P-10-10

Site investigation SFR

Boremap mapping of percussion drilled borehole HFR106

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June 2010

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Abstract

This report presents the result from the Boremap mapping of the percussion drilled borehole HFR106, which is drilled from an islet located ca 220 m southeast of the pier above SFR. The purpose of the location and orientation of the borehole is to investigate the possible occurrence of gently dipping, water-bearing structures in the area. HFR106 has a length of 190.4 m and oriented 269.4°/–60.9°.

The mapping is based on the borehole image (BIPS), investigation of drill cuttings and generalized, as well as more detailed geophysical logs.

The dominating rock type, which occupies 68% of HFR106, is fine- to medium-grained, pinkish grey metagranite-granodiorite (rock code 101057) mapped as foliated with a medium to strong intensity. Pegmatite to pegmatitic granite (rock code 101061) occupies 29% of the borehole. Subordinate rock types are felsic to intermediate metavolcanic rock (rock code 103076) and fine- to medium-grained granite (rock code 111058).

Rock occurrences (rock types < 1 m in length) occupy about 16% of the mapped interval, of which half is veins, dykes and unspecified occurrences of pegmatite and pegmatitic granite.

Only 5.5% of HFR106 is inferred to be altered, mainly oxidation in two intervals with an increased fracture frequency.

A total number of 845 fractures are registered in HFR106. Of these are 64 interpreted as open with a certain aperture, 230 open with a possible aperture, and 551 sealed. This result in the following fracture frequencies: 1.6 open fractures/m and 3.0 sealed fractures/m. Three fracture sets of open and sealed fractures with the orientations 290°/70°, 150°/85° and 200°/85° can be distinguished in HFR106.

The fracture frequency is generally higher in the second half of the borehole, and particularly in the interval 176–187.4 m.

Sammanfattning

Denna rapport presenterar resultatet från Boremapkarteringen av hammarborrhålet HFR106, som är borrat från en kobbe ca 220 m sydost om piren över SFR. Syftet med läget och orienteringen av borrhålet är att karaktärisera berget på djupet under en kommande utbyggnad av SFR och utreda den eventuella förekomsten av flackt stupande, vattenförande strukturer i området. HFR106 har en längd på 190,4 m och orienteringen 269,4°/–60,9°.

Karteringen är baserad på borrhålsbilden (BIPS), undersökning av borrkax och generaliserade och detaljerade geofysiska loggar.

Den dominerande bergarten, som utgör 68 % av HFR106, är fin- till medelkornig metagranit-granodiorit (bergartskod 101057), karterad som folierad med medelstark till stark intensitet. Pegmatit till pegmatitisk granit (bergartskod 101061) upptar 29 % av borrhålet. Underordnade bergarter är felsisk till intermediär metavulkanit (bergartskod 103076) och fin- till medelkornig granit (bergartskod 111058).

Bergartsförekomster, < 1 m i längd, upptar ca 16 % av det karterade intervallet, av vilket hälften är ådror, gångar and ospecificerade förekomster av pegmatit and pegmatitisk granit.

Endast 5,5 % av HFR106 bedöms vara omvandlad, huvudsakligen oxiderad i samband med en ökad sprick frekvens.

Ett totalt antal på 845 sprickor är registrerade i HFR106. Av dessa är 64 tolkade som öppna med säker apertur, 230 öppna med en möjlig apertur och 551 läkta. Den resulterande sprickfrekvensen är 1,6 öppna/m och 3,0 läkta/m. Tre sprickgrupper kan urskiljas med orienteringen 290°/70°, 150°/85° och 200°/85°.

Sprickfrekvensen är generellt högre i andra hälften av borrhålet, och i synnerhet i intervallet 176–187,4 m.

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1 Introduction

To be able to host the waste that will arise from closure of the nuclear power plants in the future, SKB intends to extend the existing repository for low- and intermediate-level radioactive waste in Forsmark (SFR). The existing repository, the first of its kind in the world, was ready for operation in 1988. The extension is estimated to be completed in 2020.

A lot of information about the bedrock and groundwater has been gathered during the building of SFR, but some complementary studies are necessary. This document reports the data gained by the Boremap mapping of the percussion drilled borehole HFR106, which is one of the activities performed within the site investigation at SFR. The borehole HFR106 is drilled from an islet located ca 220 m southeast of the pier above SFR (Figure 1-1), and has a length of 190.4 m, a bearing of 269.4° and an inclination of –60.9°.

The work was carried out in accordance with activity plan AP SFR-09-027. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

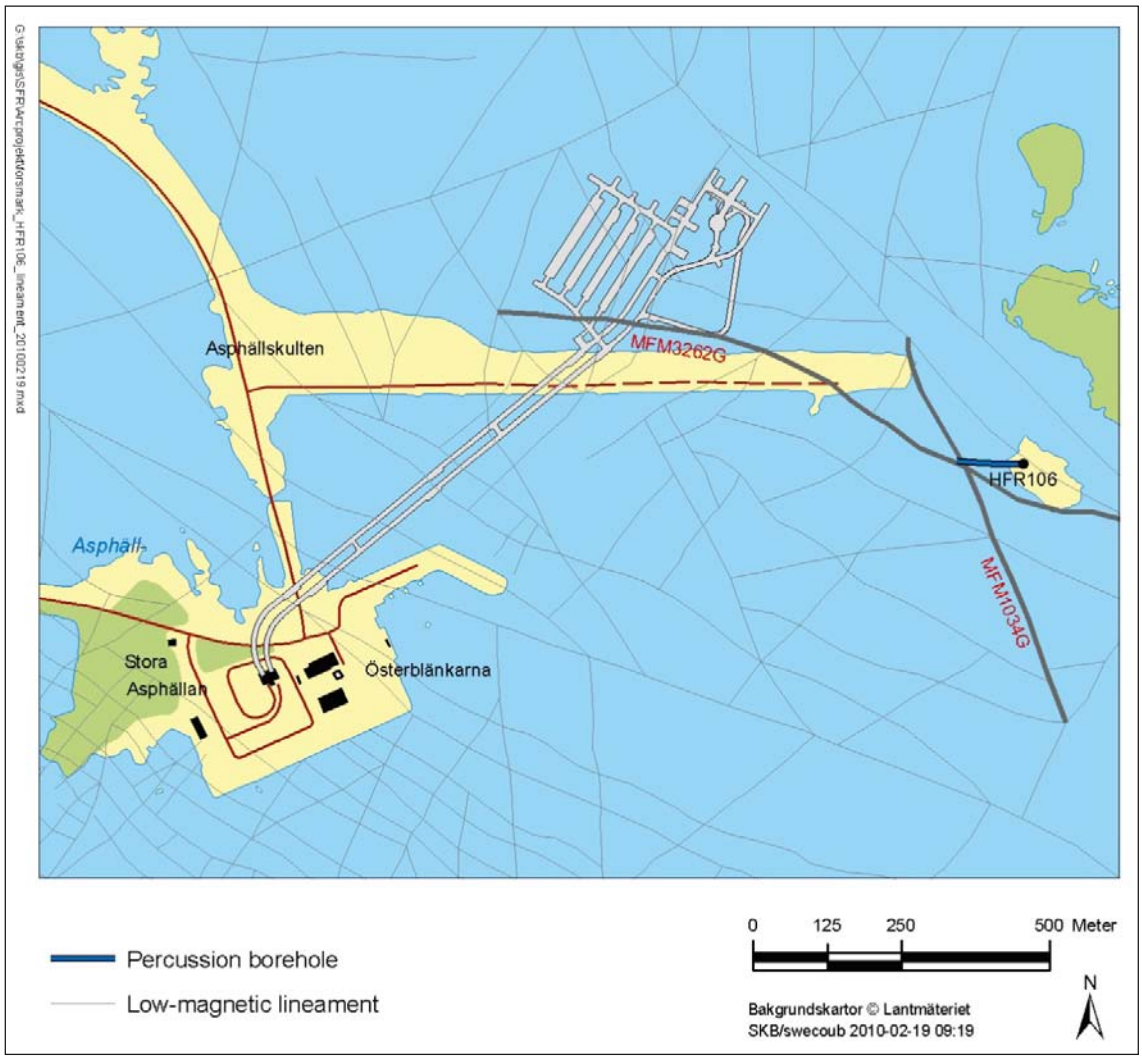

Figure 1-1. *Location of the percussion drilled borehole HFR106 in relation to SFR. Two lineaments that might be intersected by the borehole, are highlighted.*

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

Activity plan	Number	Version
Boremapkartering av hammarborrhål HFR106 och kärnborrhål KFR106	AP SFR-09-027	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

After drilling in June-July 2009 the borehole was 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 (Borehole Image Processing System).

The borehole was mapped in November and December 2009. Mapping of percussion borehole according to the Boremap method is based on the use of BIPS-images of the borehole wall supported by study of drill cuttings, and geophysical logs.

The BIPS-image enables the study of fractures and their characteristics along the borehole. Strike and dip of planar structures such as fractures, foliations and rock contacts are calculated and documented with the Boremap method. Schematic presentation of the borehole is presented in a WellCAD-diagram (Appendix 1).

2 Objective and scope

The borehole HFR106 was drilled with the aim to investigate the possible occurrence of gently dipping, hydraulically active structures in the rock volume southeast of SFR. The location of the borehole makes it also possible to gather valuable hydrological and hydrochemical information about the bedrock, and to verify the geohydrological model. Lithologies, alterations, ductile structures and the occurrence of fractures in the bedrock penetrated by HFR106 were documented. Other data, such as 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. The Boremap software is loaded with the rock types and mineral standards used for surface mapping at the Forsmark site investigation, in order to enable correlation with the surface geology. Inclination, bearing and diameter of the borehole are used as in-data for the calculations.

When investigating the drill cuttings, tap water, an ordinary kitchen strainer, a hand lens and 10% hydrochloric acid was used.

3.1.1 Used BIPS-files and image quality

Information about the BIPS-image is listed in Table 3-1.

The BIPS-image quality of the borehole is very good. The result from the BIPS-logging is presented in /1/.

Table 3-1. Used BIPS-files.

Borehole	BIPS-file	Logging date	Logging time	From recorded length (m)	To recorded length (m)
HFR106	HFR106.BIP	2009-09-23	11:45:00	9.000	189.136

4 Execution

4.1 General

Boremap mapping of the percussion drilled borehole HFR106 was performed and documented according to activity plan AP SFR 09-027 (SKB, internal document). Geophysical logs (Appendix 2) /2/, drill cuttings and the result from the adjacent cored borehole KFR106 /3/, were helpful in the mapping. The mapping was performed in accordance with the current SKB method descriptions (Table 1-1) and /4/. Information from earlier performed investigations in the area were also helpful in the interpretations /5, 6, 7, 8, 9/.

4.2 Preparations

The applied length adjustment is based on the known length of the borehole and mapping and the fact that the last ~25 cm of the borehole cannot be logged with BIPS due to equipment below the camera lens. However, there is no knowledge about the amount of drill cuttings in the bottom of the borehole, which additionally increase the unlogged interval.

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

- Borehole diameter
- Borehole direction

General information about the borehole is listed in Table 4-1.

4.3 Execution of measurements

Since no drill core is available for percussion drilled boreholes, the degree of uncertainty of the mapped features is higher compared to core drilled boreholes. Assumptions and causes of misjudgements are described below.

4.3.1 Fractures

As fractures are studied only in the BIPS-image, roughness, surface, alteration and joint alteration number of the fractures are not reported. Mineralogy is, with some exceptions, also left out. Following assumptions concerning the fractures were made during the mapping:

- Widths of thin fractures are impossible to measure accurately in the BIPS-image, and are therefore set to 0.5 mm.
- Fractures with a shadow in the central part are mapped as open with a possible aperture of 0.5 mm.
- Fractures with reddish rims were mapped as having “oxidized walls”.

Table 4-1. Borehole data for HFR106

ID-code	Bearing (degrees)	Inclination (degrees)	Diameter 9.03–114.2 m (mm)	Diameter 114.2–190.40 m (mm)	Borehole length (m)	Mapping interval (m)
HFR106	269.4	–60.9	140.3	138.8	190.4	9.03–189.042

4.3.2 Rock colour and alteration

The colour of the rocks in the BIPS-image has often a bleached appearance compared to the actual rock. Some colour appraisals are probably therefore slightly inaccurate.

Varying exposure of the BIPS-image complicates the interpretation of oxidized sections. Higher exposure gives a less reddish appearance compared to sections with lower exposure.

Albitization adjacent to amphibolitic rock is often easy to recognize, but is otherwise hard to discern.

Other rock alterations have not been distinguishable in the BIPS image.

4.3.3 Lithologies

The classification of lithology is complicated by similar appearance in the BIPS-image of different rock types. Small occurrences of dark fine-grained rock types, as felsic to intermediate metavolcanic rock and amphibolite, are especially difficult to separate due to mixing with the adjacent rock types in the drill cuttings. The mapping is facilitated by generalized geophysical logs and more detailed litho-logs (Appendix 2). Drill cuttings are examined when necessary.

4.3.4 Grain-size

Due to the limited resolution of the BIPS-image, the estimation of grain-size, especially for finer grained rock occurrences is difficult.

Rocks composed of minerals with similar colours, run the risk of getting an overestimated grain-size.

4.3.5 Foliation and lineation

The metagranite-granodiorite, which occupies most of the area in Forsmark are usually L-S tectonites, where lineation dominates over foliation /5/. However, in the SFR-area foliation is usually dominating in the metagranite-granodiorite, and hence mapped to a greater extent. Minor folds in the SFR-area deform the planar fabrics with the result of varying intensity of the foliation and lineation and an estimated average of the intensity is mapped for the rock types.

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

Foliation and lineation are difficult to separate in the BIPS-image, unless the structure is clearly developed and intersected at a right angle.

4.4 Data handling/post processing

The Boremap mapping of HFR106 was performed on Geosigma’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 Sicada, 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 Drill penetration rate

Drill penetration rate has not been used in the interpretation of the mapping.

5 Result

The data from Boremap mapping of HFR106 is stored in Sicada, and it is only these data that shall be used for further interpretation and modelling. The user of these 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, which occupies 68% of HFR106, is fine- to medium-grained, pinkish grey metagranite-granodiorite (rock code 101057). The metagranite-granodiorite is mapped as foliated with a medium to strong intensity, even though the foliation locally is invisible in the BIPS-image. The foliation is clearly developed in the interval ~110–118 m, but since it is parallel with the borehole and difficult to map accurately, no structural feature for the foliation is registered in this interval. Figure 5-1 shows the stereographic projections of the poles to foliation planes in HFR106.

Longer intervals of pegmatite to pegmatitic granite (rock code 101061) occur throughout the borehole and occupy 29% of the mapped interval. Pegmatitic granite is also frequent as smaller rock occurrences less than one meter in borehole length.

Subordinate rock types are felsic to intermediate metavolcanic rock (rock code 103076) and fine- to medium-grained granite (rock code 111058).

It is difficult to distinguish between smaller occurrences of felsic to intermediate metavolcanic rock and amphibolite (rock code 102017) solely from the BIPS-image. Felsic to intermediate metavolcanic rock is mapped to a greater extent in accordance with a lower density for this rock type (Appendix 2), and its predominance in the adjacent cored borehole KFR106. Only rock occurrences where the albitization of the adjacent rock is visible in the BIPS-image are for certain mapped as amphibolite.

Two intervals of felsic to intermediate metavolcanic rock at 61.39–63.92 and 147.07–148.43 m exceeds one meter in length.

The rock type distribution in HFR106 is presented in Table 5-1.

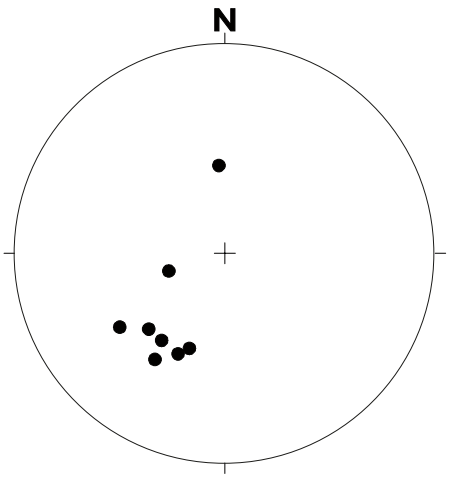

Figure 5-1. *Orientation of poles to foliation planes (n=8) in HFR106, plotted on the lower hemisphere of a Schmidt equal area stereographic projection.*

Table 5-1. Percentage distribution of rock types in HFR106 (rock occurrences excluded).

Borehole	101057	101061	103076	111058
HFR106	67.6	29.4	2.1	0.8

Rock occurrences (rock types < 1 m in length) occupy about 16% of the mapped interval, of which half is veins, dykes and unspecified occurrences of pegmatite and pegmatitic granite, and one fourth felsic to intermediate metavolcanic rock. Other rock types are except for the rock types in Table 5-1, amphibolite and quartz dominated veins (rock code 8021).

5.1.1 Alteration

5.5% of HFR106 are mapped as altered.

Four intervals of oxidation are registered at 95.13–95.42, 98.75–99.02, 151.15–154.91 and 177.95–183.68 m, of which the two longer sections are associated with more intensely fractured intervals.

Albitization is mapped in three very short intervals adjacent to amphibolitic rock at 35.76–35.77, 36.04–36.05 and 86.07–85.09 m.

5.1.2 Fractures

A total number of 845 fractures are registered in HFR106. Of these are 64 interpreted as open with a certain aperture, 230 open with a possible aperture, and 551 sealed. This results in the following fracture frequencies: 1.6 open fractures/m and 3.0 sealed fractures/m, sealed fractures included in the sealed fracture network excluded (Table 5-2). This division of fractures into open and sealed is highly uncertain, and all fractures are therefore displayed in the same plot (Figure 5-2).

Three sets of fractures, oriented 290°/70°, 150°/85° and 200°/85°, can be distinguished. Many sealed fractures coincide with the foliation, and are probably to some extent just foliation planes misinterpreted as fractures.

Table 5-2. Fracture frequencies in HFR106 (sealed fracture network excluded) expressed as fractures/m.

Borehole	Open fractures	Sealed fractures
HFR106	1.6	3.0

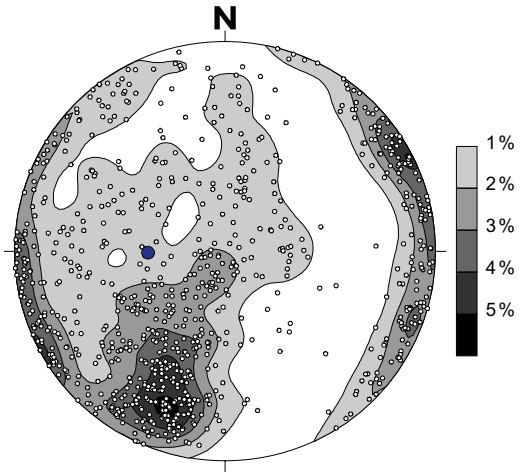

Figure 5-2. *Orientation of poles to open and sealed fracture planes (n=845) in HFR106, plotted on the lower hemisphere of a Schmidt equal area stereographic projection. Blue dot is borehole projection at start.*

The fracture frequency is generally higher in the second half of the borehole (Figure 5-3), and in the interval 176–187.4 m in particular. This interval is characterised by an increased frequency of fractures, a few with widths up to 25 mm. In addition an interpreted brittle-ductile shear zone is registered at 178.05–178.27 m, a brecciated interval at 178.39–178.74 m and an open fracture with a certain aperture of 8 mm at 178.749 m. All three with the approximate orientation 330°/85°.

The interval at 179.26–181.64 m is mapped as a sealed network, and the interval 177.95–183.68 m is considered oxidized. The rock type is mainly metagranite-granodiorite with dykes of pegmatitic granite and one occurrence of felsic to intermediate metavolcanic rock.

Fracture mineralogy has only been registered when it is determined with certainty. Totally 45 fractures have been mapped with calcite and 2 with laumontite. Oxidized walls have been registered for 40% of the fractures.

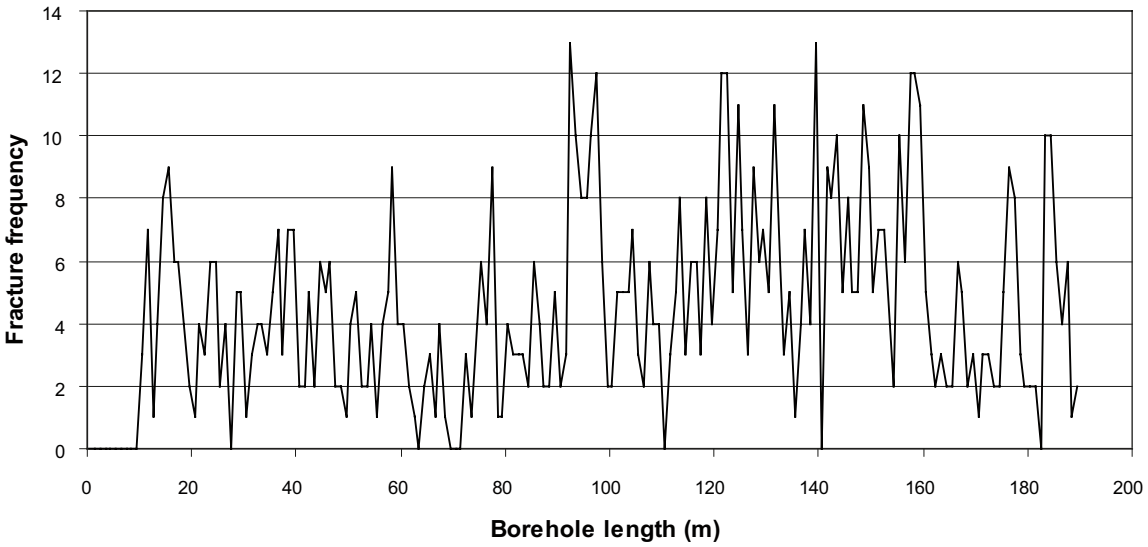

Figure 5-3. *Frequency of open and sealed fractures (excluding sealed networks) in HFR106.*

References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.se/publications.

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Title SIMPLIFIED GEOLOGY HFR106

Appendix 1

Site	FORSMARK - SFR	**Coordinate System**	RT90-RHB70
Borehole	HFR106	**Northing [m]**	6701574.11
Diameter [mm]	139	**Easting [m]**	1633579.85
Length [m]	190.400	**Elevation [m.a.s.l.]**	1.27
Bearing [°]	269.39	**Drilling Start Date**	2009-06-24 07:45:00
Inclination [°]	-60.87	**Drilling Stop Date**	2009-07-02 10:00:00
Date of mapping	2009-11-11 14:24:00	**Plot Date**	2010-06-16 23:01:27
		Signed data	

ROCKTYPE FORSMARK - SFR
- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphi
- Felsic to intermediate volcanic rock

ROCK STRUCTURE
- Massive
- Foliated
- Lineated

ROCK ALTERATION
- Oxidized
- Albitization

INTENSITY
- Weak
- Medium

FRACTURE ALTERATION

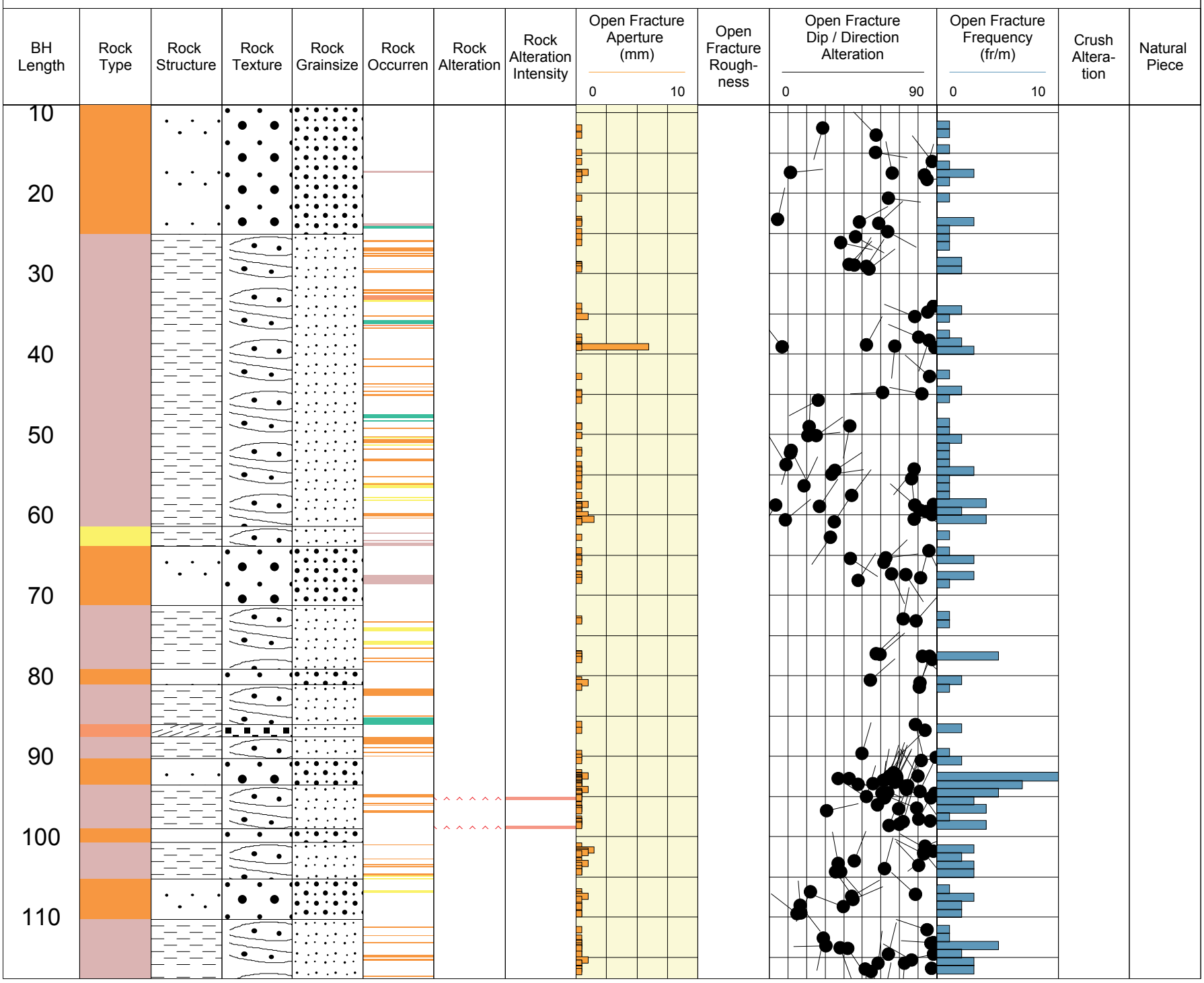
ROCK TEXTURE
- Equigranular
- Unequigranular
- Metamorphic

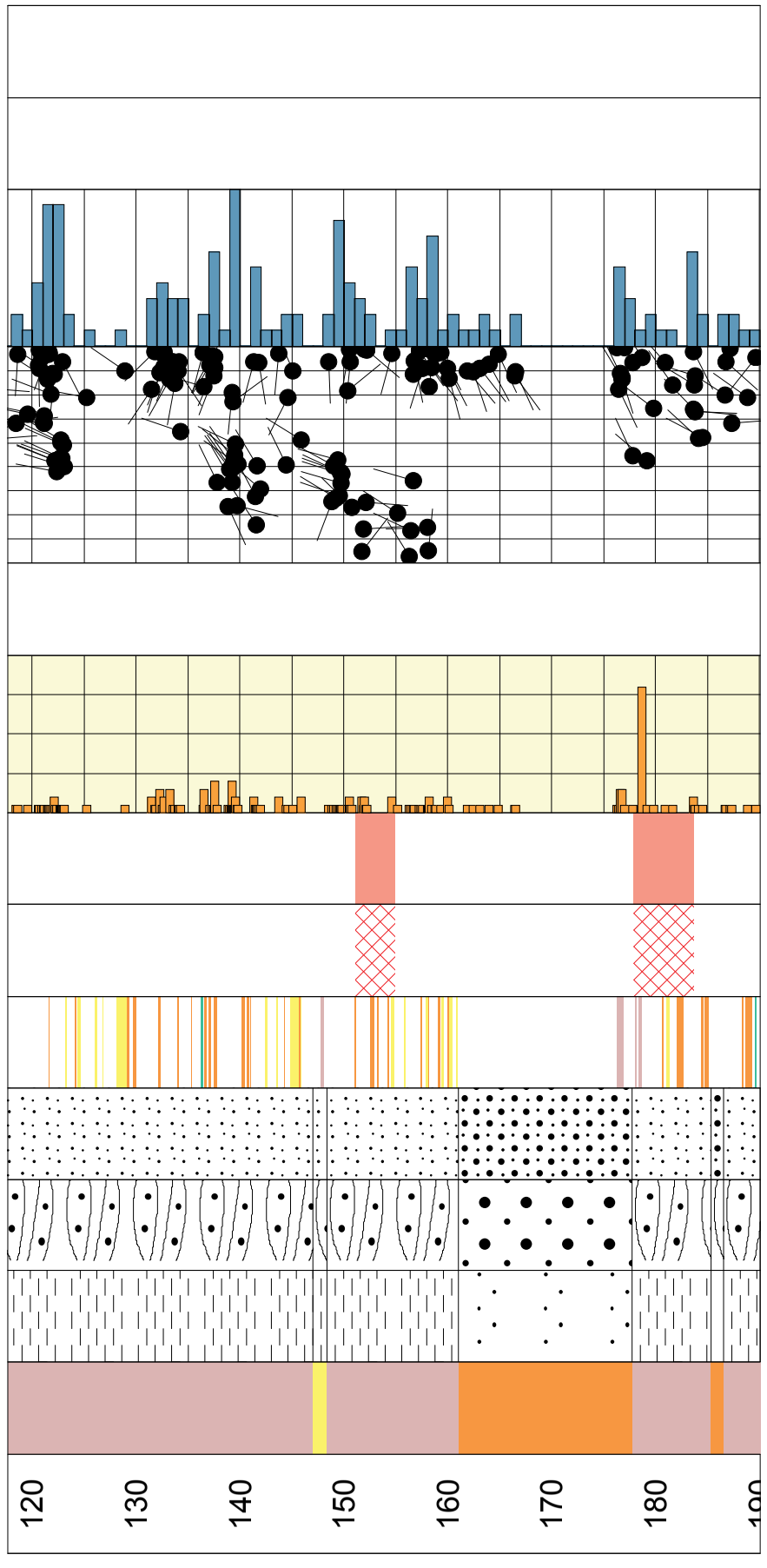
ROUGHNESS

ROCK OCCURRENCE
- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphi
- Amphibolite
- Felsic to intermediate volcanic rock

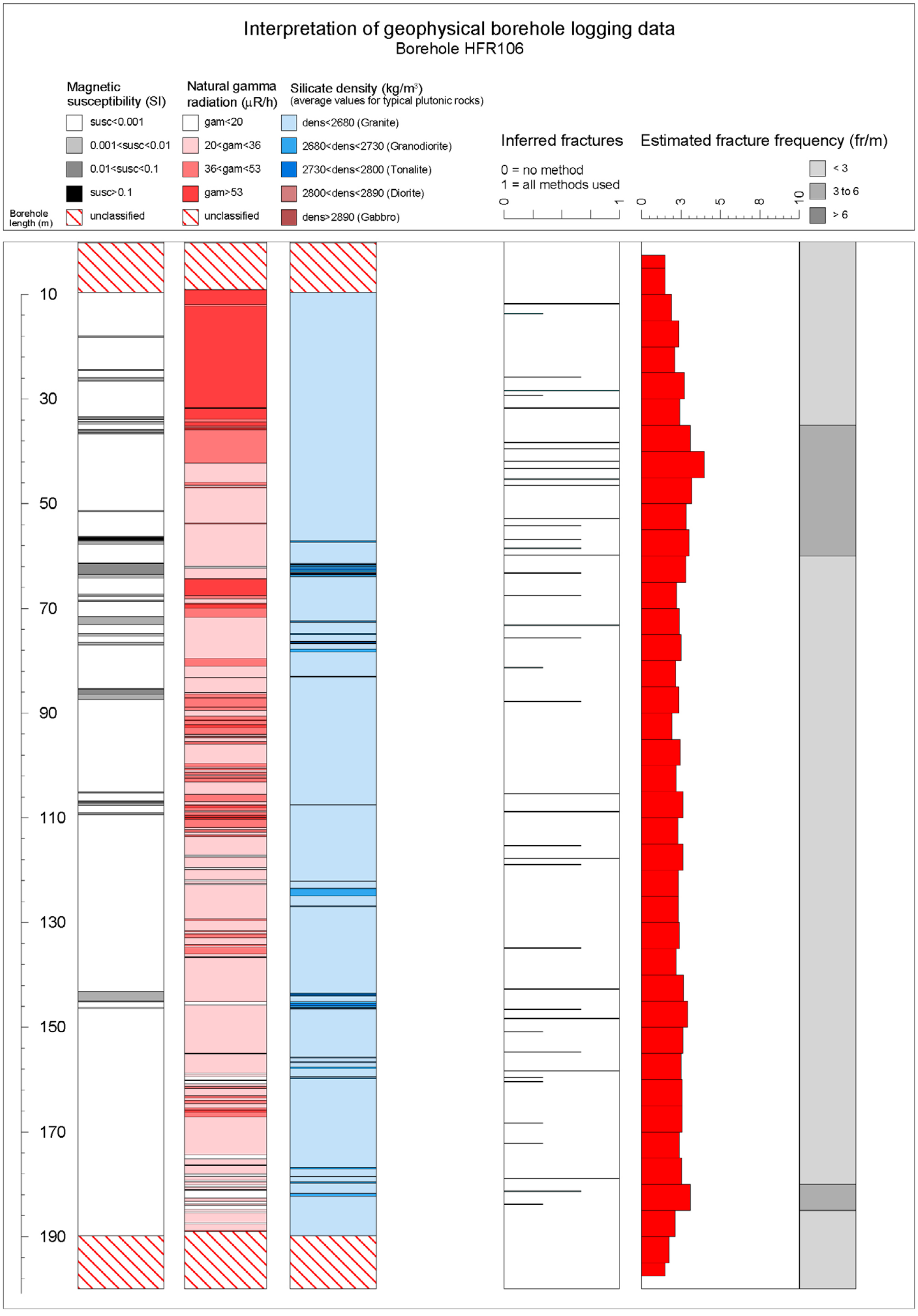
ROCK GRAINSIZE
- Fine to medium grained
- Medium to coarse grained

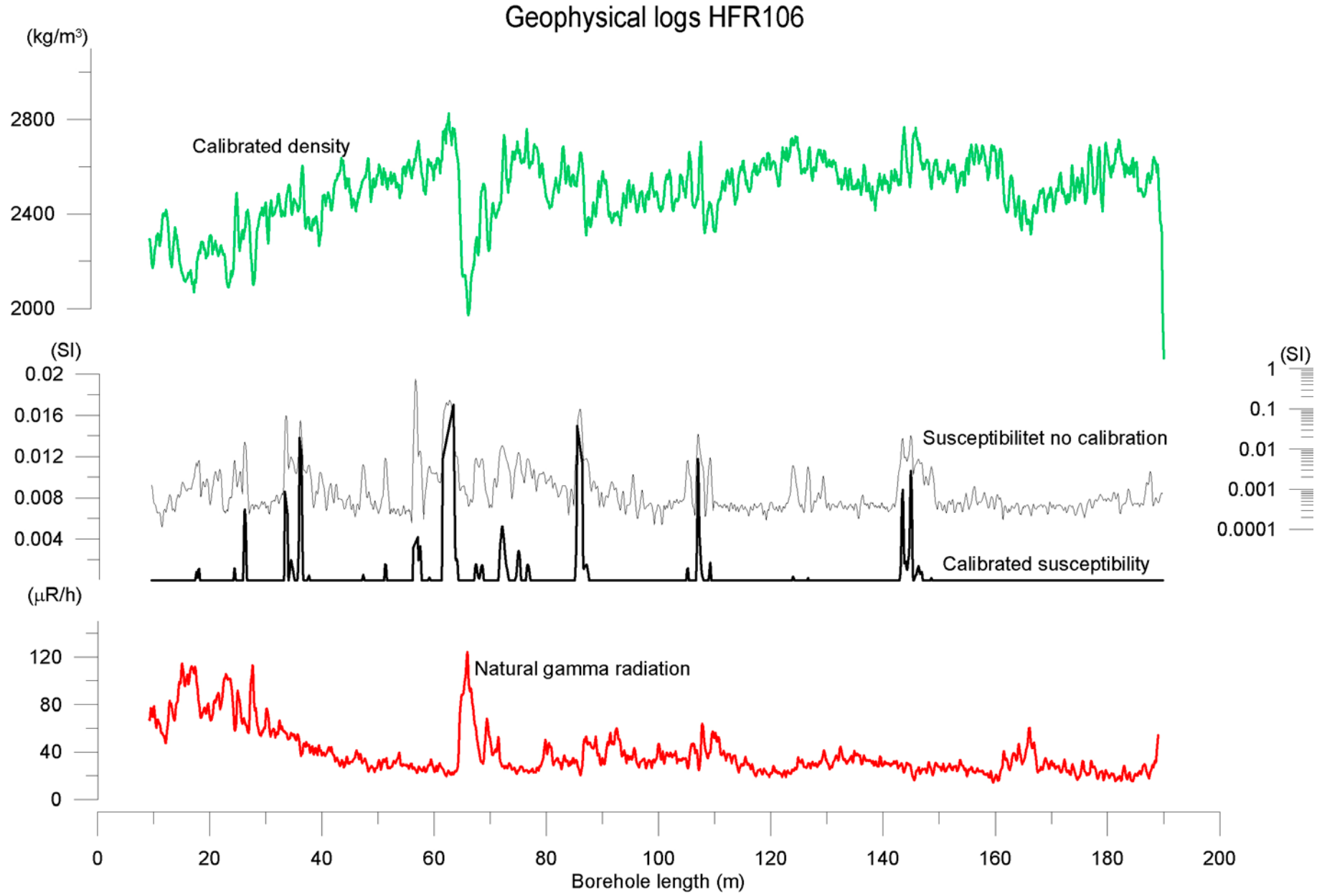
SIMPLIFIED BOREMAP MAPPING




120
130
140
150
160
170
180

Generalized geophysical logs and plots of resampled and calibrated geophysical data from HFR106




Geophysical logs HFR106
(kg/m³)
2800
2400
2000
Calibrated density
(SI)
0.02
0.016
0.012
0.008
0.004
Susceptibilitet no calibration
Calibrated susceptibility
(SI)
1
0.1
0.01
0.001
0.0001
(µR/h)
120
80
40
0
Natural gamma radiation
0
20
40
60
80
100
120
140
160
180
200
Borehole length (m)

Appendix 3

In data

Hole Diam T – Drilling: Borehole diameter

HFR106, 2009-06-24 07:45:00–2009-07-02 10:00:00 (0.000–190.400 m)

Sub Secup (m)	Sub Seclow (m)	Hole Diam (m)	Comment	QC
0.310	9.030	0.1800		*
9.030	114.200	0.1403	Startidiam 141,1 mm	*
114.200	190.400	0.1388	Startdiam at 114,20 is 140,0 mm	*

Printout from SICADA 2009-11-11 13:29:18.

Borehole Direction T – Surveying: Borehole direction

HFR106, 2009-06-29 07:00:00–2009-06-29 11:00:00

Length (m)	Bearing (degrees)	Inclination (degrees)	Bearing Err (degrees)	Inclination Err (degrees)	Magnetic Bearing (degrees)	In Use Flag	Coord System	QC
0.00	269.3900	–60.8700	0.2000	0.2000		*	RT90-RHB70	*

Printout from SICADA 2009-11-11 14:30:24.