P-08-71

Site investigation SFR

Radar and BIPS loggings in KFR101 and BIPS loggings in KFR27 (0–147 m), HFR101, HFR102 and HFR105

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Keywords: BIPS, RAMAC, Radar, TV-logging, Forsmark, SFR, AP SFR-08-003, Project SFR-extension.

Abstract

This report includes the data gained in logging operations performed within the site investigation at SFR. The logging operations presented here includes BIPS and borehole radar (RAMAC) logging in the core-drilled borehole KFR101 and BIPS logging in the core-drilled borehole KFR27 (0-147 m) and in the percussion drilled boreholes HFR101, HFR102 and HFR105. All measurements were conducted by Malå Geoscience AB during May and July 2008.

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

The objective of the BIPS logging is to achieve information of the borehole including occurrence of rock types as well as determination of fracture distribution and orientation.

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

The borehole radar data quality from KFR101 was satisfying to good, but in some parts of lower quality due to high electric conductivity of the borehole fluid. This conductive environment reduces the possibility to distinguish and interpret possible structures in the rock mass which otherwise could give a reflection. The borehole radar measurements resulted in 7 identified radar reflectors of which 4 were orientated (dip/strike).

The BIPS images show god quality for all logged boreholes. To check the quality BIPS logging has been performed in a repeat section over a distance of 10 meters for each borehole. The main aim for the repeat section is to get a record of the tool face orientation. The result shows that the orientation of the images is within what the BIPS system can perform.

Sammanfattning

Denna rapport omfattar geofysiska loggningar inom projekt SFR-Utbyggnad. Mätningarna som presenteras här omfattar BIPS-loggning och borrhålsradarmätningar (RAMAC) i kärnborrhålet KFR101 och BIPS-loggningar i kärnborrhålet KFR27 (0–147 m) samt i hammarborrhålen HFR101, HFR102 och HFR105. Alla mätningar är utförda av Malå Geoscience AB under maj och juli 2008.

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

Syftet med BIPS loggningen är att erhålla information om borrhålet inkluderande förekommande bergarter och bestämning av sprickors fördelning och deras orientering.

Rapporten beskriver utrustningen som använts liksom mätprocedurer och en beskrivning och tolkning av data som erhållits. För BIPS loggningarna presenteras data i form av plottar längs med borrhålet. Radardata presenteras i radargram, och en lista över tolkade radarreflektorer ges.

Borrhålsradardata från KFR101 var tillfredställande till bra, men tidvis av sämre kvalité, troligen till stor del beroende på en elektrisk konduktiv miljö. En hög elektrisk konduktivitet minskar möjligheterna att identifiera strukturer från borrhålsradardata. 7 radarreflektorer har identifierats i KFR101, varav 4 är orienterade (strykning och stupning).

BIPS bilderna är av god kvalitet för samtliga borrhål. En extra loggning har genomförts över en sträcka om 10 meter för att dokumentera skillnaden i systemets förmåga att orientera bilderna. Resultatet visar att orienteringen är inom vad BIPS systemet kan förväntas prestera.

Contents

1 Introduction

This document reports the results gained by the geophysical logging operations, which is one of the activities performed within the site investigation at SFR. The work was carried out in accordance with activity plan AP SFR-08-003. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

This report includes measurements in the boreholes listed in Table 1-2.

All measurements were conducted by Malå Geoscience AB during May and July 2008. Figure 1-1 shows the borehole location.

The used investigation techniques comprised:

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

The delivered raw and processed data have been inserted in the database of SKB (Sicada) and data are traceable by the activity plan number.

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

Activity plan	Number	Version
BIPS-loggning i hammarborrhålen HFR101, HFR102, HFR103, HFR104 och HFR105 samt kärnborrhålen KFR101 och KFR27	AP SFR 08-003	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för TV- loggning med BIPS	SKB MD 222.006	1.0
Metodbeskrivning för borrhålsradar	SKB MD 252.020	3.0

Table 1-2. Technical data for the boreholes.

Borehole parameter	HFR101	HFR102	HFR105	KFR101	KFR27
Coordinates (RT 90)	6701725 1632839	6701729 1632975	6701377 1632687	6701736 1633351	6701714 1633176
Direction at TOC	133.6º	85.0º	35.4º	28.8º	248º
Dip at TOC	–69.9º	–59.4º	–61.8º	–54.4º	–87.4º
Length (m)	209.3 m	55.0 m	200.5 m	341.8 m	148.5 m
Casing	8.04 m	9.04 m	21.1 m	13.7 m	11.9 m

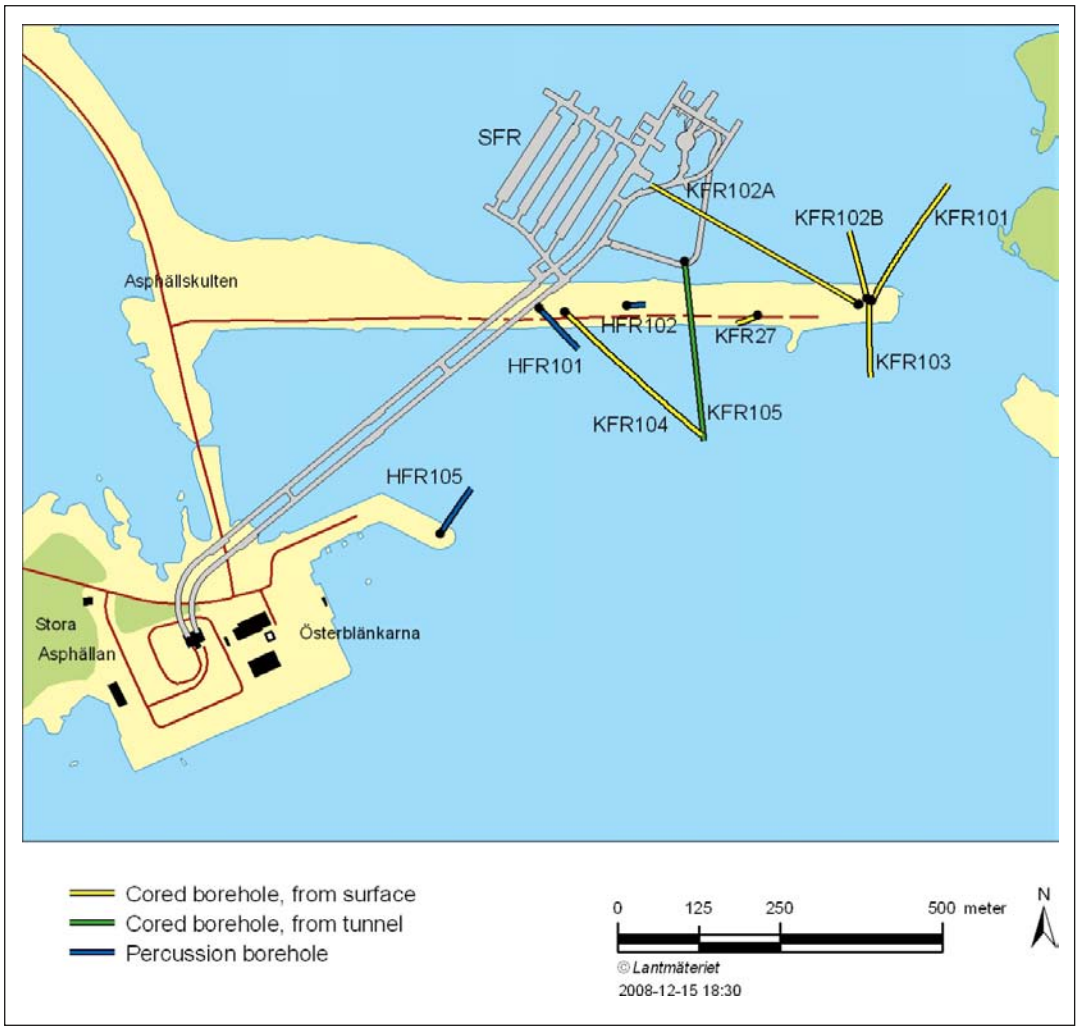


Figure 1-1. *Overview over the SFR investigation area, showing the location of the boreholes KFR101, KFR27, HFR101, HFR102 and HFR105 surveyed and presented in this report.*

2 Objective and scope

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

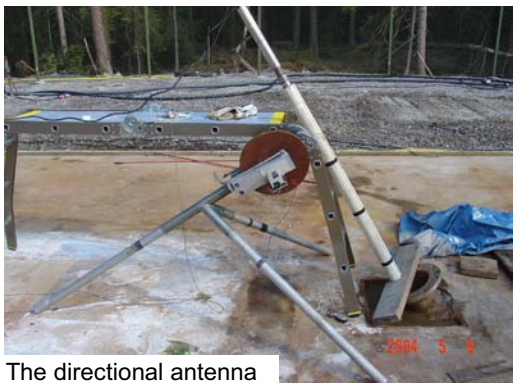
This report describes the equipment used as well as the measurement procedures and data gained. For the BIPS surveys, the results are presented as images. Radar data are presented in radargrams and the identified reflectors are listed.

3 Equipment

3.1 Radar measurements RAMAC

The RAMAC GPR system owned by SKB is a fully digital GPR system where emphasis has been laid on fast survey speed and easy field operation. The system operates dipole and directional antennas (see Figure 3-1). A system description is given in the SKB internal controlling document MD 252.021.

The borehole radar system consists of a transmitter and a receiver antenna. During operation an electromagnetic pulse, within the frequency range of 20 MHz up to 250 MHz, is emitted into the bedrock. Structural features, e.g. a water-filled fractures with sufficiently different electrical properties, causes reflected pulses which are recorded by the receiver.



The directional antenna

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

3.2 TV-Camera, BIPS

The BIPS 1500 system used is owned by SKB and described in SKB internal controlling document MD 222.005. The BIPS method for borehole logging produces a digital scan of the borehole wall. In principle, a standard CCD video camera is installed in the probe in front of a conical mirror (see Figure 3-2). An acrylic window covers the mirror part and the borehole image is reflected through the window and displayed on the cone, from where it is recorded. During the measuring operation, pixel circles are grabbed with a resolution of one pixel per degree.

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

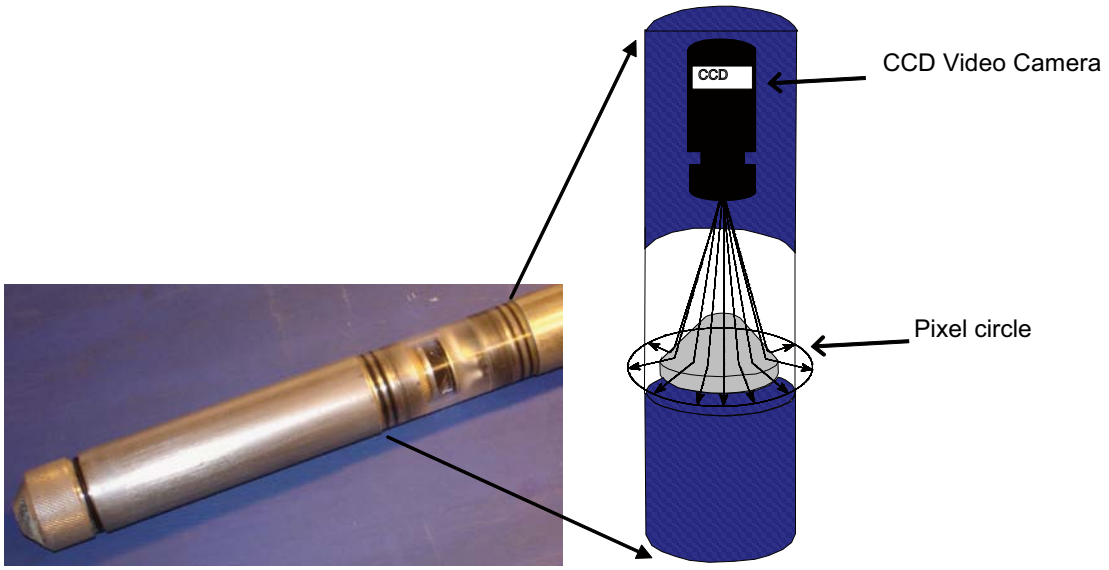


Figure 3-2. *The BIP-system. To the right a sketch showing the principles of the conical mirror.*

4 Execution

4.1.1 RAMAC Radar

The measurements in KFR101 were carried out with a dipole radar antenna with a frequency of 20 MHz. Measurements were also carried out using the directional antenna, with a central frequency of 60 MHz.

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

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

The functionality of the directional antenna was tested before measurements in KFR101. This was performed by measurements in the air, where the receiver antenna and the transmitter antenna are placed apart. While transmitting and measuring the receiver antenna is turned around and by that giving the direction from the receiver antenna to the transmitter antenna. The difference in direction is measured by compass and the result difference achieved from the directional antenna was about 2-4 degrees. This can be considered to be good, considering the disturbed environment with metallic objects etc at the test site.

For more information on system settings used in the investigation of KFR101, see Table 4-1.

4.1.2 BIPS

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

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

A gravity sensor was used to measure the orientation of the images in boreholes KFR101, HFR101, HFR102 and HFR105. A magnetic sensor was used in KFR27.

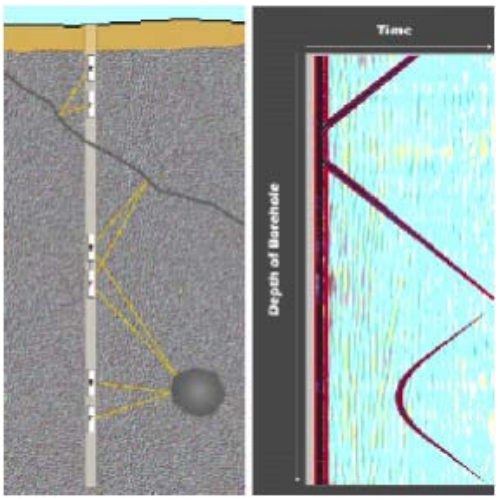


Figure 4-1. *The principle of radar borehole reflection survey (left) and an example of result (right).*

Table 4-1. Radar logging information from KFR101.

Site:	**Forsmark**	**Logging company:**	**Malå Geoscience AB**
BH:	**KFR101**	**Equipment:**	**SKB RAMAC**
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ Geoscience AB**
Operator:	**CG**	**Antenna**	
		Directional	**20 MHz**
Logging date:		2008-07-11	2008-07-10
Reference:		T.O.C.	T.O.C.
Sampling frequency (MHz):		615	239
Number of samples:		512	518
Number of stacks:		32	Auto
Signal position:		410.5	–1.42
Logging from (m):		13.4	6.25
Logging to (m):		323	329.5
Trace interval (m):		0.5	0.25
Antenna separation (m):		5.73	10.05

In order to control the image quality of the system, calibration measurements were performed in a test pipe before logging and after logging, see Figure 4-2 and 4-3. The results showed no difference regarding the colours and focus of the images. Results of the test loggings were included in the delivery of the raw data.

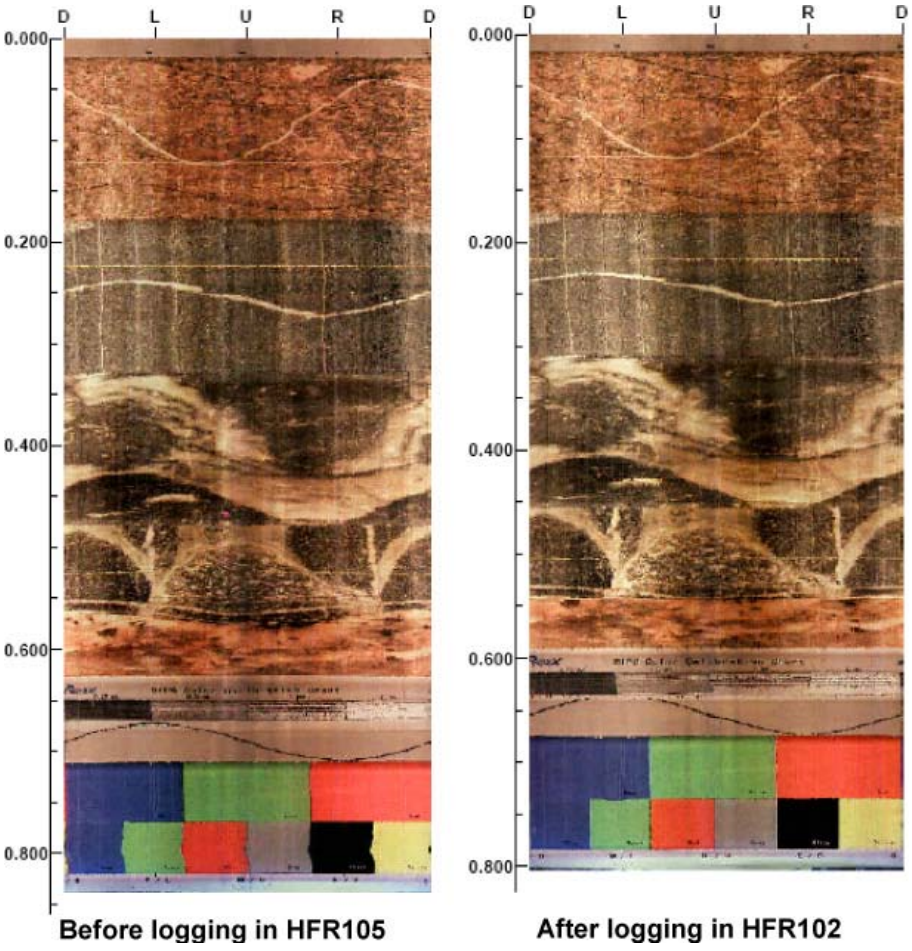


Figure 4-2. *Results from logging in the test pipe before and after the logging campaign in May, 2008. The length scales are not essential in the test measurements.*

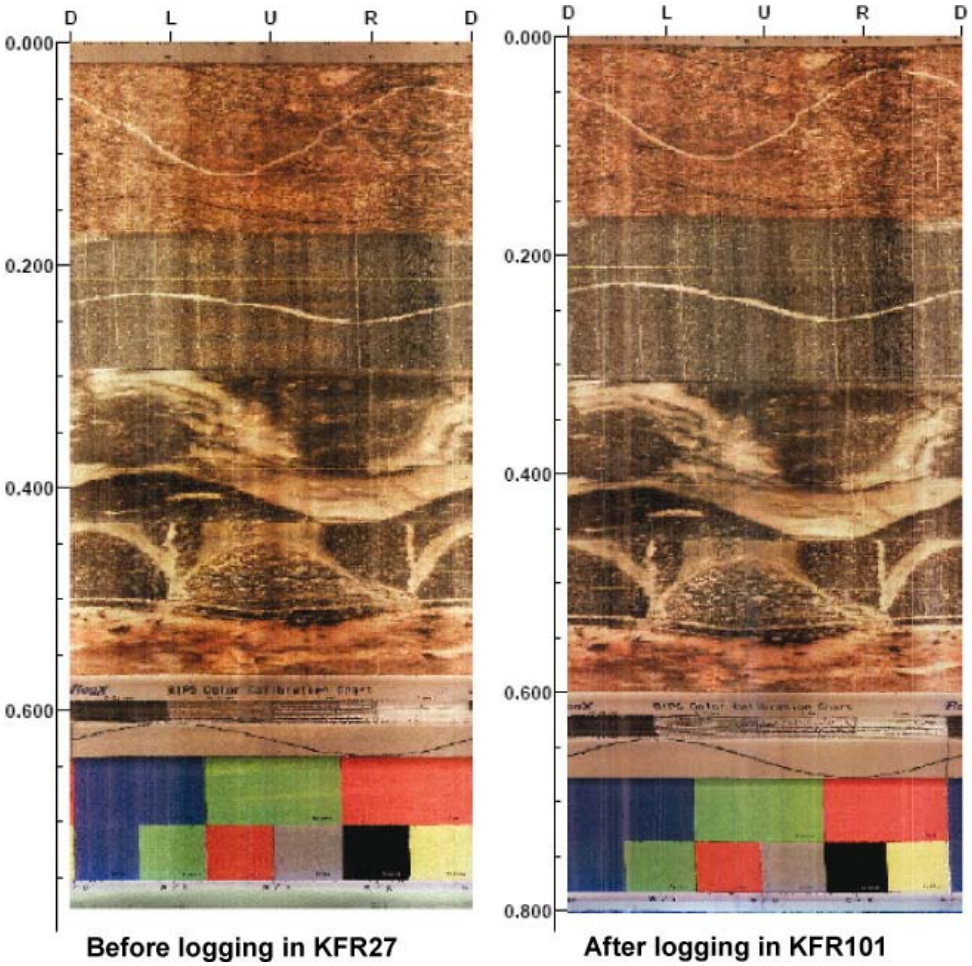


Figure 4-3. *Results from logging in the test pipe before and after the logging campaign in July, 2008. The length scales are not essential in the test measurements.*

The BIPS logging information is found in the header in the presentation in Appendix 2.

4.1.3 Length measurements

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

During the BIPS logging in core drilled boreholes, where the reference marks in the borehole wall is visible on the image, the position where the length mark is visible is marked with scotch tape on the logging cable. During BIPS logging the measured length was adjusted to true length according to length mark visible in the BIPS image. The adjusted true length is marked with red figures in the image plot together with the non-adjusted measured length. The non-adjusted length is marked with black figures as seen in Appendix 2. The tape marks on the logging cable are then used for controlling the RAMAC measurement.

The experience we have from earlier measurements with dipole antennas in the core drilled boreholes in Forsmark and Oskarshamn is that the length divergence is less than 100 cm in the deepest parts of a 1,000 meter long borehole. The length divergence is taken into account in the resulting tables in Chapter 5.

4.2 Analyses and Interpretation

4.2.1 Radar

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

The presented data in this report is adjusted for the measurement point of the antennas. The measurement point is defined to be the central point between the transmitter and the receiver antenna.

The two basic patterns to interpret in borehole measurements are point and plane reflectors. In the reflection mode, borehole radar essentially gives a high-resolution image of the rock mass, showing the geometry of plane structures which may or may not, intersect the borehole (contact between layers, thin marker beds, fractures etc) or showing the presence of local features around the borehole (cavities, lenses etc).

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

There are several ways to determine the radar wave propagation velocity. Each of them has advantages and disadvantages. In this project the velocity determination was performed by keeping the transmitter fixed in the borehole while moving the receiver downwards in the borehole. The result is plotted in Figure 4-4, and the calculation shows a velocity of 128 m/µs (metres per microsecond) /1/. The velocity measurement was performed with a 100 MHz antenna.

The visualization of data in Appendix 1 is made with ReflexWin, a Windows based processing software for filtering and analysis of borehole radar data. The processing steps for the data presented in Appendix 1 are given in Table 4-2. The filters applied affect the whole borehole length and are not always suitable in all parts, depending on the geological conditions and conductivity of the borehole fluid. During interpretation further processing can be done, most often in form of bandpass filtering. This filtering can be applied just in parts of the borehole, where needed.

For the interpretation of the intersection angle between the borehole axis and the planes visible on the radargrams the RadinterSKB software has been used. The interpreted intersection points and intersection angles of the detected structures are presented in the Table 5-2 and are also visible on the radargrams in Appendix 1.

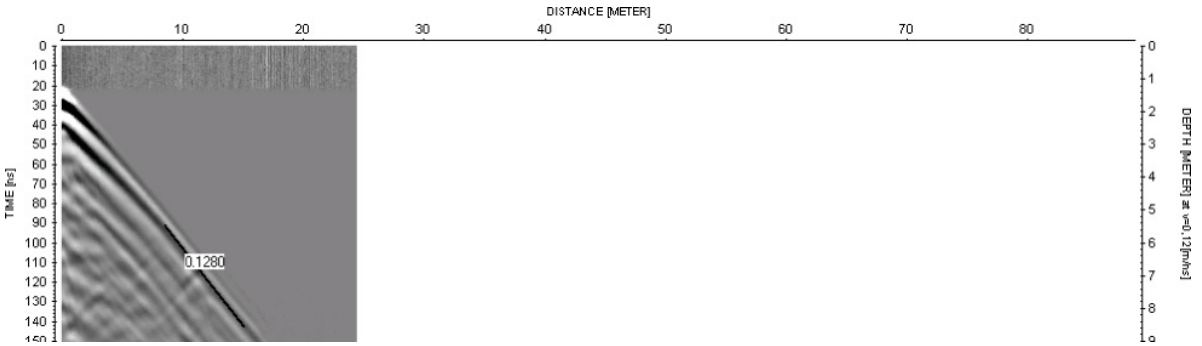


Figure 4-4. *Results from velocity measurements in HFM03.*

Table 4-2. Processing steps for borehole radar data from KFR101.

Site:	**Forsmark**	**Logging company:**	**MALÅ GeoScience AB**
BH:	**KFR101**	**Equipment:**	**SKB RAMAC**
Type:	**Directional/Dipole**	**Manufacturer:**	**MALÅ GeoScience AB**
Interpret:	**JG**	**Antenna**	
		Directional	**20 MHz**
Processing steps		Move start time (23 samples)	Move start time (–132)
		DC shift (390–510)	DC shift (1,800–2,000)
		Time gain (start 55 lin 100 exp 5)	Gain (Start 109 lin 6.2 exp 0.2)
		(FIR)	

4.2.2 BIPS

The visualization of data is made with BDPP, a Windows based processing software for filtering, presentation and analysis of BIPS data. The raw data was delivered on a CD-ROM together with printable pictures in pdf-format before the field crew left the investigation site.

The printed results were delivered with measured length, together with adjusted length according to the length marks made on the cable when logging core-drilled boreholes (where the length marks are visible in the BIPS image). For printing of the BIPS images the printing software PDPP from RaaX was used.

4.3 Nonconformities

No nonconformities occurred during the logging in May or July 2008.

5 Results

The results from the BIPS measurements in KFR101, KRF27 (0–147 m), HFR101, HFR102, HFR105 were delivered as raw data (*.bip-files) together with printable BIPS pictures in *.pdf format before the field crew left the investigation site. The information of the measurements was registered in Sicada, and the CD-ROM:s stored by SKB.

The RAMAC radar data for KFR101 was delivered as raw data (file format *.rd3 or *.rd5) with corresponding information files (file format *.rad) on CD-ROM:s to SKB before the field crew left the investigation site, whereas the data processing steps and results are presented in this report. Relevant information, including the interpretation presented in this report, was inserted into the SKB database Sicada.

5.1 RAMAC logging

The results of the interpretation of the radar measurements in KFR101 are presented in Table 5-1. Radar data are also visualized in Appendix 1. It should be remembered that the images in Appendix 1 is a composite picture of all events 360 degrees around the borehole, and do not reflect the orientation of the structures.

Only the larger clearly visible structures are interpreted in RadinterSKB. An overview of the borehole is given in Figure 5-1. Differences in data quality can be observed along the borehole. Two areas can be observed with a clearly affected depth penetration, around 106 m and around 300 m.

A number of minor structures also exist, as indicated in Appendix 1. Often clusters of structures can be noticed, but often located so close to each other that it is impossible to distinguish one from the other. Larger structures parallel to the borehole, if present, are also indicated in Appendix 1. It should also be pointed out that an interpreted reflector always results in an intersection with the borehole (unless the reflector is strictly parallel to the hole). However, sometimes this intersection point is localized outside the range of the borehole.

The data quality from KRF101 (as seen in Appendix 1) is satisfying to good, but in some parts of lower quality due to more conductive conditions. An electrical conductive environment causes an attenuation of the radar wave, which in turn decreases the penetration. This conductive environment of course also reduces the possibility to distinguish and interpret possible structures in the rock which otherwise could give a reflection.

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

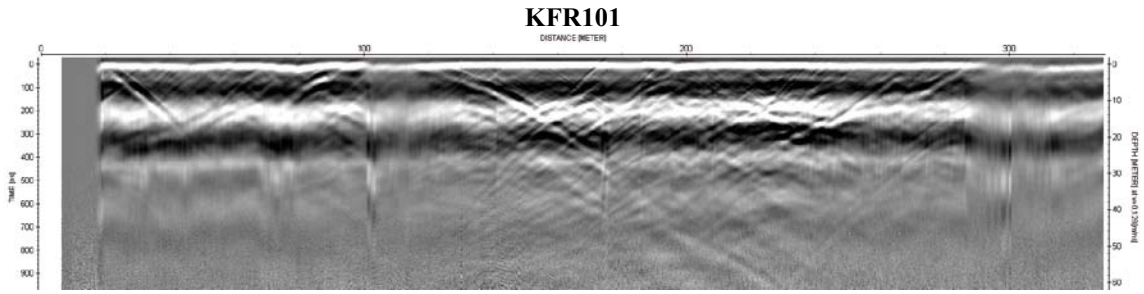


Figure 5-1. *An overview (20 MHz data) of the radar data for the borehole KFR101.*

Table 5-1 summarises the interpretation of radar data from KFR101. In the table the borehole length and intersection angle to the identified structures are listed.

As seen some radar reflectors in Table 5-1 are marked with "±", which indicates an uncertainty in the interpretation of direction. The direction can in these cases be ±180 degrees. The direction to the object (the plane) is defined in Figure 5-2. This direction and the intersection angle are recalculated to strike and dip, also given in the tables below. The plane strike is the angle between the line of the plane's intersection with the surface and the Magnetic North direction. A strike of 0 degrees implies a dip to the east while a strike of 180 degrees implies a dip to the west (right-hand rule). The strike is measured clockwise and can vary from 0 to 359 degrees. The dip of the plane is the angle between the ground surface and the plane, and can vary from 0 to 90 degrees.

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

5.2 BIPS logging

The BIPS pictures are presented in Appendices 2 to 11. The BIPS images show good quality in all logged boreholes.

To get the best possible length accuracy, the BIPS images are adjusted to the reference marks on the logging cable (in percussion-drilled boreholes) or the length calibration marks by grove milling (in core-drilled boreholes). The recorded length is adjusted to these reference length values.

In order to control the quality of the system, calibration measurements were performed in a test pipe before logging the first borehole and after logging of the last borehole in the campaign. The resulting images displayed no difference regarding the colours and focus of the images. The results of the test logging were included in the delivery of the field data and are also presented in Figure 4-2 and 4-3 in this report.

To check the quality BIPS logging has been performed in a repeat section over a distance of approximately 10 meters for each borehole. The main aim for the repeat section is to check the accuracy of the tool face orientation. Visible features in the images for the two runs have been compared and the results are presented in Table 5-2 to Table 5-6. All the repeat sections are included in Appendices 7 to 11. As seen, the results between different runs in the repeated sections are within ±5º.

Table 5-1. Interpretation of radar reflectors based on the directional antenna and the 20 MHz dipole antenna in borehole KFR101.

RADINTER MODEL INFORMATION
(Directional and dipole antennas)

Site: **Forsmark**
Borehole name: **KFR101**
Nominal velocity (m/µs): **128.0**

Name	Intersection length	Inter-section angle	RadInter direction to object (gravity roll)	Dip 1	Strike 1	Dip 2	Strike 2
1	106,4	26	18±	87	313	30	331
1x	95,9	32					
2	126,1	19					
3	181,0	65	213	21	76		
4	282,2	41	249	47	41		
5	301,8	35	180±	16	296	87	296
5x	327,5	18					

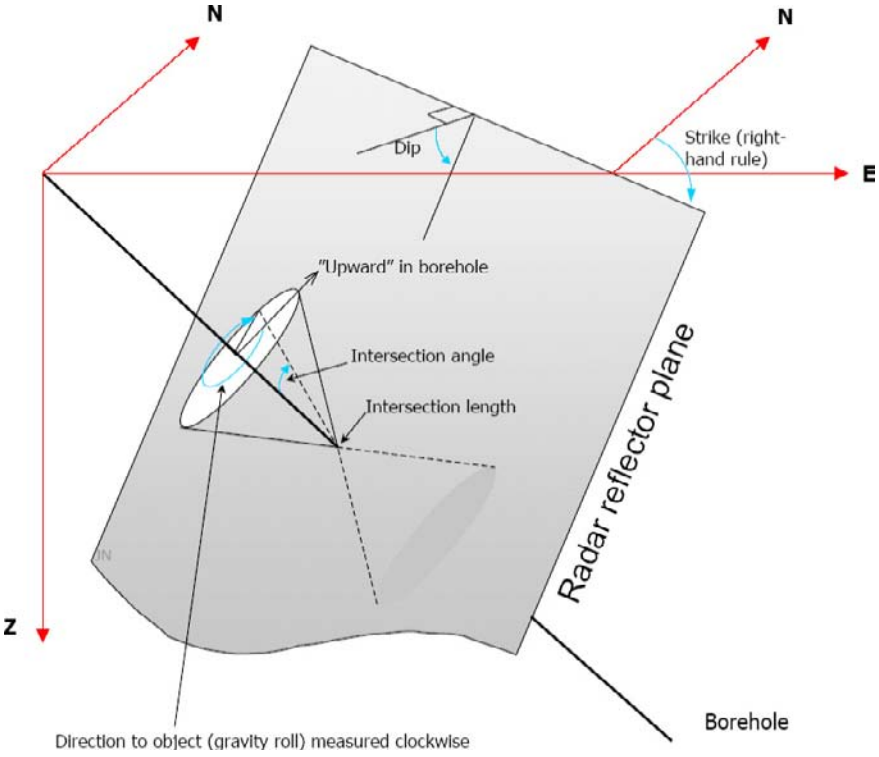


Figure 5-2. *Definition of the direction to a reflector (gravity roll) as presented in Table 5-1.*

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

Table 5-2. Difference in tool face orientation between the delivered logging and repeat section for borehole KFR101.

KFR101	Delivered	Repeat section	Difference between the two runs
(meter)	Tool face orientation	Tool face orientation	
100.1	163.5	163.9	0.4
101.4	135.0	137.5	2.5
103.1	104.6	105.3	0.7
107.9	282.4	281.1	–1.3
108.7	276.8	277.4	0.6

Table 5-3. Difference in tool face orientation between the delivered logging and repeat section for borehole KFR27.

KFR27	Delivered	Repeat section	Difference between the two runs
(meter)	Tool face orientation	Tool face orientation	
111.8	125.1	125.7	0.6
112.6	144.3	143.1	–1.2
115.5	216.1	213.1	–3.0
116.6	279.3	281.2	1.9
119.3	113.3	115.2	1.9

Table 5-4. Difference in tool face orientation between the delivered logging and repeat section for borehole HFR101.

HFR101	Delivered	Repeat section	Difference between the two runs
(meter)	Tool face orientation	Tool face orientation	
100.4	186.1	182.6	–3.5
102.2	235.9	231.0	–4.9
103.1	320.8	318.4	–2.4
105.1	251.1	252.3	1.2
107.0	312.5	313.1	0.6
109.0	283.7	279.2	–4.5

Table 5-5. Difference in tool face orientation between the delivered logging and repeat section for borehole HFR102.

HFR102	Delivered	Repeat section	Difference between the two runs
(meter)	Tool face orientation	Tool face orientation	
41.2	300.1	301.3	1.2
42.8	190.2	188.5	–1.7
44.9	286.5	288.9	2.4
45.7	149.5	148.9	–0.6
47.8	209.7	211.5	1.8
49.8	262.9	262.9	0

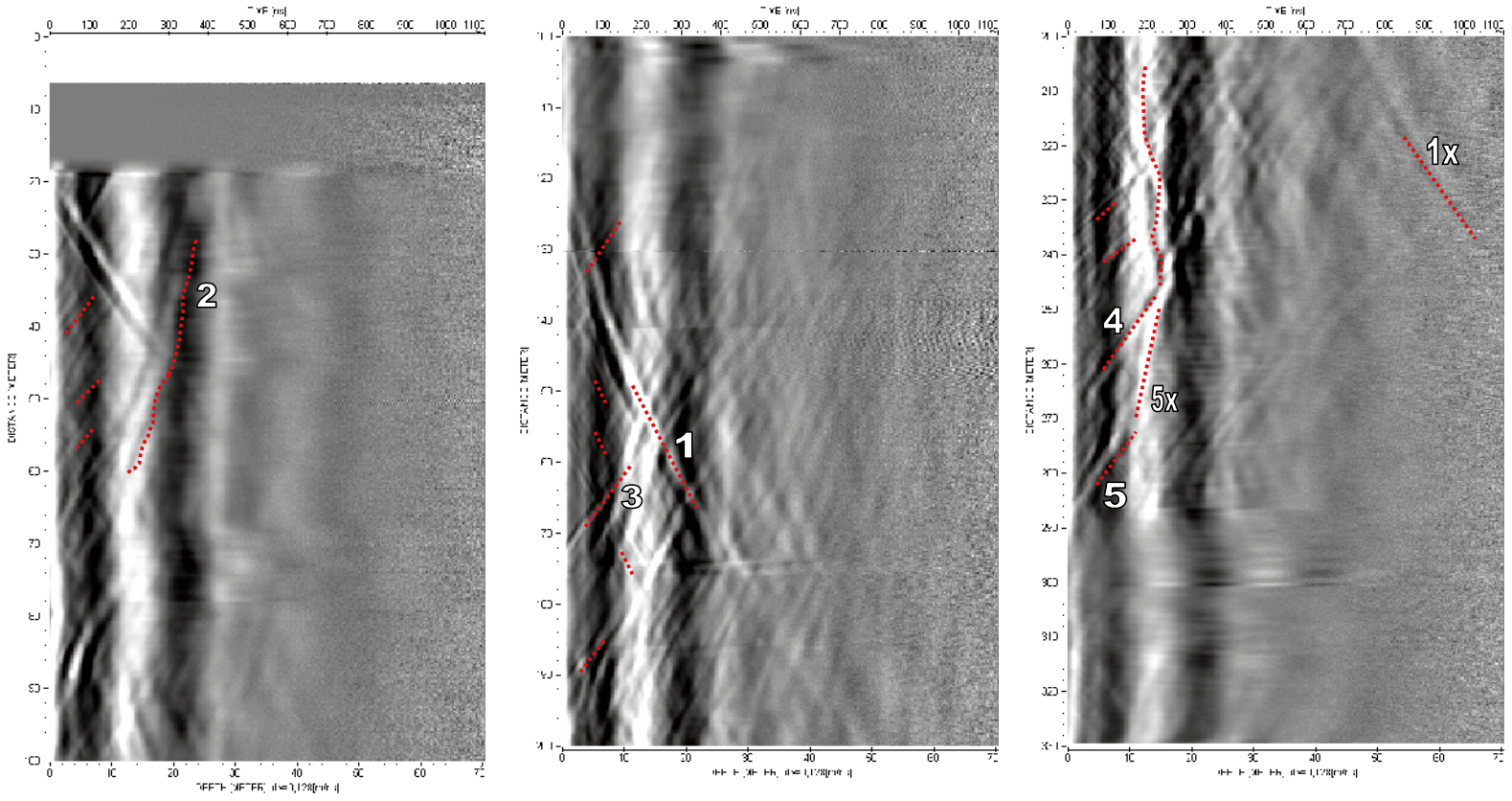
Table 5-6. Difference in tool face orientation between the delivered logging and repeat section for borehole HFR105.

HFR105	Delivered	Repeat section	Difference between the two runs
(meter)	Tool face orientation	Tool face orientation	
100.6	187.3	190.8	3.5
102.9	286.5	287.7	1.3
103.8	222.1	223.3	1.2
104.8	274.1	274.7	0.6
105.2	138.2	139.4	1.2
107.9	259.3	258.8	–0.5

References

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

Radar logging in KFR101. 6 to 330 m. Dipole antenna 20 MHz



Appendix 2

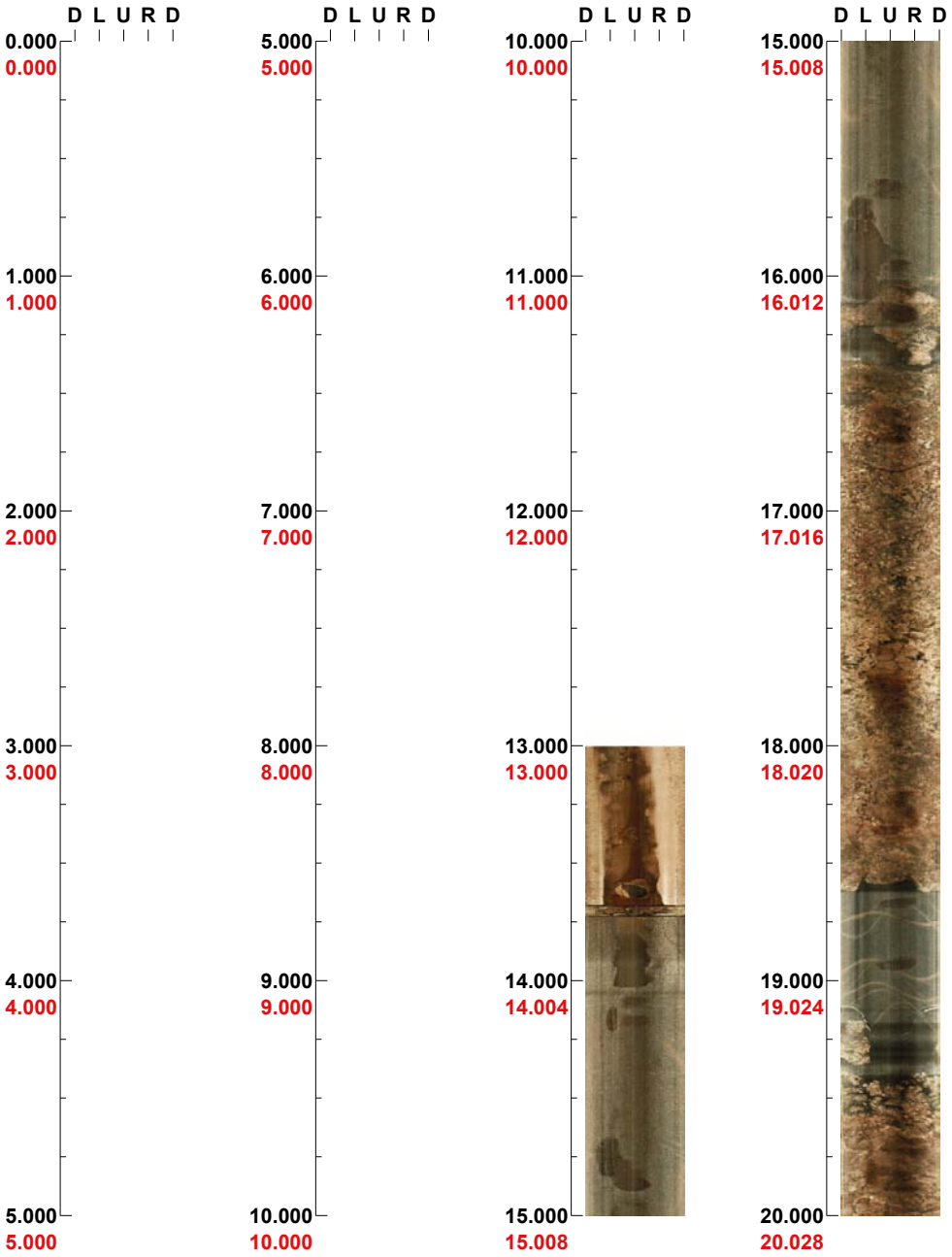
BIPS logging in KFR101. 13 to 336 m

Project name: Forsmark /SFR

Image file	**: c:\work\r5732b~1\juli09~1\bipsda~1\kfr101.bip**
BDT file	**: c:\work\r5732b~1\juli09~1\bipsda~1\kfr101.bdt**
Locality	**: SFR**
Bore hole number	**: KFR101**
Date	**: 08/07/10**
Time	**: 09:08:00**
Depth range	**: 13.000 - 335.581 m**
Azimuth	**: 29**
Inclination	**: -54**
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	**: 17**
Color	**: +0 +0 +0**

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 0.000 - 20.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 20.000 - 40.000 m

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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 40.000 - 60.000 m

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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 60.000 - 80.000 m

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

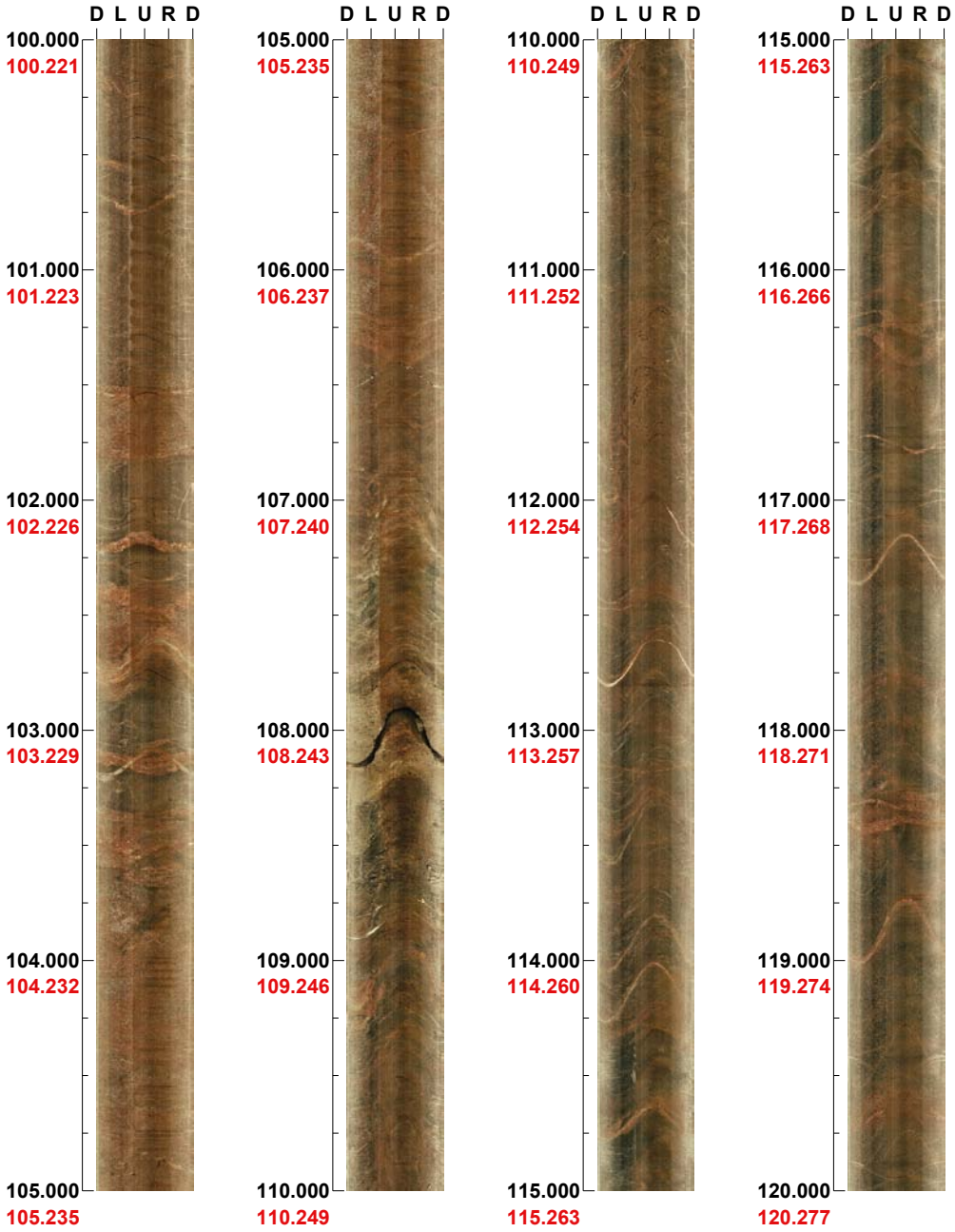
Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 80.000 - 100.000 m

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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

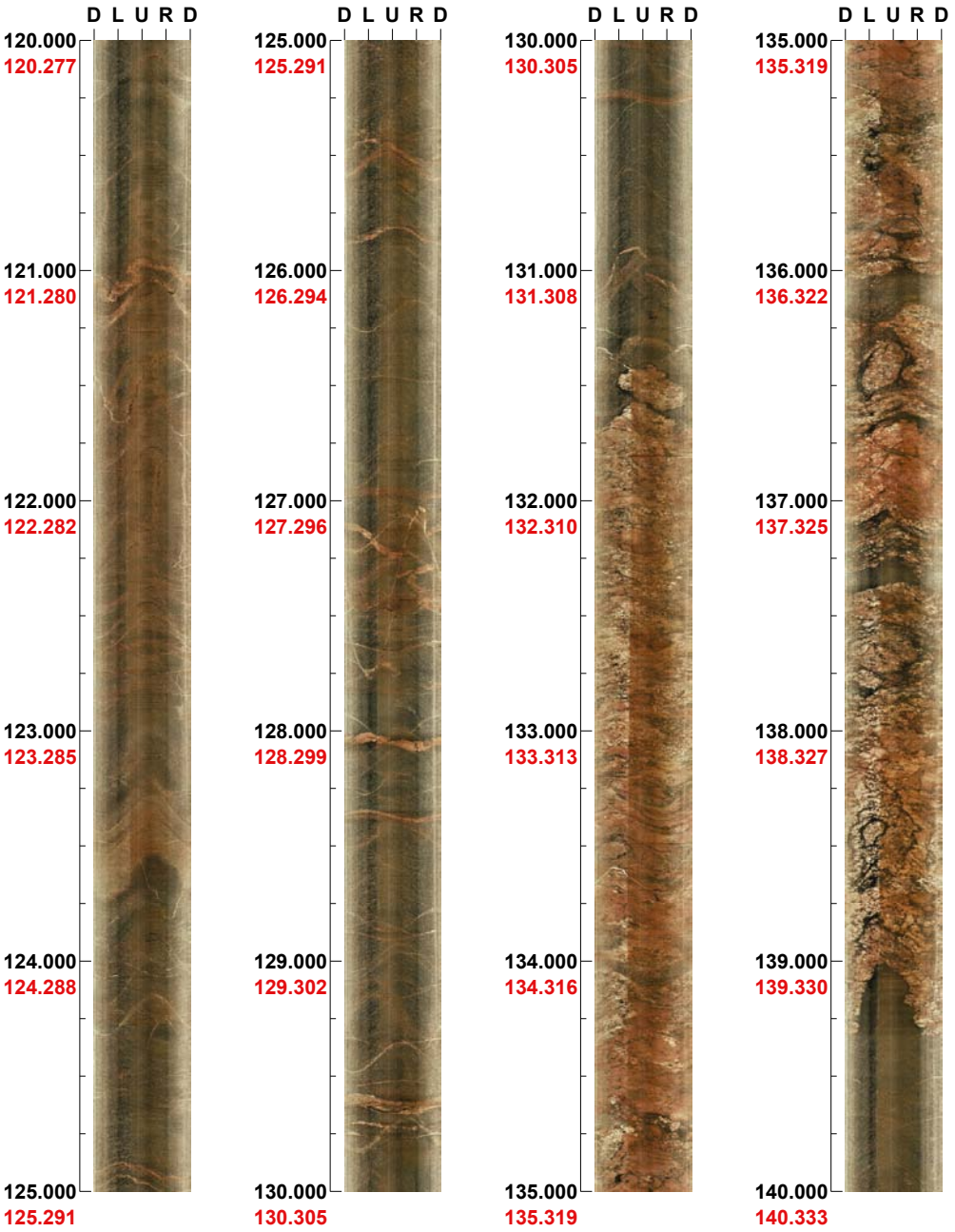
Depth range: 100.000 - 120.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

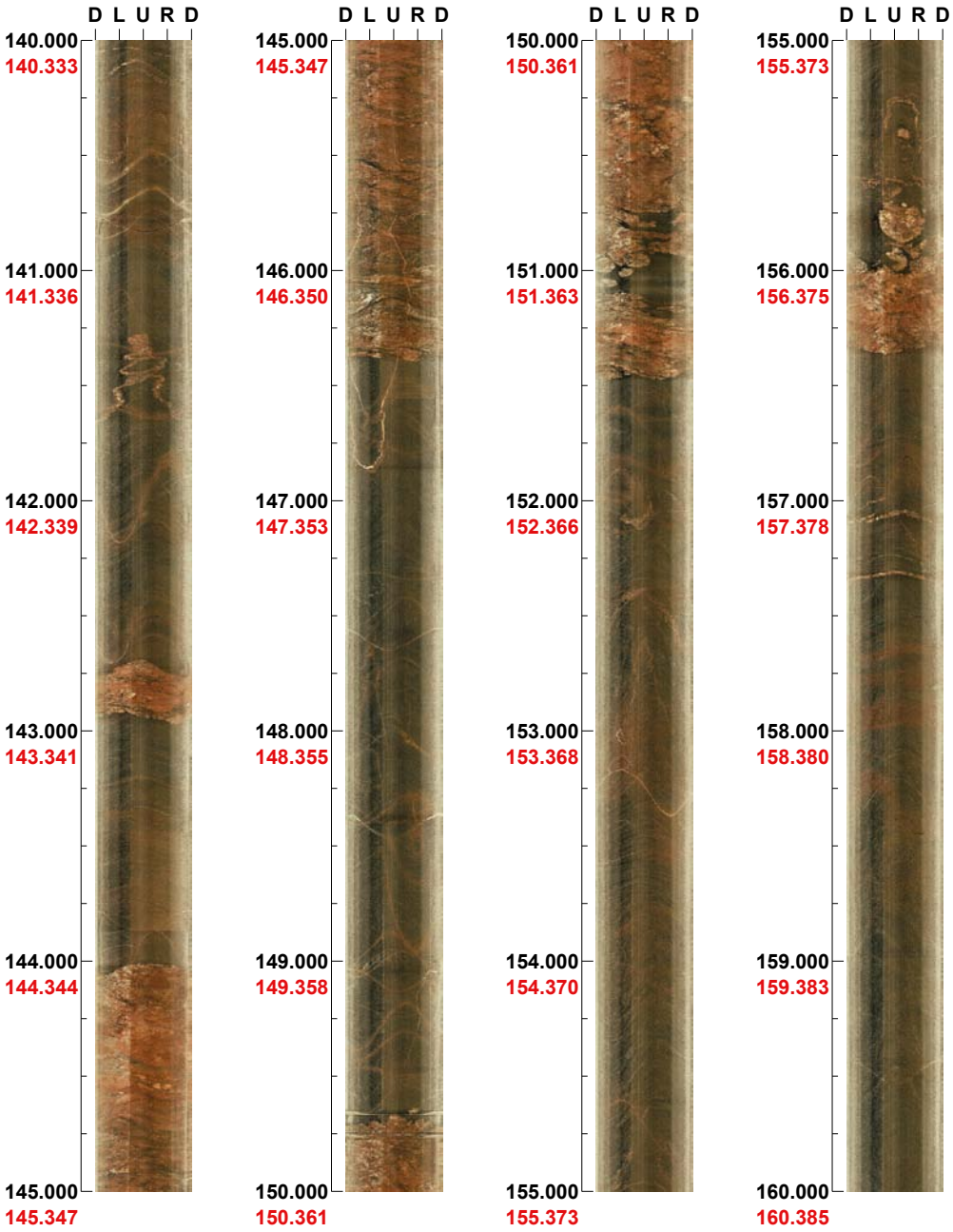
Depth range: 120.000 - 140.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 140.000 - 160.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 160.000 - 180.000 m

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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 180.000 - 200.000 m

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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 200.000 - 220.000 m

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

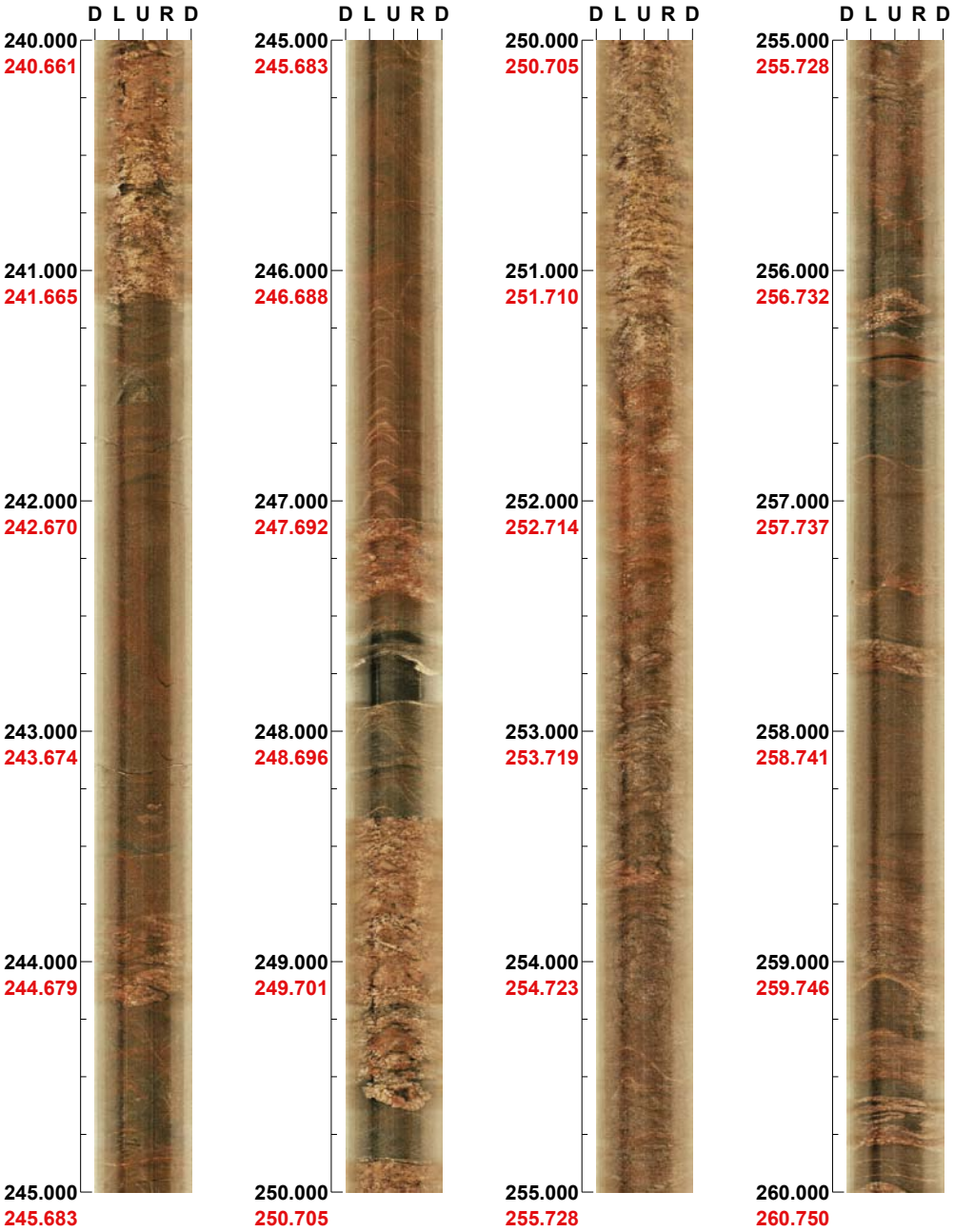
Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 220.000 - 240.000 m

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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 240.000 - 260.000 m



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

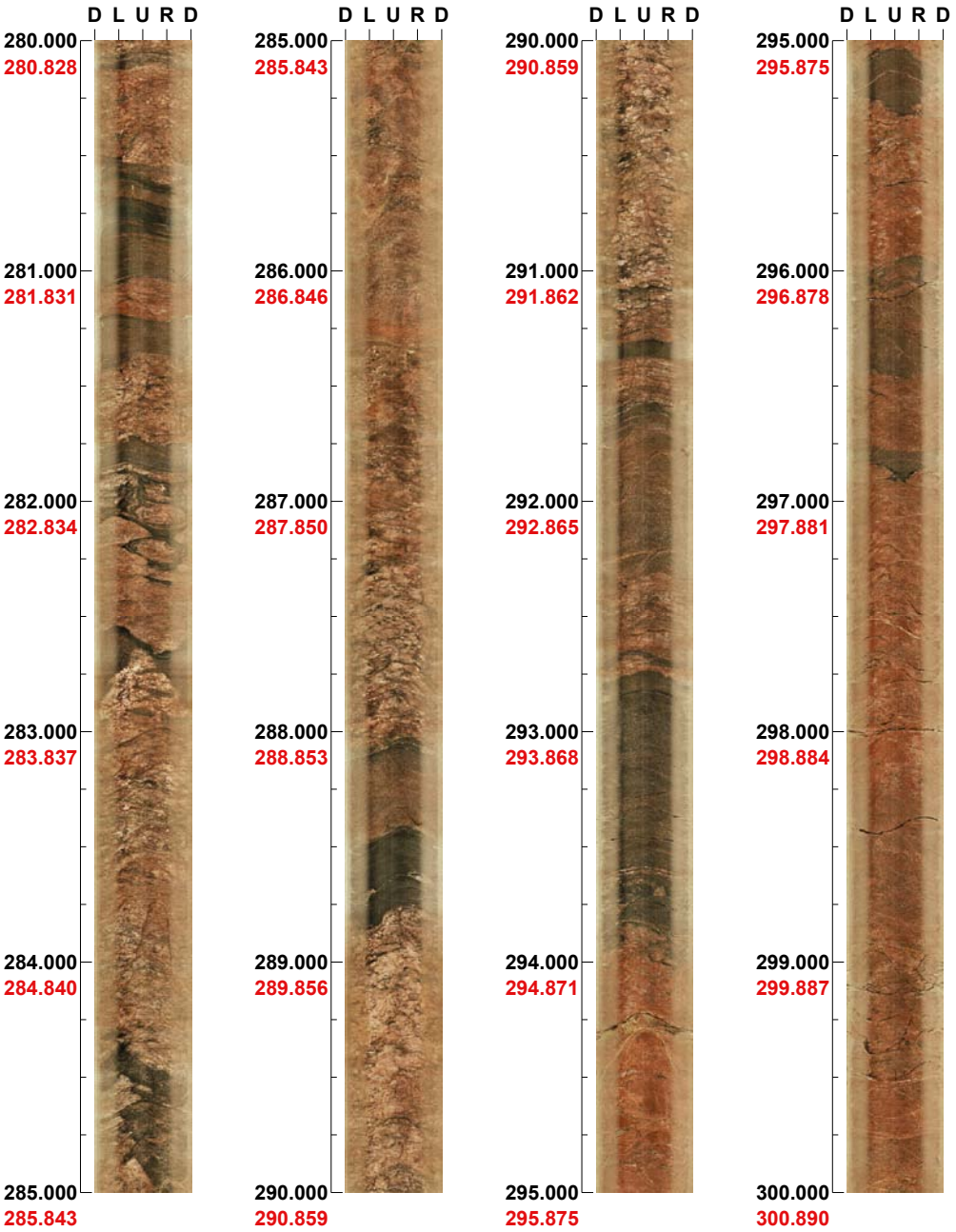
Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 260.000 - 280.000 m

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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 280.000 - 300.000 m



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

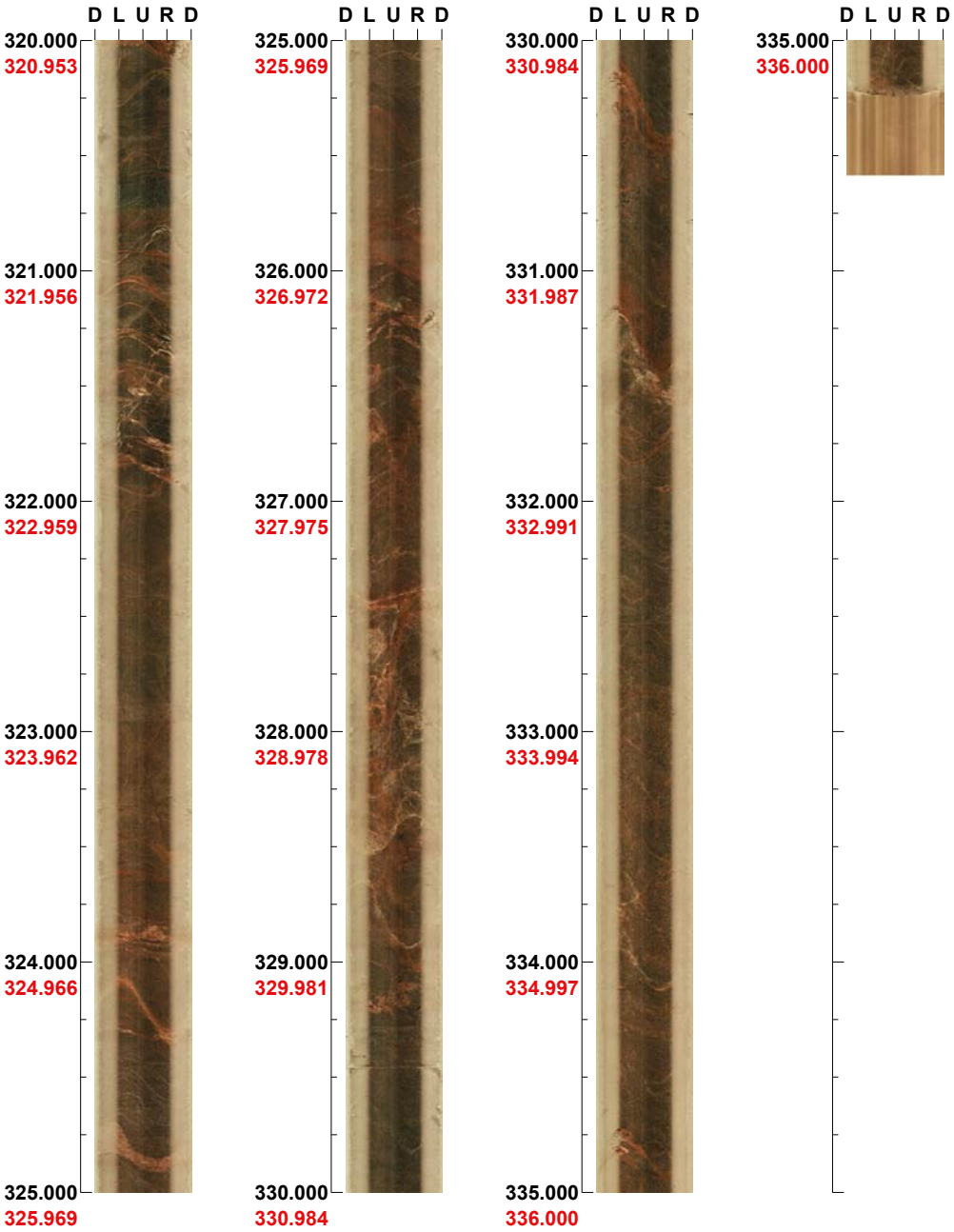
Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 300.000 - 320.000 m

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

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 320.000 - 335.581 m



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

Appendix 3

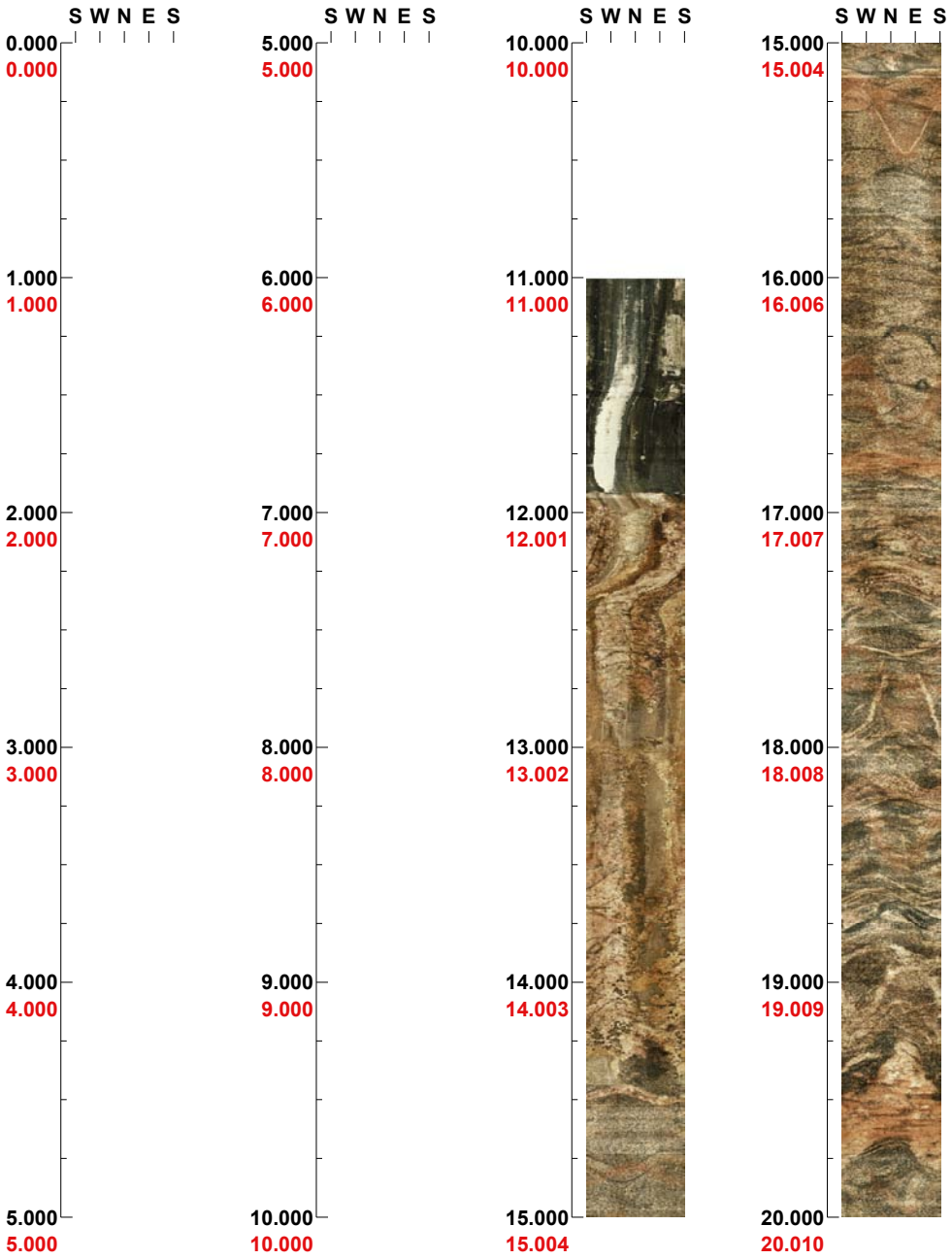
BIPS logging in KFR27. 11 to 147 m

Project name: Forsmark /SFR

Image file	**: c:\work\r5732b~1\juli09~1\bipsda~1\kfr27.bip**
BDT file	**: c:\work\r5732b~1\juli09~1\bipsda~1\kfr27.bdt**
Locality	**: SFR**
Bore hole number	**: KFR27**
Date	**: 08/07/09**
Time	**: 22:35:00**
Depth range	**: 11.000 - 147.457 m**
Azimuth	**: 0**
Inclination	**: -90**
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	**: 8**
Color	**:**  **+0 +0 +0**

Project name: Forsmark /SFR
Bore hole No.: KFR27 **Azimuth: 0** **Inclination: -90**

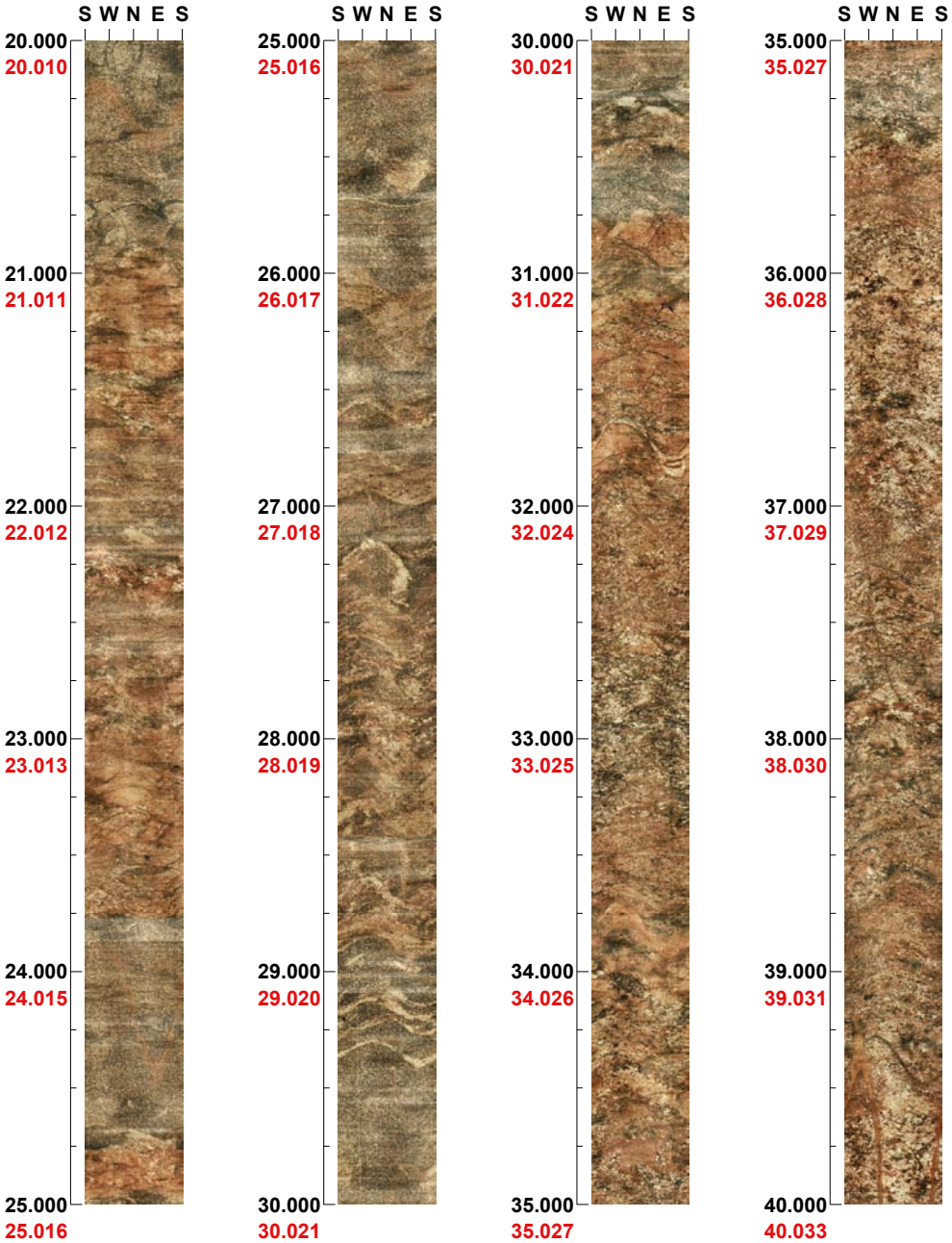
Depth range: 0.000 - 20.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR27 **Azimuth: 0** **Inclination: -90**

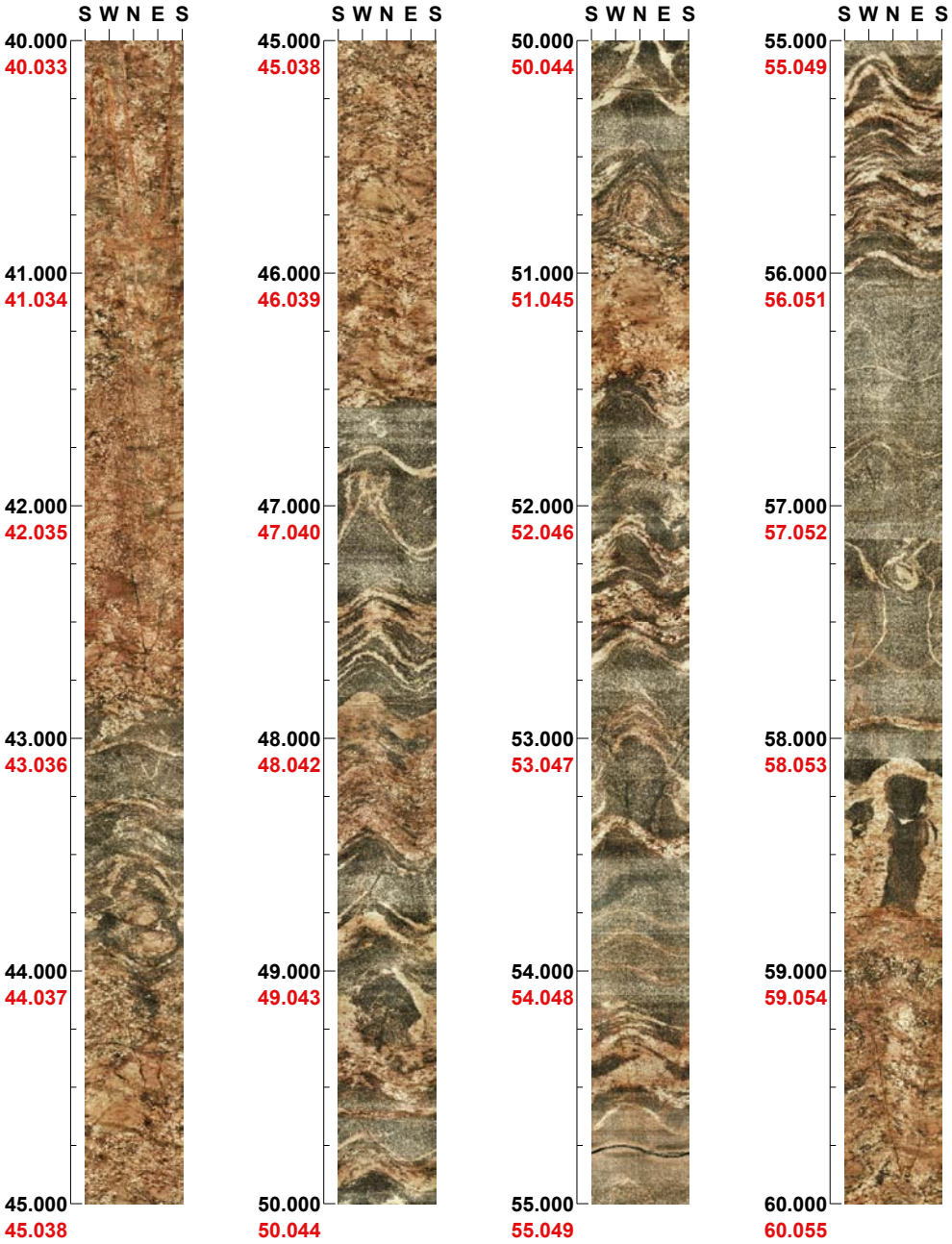
Depth range: 20.000 - 40.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR27 **Azimuth: 0** **Inclination: -90**

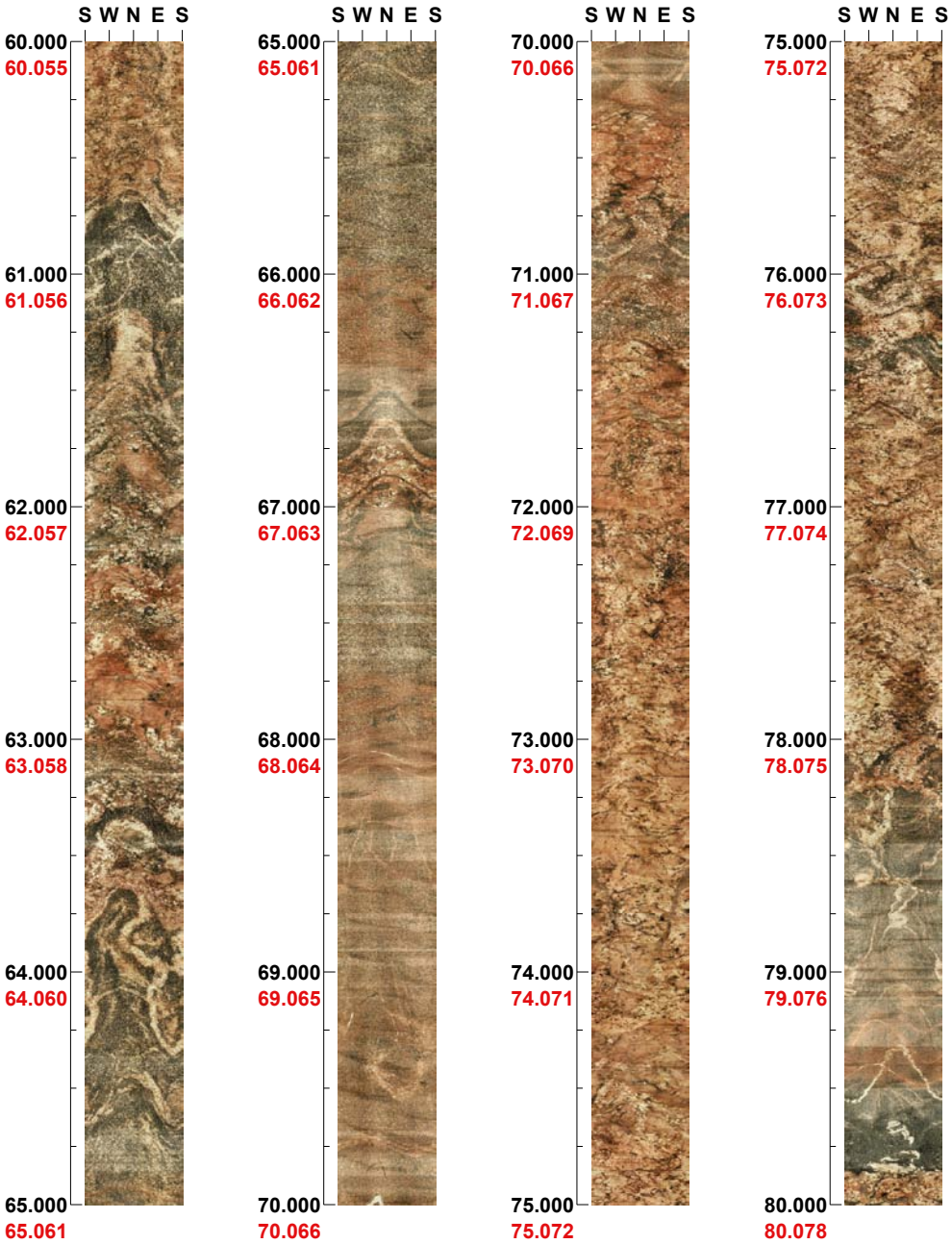
Depth range: 40.000 - 60.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR27 **Azimuth: 0** **Inclination: -90**

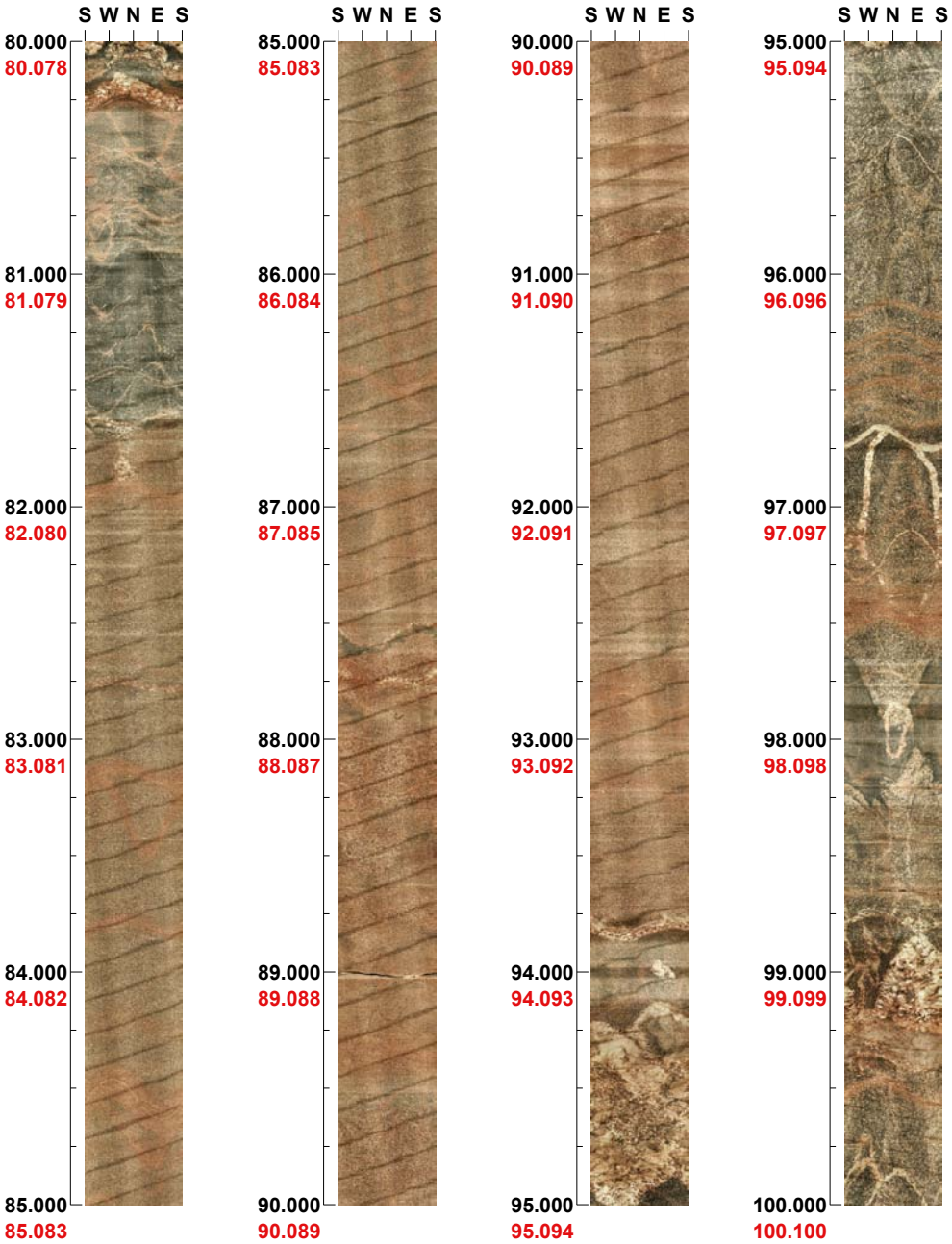
Depth range: 60.000 - 80.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR27 **Azimuth: 0** **Inclination: -90**

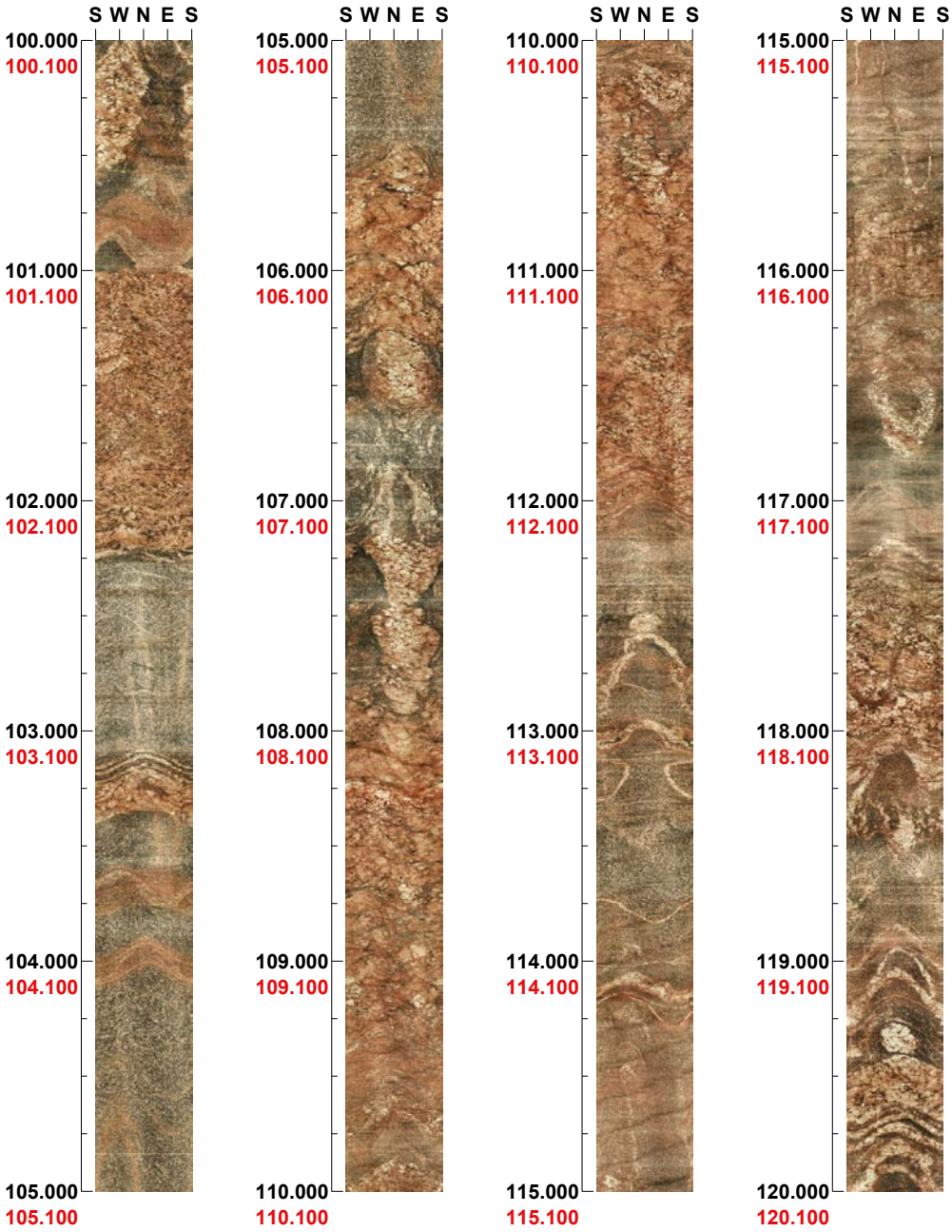
Depth range: 80.000 - 100.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR27 **Azimuth: 0** **Inclination: -90**

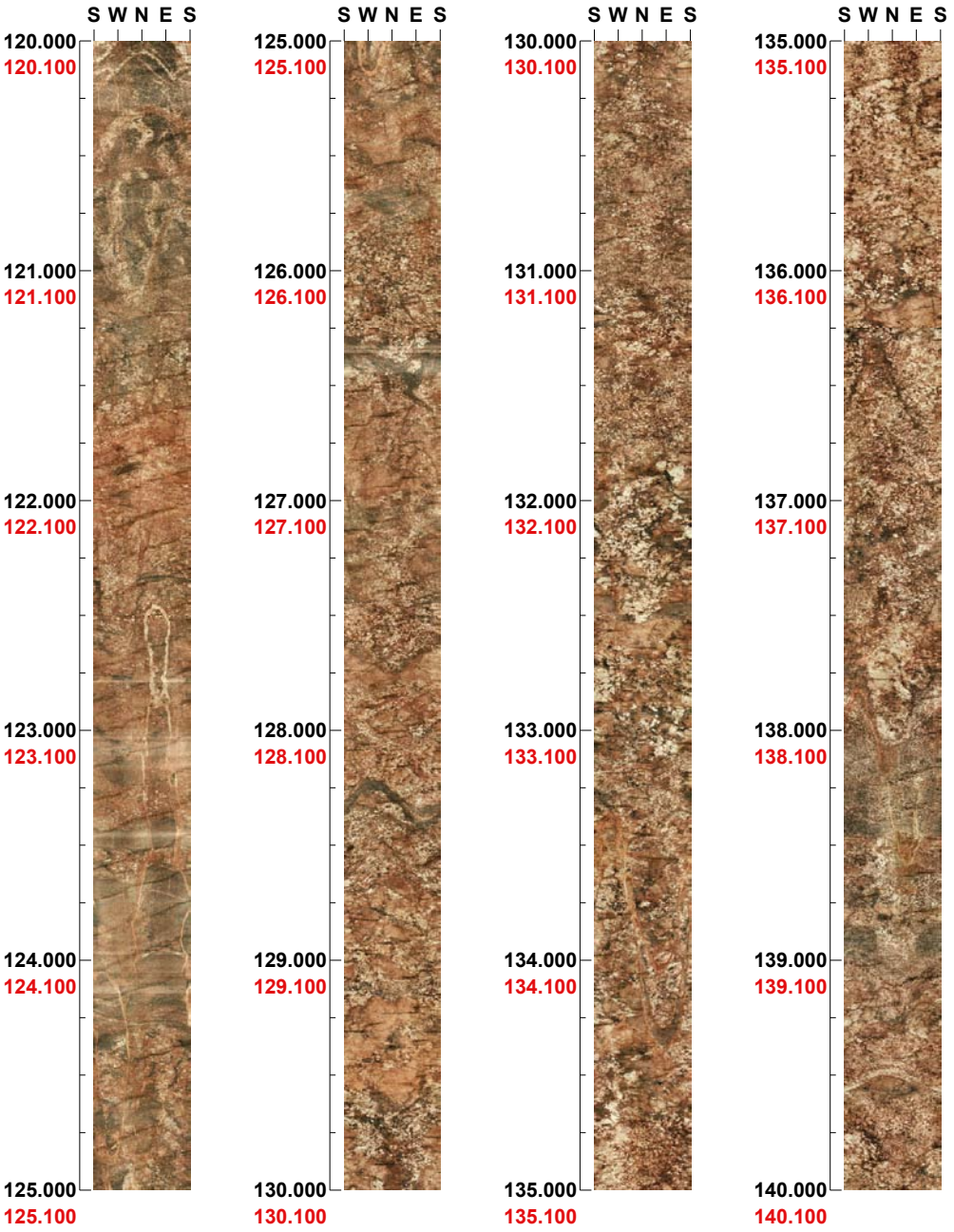
Depth range: 100.000 - 120.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR27 **Azimuth: 0** **Inclination: -90**

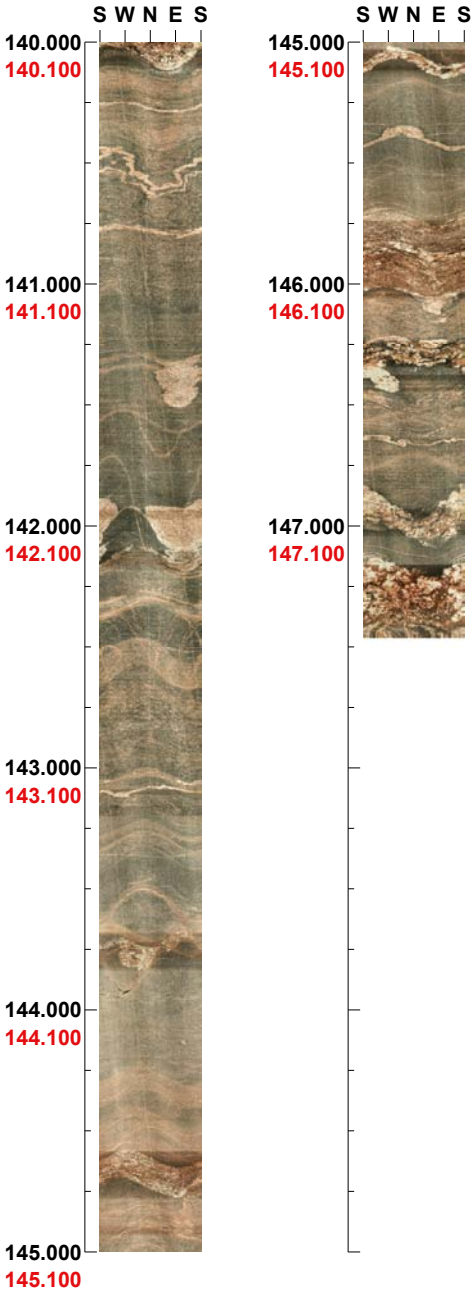
Depth range: 120.000 - 140.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR27 **Azimuth: 0** **Inclination: -90**

Depth range: 140.000 - 147.457 m



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

Appendix 4

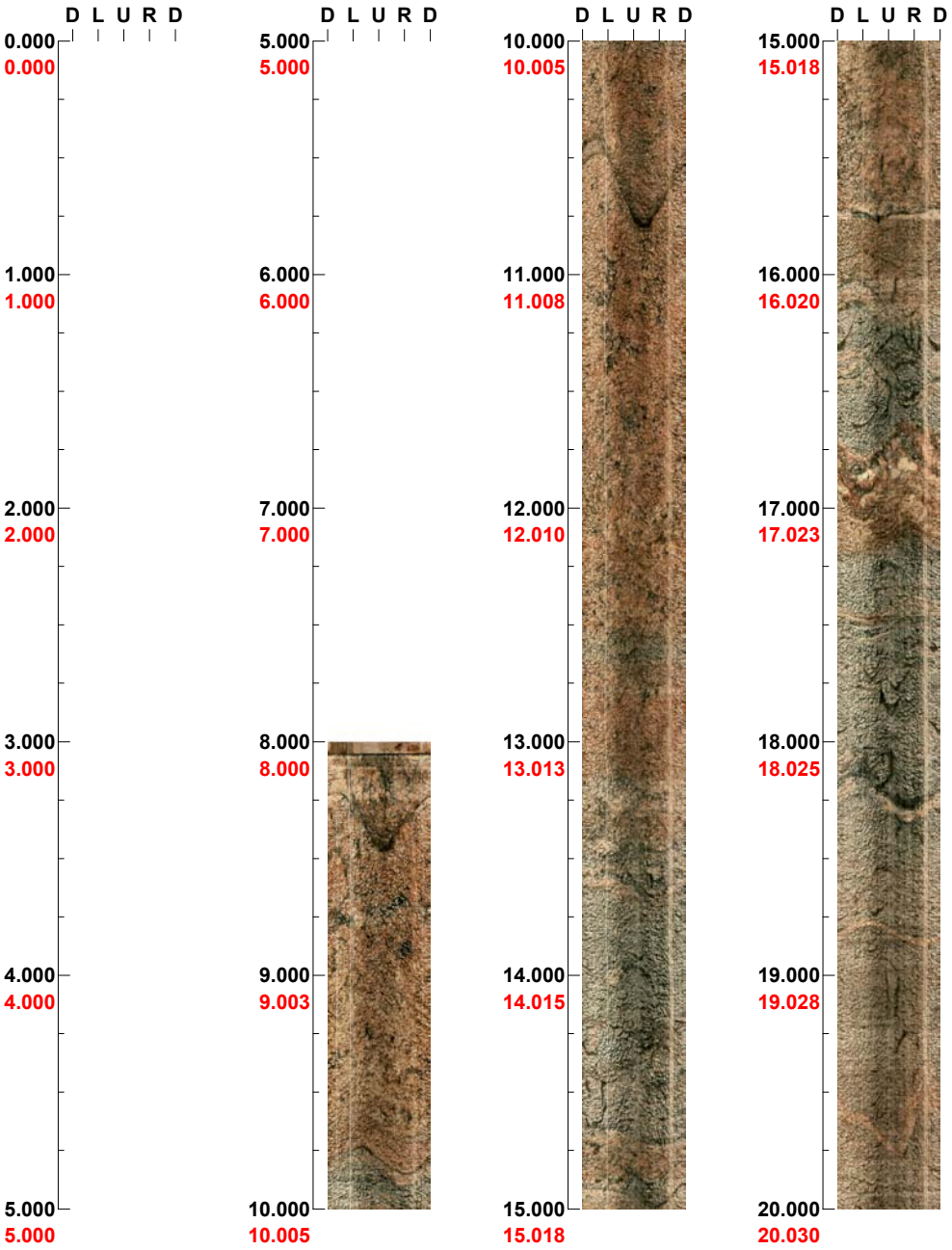
BIPS logging in HFR101. 8 to 207 m

Project name: Forsmark SFR

Image file	**: d:\work\forsmark\apsfr-~1\bipsda~1\hfr101\hfr101.b**
BDT file	**: d:\work\forsmark\apsfr-~1\bipsda~1\hfr101\hfr101.b**
Locality	**: SFR**
Bore hole number	**: HFR101**
Date	**: 08/05/20**
Time	**: 08:47:00**
Depth range	**: 8.000 - 207.299 m**
Azimuth	**: 134**
Inclination	**: -70**
Diameter	**: 140.0 mm**
Magnetic declination	**: 0.0**
Span	**: 4**
Scan interval	**: 0.25**
Scan direction	**: To bottom**
Scale	**: 1/25**
Aspect ratio	**: 100 %**
Pages	**: 11**
Color	**:**  **+0 +0 +0**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 134** **Inclination: -70**

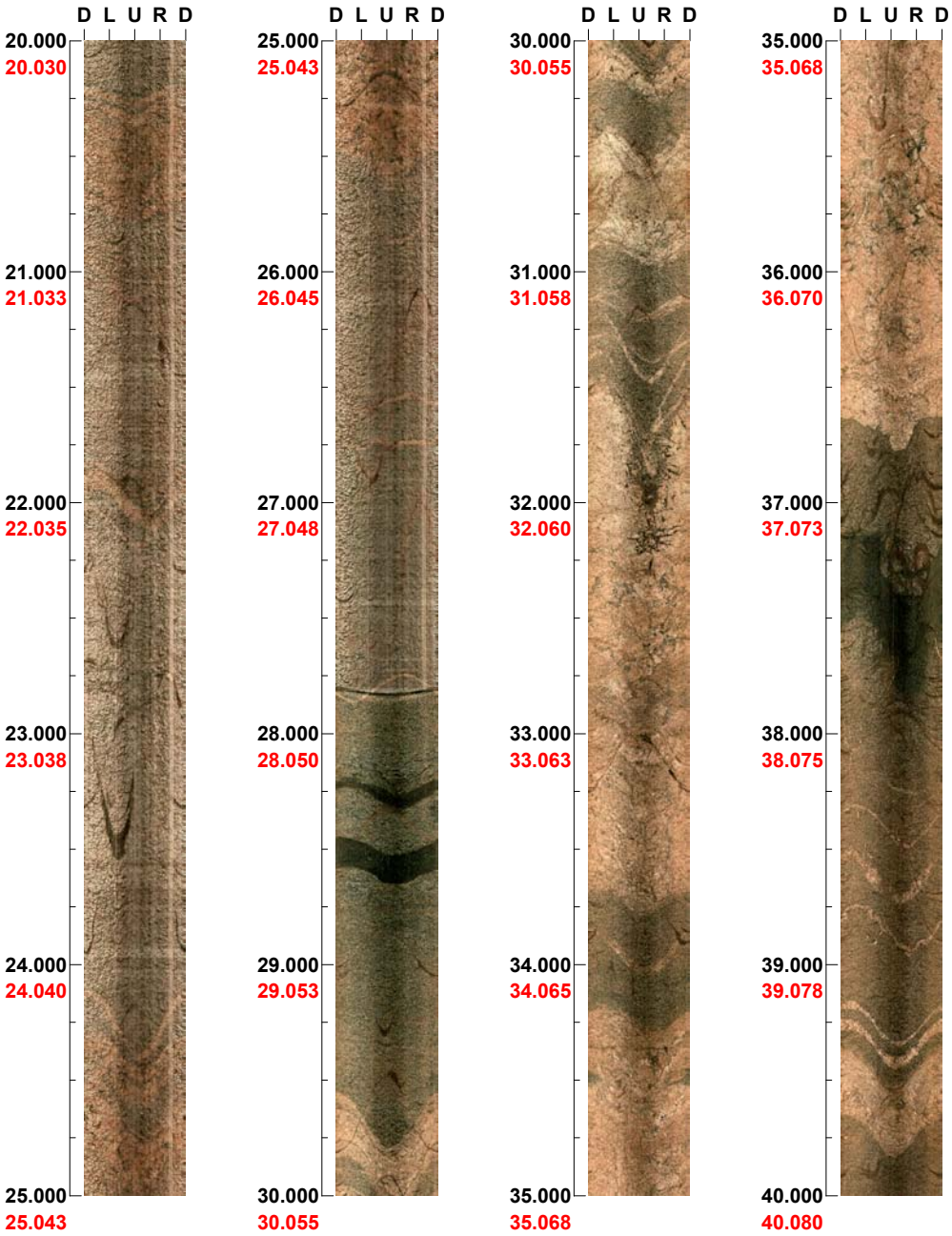
Depth range: 0.000 - 20.000 m



(1 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 134** **Inclination: -70**

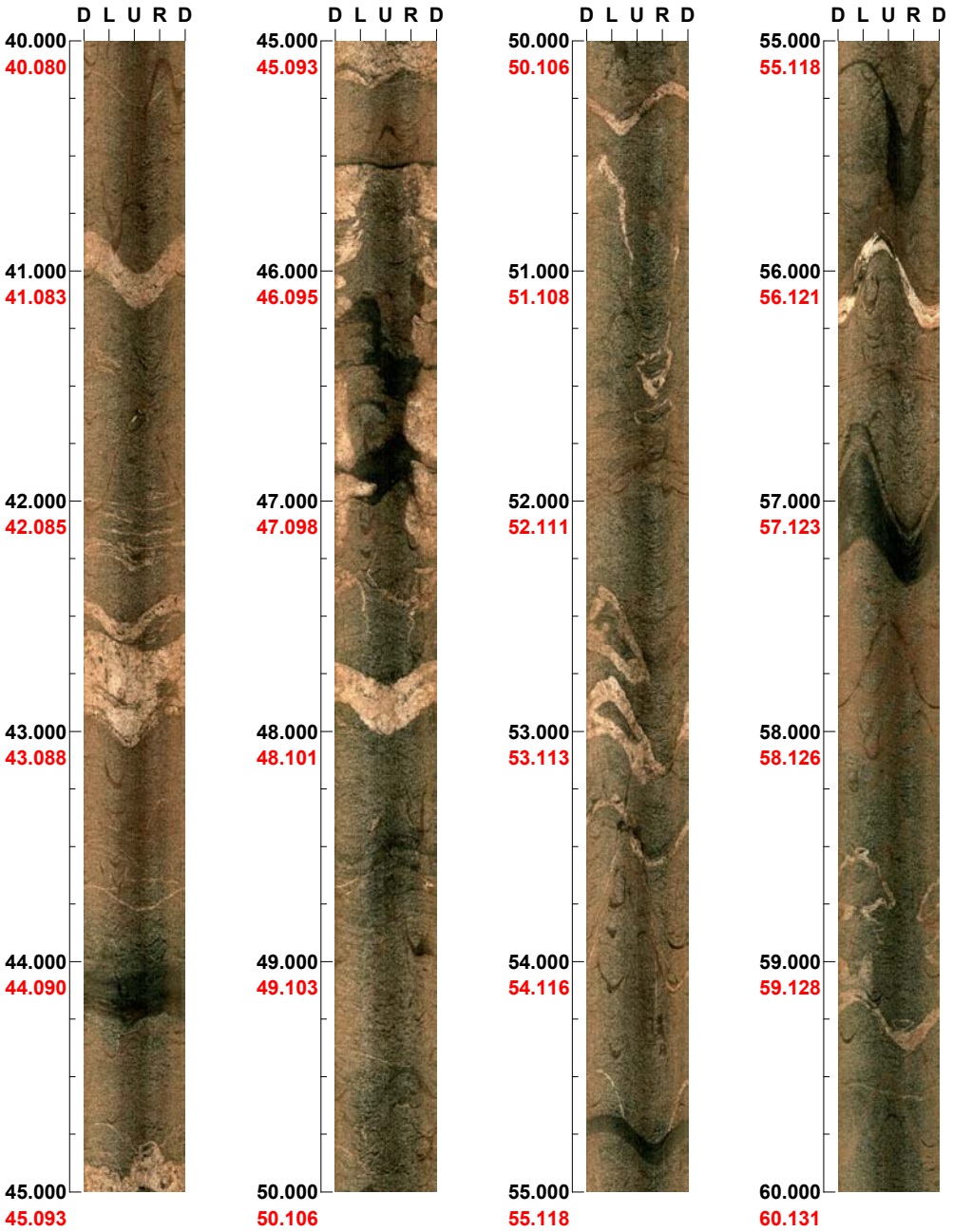
Depth range: 20.000 - 40.000 m



(2 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 134** **Inclination: -70**

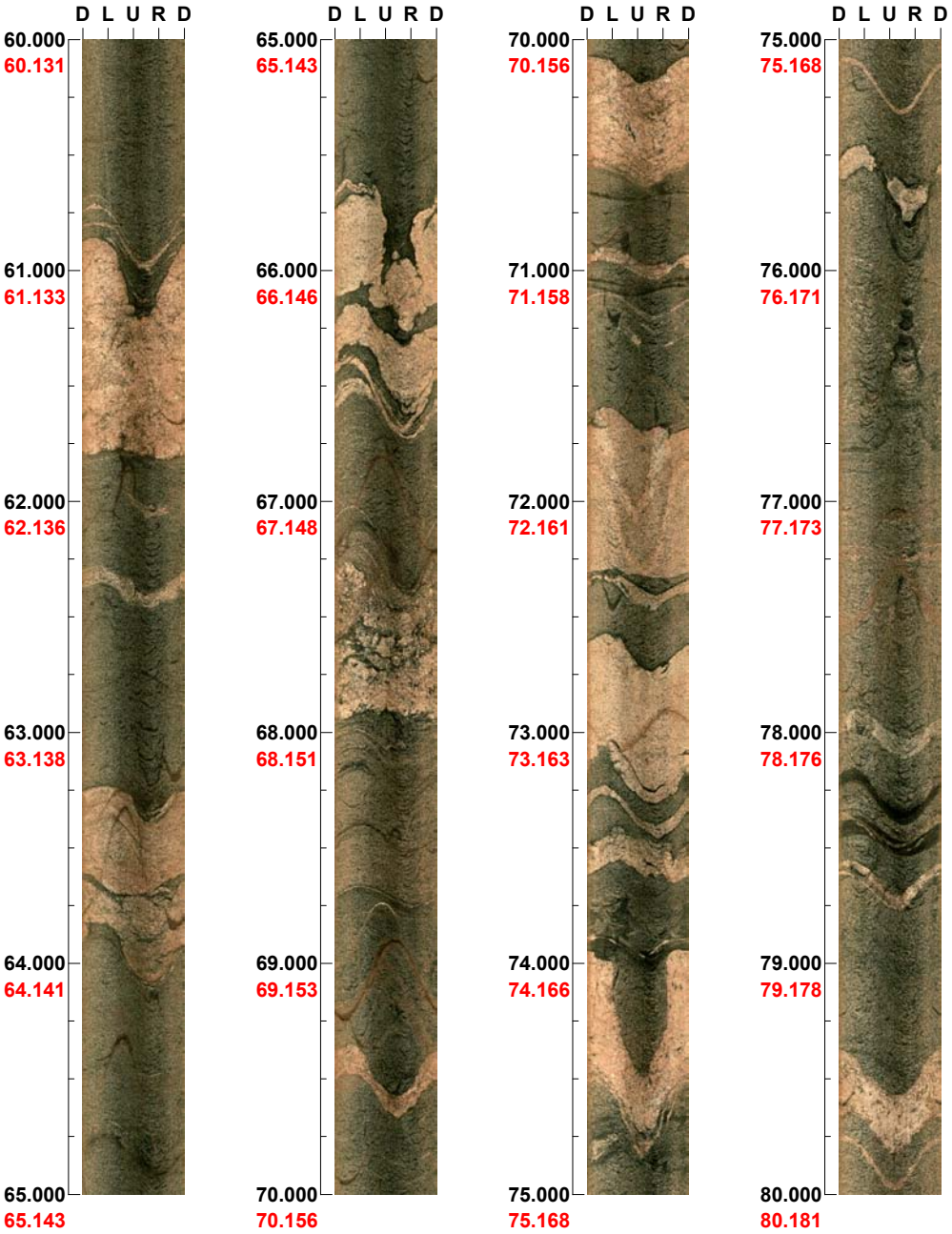
Depth range: 40.000 - 60.000 m



(3 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 134** **Inclination: -70**

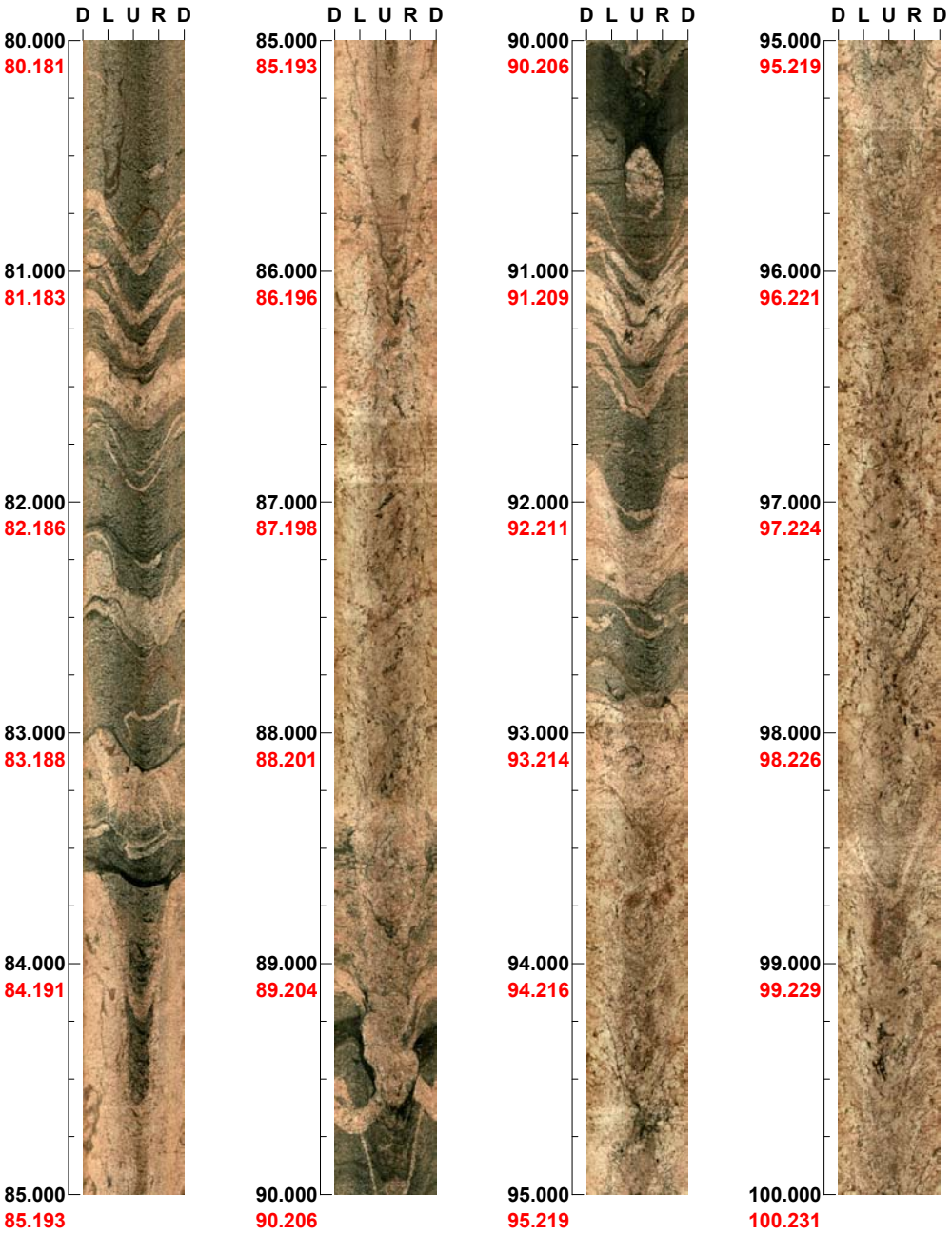
Depth range: 60.000 - 80.000 m



(4 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 134** **Inclination: -70**

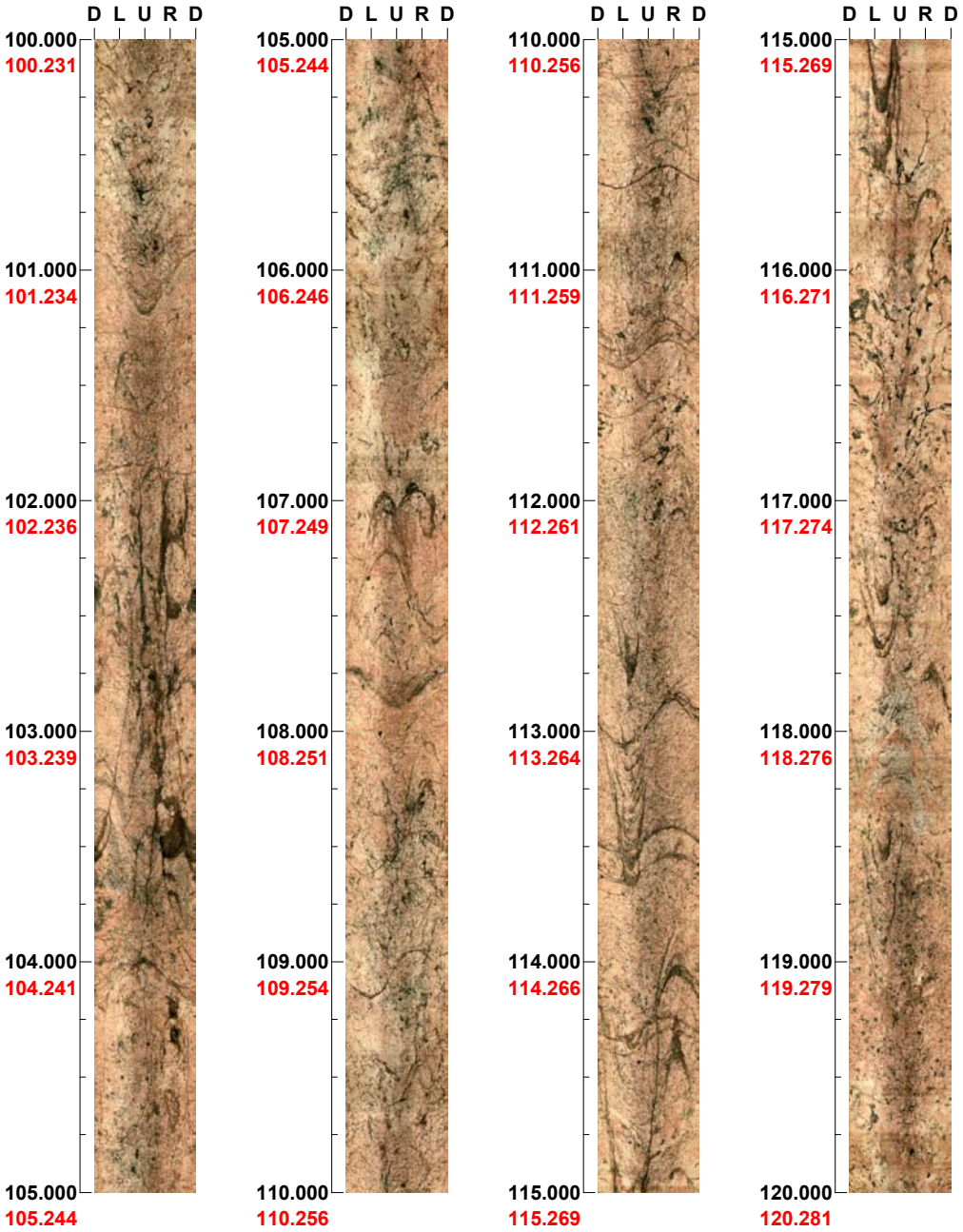
Depth range: 80.000 - 100.000 m



(5 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 134** **Inclination: -70**

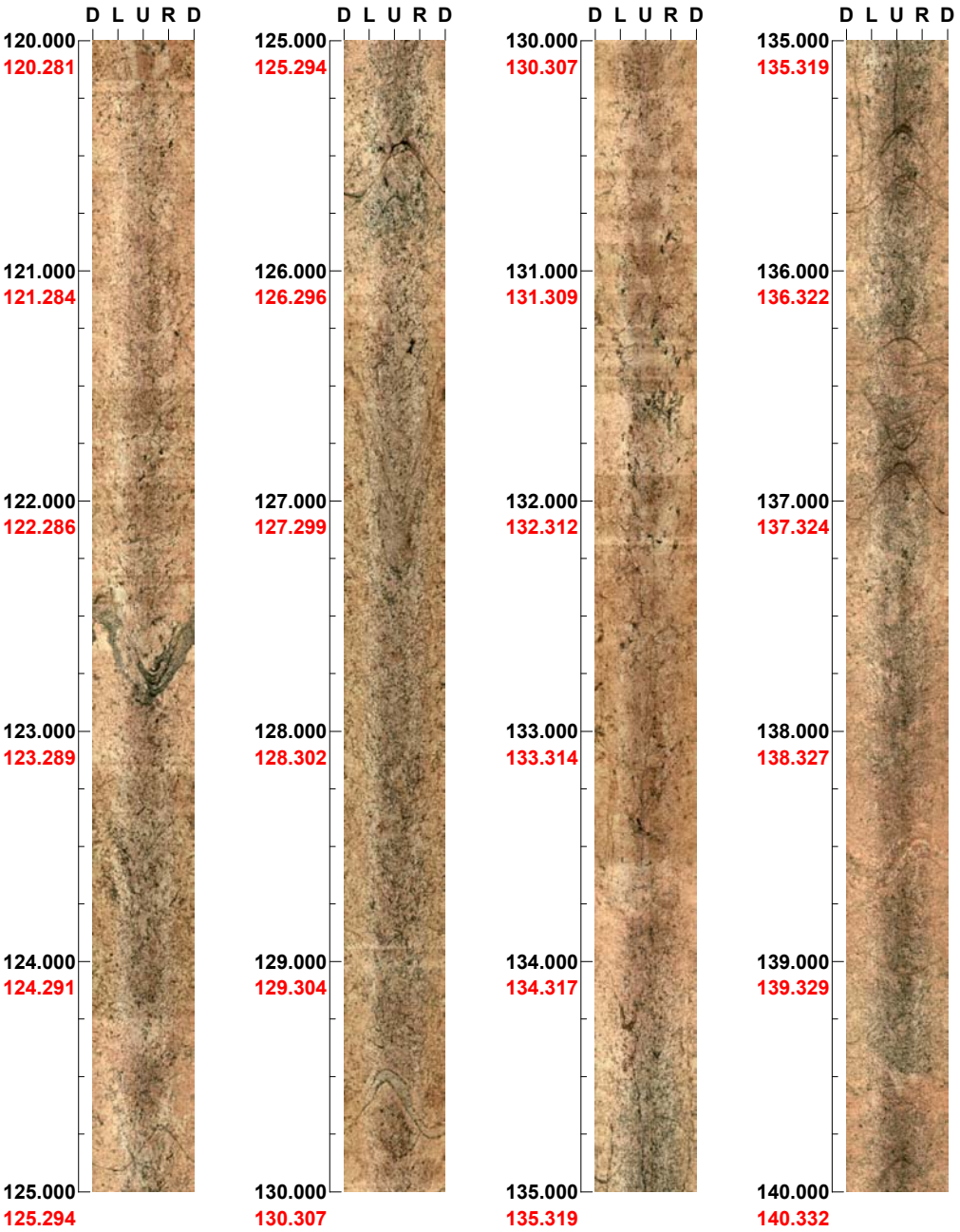
Depth range: 100.000 - 120.000 m



(6 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 134** **Inclination: -70**

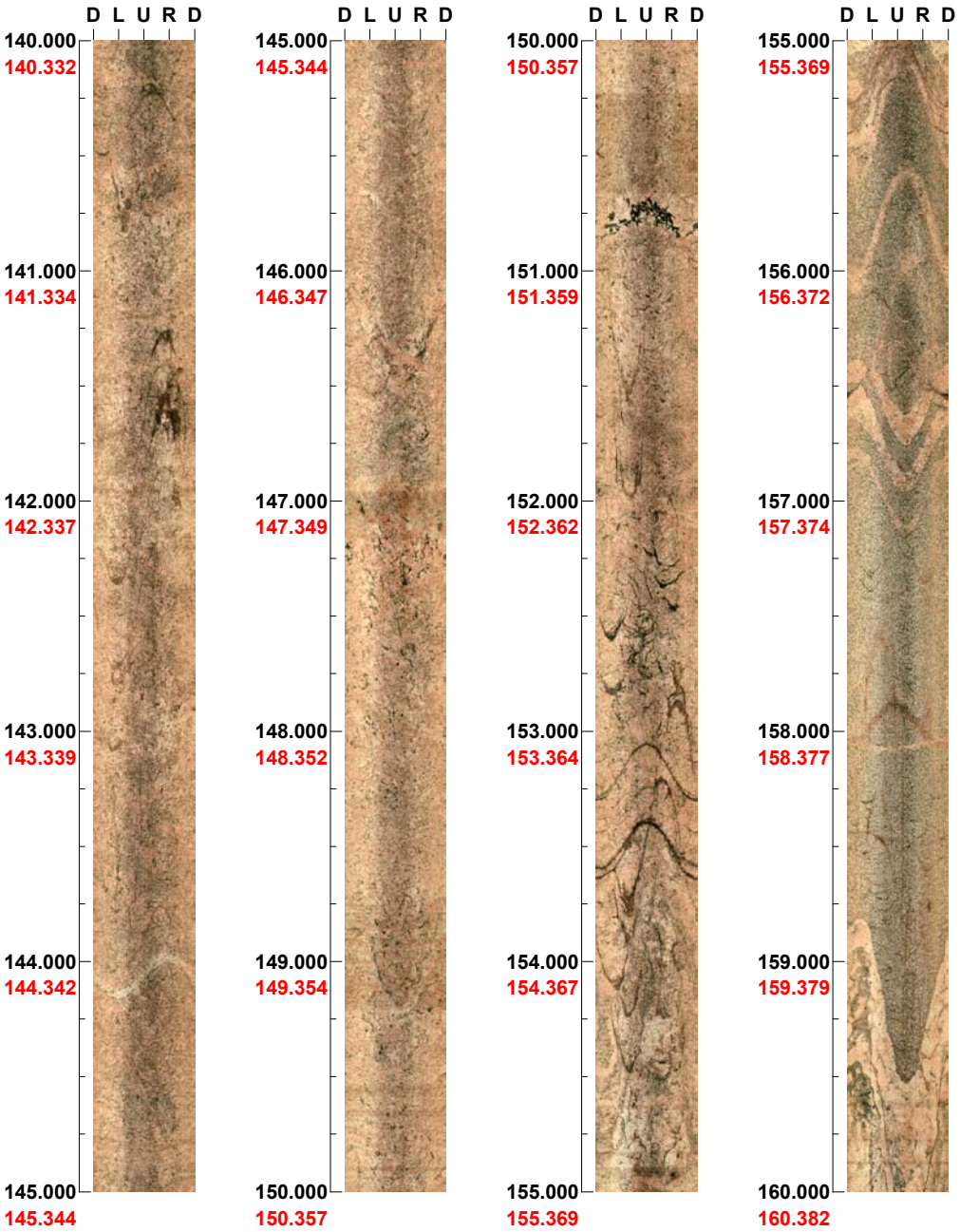
Depth range: 120.000 - 140.000 m



(7 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 134** **Inclination: -70**

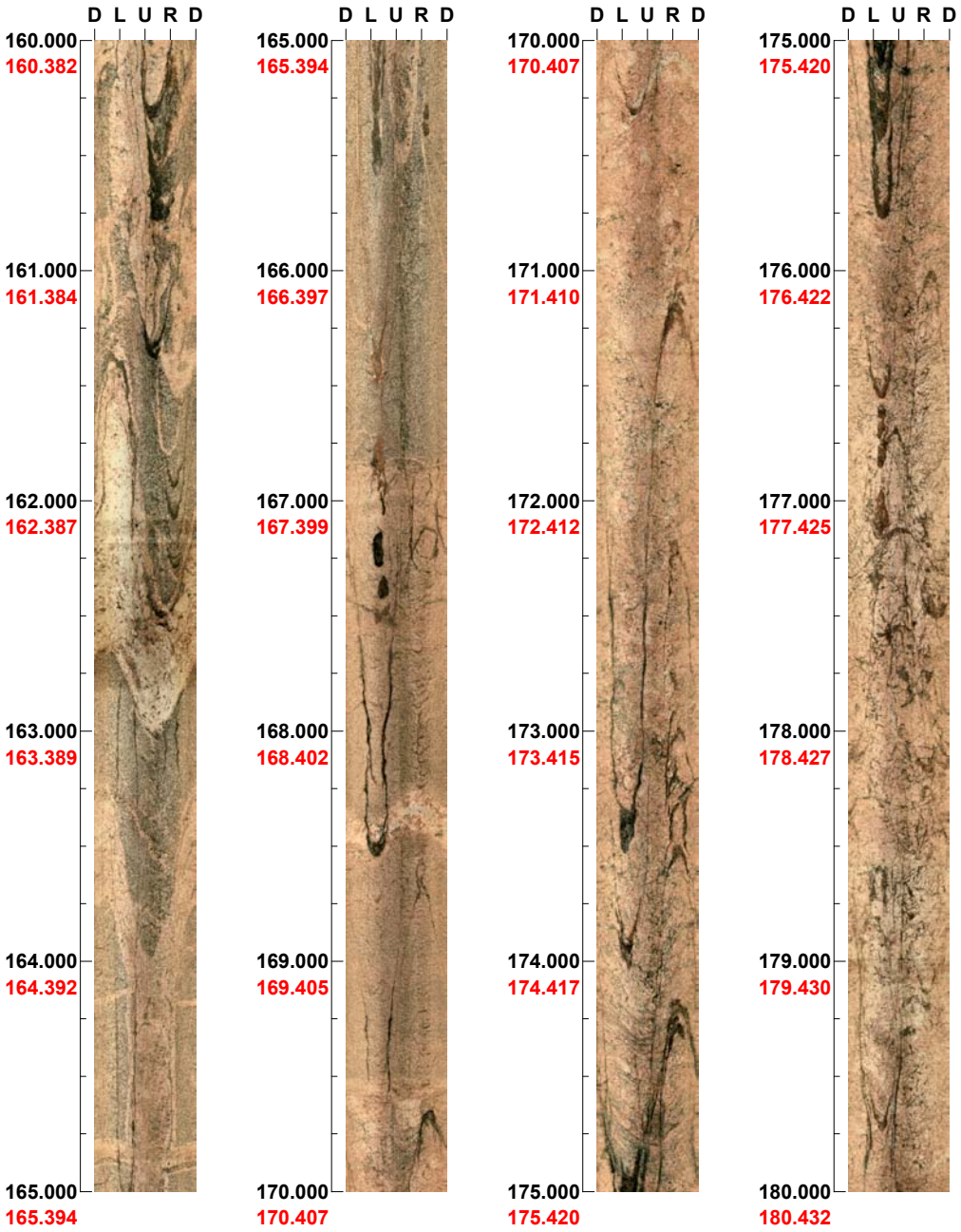
Depth range: 140.000 - 160.000 m



(8 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 134** **Inclination: -70**

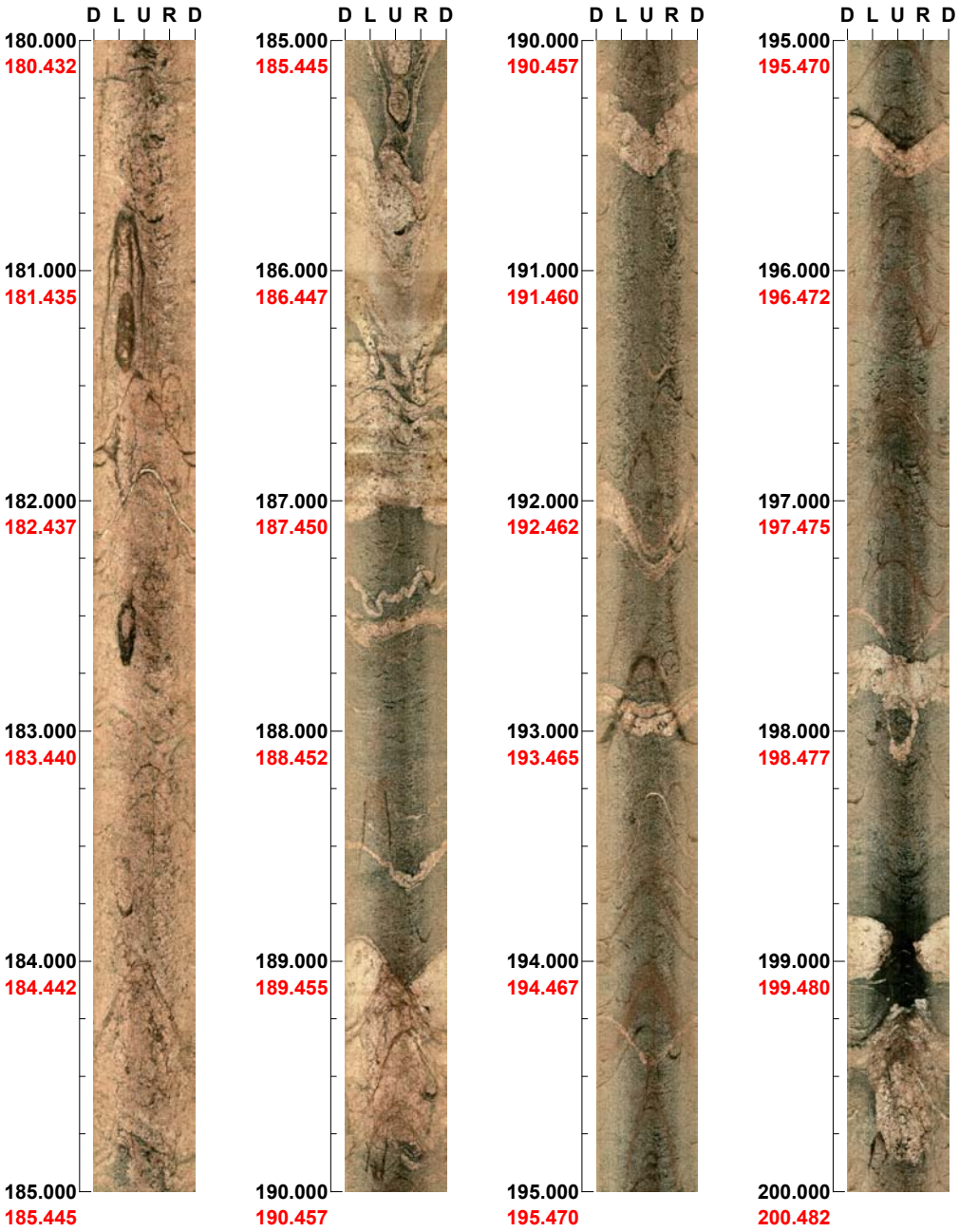
Depth range: 160.000 - 180.000 m



(9 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 134** **Inclination: -70**

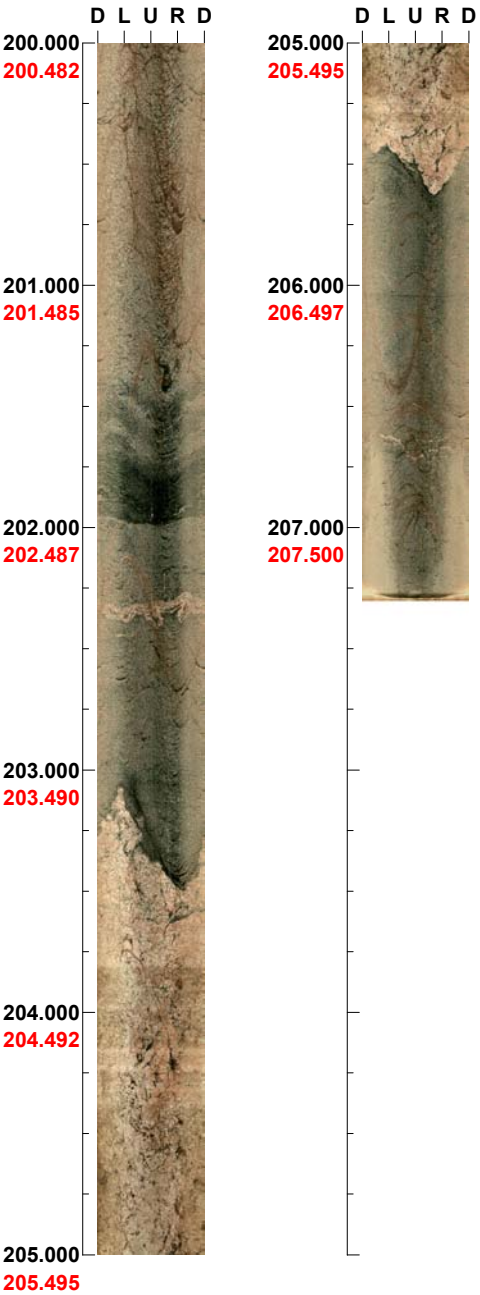
Depth range: 180.000 - 200.000 m



(10 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 134** **Inclination: -70**

Depth range: 200.000 - 207.299 m



(11 / 11) **Scale: 1/25** **Aspect ratio: 100 %**

Appendix 5

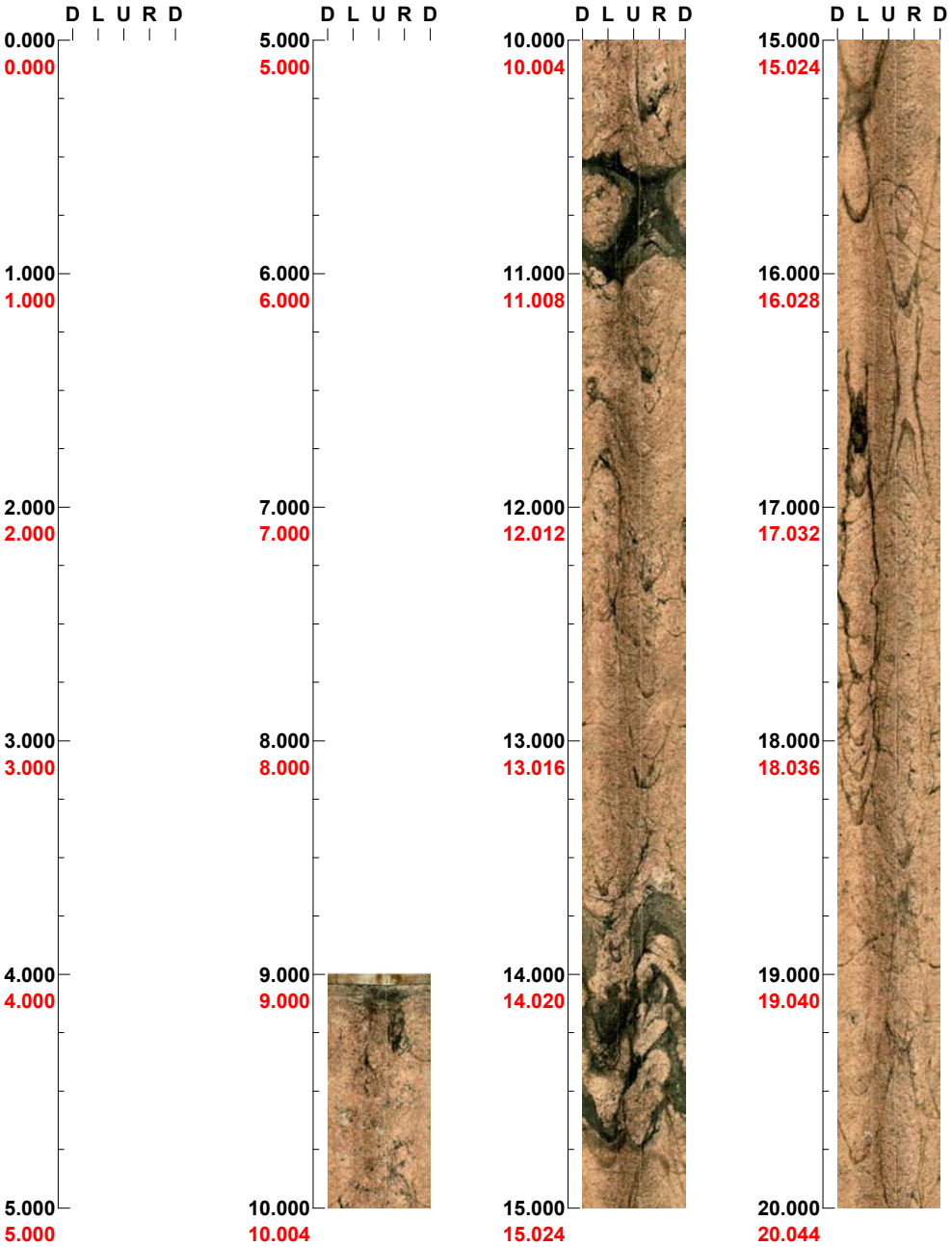
BIPS logging in HFR102. 9 to 55 m

Project name: Forsmark SFR

Image file	**: d:\work\forsmark\apsfr-~1\bipsda~1\hfr102\hfr102.b**
BDT file	**: d:\work\forsmark\apsfr-~1\bipsda~1\hfr102\hfr102.b**
Locality	**: SFR**
Bore hole number	**: HFR102**
Date	**: 08/05/20**
Time	**: 13:10:00**
Depth range	**: 9.000 - 54.723 m**
Azimuth	**: 85**
Inclination	**: -59**
Diameter	**: 140.0 mm**
Magnetic declination	**: 0.0**
Span	**: 4**
Scan interval	**: 0.25**
Scan direction	**: To bottom**
Scale	**: 1/25**
Aspect ratio	**: 100 %**
Pages	**: 3**
Color	**:**  **+0 +0 +0**

Project name: Forsmark SFR
Bore hole No.: HFR102 **Azimuth: 85** **Inclination: -59**

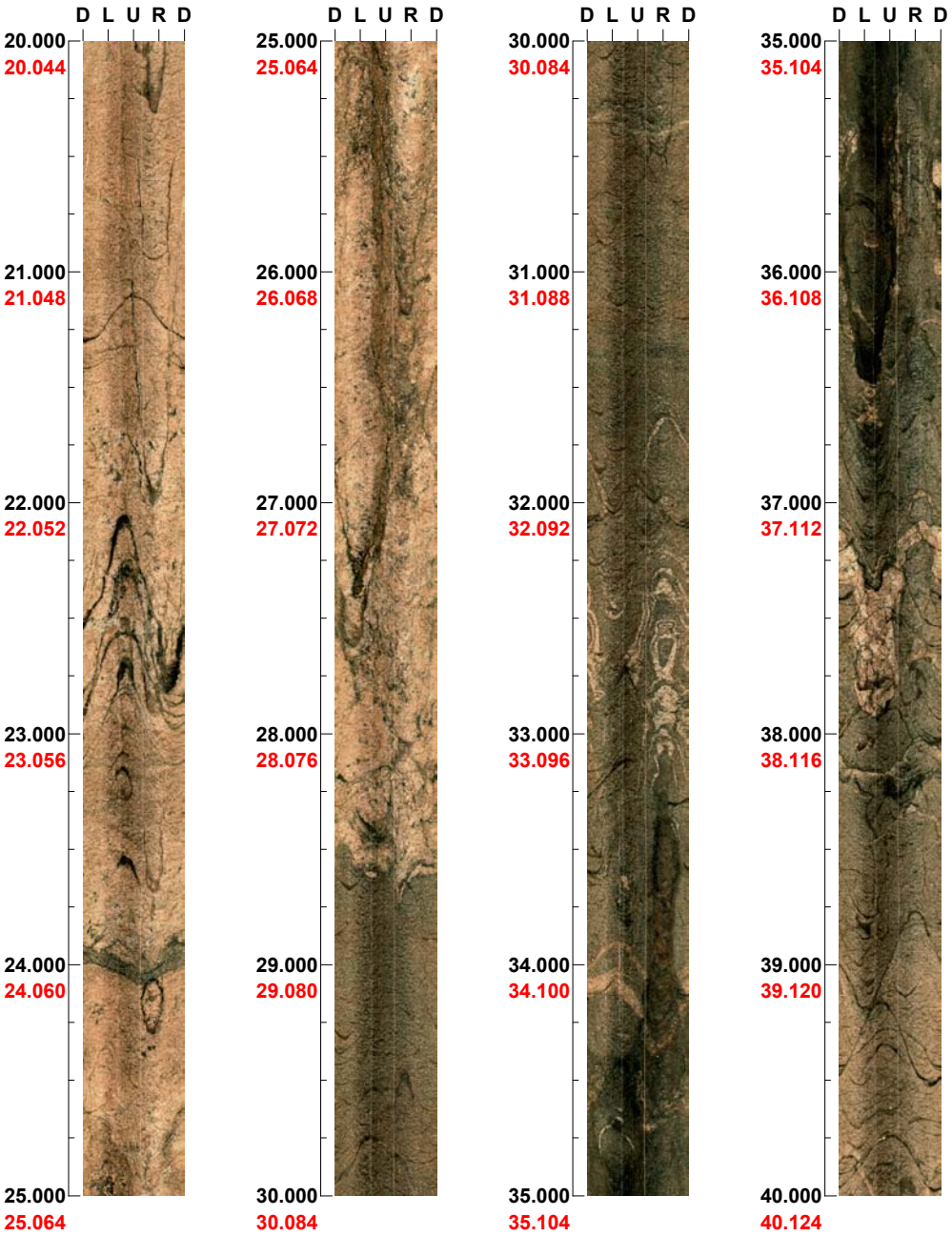
Depth range: 0.000 - 20.000 m



(1 / 3) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR102 **Azimuth: 85** **Inclination: -59**

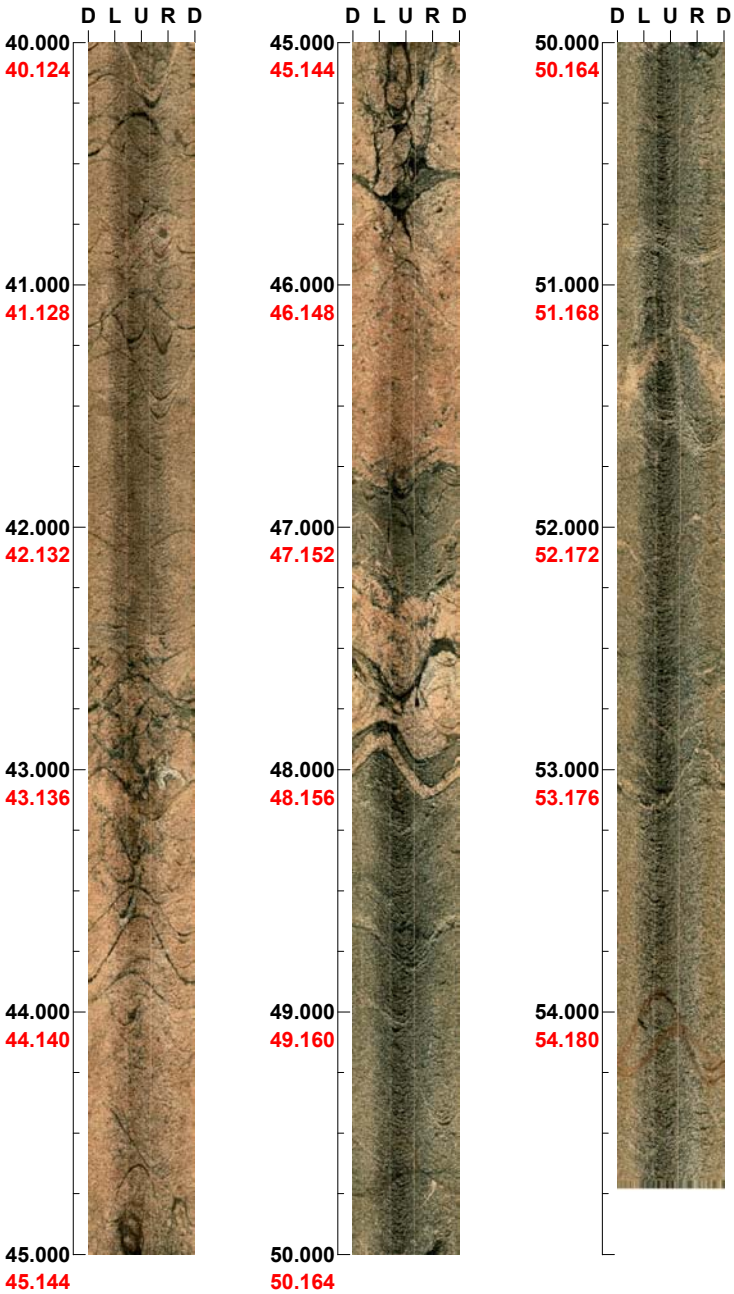
Depth range: 20.000 - 40.000 m



(2 / 3) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR102 **Azimuth: 85** **Inclination: -59**

Depth range: 40.000 - 54.723 m



(3 / 3) **Scale: 1/25** **Aspect ratio: 100 %**

Appendix 6

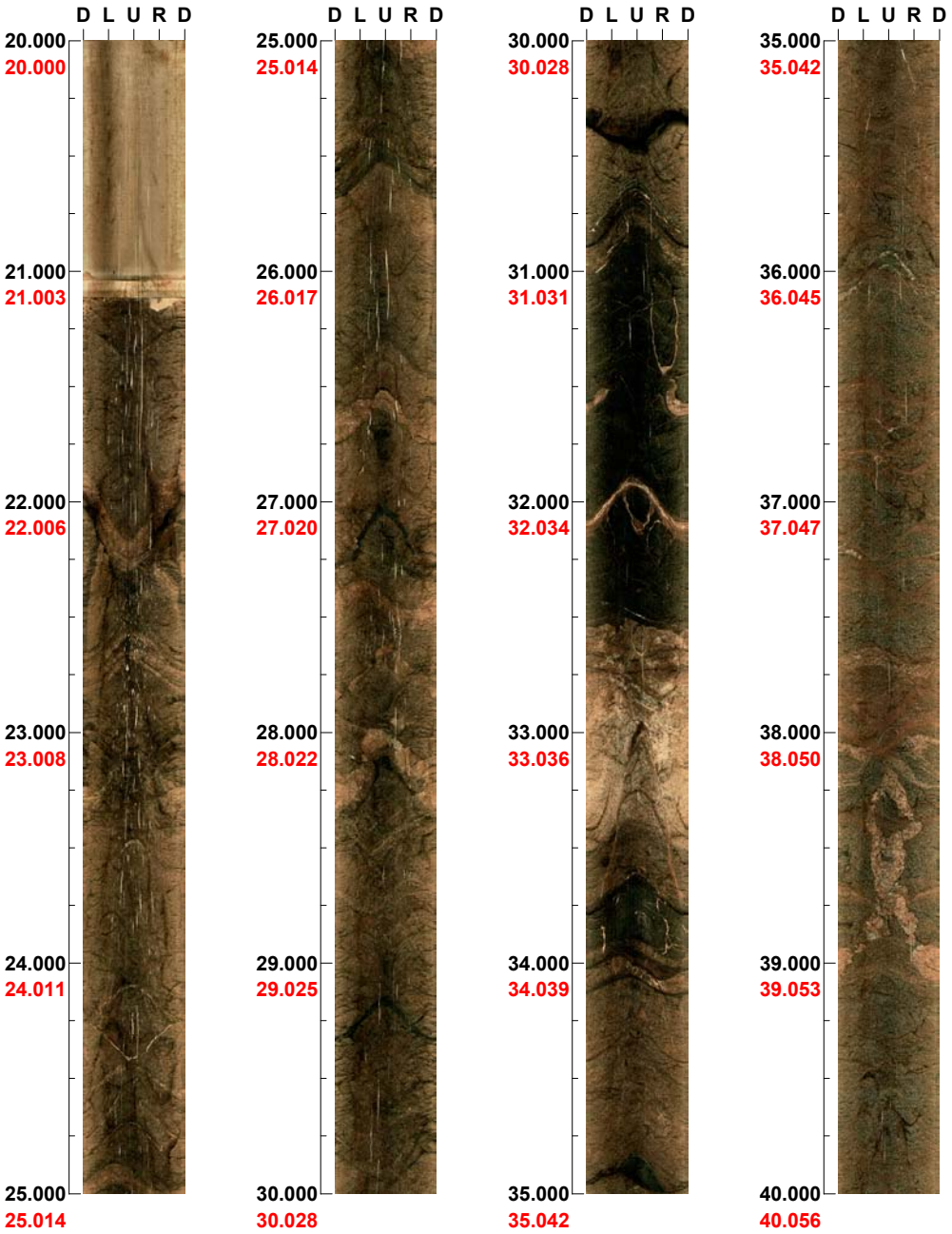
BIPS logging in HFR105. 20 to 199 m

Project name: Forsmark SFR

Image file	**: d:\work\forsmark\apsfr-~1\bipsda~1\hfr105\hfr105.b**
BDT file	**: d:\work\forsmark\apsfr-~1\bipsda~1\hfr105\hfr105.b**
Locality	**: SFR**
Bore hole number	**: HFR105**
Date	**: 08/05/19**
Time	**: 13:00:00**
Depth range	**: 20.000 - 199.090 m**
Azimuth	**: 35**
Inclination	**: -62**
Diameter	**: 140.0 mm**
Magnetic declination	**: 0.0**
Span	**: 4**
Scan interval	**: 0.25**
Scan direction	**: To bottom**
Scale	**: 1/25**
Aspect ratio	**: 100 %**
Pages	**: 9**
Color	**:**  **+0 +0 +0**

Project name: Forsmark SFR
Bore hole No.: HFR105 **Azimuth: 35** **Inclination: -62**

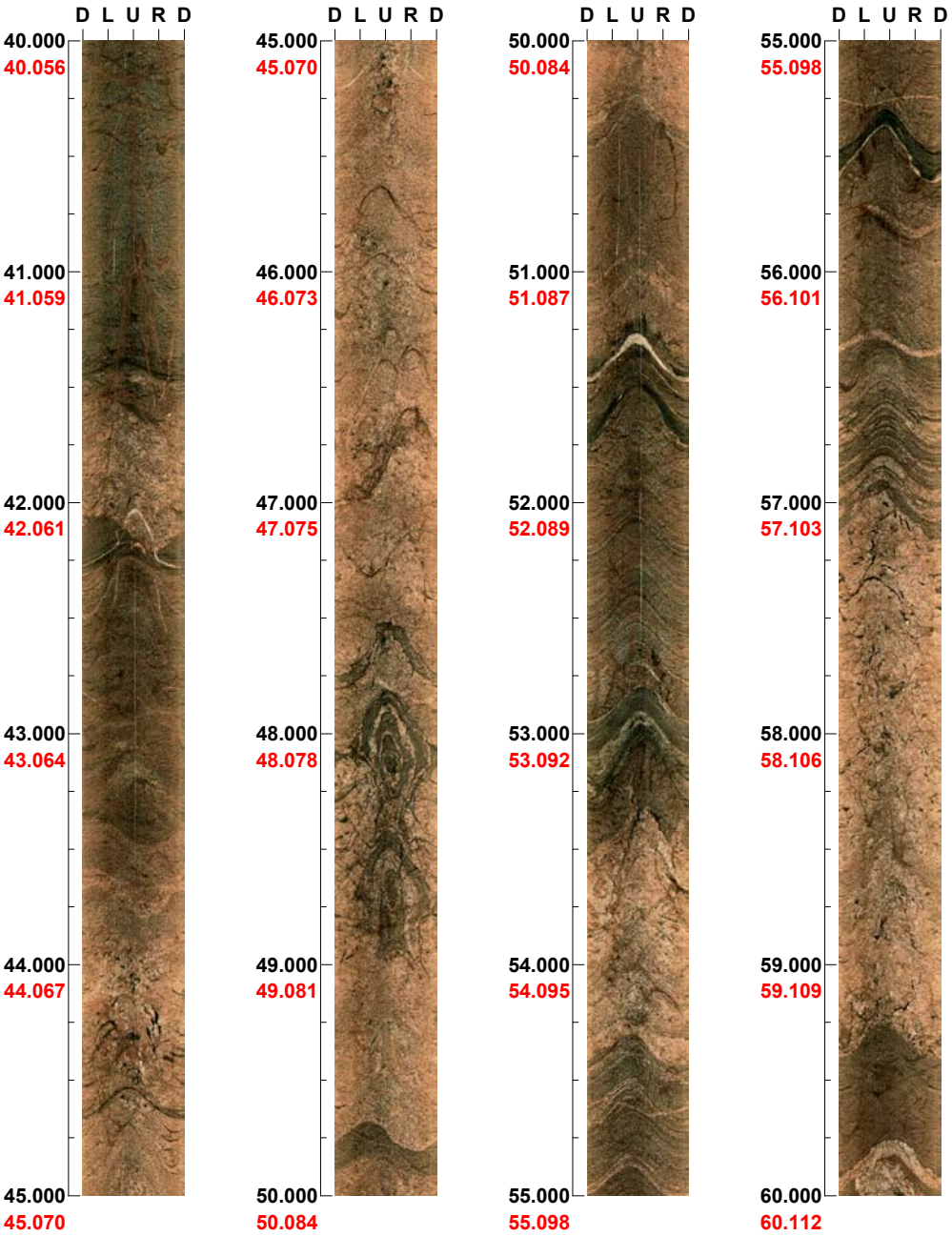
Depth range: 20.000 - 40.000 m



(1 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR105 **Azimuth: 35** **Inclination: -62**

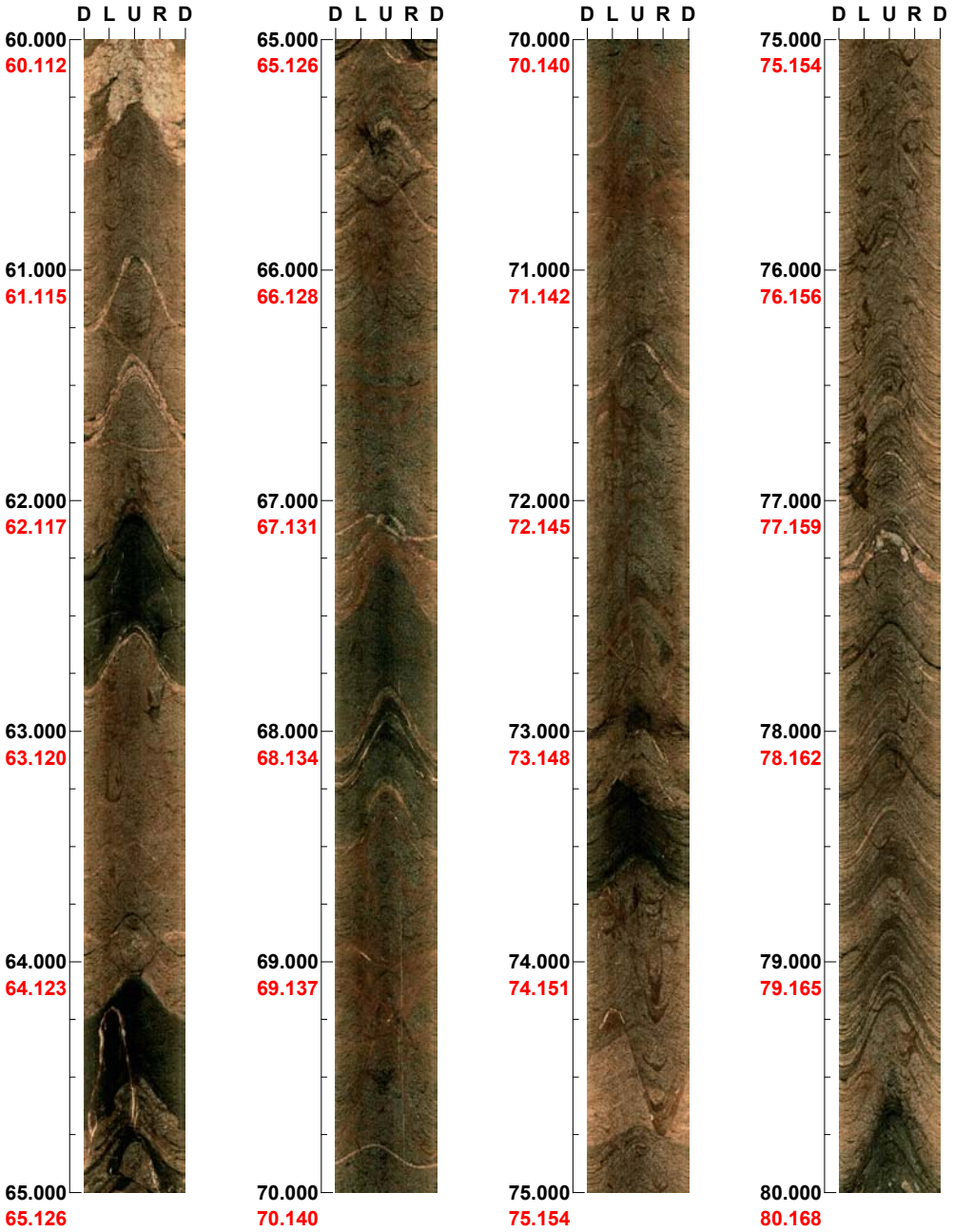
Depth range: 40.000 - 60.000 m



(2 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR105 **Azimuth: 35** **Inclination: -62**

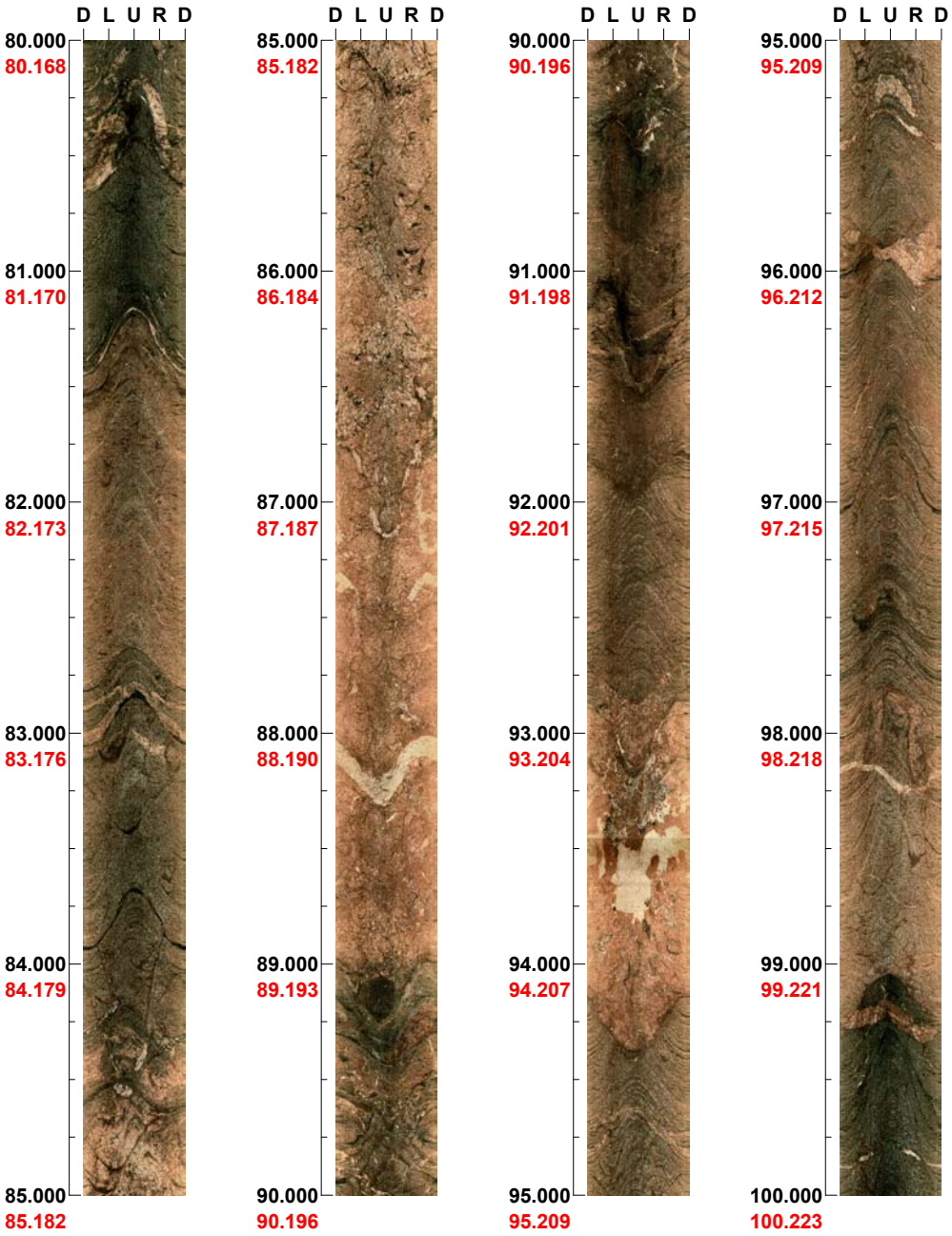
Depth range: 60.000 - 80.000 m



(3 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR105 **Azimuth: 35** **Inclination: -62**

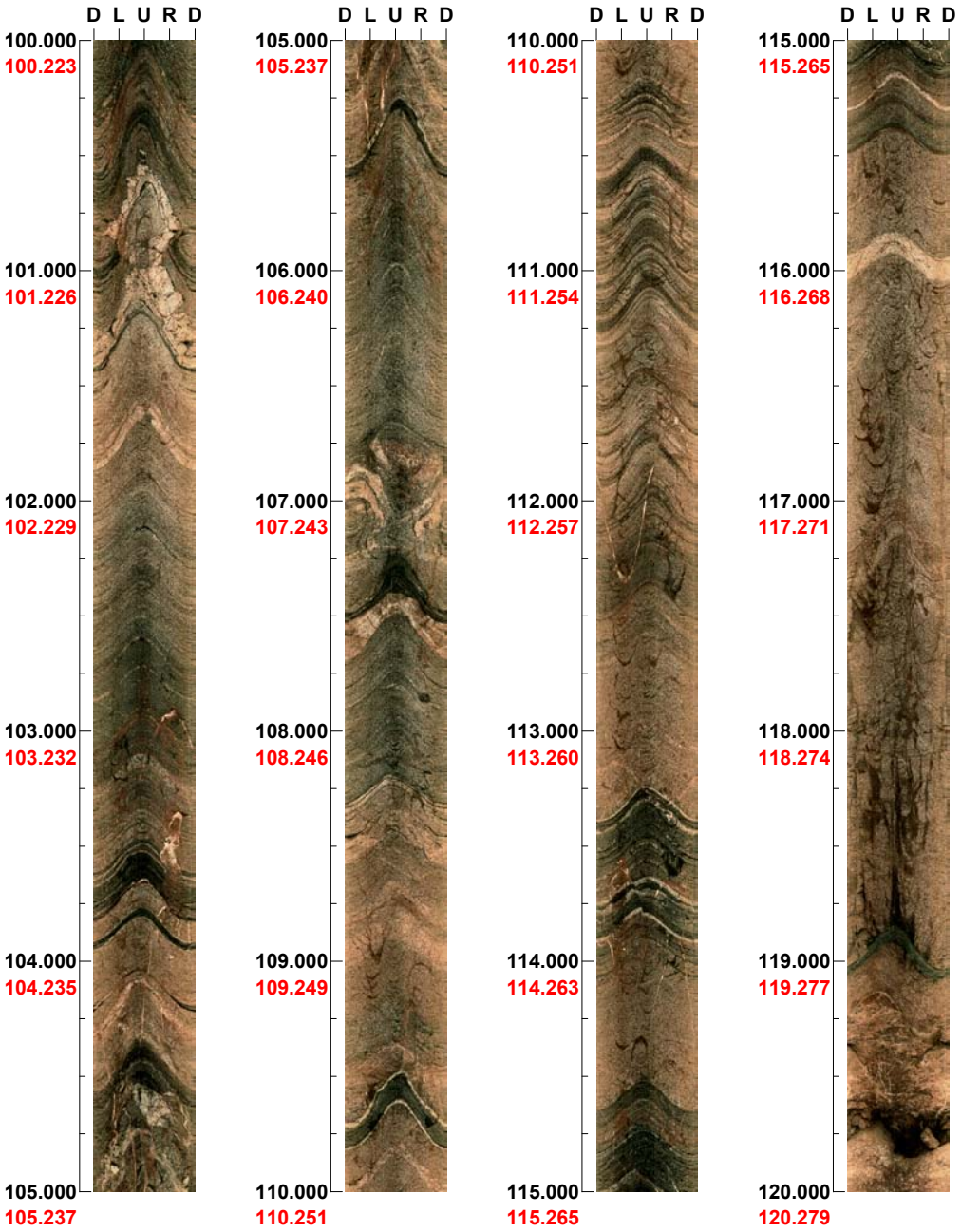
Depth range: 80.000 - 100.000 m



(4 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR105 **Azimuth: 35** **Inclination: -62**

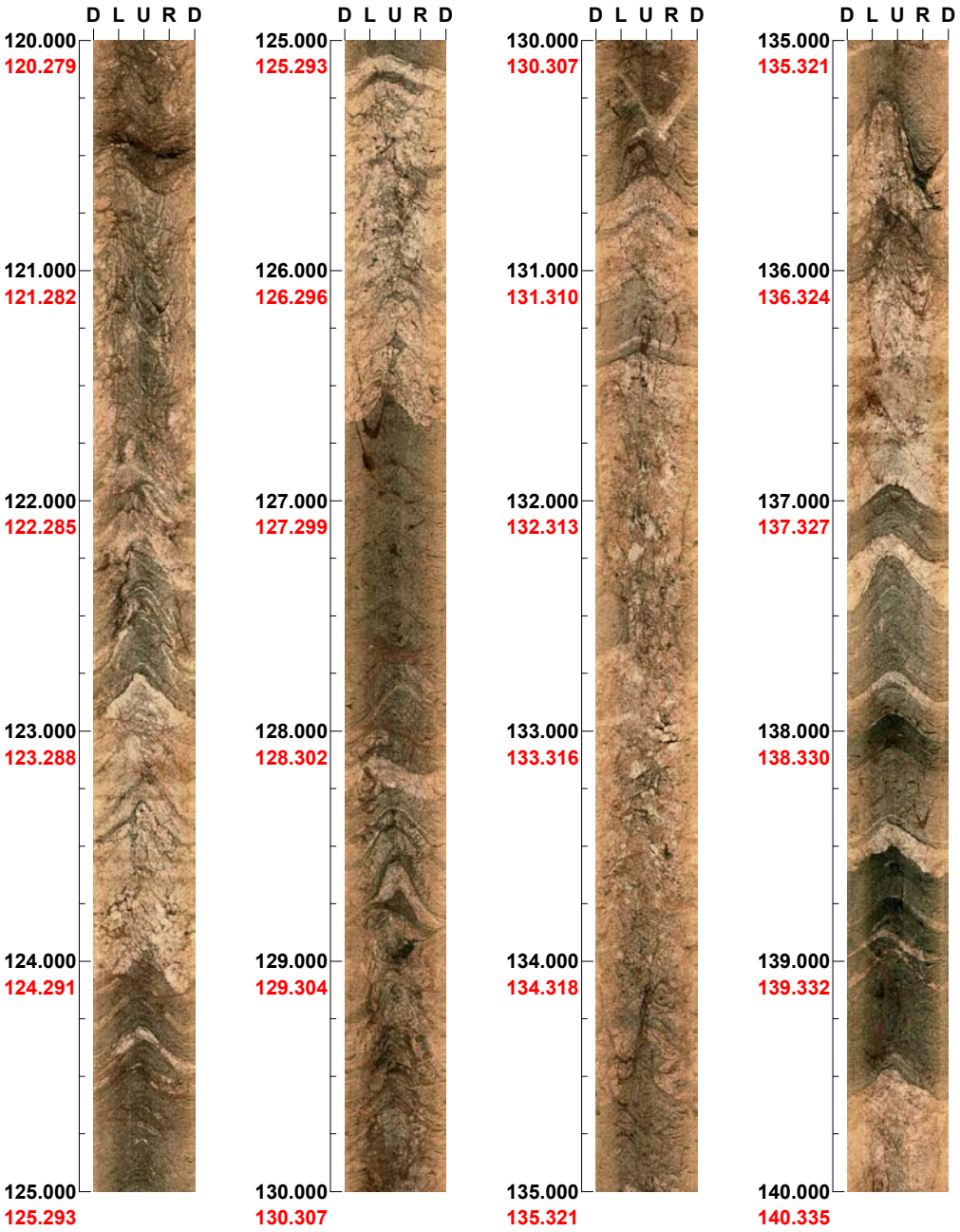
Depth range: 100.000 - 120.000 m



(5 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR105 **Azimuth: 35** **Inclination: -62**

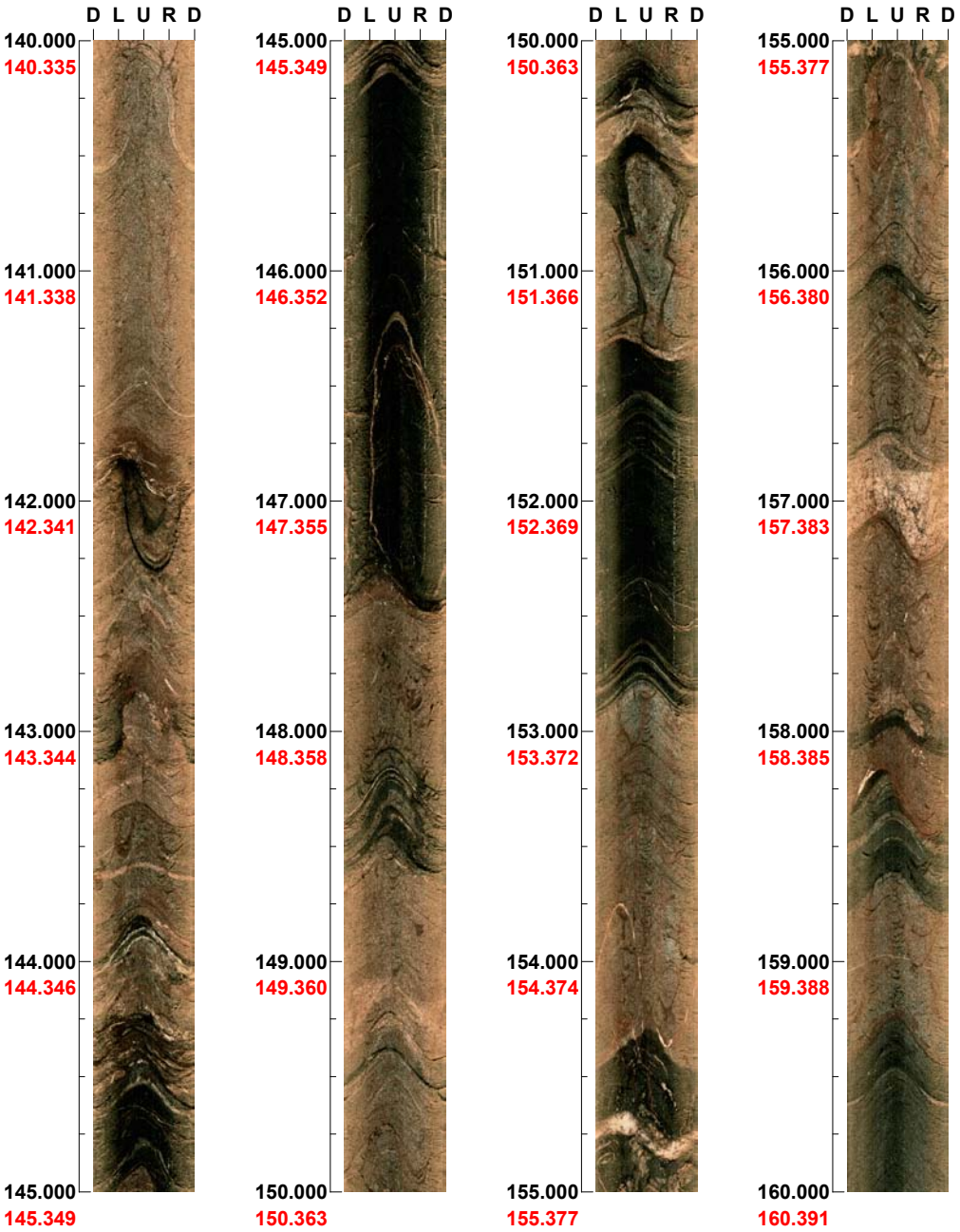
Depth range: 120.000 - 140.000 m



(6 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR105 **Azimuth: 35** **Inclination: -62**

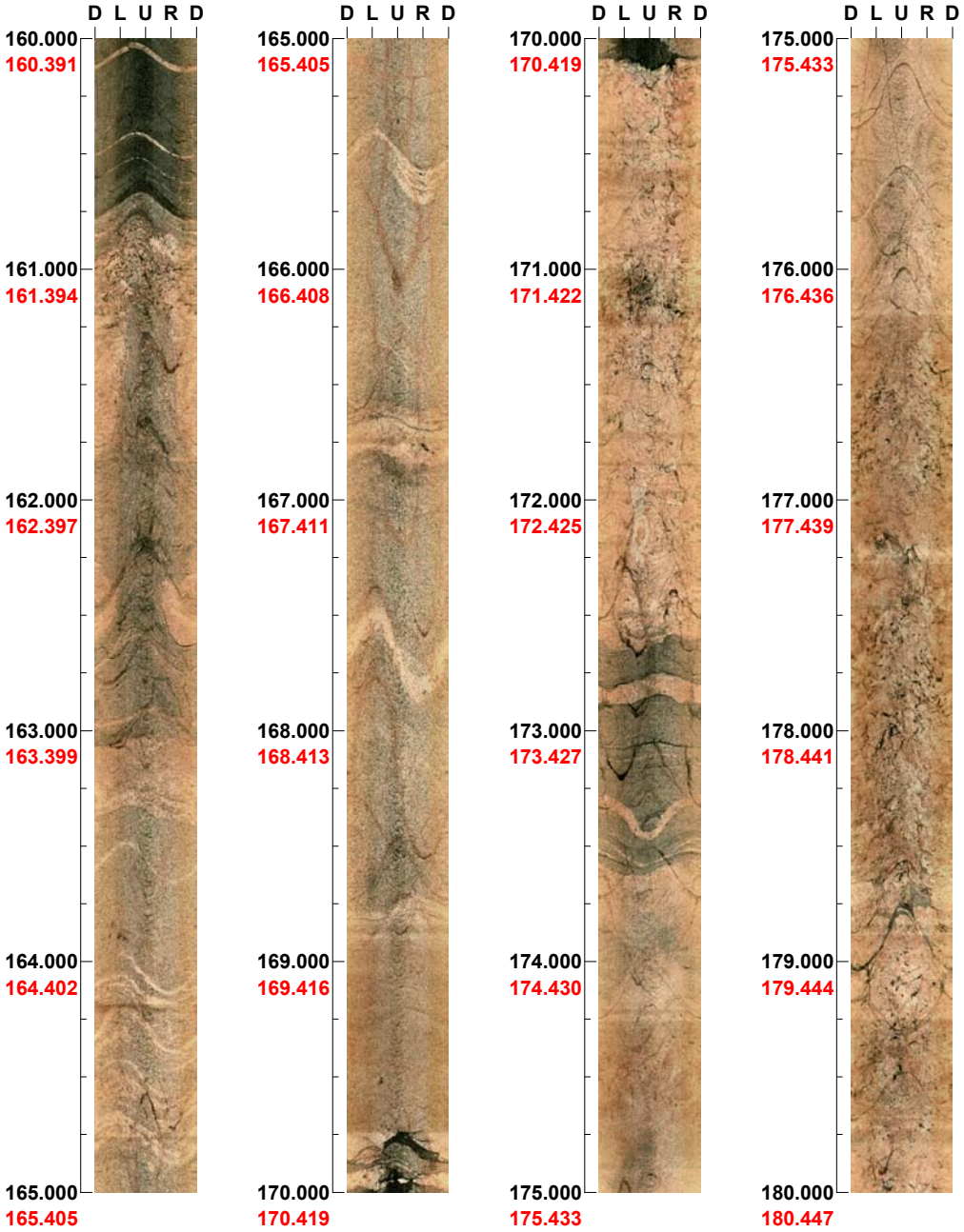
Depth range: 140.000 - 160.000 m



(7 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR105 **Azimuth: 35** **Inclination: -62**

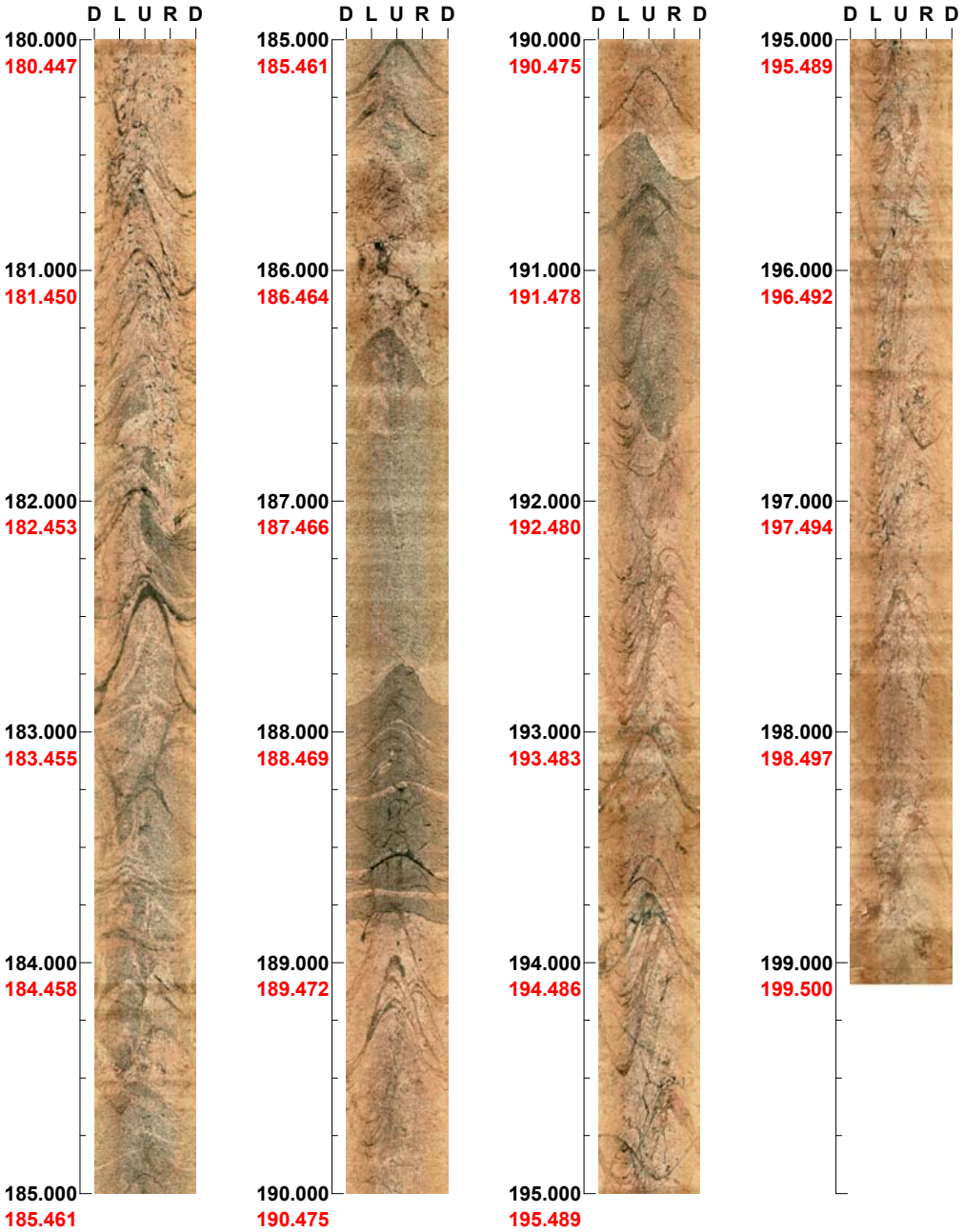
Depth range: 160.000 - 180.000 m



(8 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Project name: Forsmark SFR
Bore hole No.: HFR105 **Azimuth: 35** **Inclination: -62**

Depth range: 180.000 - 199.090 m



(9 / 9) **Scale: 1/25** **Aspect ratio: 100 %**

Appendix 7

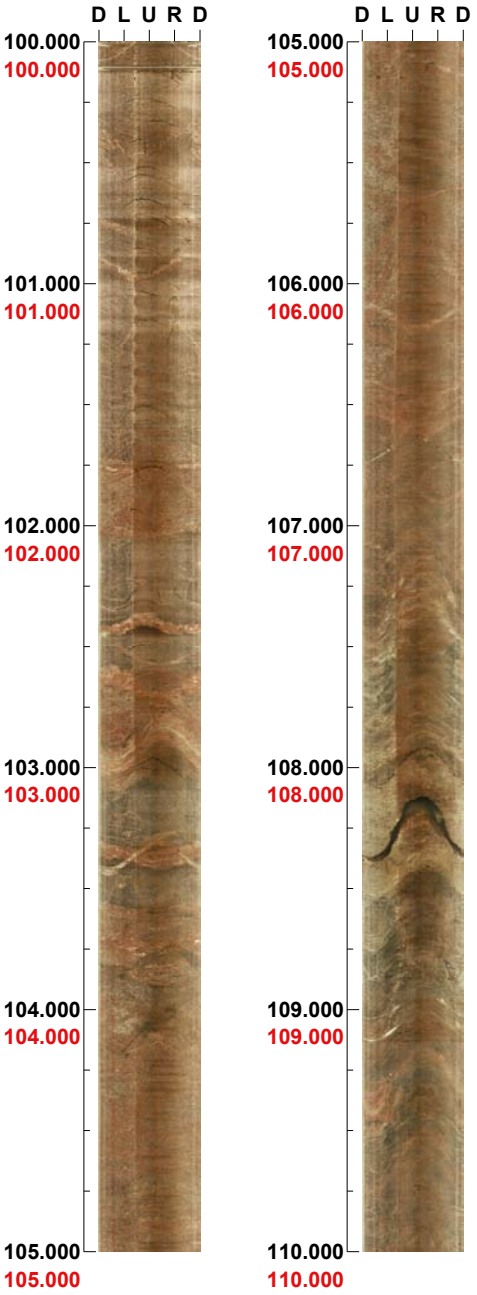
BIPS logging in KFR101. Repeat section 100–110 m

Project name: Forsmark /SFR

Image file	**: c:\work\r5732b~1\juli09~1\bipsda~1\kfr101~1.bip**
BDT file	**: c:\work\r5732b~1\juli09~1\bipsda~1\kfr101~1.bdt**
Locality	**: SFR**
Bore hole number	**: KFR101**
Date	**: 08/07/10**
Time	**: 13:51:00**
Depth range	**: 100.000 - 110.000 m**
Azimuth	**: 29**
Inclination	**: -54**
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	**: 1**
Color	**:**  **+0 +0 +0**

Project name: Forsmark /SFR
Bore hole No.: KFR101 **Azimuth: 29** **Inclination: -54**

Depth range: 100.000 - 110.000 m



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

Appendix 8

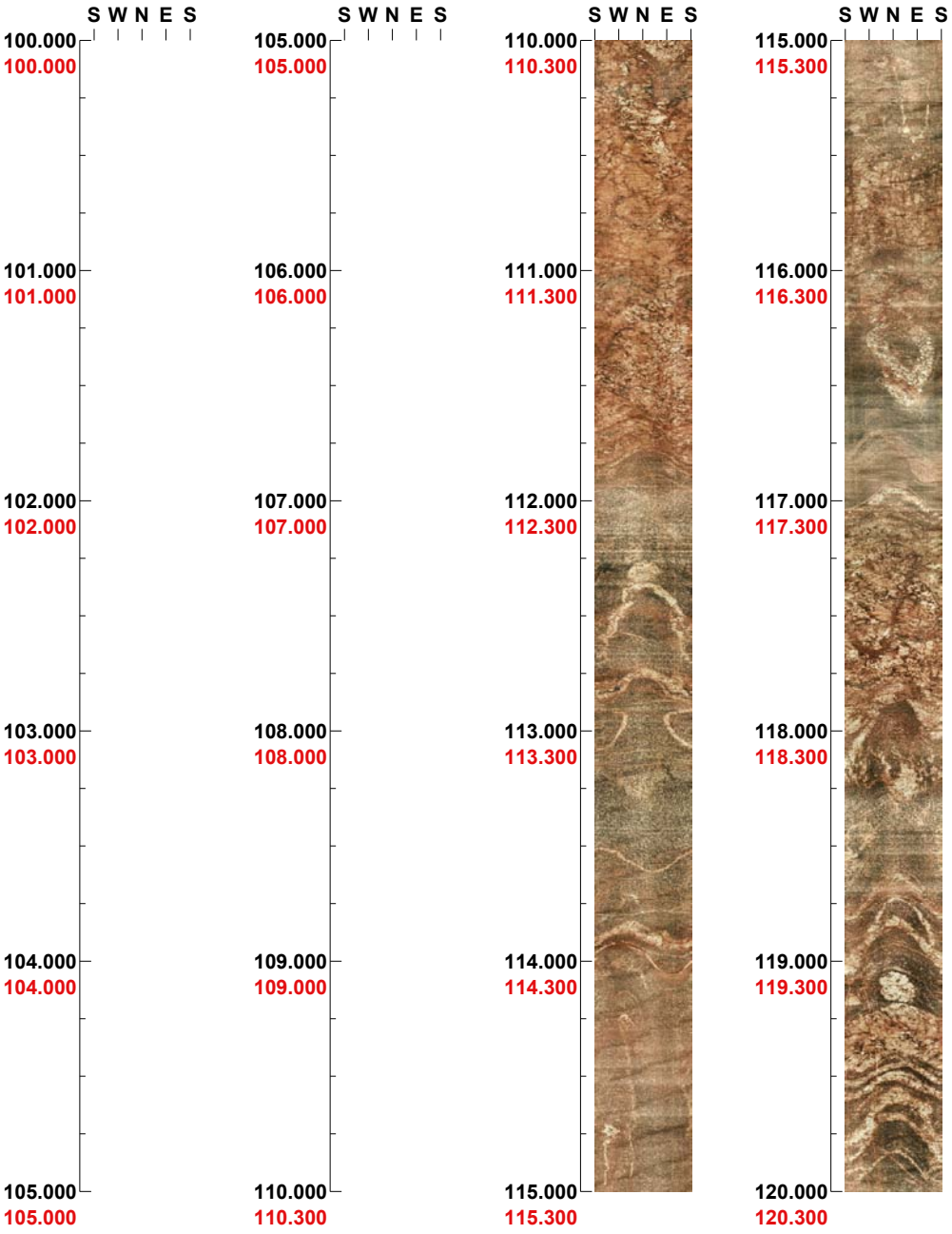
BIPS logging in KFR27. Repeat section 110–120 m

Project name: Forsmark /SFR

Image file	**: c:\work\r5732b~1\juli09~1\bipsda~1\kfr27r~1.bip**
BDT file	**: c:\work\r5732b~1\juli09~1\bipsda~1\kfr27r~1.bdt**
Locality	**: SFR**
Bore hole number	**: KFR27**
Date	**: 08/07/10**
Time	**: 00:14:00**
Depth range	**: 110.000 - 120.002 m**
Azimuth	**: 0**
Inclination	**: -90**
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	**: 2**
Color	**:**  **+0 +0 +0**

Project name: Forsmark /SFR
Bore hole No.: KFR27 **Azimuth: 0** **Inclination: -90**

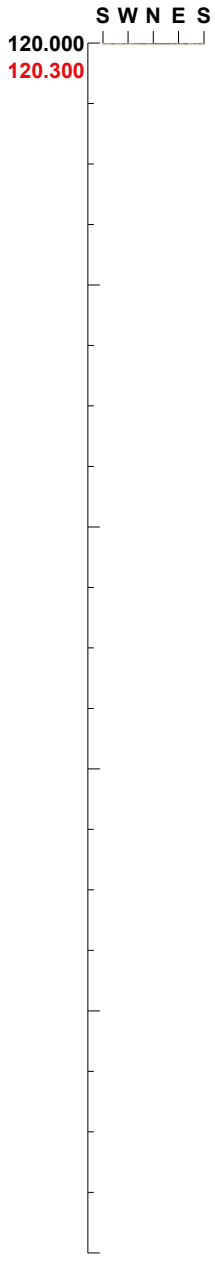
Depth range: 100.000 - 120.000 m



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

Project name: Forsmark /SFR
Bore hole No.: KFR27 **Azimuth: 0** **Inclination: -90**

Depth range: 120.000 - 120.002 m



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

Appendix 9

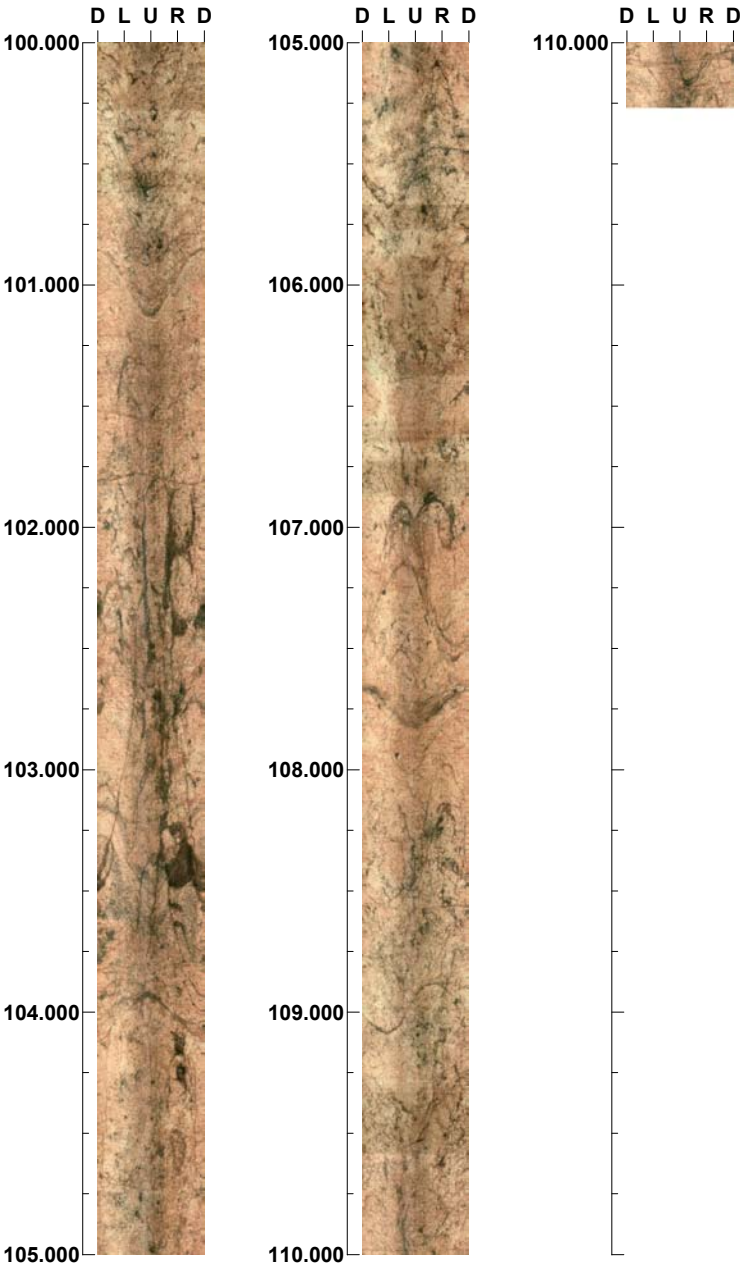
BIPS logging in HFR101. Repeat section 100 to 110 m

Project name: Forsmark SFR

Image file	**: d:\work\forsmark\apsfr-~1\bipsda~1\hfr101\hfr101~**
BDT file	**:**
Locality	**: SFR**
Bore hole number	**: HFR101**
Date	**: 08/05/20**
Time	**: 11:07:00**
Depth range	**: 100.000 - 110.272 m**
Azimuth	**: 0**
Inclination	**: -90**
Diameter	**: 140.0 mm**
Magnetic declination	**: 0.0**
Span	**: 4**
Scan interval	**: 0.25**
Scan direction	**: To bottom**
Scale	**: 1/25**
Aspect ratio	**: 100 %**
Pages	**: 1**
Color	**:**  **+0 +0 +0**

Project name: Forsmark SFR
Bore hole No.: HFR101 **Azimuth: 0** **Inclination: -90**

Depth range: 100.000 - 110.272 m



(1 / 1) **Scale: 1/25** **Aspect ratio: 100 %**

Appendix 10

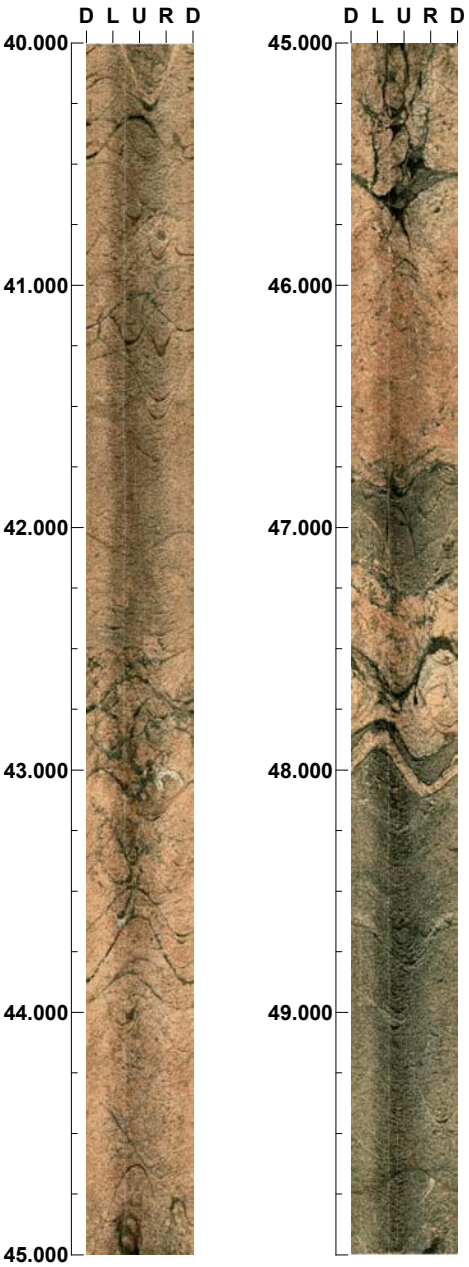
BIPS logging in HFR102. Repeat section 40 to 50 m

Project name: Forsmark SFR

Image file	**: d:\work\forsmark\apsfr-~1\bipsda~1\hfr102\hfr102~**
BDT file	**:**
Locality	**: SFR**
Bore hole number	**: HFR102**
Date	**: 08/05/20**
Time	**: 13:44:00**
Depth range	**: 40.002 - 49.994 m**
Azimuth	**: 0**
Inclination	**: -90**
Diameter	**: 140.0 mm**
Magnetic declination	**: 0.0**
Span	**: 4**
Scan interval	**: 0.25**
Scan direction	**: To bottom**
Scale	**: 1/25**
Aspect ratio	**: 100 %**
Pages	**: 1**
Color	**:**  **+0 +0 +0**

Project name: Forsmark SFR
Bore hole No.: HFR102 **Azimuth: 0** **Inclination: -90**

Depth range: 40.000 - 49.994 m



(1 / 1) **Scale: 1/25** **Aspect ratio: 100 %**

Appendix 11

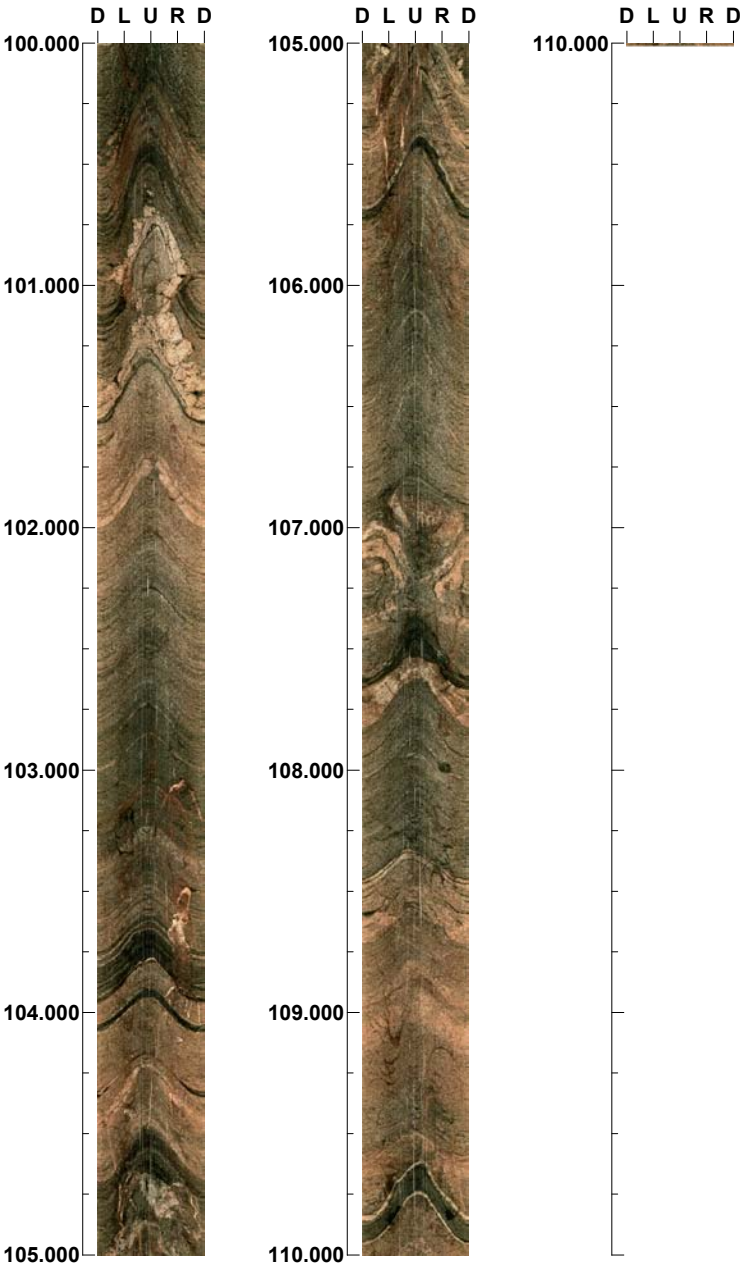
BIPS logging in HFR105. Repeat section 100–110 m

Project name: Forsmark SFR

Image file	**: d:\work\forsmark\apsfr-~1\bipsda~1\hfr105\hfr105~**
BDT file	**:**
Locality	**: SFR**
Bore hole number	**: HFR105**
Date	**: 08/05/19**
Time	**: 15:00:00**
Depth range	**: 100.000 - 110.014 m**
Azimuth	**: 0**
Inclination	**: -90**
Diameter	**: 140.0 mm**
Magnetic declination	**: 0.0**
Span	**: 4**
Scan interval	**: 0.25**
Scan direction	**: To bottom**
Scale	**: 1/25**
Aspect ratio	**: 100 %**
Pages	**: 1**
Color	**:**  **+0 +0 +0**

Project name: Forsmark SFR
Bore hole No.: HFR105 **Azimuth: 0** **Inclination: -90**

Depth range: 100.000 - 110.014 m



(1 / 1) **Scale: 1/25** **Aspect ratio: 100 %**