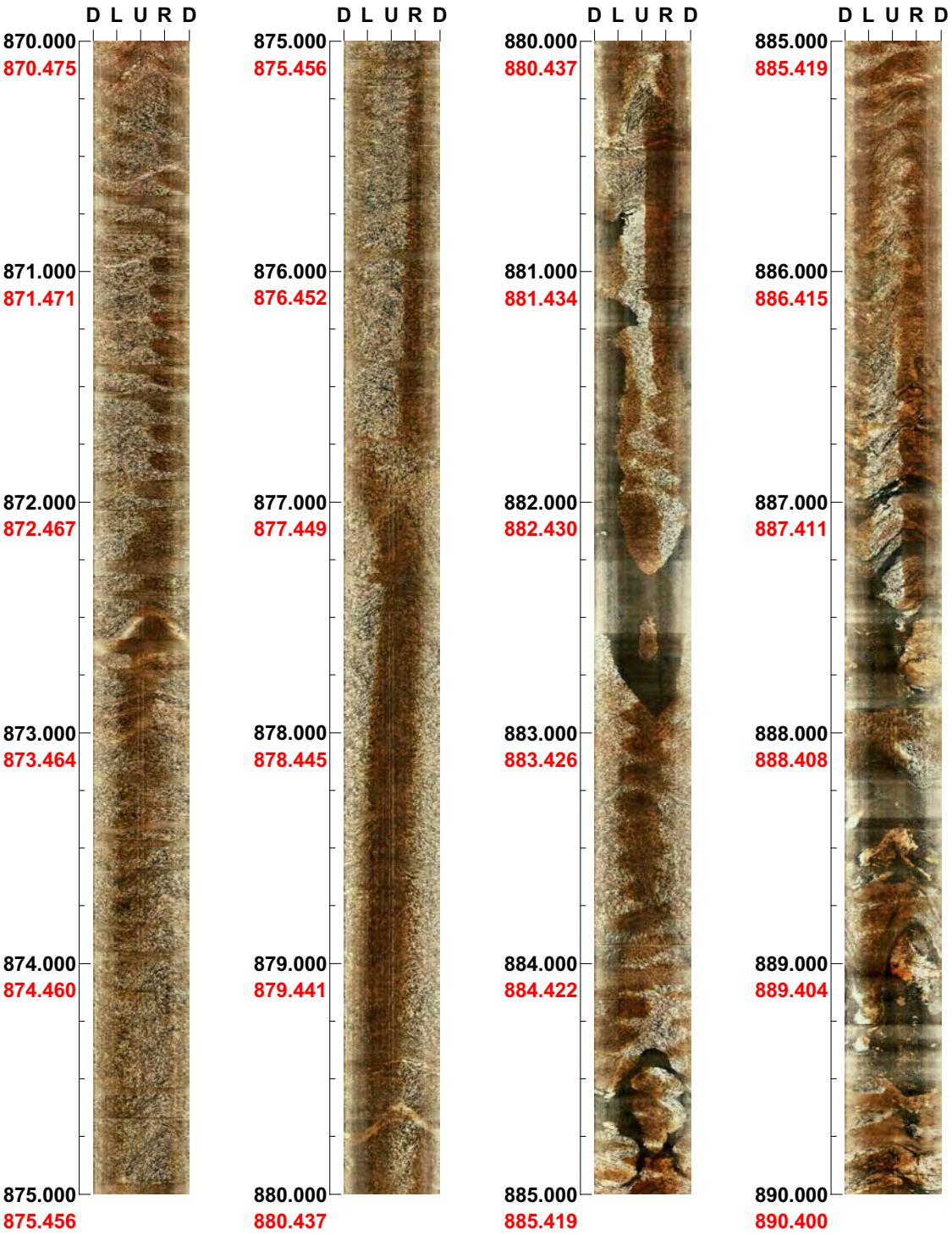
Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 850.000 - 870.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 870.000 - 890.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 890.000 - 910.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 910.000 - 930.000 m

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

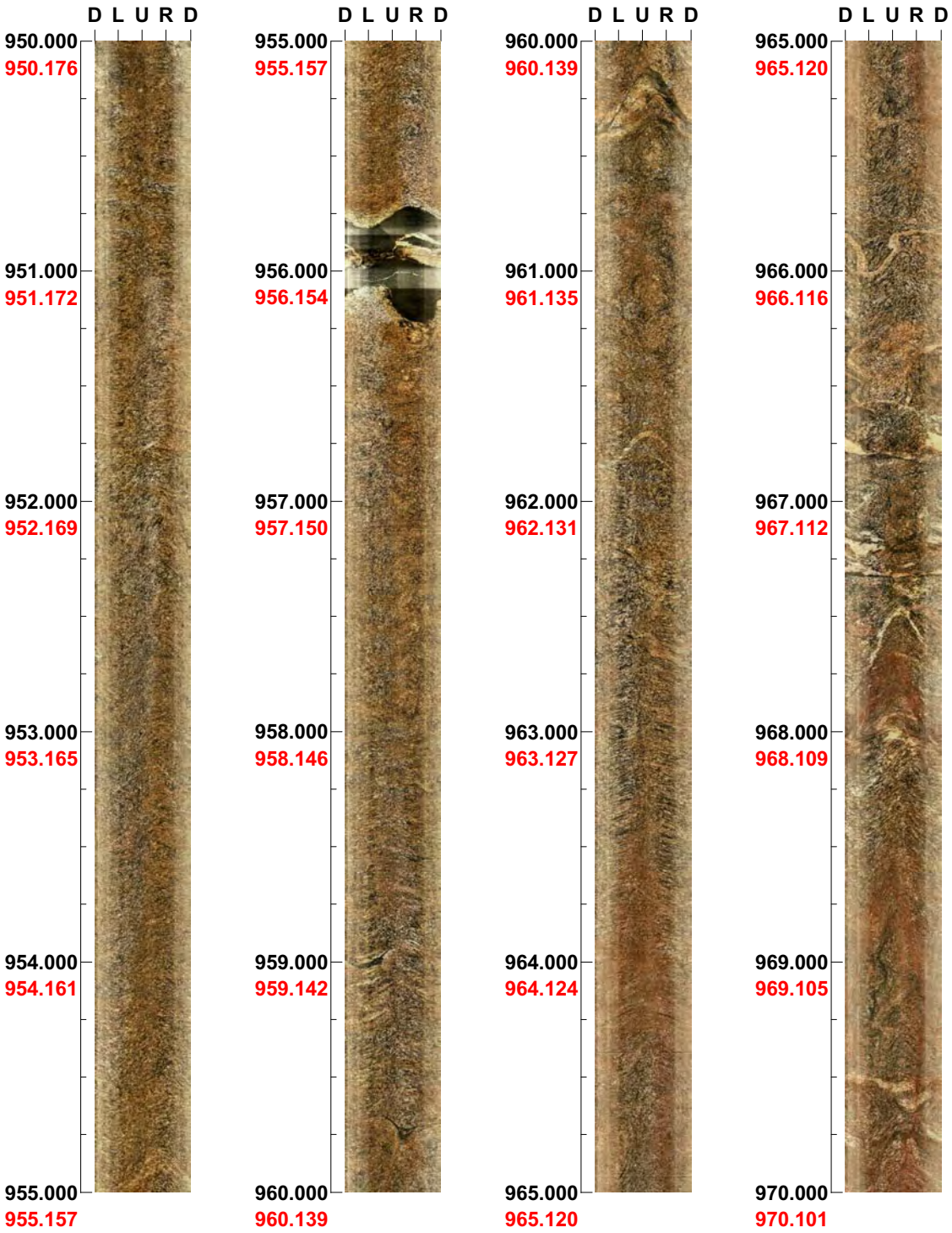
Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 930.000 - 950.000 m

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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

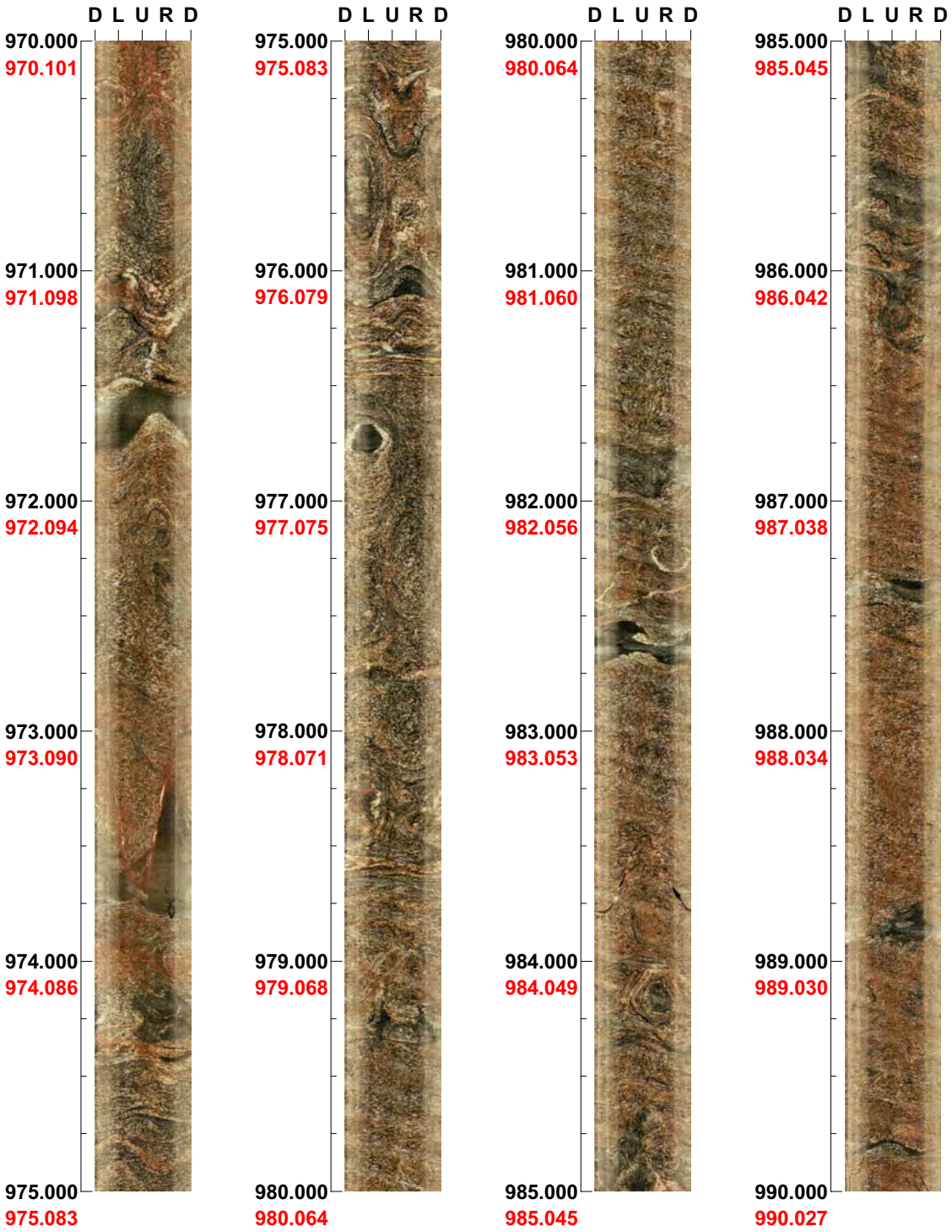
Depth range: 950.000 - 970.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

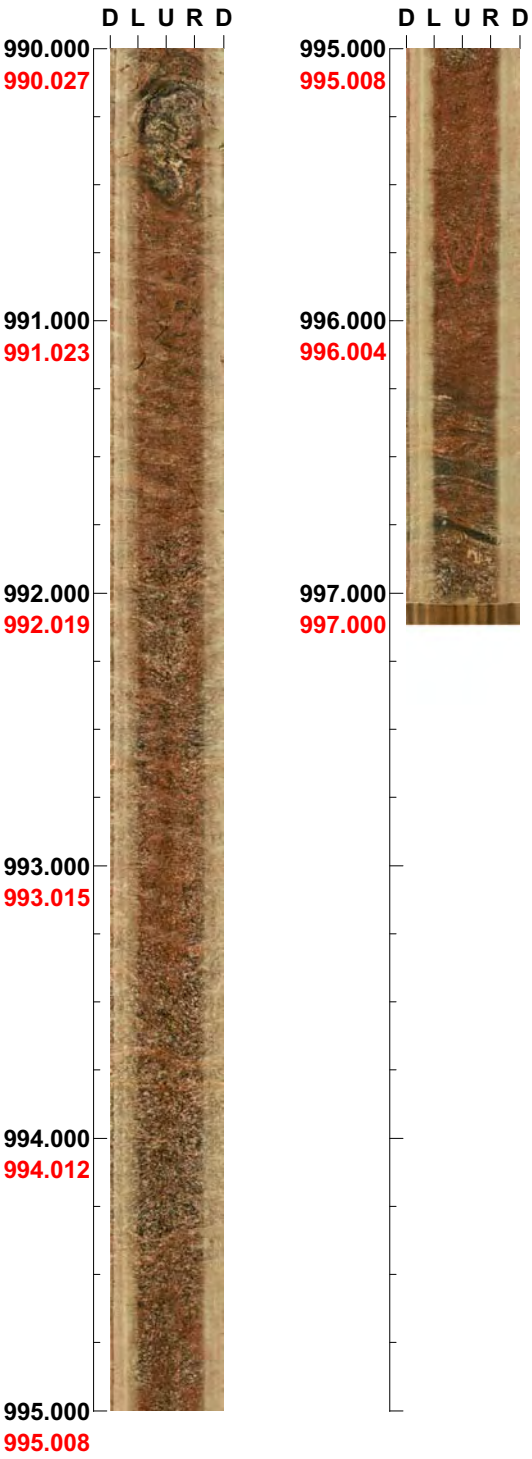
Depth range: 970.000 - 990.000 m



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

Project name: Forsmark
Bore hole No.: KFM03A **Azimuth: 271** **Inclination: -85**

Depth range: 990.000 - 997.112 m



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

Appendix 4

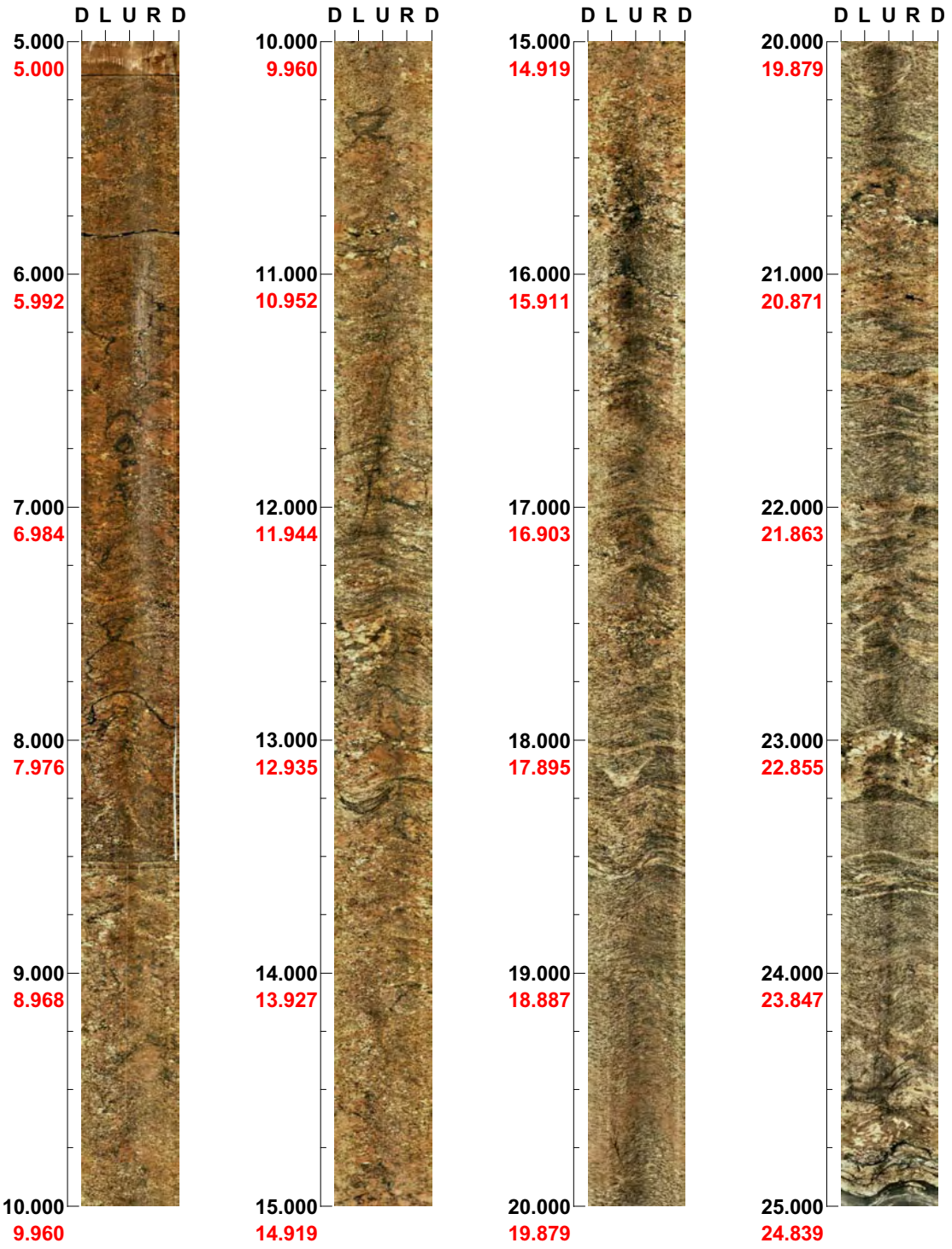
BIPS logging of KFM03B, 5 to 99.3 m

Project name: Forsmark

Image file	**: h:\work\kfm03b\bips\kfm03b.bip**
BDT file	**: h:\work\kfm03b\bips\kfm03b.bdt**
Locality	**: FORSMARK**
Bore hole number	**: KFM03B**
Date	**: 03/08/05**
Time	**: 18:36:00**
Depth range	**: 5.000 - 99.266 m (red figures = corrected values)**
Azimuth	**: 272**
Inclination	**: -86**
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	**: 5**
Color	**: +0 +0 +0**

Project name: Forsmark
Bore hole No.: KFM03B **Azimuth: 272** **Inclination: -86**

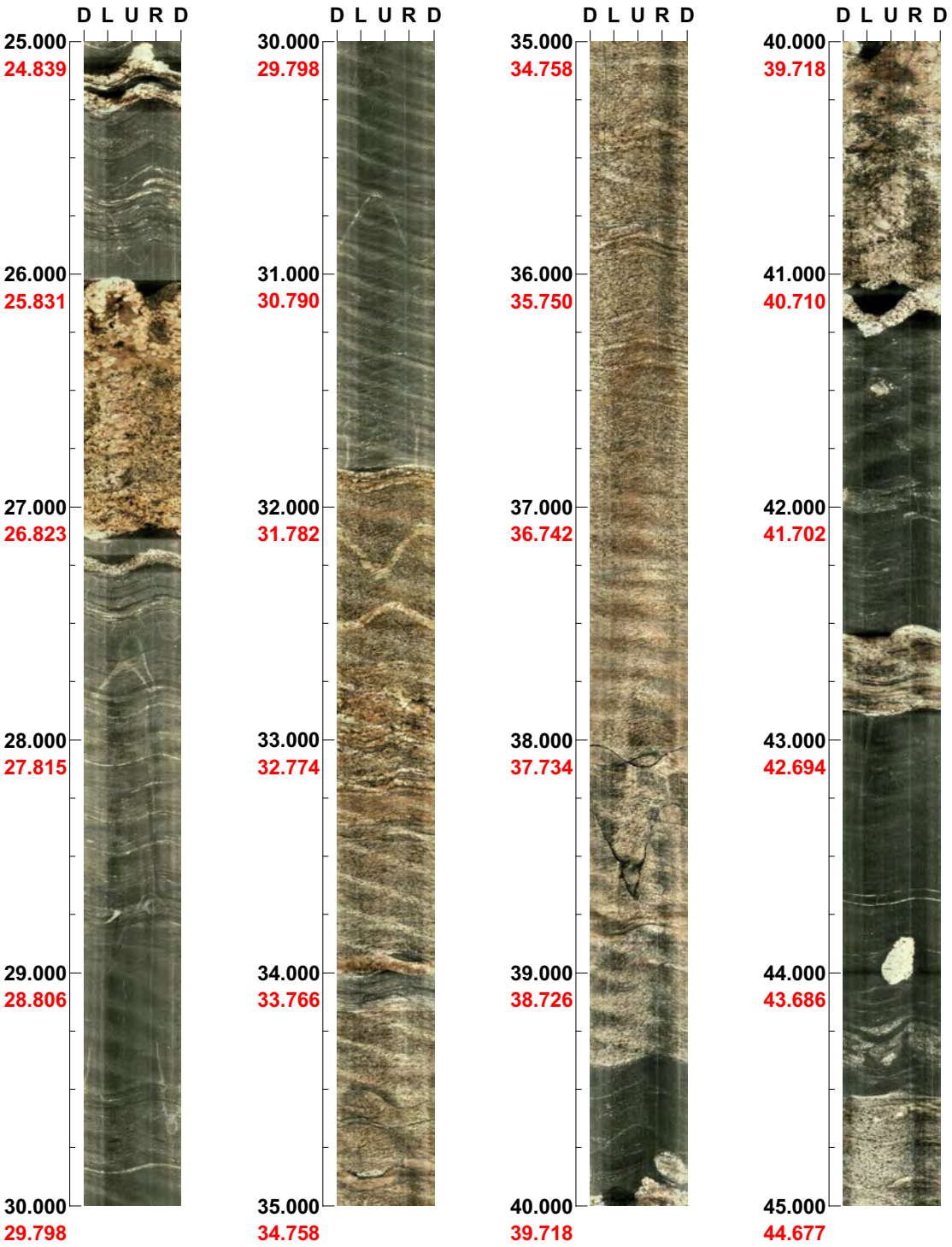
Depth range: 5.000 - 25.000 m



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

Project name: Forsmark
Bore hole No.: KFM03B **Azimuth: 272** **Inclination: -86**

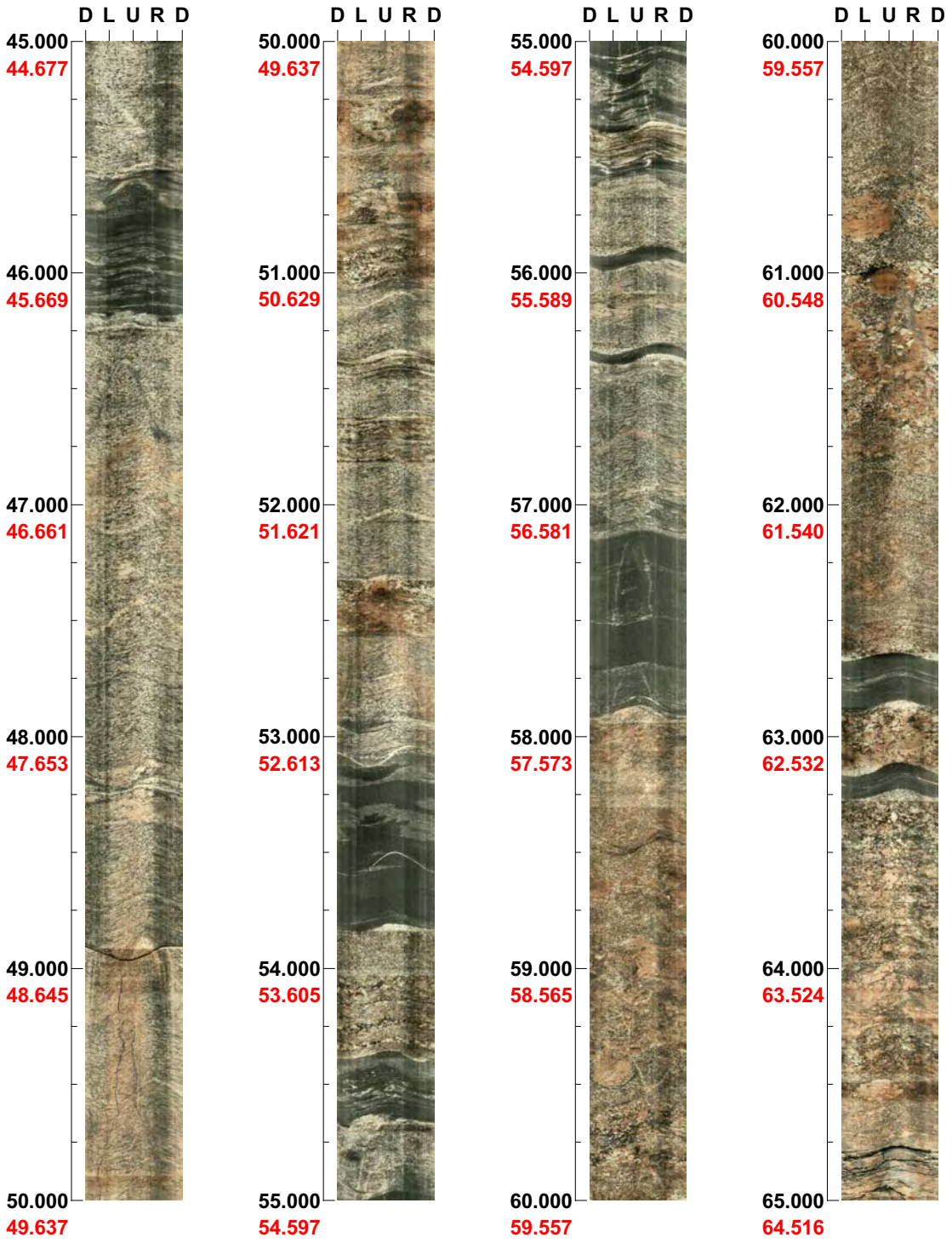
Depth range: 25.000 - 45.000 m



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

Project name: Forsmark
Bore hole No.: KFM03B **Azimuth: 272** **Inclination: -86**

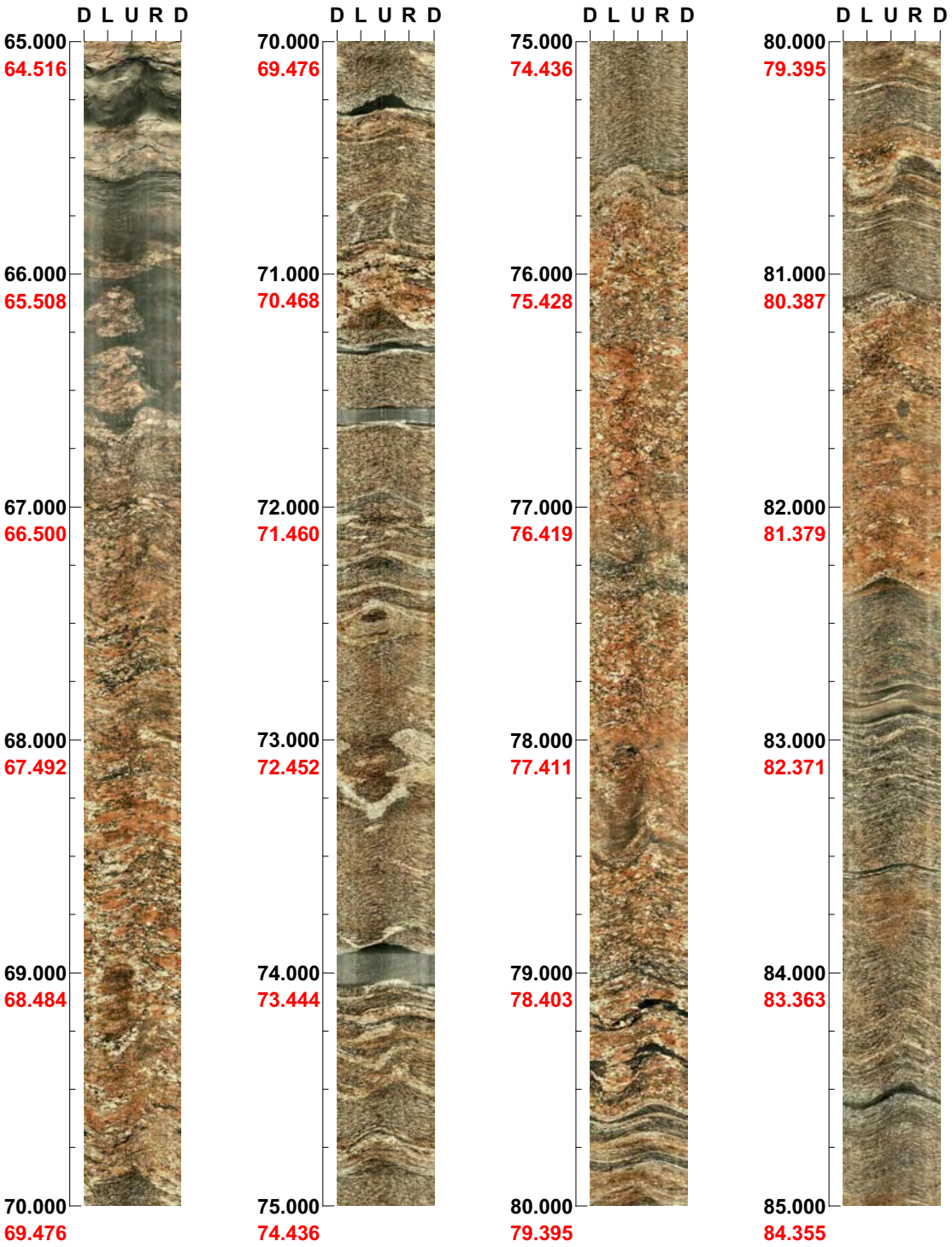
Depth range: 45.000 - 65.000 m



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

Project name: Forsmark
Bore hole No.: KFM03B **Azimuth: 272** **Inclination: -86**

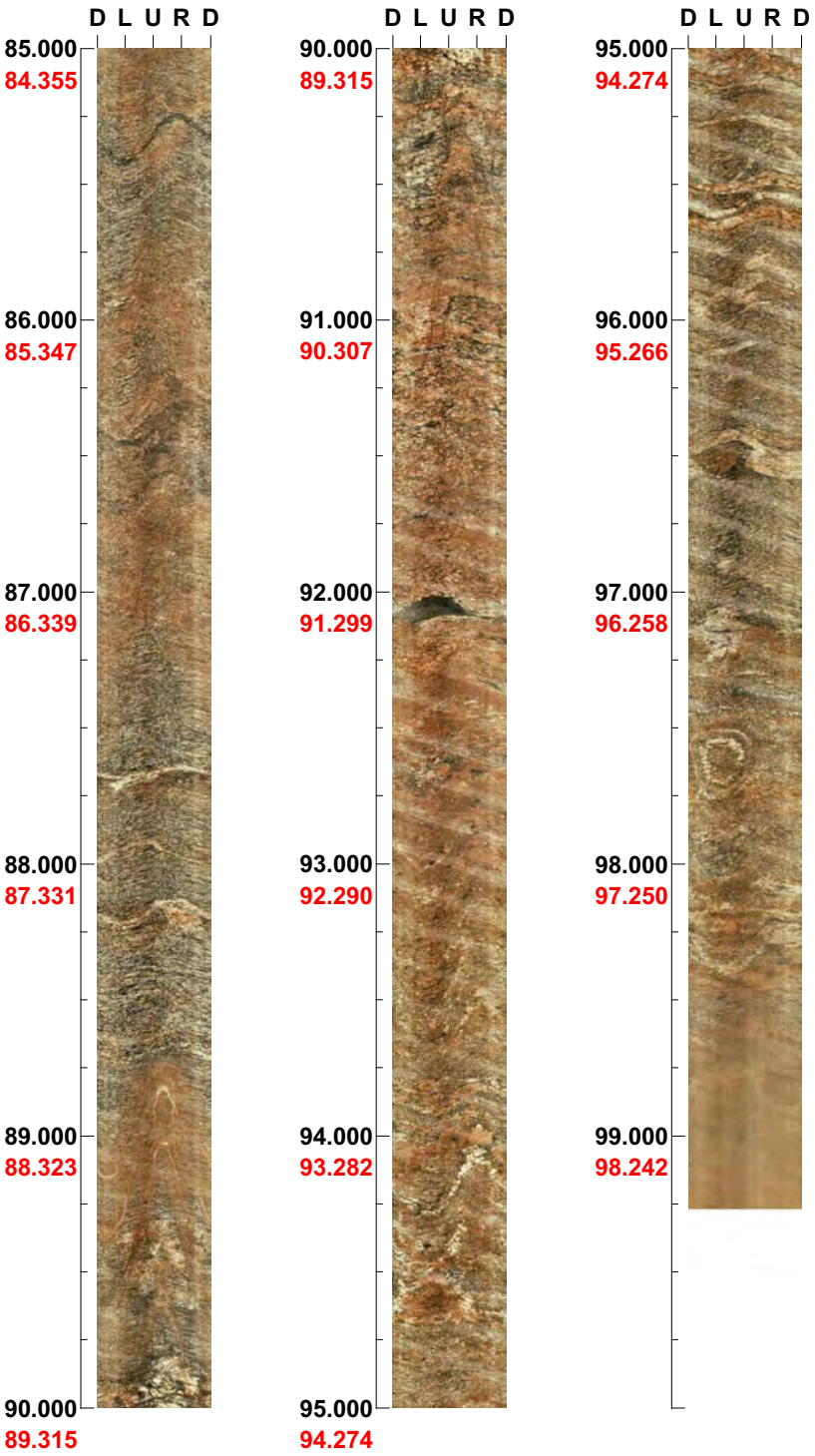
Depth range: 65.000 - 85.000 m



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

Project name: Forsmark
Bore hole No.: KFM03B **Azimuth: 272** **Inclination: -86**

Depth range: 85.000 - 99.266 m



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