P-09-52

Site investigation SFR

Boremap mapping of core drilled borehole KFR102A

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November 2009

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ISSN 1651-4416
SKB P-09-52

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Keywords: P-report SKBDoc id 1233871 , Review statement SKBDoc id 1235974, Appendix SKBDoc id 1235975, Fractures, BIPS, Boremap, Core drilling, Geophysical logs, SFR, AP SFR-09-001, KFR102A, Project SFR extension.

Abstract

This report presents the result from the Boremap mapping of the core drilled borehole KFR102A, which is drilled from the eastern part of the pier next to the existing repository for low- and intermediate-level waste, SFR. The 600.83 m long borehole was drilled in November and December 2008, with azimuth 302° and inclination –65°. The aim was to characterize possible gently dipping zones, interpreted low magnetic lineaments and to gather information about the geological- and hydrogeological properties of the bedrock at depths beneath the repository, as well as to verify the geohydrological model.

The geological mapping of the borehole started in January and was finished in April 2009. The mapping is based on the simultaneous study of the drill core and the borehole image (BIPS), supported by geophysical logs. The upper- and lowermost part of the drill core was mapped in Boremap without access to complementary BIPS-image.

The dominating rock type in KFR102A is foliated, fine- to medium-grained metagranite-granodiorite (101057), which occupy 61% of the mapped interval. Pegmatite to pegmatitic granite (101061) and fine- to medium-grained granite (111058) occupy 19 and 11%, respectively. Subordinate rock types are amphibolite (102017) and felsic to intermediate metavolcanic rock (103076). About 19% of the rock in KFR102A has been affected by alterations. The most common types of alterations are in order of abundance oxidation, muscovitization, albitization and quartz dissolution.

A total number of 6,122 fractures are registered in KFR102A. Of these are 4,248 sealed, 1,798 open and 85 partly open. The fracture frequencies are 8.0 sealed fractures/m, 3.4 open fractures/m and 0.1 partly open fractures/m. In addition there are 45 sealed networks in KFR102A, with a total length of 41.1 m. The most frequent fracture fillings in KFR102A are calcite, chlorite, quartz, adularia and laumontite. 57% of the fractures have oxidized walls.

There are four distinct sets of sealed fractures with the orientations 035°/85°, 090°/50°, 205°/05° and 330°/80°. A sub-horizontal to horizontal fracture set, with the orientation 210°/05°, dominates the open fractures.

There are 14 crushed intervals in KFR102A (drill-induced crushes excluded), with a total length of 1.97 m.

Sammanfattning

Denna rapport presenterar resultatet från Boremapkarteringen av kärnborrhål KFR102A, vilket är borrat från östra delen av piren, intill det befintliga förvaret för låg- och medelaktivt avfall, SFR. Det 600,83 m långa borrhålet borrades under november och december 2008, med azimut 302° och inklination –65°. Syftet är att karaktärisera eventuella flacka zoner, framtolkade lågmagnetiska lineament och att samla information rörande bergets geologiska och hydrogeologiska egenskaper på djupet under det befintliga förvaret, samt att verifiera den geohydrologiska modellen.

Den geologiska karteringen av borrhålet startade i januari och avslutades i april 2009. Karteringen är baserad på simultan undersökning av borrkärna och borrhålsbild (BIPS) understödd av geofysiska loggar. Den första och sista delen av borrkärnan karterades utan tillgång till BIPS-bild.

Den dominerande bergarten i KFR102A är folierad, fin- till medelkornig metagranit-granodiorit (101057), vilken upptar 61% av det karterade intervallet. Pegmatit till pegmatitisk granit (101061) och fin- till medelkornig granit (111058) upptar 19, respektive 11%, av intervallet. Underordnade bergarter är amfibolit (102017) och felsisk till intermediär metavulkanit (103076). Cirka 19% av bergarterna i KFR102A är påverkade av omvandlingar. De vanligaste omvandlingarna är i fallande ordning oxidation, muskovitisering, albitisering och kvartsupplösning.

Antalet registrerade sprickor i KFR102A är 6 122 stycken. Av dessa är 4 248 läkta, 1 798 öppna och 76 delvis öppna. Sprickfrekvensen är 8,0 läkta sprickor/m, 3,4 öppna sprickor/m och 0,1 delvis öppna sprickor/meter, Dessutom finns det 45 läkta spricknätverk i KFR102A, med en total längd av 41,1 m. De vanligaste sprickmineralen i KFR102A är kalcit, klorit, kvarts, adularia och laumontit. 57 % av alla sprickor har oxiderat sidoberg.

För de läkta sprickorna finns fyra tydliga sprickset med orienteringarna 035°/85°, 090°/50°, 205°/05° och 330°/80°. Ett sub-horisontellt till horisontellt sprickset med orienteringen 210°/05°, dominerar de öppna sprickorna.

Det finns 14 sektioner med kross i KFR102A (borrinducerade krossar exkluderade), med en total längd på 1.97 m.

Contents

1 Introduction

SKB intends to enlarge the repository for low- and intermediate-level waste in Forsmark (SFR), which was completed and ready for operation in 1988. It was then the first of its kind in the world. In the future SFR is going to host the waste that arises from the demolishing of the nuclear plants and an extension of SFR is therefore planned. It is estimated to be ready in 2020.

A lot of information about the bedrock and groundwater has already been gathered during the building of SFR, but some complementary studies are needed. This document reports the data gained by the Boremap mapping of the core drilled borehole, KFR102A, which is one of the activities performed within the site investigation at SFR. The borehole KFR102A is drilled in the eastern part of the pier at SFR (Figure 1-1), and has a length of 600.83 m, a bearing of 302° and an inclination of –65° (Appendix 3).

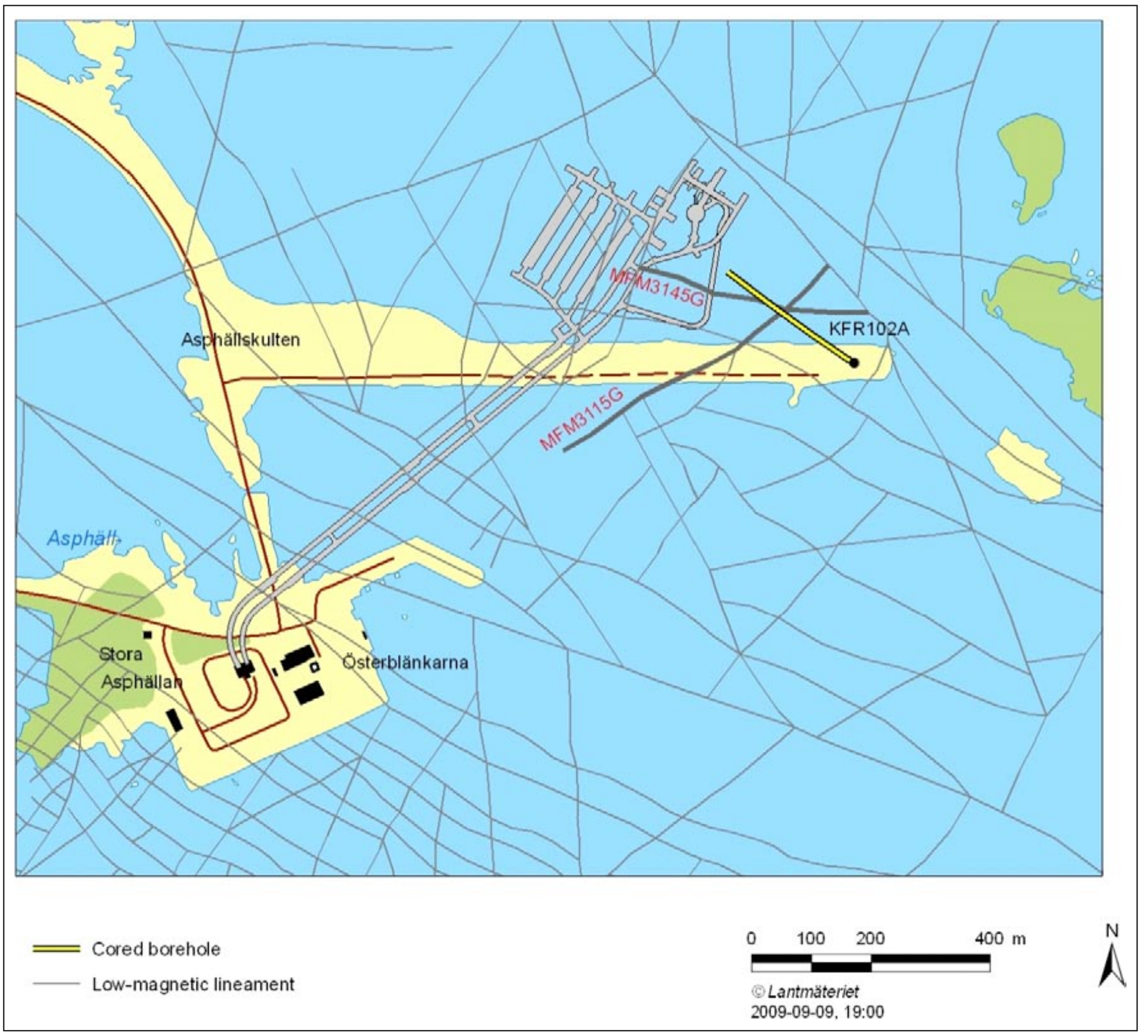

Figure 1-1. *Location of the core drilled borehole KFR102A in relation to SFR. Intersected lineaments are also shown. Two lineaments with low magnetic intensity, expected to be intersected by the boreholes, are highlighted.*

The work was carried out in accordance with activity plan AP SFR-09-001. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

The core drilled borehole was drilled in November and December 2008 and was after completion, investigated with several logging methods, such as conventional geophysical logging, radar- and TV-logging. The latter method implies logging with a colour TV-camera to produce images of the borehole wall, so called BIPS-images (Borehole Image Processing System). The method is described in SKB MD 222.006 (SKB, internal controlling document, in Swedish).

The borehole was mapped in the period between January and April 2009. Mapping of cored borehole according to the Boremap method is based on simultaneous study of the drill core and the use of BIPS-images of the borehole wall. The mapping was also supported by generalized geophysical logs (Appendix 2).

The BIPS-image enables the study of fractures and their characteristics along the borehole. Strike and dip of planar structures as fractures, foliations and rock contacts are calculated and documented with the Boremap method.

Original data from the reported activity are stored in the primary database Sicada, where they are traceable by the Activity Plan number (AP SFR-09-001). Only data in SKB's databases are accepted for further interpretation and modelling.

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

Activity plan	Number	Version
Boremapkartering av kärnborrhål KFR102A	AP SFR-09-001	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för Boremapkartering	SKB MD 143.006	2.0
Metodbeskrivning för TV-loggning med BIPS	SKB MD 222.006	
Mätsystembeskrivning för Boremap	SKB MD 146.005	1.0
Instruktion: Regler för bergarters benämningar vid platsundersökningen i Forsmark	SKB MD 132.005	1.0

2 Objective and scope

The borehole KFR102A was drilled with the aim to characterize possible gently dipping zones, interpreted lineaments with low magnetic intensity and to gather information about the geological and hydrogeological properties of the bedrock at depths beneath the repository, as well as to verify the geohydrological model. Lithologies, alterations, ductile structures and the occurrence and character of fractures in the bedrock penetrated by the core drilled borehole KFR102A were documented. Other data, such as thickness of soil cover, soil stratigraphy, groundwater level and groundwater flow will not be treated in this report.

3 Equipment

3.1 Description of equipment/interpretation tools

Mapping of the borehole based on BIPS-image was performed with the software Boremap v.3.9.6.4. Boremap software is loaded with the rock types and mineral standard used for surface mapping at the Forsmark investigation site, in order to enable correlation with the surface geology. Inclination, bearing and diameter of the borehole are used as in-data for the calculations. The BIPS-image length deviates from the true borehole length with increasing depth. Length adjustments are therefore made on the basis of reference marks cut into the borehole wall after drilling.

Schematic presentations of the boreholes are presented in WellCAD-diagrams (Appendix 1).

Equipment used to facilitate the core mapping are folding rule, 10% hydrochloric acid, rock hardness tool, hand lens, paint brush and tap water.

3.1.1 Used BIPS-files and image quality

Information about Used BIPS-files is listed in Table 3-1.

The following factors may disturb the mapping:

- Brownish coatings probably related to the drilling equipment,
- Vertical bleached bands on the borehole wall from drill cuttings, either in suspension or after precipitation.

The BIPS-image quality of the borehole KFR102A is generally very good. There are parts that are somewhat overexposed, have brownish stainings, and toward the end there are vertical bleached bands on the borehole wall. This is however not in the extent that it complicates the mapping. The results from the BIPS-loggings are presented in /1/. The intervals at 70.440–71.946 and 599.345–600.830 m, adjusted length, of the drill core KFR102A were mapped in Boremap without any complementary BIPS-image.

Table 3-1. Used BIPS-files.

Borehole	BIPS-file	Logging date	Logging time	From (m)	To (m)
KFR102A	KFR102A_71-598m_20090114.BIP	2009-01-14	16:49-22:40	71	597.662

4 Execution

4.1 General

Boremap mapping of the core drilled borehole KFR102A was performed and documented according to activity plan AP SFR-09-001 (SKB, internal document). Geophysical logs of the borehole supported the mapping. The mapping was performed in accordance with the SKB method description for Boremap mapping, SKB MD 143.006, as well as SKB MD 146.001 (SKB internal controlling documents) and /2/. Information from earlier performed investigations in the area were also helpful in the interpretations /3, 4, 5, 6, 7/.

4.2 Preparations

Background data collected from Sicada (Appendix 3) prior to the Boremap mapping included:

- Borehole direction.
- Borehole diameter.
- Reference marks in drillhole.

These background data, except for borehole diameter, are imported from Sicada by semiautomatic routines.

Detailed plots of resampled and calibrated geophysical logging data as well as generalized geophysical logs (Appendix 2), were used as supporting data for the mapping of the borehole.

General information about the borehole is listed in Table 4-1 and applied length adjustments are listed in Table 4-2.

Table 4-1. Borehole data for KFR102A.

Northing	Easting	Bearing (degrees)	Inclination (degrees)	Diameter (mm)	Borehole length (m)	Mapping interval (m)
6701730.30	1633330.21	302.26	–65.41	75.8	600.83	70.440–600.83

Table 4-2. Applied length adjustments in KFR102A.

Borehole	Recorded length (m)	Adjusted length (m)	Difference (m)
KFR102A	99.974	100.000	0.026
	145.817	146.000	0.183
	199.575	200.000	0.425
	248.335	249.000	0.665
	299.185	300.000	0.815
	350.038	351.000	0.962
	398.836	400.000	1.164
	446.576	448.000	1.424
	498.418	500.000	1.582
	548.372	550.000	1.628
	578.300	580.000	1.700

4.3 Execution of meaurements

4.3.1 Fracture definitions

Definitions of different fracture types and apertures, crush zones and sealed fracture network are found in SKB MD 143.008 and "Kalibrering av Boremapkartering" (v.0.9) which is planned to be implemented in the next version of SKB MD 143.006.

Two types of fractures are mapped in Boremap; broken and unbroken. Broken fractures split the core through the borehole axis, and unbroken do not. All fractures are described with their fracture minerals and other characteristics e.g. width, aperture and roughness. Visible aperture is measured down to 1 mm in the BIPS-image. Aperture less than 1 mm is due to the low resolution impossible to measure in the BIPS-image, and are denoted a value of 0.5 mm. If the aperture is very small but still visible in BIPS it is mapped as 0.5 mm wide and the confidence is considered "certain". If no aperture is visible, and the core pieces do not fit well, the confidence of the aperture is considered "probable". If the core pieces do fit well, but the fracture surfaces are dull or altered, the confidence of the aperture is considered "possible". Tight broken fractures having voids are mapped with a 0.5 mm aperture and are considered "probable". This is because these fractures are not considered to be fully open, as broken fractures with certain aperture.

Unbroken fractures with possible channelling are mapped as unbroken with certain/probable/possible aperture. A possible aperture is given if the fracture filling is soft and may have been flushed away.

All fractures with aperture > 0 mm are presented as open in the Sicada database. Unbroken fractures have normally apertures = 0 mm, but some have apertures > 0 mm. These are presented as partly open, and are included in the open fracture category in Sicada. The frequency of open and sealed fractures are calculated and shown in the WellCad-diagram (Appendix 1).

4.3.2 Fracture alteration and joint alteration number

Joint alteration number is mainly related to the thickness of the mineral fillings and the clay content in the fracture /8/. Fractures that are more than 1 mm wide and rich in clay minerals are usually given joint alteration numbers between 2 and 4. The majority of the broken fractures are very thin to extremely thin and seldom contain clay minerals, or very small amounts of clay and chlorite. These fractures have joint alteration numbers between 1 and 2. Since most fractures are within this span, a subdivision with joint alteration number = 1.5 was performed to facilitate both the evaluation process for fracture alterations, and the possibility to compare the alterations between different fractures in the boreholes.

4.3.3 Mapping of fractures not visible in the BIPS-image

Fractures not visible in the BIPS-image are oriented using the *guideline method* /9/. The orientation performed in this work is based on the following data:

- Amplitude (measured along the drill core), which is the interval between fracture extremes along the drill core.
- The relation between the rotation of the fracture trace, and a well defined structure visible in both drill core and BIPS-image. This rotation is measured with measuring tape on the drill core.
- Absolute borehole length relative to a well defined structure visible in both drill core and BIPS-image.

The fractures mapped with the guideline method are registered in Boremap as "non-visible in BIPS".

4.3.4 Mineral codes

In cases where properties or minerals are not represented in the mineral list, the following mineral codes have been used in the mapping of KFR102A:

- X1 = Bleached fracture walls.
- X3 = The drill core is broken at a right angle, and the broken surfaces have a polished appearance. This is caused by rotation of two core pieces along an intermediate fracture wearing away possible mineral filling. It is impossible to decide whether this fracture was open or sealed in situ.
- X8 = Epidotized walls.

4.3.5 Foliation and lineation

The metagranite-granodiorites which occupies most of the area in Forsmark is usually LS tectonites, where lineation dominates over foliation /4/. In the SFR-area, the foliation is usually dominating in the metagranite-granodiorite and therefore it is mostly foliation that is mapped. In the SFR area there are also signs of folding, resulting in varying intensity of the foliation and lineation. An estimated average intensity is mapped for rock types.

The higher strain in the SFR-area relative to the candidate area of the Forsmark site investigation also appears in the somewhat finer grain-size of the metagranite-granodiorite, which is mapped as "fine- to medium-grained" in the SFR-area.

4.3.6 Alteration

The terminology "hematitization" and "muscovitization" is not in the Boremap system. When hematitization is observed it is mapped as oxidation with a comment "hematitization" and when muscovitization is observed it is mapped as sericitization with a comment "muscovite". The muscovite seems to replace biotite in the foliation planes and is most likely of metamorphic origin, and hence not related to any brittle structures.

The intensity of argillization has been judged by scratching the core with a hardness tool to determine the amount of soft minerals.

4.3.7 Lithologies and correlation with geophysical data

As mentioned in the section before, the rock types in the SFR-area are generally more deformed relative to the rock types in the candidate area of Forsmark site investigation. This makes the determination of rock types harder, since different rock types may have very similar appearances in the SFR-area.

Detailed plots of resampled and calibrated geophysical logging data from the boreholes (Appendix 2, /10/), were helpful where there were difficulties in determining the rock type macroscopically.

4.4 Data handling/post processing

The Boremap mapping of KFR102A was performed on SKB's network, while a backup was saved on a local computer before each break exceeding 15 minutes. When the mappings were finished and quality checked by the operator and by a routine in Boremap, the data was submitted to SKB for exportation to Sicada.

All data are stored in the SKB Sicada database, and it is only these data that should be used for further interpretation.

The data presented in this report are regarded as copies of the original data. Data in the databases may be revised, if needed. Such revisions will not necessarily result in a revision of the P-report, although the normal procedure is that major revisions entail a revision of the P-report. Minor revisions are normally presented as supplements, available at www.skb.se.

4.5 Nonconformities

4.5.1 Core loss

There are two core losses in KFR102A, at 93.198–93.249 and 281.210–281.250 m. Both are mechanical.

A number of 14 drill induced crushes are registered in KFR102A. These are located at 117.706–117.726, 125.810–125.860, 138.614–138.649, 274.237–274.317, 282.344–282.374, 282.652–282.682, 347.390–347.460, 347.690–347.740, 402.615–402.645, 422.547–422.747, 431.594–431.694, 440.839–440.859, 473.670–473.710 and 473.740–473.840 m, with a total length of 85.5 cm.

4.5.2 Underestimated fracture minerals

Due to the reaction of calcite with hydrochloric acid, and the strong colouration of other minerals by hematite, these two minerals are detected even though they are macroscopically invisible. Minerals present in the same fracture as calcite and hematite run the risk of getting underestimated, as well as less conspicuous minerals in other fractures. To partly reduce this problem, hematite has only been mapped if a red streak is observed; otherwise it is considered to occur only as pigmentation.

5 Result

The data from Boremap mapping of KFR102A is stored in Sicada, and it is only these data that shall be used for further interpretation and modelling. The user of this data should be aware of the assumptions mentioned in Chapter 4. Graphical presentations of the data are given as WellCAD-diagrams in Appendix 1. A summary of rock types and fracture frequency in the borehole is presented in Table 5-1 and 5-2.

5.1 Lithology

The dominating rock type in KFR102A is pinkish grey, fine- to medium-grained metagranite-granodiorite (rock code 101057), and it occupies about 61% of the mapped interval. Pegmatite to pegmatitic granite (rock code 101061) with variable grain size and fine- to medium-grained granite (rock code 111058) occupy 19 and 11%, respectively, of the borehole length. The pegmatitic granite is massive, and the structure of the fine- to medium-grained granite varies between massive, lineated and foliated.

Subordinate rock types are amphibolite (rock code 102017) and felsic to intermediate metavolcanic rock (rock code 103076). Except for shorter rock occurrences are the amphibolite restricted to two intervals, 177–232 and 430–498 m. Dissemination of mainly magnetite but also pyrite are macroscopically visible in the amphibolite in the upper interval, and mainly hematite and pyrite in the lower interval.

The percentage rock type distribution in KFR102A is presented in Table 5-1.

Rock occurrences (rock types < 1 m in length) are registered frequently throughout the borehole and occupy about 12% of the logged drill core. Dykes, veins and unspecified occurrences of pegmatite and pegmatitic granite dominate, where most of them are less than 10 centimetres in width. Except for rock occurrences of the rock types in Table 5-1 (felsic to intermediate metavolcanic rock excluded which have no occurrence < 1m in lenght), quartz dominated veins (rock code 8021), skarn like material (rock code 108019), granite (rock code 1058), aplit (rock code 1062) and breccia (rock code 6005) are registered.

5.1.1 Deformation

The foliation in KFR102A is mostly moderately to strong, and the stereographic projections of the poles to the foliation planes are shown in Figure 5-1.

A number of 23 narrow ductile and brittle-ductile deformation zones have been mapped in KFR102A. The majority of them is just a few millimetres in width and registered in the intervals 318–325 and 484–490 m.

Table 5-1. Percentage distribution of rock types in KFR102A (rock occurrences excluded).

Borehole	101057	101061	111058	102017	103076
KFR102A	61	19	11	7	2

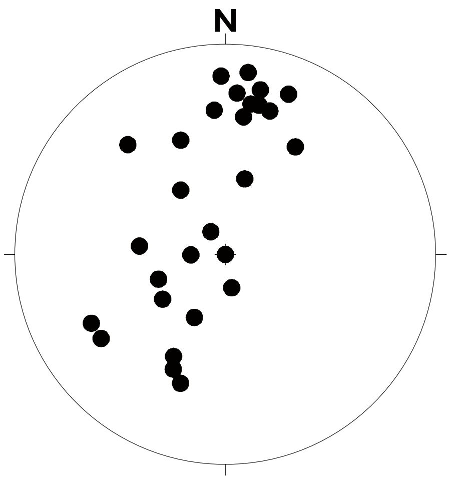

Figure 5-1. Equal area projection showing poles to foliation planes (n=28) in KFR102A.

5.1.2 Alteration

In KFR102A, 19% of the borehole length has been mapped as altered.

The most common alteration is varying degrees of oxidation and it affects 12% of the mapped interval. However, this does not include the 3,525 fractures mapped with oxidized walls. Two longer, but not continuous, intervals of oxidation occur at 286–309 and 427–502 m. The most intense oxidation is associated with a crush, and mapped with the comment hematitization.

Muscovite alteration, mapped as sericitization, occurs in 4% of the borehole length and is restricted to the interval 246–385 m. There are three intervals of albitization at 181.2–187.9, 223.9–228.9 and 373.1–378.7 m, corresponding to about 3% of the borehole length. Quartz dissolution of varying degrees affects the borehole interval 440.4–478.4 4 m, but not continuously (Figure 5-2).

Additional shorter and sporadic alterations are laumontization, argillization, carbonatization and epidotization. Laumontization is restricted to intervals with high frequency of laumontite sealed fractures, and so is one of the two intervals mapped with carbonatization. The second interval with carbonatization is associated with a fracture and additional alterations of oxidation and quartz dissolution. All three short intervals of argillization are associated with crushes.

Figure 5-2. Quartz dissolution in the borehole interval 440.4–478.4 4 m.

5.1.3 Fractures

A total number of 6,122 fractures are registered in KFR102A. Of these are 1,798 open (broken with aperture > 0), 4,248 are sealed (broken and unbroken fractures with aperture = 0) and 85 are partly open (unbroken fractures with aperture > 0). This result in the following interpreted fracture frequencies: 8.0 sealed fractures/m (sealed fractures in sealed fracture networks are excluded), 3.4 open fractures/m (crushes are excluded) and 0.1 partly open fractures/m (Table 5-2). Fractures with an aperture > 0 are registered as open, and fractures with an aperture = 0 are registered as sealed in SICADA.

The fracture frequency for open and sealed fractures changes rather coherently through the borehole (Appendix 1). The highest frequency for both broken and unbroken fractures is registered in the interval 460–500 m, and there are two intervals with a pronounced decrease in fracture frequency at 230–300 and 520–600 m.

There are four distinct sets of sealed fractures, having the orientation 035°/85°, 090°/50°, 205°/05° and 330°/80°, where the sub-vertical to vertical set is dominating (Figure 5-3a). Sub-horizontal to horizontal fractures with the orientation 210°/05° dominates the open fractures, but two subordinated sets, which coincide with the sets of the sealed fractures, are also seen (Figure 5-3b). Fractures mapped with no access to BIPS-image are not oriented (9 open and 18 sealed) and hence not plotted in the stereograms. As can be viewed from Figure 5-1 and 5-3 many fractures, both open and sealed, coincides with the foliation in the rock, and hence demonstrate a certain extent of foliation fractures.

In addition there are 15 narrow brecciated zones and 45 sealed networks in KFR102A. The total length of the sealed networks is 41.1 m. Of them 17 exceeds 1 meter in length and are located at 90.99–92.46, 120.03–121.20, 151.29–154.37, 169.96–171.15, 283.92–285.33, 307.98–310.26, 323.28–324.78, 338.73–339.73, 373.39–374.87, 426.19–429.89, 434.65–435.90, 436.89–438.00, 440.14–441.44, 472.49–474.45, 484.64–487.62, 496.81–498.71 and 500.67–501.67 m. The piece length varies from 2–50 mm, but is typically 10–30 mm. Taking into account all sealed networks, there is about 2,000 more sealed fractures in KFR102A.

Table 5-2. Fracture frequencies in KFR102A (crush and sealed fracture networks excluded) expressed as fractures/m.

Borehole	Open fractures	Partly open fractures	Sealed fractures
KFR102A	3.4	0.1	8.0

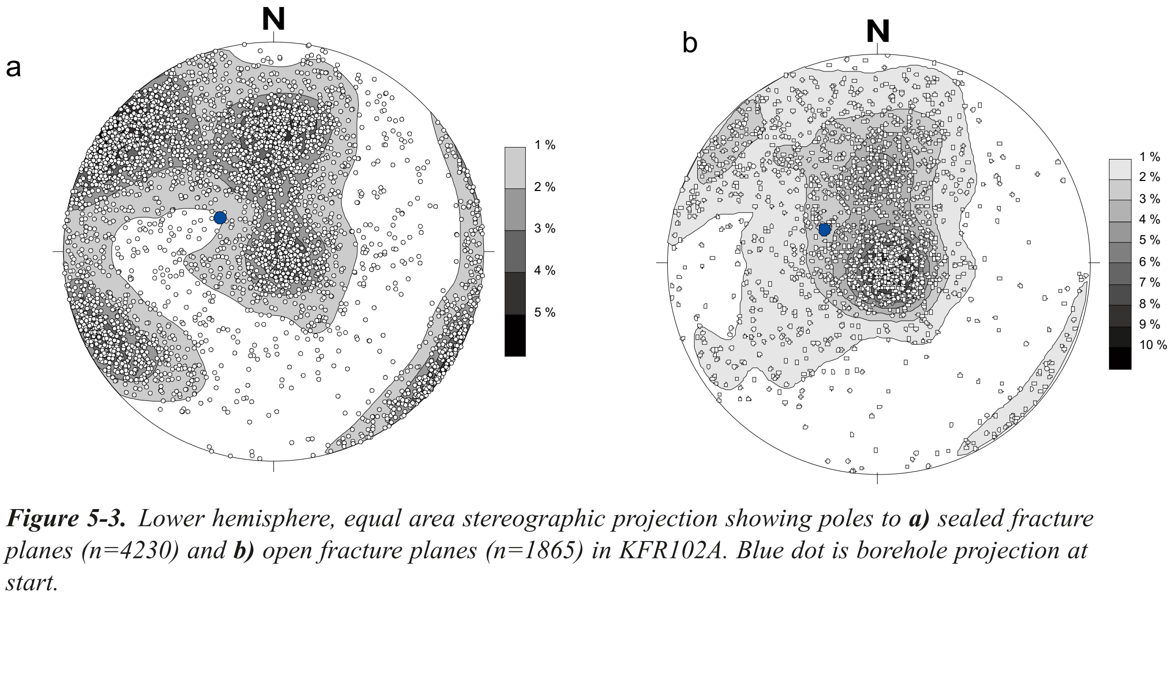

*Figure 5-3. Lower hemisphere, equal area stereographic projection showing poles to **a)** sealed fracture planes (n=4230) and **b)** open fracture planes (n=1865) in KFR102A. Blue dot is borehole projection at start.*

There are 14 crushed intervals (drill-induced excluded) in KFR102A, with a total length of 1.97 m. The largest crush stands for the majority of this length, and it reaches 1.25 m (Figure 5-4). This crush has some bigger pieces; however these were not identified in BIPS, and are therefore incorporated in the crush.

The most common minerals in the open fractures are in decreasing order: chlorite, calcite, laumontite, clay minerals and hematite. There are 47 fractures with no detectable mineral. The most common minerals in sealed fractures are calcite, quartz, chlorite, adularia and laumontite. 23% of the open fractures and 73% of the sealed fractures have oxidized walls.

Clay minerals are with a few exceptions just found in open fractures, and are most frequent in the length interval 423–488 m.

Only 39 fractures with sulphides, 34 with pyrite and 5 with chalcopyrite, are registered. These occur rather sporadically throughout the borehole.

Iron hydroxide are registered in 59 fractures, with an increased frequency in the length intervals 308–310, 424–429, 436–442 and 472–486 m.

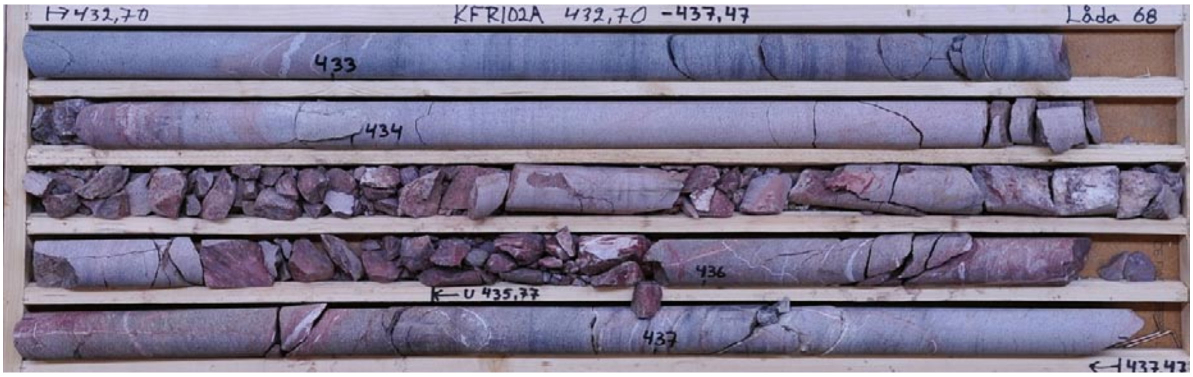

Figure 5-4. *The major crush in KFR102A at 434.65–435.90 m.*

6 References

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/5/ **Döse C, Stråhle A, Mattsson K-J, Carlsten S, 2009.** Site investigation SFR – Investigations. Boremap mapping of core drilled borehole KFR101. SKB P-09-36. Svensk Kärnbränslehantering AB.

/6/ **Döse C, Winell S, Stråhle A, Carlsten S, 2009.** Site investigation SFR – Investigations. Boremap mapping of core drilled boreholes KFR102B and KFR103. SKB P-09-38. Svensk Kärnbränslehantering AB.

/7/ **Winell S, Döse C, Stråhle A, Selnert E, Carlsten S, 2009.** Site investigation SFR – Investigations. Boremap mapping of core drilled boreholes KFR104 and KFR27 (from 147.5 m). SKB P-09-39. Svensk Kärnbränslehantering AB.

/8/ **Barton N, 2002.** Some new Q-value correlations to assist in site characterization and tunnel design. International Journal of Rock Mechanics and Mining Sciences Vol 39 (2002), pp 185–216.

/9/ **Ehrenborg J, Steiskal V, 2004.** Oskarshamn Site Investigation. Boremap mapping of core drilled boreholes KSH01A and KSH01B. SKB P-04-01. Svensk Kärnbränslehantering AB.

/10/ **Mattson H, Keisu M, 2009.** Site investigation SFR. Interpretation of geophysical borehole measurements from KFR102A, KFR102B, KFR103, KFR104 and KFR27 (0–500 m). SKB P-09-26. Svensk Kärnbränslehantering AB.

WellCAD plot KFR102A

Title	LEGEND FOR FORSMARK - SFR	KFR102A	Appendix: 1

Site	FORSMARK - SFR
Borehole	KFR102A
Plot Date	2009-10-08 23:01:43
Signed data	

ROCKTYPE FORSMARK - SFR

- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granitoid, metamorphic
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite, metamorphic, aplitic
- Granite to granodiorite, metamorphic, medium-grained
- Granodiorite, metamorphic
- Tonalite to granodiorite, metamorphic
- Diorite, quarts diorite and gabbro, metamorphic
- Ultramafic rock, metamorphic
- Amphibolite
- Calc-silicate rock (skarn)
- Magnetite mineralization associated with calc-silicate rock (skarn)
- Sulphide mineralization
- Felsic to intermediate volcanic rock, metamorphic
- Mafic volcanic rock, metamorphic
- Sedimentary rock, metamorphic
- Cataclastic rock

ROCK ALTERATION

- Oxidized
- Chloritisized
- Epidotisized
- Weathered
- Tectonized
- Sericitisized
- Quartz dissolution
- Silicification
- Argillization
- Albitization
- Carbonatization
- Saussuritization
- Steatitization
- Uralitization
- Laumontitization
- Fract zone alteration

MINERAL

- Biotite
- Hematite
- Calcite
- Chlorite
- Quartz
- Muscovite
- Pyrite
- Clay Minerals
- Laumontite
- Prehnite

STRUCTURE

- Cataclastic
- Schistose
- Gneissic
- Mylonitic
- Ductile Shear Zone
- Brittle-Ductile Zone
- Veined
- Banded
- Massive
- Foliated
- Brecciated
- Lineated

TEXTURE

- Hornfelsed
- Porphyritic
- Ophitic
- Equigranular
- Augen-Bearing
- Unequigranular
- Metamorphic

GRAINSIZE

- Aphanitic
- Fine-grained
- Fine to medium grained
- Medium to coarse grained
- Coarse-grained
- Medium-grained

STRUCTURE ORIENTATION

- Cataclastic
- Brecciated
- Bedded
- Schistose
- Mylonitic
- Foliated
- Lineated
- Ductile Shear Zone
- Veined
- Gneissic
- Brittle-Ductile Shear Zone
- Banded

ROCK ALTERATION INTENSITY

- No intensity
- Faint
- Weak
- Medium
- Strong

ROUGHNESS

- Planar
- Undulating
- Stepped
- Irregular

SURFACE

- Rough
- Smooth
- Slickensided

CRUSH ALTERATION

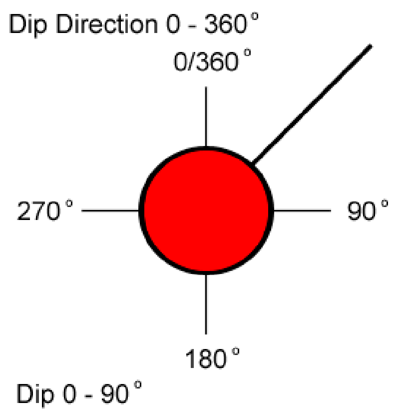
- Slightly Altered
- Moderately Altered
- Highly Altered
- Completley Altered
- Gouge
- Fresh

FRACTURE ALTERATION

- Highly Altered
- Completely Altered
- Gouge
- Fresh
- Slightly Altered
- Moderately Altered

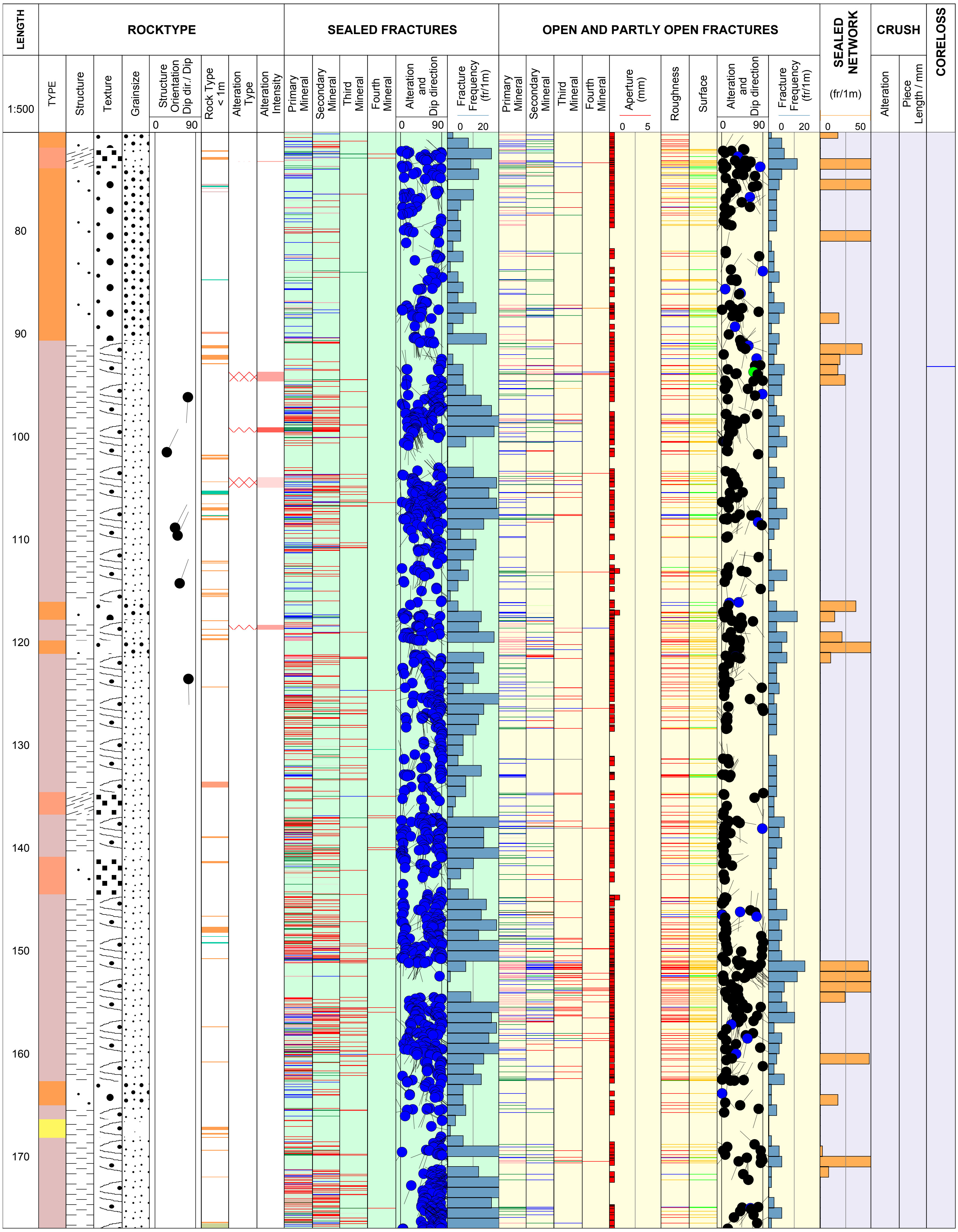
FRACTURE DIRECTION

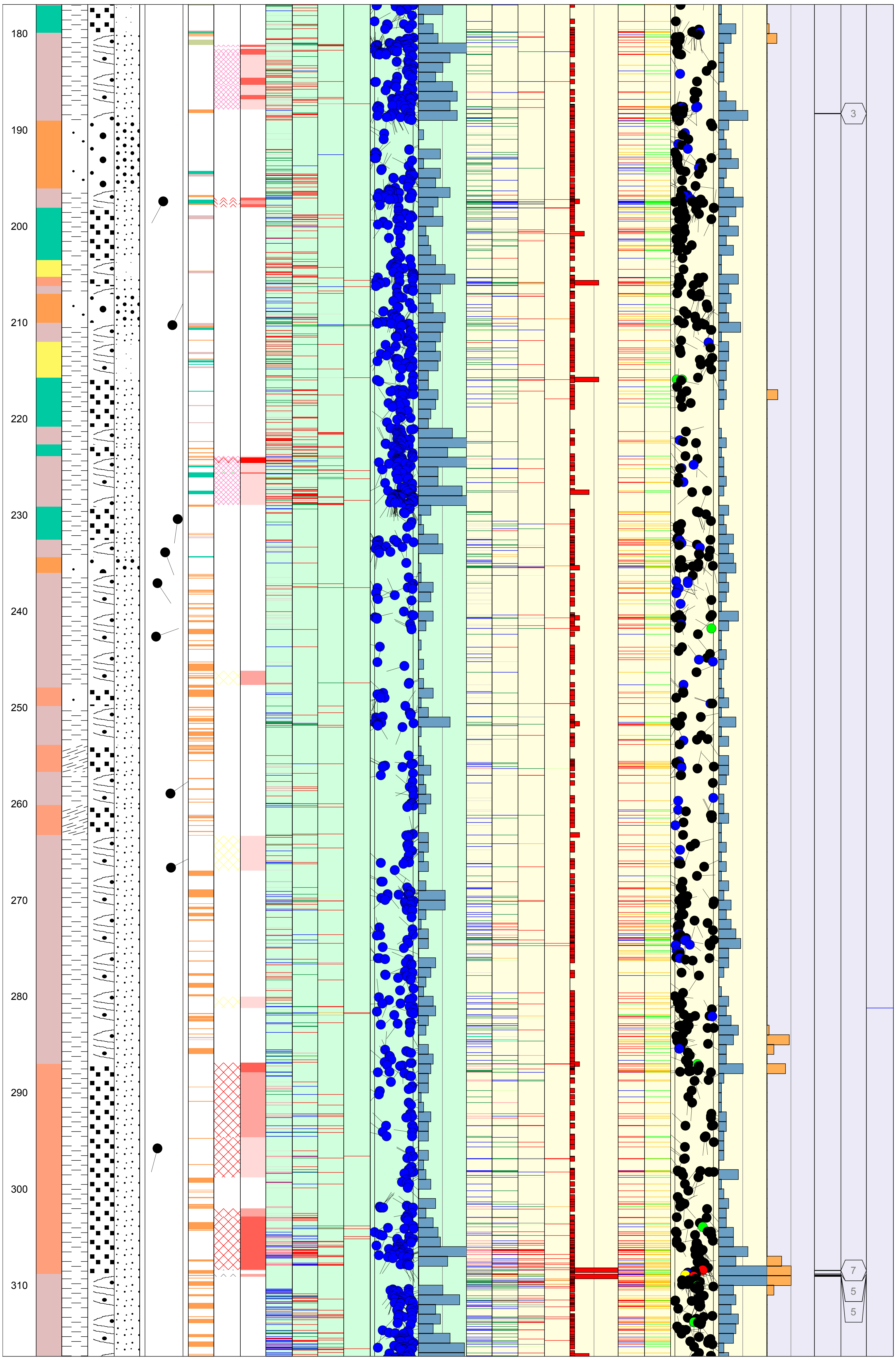
STRUKTURE ORIENTATION

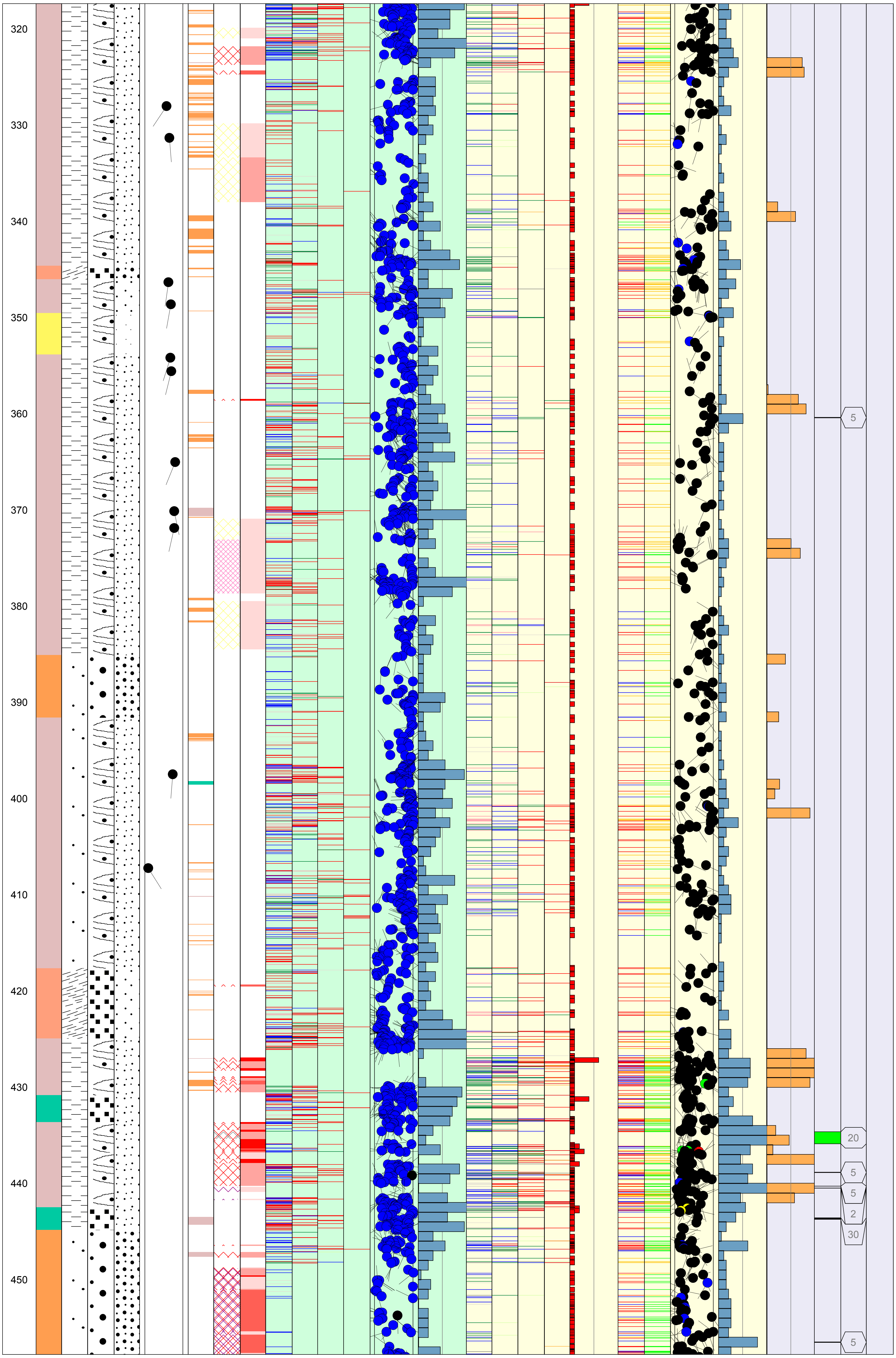


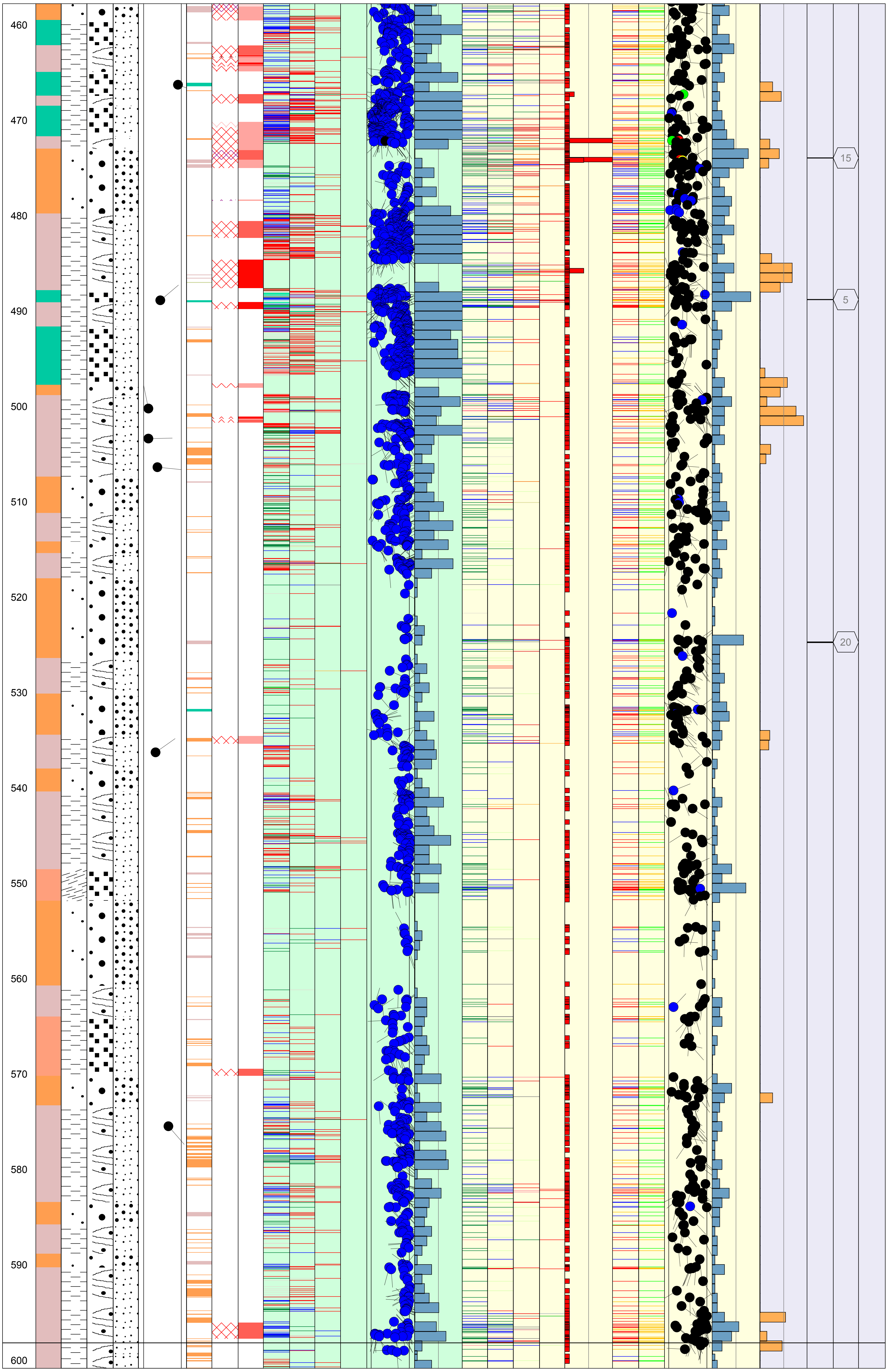
Title GEOLOGY IN KFR102A **Appendix: 1**

Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	KFR102A	**Northing [m]**	6701730.30
Diameter [mm]	75.8	**Easting [m]**	1633330.21
Length [m]	600.830	**Elevation [m.a.s.l.]**	2.66
Bearing [°]	302.26	**Drilling Start Date**	2008-11-25 15:40:00
Inclination [°]	-65.41	**Drilling Stop Date**	2008-12-12 18:00:00
Date of coremapping	2009-01-22 07:32:00	**Plot Date**	2009-10-24 23:01:44
Rocktype data from	p_rock	**Signed data**	

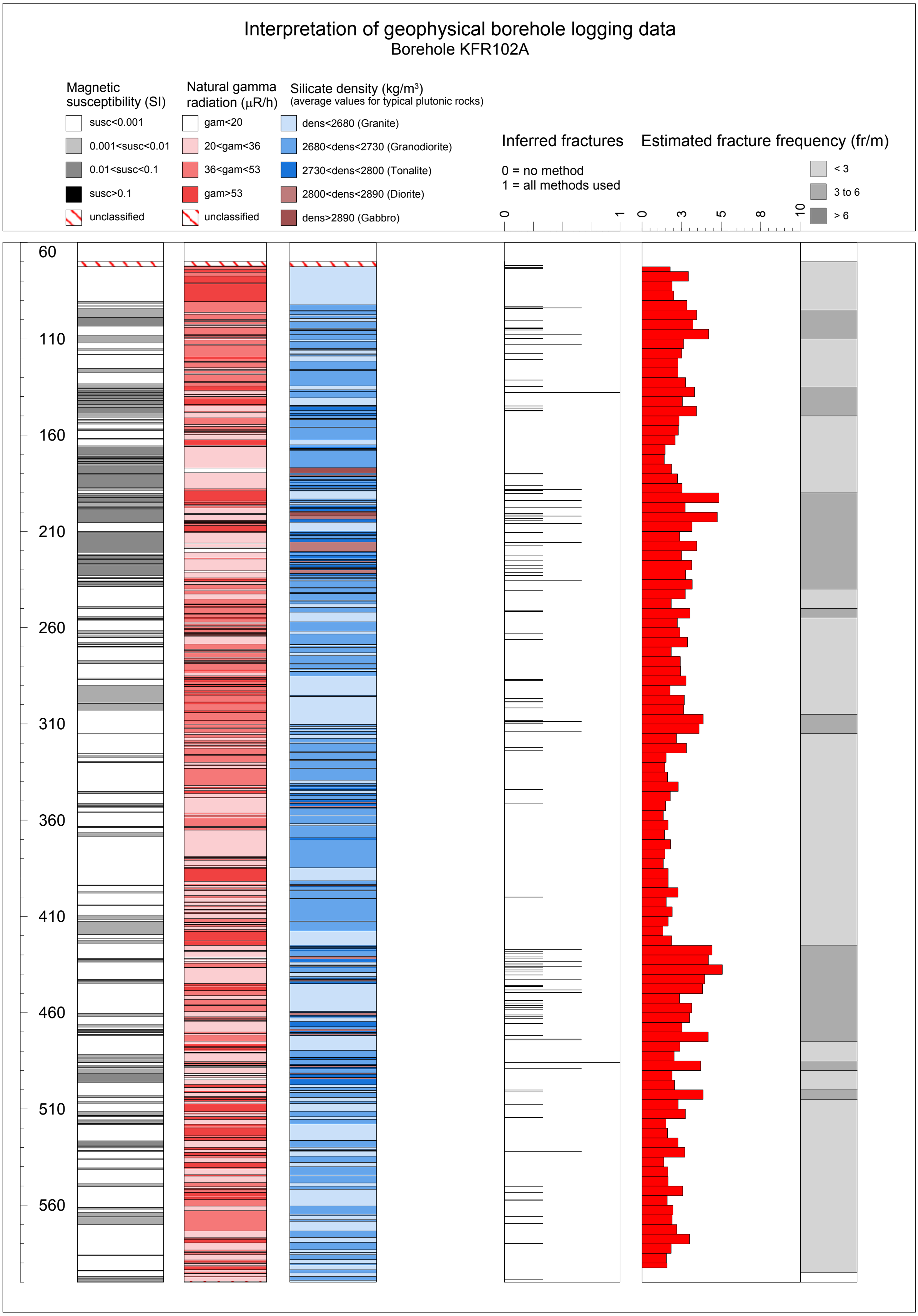


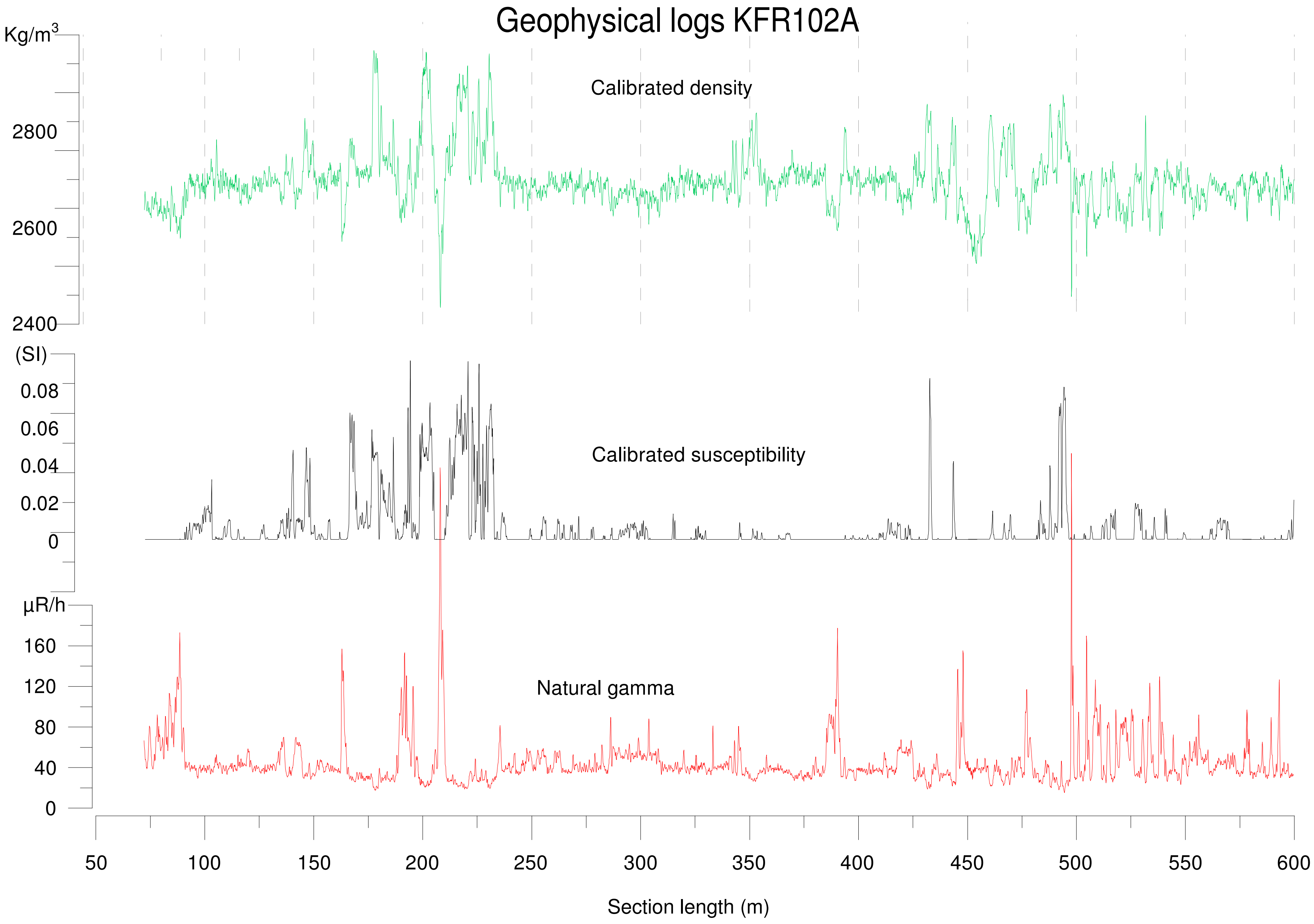

180
190
200
210
220
230
240
250
260
270
280
290
300
310
3
7
5
5


320
330
340
350
360
370
380
390
400
410
420
430
440
450
5
20
5
5
2
30
5


460
470
480
490
500
510
520
530
540
550
560
570
580
590
600
15
5
20

Generalized geophysical logs and plots of resampled and calibrated geophysical data from KFR102A




Geophysical logs KFR102A
Kg/m3
2800
2600
2400
Calibrated density
(SI)
0.08
0.06
0.04
0.02
0
Calibrated susceptibility
µR/h
160
120
80
40
0
Natural gamma
50
100
150
200
250
300
350
400
450
500
550
600
Section length (m)

Input data

Borehole Direction T – Surveying: Borehole direction

KFR102A, 2008-11-17 12:50:00

Length (m)	Bearing (degrees)	Inclination (degrees)	Bearing Err (degrees)	Inclination Err (degrees)	Magnetic Bearing (degrees)	In Use Flag	Coord System	QC
0.00	302.2583	–65.4070	0.2000	0.2000		*	RT90-RHB70	*

Printout from SICADA 2010-02-15 14:56:53.

Hole Diam T – Drilling: Borehole diameter

KFR102A, 2008-11-25 15:40:00 – 2008-12-12 18:00:00 (70.420–600.830 m)

Sub Secup (m)	Sub Seclow (m)	Hole Diam (m)	Comment	QC
70.420	72.020	0.0862	T-86	*
72.020	600.830	0.0758	Corac N3/50	*

Printout from SICADA 2009-05-05 08:36:09.

Reference Mark T – Reference mark in drillhole

KFR102A, 2008-12-09 12:45:00 – 2008-12-09 16:45:00 (100.000–580.000 m)

Bhlen (m)	Rotation Speed (rpm)	Start Flow (l/h)	Stop Flow (l/h)	Stop Pressure (bar)	Cutter Time (s)	Trace Detectable	Cutter Diameter (mm)	Comment	QC
100.00	400.00	200.000	300.000	35.0	40.00	JA	85.0		*
146.00	400.00	200.000	300.000	32.0	40.00	JA	85.0		*
200.00	400.00	200.000	300.000	32.0	40.00	JA	85.0		*
249.00	400.00	200.000	300.000	33.0	42.00	JA	85.0		*
300.00	400.00	200.000	300.000	36.0	45.00	JA	85.0		*
351.00	400.00	200.000	320.000	33.0	42.00	JA	85.0		*
400.00	400.00	200.000	300.000	36.0	48.00	JA	85.0		*
448.00	400.00	200.000	320.000	37.0	50.00	JA	85.0		*
500.00	400.00	200.000	320.000	35.0	48.00	JA	85.0		*
550.00	400.00	200.000	320.000	36.0	48.00	JA	85.0		*
580.00	400.00	200.000	320.000	36.0	46.00	JA	85.0		*

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