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Forsmark site investigation

RAMAC and BIPS logging in borehole KFM05A

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Abstract

This report includes the data gained during geophysical logging operations performed within the site investigation at Forsmark. The logging operations presented here include borehole radar (RAMAC) and BIPS in the core drilled borehole KFM05A. All measurements were conducted by Malå Geoscience AB / RAYCON during May and June 2004.

The objective of the radar survey is to achieve information on the rock mass around the borehole. Borehole radar and BIPS are used to investigate the nature and the structure of the rock mass enclosing the boreholes.

The borehole radar data quality from KFM05A was good, but in some parts of lower quality due to more conductive conditions. This electrically conductive environment reduces the possibility to distinguish and interpret possible structures in the rock mass. The borehole radar measurements resulted in a number of identified radar reflectors. In KFM05A almost 200 radar reflectors were identified and half of them also orientated (strike/dip).

Four runs with the BIPS were performed. The first logging was made to inspect a fracture zone that had been noted at a depth of 109 metre during the drilling operation. After evaluating the result from the BIPS survey it was decided to extend the casing down to 110 metre. The second logging produced images of bad quality and was discontinued and so was the third one. The final logging was carried out 2004-06-03 from 110 metre down to 995 metre and revealed almost perfect water quality. This logging produced high quality images for the core logging.

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Forsmakr. Mätningarna som presenteras här omfattar borrhålsradar- och BIPS-mätningar i kärnborrhål KFM05A. Alla mätningar är utförda av Malå Geoscience AB /RAYCON under maj och juni 2003.

Syftet med radarmätningarna och BIPS är att samla information om bergmassan runt borrhålet. Borrhålsradar och BIPS används till att karakterisera bergets egenskaper och strukturer i bergmassan närmast borrhålet.

Borrhålsradardata från KFM05A var bra, men tidvis av sämre kvalité troligen till stor del beroende på en konduktiv miljö. En elektriskt konduktiv miljö minskar möjligheterna att identifiera strukturer ur borrhålsradardata. Nästan 200 radarreflektorer identifierades i KFM05A, varav ungefär hälften har kunnat orienteras (strykning/stupning).

BIPS-loggning har utförts vid fyra tillfällen. Den första loggningen gjordes för att studera en sprickzon som noterats på 109 m djup under pågående borrning. Efter utvärdering av BIPS-bilderna togs beslut om att sätta foderrör ned till 110 m. Vid loggningstillfällena två och tre avbröts mätningarna på grund att bildernas kvalitet blev dålig. Vid det fjärde loggningstillfället producerades bilder av hög kvalitet för borrkärnekarteringen.

Contents

1 Introduction

This document reports data gained during geophysical logging operations, which is one of the activities performed within the site investigation at Forsmark. The logging operations presented here include borehole radar (RAMAC) and TV-logging (BIPS) and was carried out in the core drilled borehole KFM05A, see Table 1-1 and Figure 1-1.

The measurements in KFM05A were made from 110 m to a depth of approximately 1,000 m.

The borehole radar and BIPS measurements were conducted by Malå Geoscience AB/ RAYCON during May and June 2004, according to Activity Plan AP 400-04-47 (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 borehole.

Borehole ID	Azimuth (degrees from north)	Inclination (degrees from horizontal)	Length (metres)	Investigated section (metres)
KFM05A	81	60	1,003	110–1,000

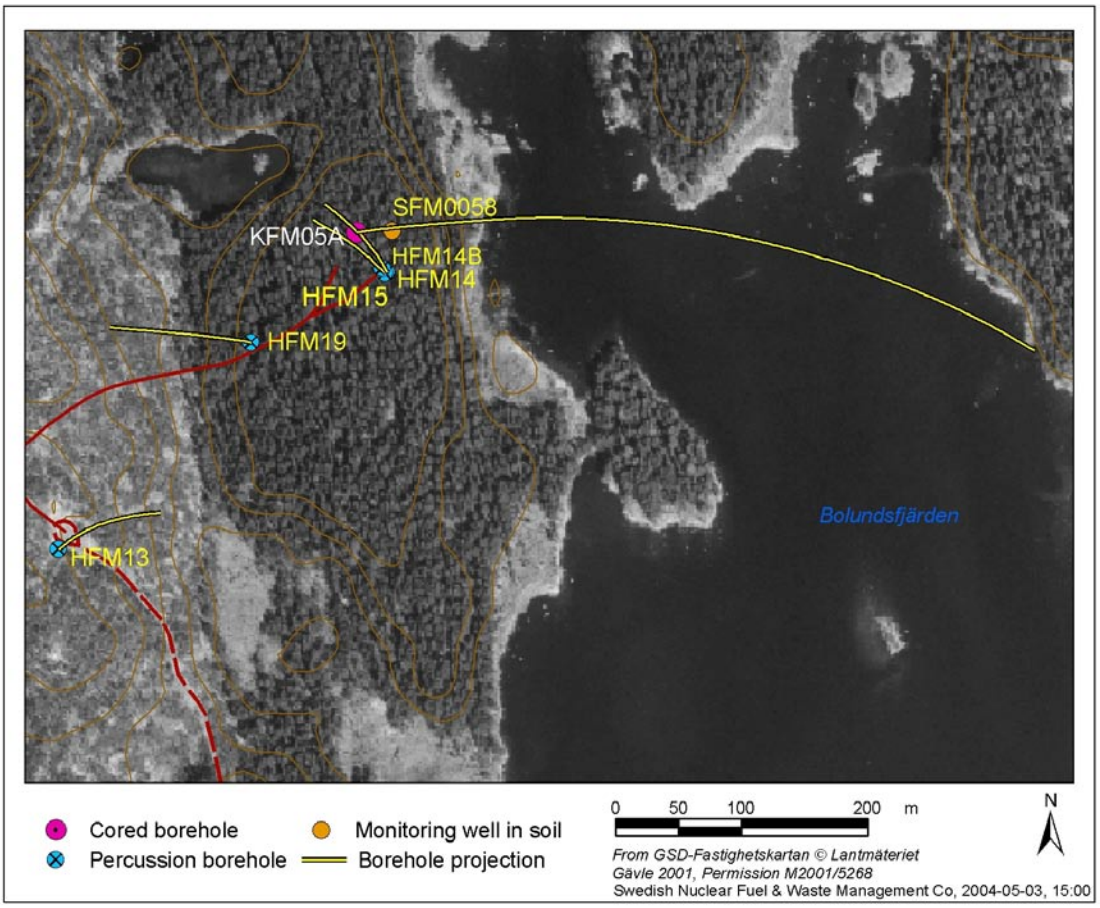


Figure 1-1. *Overview of boreholes at drill site no 5 in the Forsmark area.*

2 Objective and scope

The objective of the radar- and BIPS-surveys was to achieve information on the borehole conditions (borehole wall) as well as on the rock mass around the borehole. Borehole radar was engaged to investigate the nature and the structure of the rock mass enclosing the boreholes, and borehole TV for geological surveying of the borehole including determination of fracture distribution and orientation.

This report describes the equipment used as well the measurement procedures and data gained. For the BIPS-survey, the result is presented as images. Radar data is presented in radargrams and the identified reflectors are listed.

3 Equipment

3.1 RAMAC

The RAMAC GPR system owned by SKB is a 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 ranges 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.

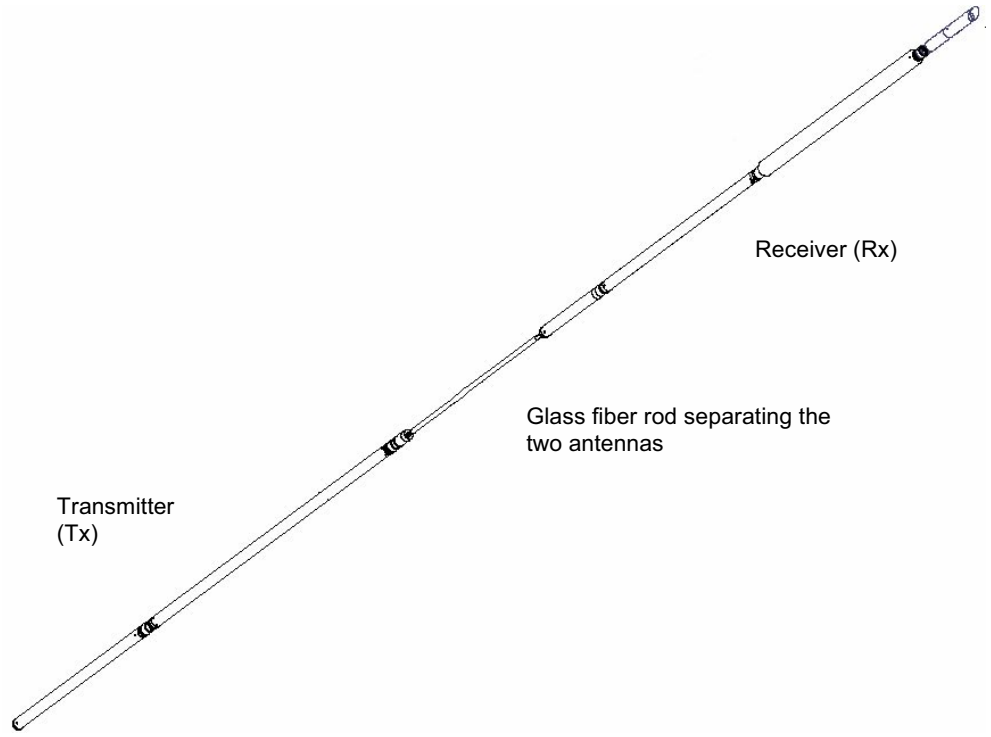


Figure 3-1. *Example of a borehole antenna.*

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

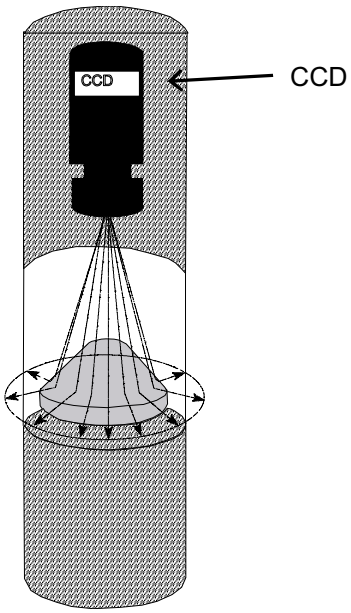


Figure 3-2. *The BIP-system. Illustration of the conical mirror scanning.*

4 Execution

4.1 Data aquisition

RAMAC

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

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

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

Information on the system settings for the different antennas used in the investigation of KFM05A is presented in Table 4-1.

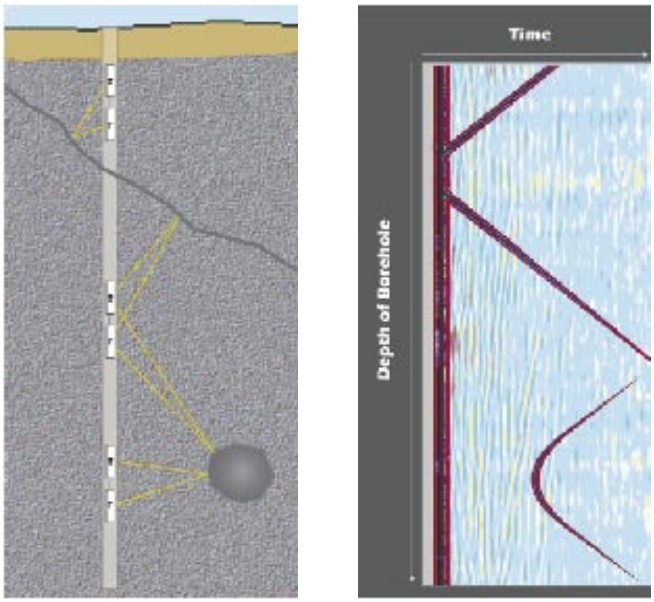


Figure 4-1. *The principle of radar borehole reflection survey (left) and a resulting radargram (right).*

Table 4-1. Radar logging information from KFM05A, 100 to 1,000 m.

Site:	Forsmark	Logging company:		RAYCON	
BH:	KFM05A	Equipment:		SKB RAMAC	
Type:	Directional / Dipole				
Operators:	CG	Manufacturer:		MALÅ GeoScience	
		Antenna			
		Directional	250 MHz	100 MHz	20 MHz
	Logging date:	04-06-04	04-05-08	04-05-09	04-05-08
	Reference:	T.O.C.	T.O.C.	T.O.C.	T.O.C.
	Sampling frequency (MHz):	656	2,588	951	257
	Number of samples:	512	619	518	518
	Number of stacks:	32	Auto	Auto	Auto
	Signal position:	365.7	–0.32	–0.32	–1.43
	Logging from (m):	113.4	111.5	112.6	116.25
	Logging to (m):	993	1,001.9	1,000.5	997.35
	Trace interval (m):	0.5	0.25	0.2	0.1
	Antenna separation (m):	5.73	1.9	2.9	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 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 BIPS images.

Depth measurements

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

The depth divergence in KFM05A is less than 10 cm in the deepest parts of the borehole.

4.2 Analyses and interpretation

Radar

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

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

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

The distance to a reflecting object or plane is determined by measuring the difference in arrival time between the direct and the reflected pulse. The basic assumption is that the speed of propagation is consistent in the rock volume investigated.

There are several ways to determine the radar wave propagation velocity. Each of them has its advantages and its disadvantages. In this project, the velocity determination was performed by keeping the transmitter fixed in a borehole at drill site no 1 (the percussion drilled borehole HFM03) while moving the receiver downwards in the borehole. The result is plotted in Figure 4-3. The calculation shows a velocity of 128 m/micro seconds. The velocity measurement was performed with the 100 MHz antenna /1/.

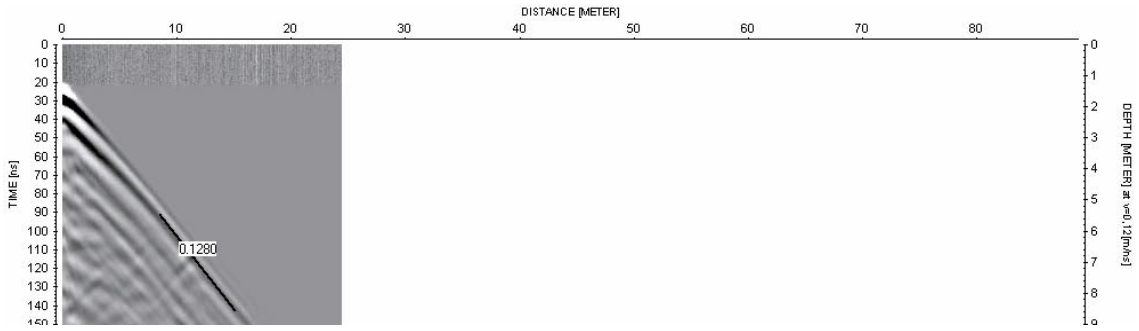


Figure 4-2. *Results from velocity measurements in HFM03 /1/.*

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 4-2.

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

Table 4-2. Processing steps for borehole radar data from KFM05A, 100 to 1,000 m.

Site:	**Forsmark**	**Logging company:**	**RAYCON**		
BH:	**KFM05A**	**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
		Gain	Move start time	Move start time	Move start time
		FIR	Gain	Gain	Gain

BIPS

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

5 Results and data delivery

The results from the radar and BIPS measurements were delivered 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 of the measurements is registered in SICADA, and the CD-ROMs stored by SKB.

RAMAC radar data have been delivered as raw data (fileformat *.rd3 or *.rd5) with corresponding information files (file format *.rad), whereas the data processing steps and results are presented in this report. Relevant information, including the interpretation presented in this report, has been inserted into the SKB database SICADA.

The SICADA reference to the BIPS and RAMAC logging activity in KFM05A is field note Forsmark no 289 and 319.

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

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

The data quality is good. However, measurements in minor parts of the borehole suffer from deteriorated quality due to increased electrical conductivity in the rock or borehole fluid. A conductive environment entails attenuation of the radar waves, resulting in decreased penetration.

As also seen in Appendix 1 and 2, the resolution and penetration of the radar waves depend of the antenna frequency. 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 KFM05A.

Depth (m)	No of structures	Depth (m)	No of structures
0–150	14	550–600	9
150–200	13	600–650	16
200–250	12	650–700	11
250–300	11	700–750	12
300–350	7	750–800	7
350–400	15	800–850	5
400–450	14	850–900	4
450–500	10	900–950	11
500–550	11	950–	17

Table 5-2 summarises the interpretation of radar data from KFM05A. 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 calculated, see Table 5-2. In some cases, however, there is an uncertainty (± 180 degrees) in the interpretation of the direction to the plane. Object direction 1, strike 1 and dip 1 in Table 5-2 then represent the most probable interpretation.

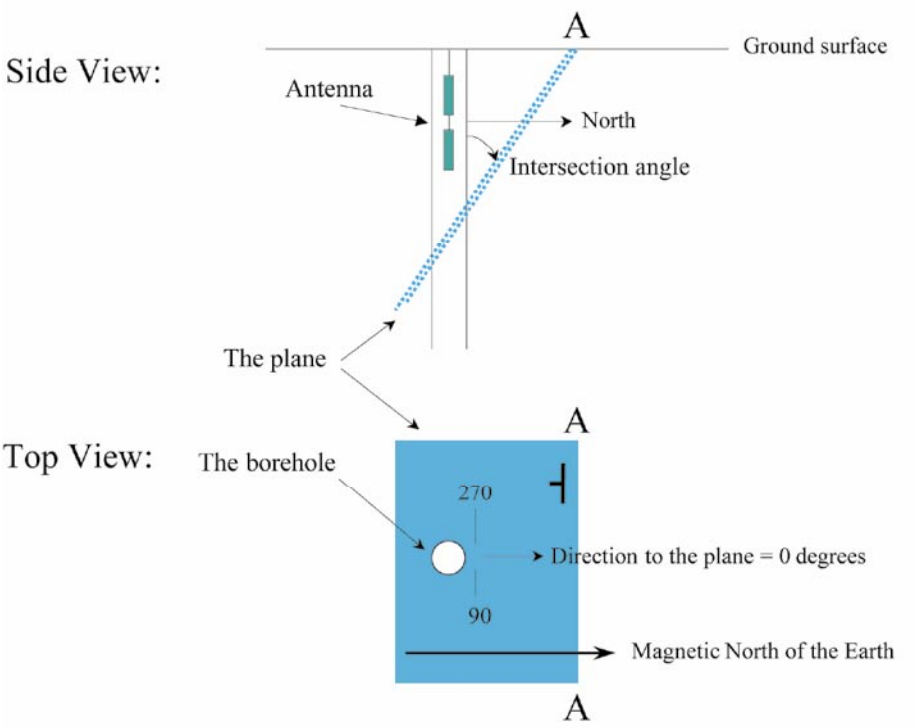


Figure 5-1. *Definition of the direction to object as presented in Table 5-2.*

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

RADINTER MODEL INFORMATION									
(20, 100 and 250 MHz Dipole Antennas and Directional Antenna)									
Site:			Forsmark						
Borehole name:			KFM05A						
Nominal velocity (m/µs):			128.00						
Object type	Name	Intersection depth (m)	Intersection angle (deg)	Object direction	Object direction	Interpreted true orientation			
				1 (deg)	2 (deg)	Strike 1 (deg)	Dip 1 (deg)	Strike 2 (deg)	Dip 2 (deg)
PLANE	136	43.4	6						
PLANE	132	103.4	37						
PLANE	A	111.3	62	42	222	348	53	80	20
PLANE	D	115.8	63						
PLANE	B	118.5	60						
PLANE	C	121.4	61						
PLANE	EE	123.9	70						
PLANE	E	127.4	47	189		166	14		
PLANE	F	132.9	45	192		164	19		
PLANE	HH	139.3	41						
PLANE	G	140.1	31						
PLANE	H	140.7	44	294		61	63		
PLANE	I	145.2	48	348		20	72		
PLANE	II	148	45						
PLANE	J	151.7	42	330		34	71		
PLANE	K	153.2	40						
PLANE	L	155.9	45						
PLANE	M	157.7	48						
PLANE	NN	163.9	59						
PLANE	N	165.1	37						
PLANE	O	165.9	55	18		359	66		
PLANE	PP	168.1	66						
PLANE	P	168.7	41						
PLANE	Q	177.9	51	12		8	67		
PLANE	QQ	180.4	31						
PLANE	R	182.8	46	21		357	73		
PLANE	T	188.3	44	357		14	78		
PLANE	S	204.8	19						
PLANE	U	208.8	21						
PLANE	VV	210	51						
PLANE	V	214.6	38	339	159	29	80	233	26
PLANE	W	215.9	43	351		19	80		
PLANE	X	218.1	41						
PLANE	Y	219.9	45						
PLANE	Z	227.9	44						
PLANE	133	229.9	28.9						
PLANE	1	231.2	58	0	180	120	70	192	8

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	236.5	49	180	360	191	12	13	72
PLANE	4a	250	47	195		150	16		
PLANE	4	250.8	41	351		18	78		
PLANE	5	256	46	0		11	76		
PLANE	6	258.8	43	165		222	25		
PLANE	7	263.5	40	165		222	23		
PLANE	8	264.6	63	192	12	39	10	4	54
PLANE	9	266.4	61						
PLANE	10	277.3	57						
PLANE	11	284.8	55						
PLANE	12	286.5	53						
PLANE	13	290.9	53	174		212	11		
PLANE	14a	302	47						
PLANE	14	304	40	33		344	79		
PLANE	134	311.8	35						
PLANE	15a	340.6	42	270		69	54		
PLANE	15	340.8	56						
PLANE	17	345	44						
PLANE	18	348.8	47						
PLANE	17a	351.7	43	339		25	78		
PLANE	19	354.4	41						
PLANE	16	356.7	17						
PLANE	135	356.3	24						
PLANE	20	356.7	57						
PLANE	21	360.9	52	333	153	26	70	268	17
PLANE	22a	364.7	51						
PLANE	22	366.9	51	327	147	30	70	272	21
PLANE	23	368.2	50	339		23	77		
PLANE	24	375.9	53						
PLANE	25	378.7	46	114		289	41		
PLANE	28a	383.6	41	24		349	79		
PLANE	25a	384.2	321		32	71			
PLANE	26	390.9	33	354	174	10	88	198	22
PLANE	27	393	48						
PLANE	28	402.4	41	348		16	81		
PLANE	29	405.6	41	63		316	76		
PLANE	30	407.6	44						
PLANE	31	409.9	44						
PLANE	31a	417.3	22	18		169	80		
PLANE	32	424.2	34	333		29	88		
PLANE	33	424.7	50	348	168	14	72	241	9
PLANE	34	427.6	53	222	42	88	24	340	65
PLANE	137	427.5	35						
PLANE	35	431.1	53						

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	36	439.5	55						
PLANE	37	445.5	42						
PLANE	38	446.9	67	264	84	48	38	328	43
PLANE	39	453.3	54	63	243	329	59	73	35
PLANE	40	461.2	54	15	195	358	66	84	8
PLANE	41	471.3	41						
PLANE	42	474.2	39						
PLANE	43	475.1	31	207		135	30		
PLANE	45	479.5	36						
PLANE	44	489.5	23						
PLANE	47	493.9	31						
PLANE	48a	496.3	69	138	318	324	23	22	53
PLANE	48	497.9	43	354	174	9	86	201	17
PLANE	49	500.1	22						
PLANE	46	507.9	17						
PLANE	50	510.2	44	6		360	81		
PLANE	50a	508.1	60	357		186	76		
PLANE	51	514.6	37	348		13	83		
PLANE	46a	516	44	351		10	78		
PLANE	52	527	69						
PLANE	54a	540.5	43						
PLANE	53	542	33	333		206	89		
PLANE	54	542	43	330		25	78		
PLANE	55	549.7	53						
PLANE	56	572.3	25						
PLANE	58	574.1	37						
PLANE	57	574.5	51	177	357	207	4	4	74
PLANE	60	582	31						
PLANE	61	583.7	41						
PLANE	62	588.7	47						
PLANE	59	588.9	21	138		242	45		
PLANE	63	595.2	38						
PLANE	63a	596.2	69						
PLANE	65	604.6	36	147		232	31		
PLANE	66	604.5	52	135		280	27		
PLANE	67	605.5	62	318	138	26	64	291	23
PLANE	64a	606.2	19	141		235	47		
PLANE	64	608.8	16						
PLANE	68	610.9	61	132		308	25		
PLANE	69a	610.2	56	339	159	13	74	256	14
PLANE	69	611.8	36						
PLANE	70	612.6	44						
PLANE	71	613.9	46	123	303	282	36	39	67
PLANE	72a	625.7	50						

Object type	Name	Intersection depth (m)	Intersection angle (deg)	Object direction	Object direction	Interpreted true orientation			
				1 (deg)	2 (deg)	Strike 1 (deg)	Dip 1 (deg)	Strike 2 (deg)	Dip 2 (deg)
PLANE	72	628.2	37	333		22	86		
PLANE	73	634.3	32						
PLANE	75	635.9	29						
PLANE	73a	641.1	42	156		239	20		
PLANE	74	651.3	40						
PLANE	76	657.4	41	159		229	20		
PLANE	77	673.9	24						
PLANE	78	671.7	56	141		282	22		
PLANE	79	678.8	63	312		21	55		
PLANE	80a	680.9	22						
PLANE	81	683.1	60						
PLANE	80	685	20						
PLANE	81a	687.9	47						
PLANE	82	694.8	45	120	300	281	38	38	68
PLANE	83	695.9	63						
PLANE	85a	700	15	117		255	62		
PLANE	84	704	31						
PLANE	85	712.8	32	285		57	71		
PLANE	138	717.1	8	60		117	80		
PLANE	86	718.1	19	165		202	37		
PLANE	85b	720	23						
PLANE	87	723.9	30						
PLANE	140	729.8	19						
PLANE	88	730.6	24						
PLANE	89	734.9	38	141	321	252	30	25	79
PLANE	90	741.4	38	132		269	32		
PLANE	91	749.2	29	117		264	51		
PLANE	92	750.2	39	87		292	62		
PLANE	93	753.2	46						
PLANE	94	757.8	36	108		272	55		
PLANE	95	763.3	38						
PLANE	96	776.6	30						
PLANE	97	779.2	24	30		148	82		
PLANE	98	784.7	36						
PLANE	99	789.9	49						
PLANE	100	814.7	54						
PLANE	101	819.4	43						
PLANE	103	836.9	34						
PLANE	102	841.9	16						
PLANE	104	842.7	66	249		41	36		
PLANE	105	860.7	52						
PLANE	107	876.8	53						
PLANE	106	885.9	25	144		226	41		
PLANE	109	896.5	41						

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	108	906.7	13						
PLANE	106a	908.8	8						
PLANE	111	909.3	34	195		139	26		
PLANE	113	913	35						
PLANE	108a	914.8	10						
PLANE	112	915.7	31						
PLANE	114	924.5	26						
PLANE	115	932.9	22	174	354	179	33	175	75
PLANE	116	941.8	28						
PLANE	117	946.1	30	87		282	65		
PLANE	118	950.9	30	60		299	81		
PLANE	119	959.6	30						
PLANE	120	960.8	47	198		109	15		
PLANE	121	965.6	31						
PLANE	124	969.8	41						
PLANE	123	975	24						
PLANE	127	977.8	26	24		320	79		
PLANE	122a	980.2	34	159		209	28		
PLANE	125	986.7	31	129		247	42		
PLANE	122	986.9	23						
PLANE	126	989.2	41						
PLANE	128	998.8	59						
PLANE	129	1,001.1	50	330		11	84		
PLANE	130	1,020.4	29	342		182	86		
PLANE	131	1,026.1	28						
PLANE	141	1,055.6	13						
PLANE	141a	1,681.8	2						

Names in table according to Appendix 1 and 2.

In Appendix 1, the amplitude of the first arrival is plotted against the depth, for the 250 MHz dipole antennas. The amplitude variation along the borehole indicates changes of the electrical conductivity of the material. A decrease in this amplitude may indicate fracture zones, clay or rock volumes with increases water content. The decrease in amplitude is seen for the following sections in KFM05A:

Depth (m)						
110–115	205–215	405	475–480	595	705	840
150	360–360	415–425	495	610–615	715–725	905
165	375	425–430	505	625–630	755	980
185	395	445	540	670–675	795	

5.2 BIPS logging

In order to control the quality of the BIP system, calibration measurements were performed in a test pipe before 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.

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

Four runs with the BIPS were performed in the borehole. The aim of the first logging 2004-04-21 was to inspect a fracture zone that had been noted at a depth of 109 metre during the drilling operation. The concern was if loose rock pieces in the borehole wall could fall in to the borehole and cause jamming. After evaluating the result from the BIPS survey it was decided to extend the casing down to 110 metre. Figure 5-2 shows the BIPS image of the zone before it was cased.

The second logging 2004-05-08 indicated quite bad water quality and was therefore discontinued at 251 metre. The third logging 2004-05-10 showed an improved visibility but still the bottom part was covered with a thin layer of mud. The logging was discontinued at a depth of 500 metre. Images from these to loggings are not presented in this report.

The last BIPS logging was carried out 2004-06-03 from 110 metre down to 995 metre and revealed almost perfect water quality, see Appendix 3. The improvement of the water quality, a couple of weeks after the finish of the drilling has been observed in several boreholes from both the Forsmark and Oskarshamn sites. Discolouring of some parts of the borehole due to the drilling is however still seen.

To sum up, the BIPS logging has produced high quality images for the core logging.

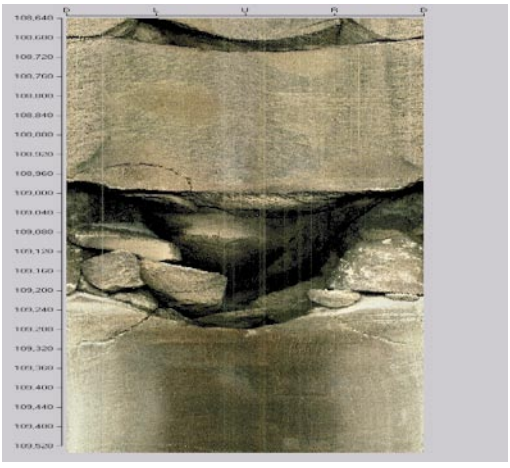
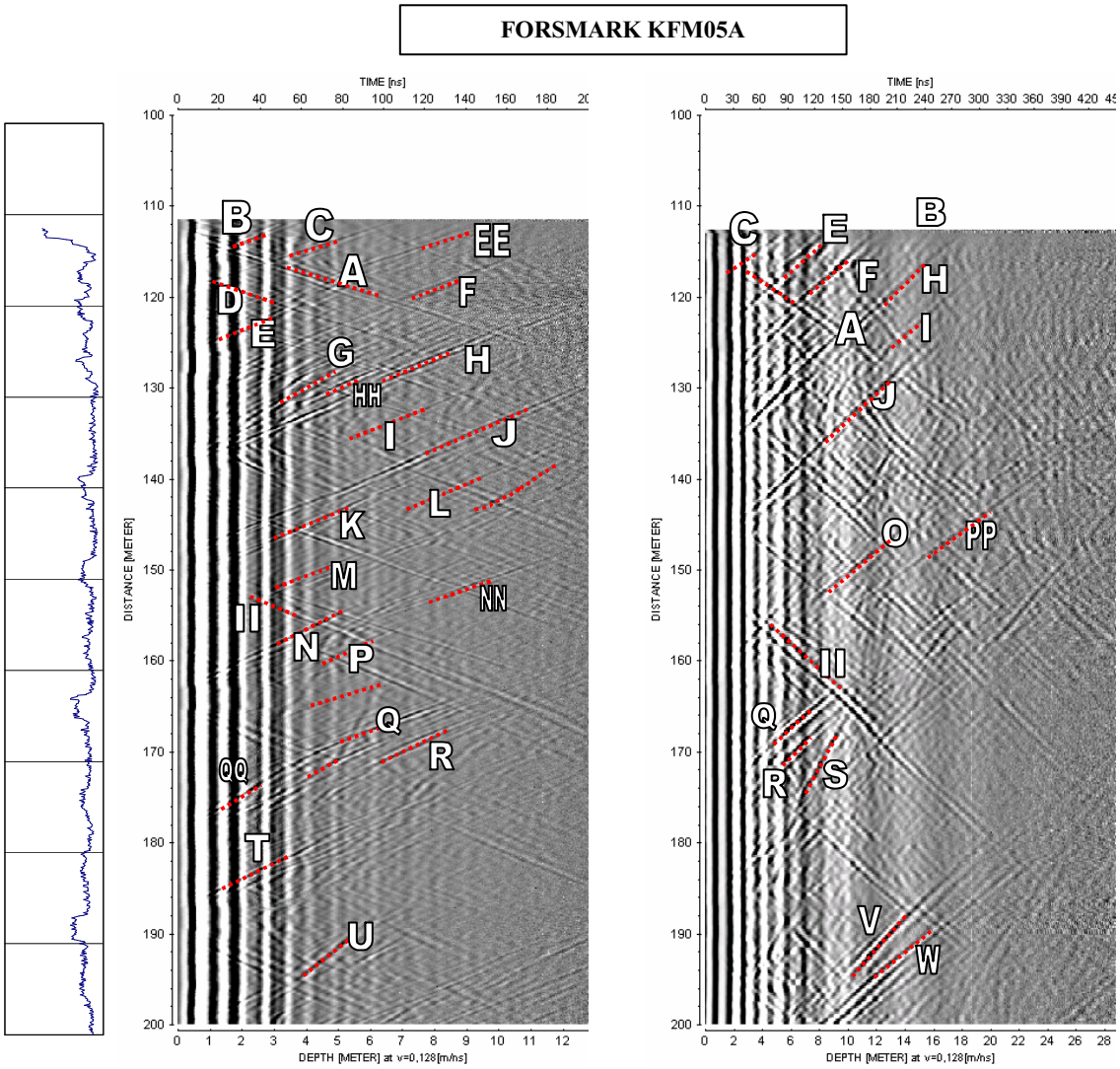


Figure 5-2. *BIPS image of the fracture zone at 109 metre.*

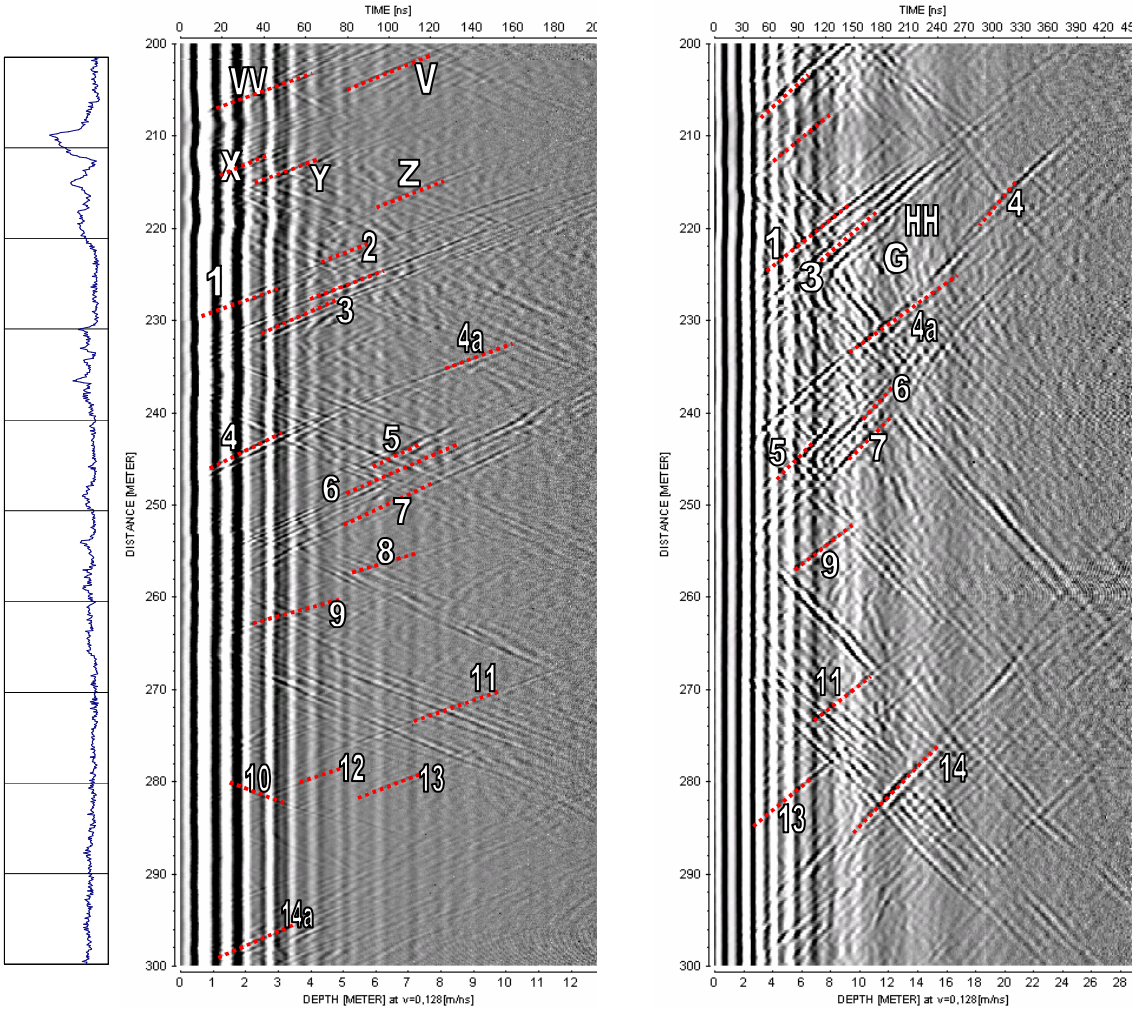
6 References

/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.

Radar logging of KFM05A 110 to 1,000 m, dipole antennas 250 and 100 MHz

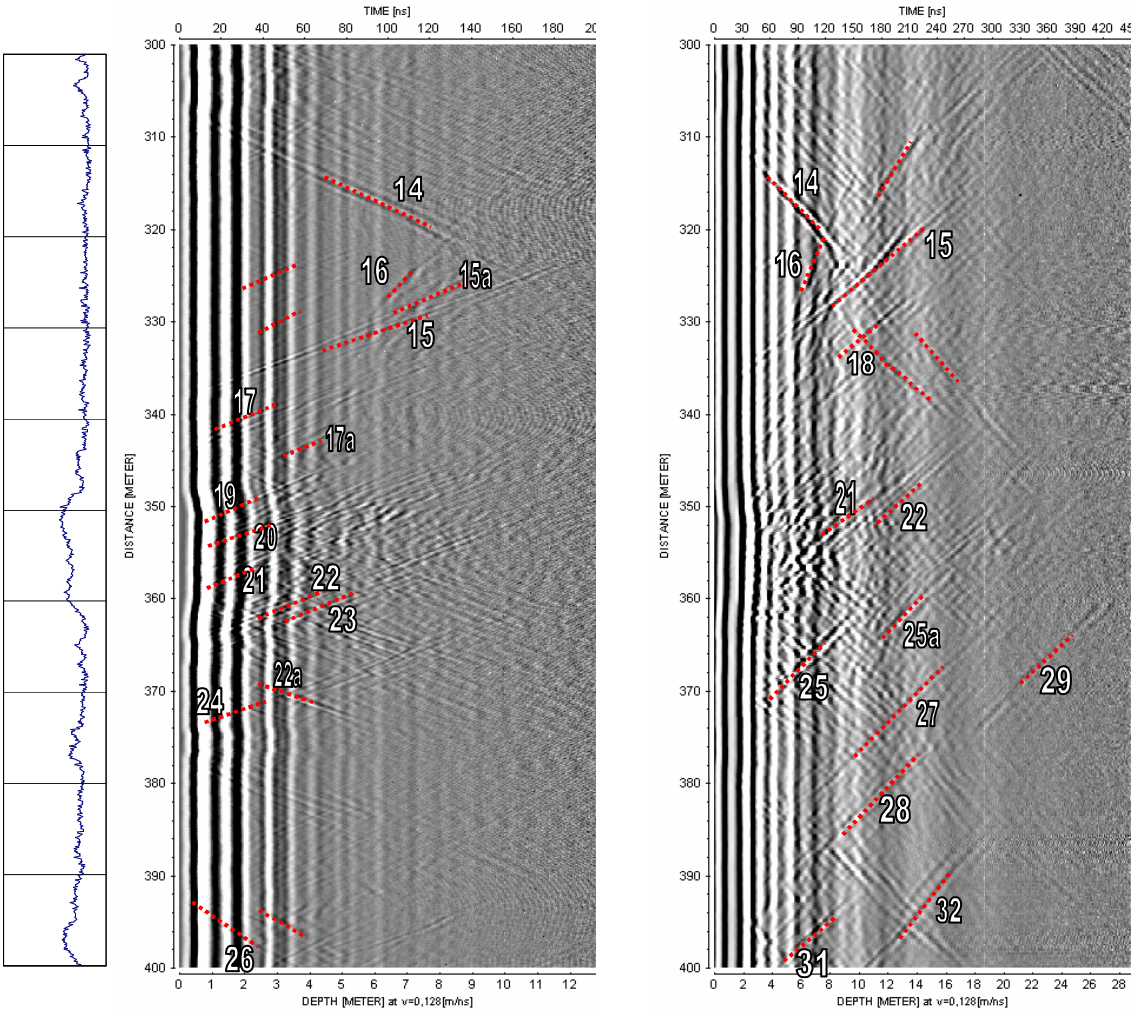


FORSMARK KFM05A



250 MHz **100 MHz**

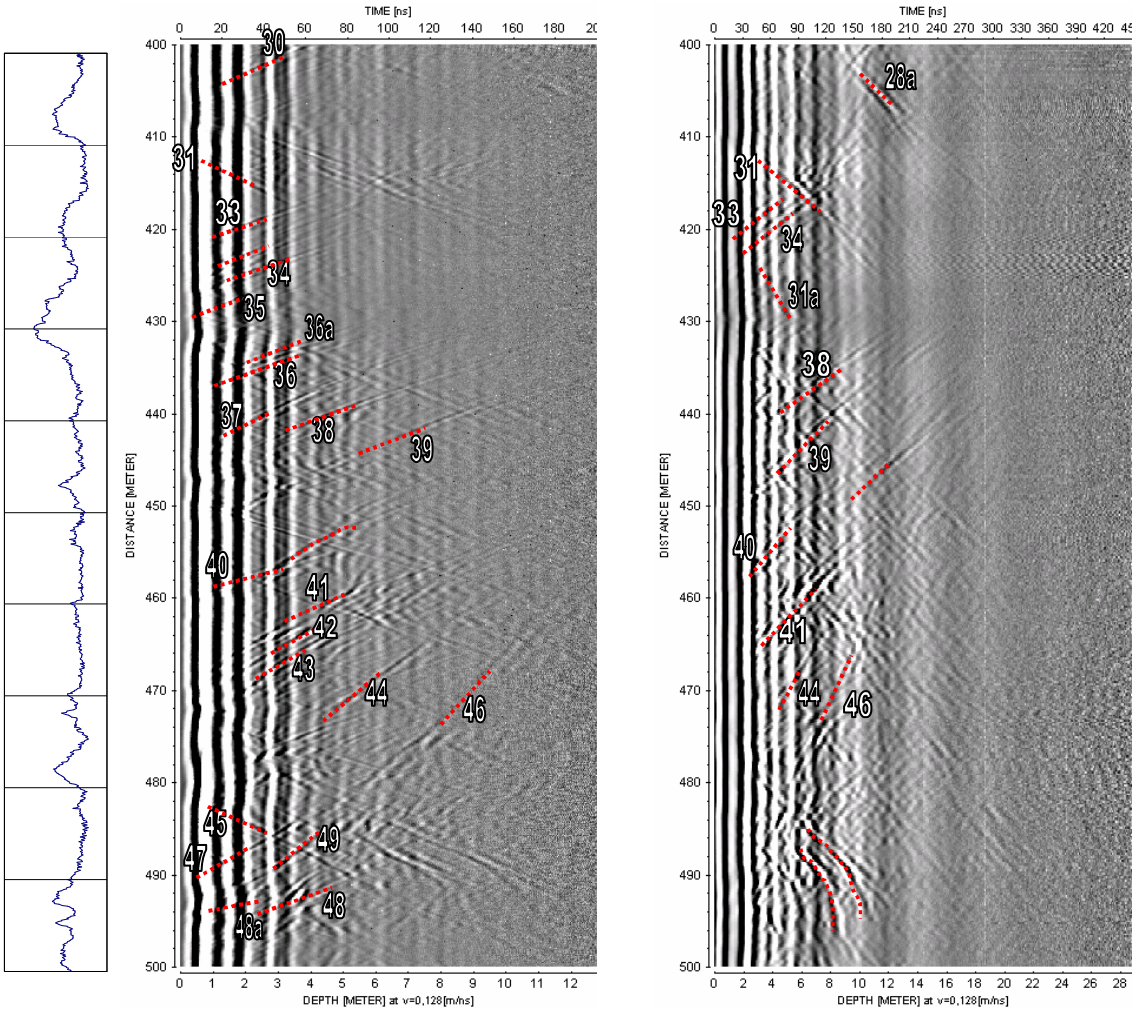
FORSMARK KFM05A



250 MHz

100 MHz

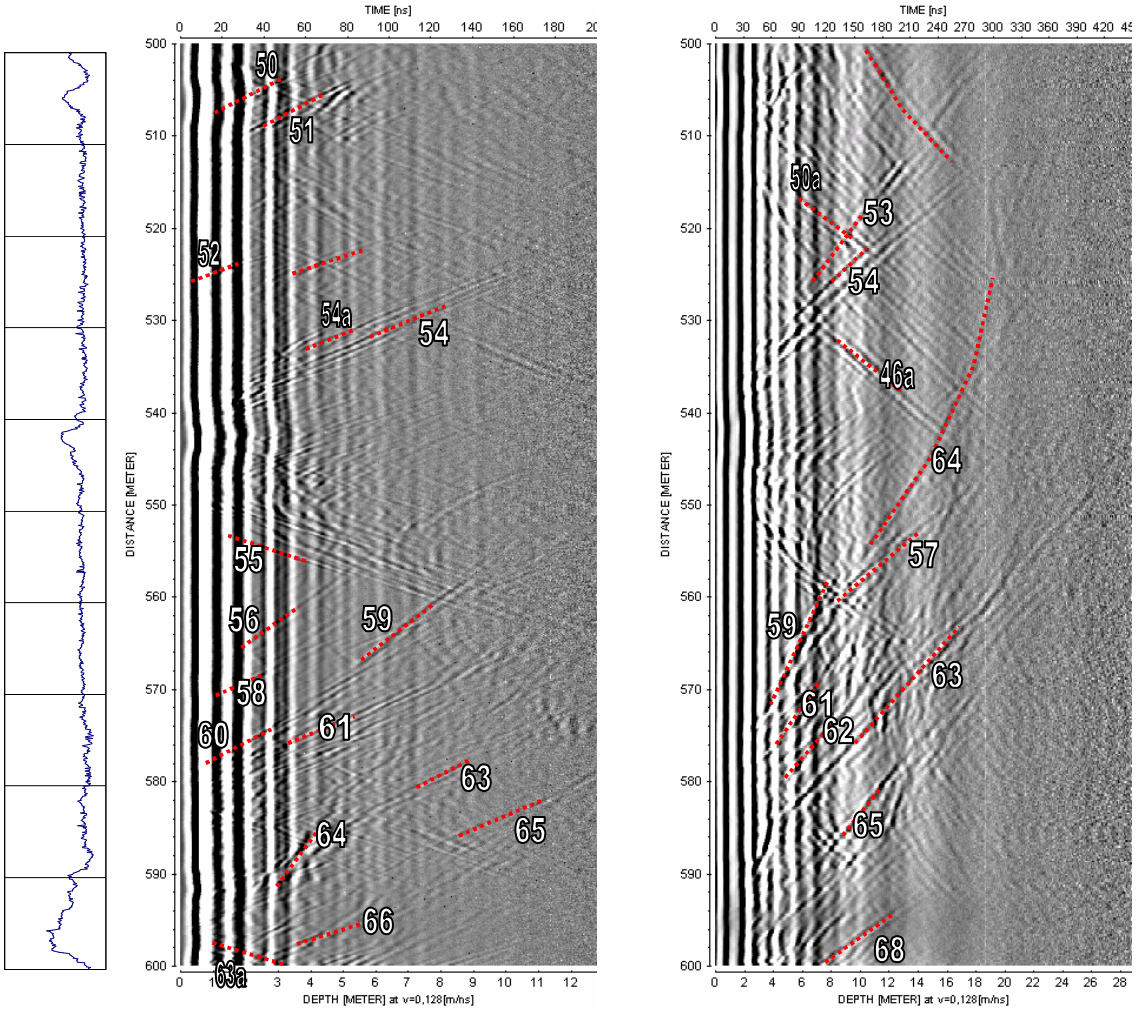
FORSMARK KFM05A



250 MHz

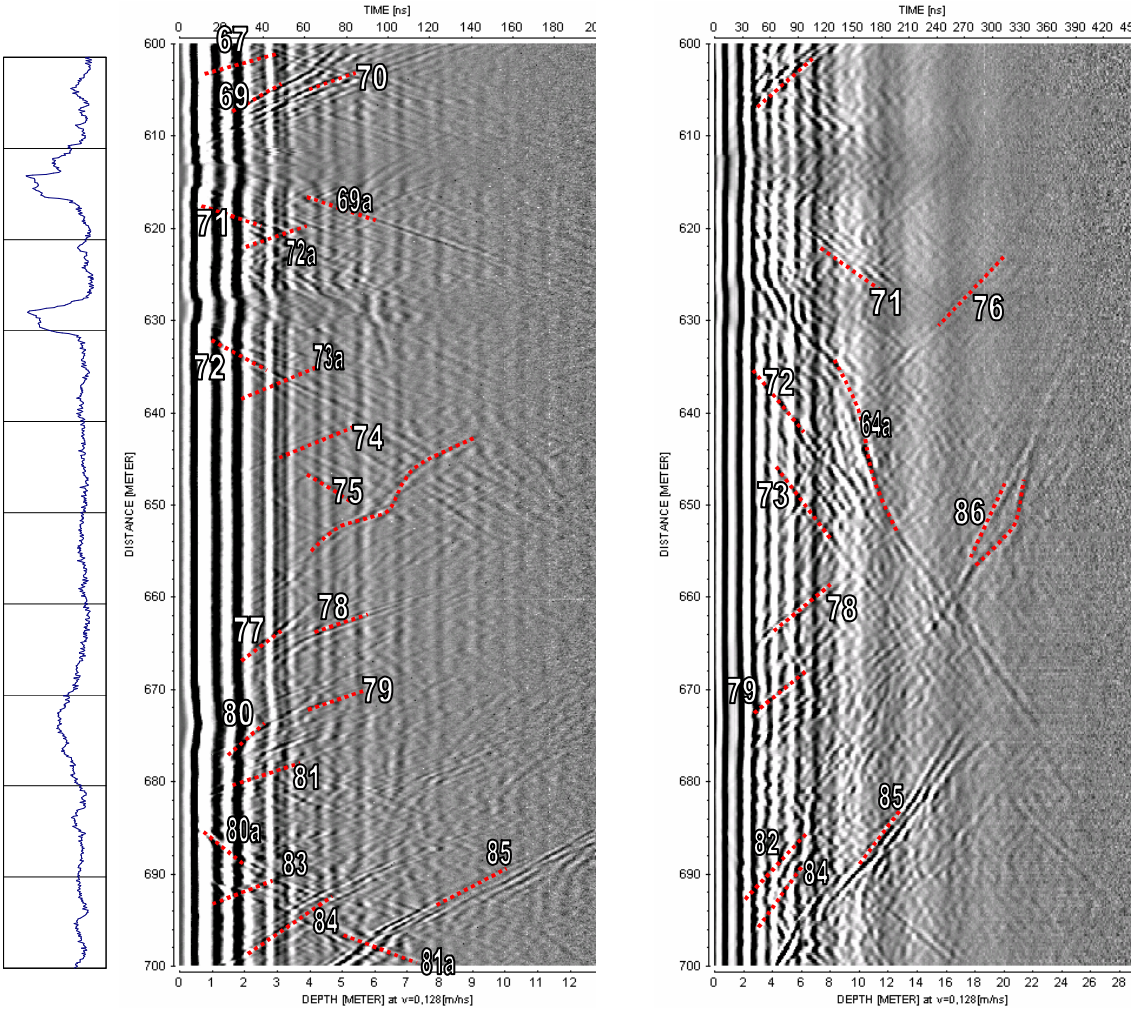
100 MHz

FORSMARK KFM05A



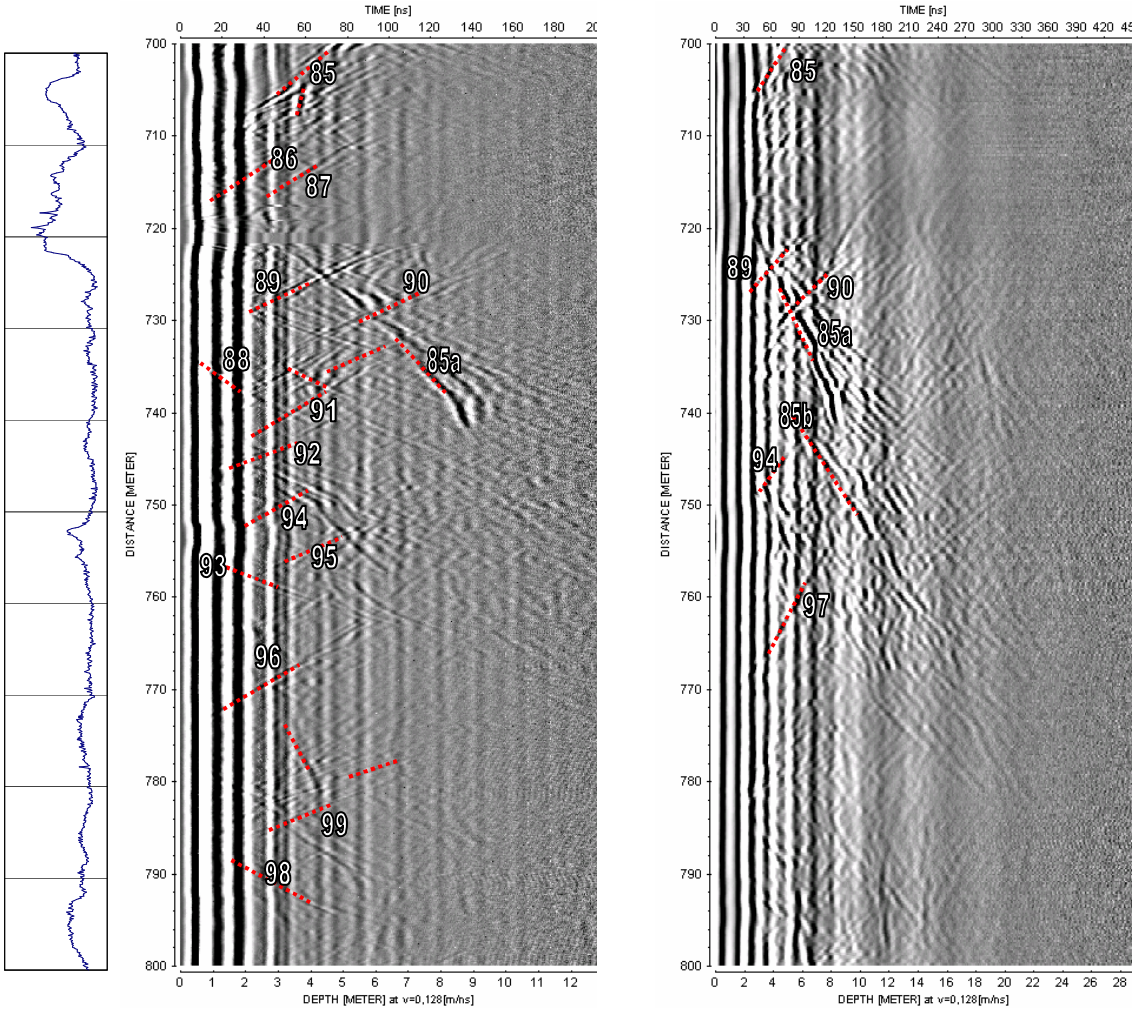
250 MHz **100 MHz**

FORSMARK KFM05A



250 MHz

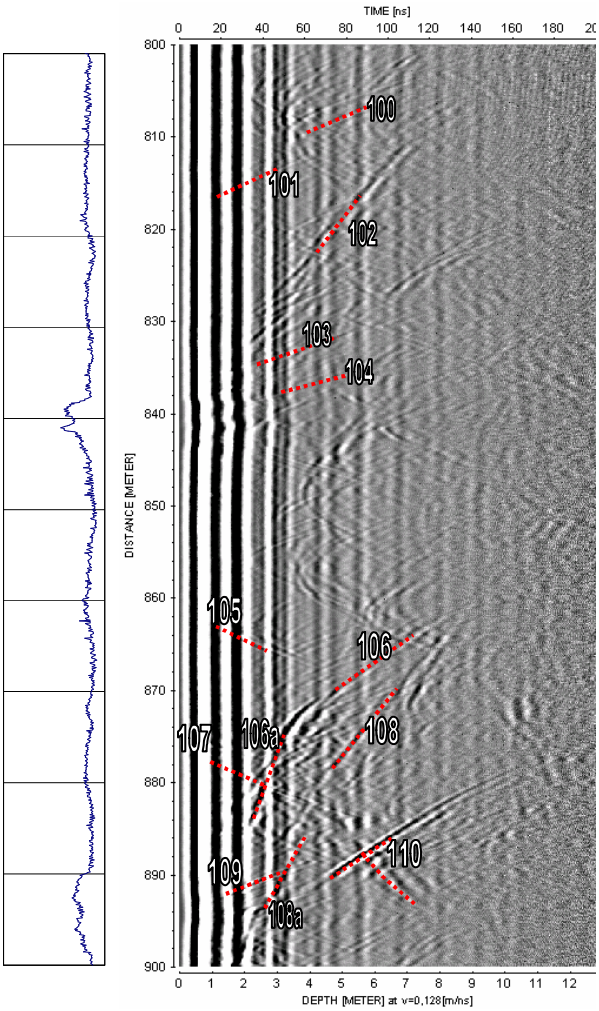
FORSMARK KFM05A



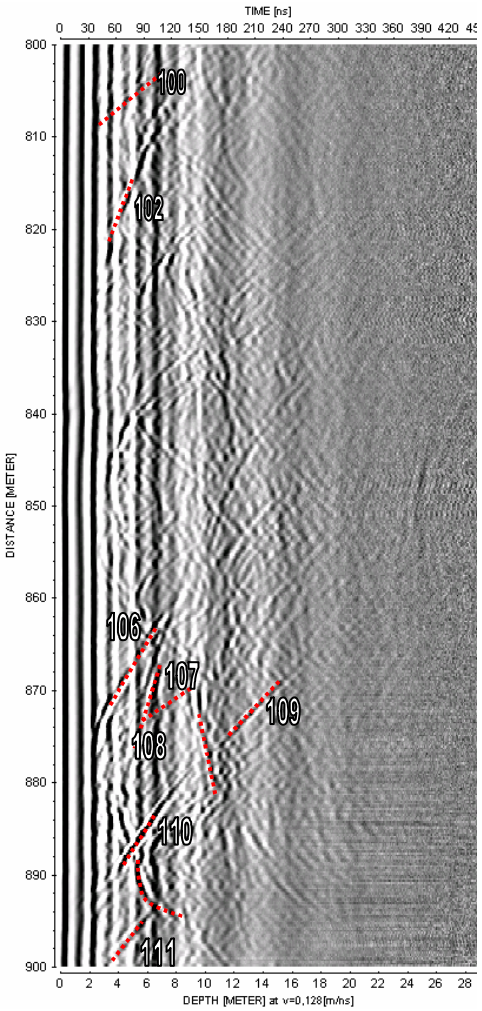
250 MHz

100 MHz

FORSMARK KFM05A

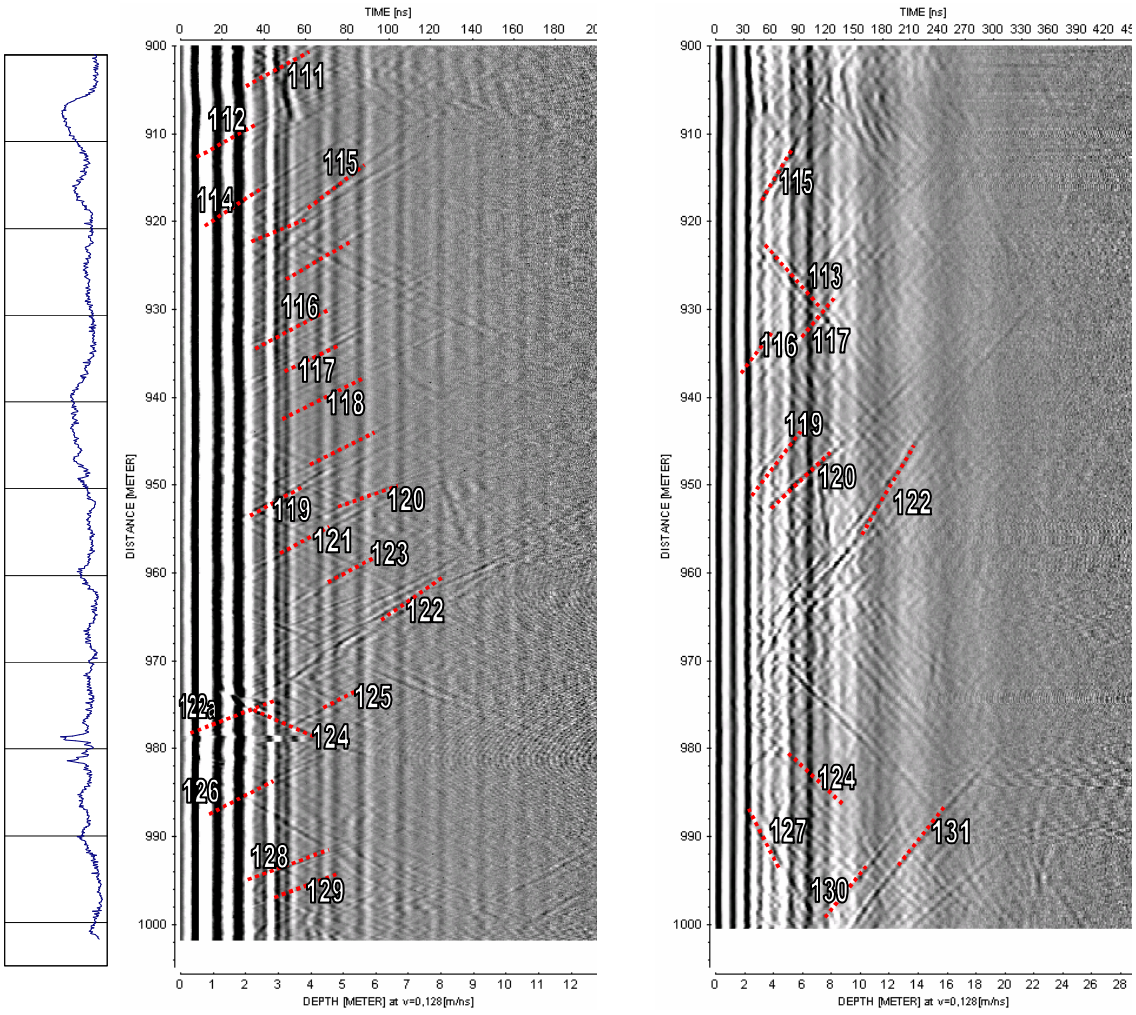


250 MHz



100 MHz

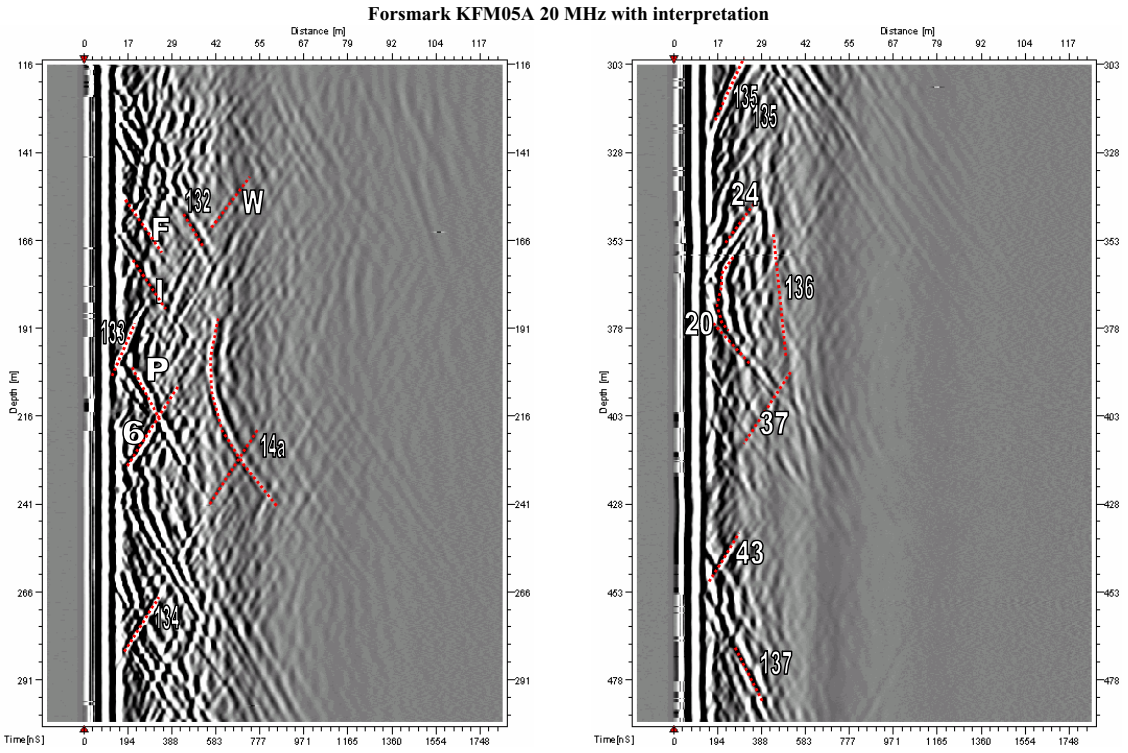
FORSMARK KFM05A

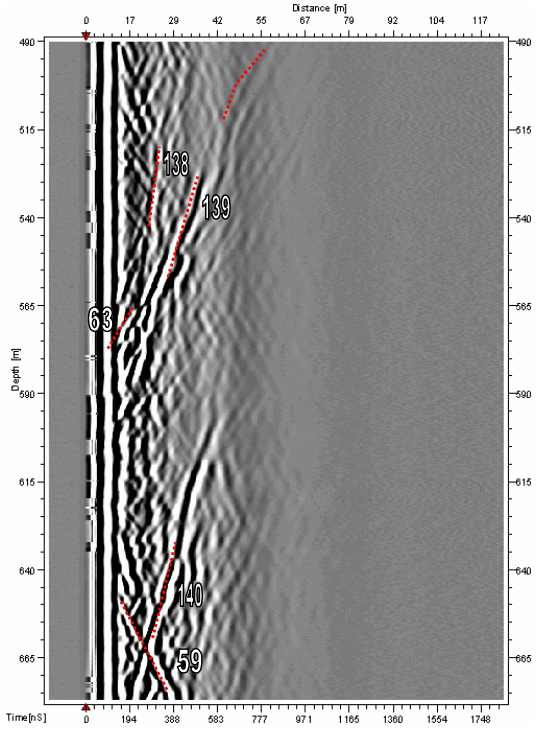


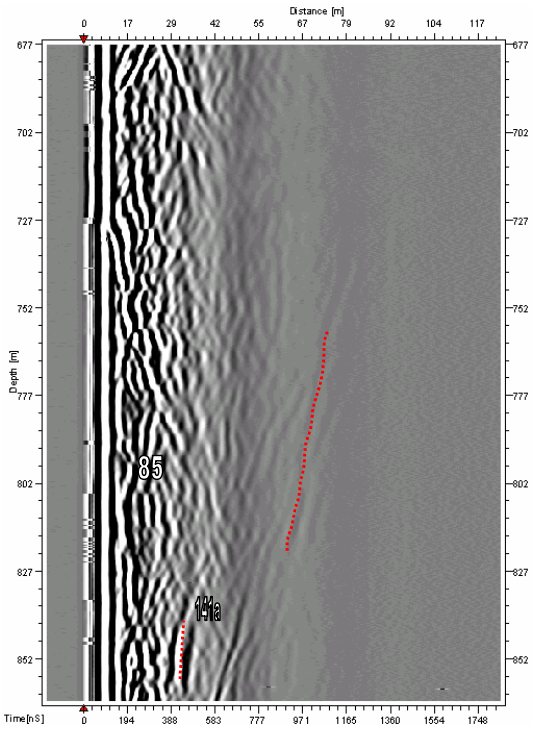
250 MHz **100 MHz**

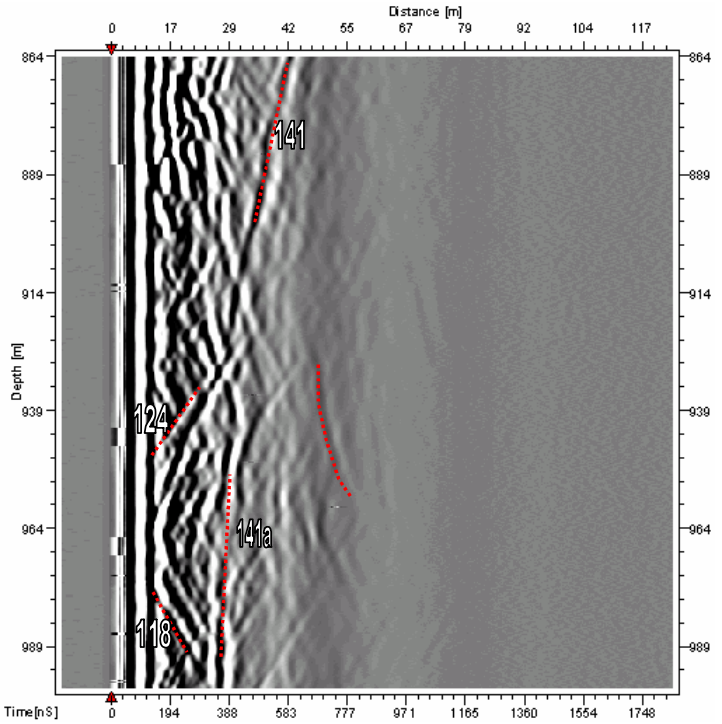
Appendix 2

Radar logging of KFM05A 110 to 1,000 m, dipole antennas 20 MHz




Distance [m]
0 17 29 42 55 67 79 92 104 117
Depth [m]
490 515 540 565 590 615 640 665
Time [nS]
0 194 388 583 777 971 1165 1360 1554 1748
138
139
63
140
59


Distance [m]
0 17 29 42 55 67 79 92 104 117
Depth [m]
677 702 727 752 777 802 827 852
Time [nS]
0 194 388 583 777 971 1165 1360 1554 1748
85
141a


Distance [m]
0
17
29
42
55
67
79
92
104
117
Depth [m]
864
889
914
939
964
989
Time[nS]
0
194
388
583
777
971
1165
1360
1554
1748
141
124
141a
118

Appendix 3

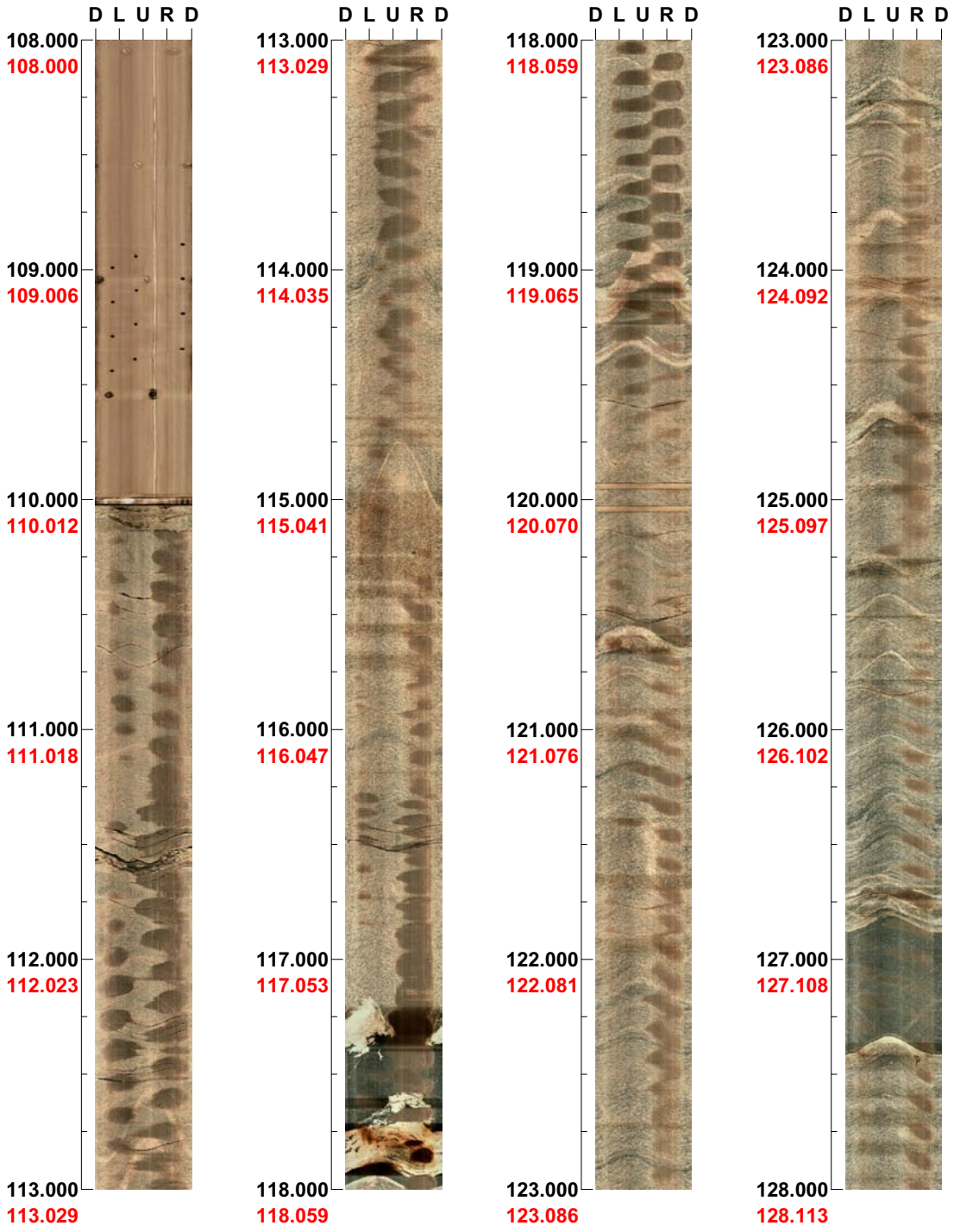
BIPS logging of KFM05A 110 to 1,000 m

Project name: Forsmark

Image file	**: c:\work\r52__s~1\bips\040603\kfm05a_1.bip**
BDT file	**: c:\work\r52__s~1\bips\040603\kfm05a_1.bdt**
Locality	**: FORSMARK**
Bore hole number	**: KFM05A**
Date	**: 04/06/03**
Time	**: 11:30:00**
Depth range	**: 108 - 995 m (red figures = corrected values)**
Azimuth	**: 81**
Inclination	**: -60**
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	**: 22**
Color	**: +0 +0 +0**

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

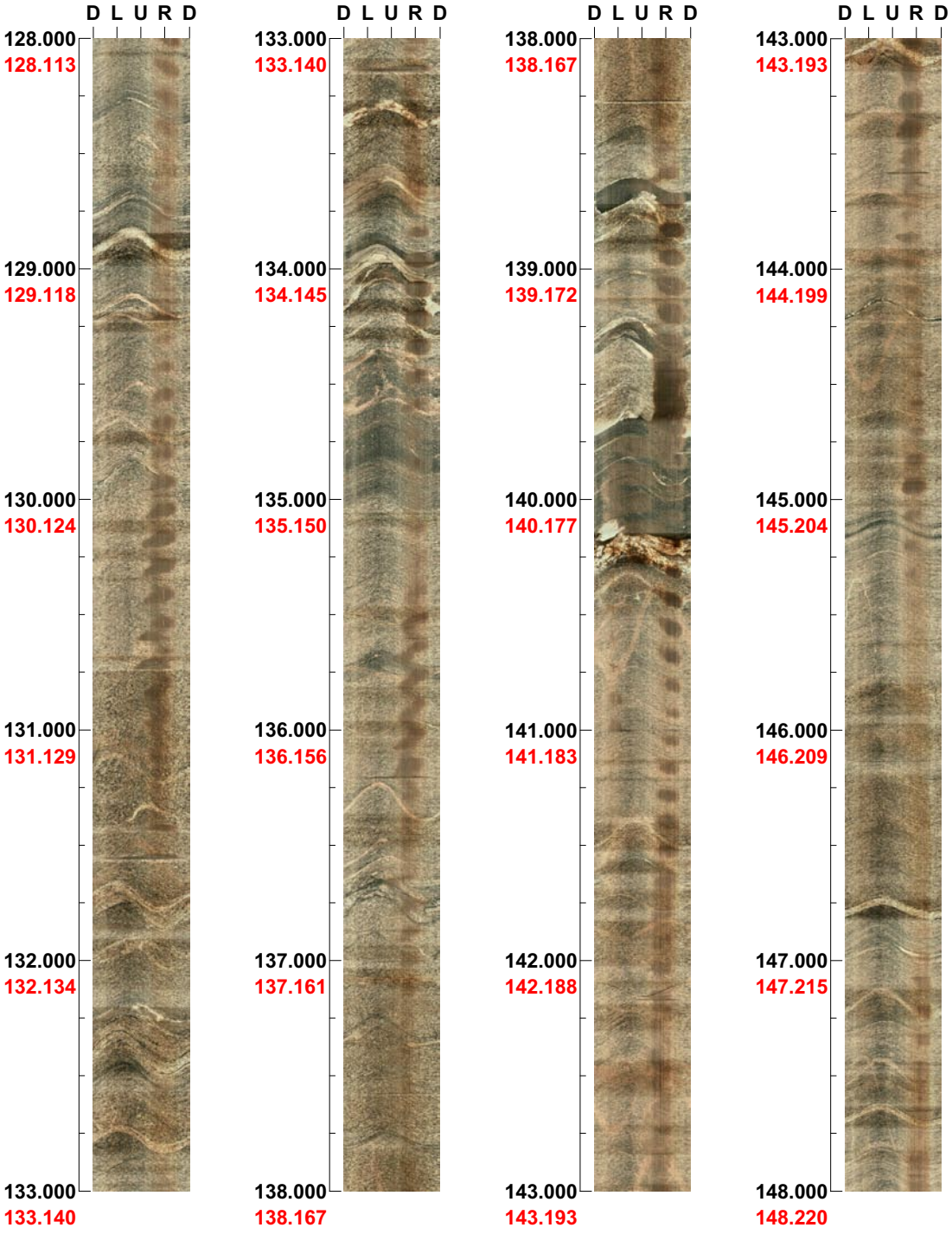
Depth range: 108.000 - 128.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

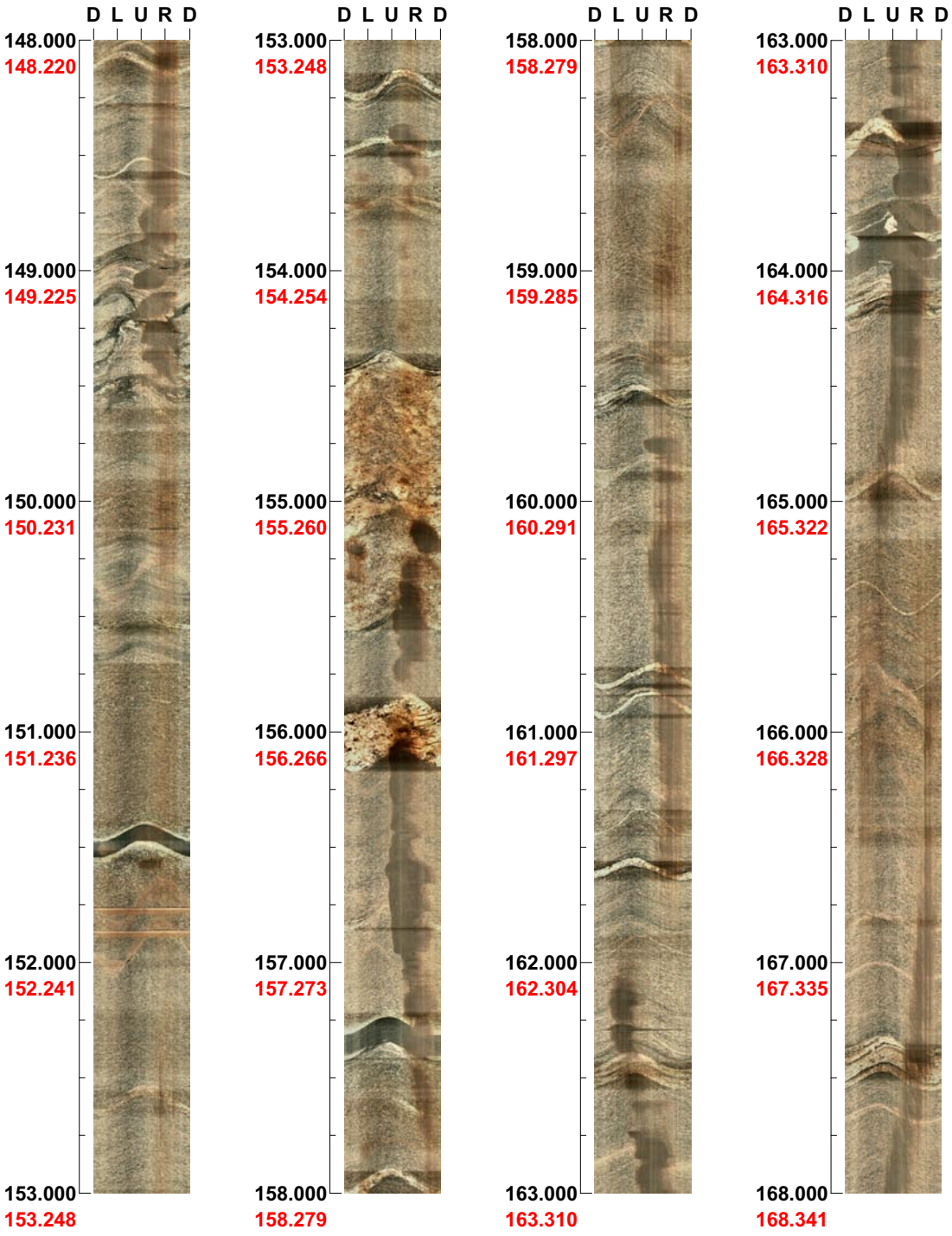
Depth range: 128.000 - 148.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

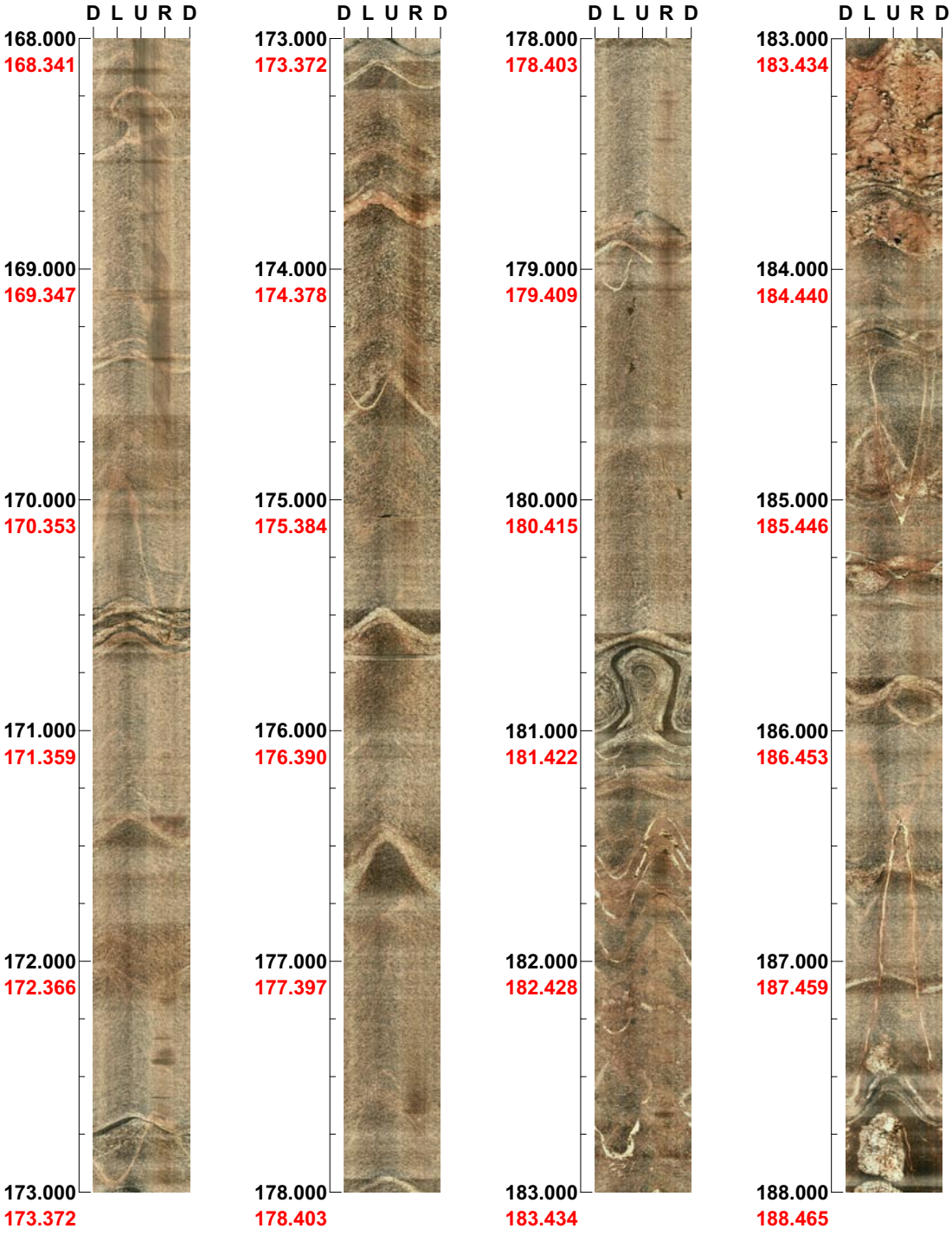
Depth range: 148.000 - 168.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

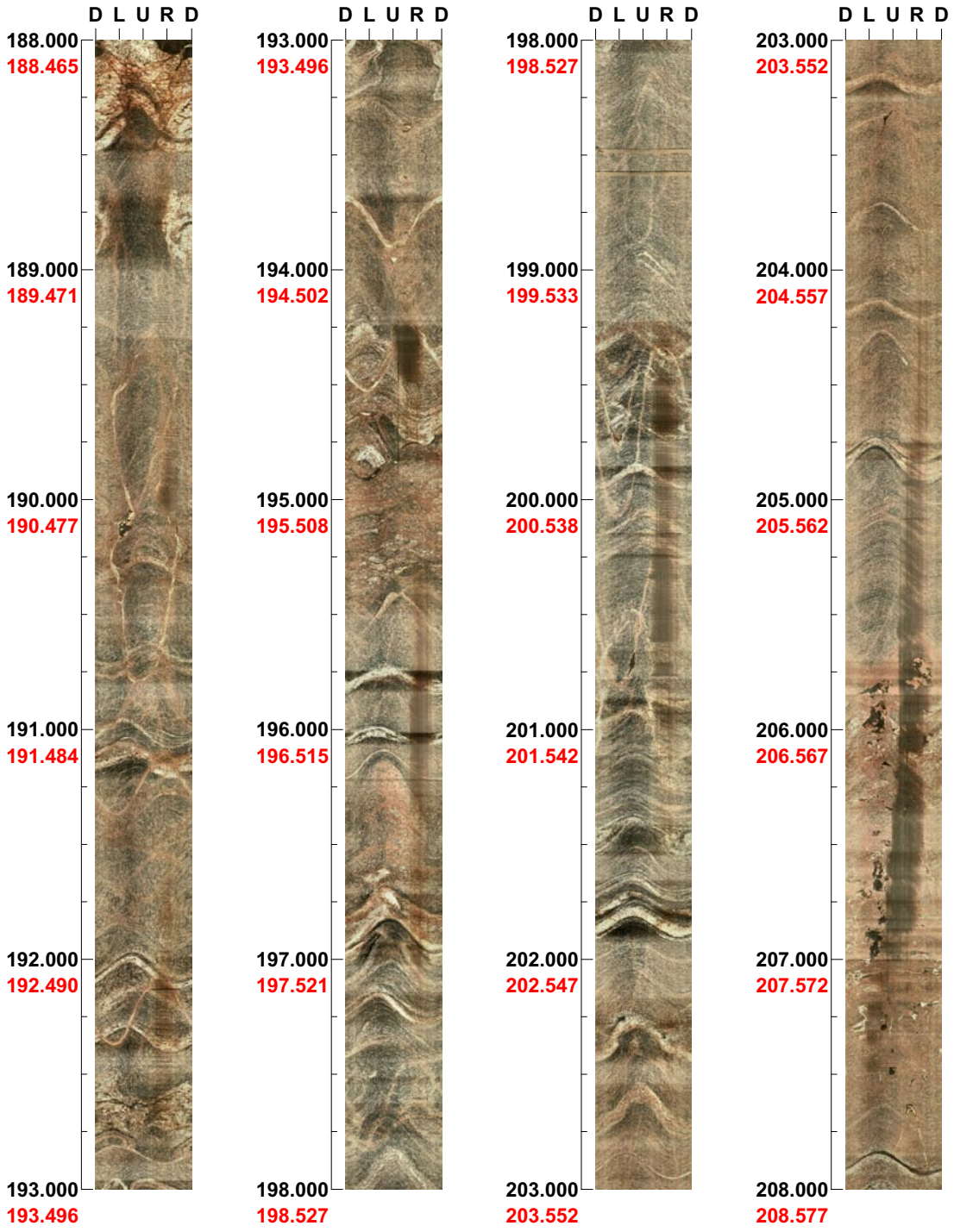
Depth range: 168.000 - 188.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

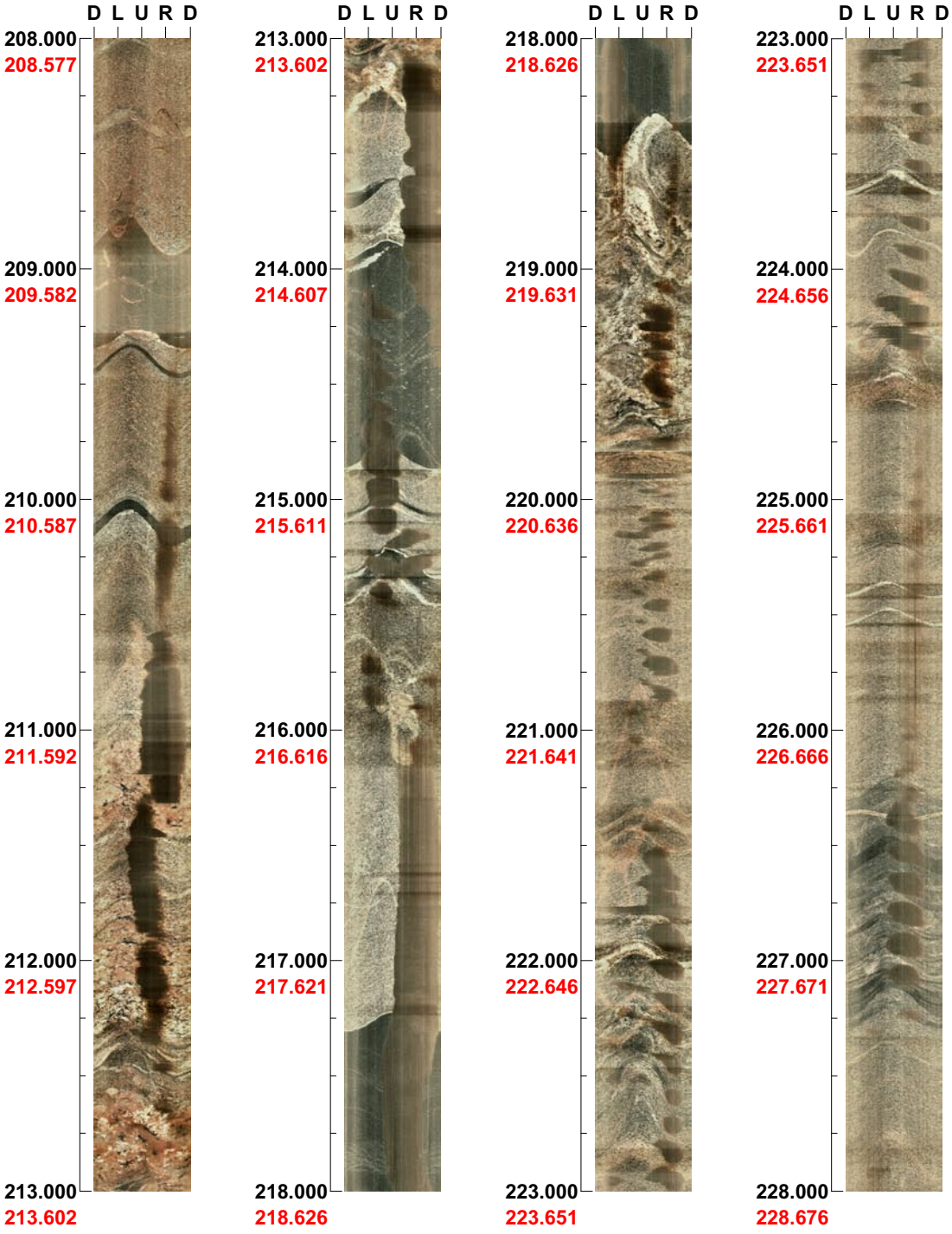
Depth range: 188.000 - 208.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

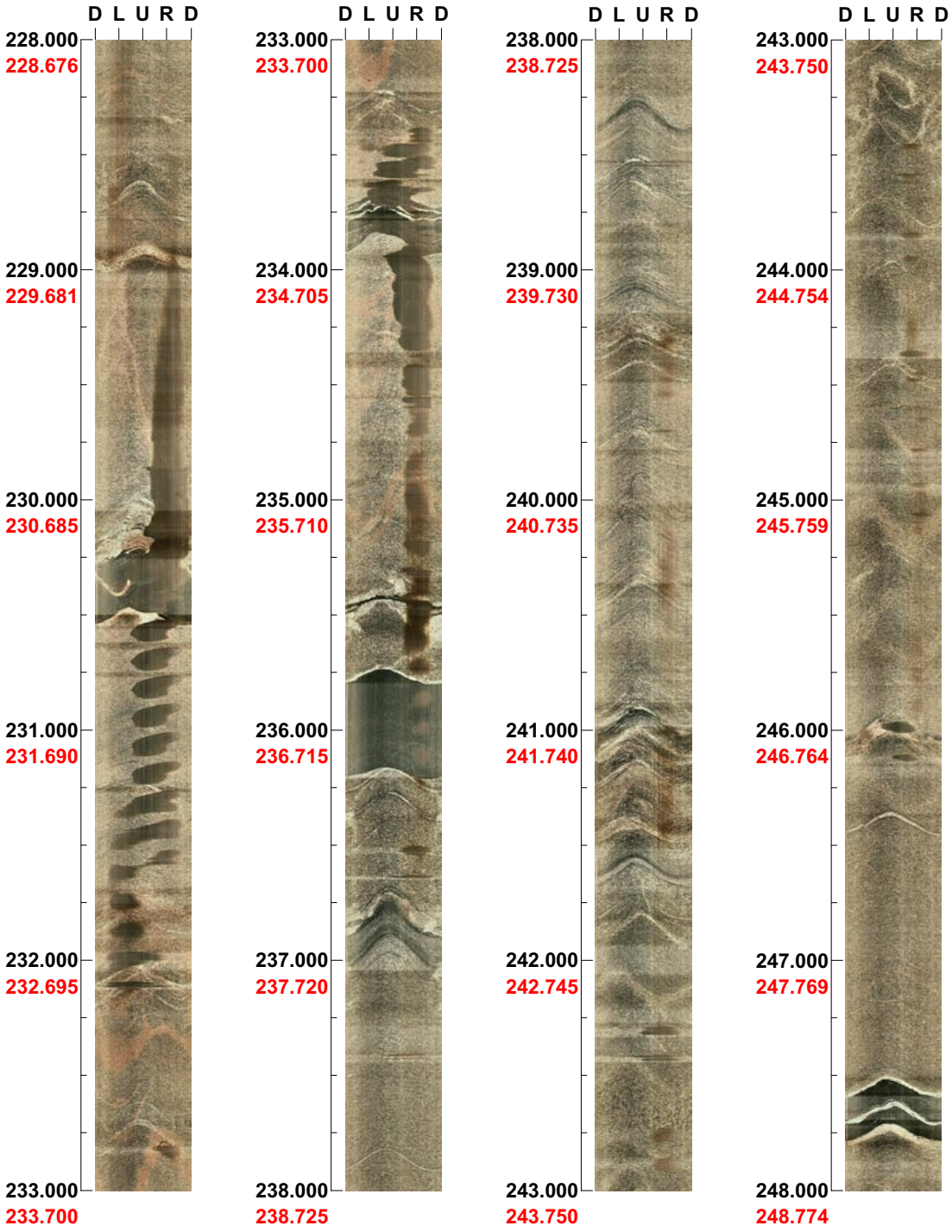
Depth range: 208.000 - 228.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

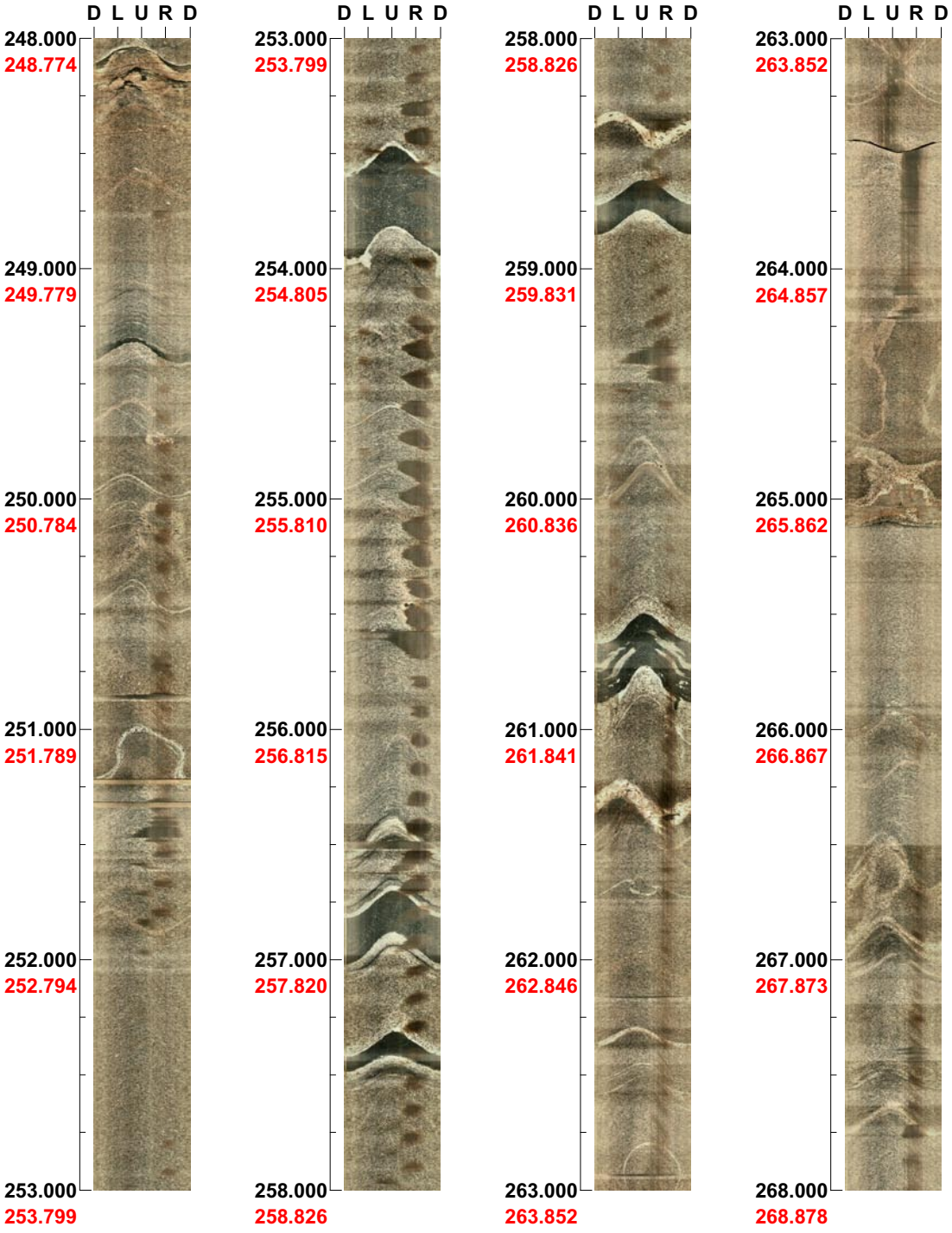
Depth range: 228.000 - 248.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

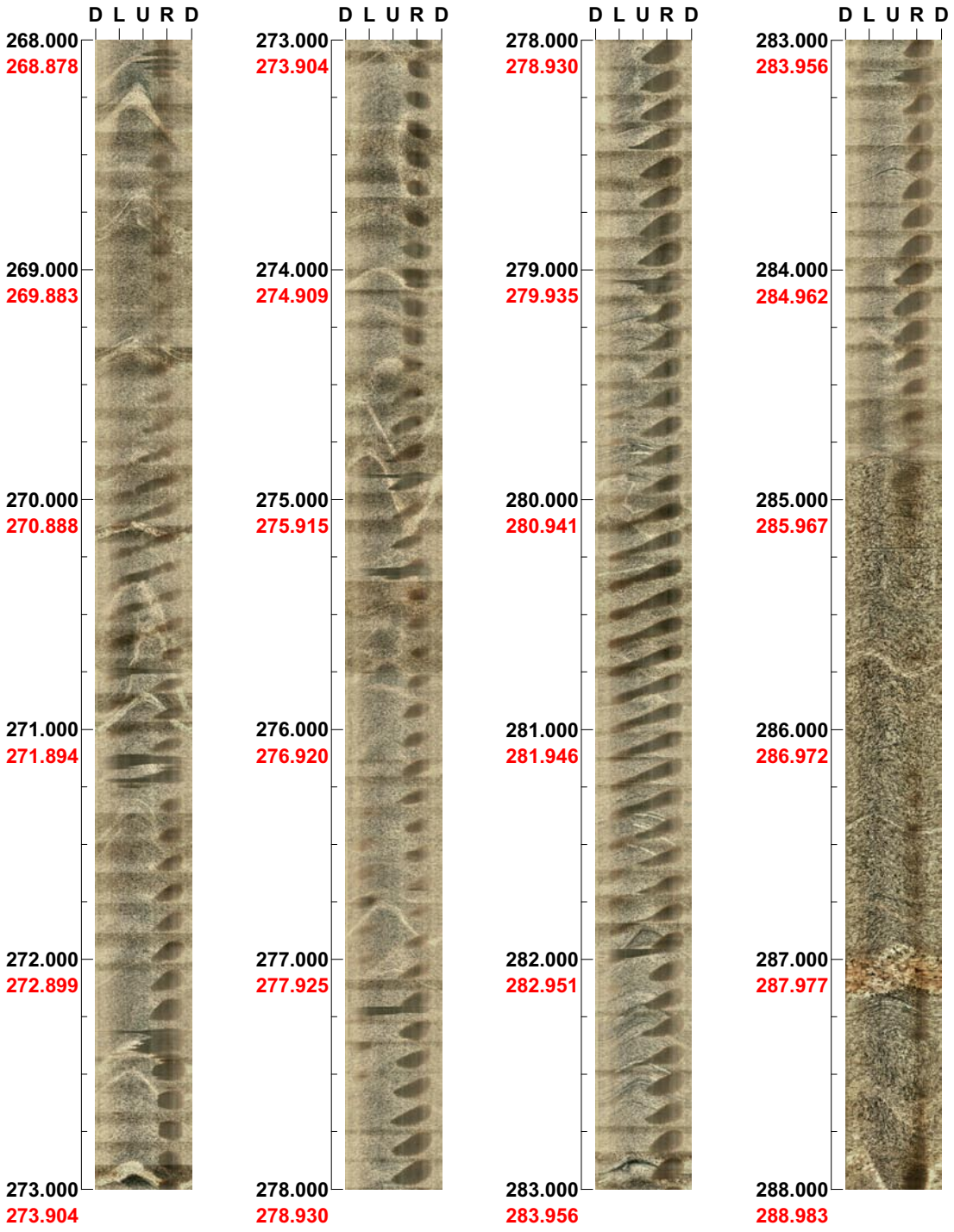
Depth range: 248.000 - 268.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

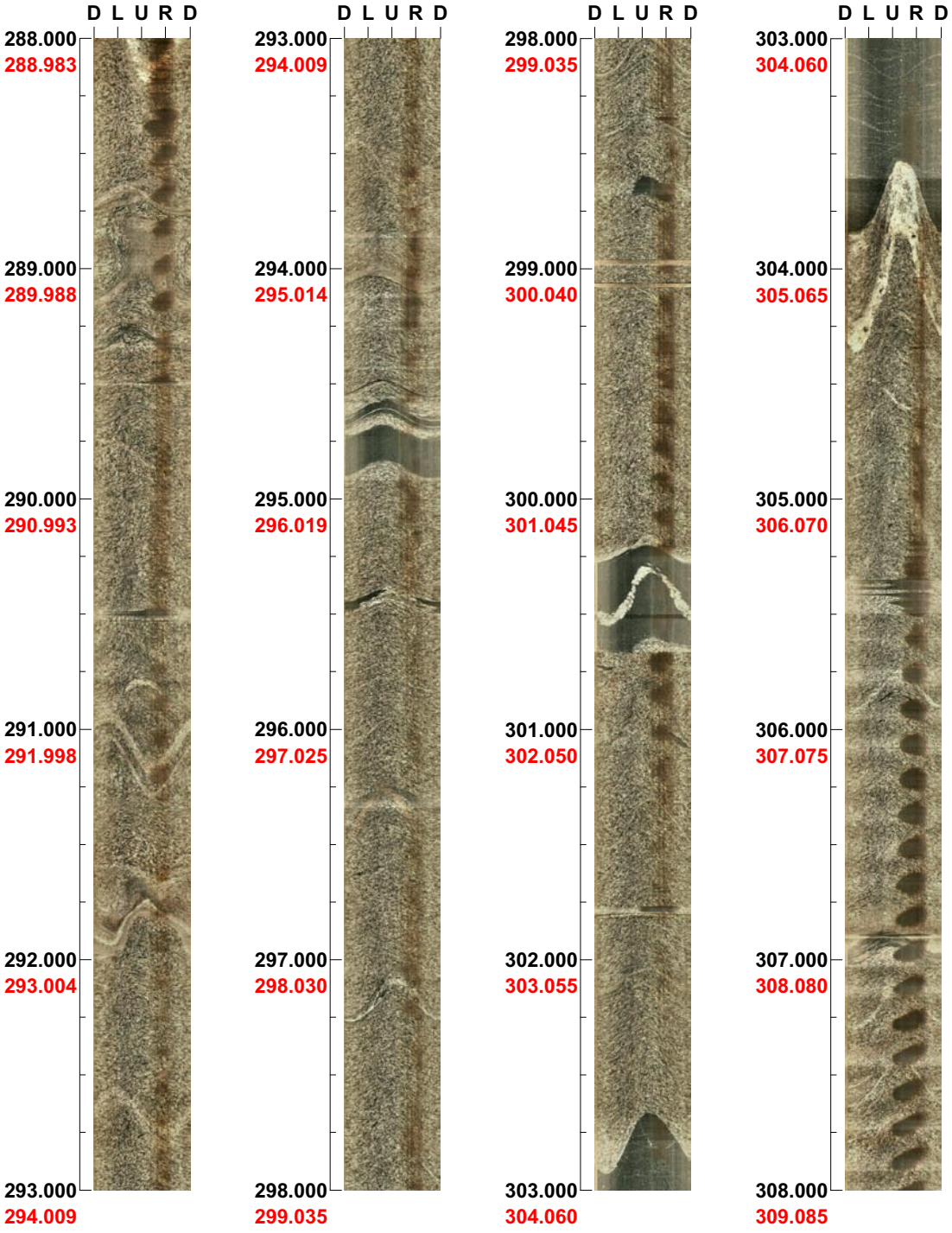
Depth range: 268.000 - 288.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 288.000 - 308.000 m



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

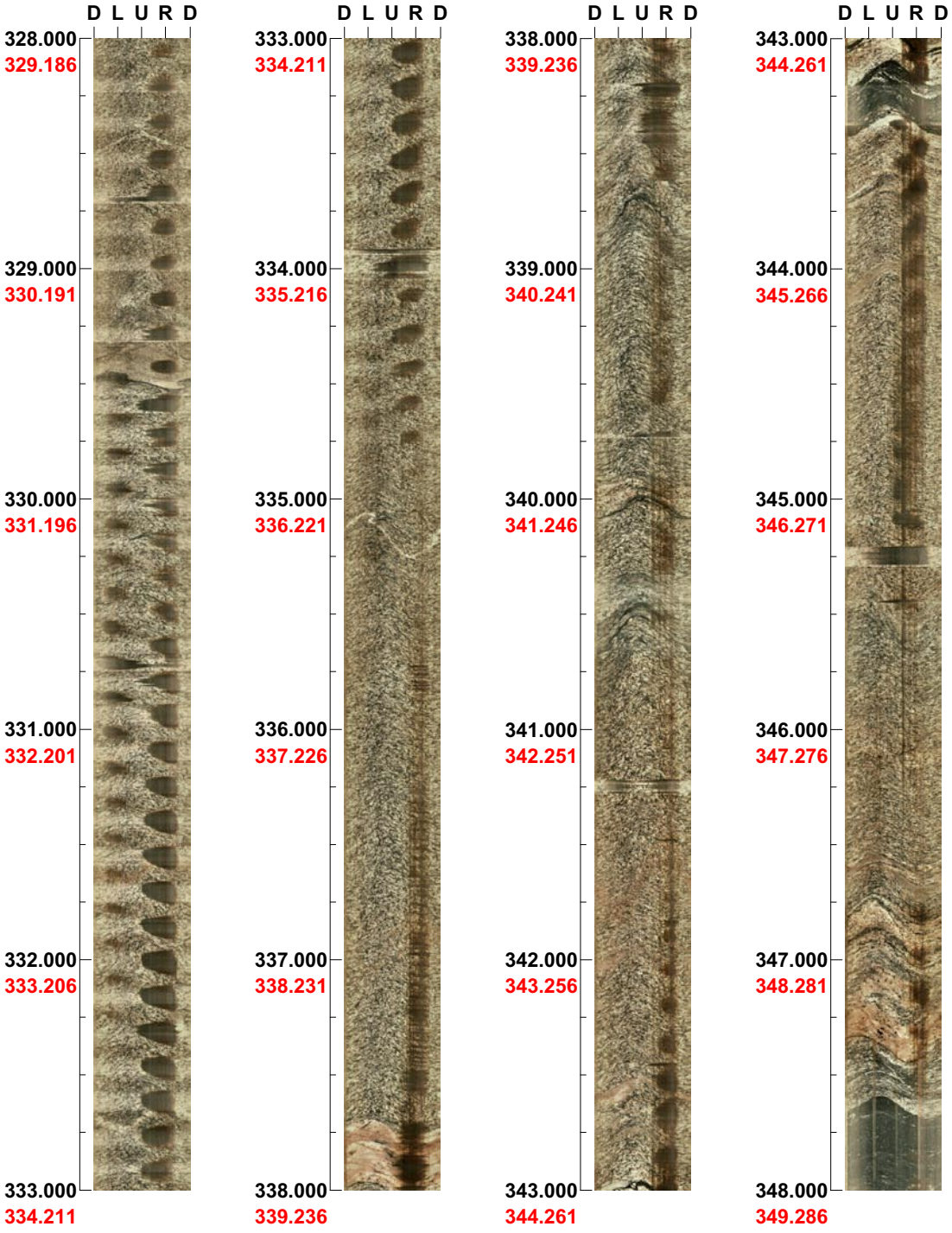
Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 308.000 - 328.000 m

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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 328.000 - 348.000 m



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

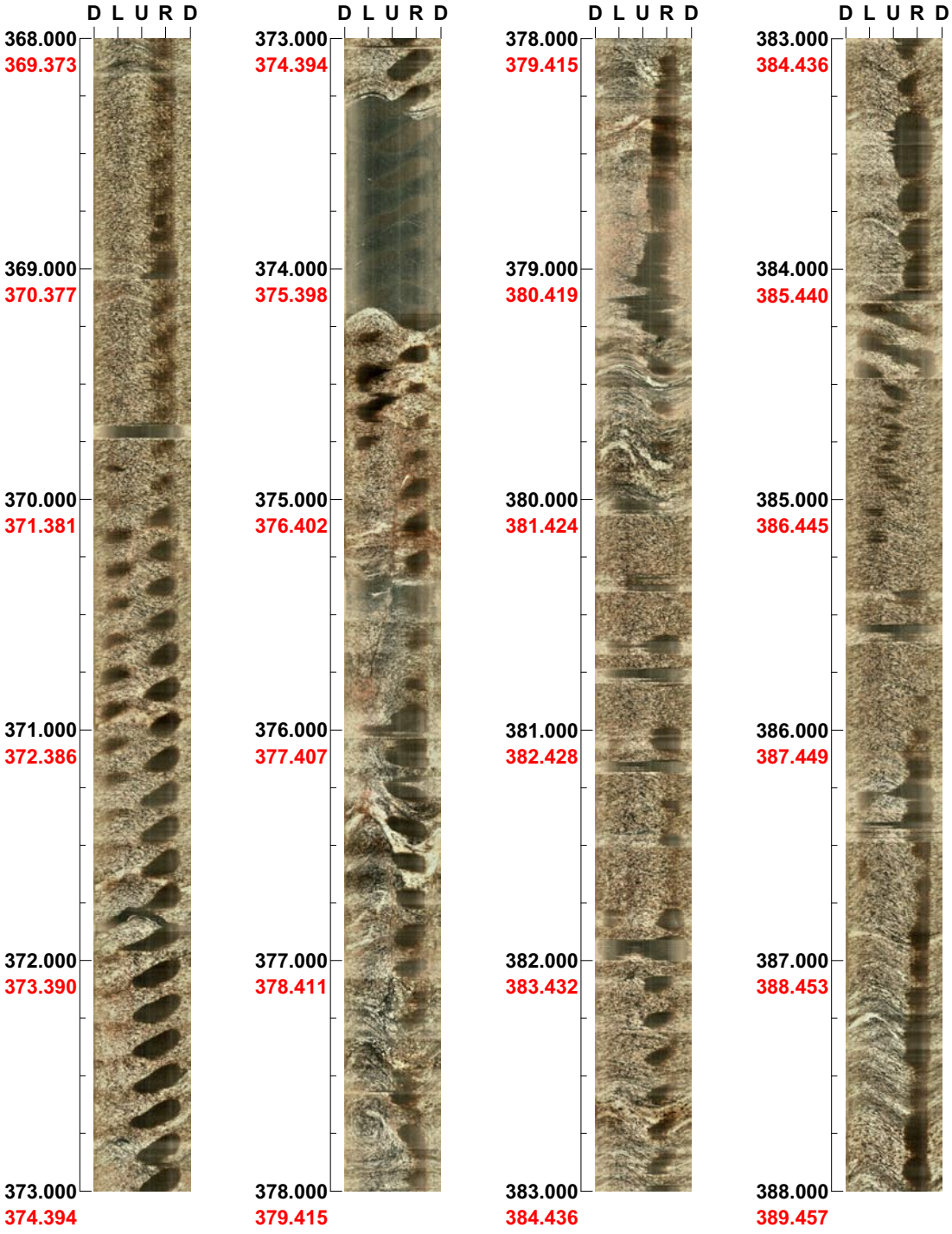
Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 348.000 - 368.000 m

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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

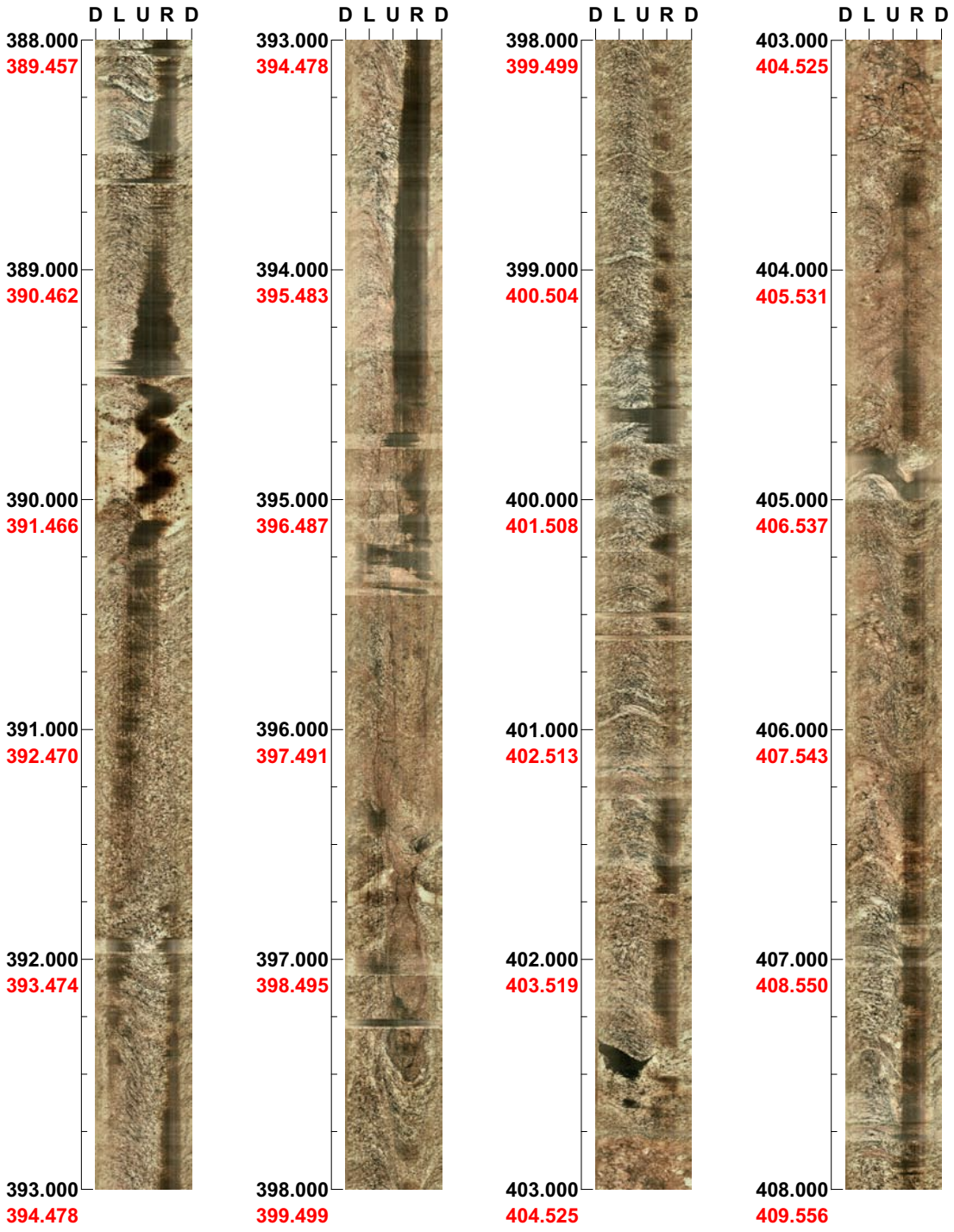
Depth range: 368.000 - 388.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

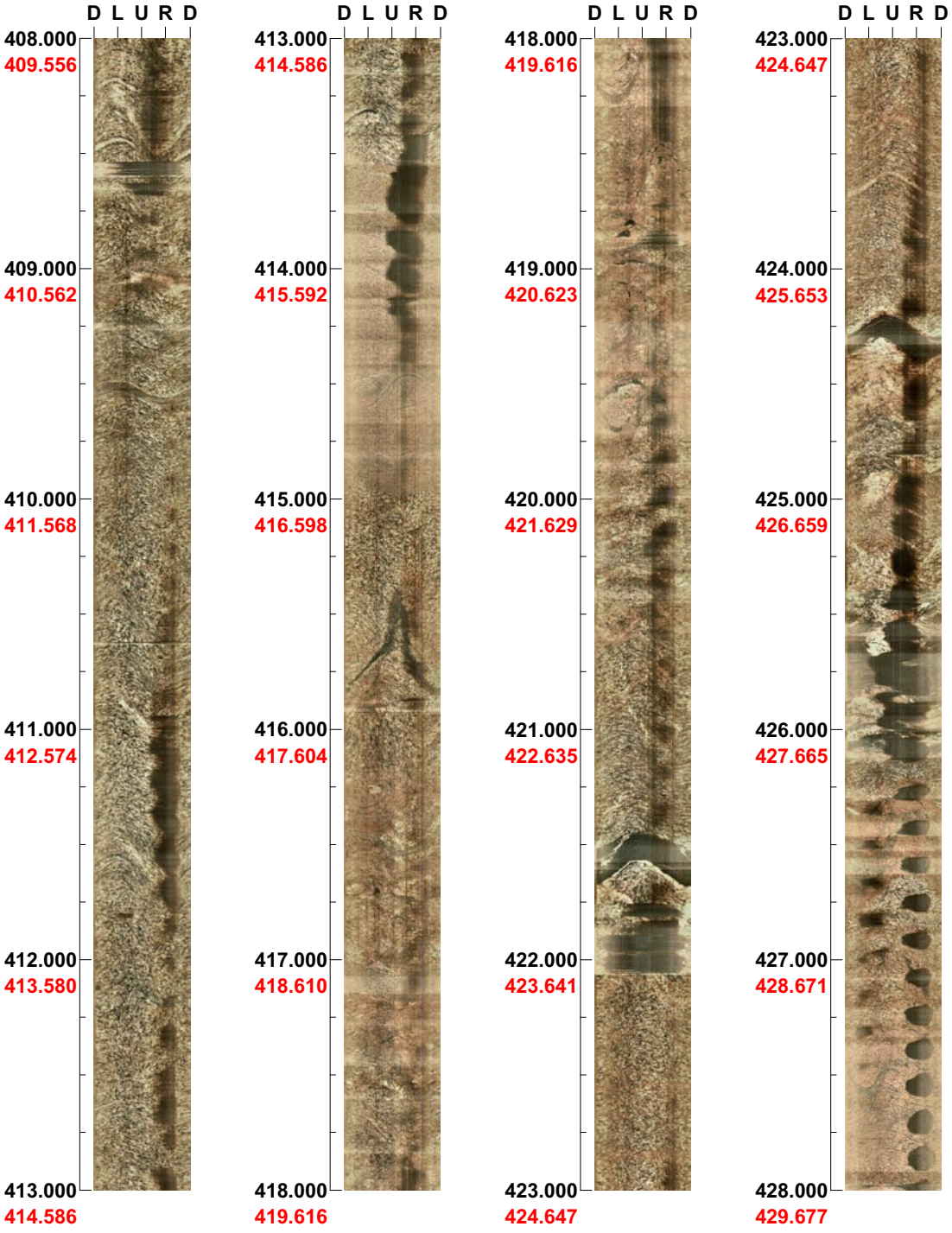
Depth range: 388.000 - 408.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 408.000 - 428.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 428.000 - 448.000 m

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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 448.000 - 468.000 m

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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 468.000 - 488.000 m

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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 488.000 - 508.000 m

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

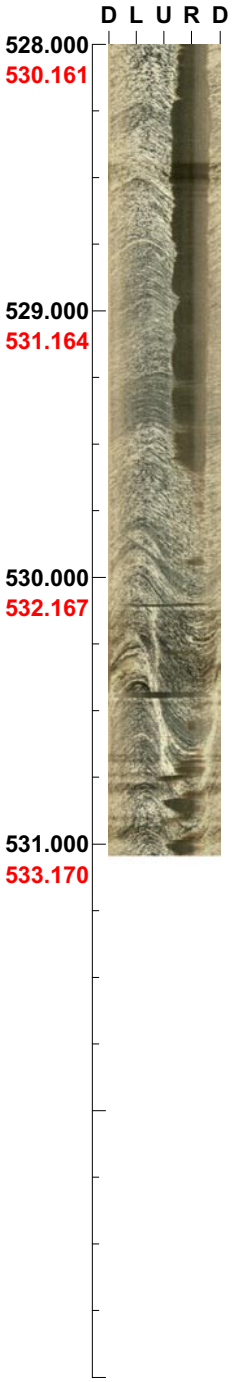
Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 508.000 - 528.000 m

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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 528.000 - 531.039 m



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

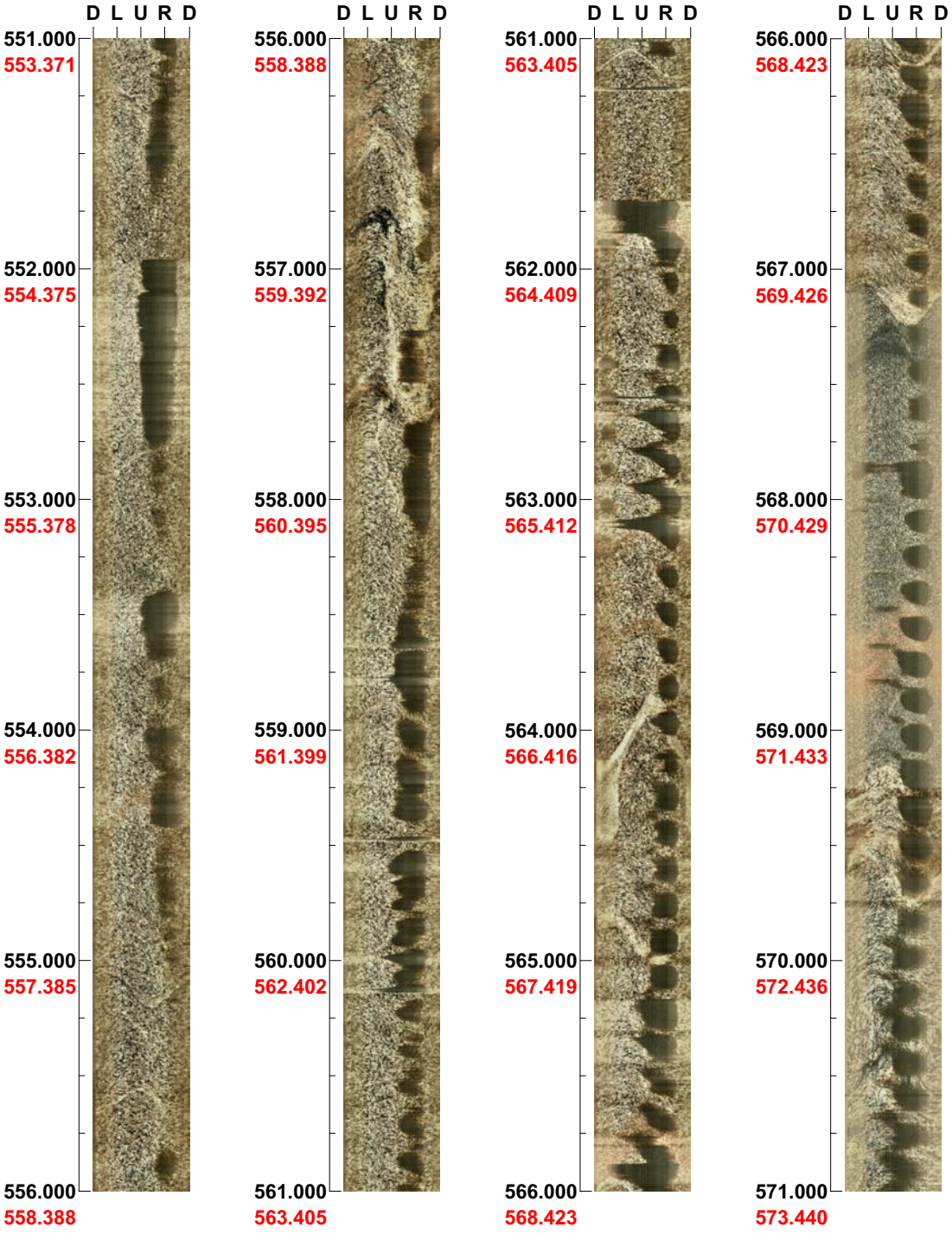
Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 531.000 - 551.000 m

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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 551.000 - 571.000 m



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

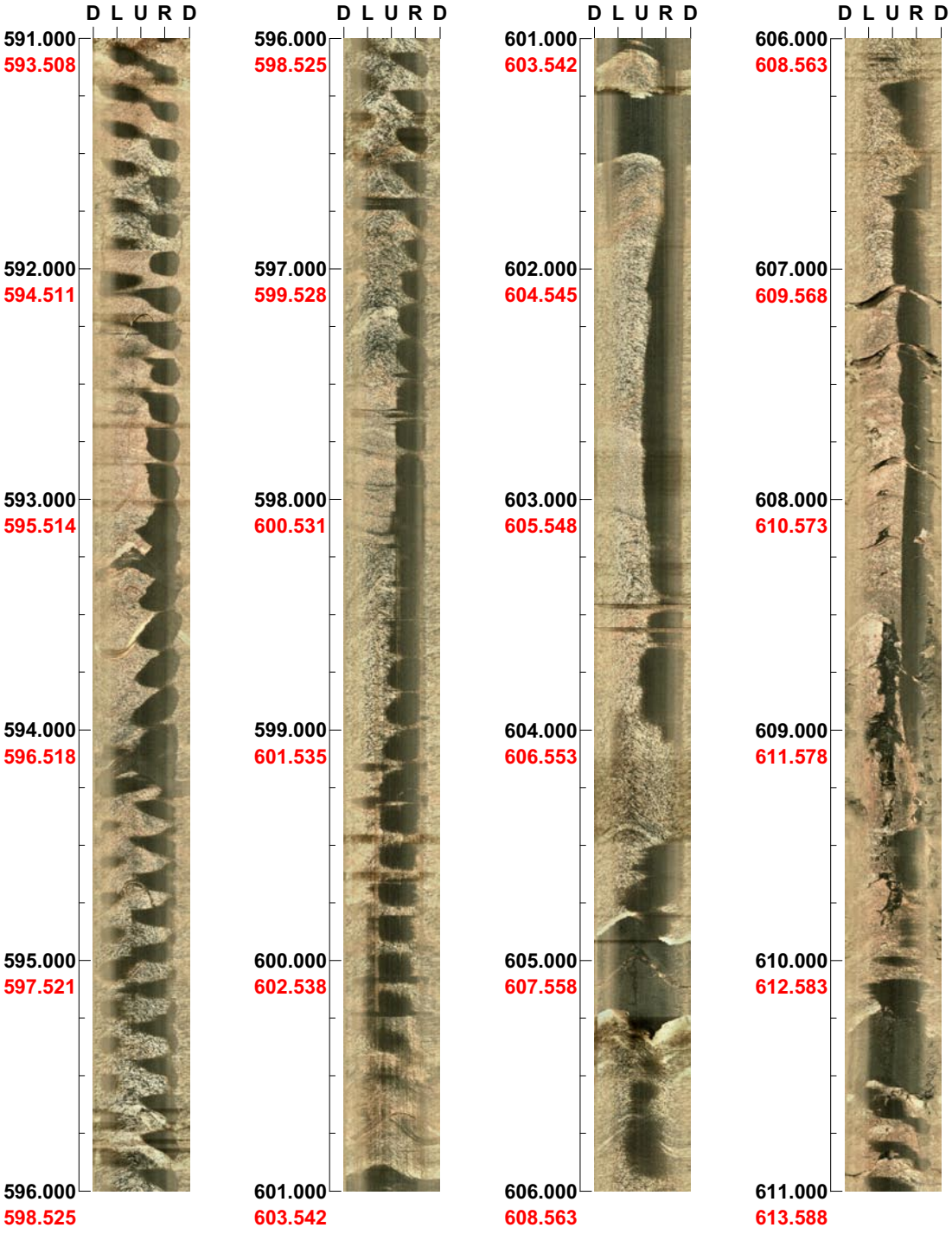
Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 571.000 - 591.000 m

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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

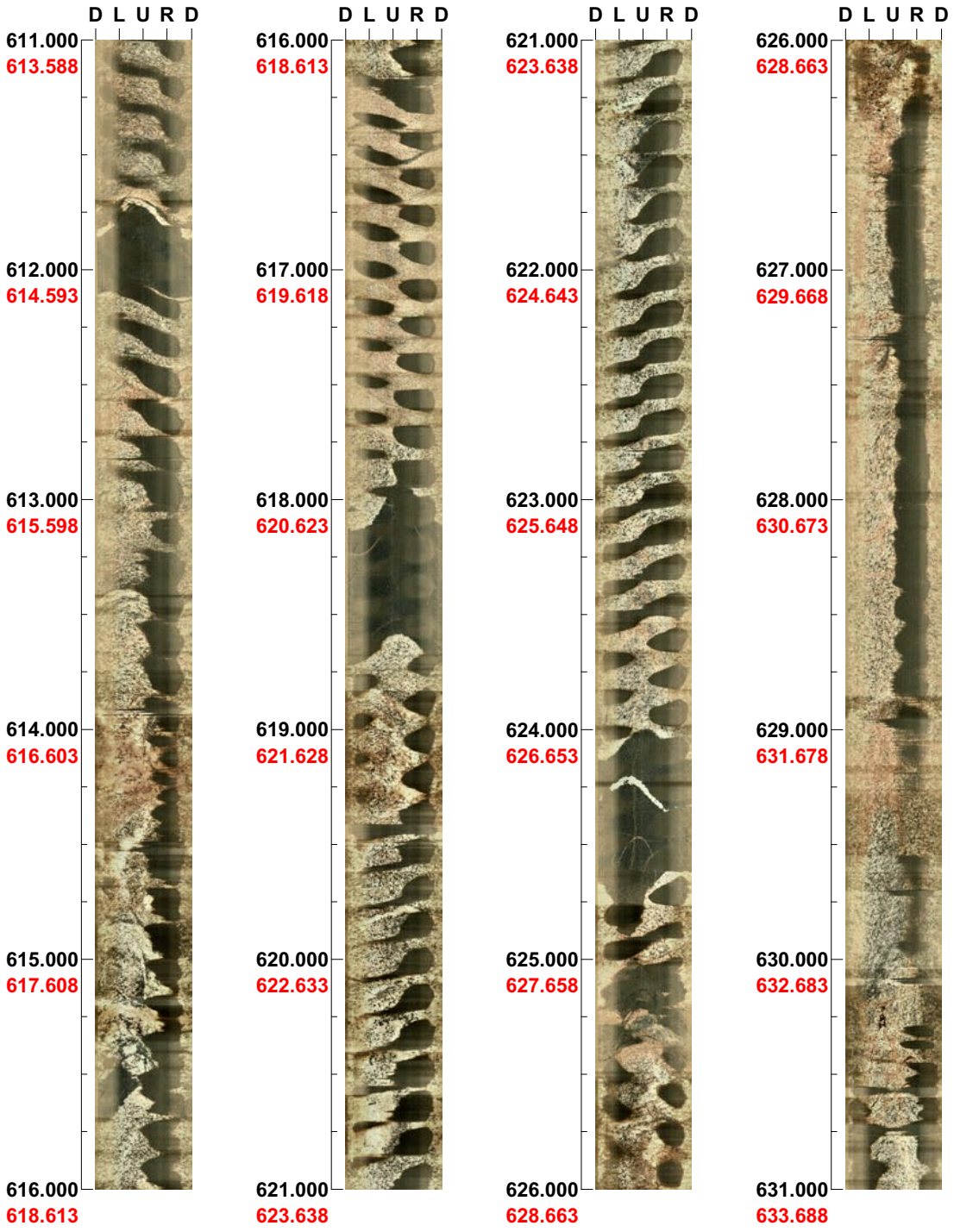
Depth range: 591.000 - 611.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

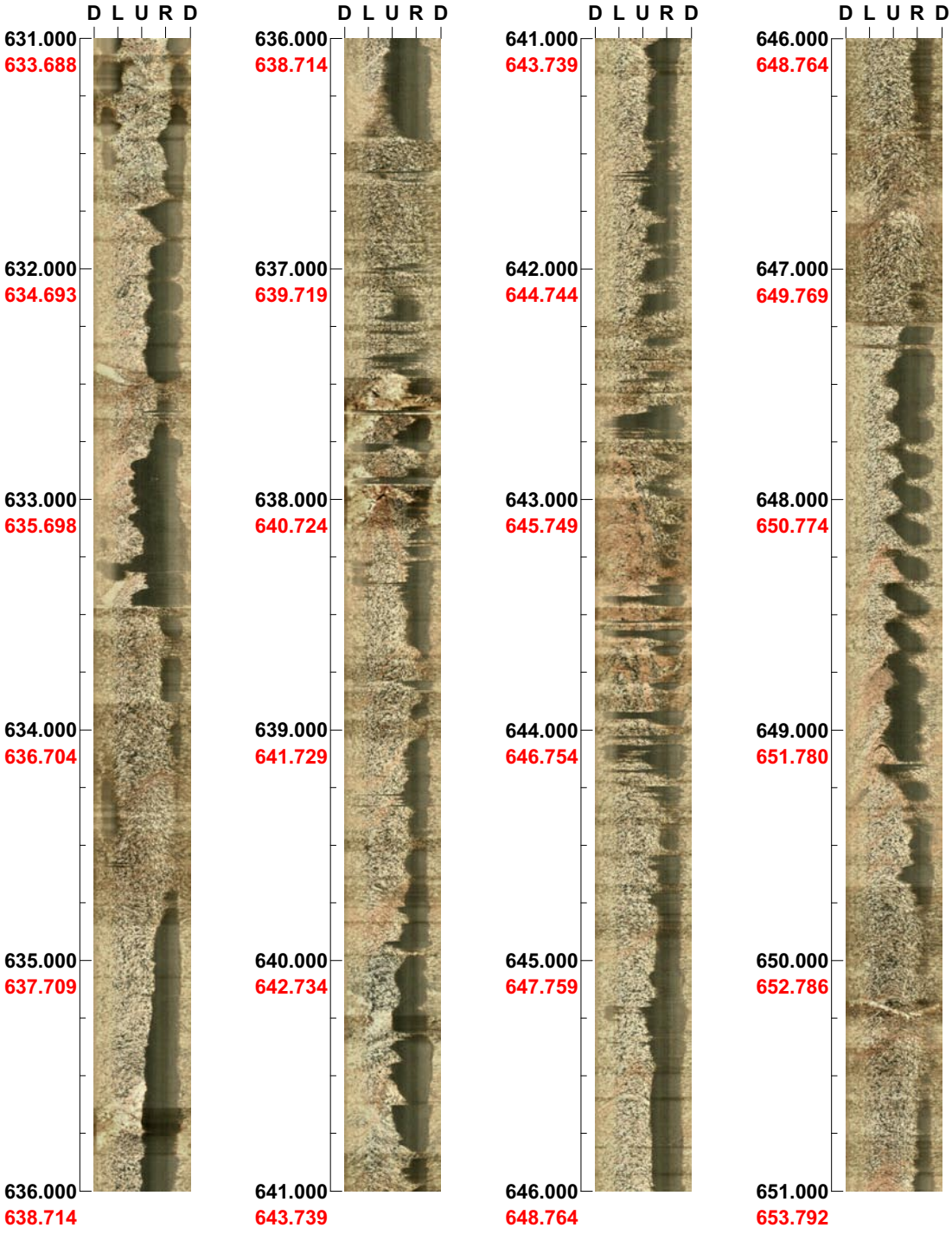
Depth range: 611.000 - 631.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

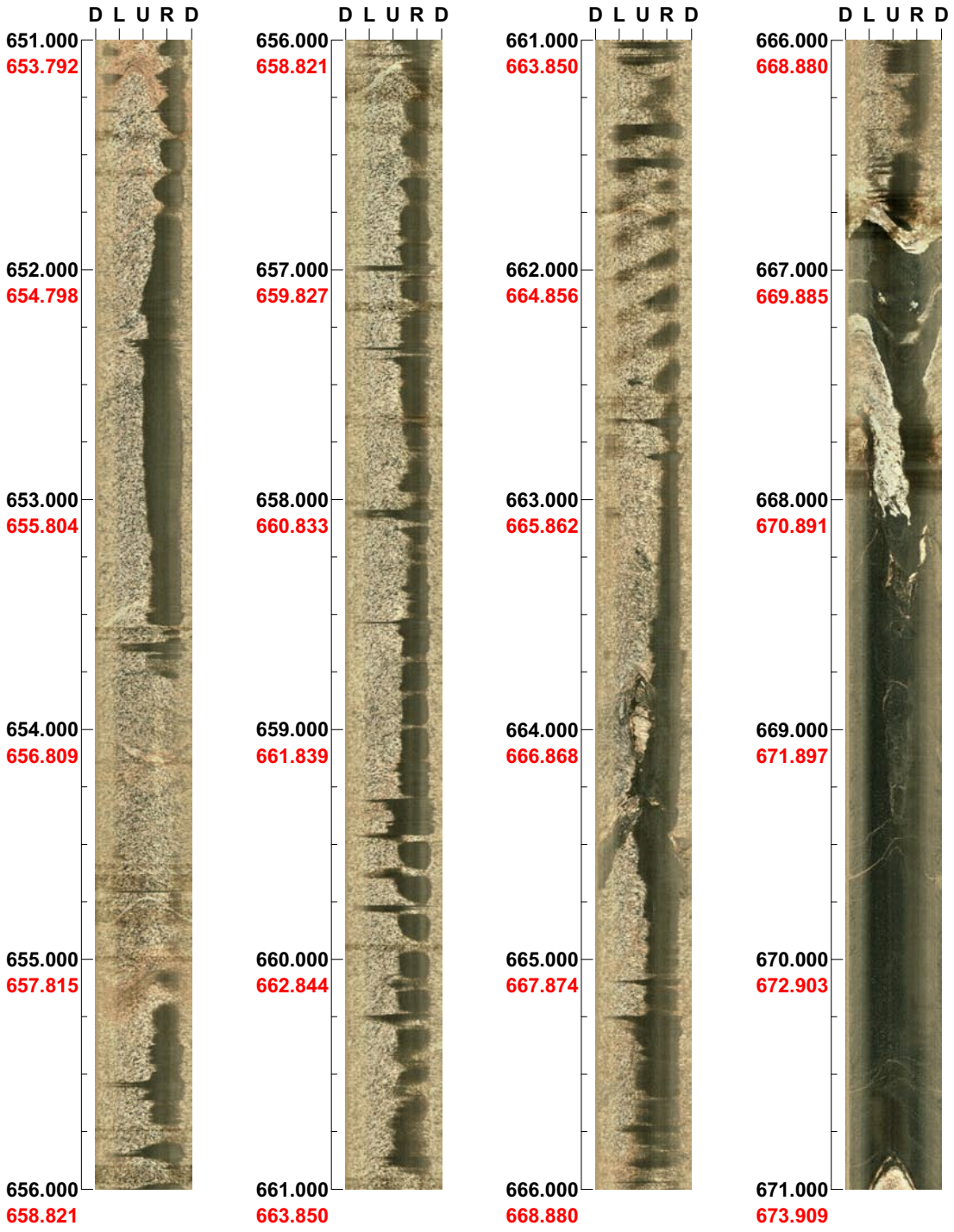
Depth range: 631.000 - 651.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

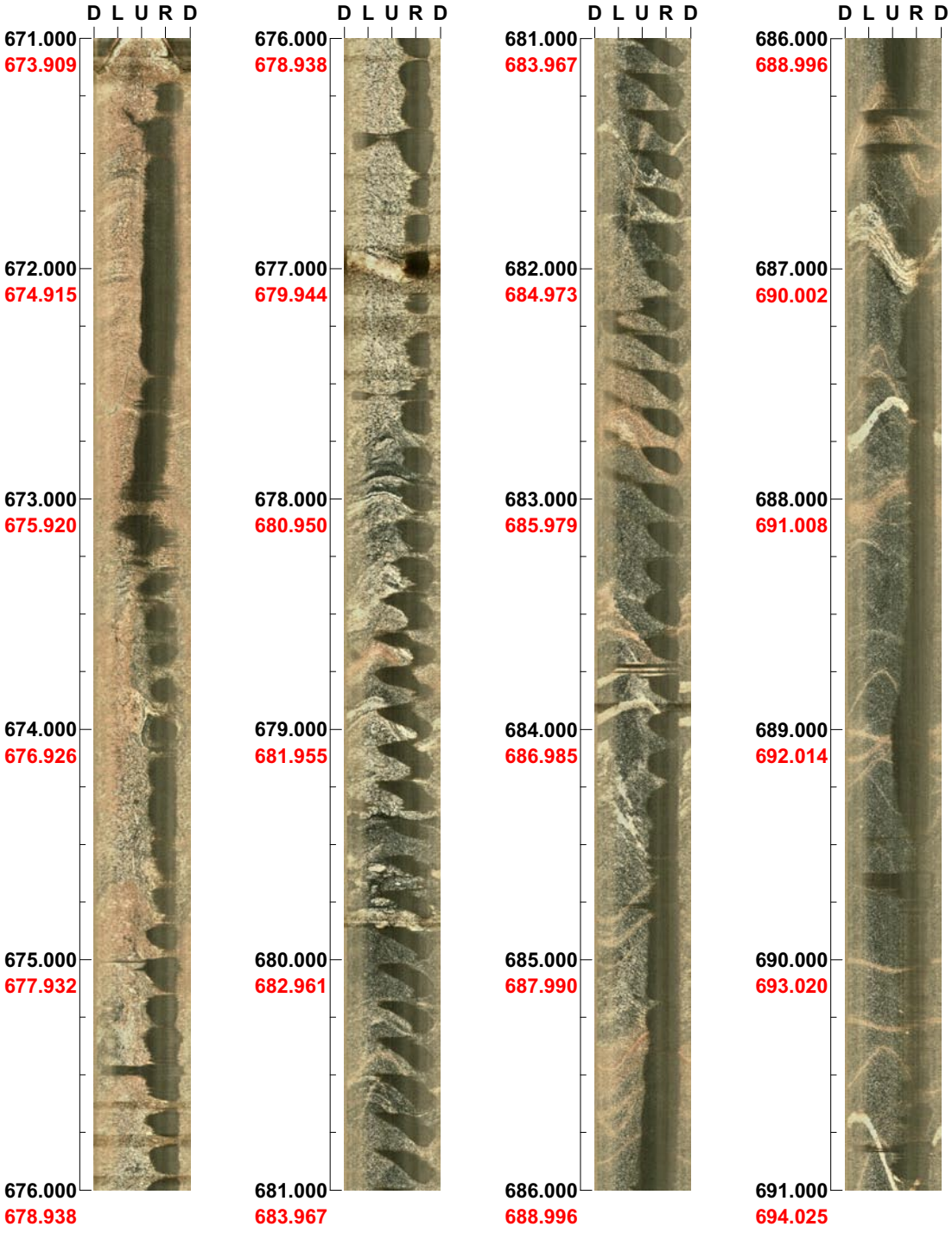
Depth range: 651.000 - 671.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

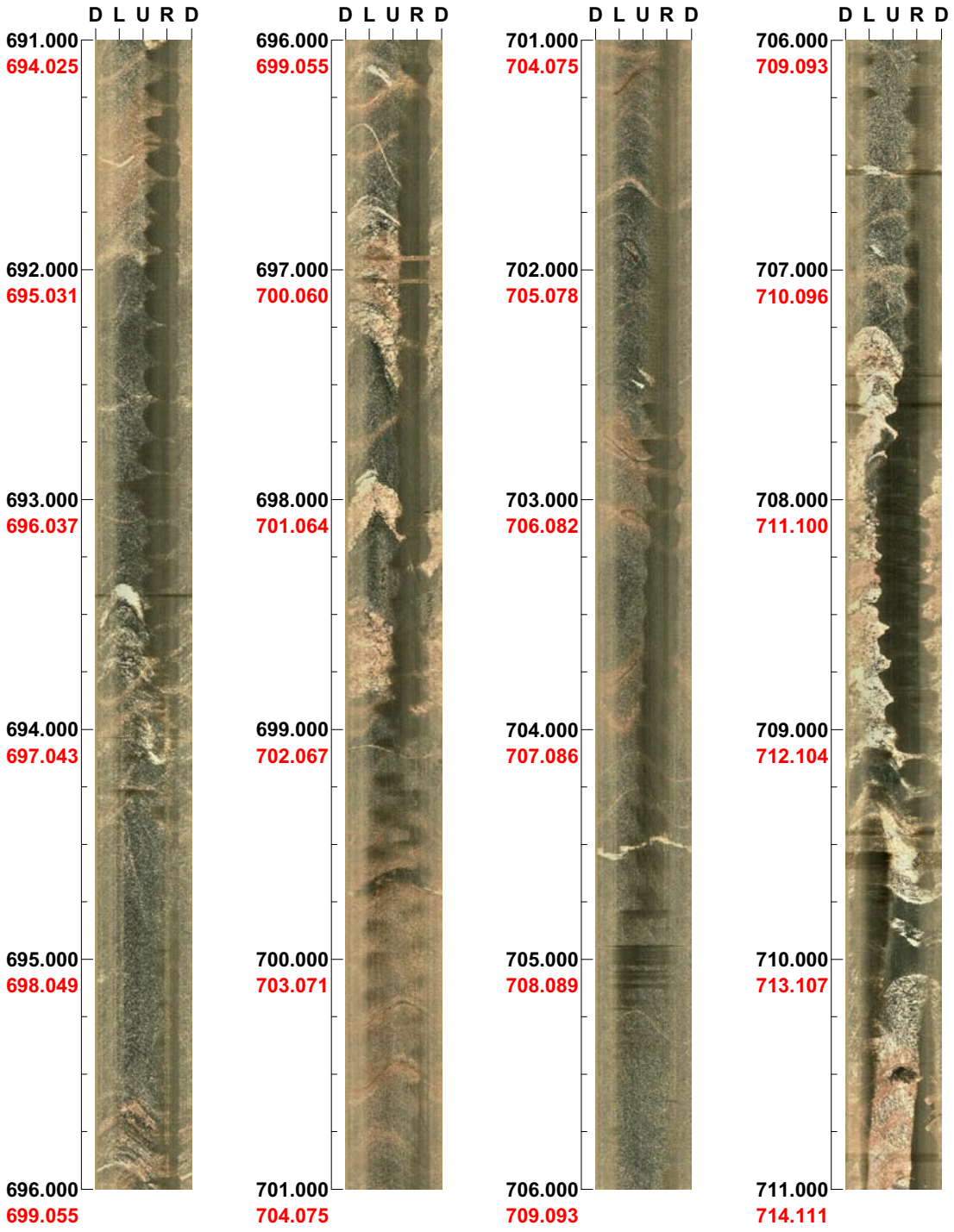
Depth range: 671.000 - 691.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

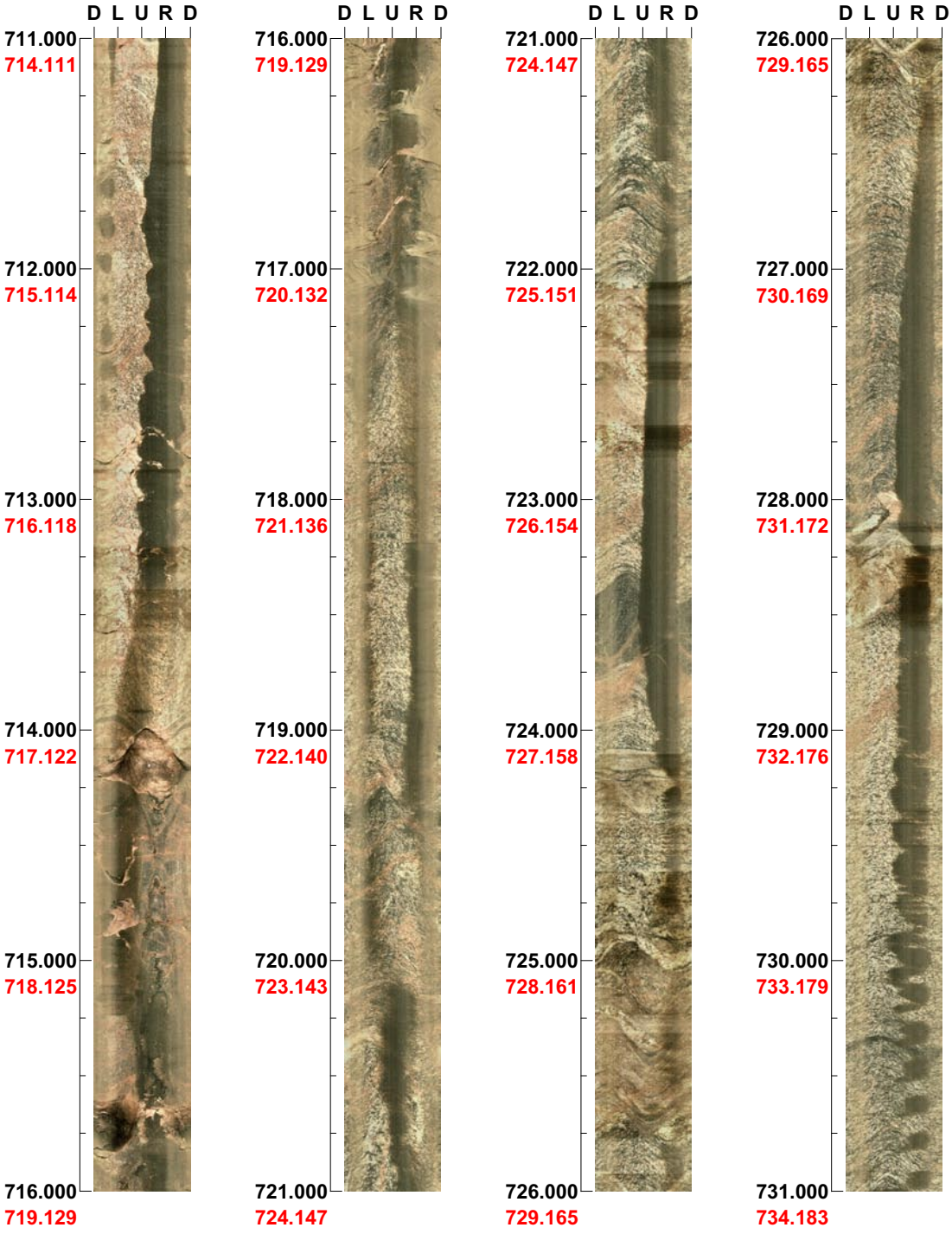
Depth range: 691.000 - 711.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

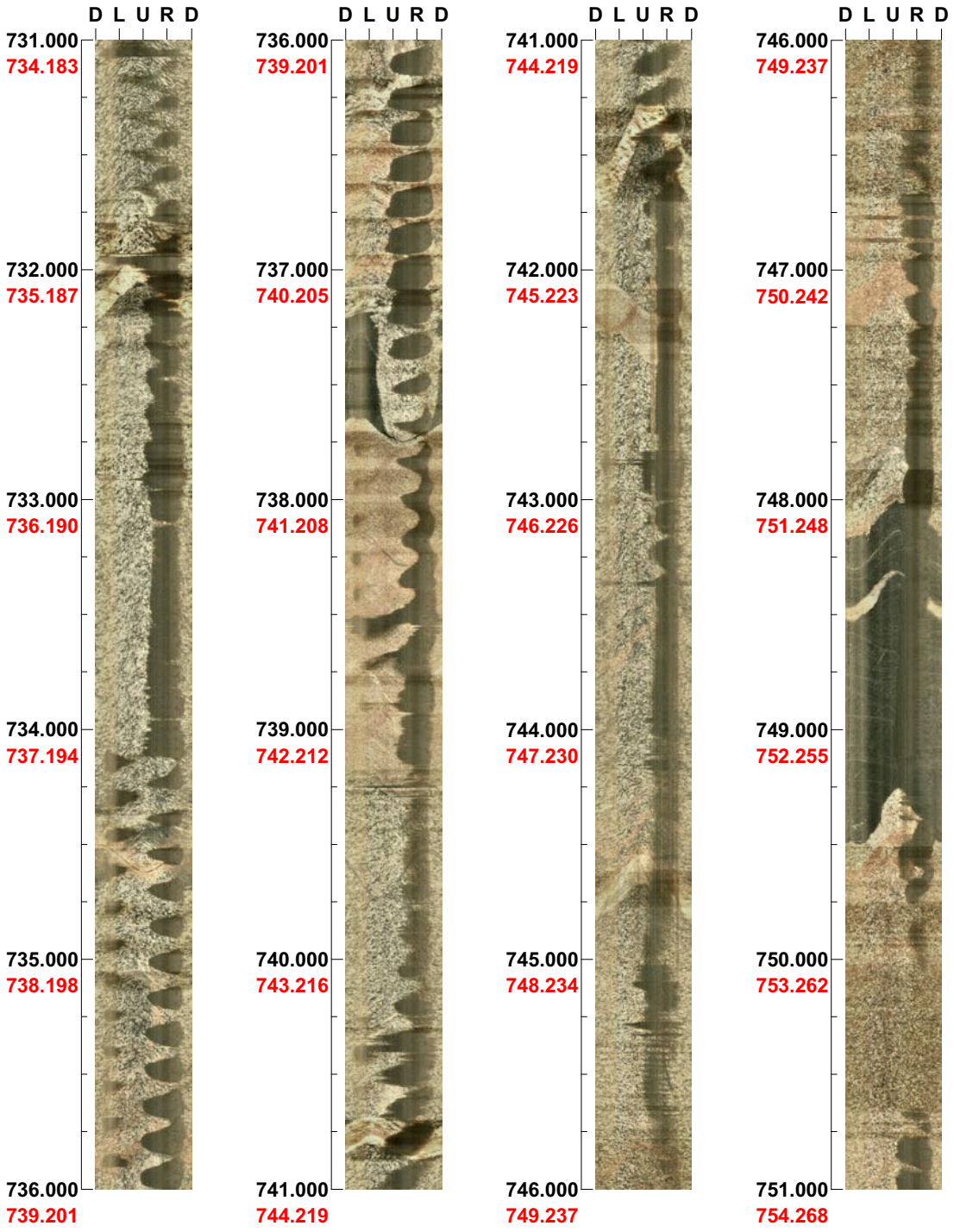
Depth range: 711.000 - 731.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

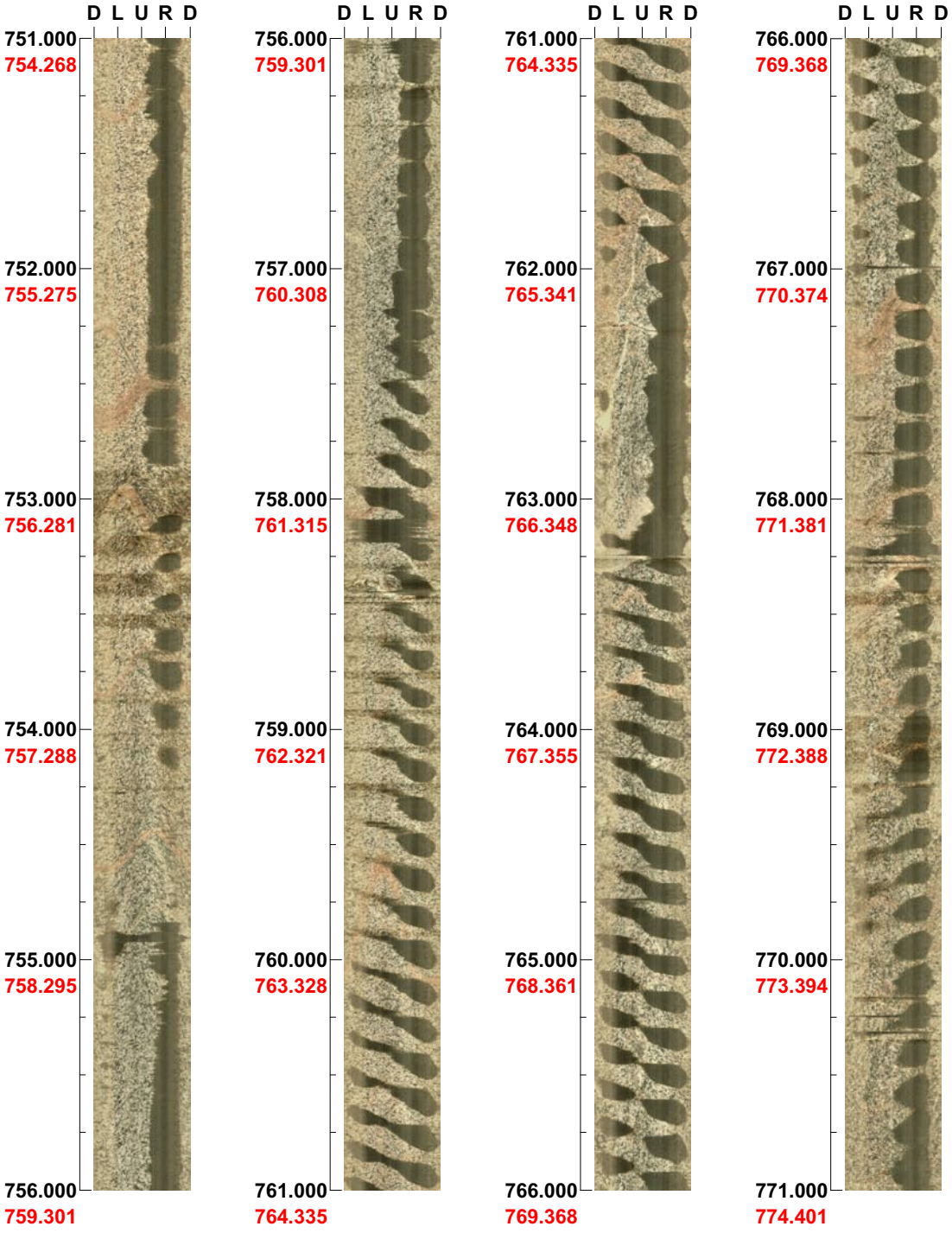
Depth range: 731.000 - 751.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 751.000 - 771.000 m



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

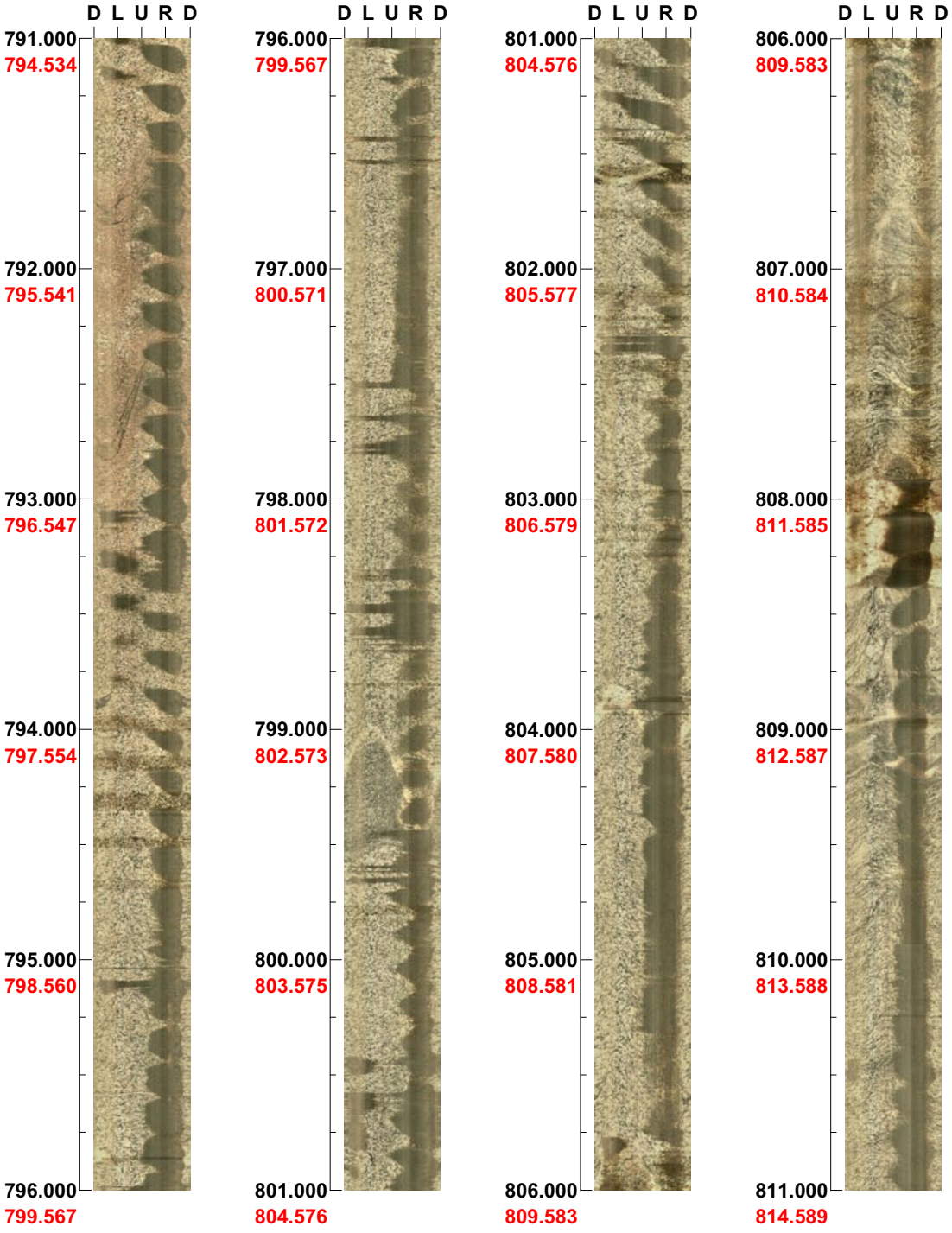
Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 771.000 - 791.000 m

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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 791.000 - 811.000 m



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

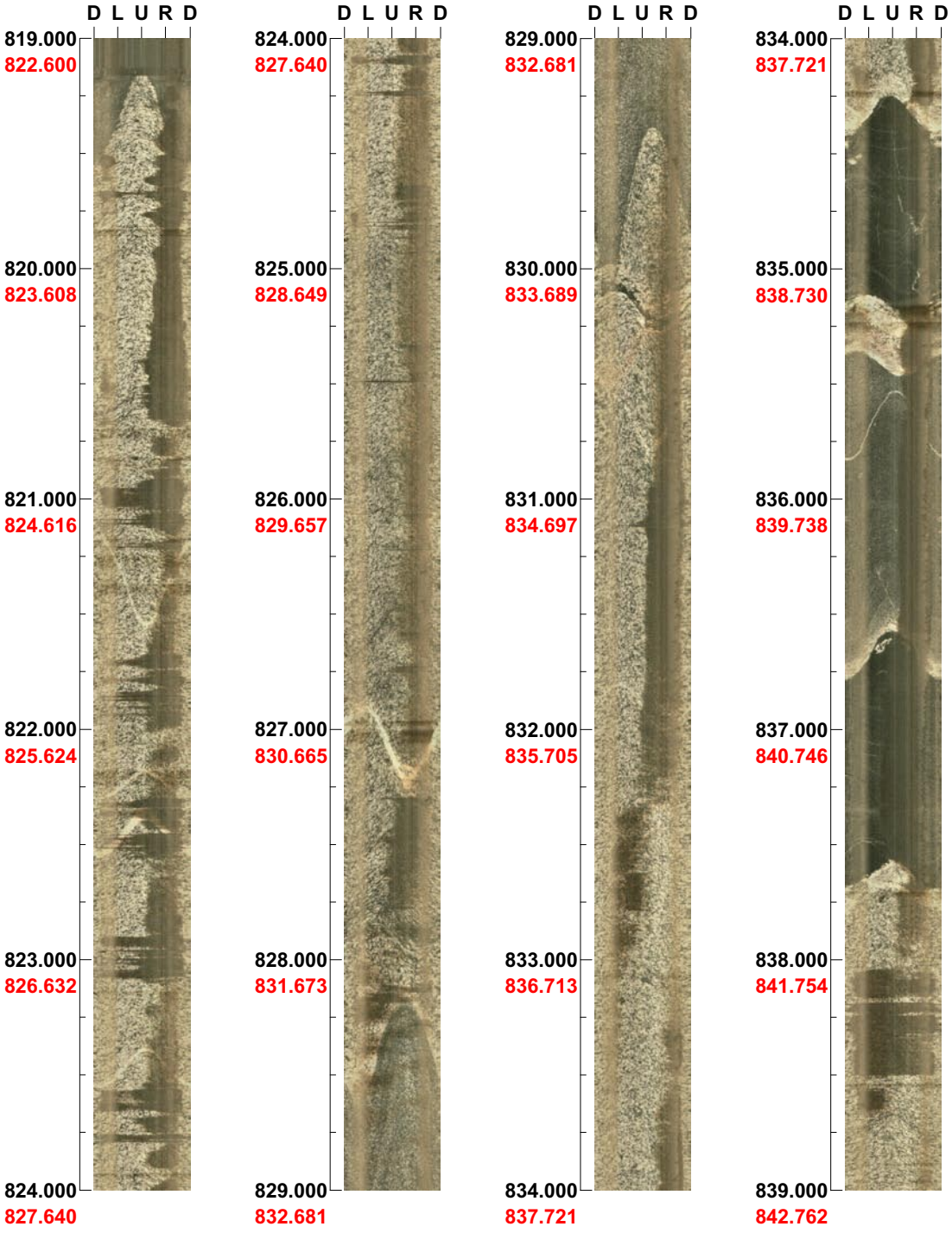
Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 811.000 - 819.345 m

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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

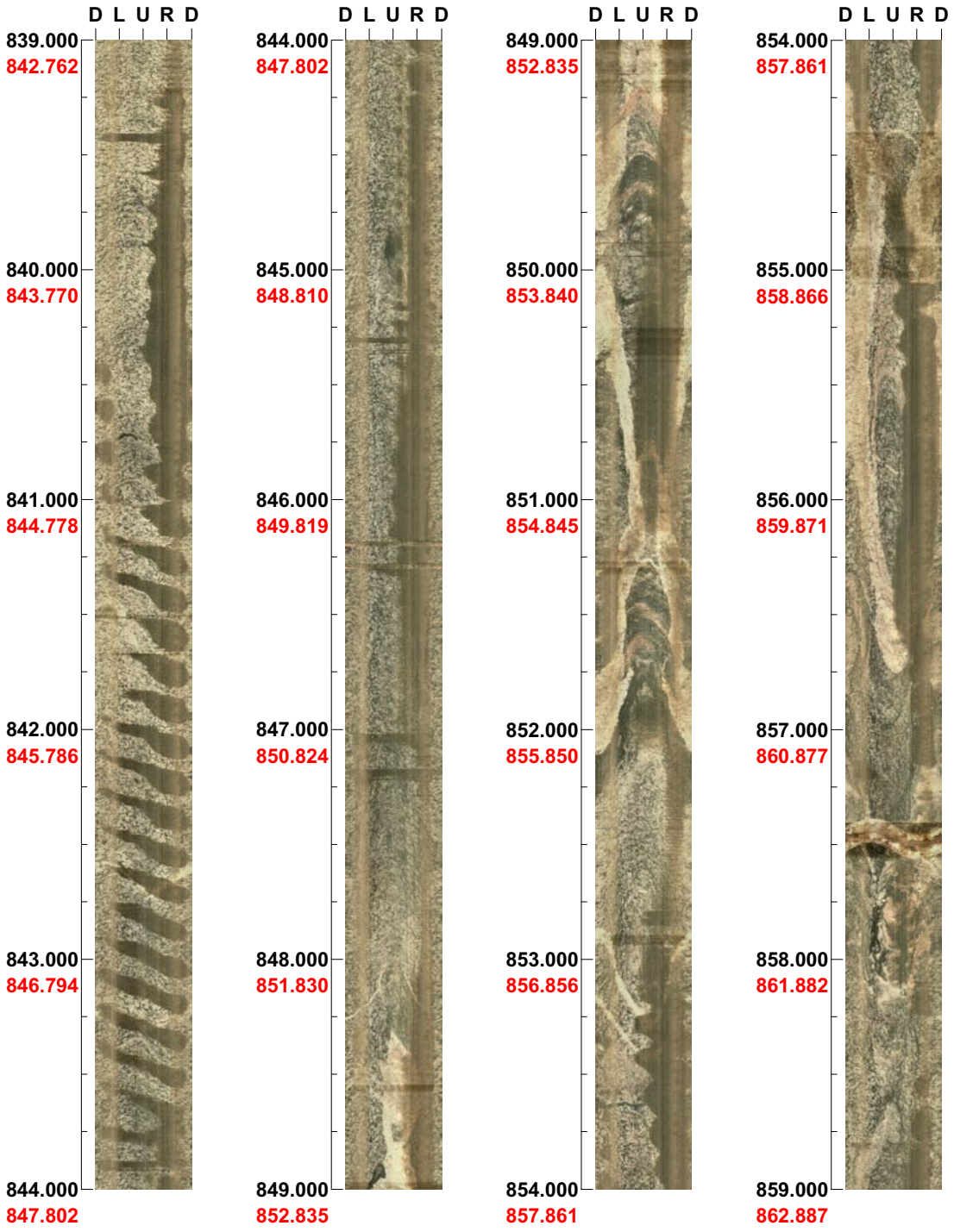
Depth range: 819.000 - 839.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

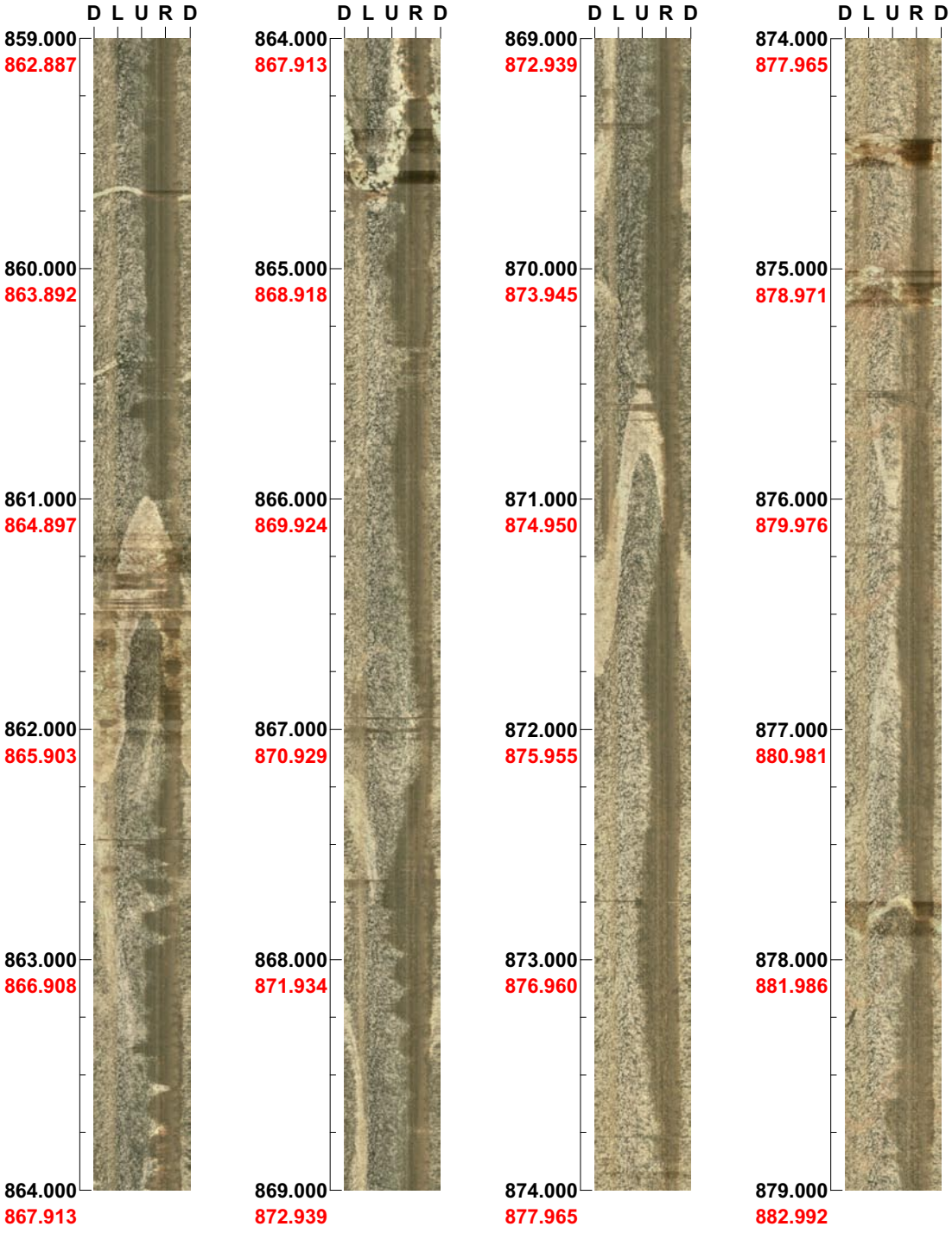
Depth range: 839.000 - 859.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

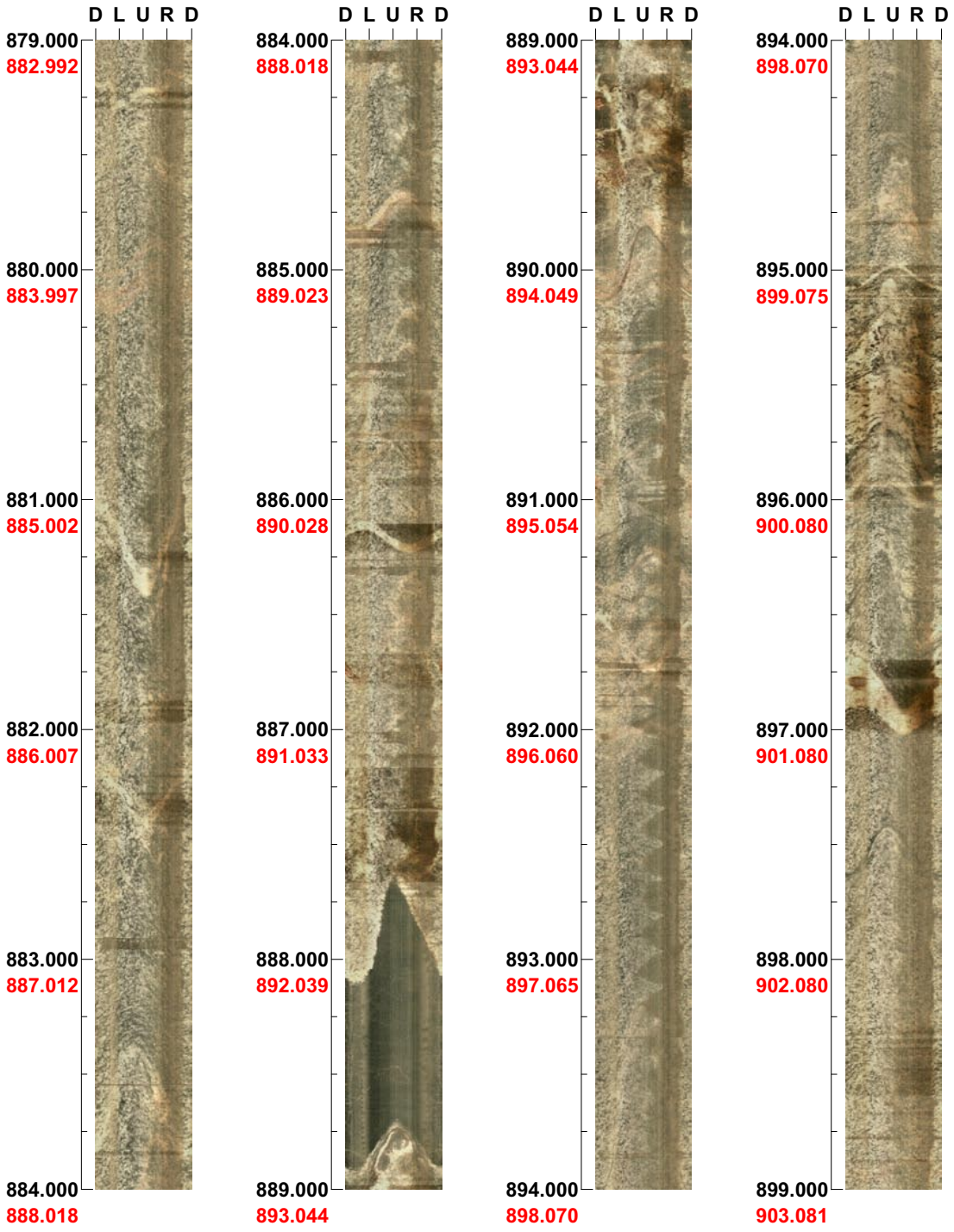
Depth range: 859.000 - 879.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

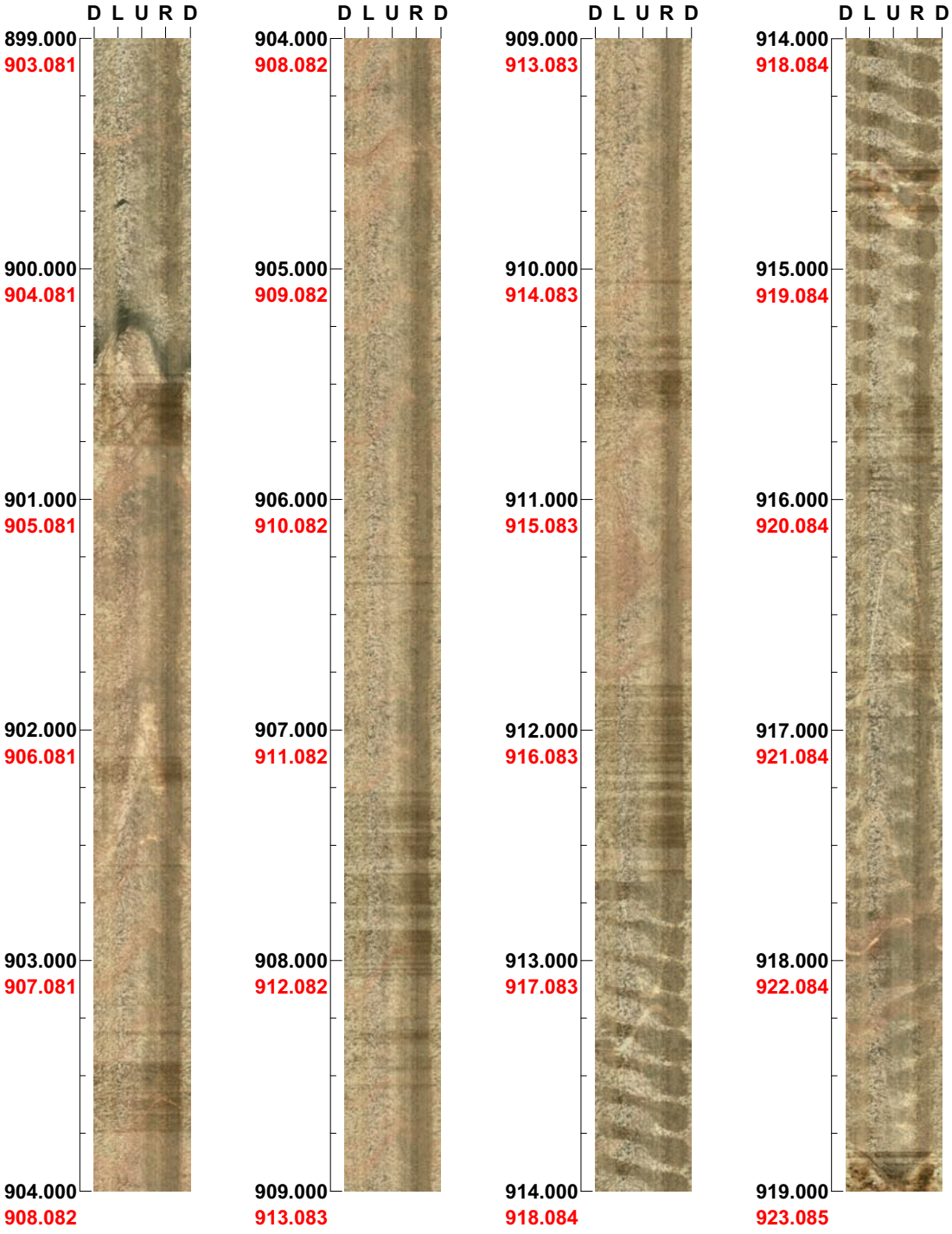
Depth range: 879.000 - 899.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

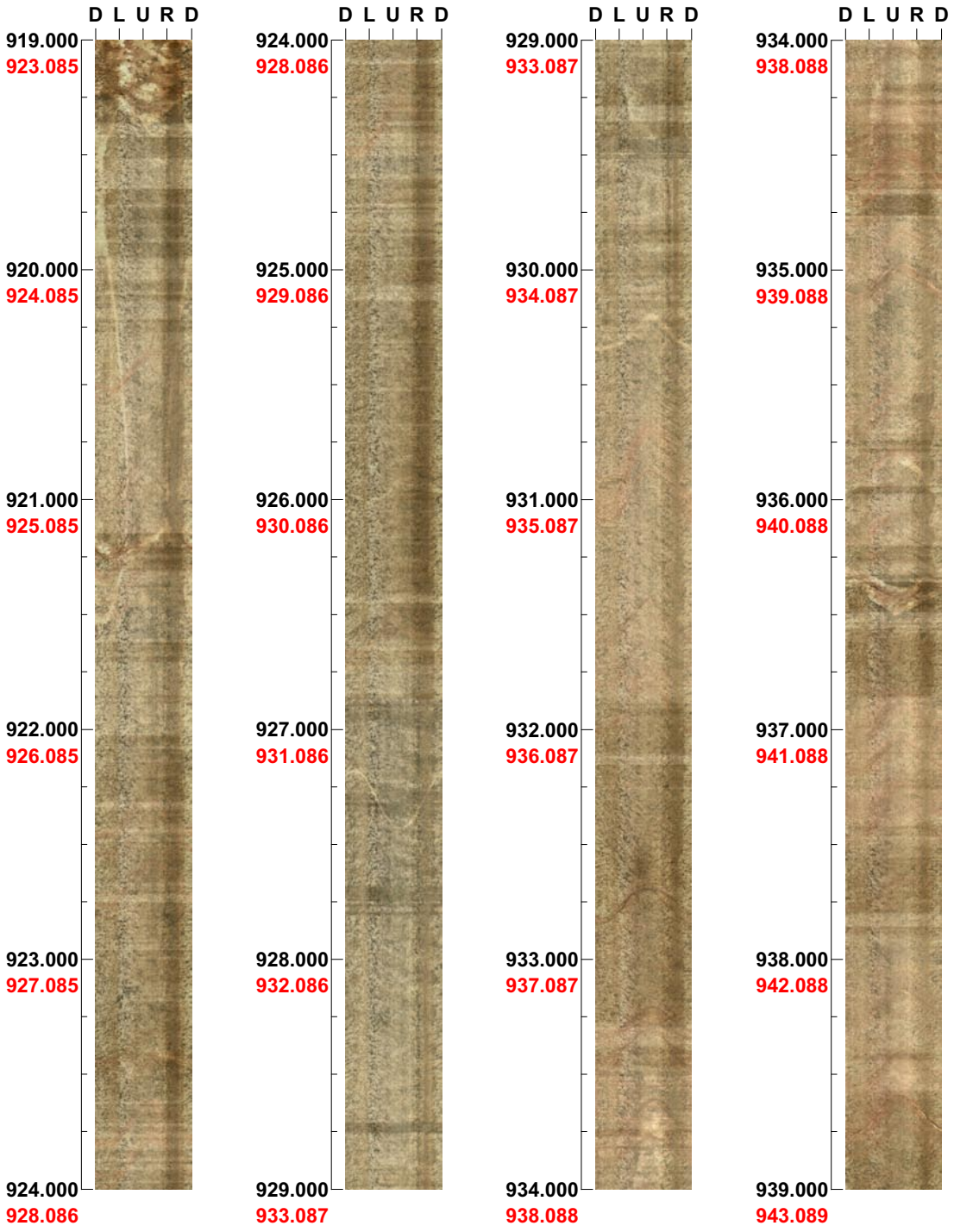
Depth range: 899.000 - 919.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

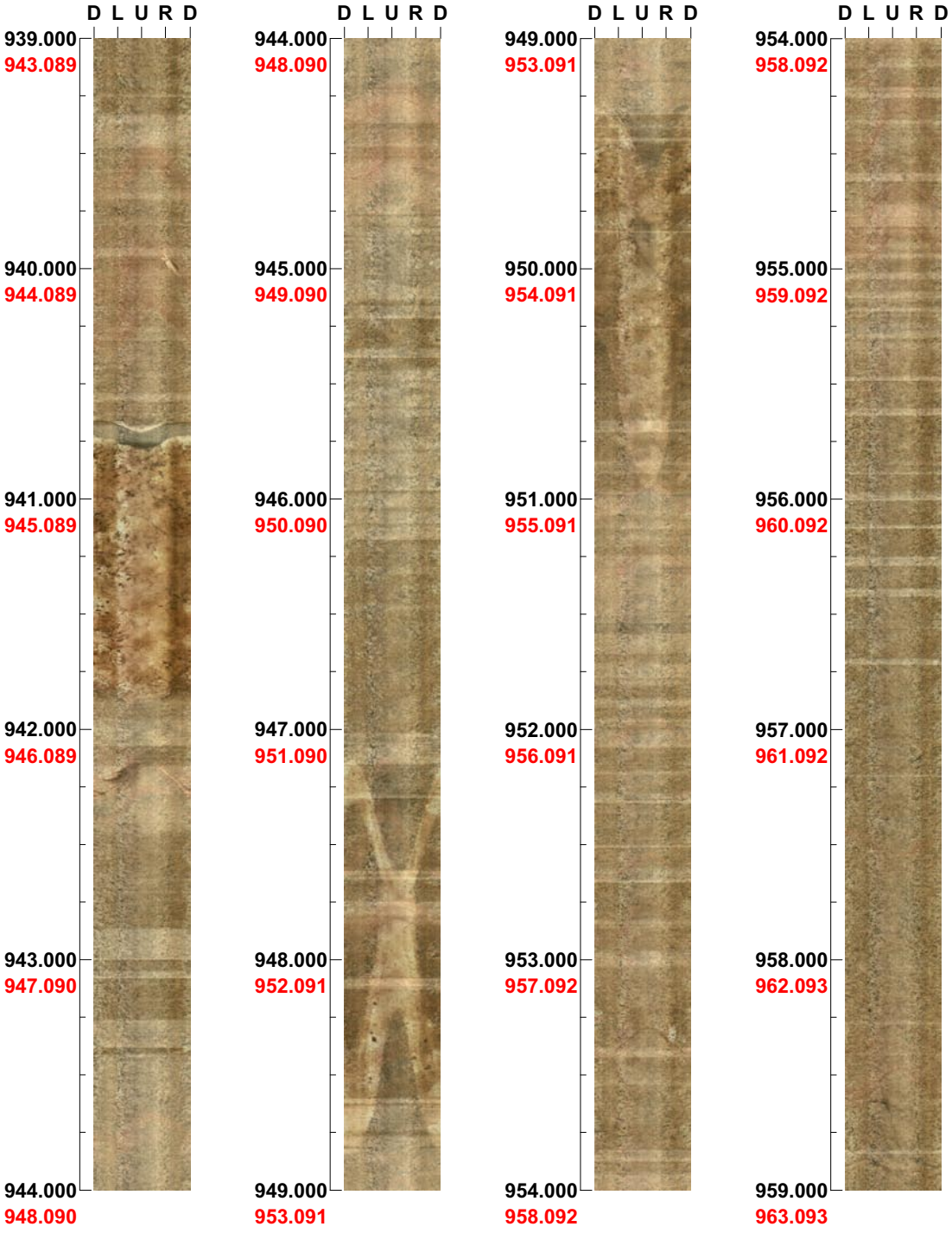
Depth range: 919.000 - 939.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

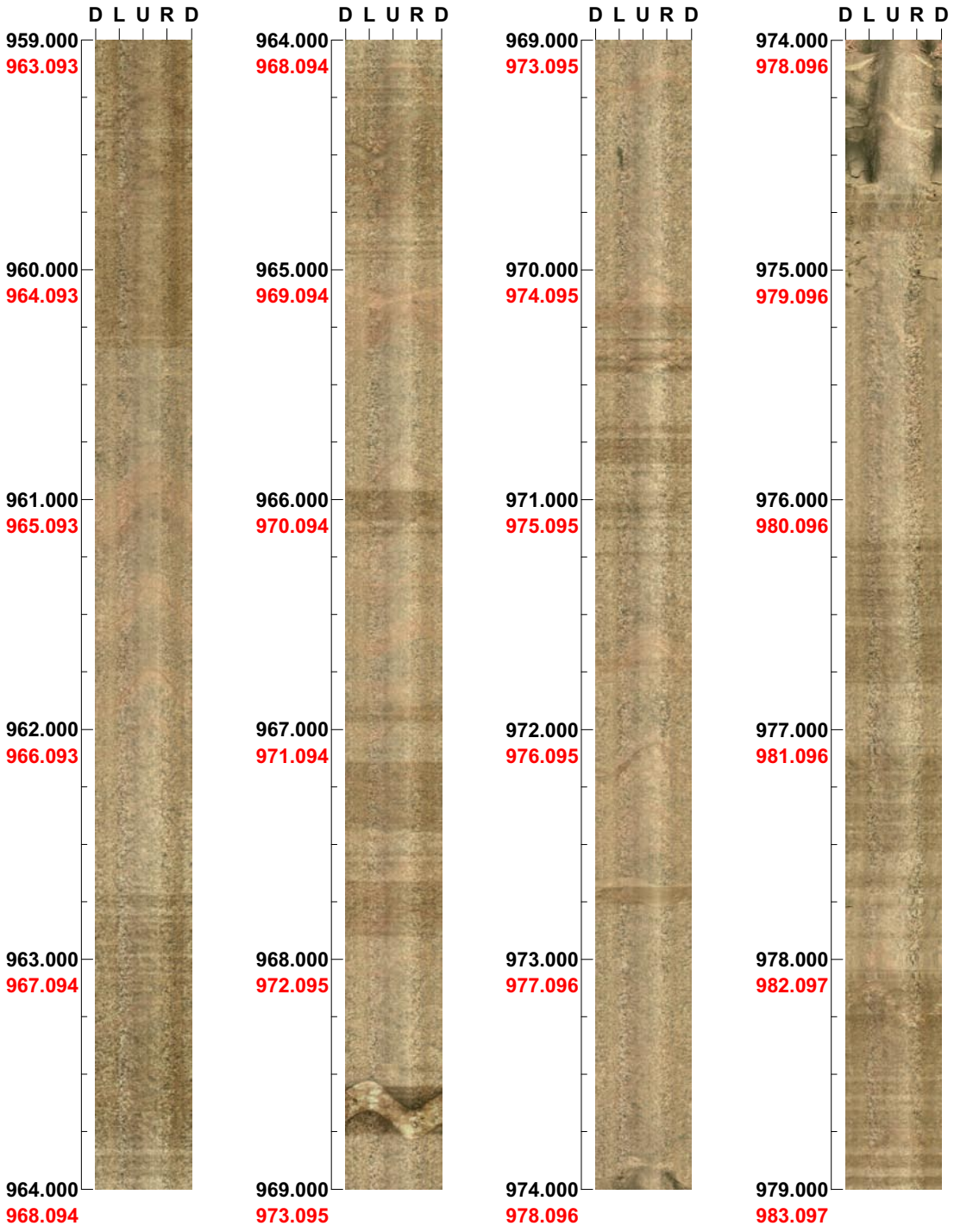
Depth range: 939.000 - 959.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

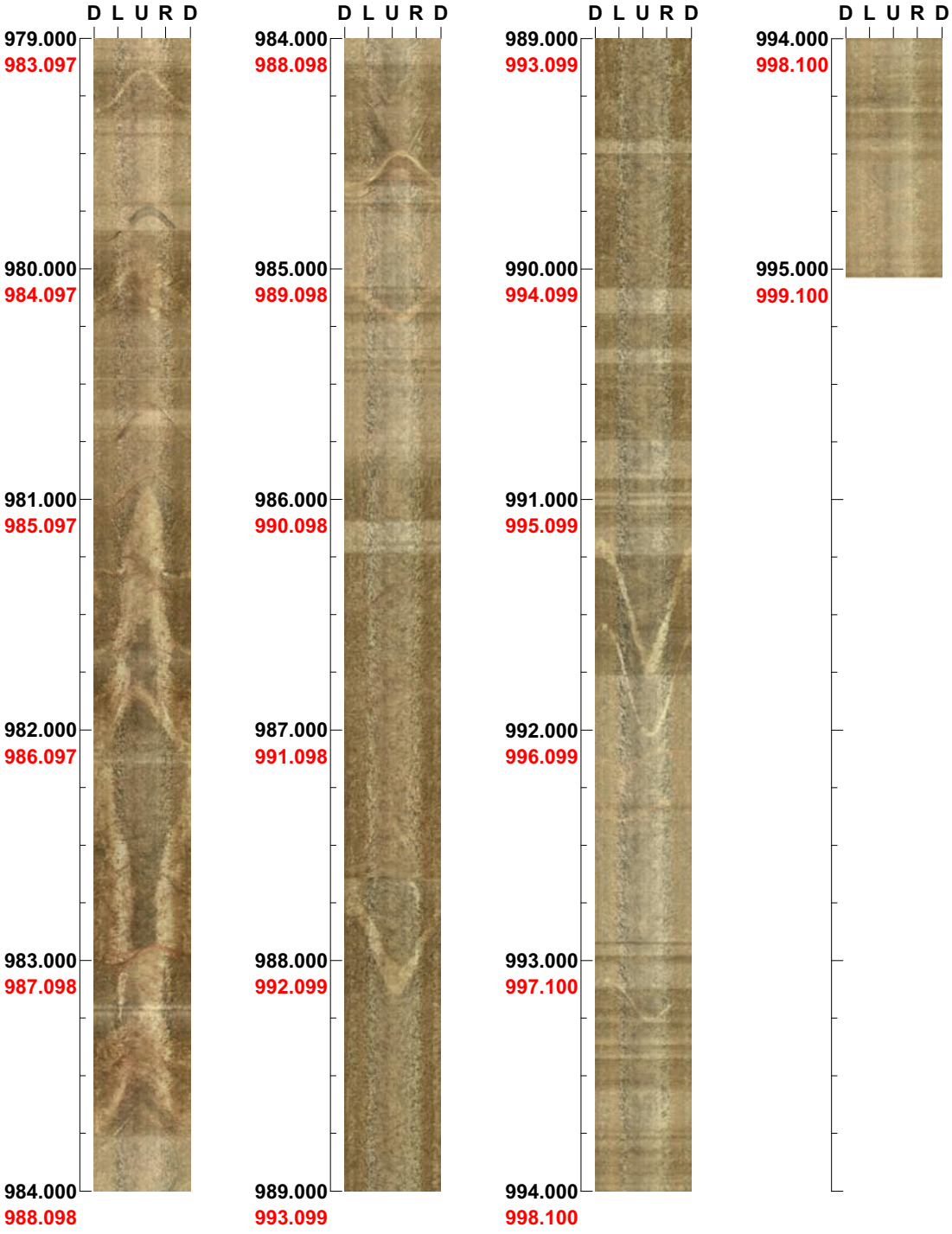
Depth range: 959.000 - 979.000 m



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

Project name: Forsmark
Bore hole No.: KFM05A **Azimuth: 81** **Inclination: -60**

Depth range: 979.000 - 995.037 m



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