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# Forsmark site investigation

# RAMAC and BIPS logging in borehole KFM06C

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December 2005

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*Keywords:* BIPS, RAMAC, Radar, TV, Forsmark, AP PF 400-05-069.

# Abstract

This report includes the data gained in geophysical logging operations performed within the site investigation at Forsmark. The logging operations presented here includes BIPS and borehole radar (RAMAC) logging in the core-drilled borehole KFM06C. All measurements were conducted by Malå Geoscience AB/RAYCON during August 2005.

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

The borehole radar data quality from KFM06C was satisfying, but in some minor parts of lower quality due to more conductive conditions. This conductive environment reduces the possibility to distinguish and interpret possible structures in the rock mass which otherwise could give a reflection. However, 360 reflectors were identified in KFM06C, and around 90 of them oriented.

The BIPS images from KFM06C are of good quality regarding the water and visibility of the borehole walls. Some discoloring effects on the borehole wall caused by the drilling are seen along the borehole.

# Sammanfattning

Denna rapport omfattar geofysiska loggningar inom platsundersökningsprogrammet för Forsmark. Mätningarna som presenteras här omfattar BIPS-loggning och borrhålsradarmätning i borrhål KFM06C. Alla mätningar är utförda av Malå Geoscience AB/RAYCON under augusti 2005.

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

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

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

Borrhålsradardata från KFM06C var tillfredställande, men i mindre delar av sämre kvalité, troligen till stor del beroende på en konduktiv miljö. En konduktiv miljö minskar möjligheterna att identifiera strukturer från borrhålsradardata. Dock har 360 radarreflektorer identifierats i KFM06C, varav cirka 90 är orienterade.

BIPS bilderna uppvisar bra kvalitet främst beroende på den goda vattenkvalitén längs borrhålet. Typiska missfärgningen, orsakade av borrningen, på borrhålsväggen försämrar kvalitén på resultatet.

# Contents

# 1 Introduction

This document reports the data gained in geophysical logging operations, which is one of the activities performed within the site investigation at Forsmark. The logging operations presented here includes borehole radar (RAMAC) and TV-logging (BIPS) in the core-drilled borehole KFM06C. The work was carried out in accordance with Activity plan AP PF 400-05-069. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

This report includes measurements from 100 to approximately 990 m in borehole KFM06C. The borehole is core drilled with a diameter of approximately 76 mm.

All measurements were conducted by Malå Geoscience AB/RAYCON during August 2005. The location of the borehole is shown in Figure 1-1.

The used investigation techniques comprised:

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

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

| **Activity plan** | **Number** | **Version** |
|---|---|---|
| BIPS och Radar loggning i KFM06C | AP PF 400-05-069 | 1.0 |
| **Method descriptions** | **Number** | **Version** |
| Metodbeskrivning för TV- loggning med BIPS | SKB MD 222.006 | 1.0 |
| Metodbeskrivning för borrhålsradar | SKB MD 252.020 | 2.0 |

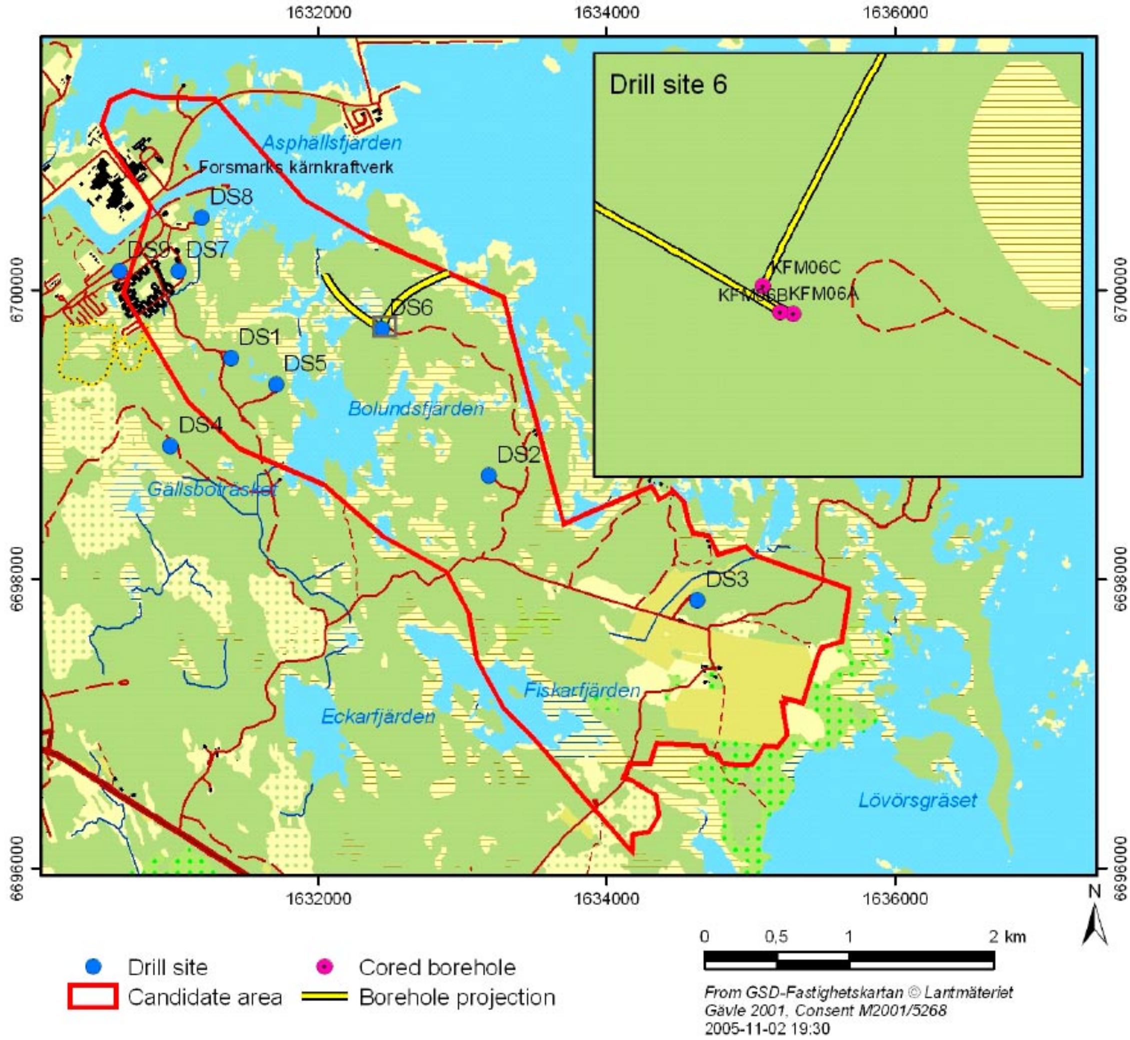



***Figure 1-1.*** *General overview over the Forsmark area showing the location of KFM06C at Drill site DS6.*

# 2 Objective and scope

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

This report describes the equipment used as well the measurement procedures and data gained. For the BIPS survey, the result is presented as images. Radar data is 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, with the frequencies 20, 100 and 250 MHz, is emitted into the bedrock. Once a feature, e.g. a water-filled fracture, with sufficiently different electrical properties is encountered, the pulse is reflected back to the receiver and recorded.

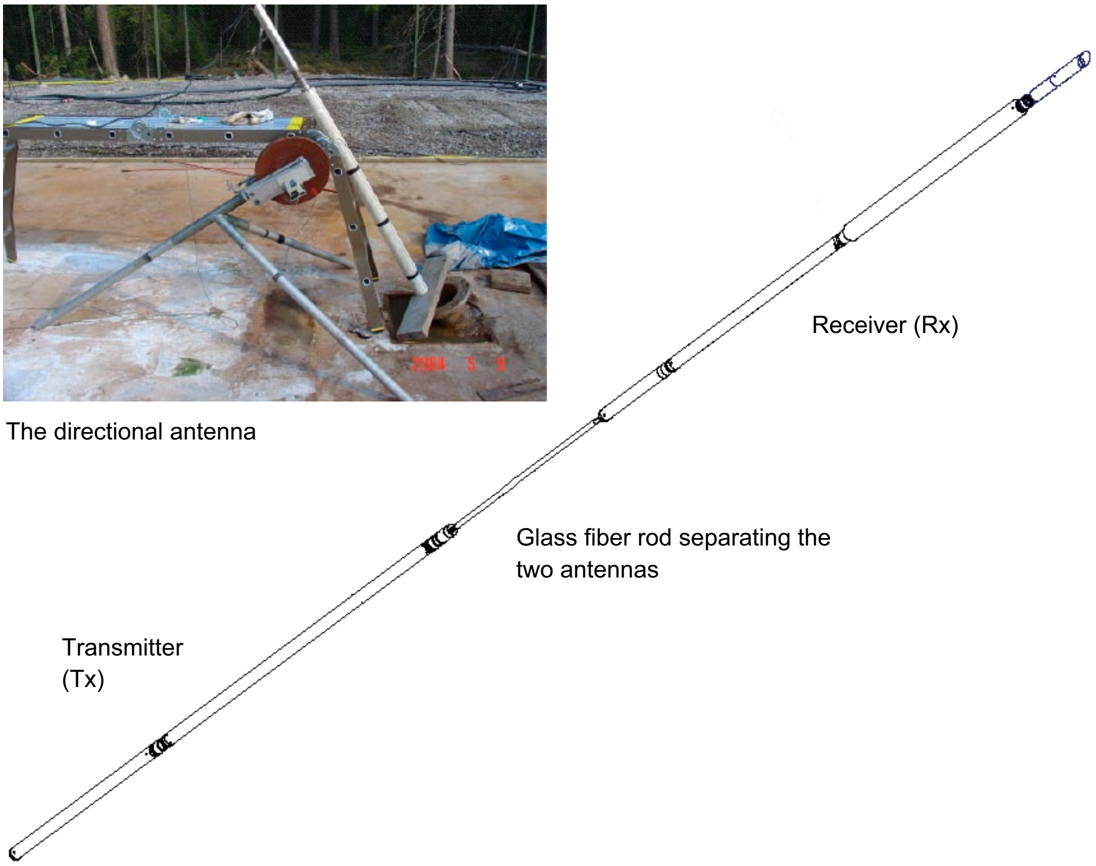



***Figure 3-1.*** *Example of a borehole radar antenna.*

## 3.2 TV-Camera, BIPS

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

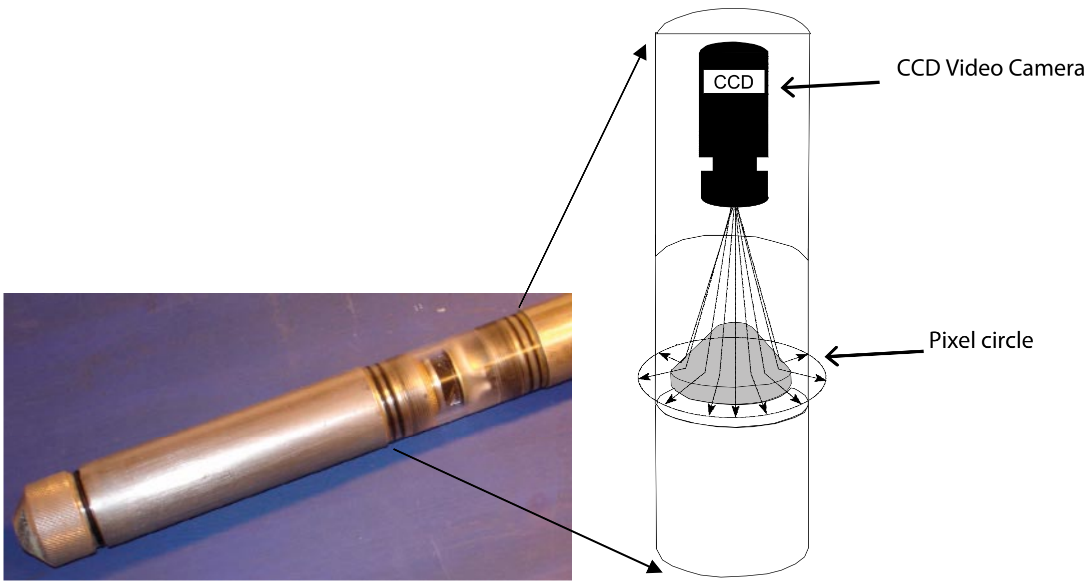



***Figure 3-2.*** *The BIPS-system. To the right an illustration of the conical mirror scanning.*

# 4 Execution

## 4.1 General

### 4.1.1 RAMAC Radar

The measurements in KFM06C were carried out with dipole radar antennas, with frequencies of 250, 100 and 20 MHz. The directional antenna was also used, 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 PC along the measured interval.
The measurement with the directional antenna is made step wise, with a short pause for each measurement occasion. The antennas (transmitter and receiver) 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). All cleaning of the antennas and cable was performed according to the internal document SKB MD 600.004 before the logging operation.

The functionality of the directional antenna was tested before measurements in KFM06C. 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 measured by compass and the result achieved from the directional antenna was about 3 degrees. This can be considered as very good, taking into account the disturbed environment with metallic objects etc at the test site.

For more information on system settings used in the investigation of KFM06C see Table 4-1.

**Table 4-1. Radar logging information from KFM06C.**

| | | | | | |
|---|---|---|---|---|---|
| **Site:** | **Forsmark** | **Logging company:** | **RAYCON** | | |
| **BH:** | **KFM06C** | **Equipment:** | **SKB RAMAC** | | |
| **Type:** | **Directional/Dipole** | **Manufacturer:** | **MALÅ GeoScience** | | |
| **Operator:** | **CG** | **Antenna** | | | |
| | | **Directional** | **250MHz** | **100MHz** | **20MHz** |
| | Logging date: | 2005-08-23 and 2005-08-25 | 2005-08-22 | 2005-08-22 | 2005-08-23 |
| | Reference: | T.O.C. | T.O.C. | T.O.C. | T.O.C. |
| | Sampling frequency (MHz): | 615 | 2,424 | 891 | 239 |
| | Number of samples: | 512 | 619 | 518 | 603 |
| | Number of stacks: | 32 | Auto | Auto | Auto |
| | Signal position: | 410.5 | –0.34 | –0.35 | –1.46 |
| | Logging from (m): | 103.4 | 101.5 | 102.6 | 106.25 |
| | Logging to (m): | 988.4 | 990.8 | 991.9 | 994.0 |
| | Trace interval (m): | 0.5 | 0.25 | 0.2 | 0.1 |
| | Antenna separation (m): | 5.73 | 1.9 | 2.9 | 10.05 |

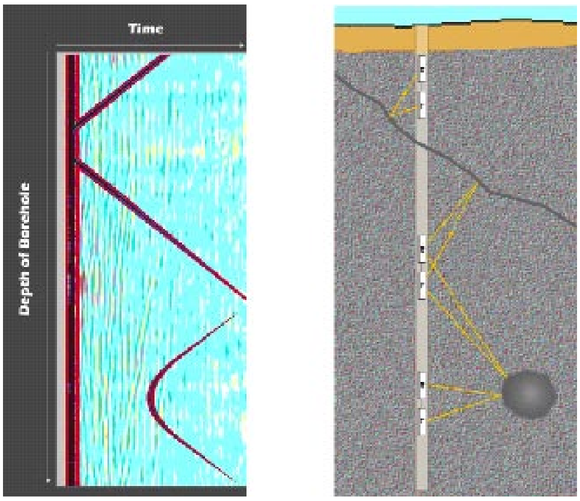



*Figure 4-1. The principle of radar borehole reflection survey and an example of result.*

### 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 circle of pixels 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.

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 the last one. Figure 4-2 corresponds to the test pipe logging before and after the logging of KFM06C in August. The results showed no difference regarding the colours and focus of the images. Results of the test loggings were included in the delivery of the raw data.

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

### 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.

During the BIPS logging in core-drilled boreholes, where the reference marks in the borehole wall is visible on the image, the position where the length mark is visible is marked with scotch tape on the logging cable. During BIPS logging the measured length was adjusted to true length according to length mark visible in the BIPS image. The adjusted true length is marked with red in the image plot together with the non-adjusted measured length. The non-adjusted length is marked with black as seen in 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 for the radar logging is that the length divergence before corrections is less than 100 cm in the deepest parts of a 1,000 m boreholes.

The results from KFM06C, the length to identified structures, are corrected according to the present length divergence, as stated in the field notes, delivered to SKB/SICADA. The correction is done by a change in the radar information file, *.rad.

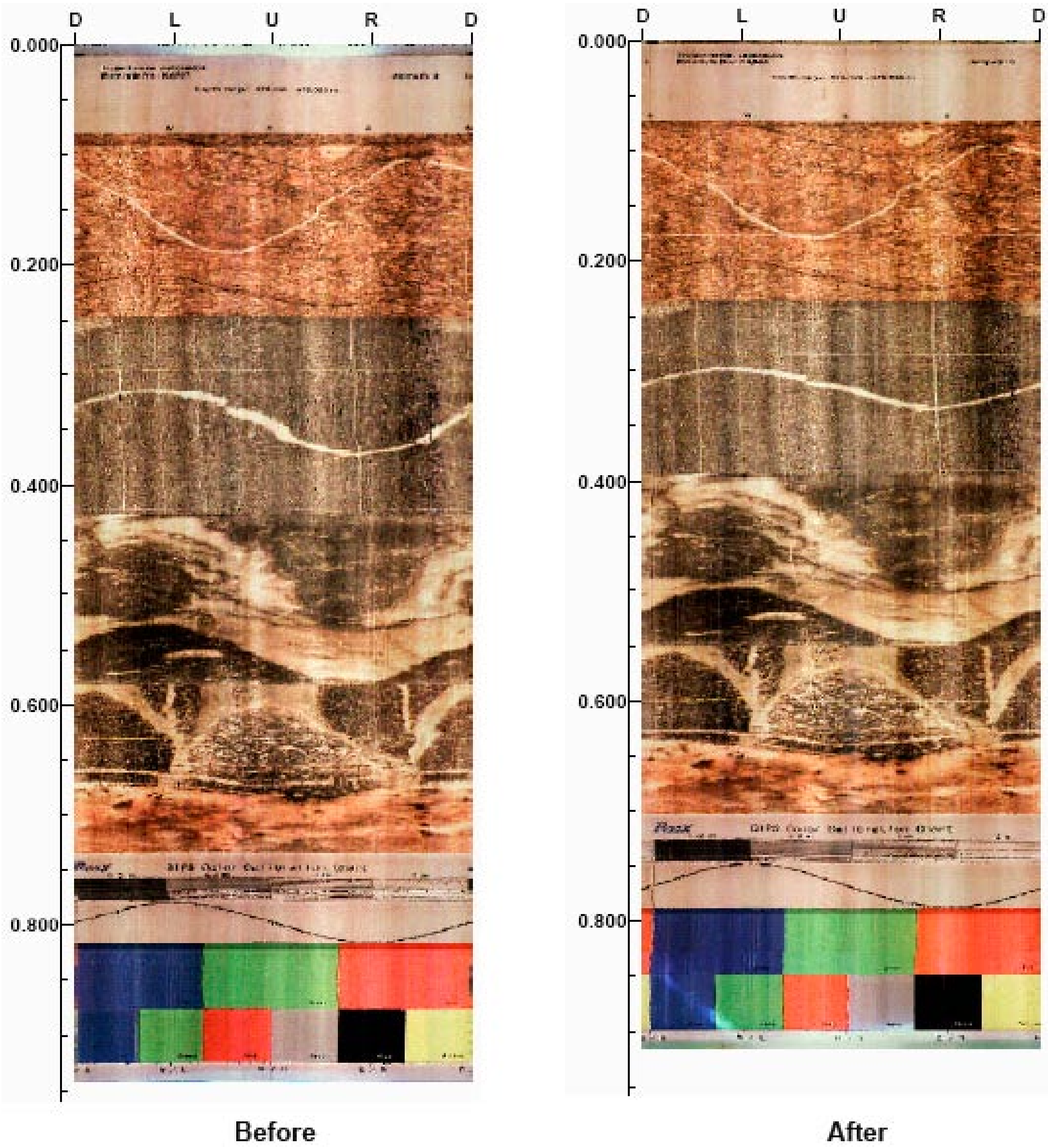



***Figure 4-2.*** *Results from logging in the test pipe before and after the logging of KFM06C in August 2005.*

## 4.2 Analyses and Interpretation

### 4.2.1 Radar

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

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

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

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

There are several ways to determine the radar wave propagation velocity. Each of them has its advantages and its disadvantages. In this project the velocity determination was performed by keeping the transmitter fixed in the borehole while moving the receiver downwards in the borehole. The result is plotted in Figure 4-3 and the calculation shows a velocity of 128 m/µs. The velocity measurement was performed with the 100 MHz antenna /1/.

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 are shown in Table 4-2. It should be observed that the processing steps below refer to the Appendix 1. 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.

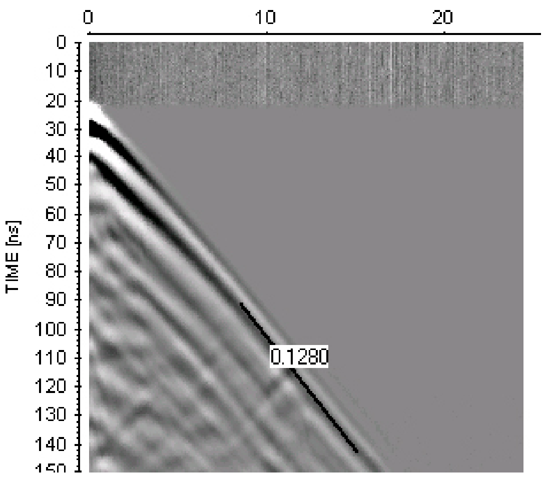



***Figure 4-3.** Results from velocity measurements in HFM03 /1/.*

**Table 4-2. Processing steps for borehole radar data from KFM06C.**

| | | | | | |
|---|---|---|---|---|---|
| **Site:** | **Forsmark** | **Logging company:** | **RAYCON** | | |
| **BH:** | **KFM06C** | **Equipment:** | **SKB RAMAC** | | |
| **Type:** | **Directional/Dipole** | **Manufacturer:** | **MALÅ GeoScience** | | |
| **Interpret:** | **JG** | **Antenna** | | | |
| | | **Directional** | **250MHz** | **100MHz** | **20MHz** |
| | **Processing:** | DC adjustment (410–520) | DC removal (200–230) | DC removal (490–520) | DC removal (1,900–2,100) |
| | | Time gain (Linear 50, exp 5) | Move start time (–25) | Move start time (–50) | Move start time (–75) |
| | | (FIR) | Gain | Gain | Gain |
| | | | (from 20, linear 0.5, exp 1.4) | (from 50, linear 2.5, exp 0.5) | (from 105, linear 2, exp 0.2) |

The software RadInter SKB, is used for the interpretation of the intersection angle between the borehole axis and the planes visible on the radargrams. The interpreted intersection points and intersection angles of the detected structures are presented in the Tables 5-1 and 5-2 and are also visible on the radargrams in Appendix 1.

### 4.2.2 BIPS

The visualization of data is made with BDPP, a Windows based processing software for filtering, presentation and analysis of BIPS data. As no fracture mapping of the BIPS image is performed, the raw data was delivered on a CD-ROM together with printable pictures in *.pdf format before the field crew left the investigation site.

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

## 4.3 Nonconformities

No non-conformities occurred during the radar- and BIPS logging campaign of KFM06C.

# 5 Results

The results from the BIPS measurements in KFM06C 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 KFM06C was delivered as raw data (file format *.rd3 or *.rd5) with corresponding information files (file format *.rad) on CD-ROM:s to SKB before the field crew left the investigation site, whereas the data processing steps and results are presented in this report. Relevant information, including the interpretation presented in this report, was inserted into the SKB database SICADA.

## 5.1 RAMAC logging

The results of the interpretation of the radar measurements are presented in Tables 5-1 to 5-4. Radar data is also visualized in Appendix 1. It should be remembered that the images in Appendix 1 is only a composite picture of all events 360 degrees around the borehole, and do not reflect the orientation of the structures.

Only the larger clearly visible structures are interpreted in RadinterSKB. A number of minor structures or other also exist as indicated in Appendix 1. Often a number of structures can be noticed, but most probably lying so close to each other that it is impossible to distinguish one from the other (see Figure 5-2). It should also be pointed out that reflections interpreted will always get an intersection point with the borehole, but being located further away, they may in some cases not reach the borehole. Parallel structures can also be identified, especially in the 20 MHz data. An overview of KFM06C (20 MHz data) is given in Figure 5-1 below, showing several large-scale structures, especially between 300 and 750 m length. Also seen in Figure 5-1 is the decrease in radar wave penetration at approximately 540 m borehole length, indicating a more conductive environment.

The data quality from KFM06C, (as seen in Appendix 1) is good, but in some parts of lower quality due to more conductive conditions. A conductive environment causes an attenuation of the radar wave, which in turn decreases the penetration. A 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.

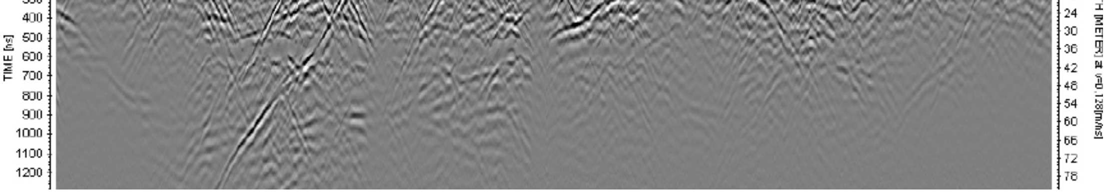



*Figure 5-1.* *Results from KFM06C, 20 MHz data.*

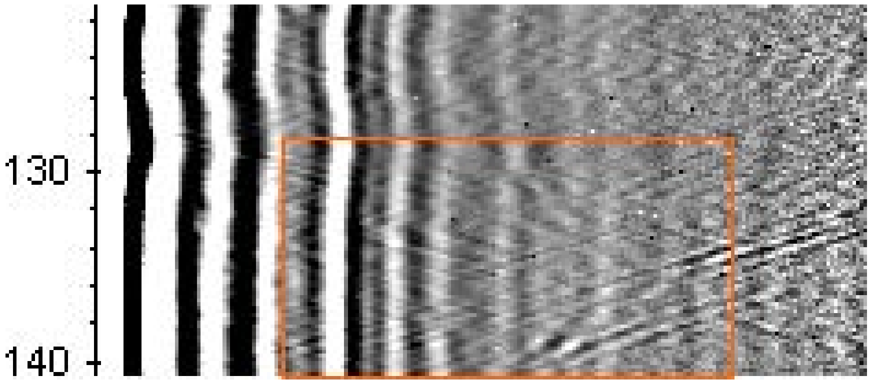



***Figure 5-2.*** *Example of data from KFM06C where a number of structures are seen (inside the marked area) but lying so close to each other that they can not be distinguished.*

In parts with an increased conductivity and thereby a decreased depth penetration most often only the edges of structures can be distinguished, giving an intersection angle of 90 degrees.

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

In Table 5-1 below, the distribution of identified structures along the borehole KFM06C is showed.

**Table 5-1. Identified structures as a function of borehole length in KFM06C.**

| Length (m) | No. of structures |
|---|---|
| –100 | 4 |
| 100 – 150 | 16 |
| 150 – 200 | 22 |
| 200 – 250 | 29 |
| 250 – 300 | 19 |
| 300 – 350 | 21 |
| 350 – 400 | 16 |
| 400 – 450 | 23 |
| 450 – 500 | 22 |
| 500 – 550 | 21 |
| 550 – 600 | 13 |
| 600 – 650 | 21 |
| 650 – 700 | 26 |
| 700 – 750 | 21 |
| 750 – 800 | 23 |
| 800 – 850 | 16 |
| 850 – 900 | 17 |
| 900 – 950 | 14 |
| 950 – | 16 |

Table 5-2 summarises the interpretation of radar data from KFM06C. In the table the borehole length and intersection angle to the identified structures are listed. As seen, some radar reflectors 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 5-3.

This direction and the intersection angle are also given as strike and dip. The plane strike is the angle between 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 between 0 and 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 values for intersection angle and intersection length. An example of this phenomenon is seen in Table 5-2: the reflectors named 185, 185x, 185xx, 185xxx and 185xxxx most likely originates from the same geological structure.

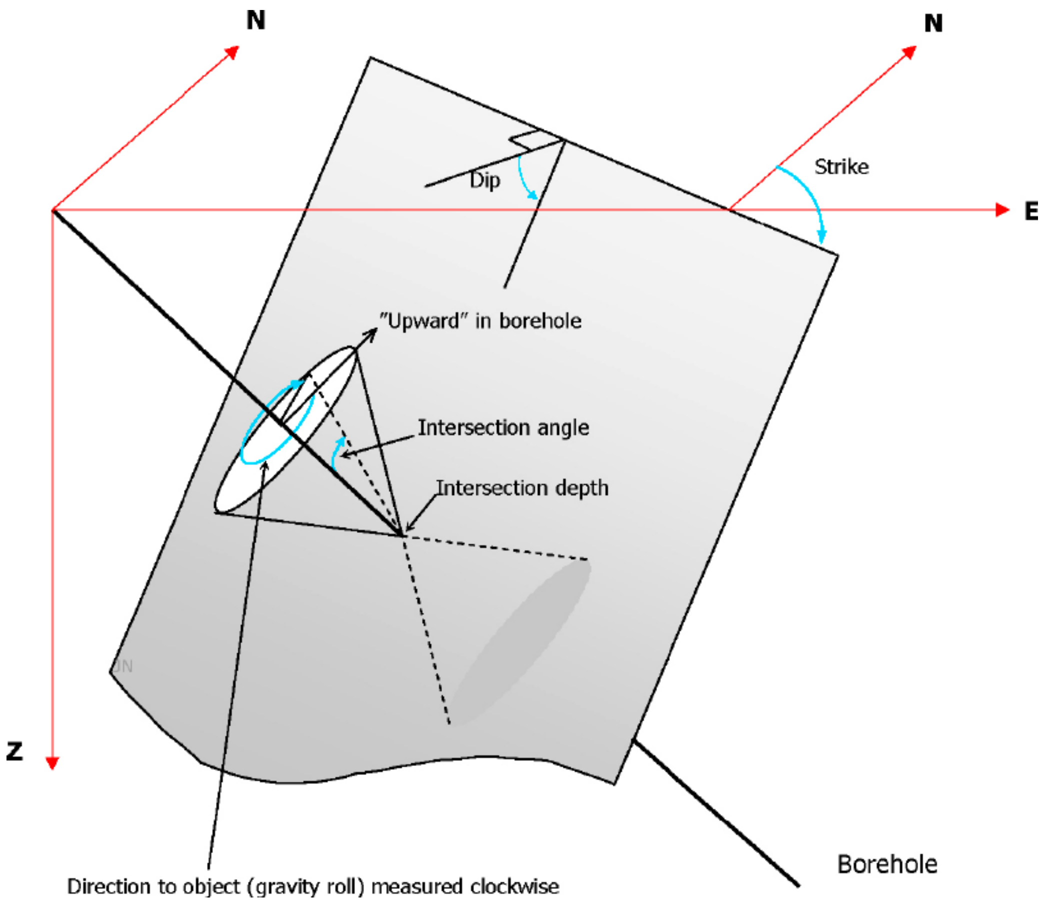



***Figure 5-3.*** *Definition of direction to reflector as presented in Table 5-2.*

**Table 5-2. Interpretation of radar reflectors from dipole antennas 20, 100 and 250 MHz and the directional antenna in borehole KFM06C.**

| **RADINTER MODEL INFORMATION (20, 100 and 250 MHz Dipole Antennas and Directional antenna)** | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Site:** | | **Forsmark** | | | | | |
| **Borehole name:** | | **KFM06C** | | | | | |
| **Nominal velocity (m/μs):** | | **128.0** | | | | | |
| **Name** | **Intersection length** | **Intersection angle** | **Object direction** | **Dip 1** | **Strike 1** | **Dip 2** | **Strike 2** |
| 311x | –890.0 | 3 | | | | | |
| 312 | 3.6 | 16 | 120 ± | 61 | 216 | 88 | 232 |
| 311 | 7.6 | 21 | | | | | |
| 21xx | 81.8 | 6 | 78 | 88 | 12 | | |
| 5 | 104.2 | 59 | | | | | |
| 4 | 107.0 | 34 | | | | | |
| 295 | 109.0 | 51 | | | | | |
| 1 | 115.1 | 40 | | | | | |
| 2 | 118.7 | 60 | | | | | |
| 3 | 120.2 | 64 | | | | | |
| 284 | 124.1 | 63 | | | | | |
| 6 | 125.6 | 67 | | | | | |
| 7 | 128.1 | 68 | | | | | |
| 21x | 138.5 | 11 | 75 | 89 | 180 | | |
| 8 | 139.8 | 52 | 153 ± | 17 | 209 | 68 | 90 |
| 9 | 141.6 | 61 | | | | | |
| 10 | 143.7 | 58 | | | | | |
| 11 | 145.9 | 55 | 354 | 67 | 104 | | |
| 13 | 147.4 | 45 | | | | | |
| 12 | 149.0 | 58 | | | | | |
| 14 | 151.9 | 57 | 6 ± | 64 | 112 | 3 | 20 |
| 21 | 152.6 | 15 | 81 | 82 | 183 | | |
| 15 | 153.9 | 68 | | | | | |
| 16 | 155.3 | 67 | | | | | |
| 17 | 156.0 | 66 | | | | | |
| 19 | 158.3 | 49 | | | | | |
| 28 | 159.1 | 54 | | | | | |
| 18 | 165.9 | 47 | | | | | |
| 20 | 168.2 | 46 | | | | | |
| 22 | 173.2 | 53 | | | | | |
| 23 | 177.0 | 49 | | | | | |
| 24 | 178.0 | 46 | 171 | 11 | 256 | | |
| 25 | 179.1 | 46 | | | | | |
| 26 | 180.8 | 45 | 189 ± | 16 | 313 | 78 | 115 |
| 27 | 180.8 | 50 | | | | | |
| 313 | 181.1 | 65 | | | | | |
| 29 | 183.0 | 46 | | | | | |
| 30 | 185.5 | 57 | | | | | |
| 31 | 191.5 | 54 | 336 ± | 65 | 93 | 14 | 209 |

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

| **Site:** | **Forsmark** |
|---|---|
| **Borehole name:** | **KFM06C** |
| **Nominal velocity (m/μs):** | **128.0** |

| **Name** | **Intersection length** | **Intersection angle** | **Object direction** | **Dip 1** | **Strike 1** | **Dip 2** | **Strike 2** |
|---|---|---|---|---|---|---|---|
| 32 | 197.1 | 48 | | | | | |
| 34 | 196.5 | 56 | 318 ± | 61 | 94 | 22 | 177 |
| 33 | 198.8 | 43 | | | | | |
| 35 | 200.8 | 69 | | | | | |
| 326 | 201.7 | 49 | 297 | 63 | 75 | | |
| 315 | 202.8 | 60 | | | | | |
| 38 | 205.6 | 58 | | | | | |
| 39 | 208.9 | 69 | | | | | |
| 36 | 209.0 | 54 | 171 | 8 | 245 | | |
| 37 | 209.5 | 59 | | | | | |
| 296 | 211.8 | 54 | | | | | |
| 40 | 213.7 | 66 | | | | | |
| 324 | 215.8 | 57 | | | | | |
| 41 | 221.7 | 54 | | | | | |
| 44 | 223.0 | 46 | | | | | |
| 42 | 223.2 | 54 | | | | | |
| 43 | 224.8 | 58 | 339 | 71 | 102 | | |
| 44x | 225.0 | 46 | | | | | |
| 45 | 225.7 | 58 | | | | | |
| 47 | 228.0 | 73 | | | | | |
| 46 | 231.1 | 47 | 33 ± | 74 | 138 | 22 | 17 |
| 48 | 232.5 | 71 | | | | | |
| 316 | 233.0 | 80 | | | | | |
| 49 | 235.3 | 64 | | | | | |
| 51 | 236.7 | 55 | | | | | |
| 50 | 237.4 | 53 | 210 | 17 | 38 | | |
| 297 | 242.0 | 78 | | | | | |
| 52 | 242.1 | 60 | | | | | |
| 53 | 243.6 | 78 | | | | | |
| 54 | 243.9 | 47 | | | | | |
| 325 | 246.8 | 70 | 189 ± | 15 | 104 | 54 | 119 |
| 314 | 249.1 | 42 | | | | | |
| 55 | 251.6 | 57 | | | | | |
| 285 | 252.2 | 11 | 285 ± | 88 | 37 | 72 | 205 |
| 56 | 254.8 | 53 | | | | | |
| 298 | 255.5 | 64 | | | | | |
| 57 | 258.2 | 65 | | | | | |
| 59 | 259.4 | 55 | | | | | |
| 61 | 261.4 | 67 | 285 | 47 | 82 | | |
| 60 | 262.5 | 58 | | | | | |
| 62 | 265.0 | 55 | 261 | 43 | 61 | | |

| RADINTER MODEL INFORMATION<br>(20, 100 and 250 MHz Dipole Antennas and Directional antenna) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Site:**<br>**Borehole name:**<br>**Nominal velocity (m/μs):** | | **Forsmark**<br>**KFM06C**<br>**128.0** | | | | | |
| **Name** | **Intersection length** | **Intersection angle** | **Object direction** | **Dip 1** | **Strike 1** | **Dip 2** | **Strike 2** |
| 58 | 268.7 | 61 | | | | | |
| 63 | 283.0 | 63 | 324 | 61 | 96 | | |
| 63x | 285.6 | 37 | | | | | |
| 64 | 285.7 | 69 | | | | | |
| 65 | 286.8 | 75 | | | | | |
| 320 | 288.3 | 5 | | | | | |
| 66 | 291.6 | 64 | | | | | |
| 67 | 292.8 | 63 | 195 ± | 10 | 72 | 63 | 124 |
| 68 | 295.2 | 65 | | | | | |
| 69 | 296.0 | 55 | | | | | |
| 78 | 300.7 | 54 | | | | | |
| 70 | 302.3 | 54 | | | | | |
| 71 | 302.7 | 65 | | | | | |
| 299 | 308.6 | 56 | | | | | |
| 72 | 309.7 | 57 | | | | | |
| 73 | 312.3 | 54 | | | | | |
| 74 | 314.1 | 57 | 210 | 17 | 43 | | |
| 75 | 316.2 | 53 | | | | | |
| 76 | 317.8 | 57 | 162 | 10 | 182 | | |
| 77 | 320.0 | 8 | | | | | |
| 79 | 324.2 | 54 | | | | | |
| 80 | 326.1 | 73 | | | | | |
| 81 | 329.4 | 58 | 348 ± | 69 | 108 | 7 | 205 |
| 84 | 333.4 | 60 | | | | | |
| 82 | 334.4 | 66 | 345 ± | 59 | 108 | 12 | 147 |
| 83 | 336.0 | 52 | 201 | 14 | 11 | | |
| 89 | 339.8 | 56 | | | | | |
| 85 | 344.6 | 52 | | | | | |
| 86 | 347.5 | 57 | 183 | 4 | 92 | | |
| 86x | 348.6 | 59 | | | | | |
| 88 | 349.4 | 56 | | | | | |
| 87 | 350.2 | 60 | | | | | |
| 90 | 356.1 | 57 | 153 ± | 15 | 195 | 67 | 102 |
| 91 | 360.0 | 58 | | | | | |
| 92 | 361.7 | 57 | 165 ± | 9 | 190 | 68 | 109 |
| 95 | 375.1 | 51 | | | | | |
| 94 | 376.4 | 49 | | | | | |
| 93 | 376.6 | 46 | 24 ± | 79 | 135 | 19 | 2 |
| 96 | 380.9 | 32 | 21 | 90 | 140 | | |
| 286 | 383.3 | 49 | | | | | |
| 97 | 383.7 | 59 | | | | | |

| RADINTER MODEL INFORMATION<br>(20, 100 and 250 MHz Dipole Antennas and Directional antenna) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Site:** | | **Forsmark** | | | | | |
| **Borehole name:** | | **KFM06C** | | | | | |
| **Nominal velocity (m/µs):** | | **128.0** | | | | | |
| **Name** | **Intersection length** | **Intersection angle** | **Object direction** | **Dip 1** | **Strike 1** | **Dip 2** | **Strike 2** |
| 98 | 386.3 | 75 | | | | | |
| 100 | 388.4 | 60 | 354 ± | 66 | 116 | 5 | 161 |
| 99x | 392.9 | 46 | 171 ± | 11 | 262 | 79 | 111 |
| 99 | 394.6 | 38 | | | | | |
| 101 | 397.0 | 60 | | | | | |
| 102x | 399.4 | 40 | | | | | |
| 102 | 402.4 | 55 | 324 | 67 | 102 | | |
| 99xxx | 403.8 | 34 | | | | | |
| 103 | 404.1 | 63 | | | | | |
| 104 | 404.8 | 35 | | | | | |
| 288 | 411.2 | 63 | | | | | |
| 105 | 413.5 | 63 | | | | | |
| 106 | 415.2 | 52 | | | | | |
| 107 | 416.6 | 61 | | | | | |
| 300 | 421.2 | 71 | | | | | |
| 287 | 423.6 | 52 | | | | | |
| 108 | 424.8 | 69 | | | | | |
| 109 | 425.9 | 69 | 282 ± | 46 | 91 | 38 | 161 |
| 110 | 427.5 | 67 | | | | | |
| 111 | 430.0 | 65 | 99 ± | 39 | 160 | 45 | 90 |
| 112 | 431.4 | 61 | | | | | |
| 113 | 432.9 | 68 | | | | | |
| 114 | 439.2 | 64 | | | | | |
| 115 | 443.7 | 60 | | | | | |
| 322 | 443.9 | 53 | | | | | |
| 327 | 444.9 | 55 | 288 | 57 | 84 | | |
| 116 | 446.5 | 70 | | | | | |
| 317x | 449.0 | 13 | 288 ± | 89 | 48 | 75 | 313 |
| 117 | 449.4 | 66 | 273 ± | 45 | 84 | 43 | 163 |
| 118 | 453.8 | 65 | 279 ± | 48 | 89 | 41 | 167 |
| 119 | 457.1 | 70 | | | | | |
| 120 | 458.5 | 65 | | | | | |
| 121 | 459.6 | 66 | | | | | |
| 122 | 460.8 | 70 | 243 | 32 | 94 | | |
| 123 | 466.7 | 50 | | | | | |
| 124 | 469.2 | 81 | | | | | |
| 125 | 469.4 | 68 | | | | | |
| 126 | 475.2 | 64 | | | | | |
| 127 | 476.4 | 74 | | | | | |
| 321 | 477.0 | 50 | | | | | |
| 128 | 480.1 | 59 | 33 ± | 64 | 144 | 20 | 77 |

| RADINTER MODEL INFORMATION<br>(20, 100 and 250 MHz Dipole Antennas and Directional antenna) | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Site:** | | **Forsmark** | | | | | |
| **Borehole name:** | | **KFM06C** | | | | | |
| **Nominal velocity (m/μs):** | | **128.0** | | | | | |
| **Name** | **Intersection length** | **Intersection angle** | **Object direction** | **Dip 1** | **Strike 1** | **Dip 2** | **Strike 2** |
| 129 | 483.4 | 65 | | | | | |
| 130 | 484.9 | 17 | | | | | |
| 132 | 488.0 | 61 | | | | | |
| 131 | 490.8 | 59 | | | | | |
| 131x | 491.1 | 46 | | | | | |
| 134 | 493.5 | 56 | | | | | |
| 99xx | 493.7 | 17 | | | | | |
| 328 | 496.6 | 47 | 279 | 59 | 74 | | |
| 135 | 498.0 | 59 | | | | | |
| 136 | 498.2 | 45 | | | | | |
| 137 | 502.4 | 55 | | | | | |
| 138 | 503.7 | 58 | | | | | |
| 141 | 507.4 | 26 | 39 ± | 89 | 340 | 37 | 14 |
| 139 | 507.5 | 50 | | | | | |
| 140 | 509.8 | 64 | 231 ± | 56 | 150 | 29 | 85 |
| 142 | 510.7 | 77 | | | | | |
| 144 | 513.3 | 50 | | | | | |
| 143 | 515.5 | 52 | | | | | |
| 145 | 516.5 | 61 | | | | | |
| 146 | 522.0 | 56 | | | | | |
| 147 | 528.4 | 47 | | | | | |
| 148 | 533.8 | 66 | 108 ± | 38 | 171 | 51 | 97 |
| 150 | 535.5 | 61 | | | | | |
| 151 | 536.9 | 54 | | | | | |
| 317 | 537.3 | 9 | 285 | 88 | 223 | | |
| 149x | 537.6 | 89 | | | | | |
| 149 | 537.8 | 64 | | | | | |
| 152 | 540.2 | 55 | 294 | 62 | 90 | | |
| 153 | 546.9 | 51 | | | | | |
| 154 | 547.7 | 57 | | | | | |
| 155 | 549.9 | 56 | | | | | |
| 156 | 555.4 | 58 | | | | | |
| 157 | 557.6 | 53 | | | | | |
| 158 | 560.6 | 51 | | | | | |
| 159 | 563.6 | 59 | 276 ± | 49 | 93 | 44 | 173 |
| 161 | 572.8 | 44 | | | | | |
| 160 | 573.4 | 36 | | | | | |
| 162 | 577.4 | 44 | | | | | |
| 165 | 582.6 | 47 | | | | | |
| 163 | 583.6 | 42 | | | | | |
| 164 | 584.3 | 49 | 330 | 77 | 111 | | |

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

| | |
|---|---|
| **Site:** | **Forsmark** |
| **Borehole name:** | **KFM06C** |
| **Nominal velocity (m/μs):** | **128.0** |

| Name | Intersection length | Intersection angle | Object direction | Dip 1 | Strike 1 | Dip 2 | Strike 2 |
|---|---|---|---|---|---|---|---|
| 168 | 590.9 | 49 | | | | | |
| 166 | 595.5 | 48 | | | | | |
| 329 | 599.1 | 50 | 138 ± | 26 | 206 | 73 | 104 |
| 301 | 601.0 | 48 | | | | | |
| 169 | 602.1 | 53 | | | | | |
| 167 | 603.4 | 46 | | | | | |
| 170 | 611.9 | 47 | | | | | |
| 289 | 612.7 | 70 | | | | | |
| 171x | 614.6 | 51 | | | | | |
| 171 | 614.9 | 59 | | | | | |
| 172 | 617.4 | 53 | | | | | |
| 173 | 620.0 | 51 | 138 ± | 26 | 204 | 72 | 109 |
| 174 | 623.2 | 55 | | | | | |
| 175 | 626.6 | 51 | | | | | |
| 176 | 630.2 | 51 | 318 ± | 74 | 106 | 27 | 211 |
| 177 | 633.9 | 56 | 159 ± | 13 | 200 | 74 | 119 |
| 178 | 635.9 | 64 | | | | | |
| 290 | 638.4 | 52 | | | | | |
| 180 | 639.5 | 42 | | | | | |
| 333 | 640.1 | 10 | 30 | 65 | 354 | | |
| 179 | 640.4 | 43 | | | | | |
| 190 | 641.7 | 28 | | | | | |
| 181 | 642.5 | 47 | | | | | |
| 182 | 645.9 | 65 | | | | | |
| 186 | 652.6 | 32 | | | | | |
| 205x | 653.6 | 17 | 87 | 79 | 217 | | |
| 330 | 655.6 | 46 | 171 ± | 6 | 230 | 80 | 130 |
| 205 | 659.3 | 19 | 81 | 81 | 210 | | |
| 302 | 659.4 | 51 | | | | | |
| 187 | 660.9 | 44 | | | | | |
| 183 | 662.6 | 14 | 279 | 84 | 59 | | |
| 185x | 662.6 | 25 | 273 ± | 67 | 208 | 71 | 66 |
| 303 | 663.2 | 49 | | | | | |
| 184 | 663.6 | 18 | 81 ± | 81 | 203 | 70 | 48 |
| 188 | 663.9 | 44 | | | | | |
| 185xx | 664.0 | 22 | | | | | |
| 189 | 664.2 | 51 | | | | | |
| 185 | 666.3 | 22 | 26 | 69 | 52 | | |
| 191 | 666.8 | 49 | | | | | |
| 185xxxx | 675.8 | 19 | 282 ± | 68 | 222 | 83 | 66 |
| 193 | 677.3 | 48 | | | | | |

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

| **Site:** | **Forsmark** |
|---|---|
| **Borehole name:** | **KFM06C** |
| **Nominal velocity (m/µs):** | **128.0** |

| Name | Intersection length | Intersection angle | Object direction | Dip 1 | Strike 1 | Dip 2 | Strike 2 |
|---|---|---|---|---|---|---|---|
| 291 | 677.8 | 59 | | | | | |
| 197 | 680.3 | 55 | | | | | |
| 192 | 681.8 | 25 | 255 ± | 59 | 55 | 77 | 196 |
| 205xx | 687.7 | 34 | | | | | |
| 194 | 688.2 | 69 | | | | | |
| 195 | 689.5 | 65 | | | | | |
| 196 | 693.3 | 65 | 309 ± | 60 | 111 | 30 | 181 |
| 198 | 697.2 | 56 | 84 ± | 53 | 179 | 47 | 91 |
| 202 | 699.9 | 24 | 60 ± | 88 | 189 | 52 | 43 |
| 199 | 700.3 | 60 | | | | | |
| 200 | 702.2 | 56 | | | | | |
| 201 | 704.0 | 64 | 249 ± | 38 | 93 | 54 | 166 |
| 203 | 705.5 | 63 | | | | | |
| 204 | 708.2 | 54 | | | | | |
| 206 | 710.2 | 46 | | | | | |
| 207 | 713.9 | 52 | | | | | |
| 208 | 716.4 | 63 | | | | | |
| 209 | 726.9 | 60 | | | | | |
| 209x | 727.2 | 64 | | | | | |
| 210 | 728.4 | 58 | | | | | |
| 306 | 729.7 | 61 | | | | | |
| 305 | 730.5 | 54 | | | | | |
| 211 | 733.0 | 57 | 6 | 74 | 141 | | |
| 307 | 736.1 | 58 | | | | | |
| 304 | 739.1 | 52 | | | | | |
| 212 | 739.9 | 71 | | | | | |
| 213 | 744.5 | 57 | 282 ± | 55 | 98 | 44 | 185 |
| 214 | 747.9 | 57 | 225 | 28 | 86 | | |
| 308 | 746.4 | 62 | | | | | |
| 215 | 749.9 | 86 | | | | | |
| 217 | 750.3 | 46 | 108 ± | 46 | 207 | 65 | 99 |
| 216 | 753.0 | 64 | 309 ± | 60 | 118 | 31 | 84 |
| 218 | 756.5 | 60 | | | | | |
| 219 | 757.0 | 48 | | | | | |
| 331 | 757.9 | 19 | 90 | 76 | 215 | | |
| 332 | 759.2 | 52 | 330 | 76 | 120 | | |
| 309 | 760.8 | 82 | | | | | |
| 220 | 764.3 | 53 | | | | | |
| 221 | 764.8 | 65 | | | | | |
| 222 | 766.2 | 54 | | | | | |
| 223 | 764.8 | 50 | | | | | |

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

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Site:** | | **Forsmark** | | | | | |
| **Borehole name:** | | **KFM06C** | | | | | |
| **Nominal velocity (m/μs):** | | **128.0** | | | | | |
| **Name** | **Intersection length** | **Intersection angle** | **Object direction** | **Dip 1** | **Strike 1** | **Dip 2** | **Strike 2** |
| 224 | 771.2 | 55 | | | | | |
| 220x | 766.6 | 77 | | | | | |
| 224 | 775.6 | 83 | | | | | |
| 335 | 784.0 | 47 | 144 ± | 24 | 222 | 78 | 117 |
| 323 | 787.2 | 15 | | | | | |
| 225 | 788.1 | 64 | | | | | |
| 226 | 788.5 | 72 | | | | | |
| 231 | 792.1 | 52 | | | | | |
| 227 | 793.7 | 46 | | | | | |
| 334 | 795.2 | 75 | 24 ± | 55 | 149 | 27 | 127 |
| 228 | 798.6 | 49 | | | | | |
| 185xxx | 799.2 | 7 | 282 | 89 | 236 | | |
| 230 | 801.2 | 51 | | | | | |
| 229 | 801.8 | 68 | | | | | |
| 234 | 804.8 | 59 | | | | | |
| 232 | 808.9 | 52 | | | | | |
| 235 | 810.4 | 54 | | | | | |
| 233 | 811.8 | 56 | | | | | |
| 236 | 819.9 | 54 | 354 ± | 78 | 140 | 6 | 179 |
| 237 | 820.6 | 56 | | | | | |
| 239 | 827.1 | 51 | | | | | |
| 240 | 834.4 | 62 | | | | | |
| 250 | 835.9 | 22 | 63 ± | 88 | 198 | 55 | 51 |
| 238 | 837.9 | 48 | | | | | |
| 241 | 839.3 | 65 | 315 ± | 61 | 124 | 29 | 183 |
| 292 | 842.1 | 55 | | | | | |
| 242 | 847.8 | 64 | | | | | |
| 243 | 848.9 | 56 | | | | | |
| 244 | 850.0 | 58 | | | | | |
| 340 | 851.8 | 58 | 262 ± | 47 | 97 | 55 | 185 |
| 310 | 855.4 | 58 | | | | | |
| 245 | 856.7 | 48 | | | | | |
| 246 | 860.8 | 48 | 99 ± | 49 | 198 | 58 | 102 |
| 248 | 868.2 | 66 | | | | | |
| 342 | 873.8 | 54 | 99 ± | 49 | 197 | 57 | 103 |
| 252 | 877.5 | 48 | | | | | |
| 253 | 878.4 | 54 | | | | | |
| 254 | 879.8 | 64 | | | | | |
| 256 | 887.5 | 47 | | | | | |
| 251 | 889.3 | 22 | 63 | 89 | 199 | | |
| 255 | 889.9 | 49 | | | | | |

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

| **Site:** | | **Forsmark** | | | | | |
|---|---|---|---|---|---|---|---|
| **Borehole name:** | | **KFM06C** | | | | | |
| **Nominal velocity (m/μs):** | | **128.0** | | | | | |
| **Name** | **Intersection length** | **Intersection angle** | **Object direction** | **Dip 1** | **Strike 1** | **Dip 2** | **Strike 2** |
| 257 | 892.0 | 53 | | | | | |
| 259 | 892.8 | 50 | | | | | |
| 258 | 895.2 | 53 | | | | | |
| 260 | 899.0 | 50 | 162 ± | 12 | 234 | 86 | 134 |
| 261 | 900.7 | 66 | | | | | |
| 262 | 902.6 | 50 | | | | | |
| 263 | 906.4 | 40 | | | | | |
| 338 | 915.9 | 44 | 248 ± | 48 | 79 | 73 | 187 |
| 339 | 917.4 | 30 | 261 | 63 | 70 | | |
| 264 | 921.5 | 49 | | | | | |
| 265 | 922.6 | 60 | | | | | |
| 268 | 924.1 | 31 | | | | | |
| 336 | 925.7 | 46 | 57 | 77 | 179 | | |
| 266 | 931.3 | 60 | | | | | |
| 267 | 932.5 | 48 | | | | | |
| 271 | 936.1 | 53 | | | | | |
| 293 | 937.9 | 46 | 306 | 77 | 108 | | |
| 294 | 942.4 | 46 | | | | | |
| 270 | 951.5 | 52 | | | | | |
| 272 | 951.8 | 44 | | | | | |
| 319 | 953.1 | 63 | | | | | |
| 273 | 962.3 | 55 | | | | | |
| 269 | 963.3 | 8 | | | | | |
| 274 | 963.7 | 50 | | | | | |
| 275 | 968.7 | 53 | | | | | |
| 276 | 971.7 | 46 | 189 ± | 90 | 329 | 7 | 70 |
| 277 | 973.2 | 51 | | | | | |
| 278 | 974.4 | 49 | | | | | |
| 279 | 976.5 | 55 | | | | | |
| 280 | 977.3 | 45 | | | | | |
| 281 | 985.0 | 49 | | | | | |
| 282 | 997.8 | 48 | | | | | |
| 283 | 1,013.6 | 41 | | | | | |
| 318 | 1,037.9 | 20 | | | | | |

In Appendix 1, the amplitude of the first arrival is plotted against the borehole length, for the 250 MHz dipole antennas. The amplitude variation along the borehole indicates changes of the electrical conductivity of the rock volume surrounding the borehole. A decrease in this amplitude may indicate fracture zones, clay or rock volumes with increased water content, i.e. increased electric conductivity. The borehole length intervals showing decreased amplitude are listed in Table 5-3.

Finally, the structures considered as the most important (clearly seen in the radargram, identified with several antenna frequencies, stretching out far from the borehole wall etc.) are listed in Table 5-4 below.

**Table 5-3. Borehole length intervals in KFM06C with decreased amplitude for the 250 MHz antenna.**

| Borehole length (m) | |
|---|---|
| 105 | 555–565 |
| 115–120 | 620 |
| 125–130 | 640 |
| 140–150 | 650 |
| 155 | 665–670 |
| 230 | 675 |
| 235 | 685 |
| 240–250 | 690 |
| 260 | 700 |
| 285 | 745–765 |
| 335 | 810 |
| 350 | 835–840 |
| 360 | 865–895 |
| 395 | 920 |
| 420–435 | 930–935 |
| 450–460 | 940 |
| 470 | 950–960 |
| 490 | 965–975 |
| 530–540 | 990 |

**Table 5-4. Some important structures in KFM06C.**

| Borehole | KFM06C |
|---|---|
| Structures | 11, 13, 24, 42, 61, 63, 83, 86x, 87, 99, 99x, 99xx, 99xxx, 101, 109, 117, 122, 131, 149, 177, 183, 184, 185, 185x, 185xx, 185xxx, 185xxxx, 192, 205, 205x, 212, 251, 267, 268, 270, 283, 311, 311x, 312, 314, 316, 317, 317x, 318, 319, 320, 321 |

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

## 5.2 BIPS logging

The BIPS pictures are presented in Appendix 2.

To get the best possible length accuracy, the BIPS images are adjusted to reference marks on the logging cable. Additionally the marks on the borehole wall created by the drill rig in core-drilled boreholes are visible on the BIPS screen. The recorded length is adjusted to these visible marks. In percussion drilled boreholes we use marks on the logging cable as references for the depth adjustment. These marks on the cable are calibrated against the visible marks in core-drilled boreholes. At present we have marks at 110, 150 and 200 metre on the logging cable that are used for depth adjustments of the BIPS results in percussion drilled boreholes.

The BIPS images in the appendix are adjusted for the tension of the cable and error of the length readings from the measuring wheel. The adjusted length is showed in red.

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. 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 field data and are also presented in Figure 4-2 in this report.

During the logging campaign in KFM06C we had problem with jamming probes. Several dummy logging runs confirmed that there was problems to pass several parts in the borehole. To get a better understanding of the problem, a front viewing camera lens was used on the BIPS camera. This run demonstrated the existence of metallic objects in the borehole.

It was finally concluded that the metallic parts was broken treads from the inner casing, used during the core drilling, that was broken in several parts when retrieving back the casing. During the operation in the borehole with the front viewing camera we also succeeded to retrieve back parts of the tread. In Figure 5-4 the result from the front viewing camera shows a part of a tread at 512.60 metre.

To avoid an expensive mobilization for a drill rig a special dummy probe was constructed to collect or push metallic objects to the bottom of the borehole. This dummy operation was successful to push the tread to the bottom of the borehole, and the final BIPS survey was performed.

The final results from the images shows a borehole that is heavily affected by discolouring of the borehole walls. However, the water quality is good along the borehole. From 600 metre down to the bottom, mud is covering the lowermost part of the borehole wall. This limits the visibility, but still the image quality is sufficient for geological mapping.

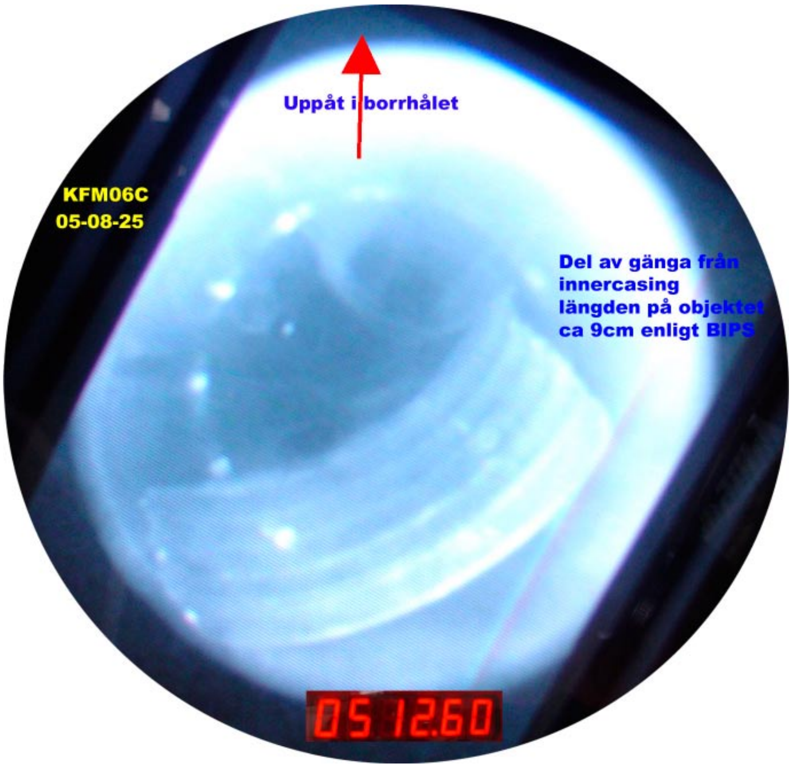



***Figure 5-4.*** *Metal tread at 512.60 metre in KFM06C.*

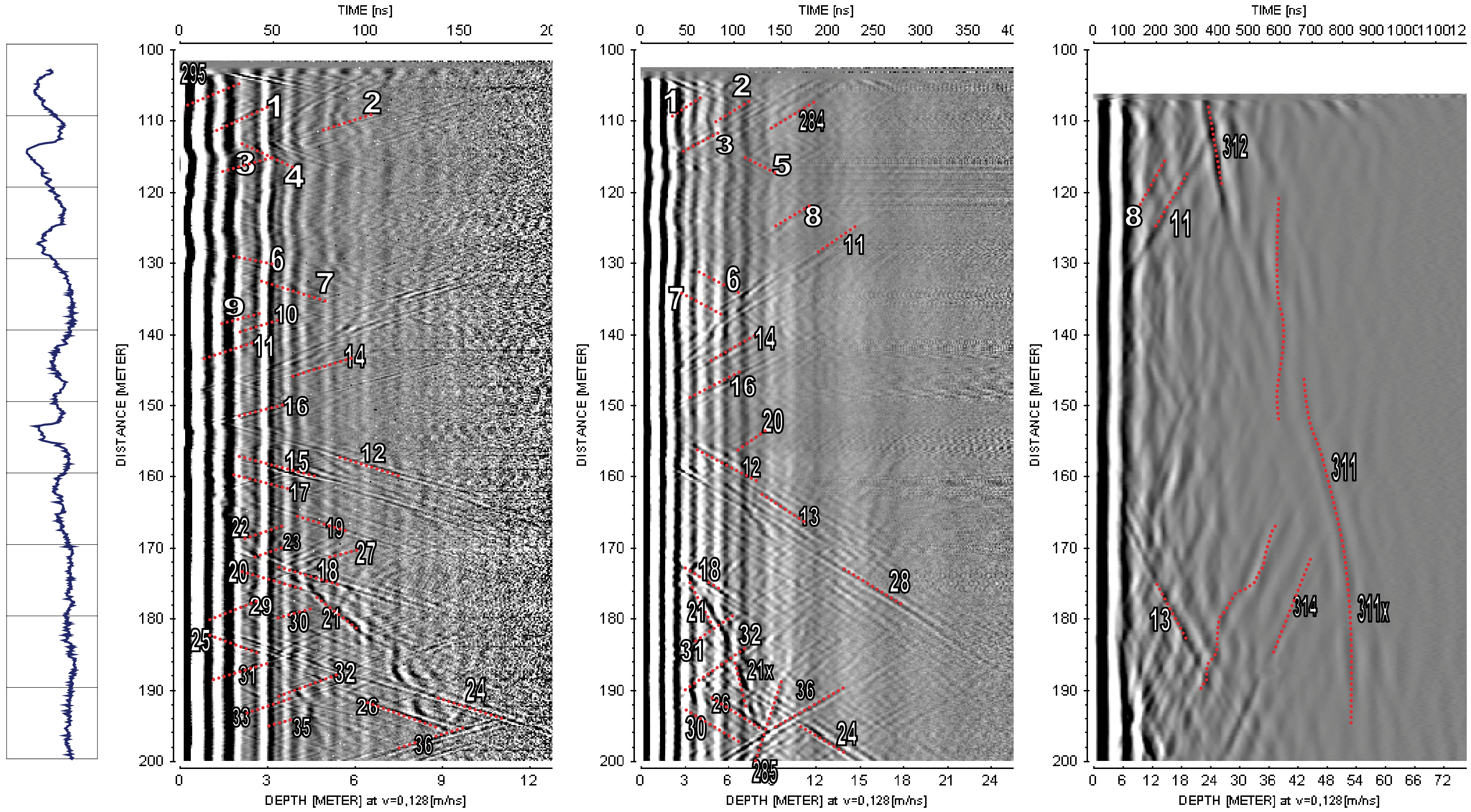
# References

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

# Appendix 1

## Radar logging in KFM06C, 100 to 990 m, dipole antennas 250, 100 and 20 MHz

FORSMARK KFM06C

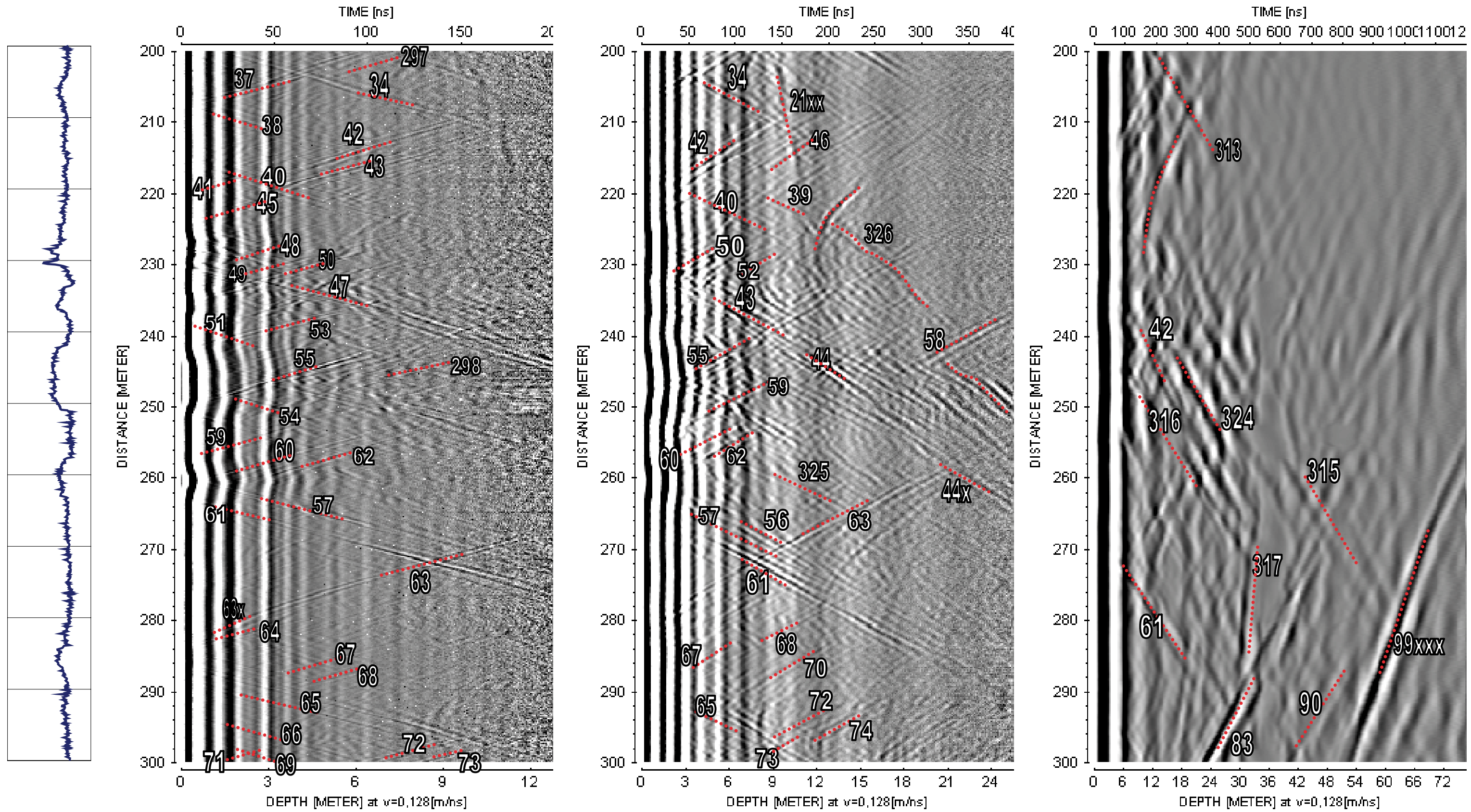



250 MHz

100 MHz

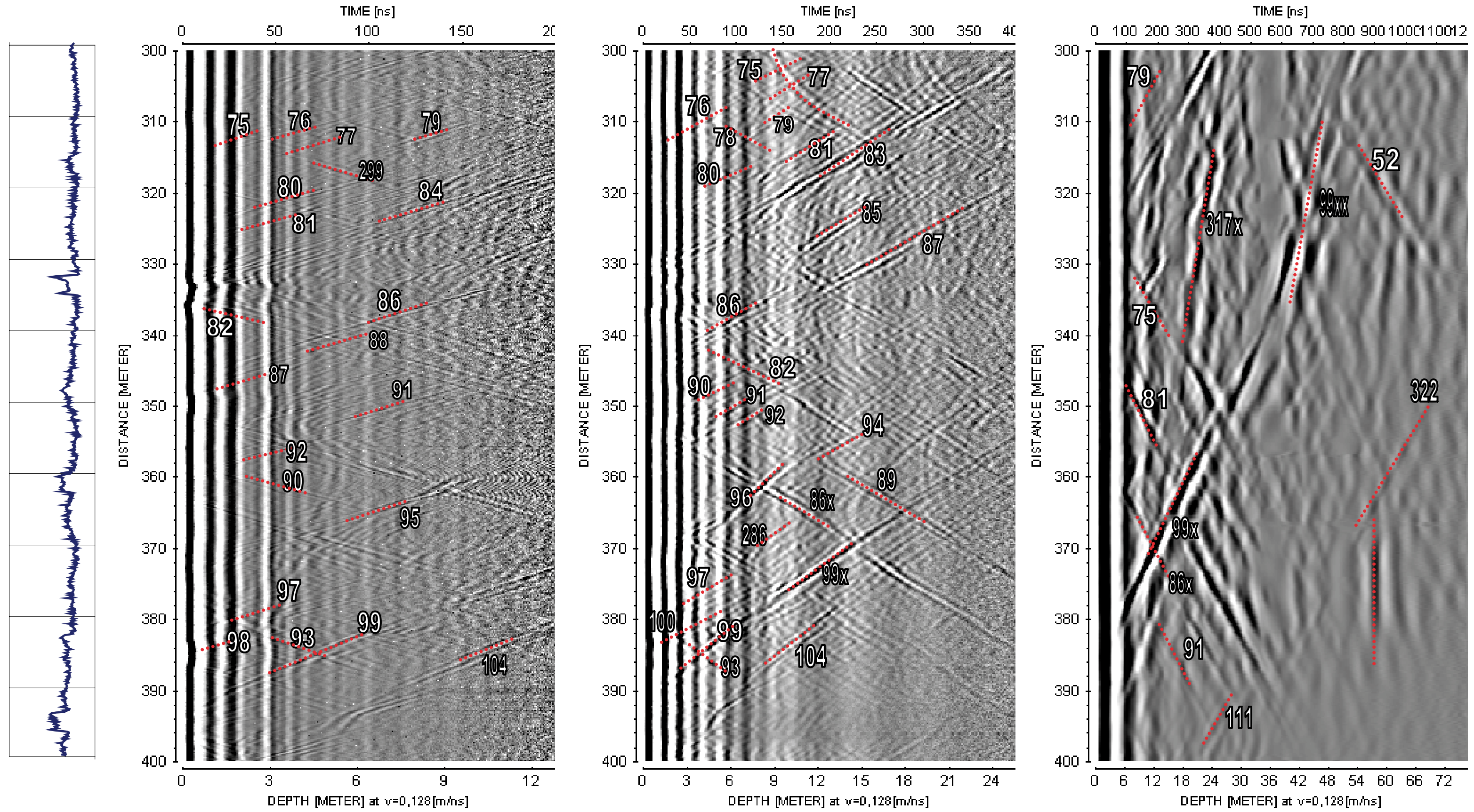
20 MHz

**FORSMARK KFM06C**



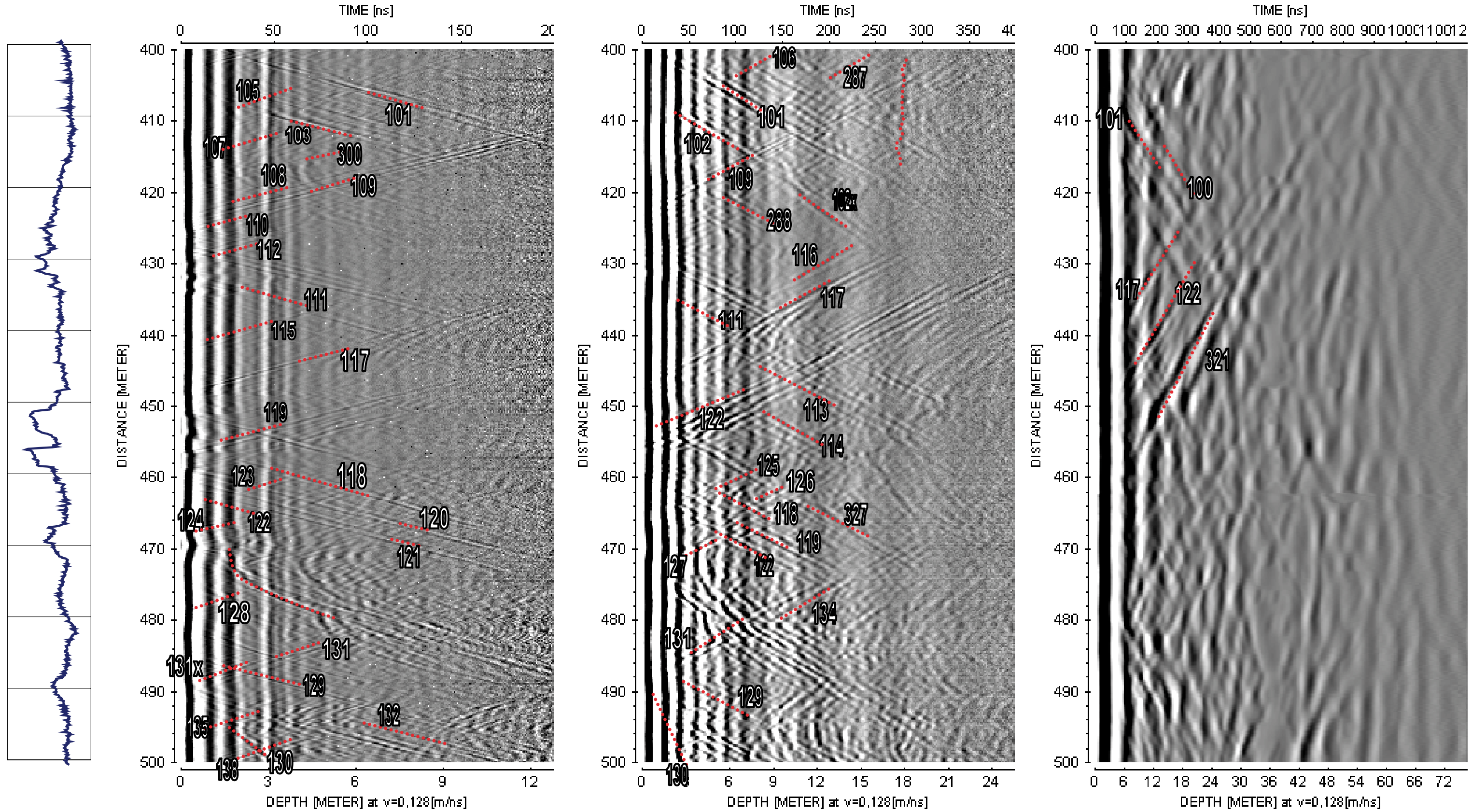

**250 MHz** **100 MHz** **20 MHz**

**FORSMARK KFM06C**




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

**FORSMARK KFM06C**

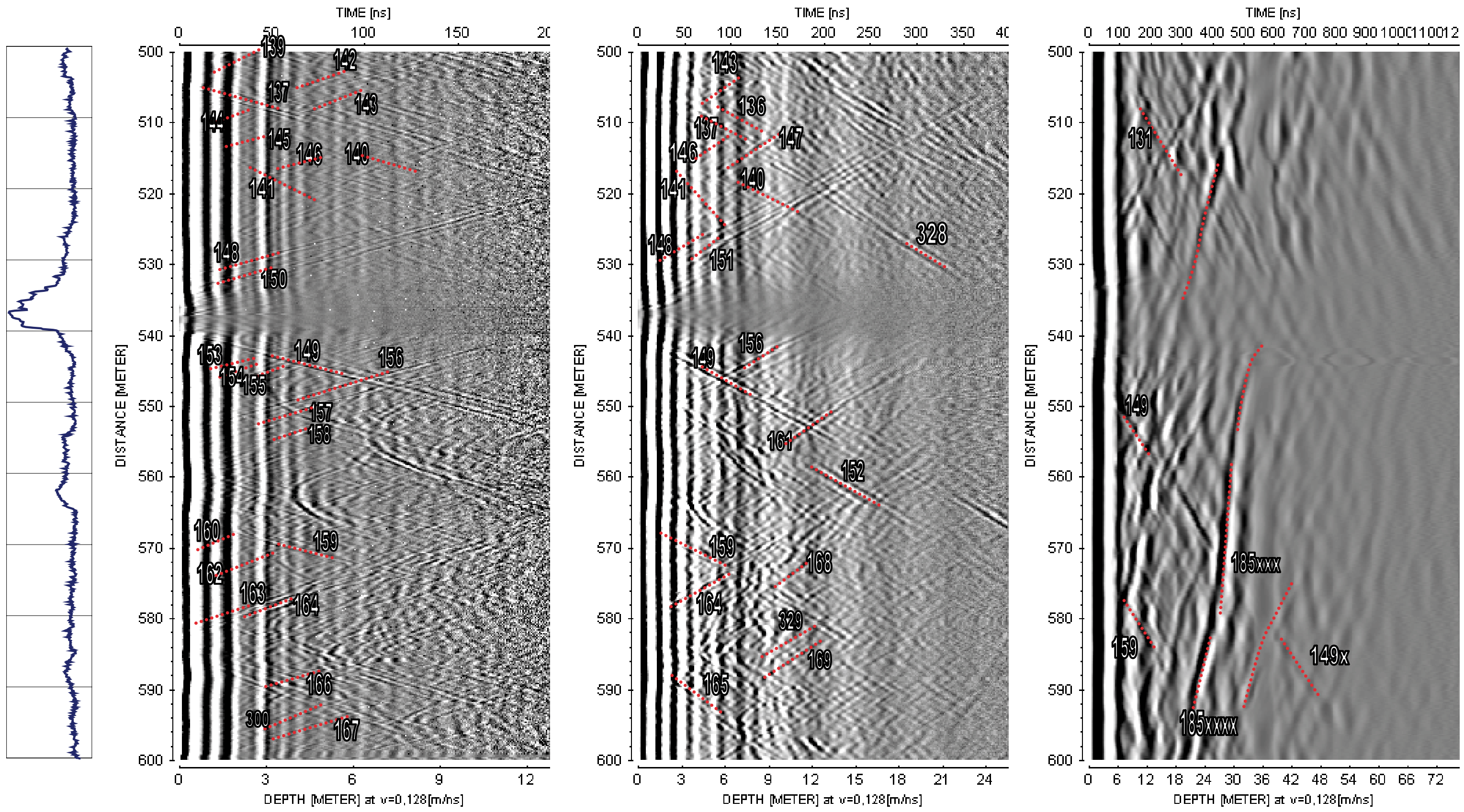



**250 MHz**

**100 MHz**

**20 MHz**

**FORSMARK KFM06C**

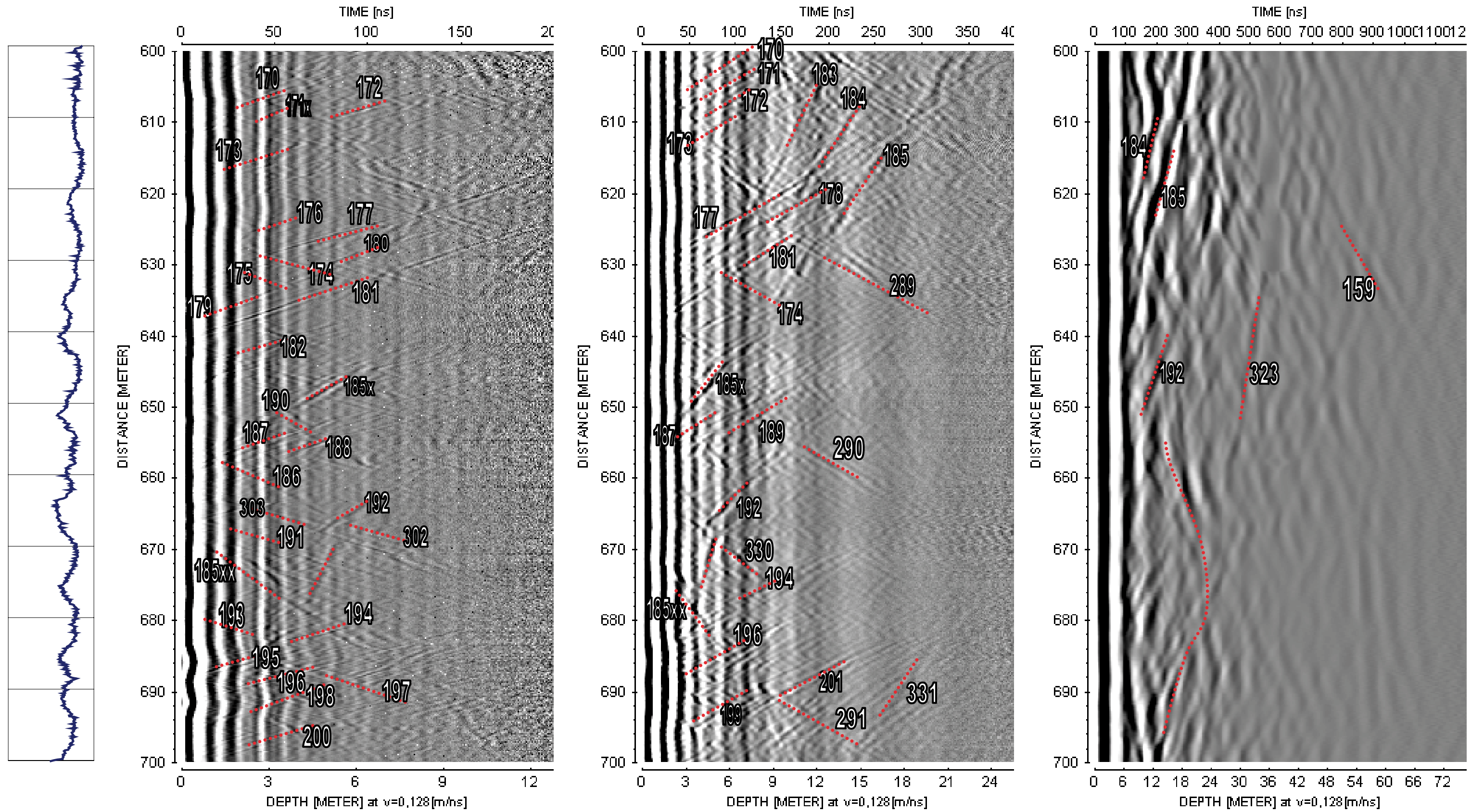



250 MHz

100 MHz

20 MHz

FORSMARK KFM06C

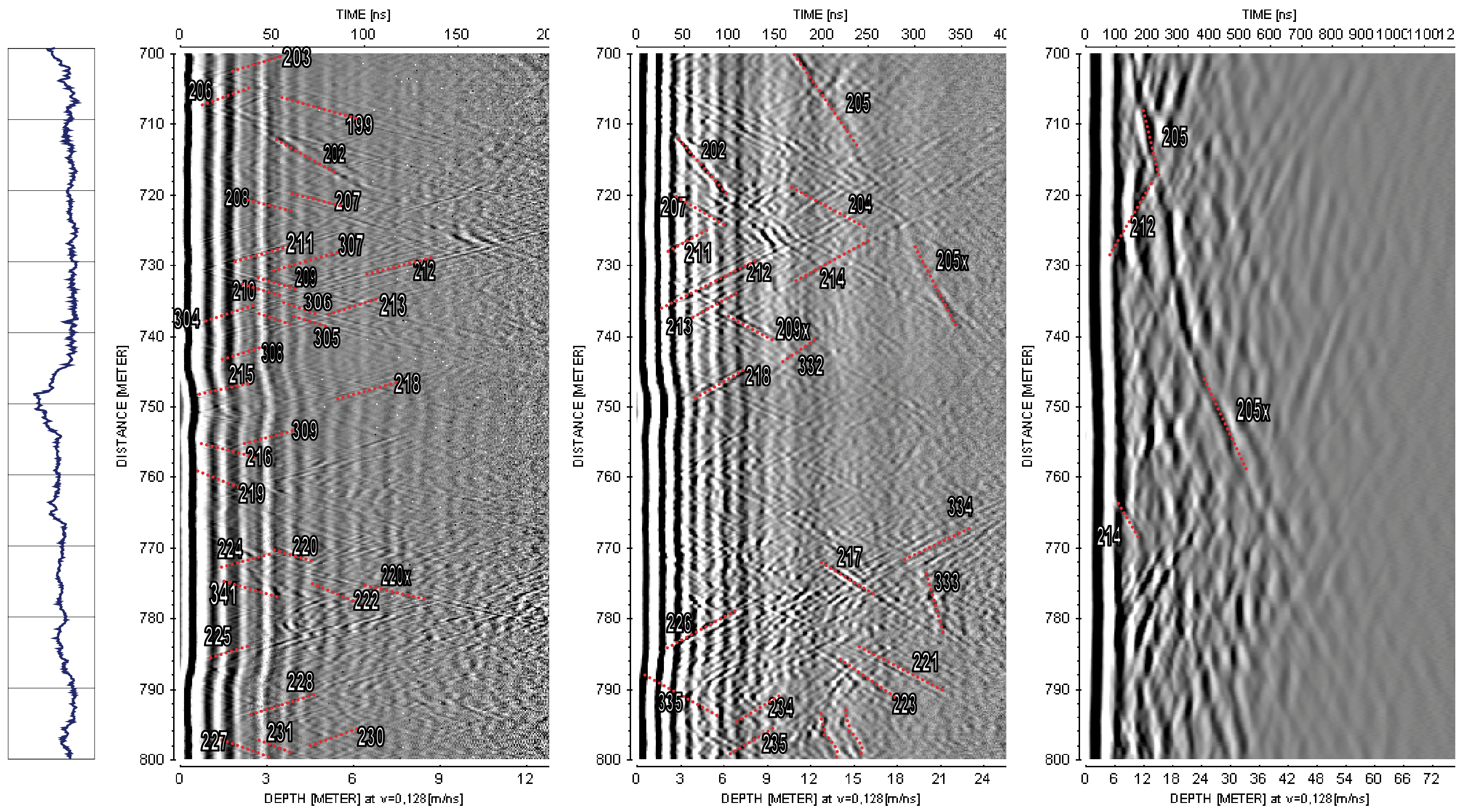



250 MHz

100 MHz

20 MHz

**FORSMARK KFM06C**

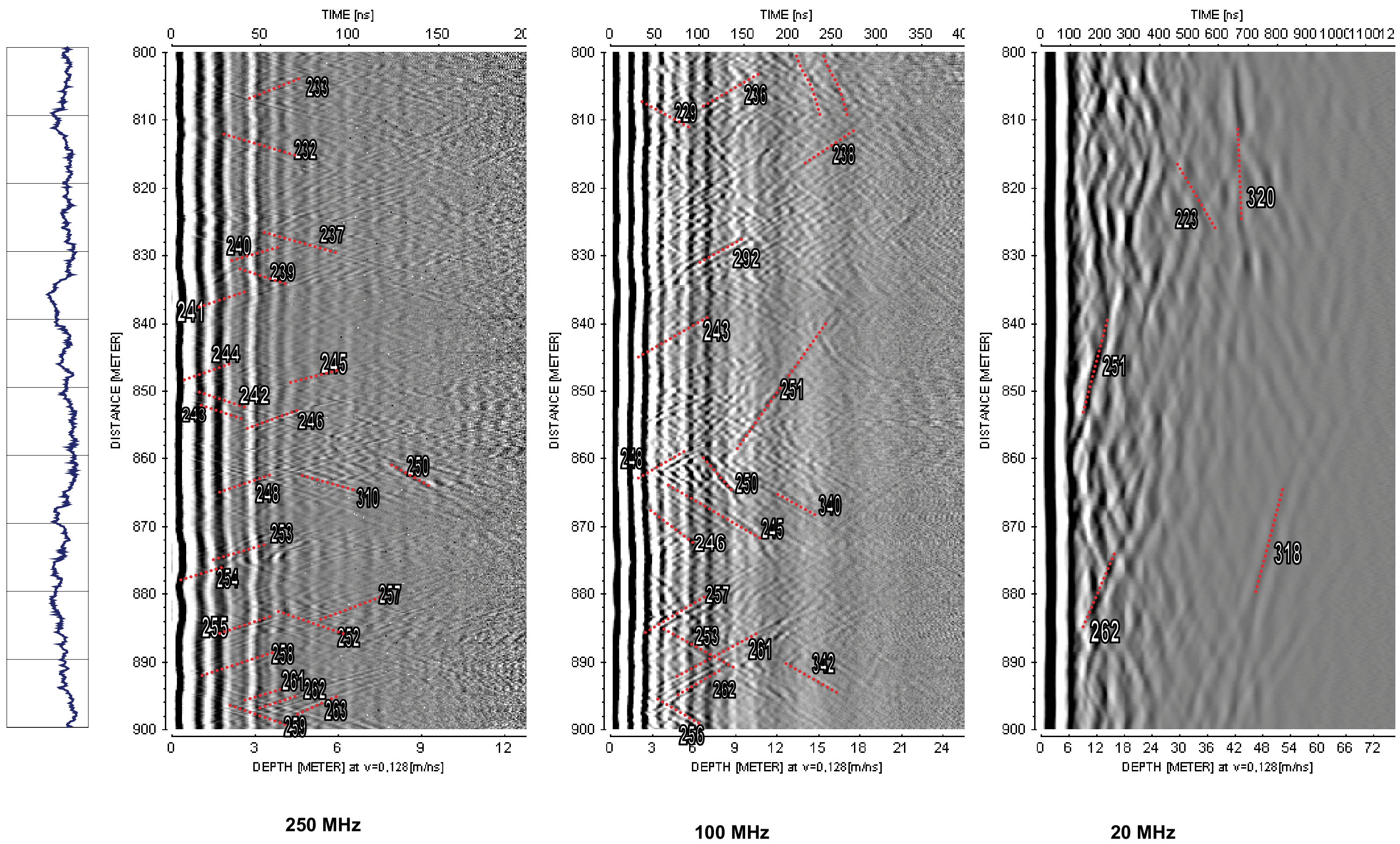



250 MHz

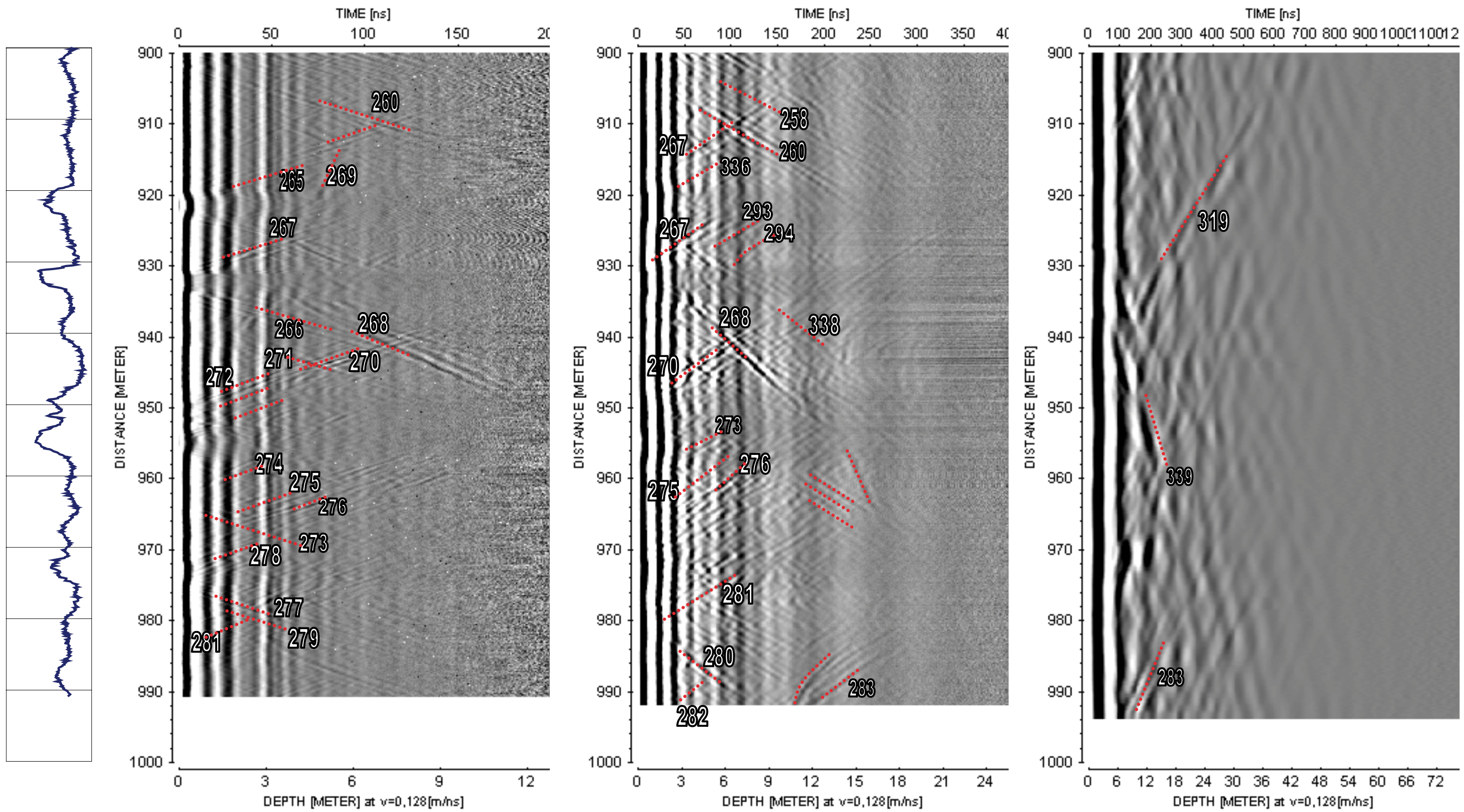
100 MHz

20 MHz

**FORSMARK KFM06C**



**FORSMARK KFM06C**




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

## BIPS logging in KFM06C, 101 to 992 m

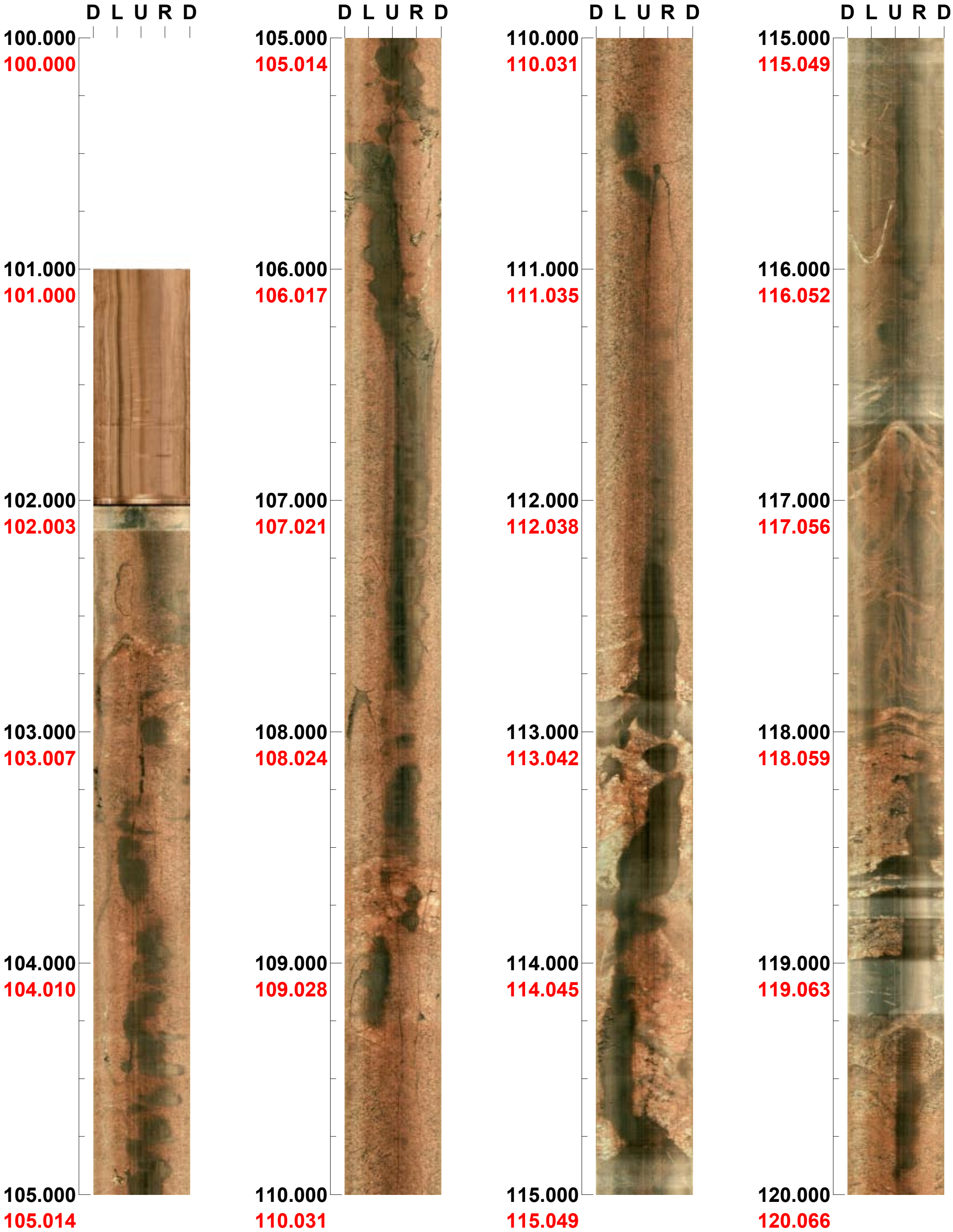
**Project name: Forsmark**

| | |
|---|---|
| Image file | : c:\work\r5449f~1\bips\kfm06c_1.bip |
| BDT file | : c:\work\r5449f~1\bips\kfm06c_1.bdt |
| Locality | : FORSMARK |
| Bore hole number | : KFM06C |
| Date | : 05/08/23 |
| Time | : 15:00:00 |
| Depth range | : 101.000 - 992.501 m |
| Azimuth | : 26 |
| 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 | : 47 |
| Color | : +0 +0 +0 |

**Project name: Forsmark**

**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

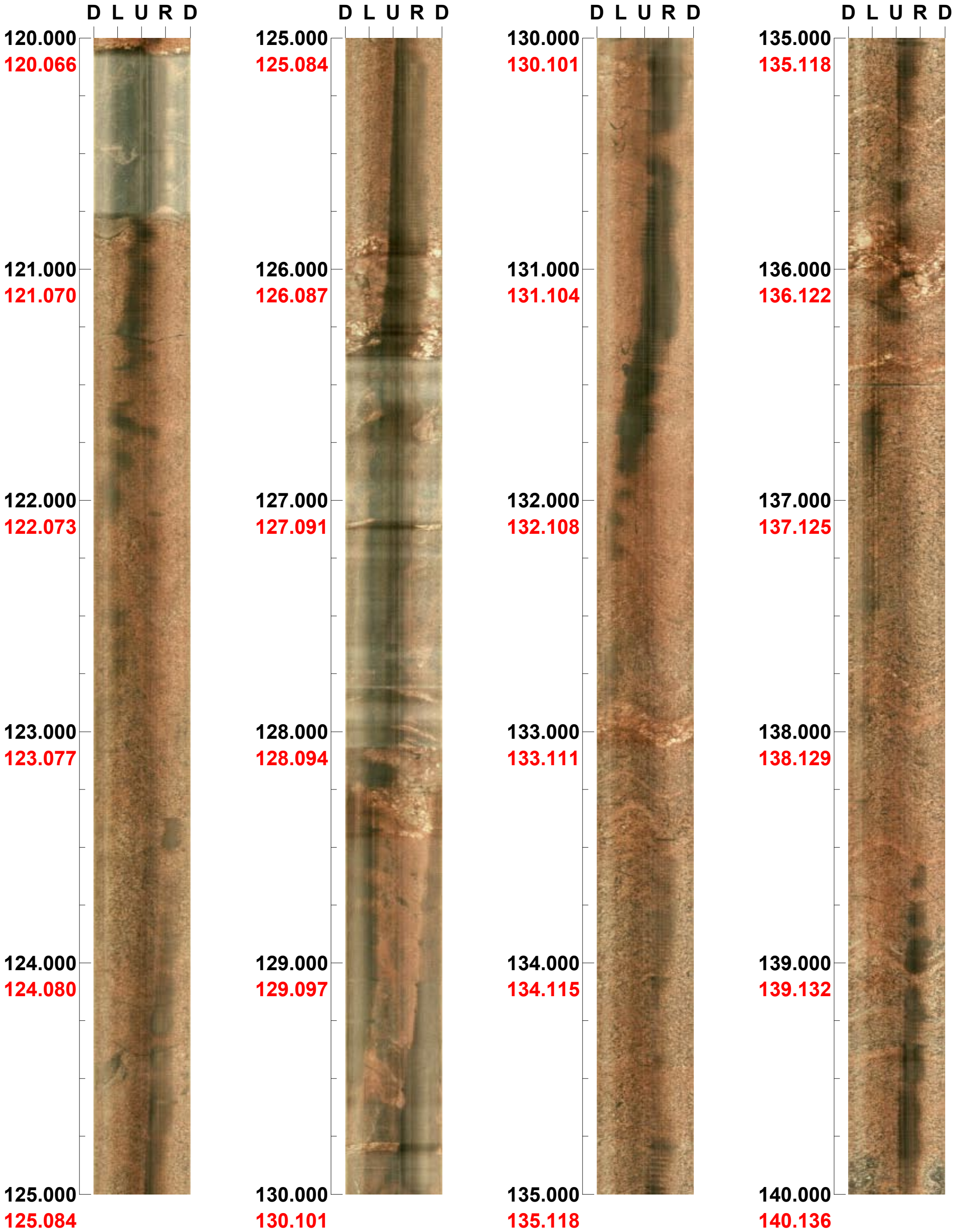
**Depth range: 100.000 - 120.000 m**




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

Project name: Forsmark
Bore hole No.: KFM06C　　Azimuth: 26　　Inclination: -60

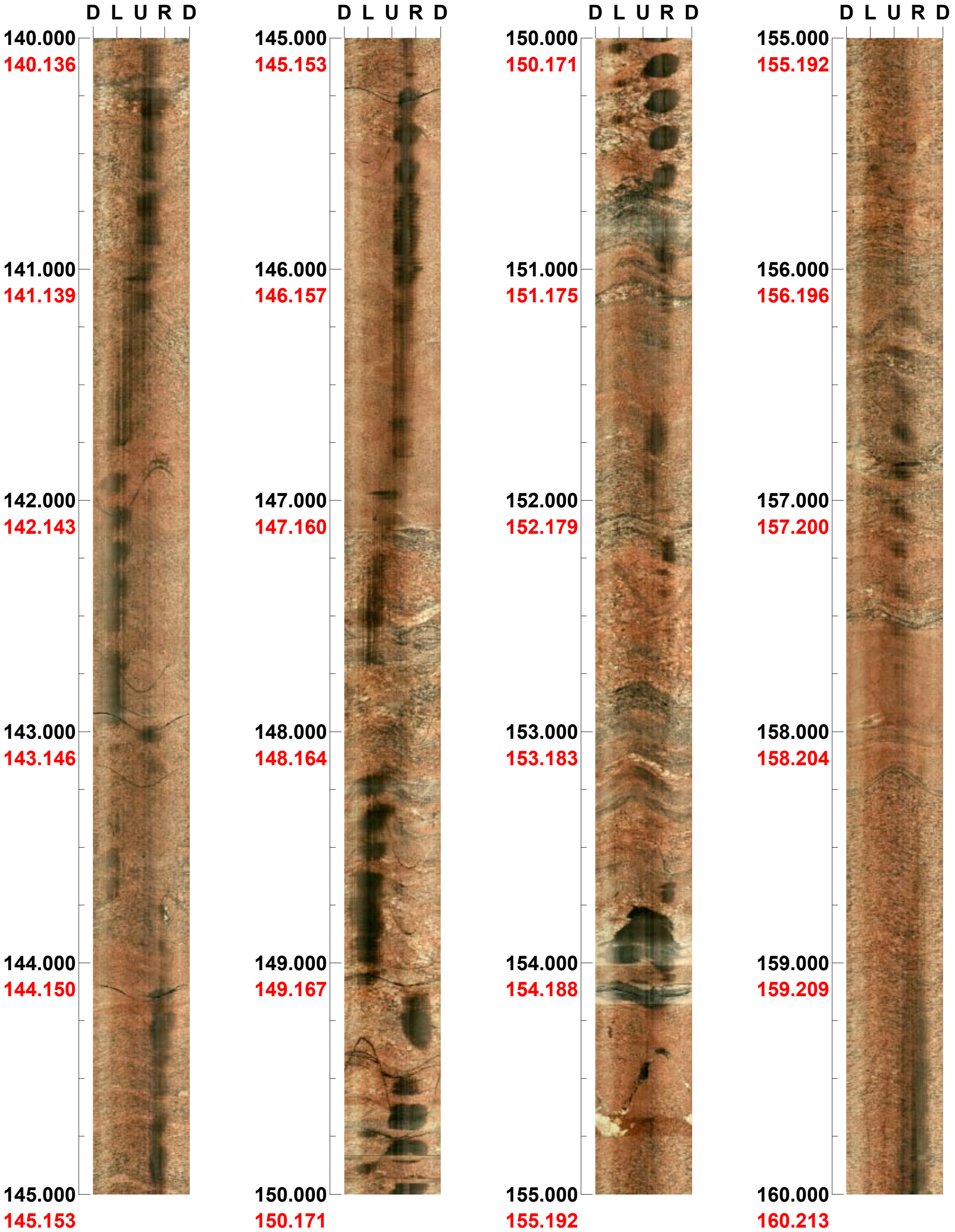
Depth range: 120.000 - 140.000 m




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

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 140.000 - 160.000 m**




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

Project name: Forsmark
Bore hole No.: KFM06C		Azimuth: 26		Inclination: -60

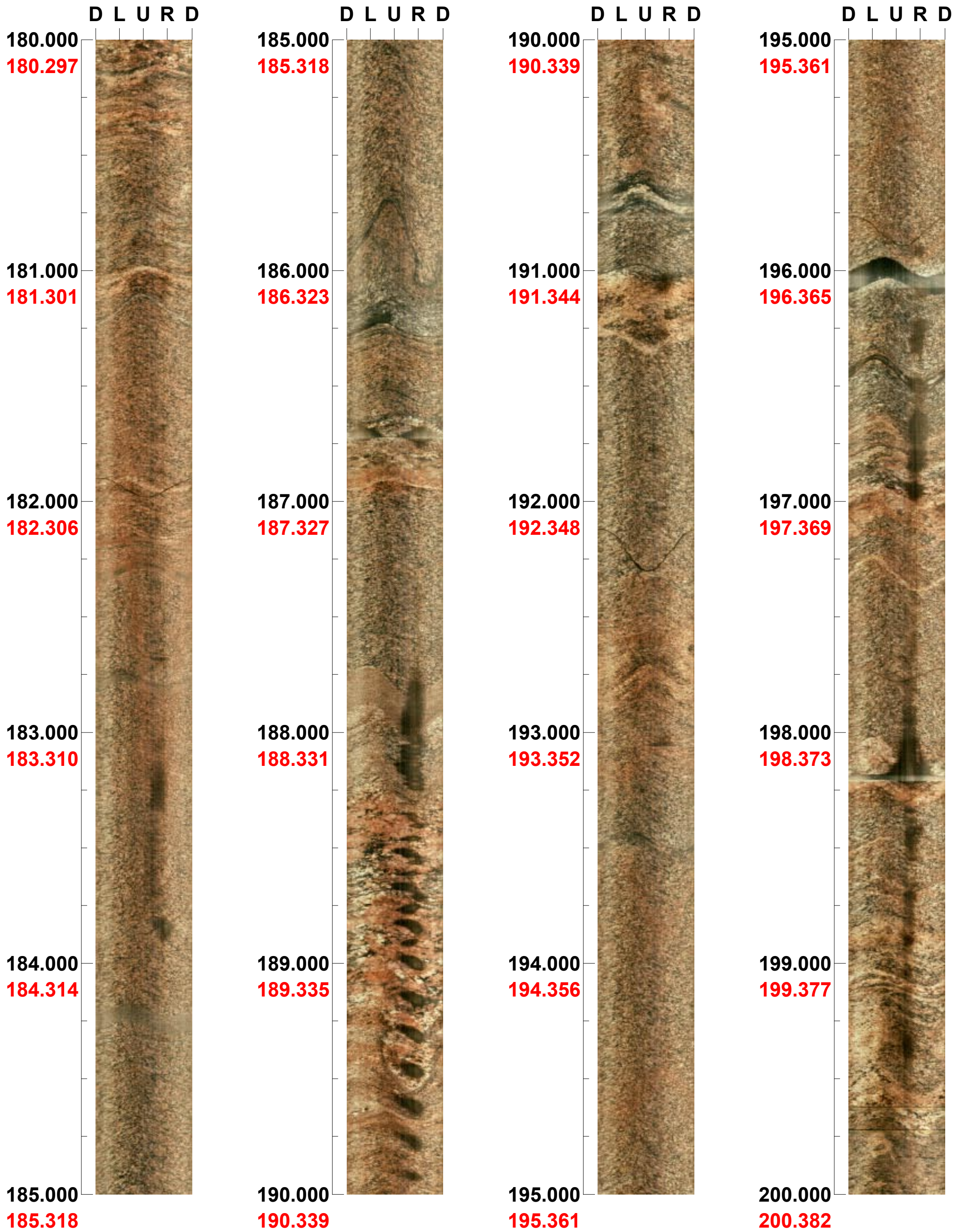
Depth range: 160.000 - 180.000 m


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

**Project name: Forsmark**

**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

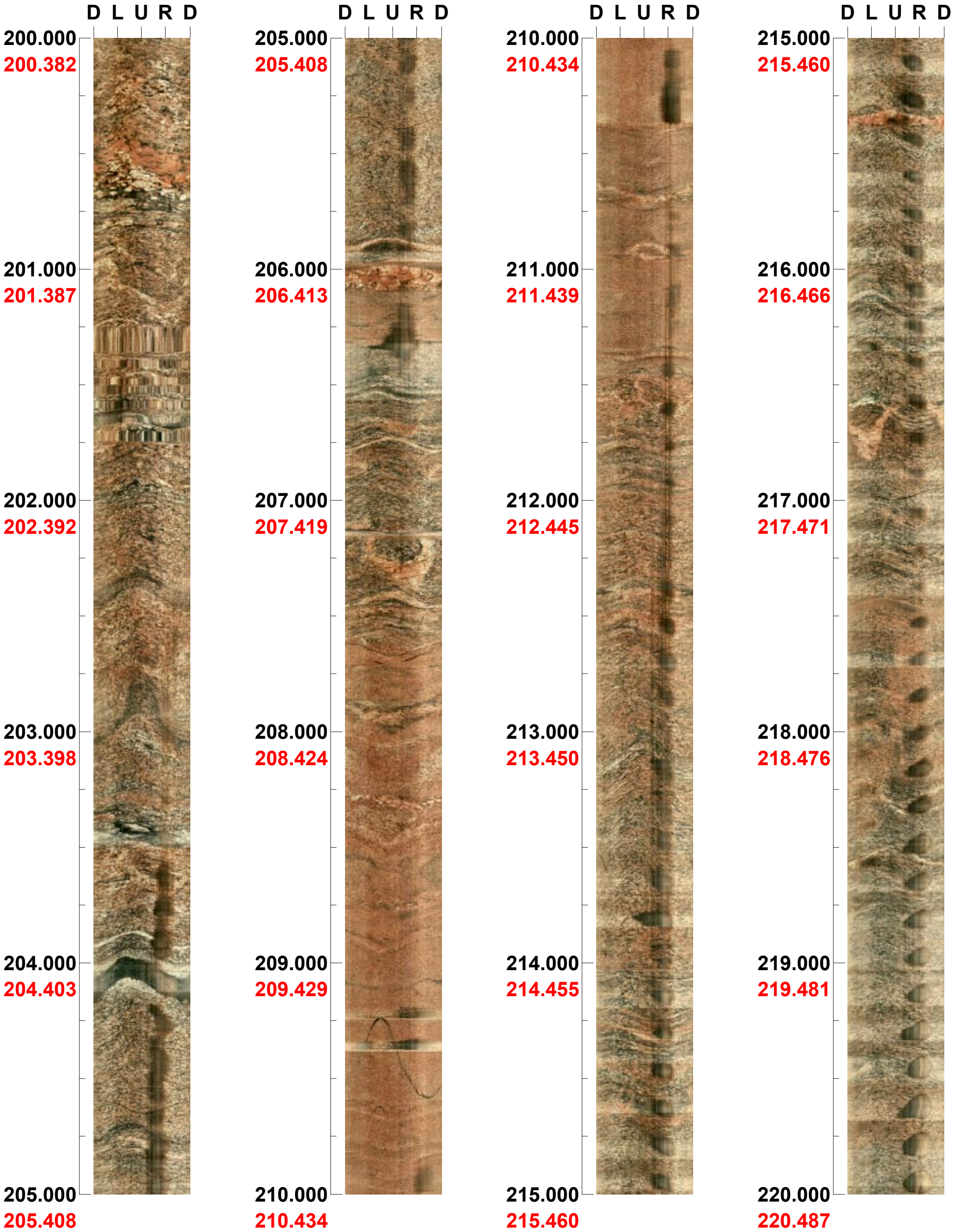
**Depth range: 180.000 - 200.000 m**




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

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 200.000 - 220.000 m**




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

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 220.000 - 240.000 m**


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

**Project name: Forsmark**

**Bore hole No.: KFM06C** Azimuth: 26 Inclination: -60

**Depth range: 240.000 - 260.000 m**


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

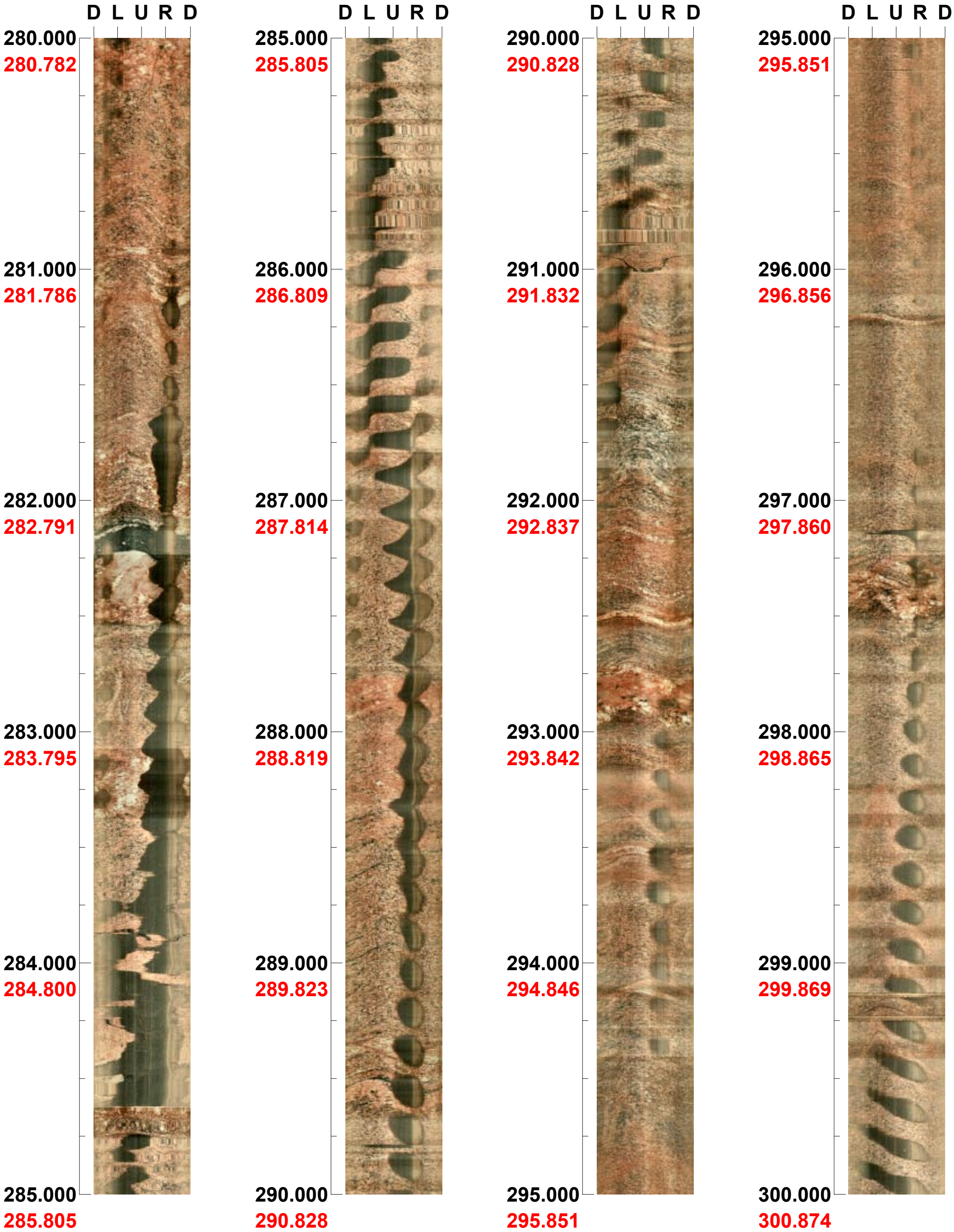
**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 260.000 - 280.000 m**


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

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

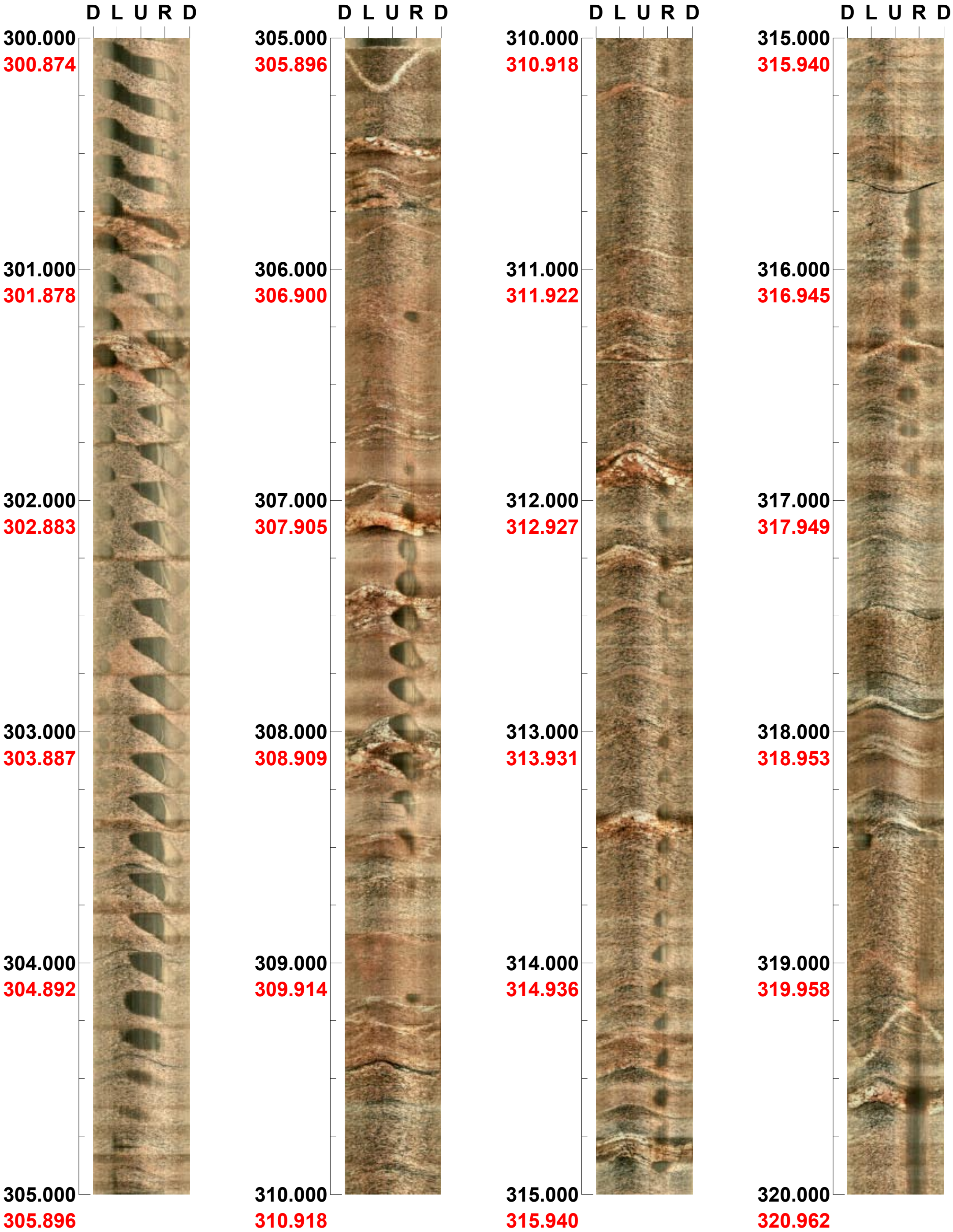
**Depth range: 280.000 - 300.000 m**




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

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 300.000 - 320.000 m**




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

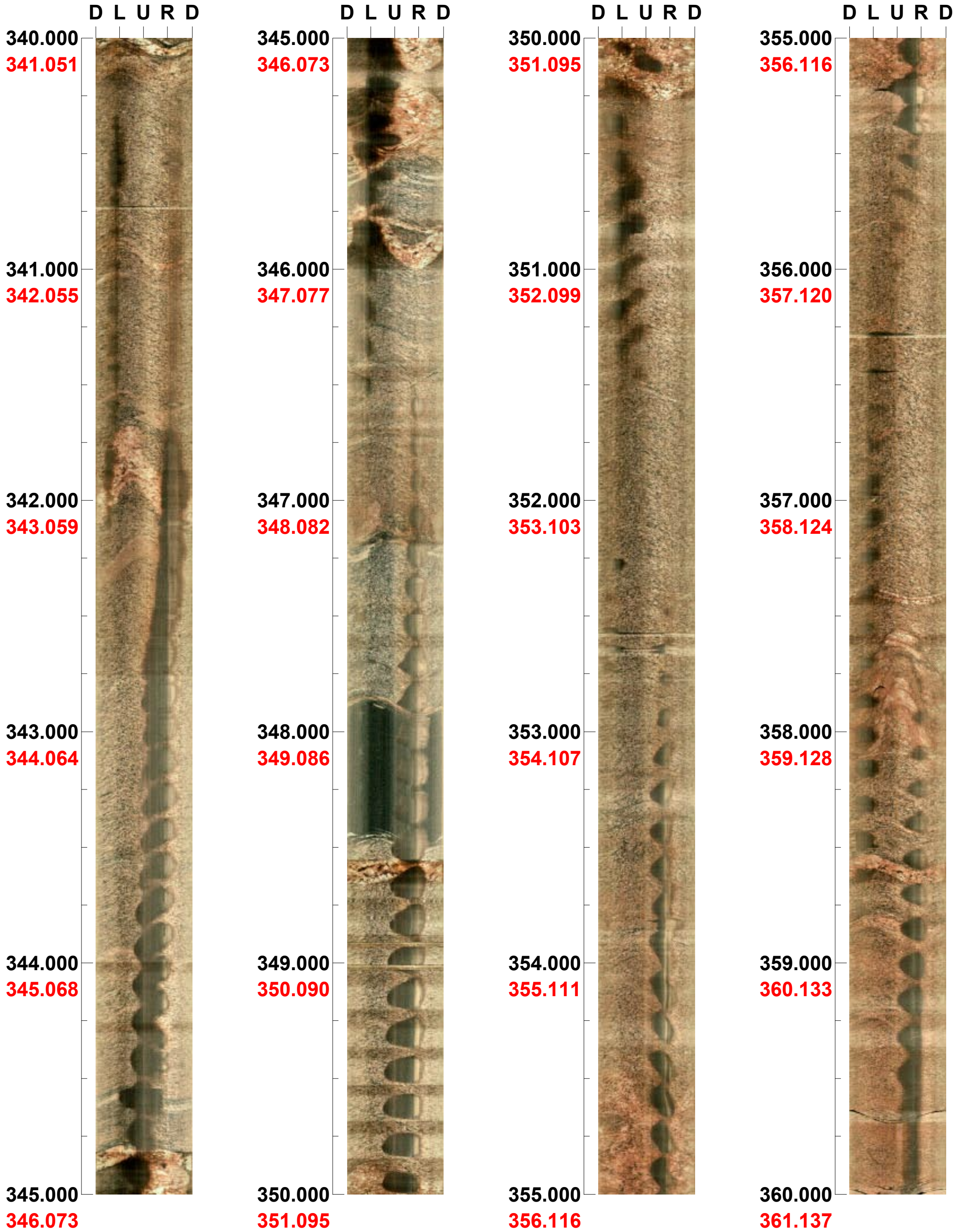
**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 320.000 - 340.000 m**


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

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 340.000 - 360.000 m**




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

**Project name: Forsmark**

**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 360.000 - 380.000 m**


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

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

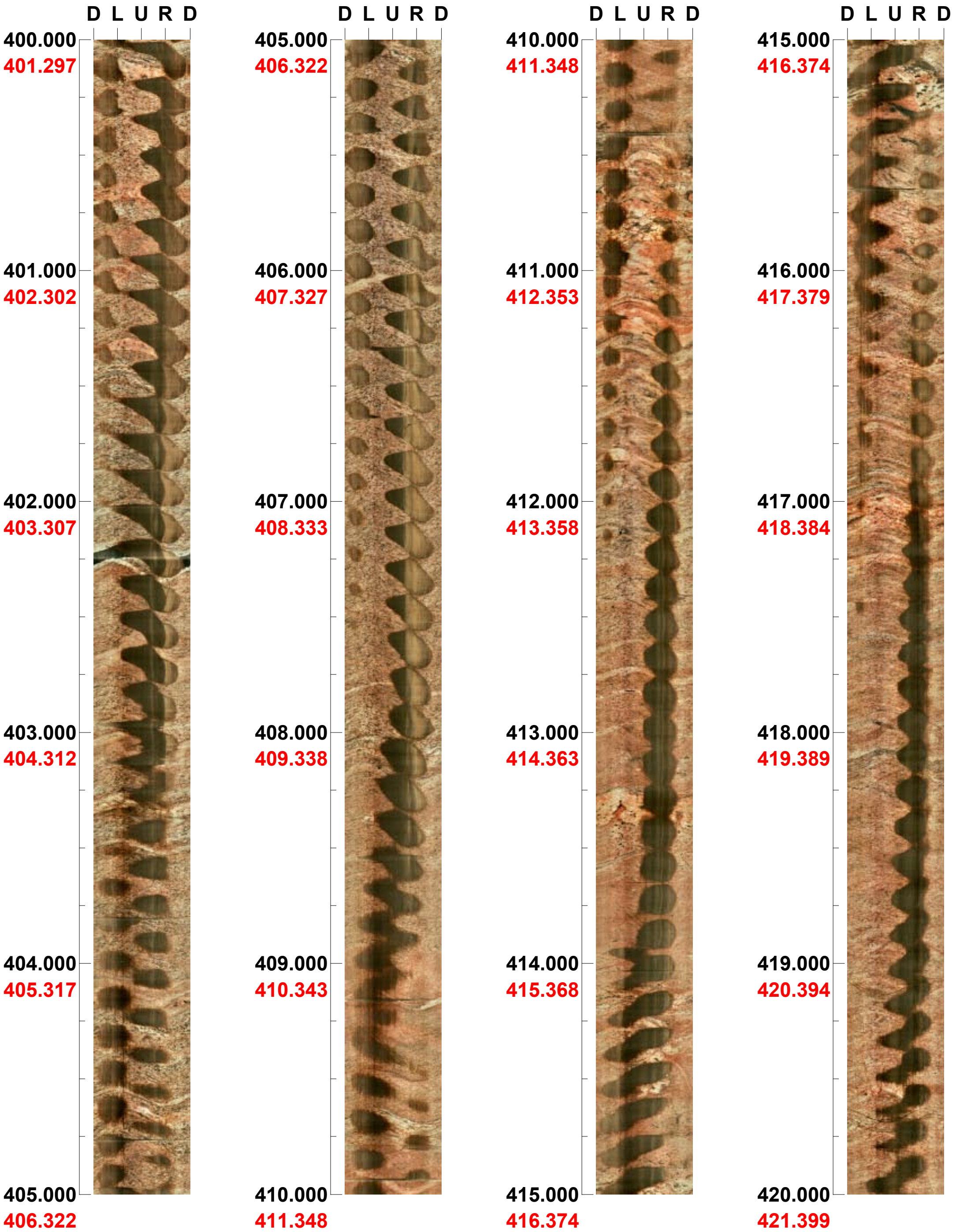
**Depth range: 380.000 - 400.000 m**


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

**Project name: Forsmark**

**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 400.000 - 420.000 m**




**( 2 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

**Project name: Forsmark**

**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 420.000 - 440.000 m**


( 3 / 21 ) **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM06C                                   Azimuth: 26        Inclination: -60

Depth range:  440.000 - 460.000 m


( 4 / 21 )        Scale: 1/25        Aspect ratio: 175 %

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 460.000 - 480.000 m**

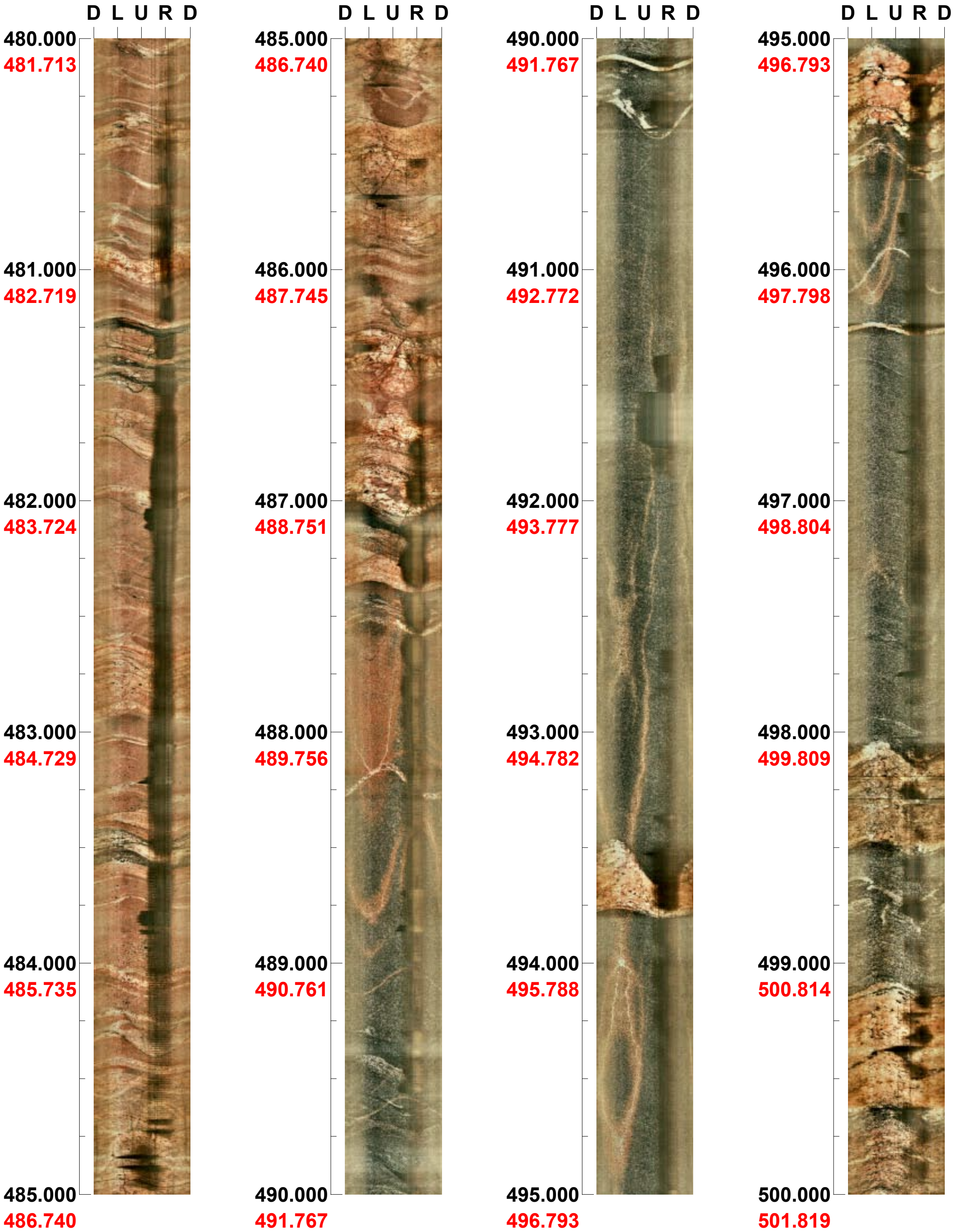

**( 5 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM06C

Azimuth: 26

Inclination: -60

Depth range: 480.000 - 500.000 m

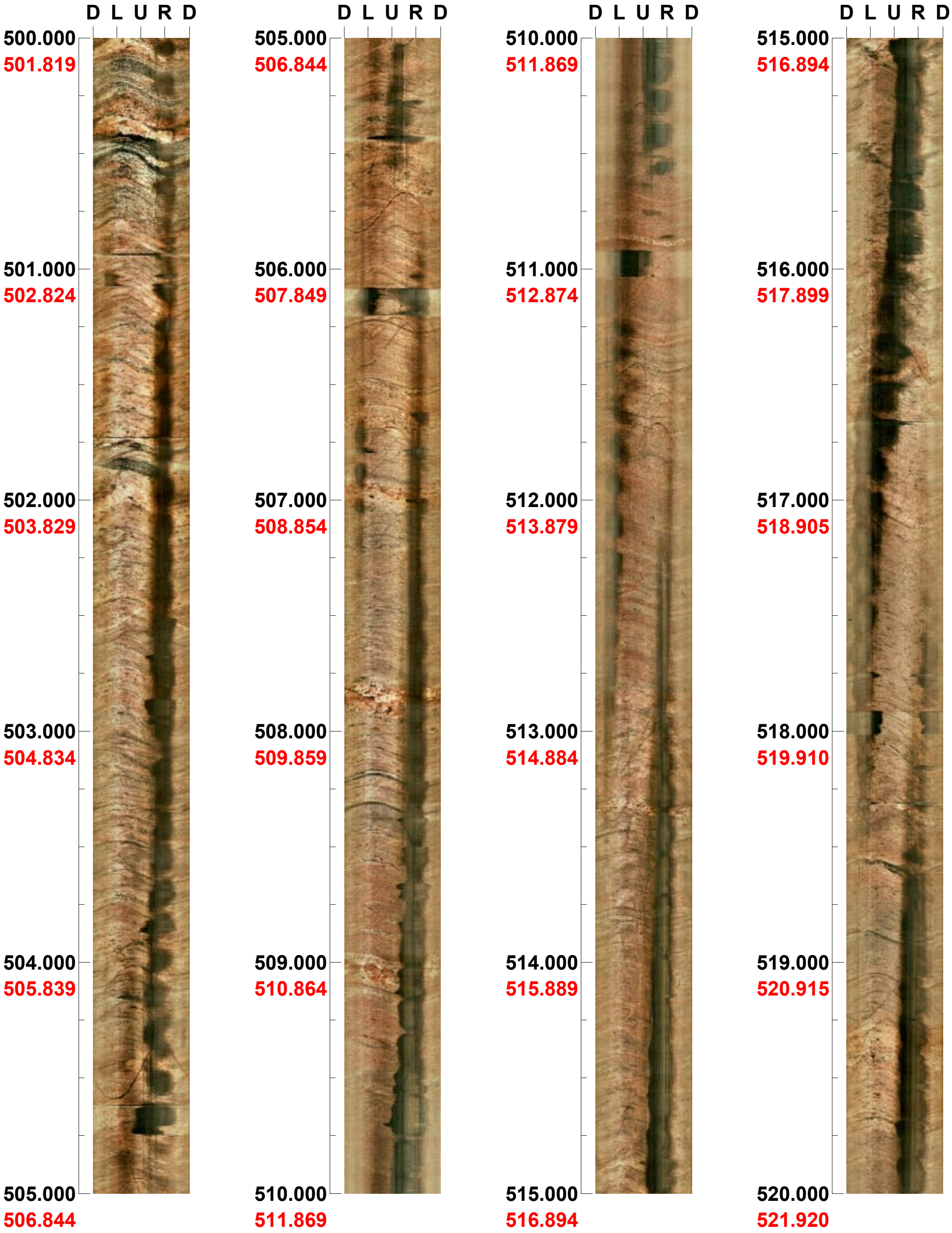



( 6 / 21 ) Scale: 1/25 Aspect ratio: 175 %

**Project name: Forsmark**

**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 500.000 - 520.000 m**




**( 7 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 520.000 - 540.000 m**


**( 8 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM06C

Azimuth: 26 Inclination: -60

Depth range: 540.000 - 560.000 m


( 9 / 21 ) Scale: 1/25 Aspect ratio: 175 %

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 560.000 - 580.000 m**


**( 10 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 580.000 - 600.000 m**


**( 11 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 600.000 - 620.000 m**


**( 12 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 620.000 - 640.000 m**


( 13 / 21 ) Scale: 1/25 Aspect ratio: 175 %

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 640.000 - 660.000 m**


**( 14 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

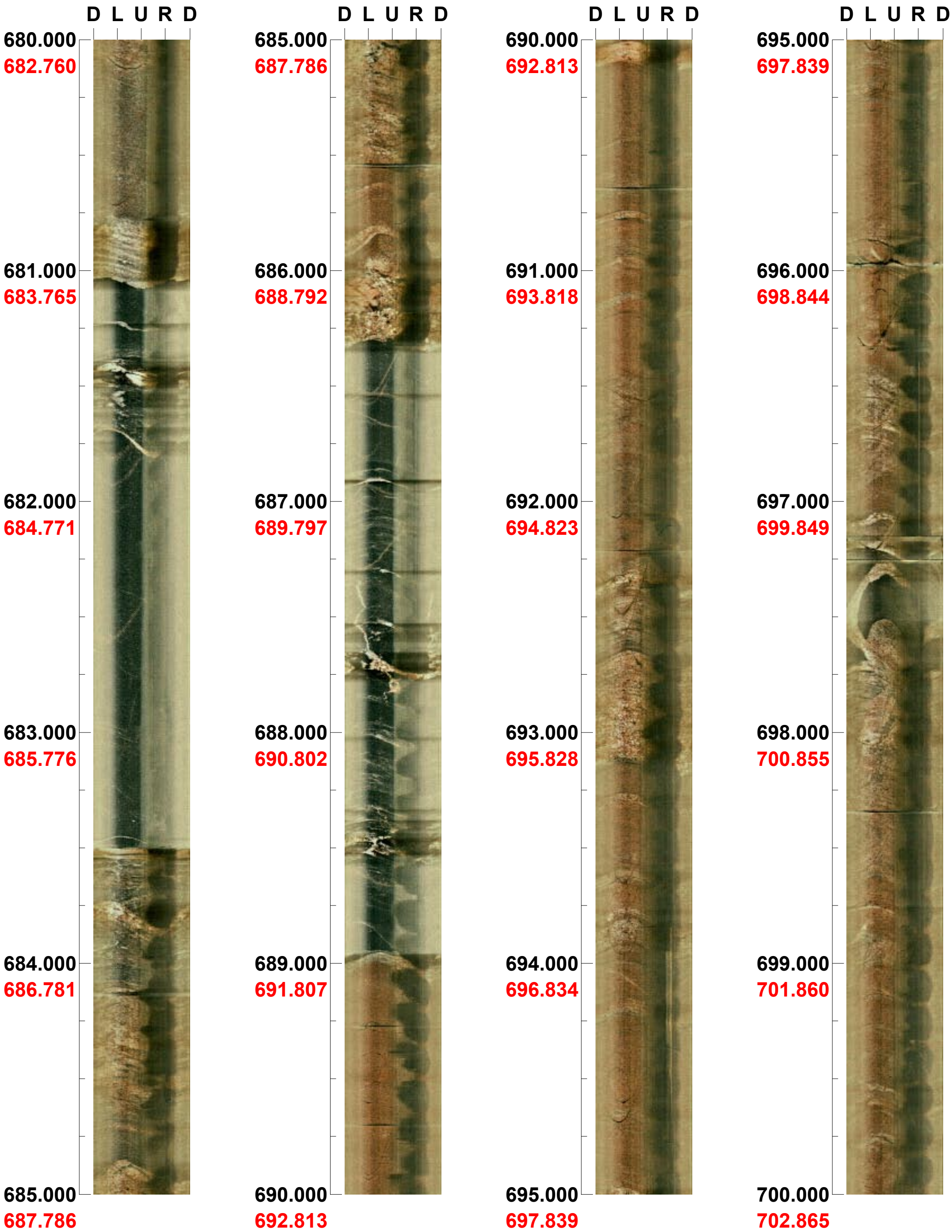
**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 660.000 - 680.000 m**


**( 15 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

Project name: Forsmark
Bore hole No.: KFM06C Azimuth: 26 Inclination: -60

Depth range: 680.000 - 700.000 m




( 16 / 21 ) Scale: 1/25 Aspect ratio: 175 %

Project name: Forsmark
Bore hole No.: KFM06C Azimuth: 26 Inclination: -60

Depth range: 700.000 - 720.000 m


( 17 / 21 ) Scale: 1/25 Aspect ratio: 175 %

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 720.000 - 740.000 m**


**( 18 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 740.000 - 760.000 m**


**( 19 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 760.000 - 780.000 m**


**( 20 / 21 )** **Scale: 1/25** **Aspect ratio: 175 %**

**Project name: Forsmark**

**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 780.000 - 798.547 m**


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

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 780.000 - 800.000 m**

D L U R D
780.000
780.000
781.000
781.000
782.000
782.000
783.000
783.000
784.000
784.000
785.000
785.000

D L U R D
785.000
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786.000
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787.000
788.000
788.000
789.000
789.000
790.000
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D L U R D
790.000
790.000
791.000
791.000
792.000
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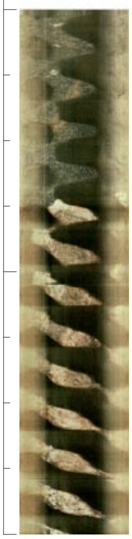
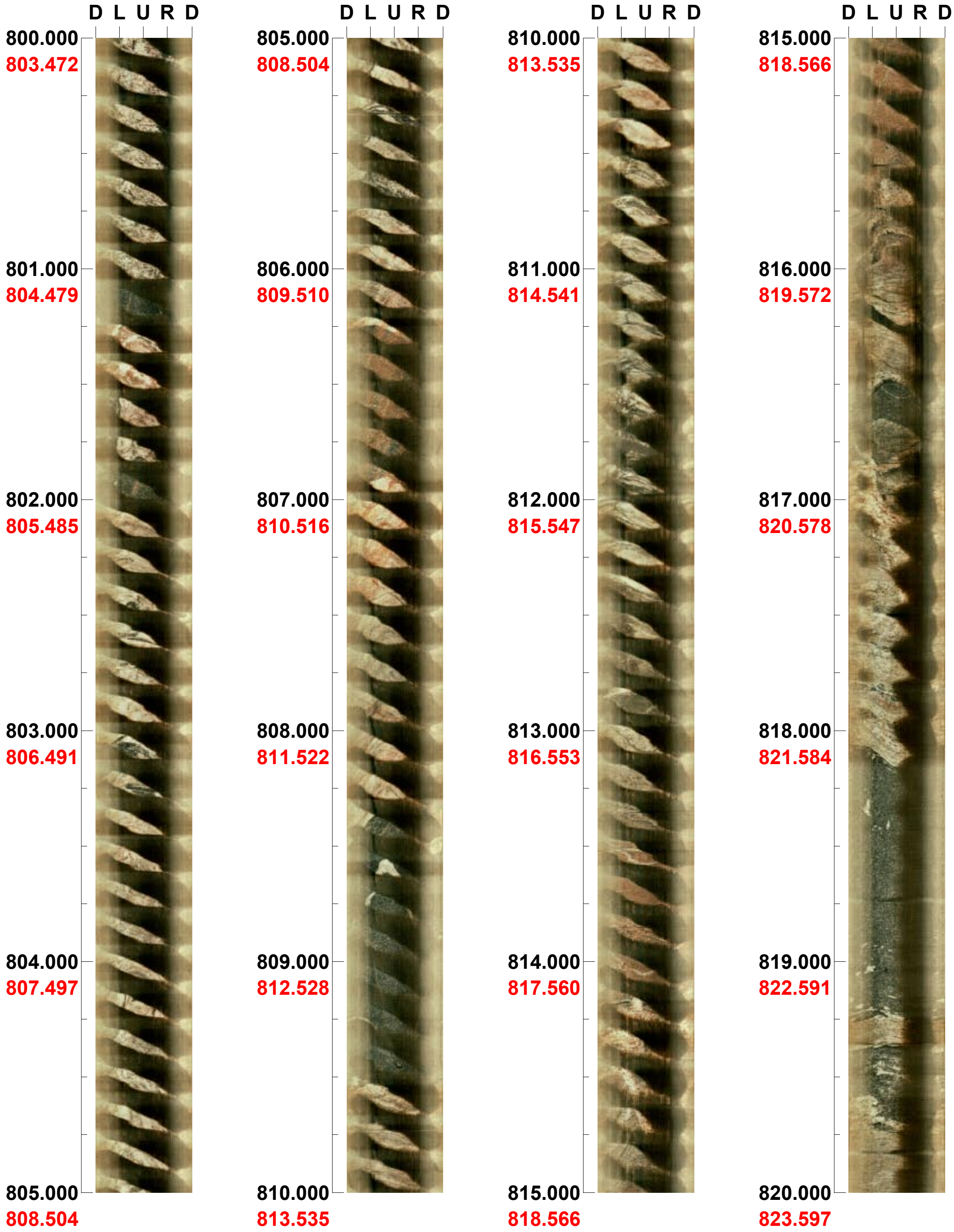
793.000
793.000
794.000
794.000
795.000
795.000

D L U R D
795.000
795.000
796.000
796.000
797.000
797.000
798.000
801.460

799.000
802.466
800.000
803.472

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

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 800.000 - 820.000 m**




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

Project name: Forsmark
Bore hole No.: KFM06C Azimuth: 26 Inclination: -60

Depth range: 820.000 - 840.000 m


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

**Project name: Forsmark**

**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 840.000 - 860.000 m**


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

**Project name: Forsmark**
**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 860.000 - 880.000 m**


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

**Project name: Forsmark**

**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 880.000 - 900.000 m**


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

**Project name: Forsmark**
**Bore hole No.: KFM06C** Azimuth: 26 Inclination: -60

**Depth range: 900.000 - 920.000 m**


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

**Project name: Forsmark**
**Bore hole No.: KFM06C** Azimuth: 26 Inclination: -60

**Depth range: 920.000 - 940.000 m**

D L U R D

920.000 924.254
921.000 925.260
922.000 926.267
923.000 927.274
924.000 928.280
925.000 929.287

D L U R D

925.000 929.287
926.000 930.294
927.000 931.300
928.000 932.307
929.000 933.314
930.000 934.320

D L U R D

930.000 934.320
931.000 935.327
932.000 936.333
933.000 937.340
934.000 938.347
935.000 939.353

D L U R D

935.000 939.353
936.000 940.360
937.000 941.367
938.000 942.373
939.000 943.380
940.000 944.387

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

**Project name: Forsmark**
**Bore hole No.: KFM06C** Azimuth: 26 Inclination: -60

**Depth range: 940.000 - 960.000 m**


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

Project name: Forsmark
Bore hole No.: KFM06C　　Azimuth: 26　　Inclination: -60

Depth range: 960.000 - 980.000 m


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

**Project name: Forsmark**

**Bore hole No.: KFM06C** **Azimuth: 26** **Inclination: -60**

**Depth range: 980.000 - 992.696 m**


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