P-09-39

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Abstract

This report presents the result from the Boremap mapping of the core drilled boreholes KFR104 and KFR27 (from 147.5 m), which are drilled from the pier next to the existing repository for low- and intermediate-level waste, SFR. The boreholes were drilled during autumn 2008 with the aim to gather information about the geological and hydrogeological properties of the near surface bedrock as well as to verify the geohydrological model. To this, the possible connection between deformation zones and four interpreted magnetic lineaments was checked.

The geological mapping of the boreholes was started in November 2008 and finished in February 2009. The mapping is based on the simultaneous study of the drill core and the borehole image (BIPS) supported by generalized as well as more detailed geophysical logs.

The dominating rock types in KFR104 are younger pegmatite to pegmatitic granite (53%) and metagranite-granodiorite (33%). In KFR27 the metagranite-granodiorite (50%) dominates over pegmatite to pegmatitic granite (21%). The metagranite-granodiorite is a mostly foliated or lineated, and the pegmatite to pegmatitic granite is massive or somewhat lineated in both KFR104 and KFR27. Subordinate rocktypes are amphibolite, felsic to intermediate metavolcanic rock, aplitic metagraite and fine- to medium-grained granite.

The number of fractures registered in KFR104 is 3,521, of which 1,514 are open, 1,916 are sealed and 91 are partly open. The fracture frequencies are 3.4 open fractures/m, 4.3 sealed fractures/m and 0.2 partly open fractures/m. In addition there are 100 sealed networks in KFR104, with a total length of 88 m. Two dominating sets of open, partly open and sealed fractures are seen with the orientations 190°/10° and 220°/85°. The most common minerals are calcite, chlorite, laumontite and oxidized walls. There are two crushes in KFR104 with a total length of 0.57 m.

A few shorter sections (37.3–53.0, 274.2–275.1 and 448.6–452.1 m) in KFR104 are affected by several kinds of alterations; oxidation, quartz dissolution, lamontization, carbonatization, epidotization and muscovite alteration.

The number of fractures registered in KFR27 (from 147.5 m) is 3,625, of which 1,472 are open, 1,959 are sealed and 194 are partly open. The fracture frequencies are 4.2 open fractures/m, 5.5 sealed fractures/m and 0.5 partly open fractures/m. In addition there are 101 sealed networks in KFR27, with a total length of 71 m. There is one dominating set of open and partly open fractures in KFR27 with the orientation 015°/03°, and one less well-defined set of sealed fractures with the orientation 020°/10°. The most common minerals are chlorite, calcite, oxidized walls and hematite. There are 24 crushes in KFR27, with a total length of 2.6 m.

The interval between 422 and 470 m in KFR27, is clearly affected by both by strong alterations and deformation of predominantly ductile character.

Sammanfattning

Denna rapport presenterar resultaten från Boremapkarteringen av kärnborrhålen KFR104 och KFR27 (från 147,5 m), vilka är borrade från piren intill det befintliga förvaret för låg- och medelaktivt avfall, SFR. Borrningen utfördes under hösten 2008 med syftet att erhålla information rörande ytbergets geologiska och hydrogeologiska egenskaper, samt att verifiera den geohydrologiska modellen. Man ville också kontrollera eventuella samband mellan tolkade lågmagnetiska lineament och deformationszoner.

Den geologiska karteringen av borrhålen påbörjades i november 2008 och slutfördes i februari 2009. Karteringen är baserad på simultan undersökning av borrkärna och borrhålsbild (BIPS) understödd av geofysiska loggar.

De dominerande bergarterna i KFR104 är yngre pegmatit och pegmatitisk granit (53 %) samt metagranit-granodiorit (33 %). I KFR27 dominerar metagranit-granodiorit (50 %) över pegmatit och pegmatitisk granit (21 %). Metagraniten-granodioriten är i förekommande fall mestadels folierad eller linerad, medans pegmatit och pegmatitisk granit är massiv eller i ett fåtal fall linerad. Underordnade bergarter i KFR104 och KFR27 är amfibolit, felsisk till intermediär metavulkanit, aplitisk metagranit samt fin- till medelkornig granit.

Antalet registrerade sprickor i KFR104 är 3 521, av vilka 1 514 är öppna, 1 916 är läkta och 91 är delvis öppna. Sprickfrekvensen är 3,4 öppna sprickor/meter, 4,3 läkta sprickor/meter och 0,2 delvis öppna sprickor/meter. Dessutom är det 100 registrerade läkta spricknätverk med en total längd av 88 m. Två dominerande set av öppna, delvis öppna och läkta sprickor finns i KFR104 med orienteringen 190°/10° and 220°/85°. De vanligaste mineralen är kalcit, klorit, laumontit och oxiderat sidoberg. Det finns två krossar i KFR104, med en total längd av 0,57 m.

Det förekommer några kortare intervall (37,3–530, 274,2–275,1 och 448,6–452,1 m) i KFR104 som är påverkade av ett flertal olika omvandlingar; oxidering, kvarts upplösning, lamontisering, karbonatisering, epidotisering and muskovit omvandling.

Antalet registrerade sprickor i KFR27 (från 147,5 m) är 3 625, av vilka 1 472 är öppna, 1 959 är läkta och 194 är delvis öppna. Sprickfrekvensen är 4,2 öppna sprickor/meter, 5,5 läkta sprickor/meter och 0,5 delvis öppna sprickor/meter. Dessutom är det 101 registrerade läkta spricknätverk med en total längd av 71 m. Det finns ett dominerande set med öppna och delvis öppna sprickor med orienteringen 015°/03°, och ett mindre väldefinierat set med läkta sprickor med orienteringen 020°/10°. De vanligast förekommande mineralen är klorit, kalcit, oxiderat sidoberg och hematit. Det finns 24 krossar i KFR27 med en total längd av 2,6 m.

Intervallet mellan 422 och 470 m i KFR 27 är tydligt påverkat av både kraftiga omvandlingar och deformation. Deformationen är till övervägande del av duktil karaktär.

Contents

1 Introduction

SKB intends to extend 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 also 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.

Information about the bedrock and groundwater has already been gathered during the building of SFR, but some complementary studies have to be done. This document reports the data gained by the Boremap mapping of two core drilled boreholes, KFR104 and KFR27 (from 147.5 m), which is one of the activities performed within the site investigation at SFR. The boreholes KFR104 and KFR27 are drilled in the middle and eastern part, respectively, of the pier at SFR (Figure 1-1). KFR104 has a length of 454.57 m, a bearing of 134° and an inclination of –54° (Appendix 3). KFR27 is an already existing borehole /1/, which was extended from 148.5 to 501.6 m. Directional drilling was performed between 154.4 and 212.5 m, turning the vertical borehole towards southwest. Bearing and inclination for KFR27 is 248° and –87°, respectively (Appendix 3).

The work was carried out in accordance with activity plan AP SFR-08-028. 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 boreholes were drilled in the autumn 2008 and were after completion, investigated with several logging methods, such as conventional geophysical logging and TV-logging. The latter method implies logging with a colour TV-camera to produce images of the borehole wall, so called BIPS-images (**B**orehole **I**mage **P**rocessing **S**ystem). The method is described in SKB MD 222.006 Metodbeskrivning för TV-loggning med BIPS (SKB, internal controlling document, in Swedish).

The boreholes were mapped in the period November 2008–February 2009. Mapping of cored boreholes 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-images enables the study of fractures and their characteristics along the boreholes. 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-08-028). 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 KFR27 (förlängning) och KFR104	AP SFR-08-028	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	2.0
Mätsystembeskrivning för Boremap	SKB MD 146.005	1.0
Instruktion: Regler för bergarters benämningar vid platsundersökningen i Forsmark	SKB MD 132.005	1.0
Nomenklatur vid Boremapkartering	SKB MD 143.008	1.0

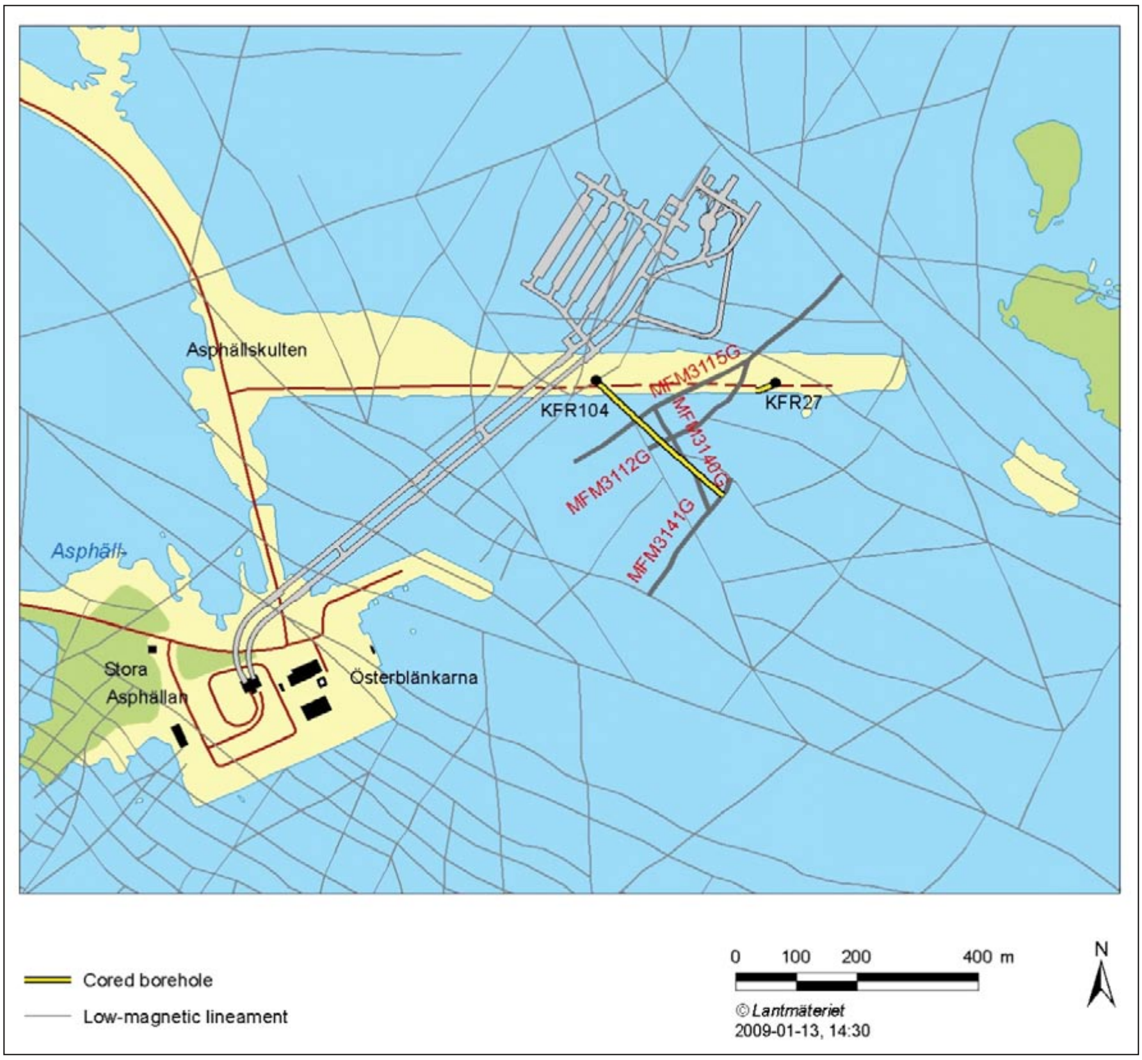

Figure 1-1. *Location and horizontal projections of the core drilled boreholes KFR104 and KFR27 in relation to SFR. Four lineaments with low magnetic intensity, expected to be intersected by the borehole KFR104, are highlighted.*

2 Objective and scope

The boreholes KFR104 and KFR27 (from 147.5 m) were drilled with the aim to gather information about the geological and hydrogeological properties of the near surface bedrock, as well as to verify the geohydrological model. KFR27 is an already existing borehole (AP SFR-08-006, /1/), which was extended from 148.5 to 501.6 m in autumn 2008. The direction of KFR27 was changed between 154.4 and 212.5 m. To this, the possible connection between deformation zones and the four interpreted low magnetic lineaments was checked. Lithologies, alterations, ductile structures and the occurrence and character of fractures in the bedrock penetrated by the core drilled boreholes KFR104 and KFR27 (from 147.5 m) 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 boreholes based on BIPS-images 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 (SKB MD 132.005), 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 lengths were calibrated by reference marks in the borehole wall (Appendix 3).

Schematic presentations of the borehole mapping 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 related to the drilling equipment.
- Vertical bleached bands on the borehole wall from drill cuttings, either in suspension or after precipitation.
- Light and dark bands at high angle to the borehole related to the automatic aperture of the video camera.
- Vertical enlargement of pixels due to stick-slip movement of the camera probe.

The BIPS-image qualities of the boreholes are listed in Table 3-2. The results from the BIPS-loggings are presented in /2/.

Table 3-1. Used BIPS-files.

Borehole	BIPS-file	Logging date	Logging time	From (m)	To (m)
KFR104	KFR104_8_440m.BIP	2008-10-14	18:13	8.000	440.490
KFR27	KFR27_140_500m.BIP	2008-10-04	13:37	140.000	500.003

Table 3-2. BIPS-image quality of used BIPS-files.

Borehole	From (m)	To (m)	Visible %	Comment
KFR104	8.7	29	75	Acceptable. Vertical band with brownish coatings covering 1/3 of the borehole, and some suspension.
	29	183	90–100	Quite good. Some brownish staining and overexposed parts.
	183	200	80–100	Quite good. Brownish semi-transparent coating covering 1/3 of the borehole.
	200	259	60–90	Acceptable. Suspension and overexposure, mostly affecting dark rock types.
	259	442	60–80	Acceptable. Precipitated material, suspension and overexposure on the lower side of the borehole, brownish coatings.
	291.25	291.28	0	Vertical enlargement of pixels due to stick-slip movement of the camera.
	291.37	291.63		
	291.99	292.04		
	294.27	294.53		
	296.22	296.23		
	297.05	297.35		
	440.81	442.05		
KFR27	147.5	158.7	70–80	Acceptable. Mud and brownish coatings.
	158.7	173	30–60	Poor quality. Brownish coatings and mud cover most parts of the borehole.
	173	175	80–90	Quite good. Some mud and brownish coatings.
	175	182	20–60	Poor quality. Borehole covered with mud.
	182	187.93	80–100	Quite good. Some brownish coatings.
	187.93	188.54	0	No BIPS image.
	188.54	196.3	85–100	Quite good. Brownish coatings and somewhat overexposed borehole wall.
	196.3	212.6	60–70	Acceptable. Mud and brownish coatings.
	212.6	281	80–100	Quite good. Brownish stainings.
	281	307	70–90	Acceptable. Brownish coatings.
	307	322	50–70	Bad. Borehole wall covered with brownish coatings.
	322	371	70–90	Acceptable.
	371	380.7	60–70	Poor quality. Very diffuse and brownish image.
	380.7	390	80–100	Quite good.
	390	401	60–90	Acceptable. Brownish coatings.
	401	411	80–100	Quite good.
	411	500.9	70–90	Acceptable. Diffuse image. Brownish coatings and suspension.

4 Execution

4.1 General

Boremap mappings of the core drilled boreholes KFR104 and KFR27 were performed and documented according to activity plan AP SFR-08-028 (SKB, internal document). 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 /3/. Information from earlier performed investigations in the area were also helpful in the interpretations /4, 5, 6, 7, 8/.

4.2 Preparations

Background data collected from Sicada prior to the Boremap mapping included:

- borehole diameter (Appendix 3),
- reference marks in the borehole wall (Appendix 3),
- total borehole length (Appendix 3),
- borehole deviation data.

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 from Geovista AB were used as supporting data for the mapping of the boreholes (Appendix 2).

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

Table 4-1. Borehole data for KFR104 and KFR27.

ID-code	Northing	Easting	Bearing (degrees)	Inclination (degrees)	Diameter (mm)	Borehole length (m)	Mapping interval (m)	End of casing
KFR104	6701719.45	1632879.34	133.78	–53.81	76	454.57	8.735–454.57	8.73
KFR27	6701714.42	1633175.52	248.20	–87.42	76	501.64	147.485–501.64	11.91

Table 4-2. Applied length adjustments in KFR104 and KFR27.

Borehole	Recorded length (m)	Adjusted length (m)	Difference (m)
KFR104	99.806	100	0.194
	148.679	149	0.321
	199.436	200	0.564
	249.231	250	0.769
	299.094	300	0.906
	351.949	353	1.051
	398.724	400	1.276
	433.492	435	1.508
KFR27	149.933	150	0.067
	200.772	201	0.228
	248.552	249	0.448
	299.453	300	0.547
	357.355	358	0.645
	398.290	399	0.710
	449.100	450	0.900

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 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 /9/. Fractures wider than 1 mm 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 do 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

Not all fractures are visible in the BIPS-image, and these fractures are oriented using the *guideline method* /10/. The orientation 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 depth 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 KFR27 and KFR104:

- X1 = Bleached fracture walls.
- X2 = Apophyllite.
- 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 (only observed in KFR27).

4.3.5 Foliation and lineation

The metagranite-granodiorites which occupies most of the area in Forsmark are usually LS tectonites, where lineation dominates over foliation /5/. 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. The judgement is supported by the study of the BIPS-image, i.e. on the basis of how much material that seems to be flushed away from the borehole wall during drilling.

4.3.7 Lithologies and correlation with geophysical data

As mentioned in section 4.3.5, 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 resample and calibrated geophysical logging data from the boreholes (Appendix 2, /11/), were helpful where there were difficulties in determining the rock type macroscopically.

4.4 Data handling/post processing

The Boremap mappings of KFR27 and KFR104 were performed on SKB’s network, and a backup was saved on a local computer before each break exceeding 15 minutes. When the mappings were finished and quality checked by the author and by a routine in Boremap, the data were 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 is one core loss in KFR104, at 452.60–452.61 m, which is mechanical. In KFR27 there are seven core losses. These occur in the following intervals: 163.00–163.40, 179.32–179.39, 180.37–180.44, 189.02–189.05, 192.57–192.67, 432.14–432.29 and 501.05–501.05 m. The first one is mechanical, the second, third and fourth is due to missing core pieces, the fifth and sixth are in a crush zone and the last one is also mechanical.

4.5.2 Underestimation of 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.

The same problem applies for graphite, found only in two broken fractures in KFR104 but more frequent in KFR27. Graphite is easily detected due to its hydroscopic properties, which make it float on water and diluted hydrochloric acid added on the fracture surface.

4.5.3 Diverging borehole diameter

The borehole diameter is ~76 mm in the boreholes, except for the interval 430.80–433.00 m in KFR27 where it is ~84 mm according to Sicada database. The orientations of observations within this interval will therefore have an overestimated alpha-angle, resulting in wrongly calculated strike and dip (mostly dip, since the borehole is almost vertical). Features that have not been visible in BIPS and therefore have been oriented with the guideline method will on the other hand have correct alpha-angles also in this interval.

5 Results

The data from Boremap mappings of KFR104 and KFR27 are 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. Summaries of rock types and fracture frequency in the boreholes are presented in Table 5-1 and 5-2.

5.1 KFR104

5.1.1 Lithology

The dominating rock type in KFR104 (Table 5-1) is medium to-coarse-grained pegmatite or pegmatitic granite (rock code 101061), which occupy 53% of the logged interval. Except for two small lineated sections (383.35–384.37 and 422.62–424.65 m) the structure of the pegmatitic granite is massive. The second most common rock type by 33% is fine- to medium-grained metagranite-granodiorite (rock code 101057), with a medium to strong foliation or lineation. Subordinated rock types are felsic- to intermediate metavolcanic rock (rock code 103076), aplitic metagranite (rock code 101058), amphibolite (rock code 102017), and fine- to medium-grained granite (rock code 111058).

A number of 14 narrow brittle-ductile and one ductile deformation zone have been registered in KFR104. Four of the zones exceed one decimetre in length, but generally they are just a few millimetres to centimetres in width.

5.1.2 Alteration

In KFR104, 22% of the borehole length has been mapped as altered. This does not include the 785 fractures that have been mapped with oxidized walls.

Oxidation with varying intensity is the most common alteration, occurring throughout the borehole. Muscovite alteration, mapped as sericitization, is registered in three intervals; 47.9–53.1, 283.6–294.7 and 334.0–355.3 m (not continuously). One long interval of albitization is registered at 334.6–349.4 m, and two shorter at 298.3–298.4 and 334.6–349.4 m. Additional sporadic alterations are epidotization, argillization, chloritization, quartz dissolution, lamontization and carbonatization.

Table 5-1. Percentage distribution of rock types in KFR104 and KFR27 (rock occurrences excluded).

Borehole	101057	101061	102017	103076	111058	101058
KFR104	33	53	1	5	4	4
KFR27	50	21	16	2	11	

Table 5-2. Fracture frequencies in KFR104 and KFR27 (crush and sealed fracture networks excluded) expressed as fractures/m.

Borehole	Open fractures	Partly open fractures	Sealed fractures
KFR104	3.4	0.2	4.3
KFR27	4.2	0.5	5.5

Longer sections affected by several alterations are:

- 37.4–53.1 m altered by oxidation, quartz dissolution, epidotization and sericitization,
- 275.1–276.0 m altered by oxidation, laumontitzation and carbonatization, and
- 450.2–453.7 m altered by laumontization and oxidation.

5.1.3 Fractures

A total number of 3,521 fractures are registered in KFR104. Of these are 1,514 open (broken with aperture > 0), 1,916 are sealed (broken and unbroken fractures with aperture = 0) and 91 partly open (unbroken fractures with aperture > 0). This result in the following interpreted fracture frequencies: 3.4 open fractures/m (crushes are excluded), 4.3 sealed fractures/m (sealed fractures in sealed fracture networks are excluded) and 0.2 partly open fractures/m (Table 5-2).

In addition there are 100 sealed networks, with a total length of 88 m, 21 breccias or brecciated intervals, and four cataclasites in KFR104. Except for one 4 dm wide brecciated interval at 150.97–151.38 m, the majority of them are just a few centimetres wide.

There are two dominating sets of open, partly open and sealed fractures in KFR104 with the orientations 190°/10° and 220°/85° (Figure 5-1 and 5-2). Fractures mapped without access to complementary BIPS-image are not oriented and hence not plotted in the stereograms.

The most common minerals in the open fractures are in decreasing order: chlorite, calcite, hematite, laumontite, clay minerals, muscovite and no detectable mineral. In the sealed fractures calcite, oxidized walls, chlorite, laumontite, hematite, quartz and adularia are in decreasing order the most common minerals.

131 fractures in KFR104 are registered as having no detectable mineral.

There are two crushes in KFR104. The first one is at 276.36–276.64 m with the approximate orientation 260°/45°, and the second at 277.46–277.75 m with the approximate orientation 085°/55°.

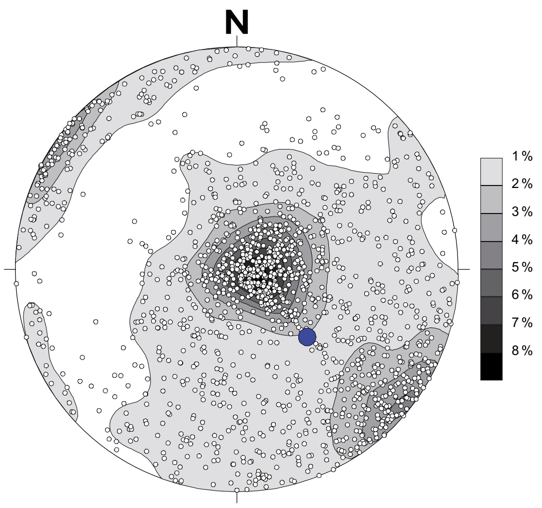

__Figure 5-1.__ Stereographic projection showing contoured poles to open and partly open fracture planes (n=1,564) in KFR104, Schmidt net, lower hemisphere. Blue dot is borehole projection.

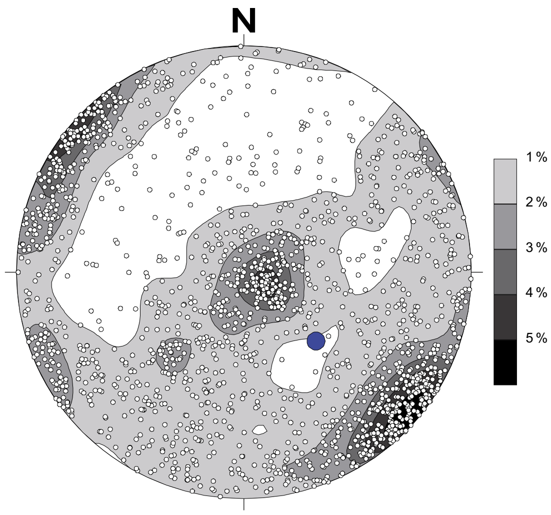

__Figure 5-2.__ Stereographic projection showing contoured poles to sealed fracture planes (n=1,821) in KFR104, Schmidt net, lower hemisphere. Blue dot is borehole projection.

5.2 KFR27

5.2.1 Lithology

The dominating rock type in KFR27 is pinkish- or reddish grey, fine- to medium-grained metagranite-granodiorite (rock code 101057), which occupy 50% of the logged interval. The metagranite-granodiorite is mostly moderately foliated, but sections where lineation dominates over foliation are present. Pegmatite to pegmatitic granite (rock code 101061) and amphibolite (rock code 102017) occupies 21 and 16%, respectively, of the logged interval in KFR27. Amphibolite is except for small rock occurrences, found at borehole lengths > 290 m. The structure of the pegmatite to pegmatitic granite is mostly massive, but lineation is also observed.

Subordinate rock types are felsic to intermediate metavolcanic rock (rock code 103076) and fine- to medium-grained granite (rock code 111058). The percentage rock type distribution in KFR27 is presented in Table 5-1.

5.2.2 Deformation

The foliation and lineation in KFR27 are mostly weak to medium in intensity, and the orientation can be seen in Figure 5-3.

The interval at 422–470 m in KFR27 has characteristics of a possible deformation zone. Most prominent is the deformation in the interval 446–463 m. The pegmatitic granite in the upper part of this interval is brecciated, followed by amphibolite affected by both ductile- and brittle -ductile shearing, with a brecciated interval in the middle at 450.9–455.3 m. Figure 5-4 shows the amphibolite in the interval between 446.2 and 451.7 m. The most deformed interval ends with a brittle-ductile metagranite to granodiorite at 458.9–463.6 m.

Of the totally 34 narrow deformation zones registered in KFR27, 30 are brittle-ductile, 2 ductile and 2 mylonites. 25 of them are found in the interval 422–470 m. The majority of the narrow zones are just a few millimetres to centimetres, but 10 of them exceed 1 dm in width.

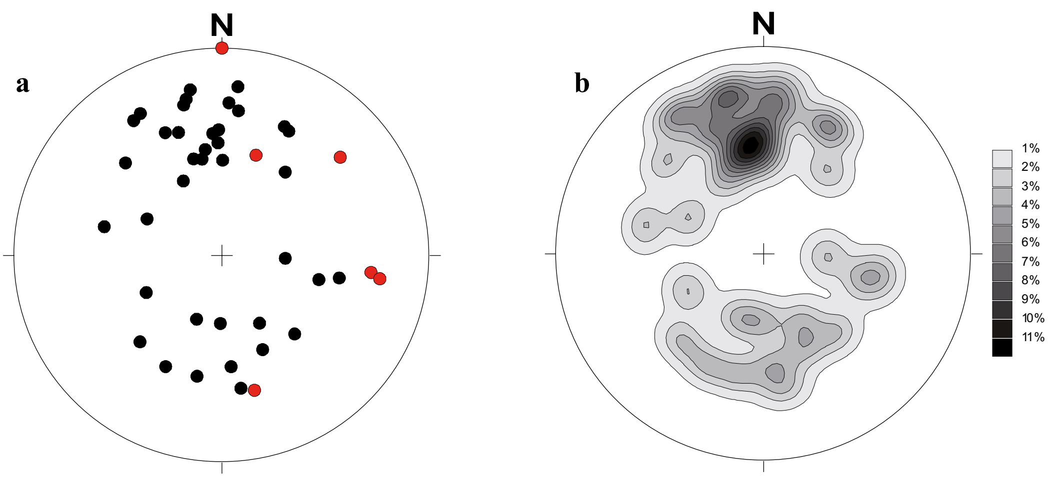

Figure 5-3. *Stereographic projection showing **a)** lineation (•, n=6) and poles to foliation planes (•, n=38) and **b)** contoured poles to foliation planes (n=38) in KFR27.*

Figure 5-4. Altered and deformed amphibolite in the interval 446.2 and 451.7 m

5.2.3 Alteration

In KFR27 approximately 32% of the borehole length, predominantly the second half, has been affected by alterations. This does not include the 1,328 fractures mapped with oxidized or bleached walls.

The interval at 422–470 m is intensely altered by several kinds of alterations. Different degrees of oxidation affect almost the entire interval, and the most intense oxidation is registered as hematitization. Except for one short section, all quartz dissolution (Figure 5-5) in KFR27 is registered in this interval, and affects several rock types; fine to medium grained granite (111058), metagranite-granodiorite (101057), pegmatitic granite (101061) and amphibolite (102017). Chloritization, argillization and epidotization are also predominantly found within the interval, 422–470 m. There are sections with argillization in KFR27 that despite an intact core, looks like crushes (Figure 5-6) in the BIPS-image (452.10–452.91 m and 456.99–457.22 m). These sections are mapped as having moderate argillization.

Additional alterations are muscovitization (mapped as sericitization), albitization, silicification, and lamontization. The albitization is mainly observed at contacts with amphibolite.

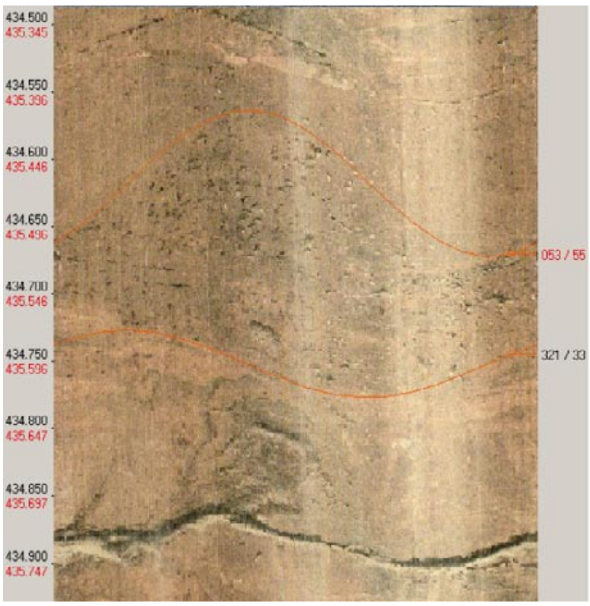

Figure 5-5. Quartz dissolution at 434.618 m.

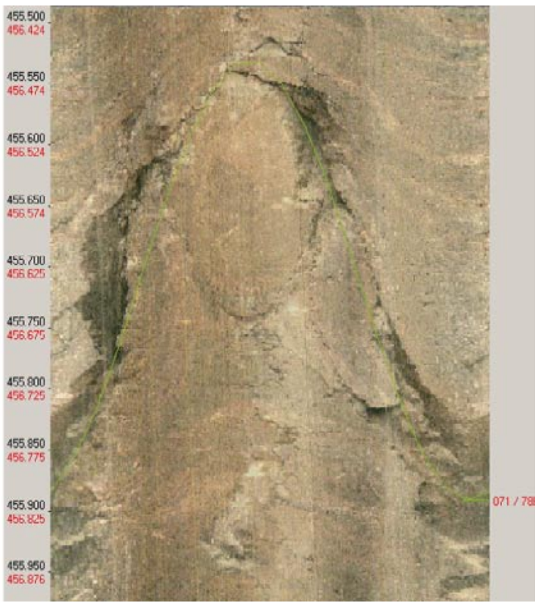

Figure 5-6. A sealed fracture that looks like a crush in the BIPS-image, despite an intact core.

5.2.4 Fractures

A total number of 3,625 fractures are registered in KFR27. Of these are 1,472 open (broken with aperture > 0), 1,959 are sealed (broken and unbroken fractures with aperture = 0) and 194 partly open (unbroken fractures with aperture > 0). This result in the following interpreted fracture frequencies: 4.2 open fractures/m (crushes are excluded), 5.5 sealed fractures/m (sealed fractures in sealed fracture networks are excluded) and 0.5 partly open fractures/m (Table 5-2).

There is one dominating set of open and partly open fractures with the orientation 015°/03° (Figure 5-7), and one less well-defined set of sealed fractures with the orientation 020°/10° (Figure 5-8). Fractures mapped without access to complementary BIPS-image are not oriented and hence not plotted in the stereograms.

In addition there are 101 sealed networks, with a total length of 71 m, 18 breccia or brecciated intervals, and 15 cataclasites. Except for two brecciated intervals that exceed 1 dm, the widths range from millimetres to a few centimetres.

The most common minerals in the open fractures are in decreasing order: chlorite, calcite, hematite, clay minerals, laumontite, oxidized walls, muscovite, quartz, adularia and graphite.

In the sealed fractures oxidized walls, calcite, quartz, adularia chlorite, laumontite, hematite and epidote are the most common minerals. 57% of the sealed fractures have oxidized walls.

There are 73 fractures in KFR27 with no detectable mineral.

There are 24 crushes in KFR27, with a total length of 2.6 m (Table 5-3).

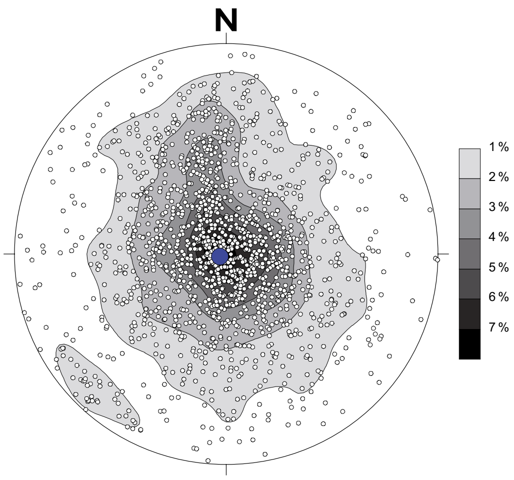

Figure 5-7. *Stereographic projection showing contoured poles to open and partly open fracture planes (n=1,663) in KFR27, Schmidt net, lower hemisphere. Blue dot is borehole projection.*

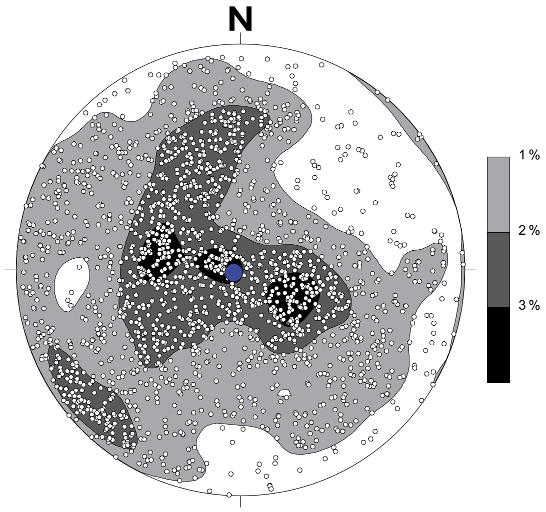

Figure 5-8. *Stereographic projection showing contoured poles to sealed fracture planes (n=1,956) in KFR27, Schmidt net, lower hemisphere. Blue dot is borehole projection.*

Table 5-3. Crushes in KFR27

From (m)	To (m)	Piece length (mm)	Orientation upper contact (°)	Orientation lower contact (°)
192.506	192.707	7	349/8	075/44
324.186	324.344	10	221/53	143/18
324.5	324.855	15	132/17	250/11
331.649	331.758	5	098/28	203/10
343.718	343.925	25	093/79	329/15
349.61	349.786	10	088/33	089/32
354.388	354.545	20	246/39	255/33
360.523	360.572	7	104/35	099/33
364.96	364.981	10	084/45	070/27
366.213	366.232	8	072/17	077/32
368.508	368.545	5	053/52	039/49
371.497	371.716	15	078/39	281/13
372.652	372.676	10	279/27	282/16
377.943	377.998	10	095/45	077/48
394.706	394.754	15	086/68	086/68
424.751	424.804	8	312/79	307/81
431.472	431.51	10	050/22	021/34
431.513	431.576	5	020/35	034/34
431.755	431.795	15	115/34	086/31
431.95	432.394	15	018/6	329/21
433.481	433.52	10	002/26	002/26
446.862	446.911	10	70/56	50/50
448.124	448.139	8	351/49	5/45
458.305	458.333	5	46/58	46/58

6 References

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/2/ **Gustafsson J, Gustafsson G, 2008.** Site investigation SFR. BIPS logging in the core drilled boreholes KFR102A, KFR102B, KFR103, KFR104 and KFR27 (140–500 m) and radar logging in KFR102A and KFR104. SKB P-09-11, Svensk Kärnbränslehantering AB.

/3/ **Stråhle A, 2001.** Definition och beskrivning av parametrar för geologisk, geofysisk och bergmekanisk kartering av berg. SKB R-01-19, Svensk Kärnbränslehantering AB.

/4/ **Stephens M B, Lundqvist S, Bergman T, Andersson J, Ekström M, 2003.** Forsmark site investigation. Bedrock mapping – Rock types, their petrographic and geochemical characteristics, and a structural analysis of the bedrock based on Stage 1 (2002) surface data. SKB P-03-75, Svensk Kärnbränslehantering AB.

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/7/ **Döse C, Stråhle A, Mattsson K-J, Carlsten S, 2009.** Site investigation SFR. Boremap mapping of core drilled borehole KFR101. SKB P-09-36, Svensk Kärnbränslehantering AB.

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/9/ **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.

/10/ **Ehrenborg J, Steiskal V, 2004.** Oskarshamn site investigation. Boremap mapping of core drilled boreholes KSH01A and KSH01B. SKB P-04-01, Svensk Kärnbränslehantering AB.

/11/ **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.

Appendix 1

WellCad-diagrams of KFR27 and KFR104

Title	LEGEND FOR FORSMARK - SFR	KFR27	Appendix: 1

Site	FORSMARK - SFR
Borehole	KFR27
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, quartz 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

- Flourite
- White Feldspar
- Graphite
- Hematite
- Calcite
- Chlorite
- Chalcopyrite
- Quartz
- Muscovite
- Unknown
- Pyrite
- Clay Minerals
- Laumontite
- Prehnite
- Iron Hydroxide
- Oxidized Walls

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

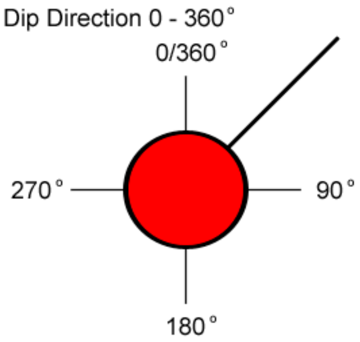
FRACTURE ALTERATION

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

FRACTURE DIRECTION

STRUKTURE ORIENTATION

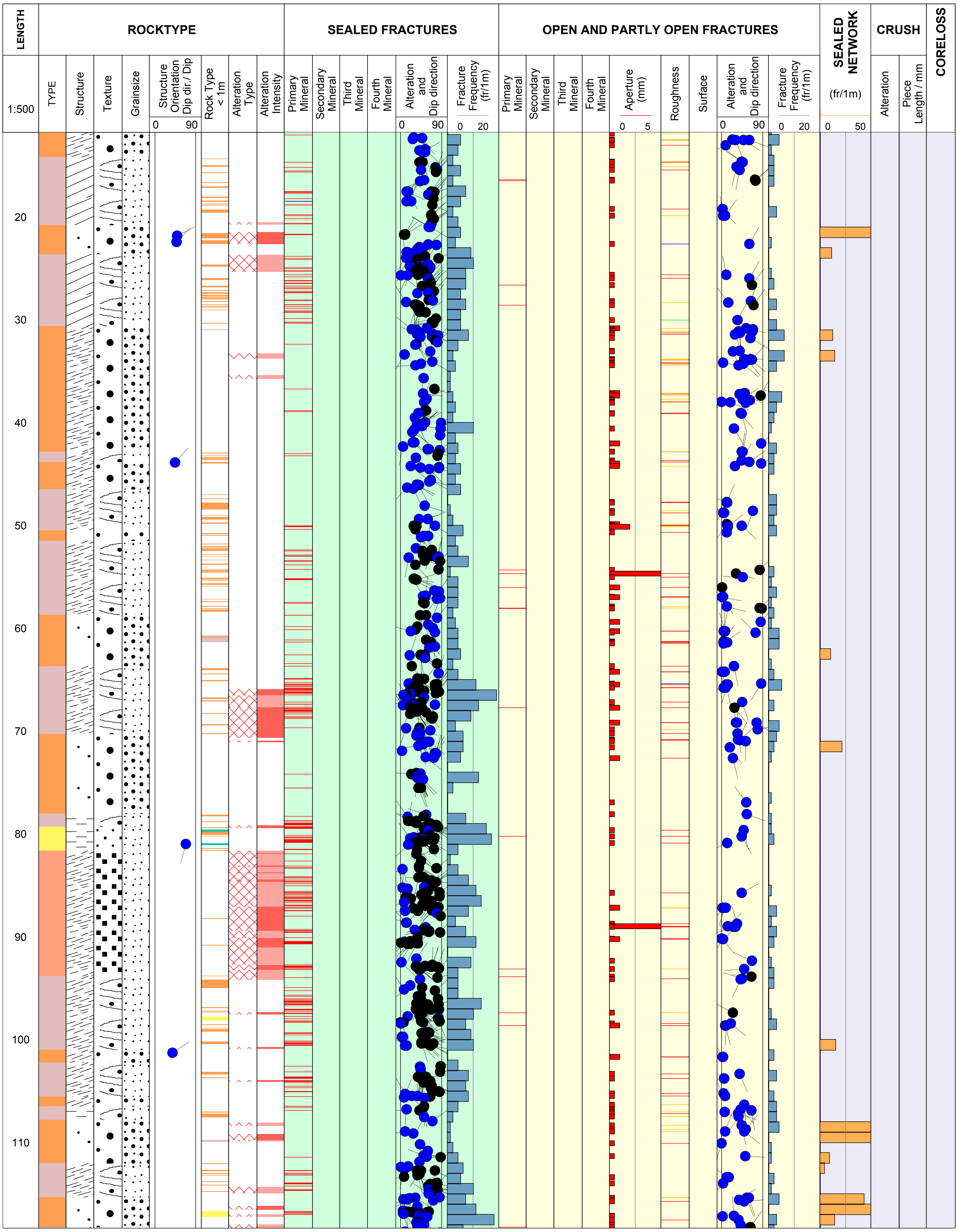
Dip Direction 0 - 360°

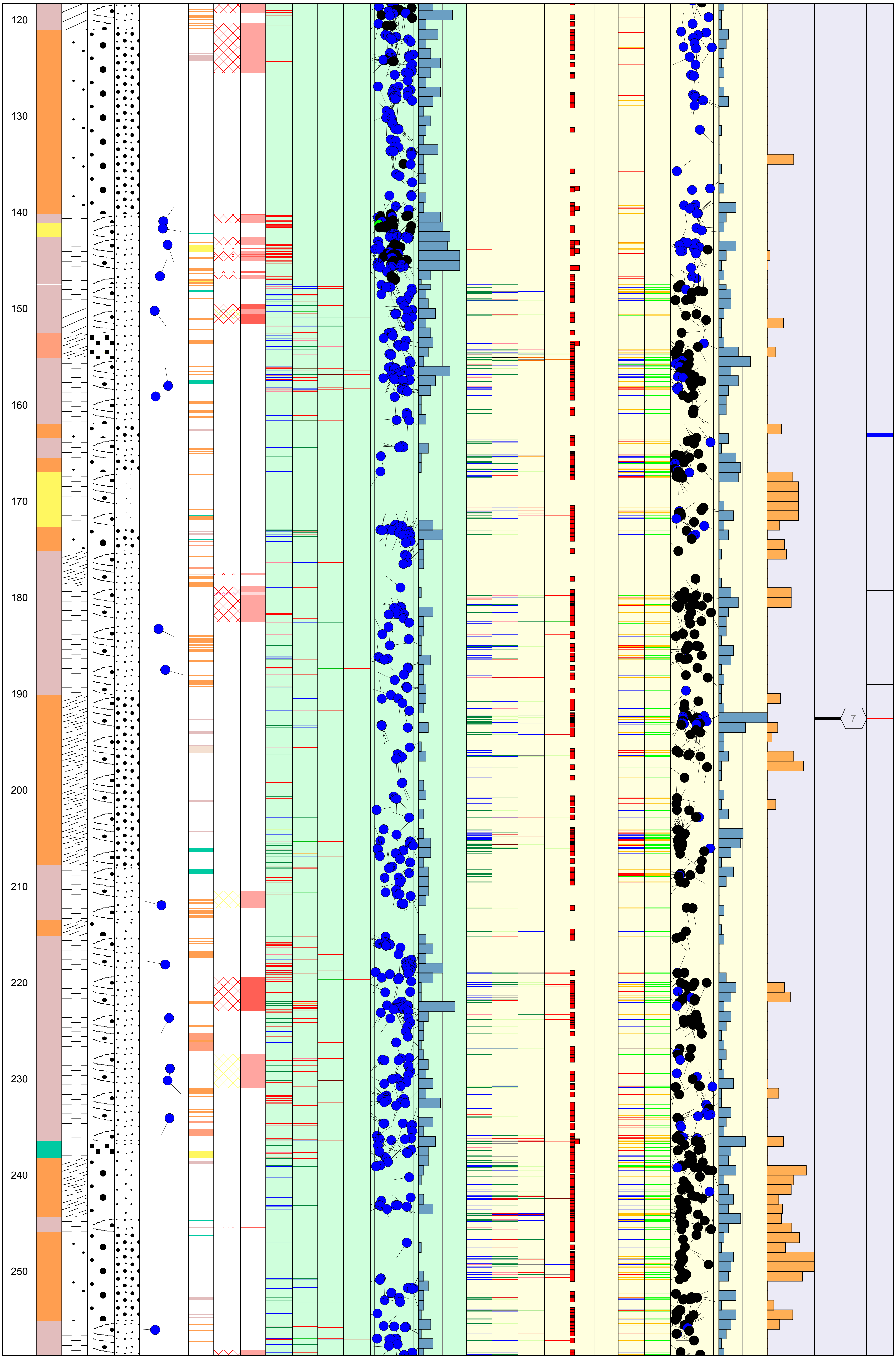


Dip 0 - 90°

Title **GEOLOGY IN KFR27** **Appendix: 1**

Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	KFR27	**Northing [m]**	6701714.42
Diameter [mm]	76	**Easting [m]**	1633175.52
Length [m]	501.640	**Elevation [m.a.s.l.]**	2.87
Bearing [°]	248.20	**Drilling Start Date**	1981-08-06 00:00:00
Inclination [°]	-87.60	**Drilling Stop Date**	2008-06-10 00:00:00
Date of coremapping	2008-11-12 19:04:00	**Plot Date**	2009-10-24 23:01:44
Rocktype data from	p_rock	**Signed data**	

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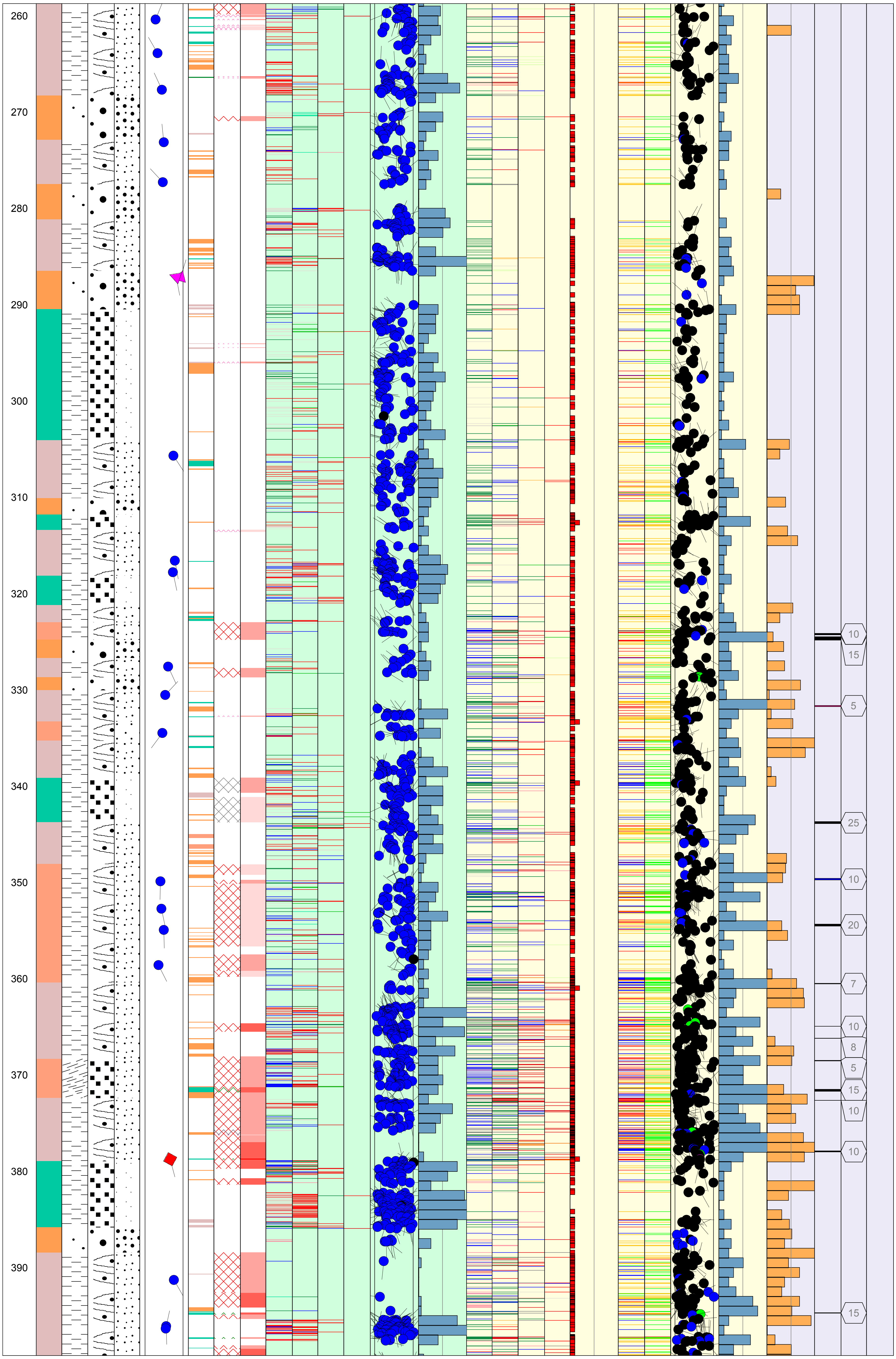

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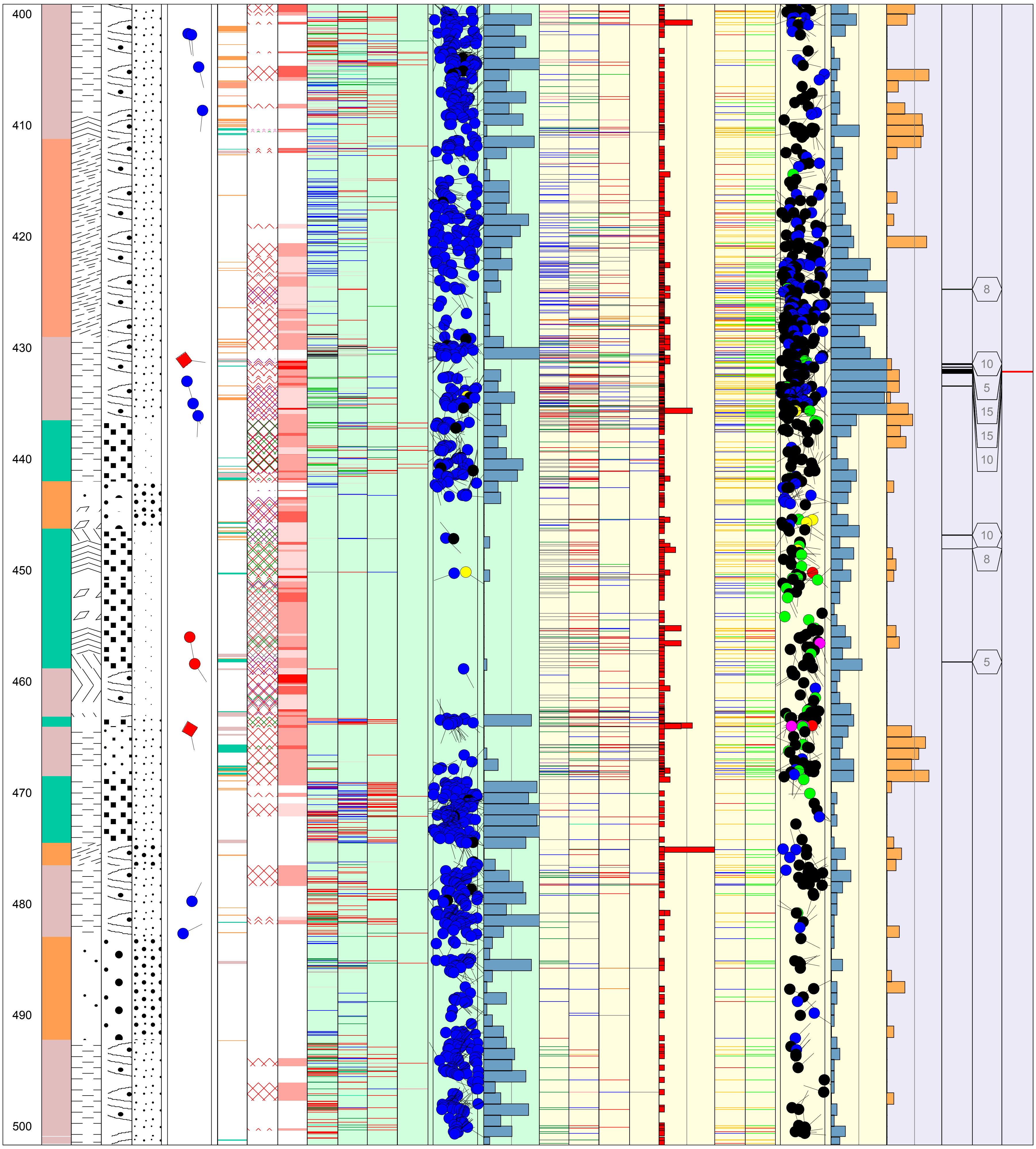
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500
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10
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10
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Title	LEGEND FOR FORSMARK - SFR	KFR104	Appendix: 1

Site	FORSMARK - SFR
Borehole	KFR104
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, quartz 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

- Epidote
- Flourite
- White Feldspar
- Hematite
- Calcite
- Chlorite
- Quartz
- Muscovite
- Unknown
- Pyrite
- Clay Minerals
- Laumontite
- Prehnite
- Asphalt
- Iron Hydroxide
- Oxidized Walls

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
- Veined
- Ductile Shear Zone
- Banded
- Brittle-Ductile Shear Zone
- Gneissic

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

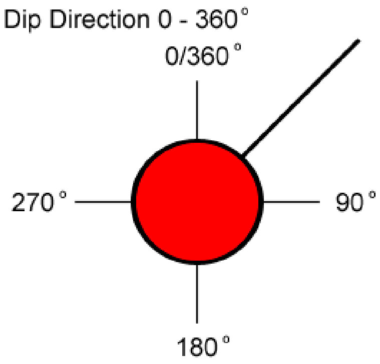
FRACTURE ALTERATION

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

FRACTURE DIRECTION

STRUKTURE ORIENTATION

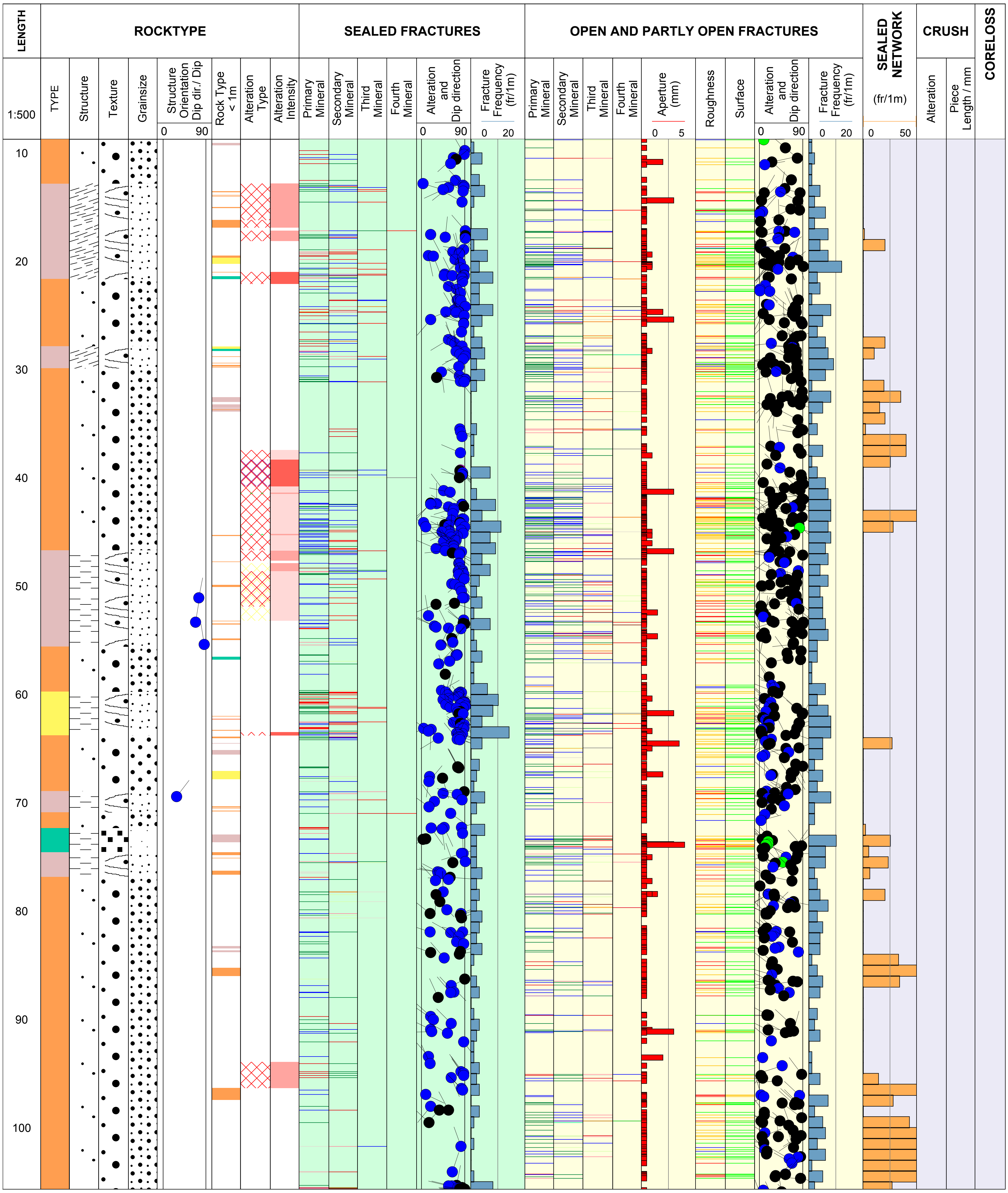
Dip Direction 0 - 360°

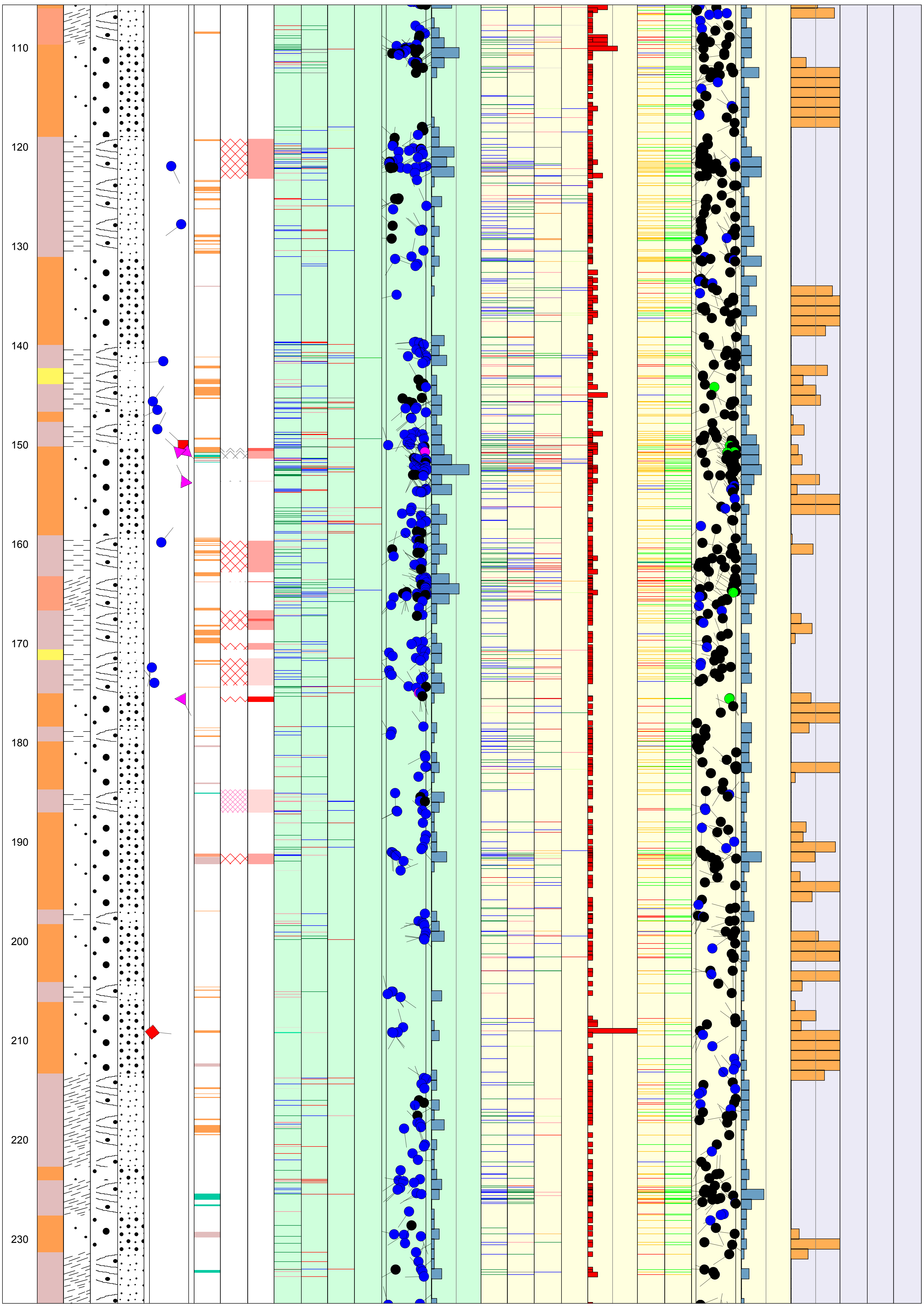


Dip 0 - 90°

Title GEOLOGY IN KFR104 — Appendix: 1

Site	FORSMARK - SFR	Coordinate System	RT90-RHB70
Borehole	KFR104	Northing [m]	6701719.45
Diameter [mm]	76	Easting [m]	1632879.34
Length [m]	454.570	Elevation [m.a.s.l.]	2.83
Bearing [°]	133.78	Drilling Start Date	2008-09-02 11:50:00
Inclination [°]	-54.86	Drilling Stop Date	2008-09-29 18:15:00
Date of coremapping	2008-11-10 14:37:00	Plot Date	2009-10-24 23:01:44
Rocktype data from	p_rock	Signed data	

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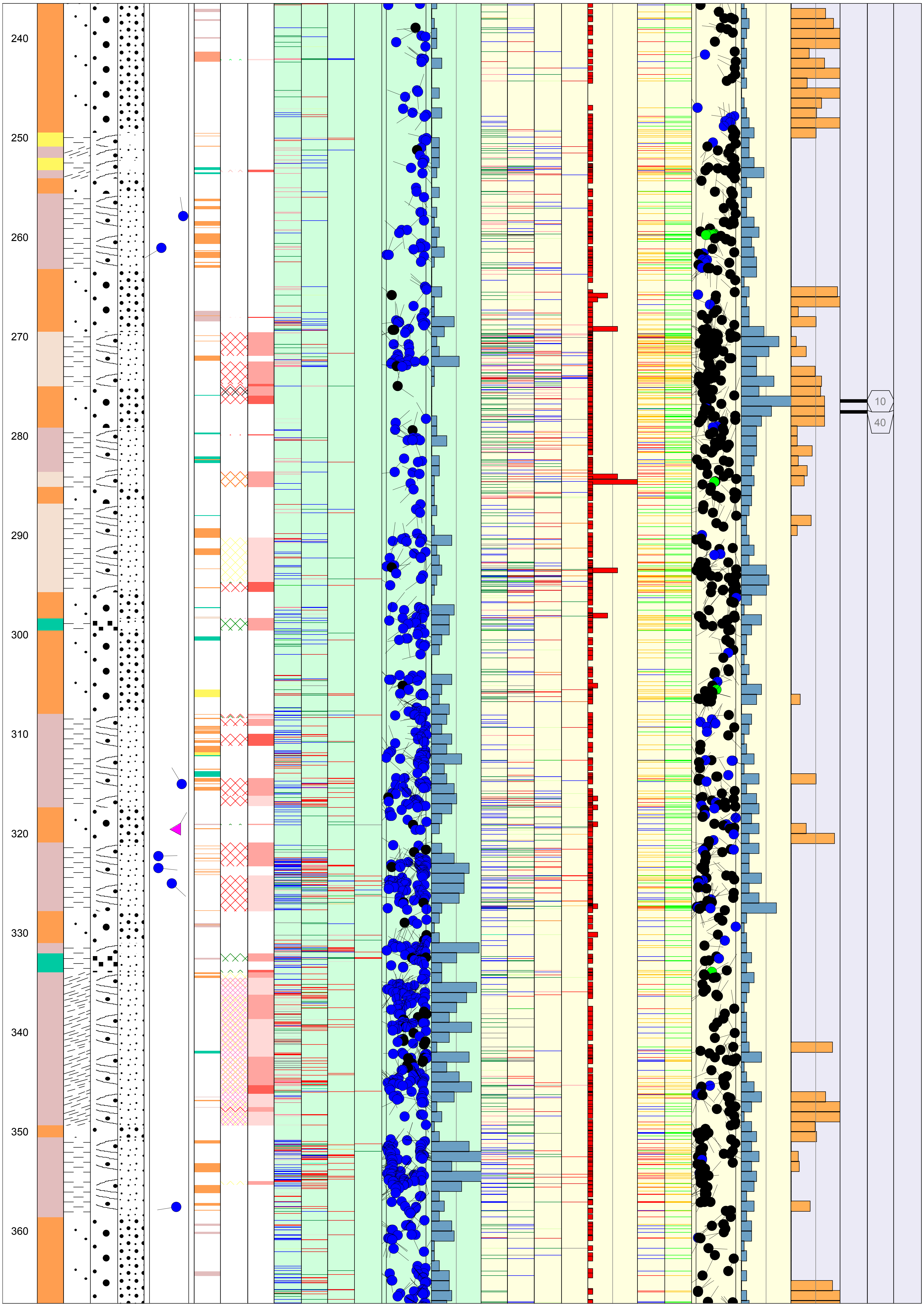
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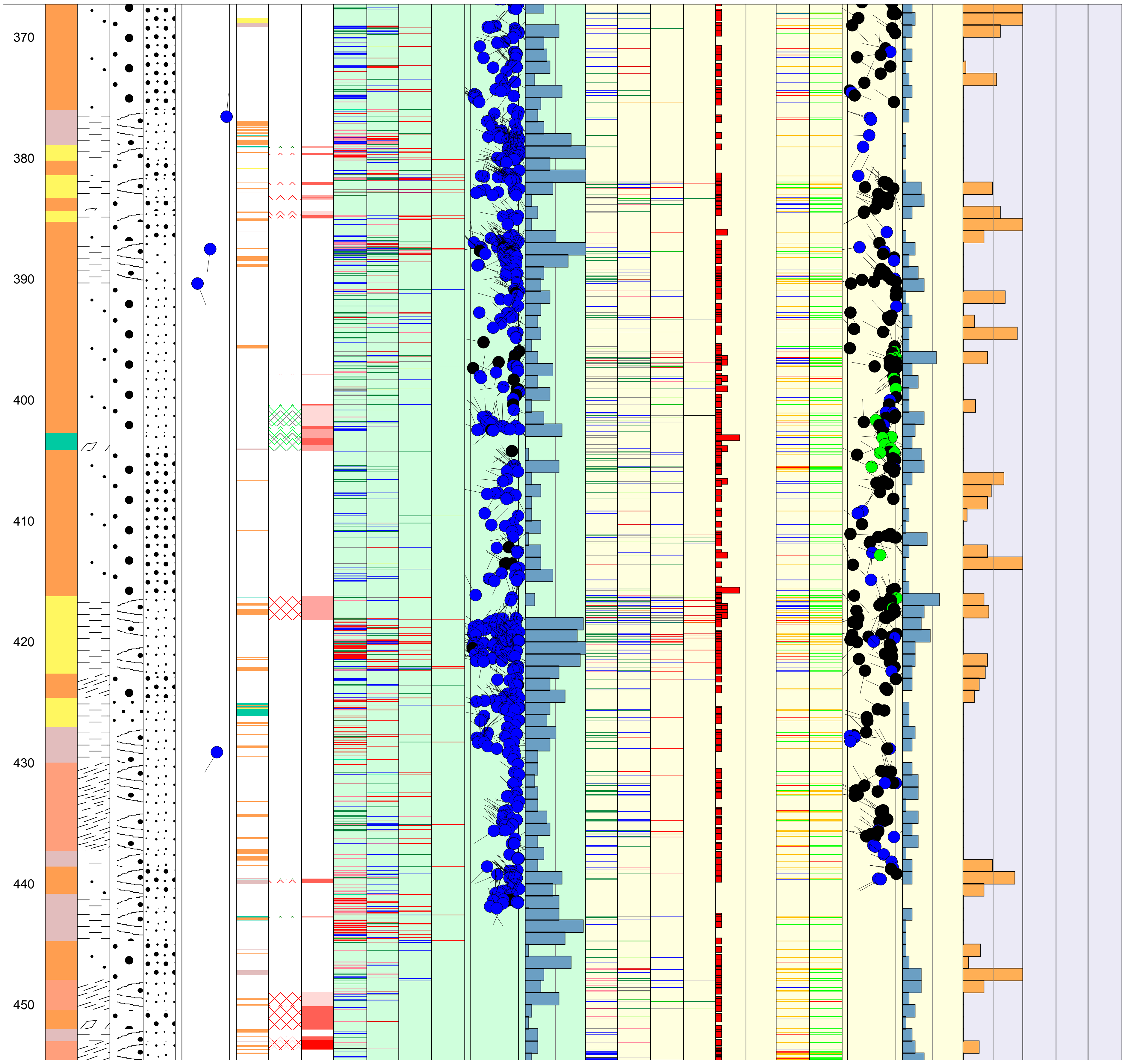
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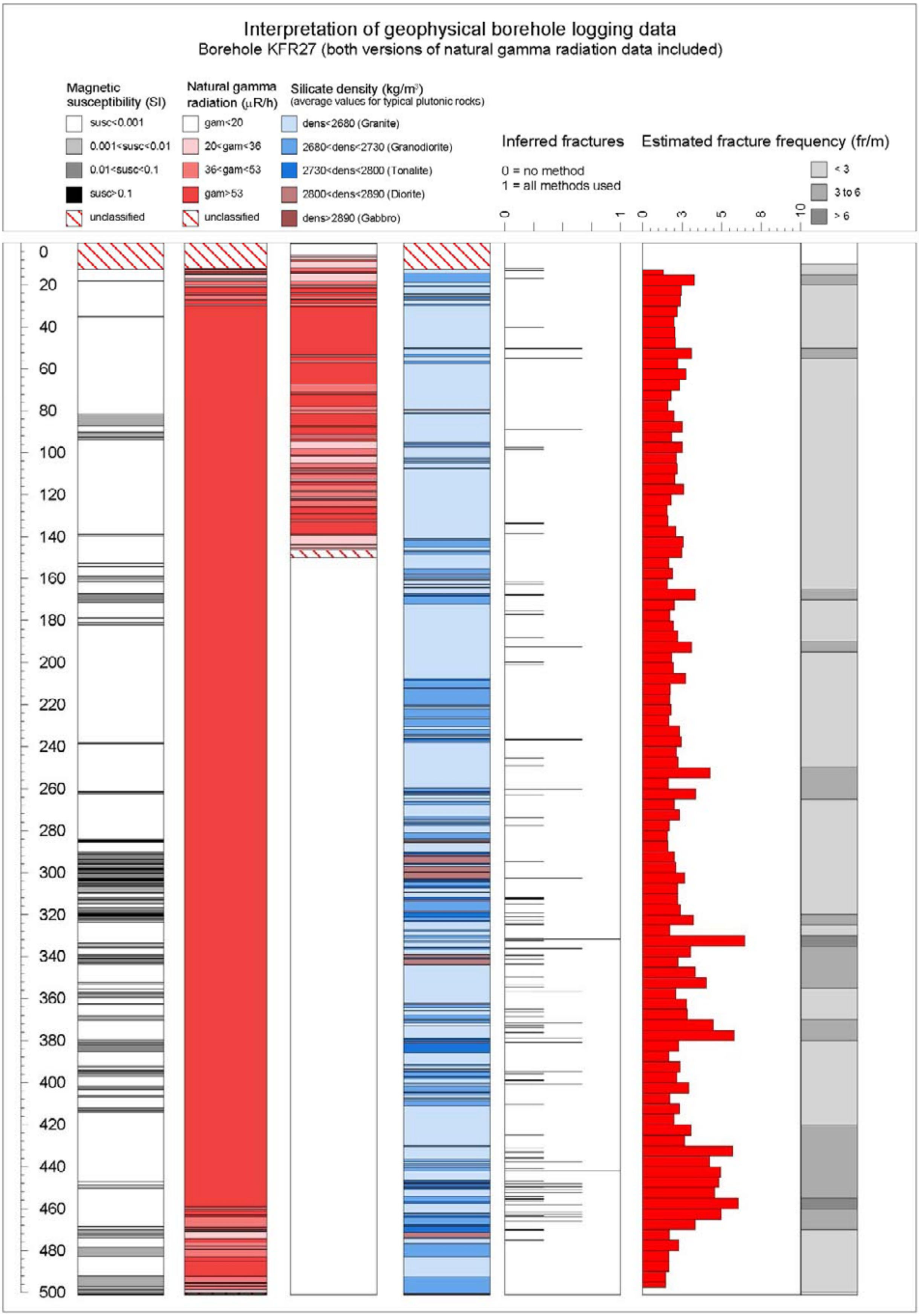
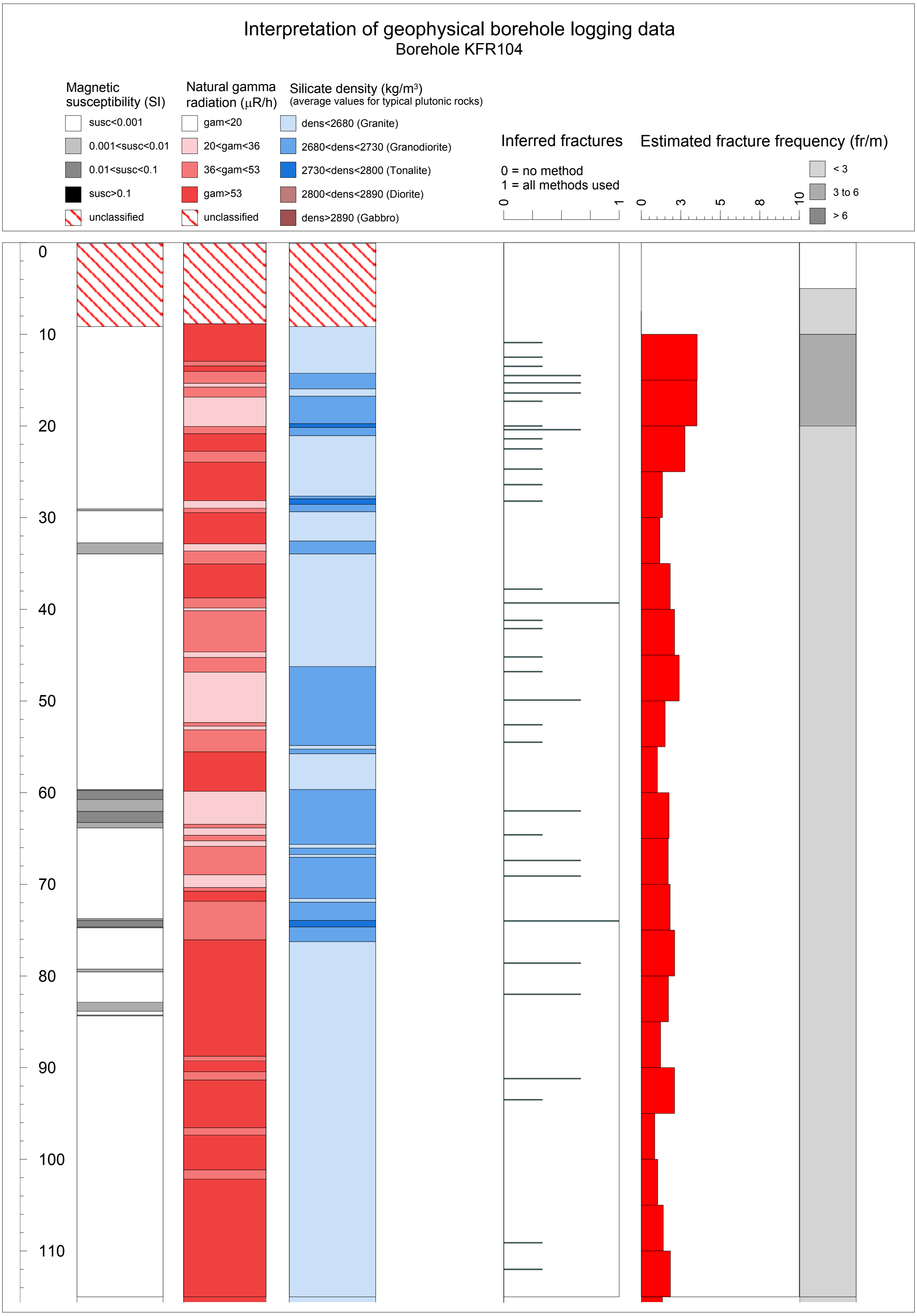
Generalized geophysical logs and plots of resampled and calibrated geophysical data from KFR27 (from 147.5 m) and KFR104




Interpretation of geophysical borehole logging data
Borehole KFR104
Magnetic susceptibility (SI)
susc<0.001
0.001<susc<0.01
0.01<susc<0.1
susc>0.1
unclassified
Natural gamma radiation (μR/h)
gam<20
20<gam<36
36<gam<53
gam>53
unclassified
Silicate density (kg/m³)
(average values for typical plutonic rocks)
dens<2680 (Granite)
2680<dens<2730 (Granodiorite)
2730<dens<2800 (Tonalite)
2800<dens<2890 (Diorite)
dens>2890 (Gabbro)
Inferred fractures
0 = no method
1 = all methods used
Estimated fracture frequency (fr/m)
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3 to 6
> 6
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80
90
100
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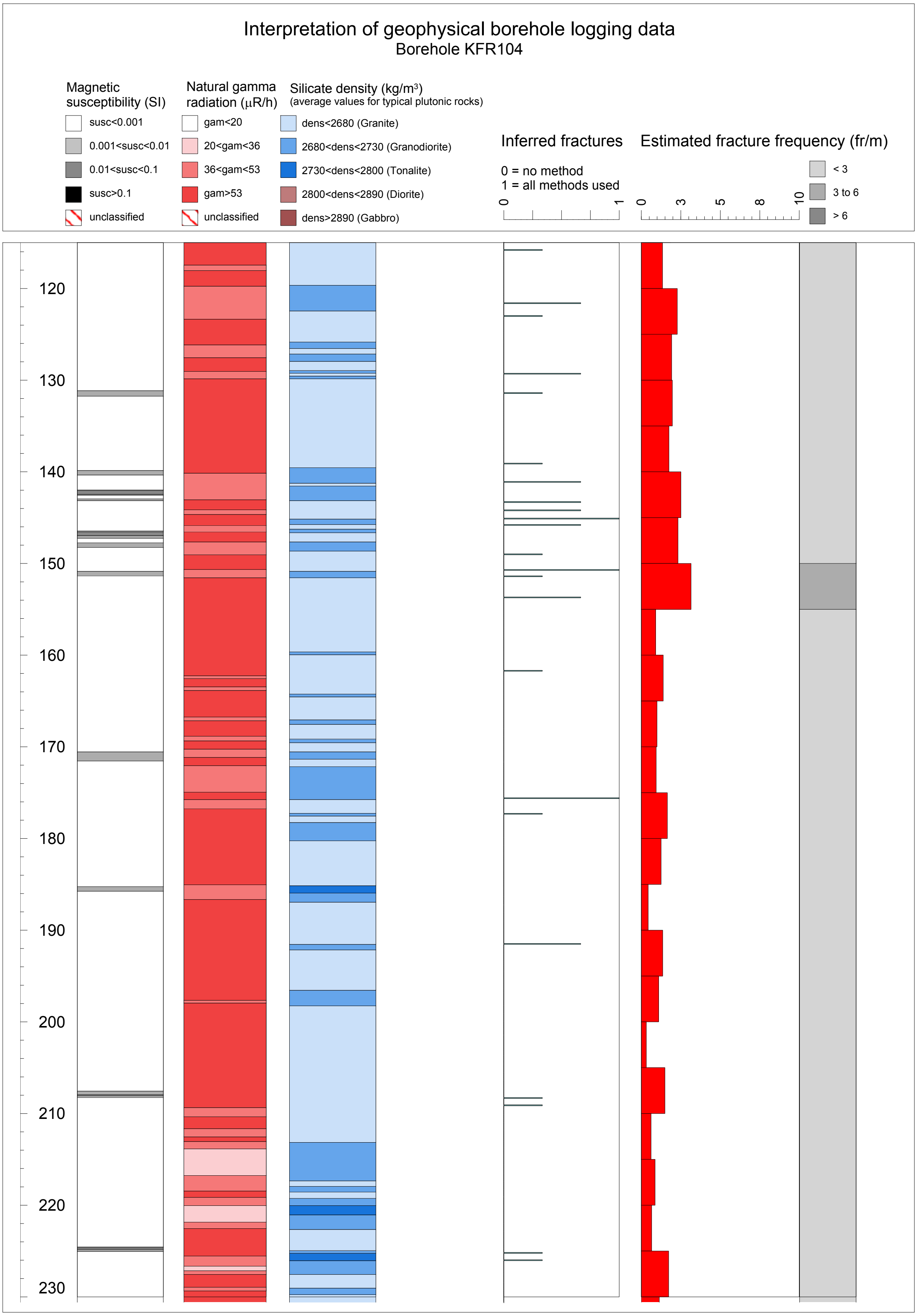
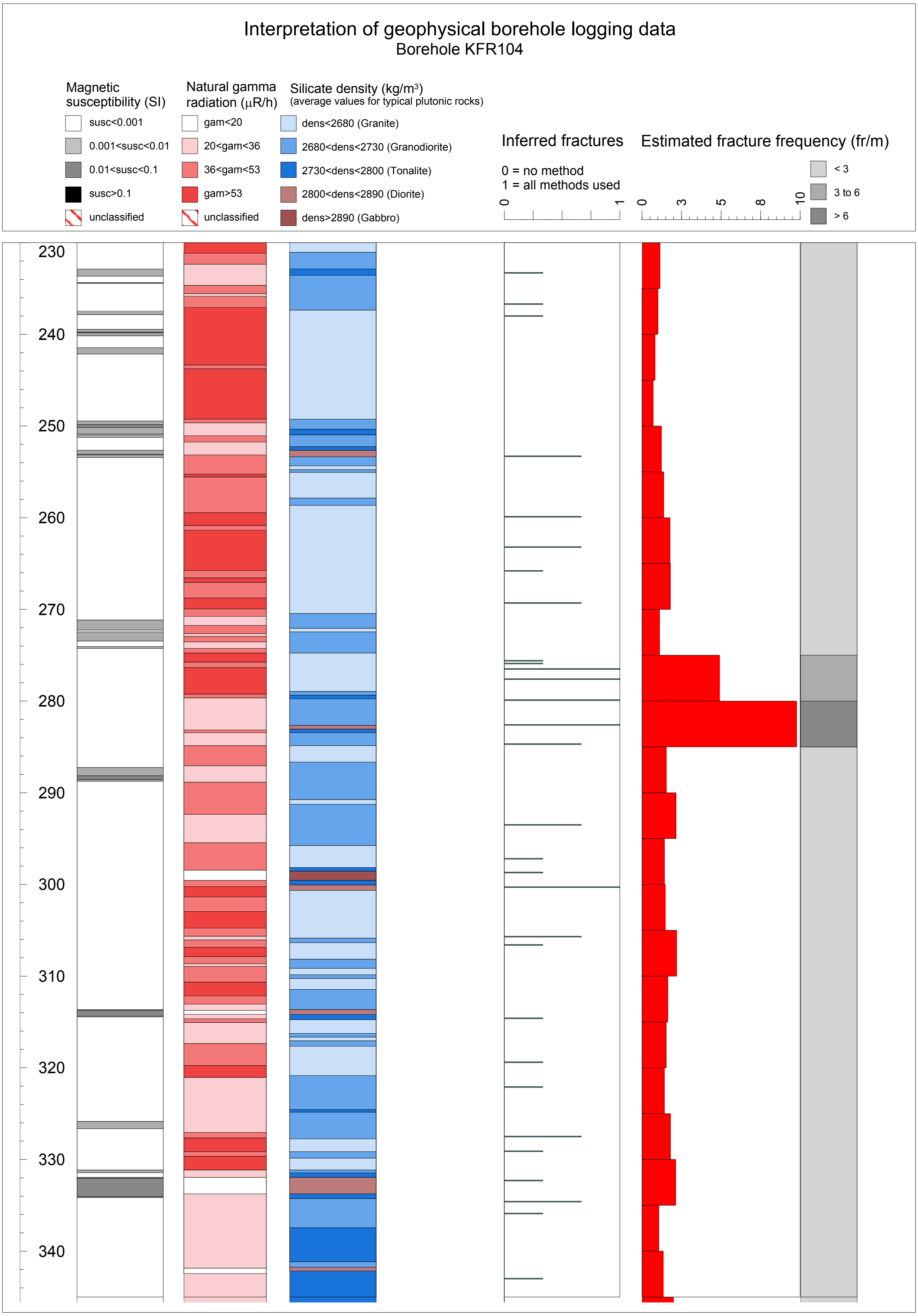
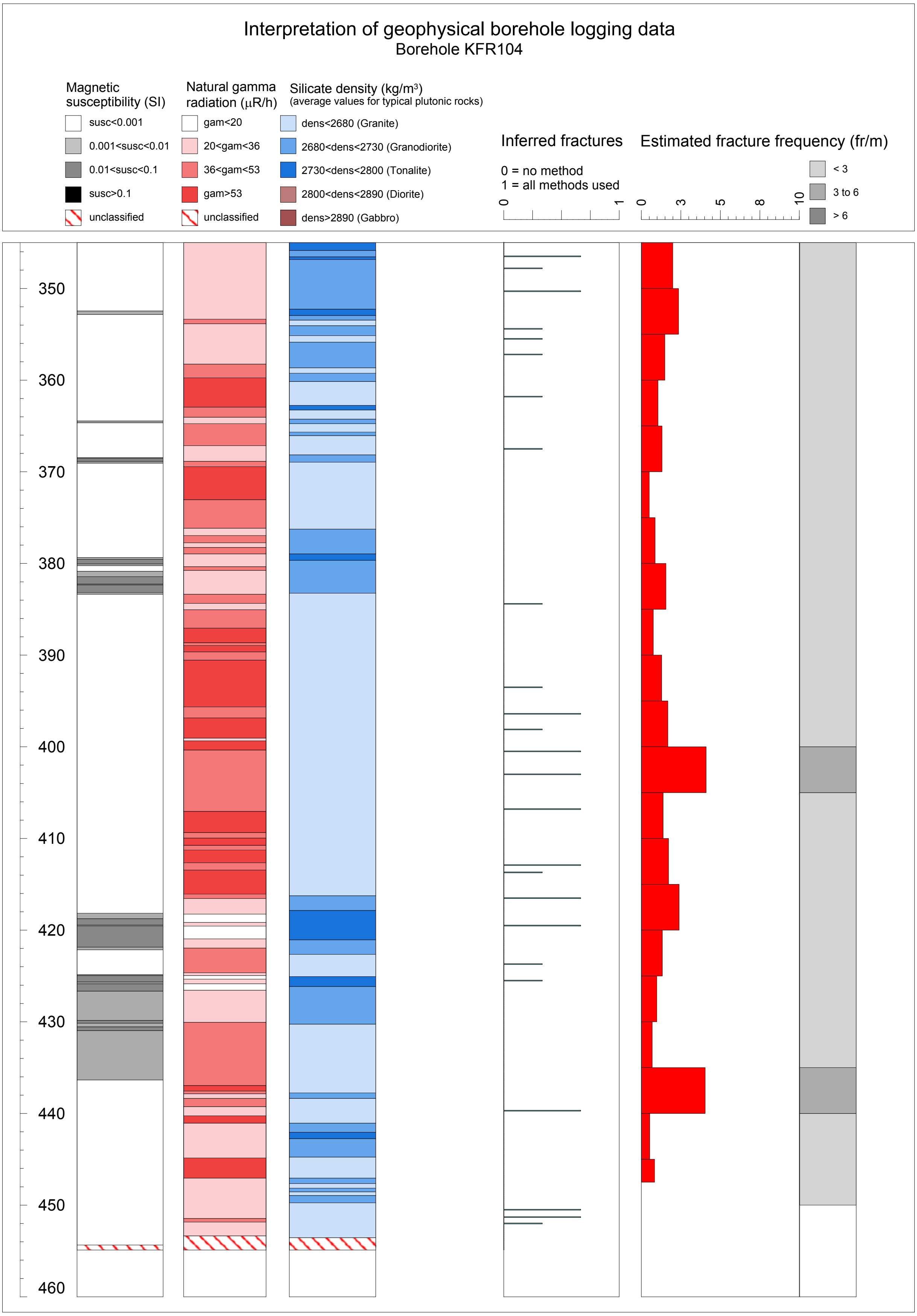


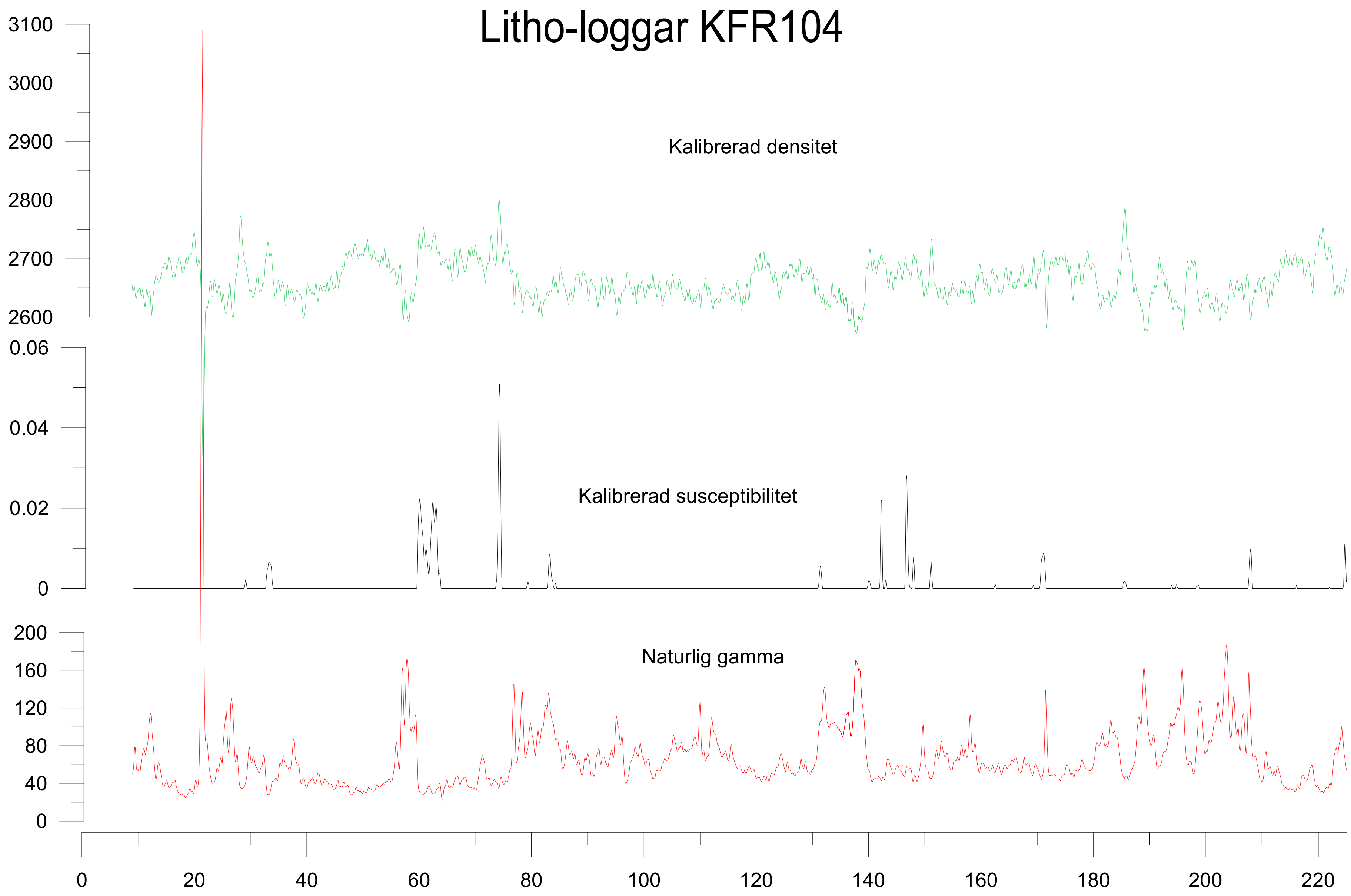
Interpretation of geophysical borehole logging data
Borehole KFR104
Magnetic susceptibility (SI)
susc<0.001
0.001<susc<0.01
0.01<susc<0.1
susc>0.1
unclassified
Natural gamma radiation (μR/h)
gam<20
20<gam<36
36<gam<53
gam>53
unclassified
Silicate density (kg/m³)
(average values for typical plutonic rocks)
dens<2680 (Granite)
2680<dens<2730 (Granodiorite)
2730<dens<2800 (Tonalite)
2800<dens<2890 (Diorite)
dens>2890 (Gabbro)
Inferred fractures
0 = no method
1 = all methods used
0
1
Estimated fracture frequency (fr/m)
0
3
5
8
10
< 3
3 to 6
> 6
120
130
140
150
160
170
180
190
200
210
220
230



Interpretation of geophysical borehole logging data
Borehole KFR104
Magnetic susceptibility (SI)
susc<0.001
0.001<susc<0.01
0.01<susc<0.1
susc>0.1
unclassified
Natural gamma radiation (μR/h)
gam<20
20<gam<36
36<gam<53
gam>53
unclassified
Silicate density (kg/m³)
(average values for typical plutonic rocks)
dens<2680 (Granite)
2680<dens<2730 (Granodiorite)
2730<dens<2800 (Tonalite)
2800<dens<2890 (Diorite)
dens>2890 (Gabbro)
Inferred fractures
0 = no method
1 = all methods used
Estimated fracture frequency (fr/m)
< 3
3 to 6
> 6
0 1
0 3 5 8 10
230
240
250
260
270
280
290
300
310
320
330
340



Interpretation of geophysical borehole logging data
Borehole KFR104
Magnetic susceptibility (SI)
susc<0.001
0.001<susc<0.01
0.01<susc<0.1
susc>0.1
unclassified
Natural gamma radiation (μR/h)
gam<20
20<gam<36
36<gam<53
gam>53
unclassified
Silicate density (kg/m³)
(average values for typical plutonic rocks)
dens<2680 (Granite)
2680<dens<2730 (Granodiorite)
2730<dens<2800 (Tonalite)
2800<dens<2890 (Diorite)
dens>2890 (Gabbro)
Inferred fractures
0 = no method
1 = all methods used
Estimated fracture frequency (fr/m)
< 3
3 to 6
> 6
350
360
370
380
390
400
410
420
430
440
450
460

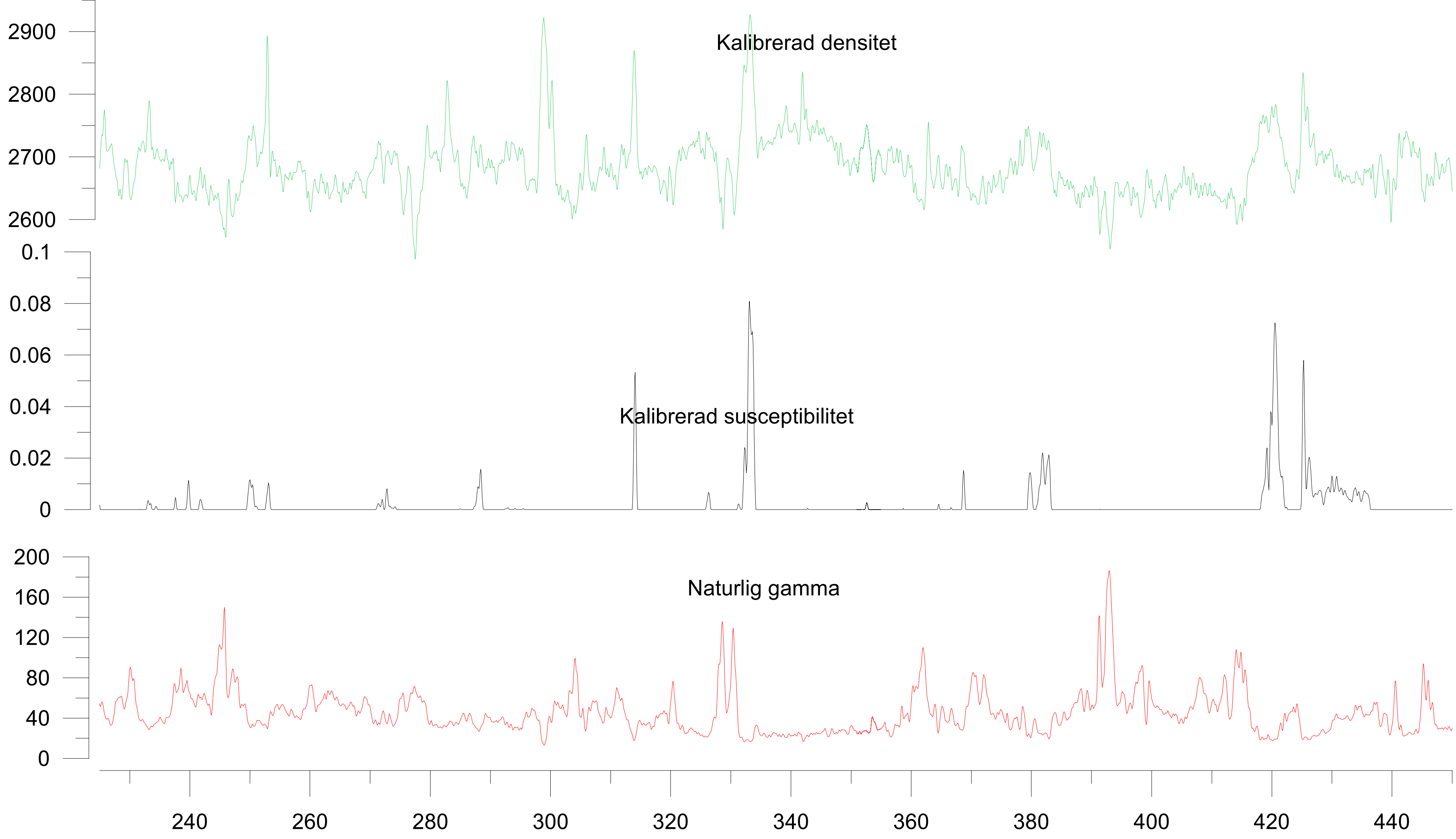


Litho-loggar KFR104
Kalibrerad densitet
Kalibrerad susceptibilitet
Naturlig gamma
3100
3000
2900
2800
2700
2600
0.06
0.04
0.02
0
200
160
120
80
40
0
0
20
40
60
80
100
120
140
160
180
200
220

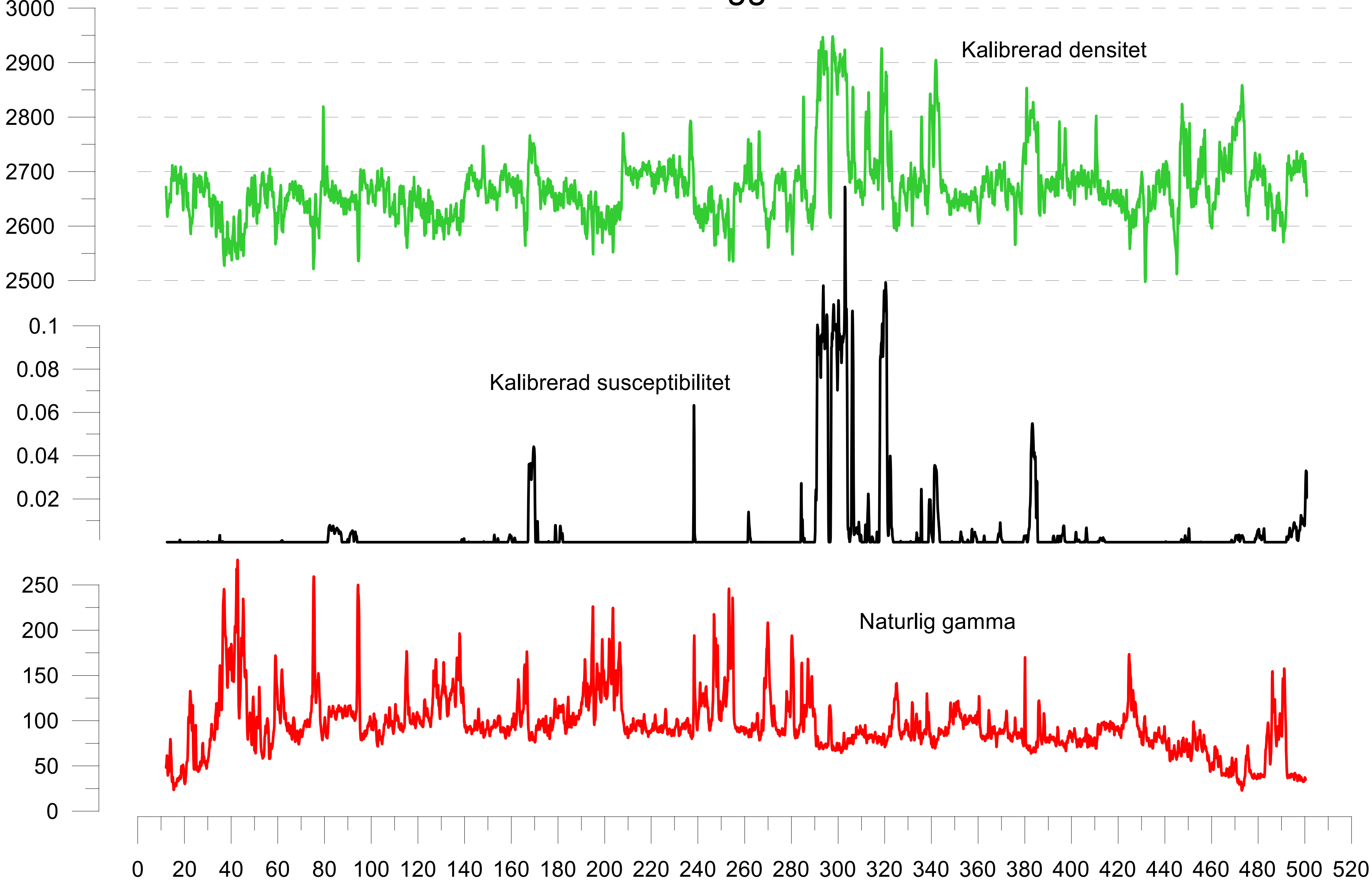
50

P-09-39

Litho-loggar KFR104 del2



Litho-loggar KFR27



Appendix 3

In-data

Hole Diam T – Drilling: Borehole diameter

KFR27, 2008-10-02 14:23:00 – 2008-10-21 16:51:00 (148.510–501.640 m)

Sub Secup (m)	Sub Seclow (m)	Hole Diam (m)	Comment	QC
148.510	501.640	0.0758	Corac dimensionen borrad från 146.92 m	*
430.800	433.000	0.0840	PLEX, reamed section	*

Printout from SICADA 2009-01-22 08:01:13.

Borehole Direction T – Surveying: Borehole direction

KFR27, 2008-05-06 16:00:00

Length (m)	Bearing (degrees)	Inclination (degrees)	Bearing Err (degrees)	Inclination Err (degrees)	Magnetic Bearing (degrees)	In Use Flag	Coord System	QC
0.00	248.1986	–87.4225	0.2000	0.2000		*	RT90-RHB70	*

Printout from SICADA 2009-01-22 08:03:11.

Borehole Surveying T – Surveying: Borehole coordinates

KFR27, 2008-05-06 16:00:00 – 2008-05-07 16:00:00

Length (m)	Northing (m)	Easting (m)	Elevation (m.a.s.l.)	Northing Err (m)	Easting Err (m)	Elevation Err (m)	Coord System	Is End-point	Comment	QC
0.00	6701714.424	1633175.516	2.871	0.010	0.010	0.010	RT90-RHB70	N	Casing	*
3.00	6701714.374	1633175.390	–0.126	0.010	0.010	0.010	RT90-RHB70	N		*

Printout from SICADA 2009-01-22 08:04:08.

Reference Mark T – Reference mark in drillhole

KFR27, 2008-08-16 13:00:00 – 2008-09-29 20:30:00 (48.000–484.000 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
48.00	400.00	200.000	380.000	35.0	35.00	JA		Klar signal OK	*
102.00	400.00	200.000	380.000	35.0	40.00	JA		Klar signal OK	*
150.00	400.00	200.000	380.000	35.0	35.00	JA		Klar signal OK	*
201.00	400.00	200.000	400.000	37.0	45.00	JA		Klar signal OK	*
249.00	400.00	200.000	400.000	38.0	40.00	JA		Klar signal OK	*
300.00	400.00	200.000	380.000	35.0	40.00	JA		Klar signal OK	*
358.00	400.00	200.000	400.000	40.0	45.00	JA		Klar signal OK	*
399.00	400.00	200.000	380.000	36.0	40.00	JA		Klar signal OK	*
450.00	400.00	200.000	380.000	40.0	45.00	JA		Klar signal OK	*
484.00	400.00	200.000	400.000	40.0	45.00	JA		Klar signal OK	*

Printout from SICADA 2009-03-20 10:32:23.

Hole Diam T – Drilling: Borehole diameter

KFR104, 2008-09-02 11:50:00 – 2008-09-29 18:15:00 (8.730–454.570 m)

Sub Secup (m)	Sub Seclow (m)	Hole Diam (m)	Comment	QC
8.730	454.570	0.0758	Corac N3/50	*

Printout from SICADA 2008-11-10 14:27:04.

Borehole Direction T – Surveying: Borehole direction

KFR104, 2008-06-10 13:50:00

Length (m)	Bearing (degrees)	Inclination (degrees)	Bearing Err (degrees)	Inclination Err (degrees)	Magnetic Bearing (degrees)	In Use Flag	Coord System	QC
0.00	133.7844	–53.8138	0.2000	0.2000		*	RT90-RHB70	*

Printout from SICADA 2008-11-10 14:33:34.

Reference Mark T – Reference mark in drillhole

KFR104, 2008-09-29 06:00:00 – 2008-09-29 12:00:00 (49.000–435.000 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
49.00	400.00	200.000	400.000	35.0	35.00	JA		Klar signal OK	*
100.00	400.00	200.000	400.000	35.0	40.00	JA		Klar signal OK	*
149.00	400.00	200.000	400.000	35.0	40.00	JA		Klar signal OK	*
200.00	400.00	200.000	400.000	35.0	40.00	JA		Klar signal OK	*
250.00	400.00	200.000	400.000	37.0	30.00	JA		Klar signal OK	*
300.00	400.00	200.000	400.000	37.0	40.00	JA		Klar signal OK	*
353.00	400.00	200.000	400.000	37.0	40.00	JA		Klar signal OK	*
400.00	400.00	200.000	400.000	37.0	40.00	JA		Klar signal OK	*
435.00	400.00	200.000	400.000	37.0	40.00	JA		Klar signal OK	*

Printout from SICADA 2008-11-10 14:29:09.