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Oskarshamn site investigation

Interpretation of geophysical borehole data from HLX17, HLX18 and HLX19

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Abstract

This report presents the compilation and interpretations of geophysical log data from the percussion drilled boreholes HLX17, HLX18 and HLX19.

The main objective of these investigations is to gain knowledge of the physical properties along the boreholes, and the results are used as supportive information during the geological core and drill chip mappings and as supportive information during the single-hole interpretations.

The silicate density logs indicate a dominance of rocks with a mineral composition that corresponds to that of granodiorite to tonalite in all three boreholes. The section c 110–180 m in HLX17 is dominated by relatively lower silicate density and high natural gamma radiation, which is a clear indication of the occurrence of rocks with a more acidic (granitic) composition. Along the lowermost c 80 m (section 120–202 m) of HLX19 there is a dominance of high silicate density (2,800–3,000 kg/m^3), low gamma radiation and moderate to high magnetic susceptibility. This combination of physical properties strongly indicates that the rock along this section is diorite to gabbro. Several thin positive natural gamma radiation anomalies occur in the boreholes, especially in HLX17, and these probably indicate fine-grained granite or pegmatite dykes. The magnetic susceptibility of the rocks in HLX18 is significantly lower compared to that of HLX17 and HLX19.

The fracture frequency estimations indicate possible deformation zones along the sections c 10–70 m of HLX17 and c 125–165 m of HLX19.

Sammanfattning

Föreliggande rapport presenterar en sammanställning och tolkning av geofysiska borrhålsdata från de hammarborrade hålen HLX17, HLX18 och HLX19.

Syftet med denna undersökning är framförallt att ta fram ett material som på ett förenklat sätt åskådliggör resultaten av de geofysiska loggningarna, s.k. generaliserade geofysiska loggar. Materialet används dels som stödjande data vid borrkärne- (borrkax-) karteringen samt som underlag vid enhålstolkningen för respektive borrhål.

Berggrunden runt HLX17, HLX18 och HLX19 består till stor del av bergarter med en silikatdensitet mellan c 2 700–2 800 kg/m^3, vilket indikerar en mineralsammansättning motsvarande den för granodiorit till tonalit. Längs sektionen 110–180 m i HLX17 är densiteten lägre samtidigt som den naturliga gammastrålningen är relativt hög, vilket indikerar bergarter med mer granitisk sammansättning. I HLX19 finns en c 80 m lång sektion (120–202 m) med mycket hög silikatdensitet, låg naturlig gammastrålning och relativt hög magnetisk susceptibilitet. Denna kombination av fysikaliska egenskaper är mycket typisk för bergarten diorit till gabbro. Ett flertal tunna högstrålande anomalier förekommer i alla tre borrhål, dock främst i HLX17. Dessa orsakas troligen av förekomst av finkornig granit och/eller pegmatitgångar. Den magnetiska susceptibiliteten är betydligt lägre i HLX18 jämfört med HLX17 och HLX19, vilket tyder på en lägre magnetithalt i berget runt förstnämnda borrhål.

Resultaten av beräknad sprickfrekvens indikerar möjlig förekomst av deformationszoner längs sektionerna c 10–70 m av HLX17 och c 125–165 m av HLX19.

Contents

1 Introduction

SKB performs site investigations for localization of a deep repository for high level radioactive waste. The site investigations are performed at two sites, Forsmark and Oskarshamn. This document reports the results gained from the interpretation of geophysical borehole data from the percussion drilled boreholes HLX17, HLX18 and HLX19 in the Laxemar subarea of the Oskarshamn Site investigation. Drilling and investigations of the holes HLX17, 18 and 19 were part of an investigation for evaluating a possible tunnel to the Laxemar subarea.

Generalized geophysical logs related to lithological variations are presented together with indicated fracture logs, including estimated fracture frequency. The logging measurements were conducted in 2004 by Rambøll.

The interpretation presented in this report is performed by GeoVista AB in accordance with the instructions and guidelines from SKB (activity plan AP PS 400-04-068 and method description MD 221.003, SKB internal controlling documents, Table 1-1). The single-hole interpretation which is stipulated in AP PS 400-04-068 was not performed because the tunnel investigation was discontinued.

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

Activity plan	Number	Version
Tolkning av borrhålsgeofysiska data från HLX17–19	AP PS 400-04-068	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för tolkning av geofysiska borrhålsdata	SKB MD 221.003	2.0

The locations of the boreholes are shown in Figure 1-1.

The data from the activity was stored in the SICADA database, see Table 1-2.

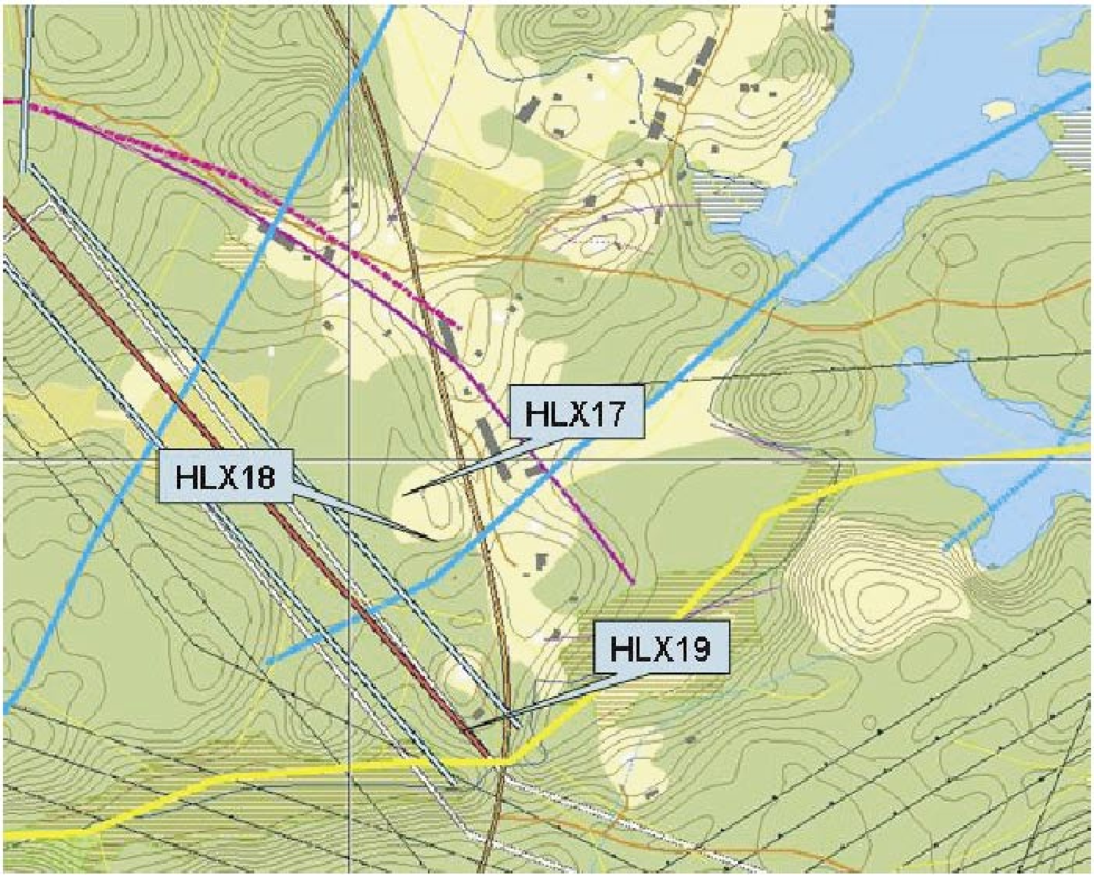

Figure 1-1. Location of HLX17, HLX18 and HLX19 in the Laxemar subarea.

Table 1-2. Data references.

Subactivity	Database	Field note number
Geophysical interpretation in HLX17, HLX18 and HLX19	SICADA	FN 445

2 Objective and scope

The purpose of geophysical measurements in boreholes is to gain knowledge of the physical properties of the bedrock in the vicinity of the borehole. A combined interpretation of the silicate density, magnetic susceptibility and natural gamma radiation, together with petrophysical data, makes it possible to estimate the physical signature of different rock types. The three logs are generalized and are then presented in a simplified way in the borehole software WellCad. The location of major fractures and an estimation of the fracture frequency along the borehole are calculated by interpreting data from the resistivity logs, the single point resistance (SPR), caliper and sonic logs.

The main objective of these investigations is to use the results as supportive information during the geological mappings and as supportive information during the so called “single-hole interpretation”, which is a combined borehole interpretation of geological mapping data (Boremap), geophysical data and radar data.

The planned single-hole interpretation was not performed. The reason was that the tunnel investigation was discontinued.

3 Equipment

3.1 Description of equipment for analyses of log data

The software used for the interpretation are WellCad v3.2 (ALT) and Strater 1.00.24 (Golden Software), that are mainly used for plotting, Grapher v4 (Golden Software), mainly used for plotting and some statistical analyses, and a number of in-house software developed by GeoVista AB on behalf of SKB.

4 Execution

4.1 Preparations of the data

The log data were delivered as a Microsoft Excel file via email from Rambøll. The data used for interpretation are:

Density (gamma-gamma)
Magnetic susceptibility
Natural gamma radiation
Focused resistivity (300 cm)
Focused resistivity (140 cm)
Sonic (P-wave)
Caliper mean
SPR
Short normal resistivity (16 inch)
Long normal resistivity (64 inch)

The gamma-gamma and magnetic susceptibility logs were adjusted by use of a combination of petrophysical data from the boreholes KSH01, KSH02, KSH03 and KAV04, see /1, 2, 3 and 4/. The levels of the magnetic susceptibility logs were slightly decreased, in order to adjust the data for the true zero level.

The log data was prepared by calculations of noise levels, median filtering, error estimations, re-sampling, drift correction and length adjustment.

The logs are median filtered (generally 5 point filters for the resistivity logs and 3 point filters for other logs) and re-sampled to common depth coordinates (0.1 m point distance).

4.2 Interpretation of the log data

The execution of the interpretation can be divided in two steps:

Interpretation rock types

Rock type interpretation means generalization of the silicate density, magnetic susceptibility and natural gamma radiation logs into sections that can be related to specific rock types or mineral composition.

The silicate density is calculated with reference to /5/ and the data are then divided into 5 sections indicating a mineral composition corresponding to granite, granodiorite, tonalite, diorite and gabbro rocks, according to /6/. The sections are bounded by the threshold values, see Table 4-1.

Table 4-1. Threshold values for rock type classification based on silicate density.

Rock type	Silicate density (kg/m^3) lower boundary	Silicate density (kg/m^3) upper boundary
Granite	–	2,680
Granodiorite	2,680	2,730
Tonalite	2,730	2,800
Diorite	2,800	2,890
Gabbro	2,890	–

The magnetic susceptibility log is subdivided into steps of decades and the natural gamma radiation is divided into ”low”, ”medium” or ”high” radiation, where the threshold values for each level are adjusted with respect to the geological environment at the measurement site.

Interpretation of the position of large fractures and estimated fracture frequency

This step involves the calculation of an inferred fracture log and an estimated fracture frequency log. These are based on analyses of the short and long normal resistivity, caliper mean, single point resistance (SPR), focused resistivity (140 and 300 cm) and sonic logs.

The position of large fractures is estimated by applying a second derivative filter to the log data and then locating maxima (or minima depending on the logging method) in the filtered log. Maxima (or minima) above (below) a certain threshold value (Table 4-2) are selected as probable fractures. The result is presented as a column diagram where column height 0 = no fracture, column height 1 = fracture indicated by all logging methods. The estimated fracture frequency is calculated by applying a power function to the weighted sum of the maxima (minima) derivative logs.

The estimated fracture frequency calculations for HLX17, HLX18 and HLX19 are based on individual power functions for each method, and the levels of the weights were set so that the background frequency (in “solid” rock) would be c 1–2 fractures/m. The amplitudes are therefore uncertain.

Table 4-2. Threshold values, powers and weights used for estimating position of fractures and calculate estimated fracture frequency, respectively.

	Borehole	Sonic	Focused res. 140	Focused res. 300	Caliper	SPR	Normal res 64	Normal res 16
Threshold	HLX17	1.0	1.2	1.2	0.2	1.0	2.5	2.5
Power	HLX17	1.5	1.0	1.6	1	0.5	0.5	0.6
Weight	HLX17	1	1	1	1	1	1	1
Threshold	HLX18	0.9	1.2	1.2	0.7	1.0	4.0	2.5
Power	HLX18	1.5	1.0	1.6	1	0.5	0.5	0.6
Weight	HLX18	1	1	1	0.5	1	1	1
Threshold	HLX19	0.9	1.2	1.2	0.7	1.0	2.5	2.5
Power	HLX19	1.5	1.0	1.6	1	0.5	0.5	0.6
Weight	HLX19	1	1	1	0.2	1	1	1

4.3 Nonconformities

None registered.

A minor deviance from the activity plan was that the planned single-hole interpretation was not performed. The reason was that the tunnel investigation was discontinued.

5 Results

5.1 Controll of the log data

5.1.1 Noise levels and qualitative controll

Noise levels of the raw data for each logging method are presented in Table 5-1 below. The magnetic susceptibility, density and sonic logs have noise levels above the recommended levels. To reduce the influence of the noise, all logs were average or median filtered prior to the interpretation.

A qualitative inspection was performed on the logs. The data were checked for spikes and/or other obvious incorrect data points. Erroneous data were replaced by null values (–999) by the contractor Rambøll prior to the delivery of the data, and all null values were disregarded in the interpretation.

Table 5-1. Noise levels in geophysical log data for HLX17, HLX18 and HLX19.

Log method	HLX17	HLX18	HLX19	Recommended max noise level
Density (kg/m^3)	12	15	16	3–5
Magnetic susceptibility (SI)	5.5×10^{-4}	1.4×10^{-4}	7.8×10^{-4}	1×10^{-4}
Natural gamma radiation (μR/h)	0.4	0.3	0.3	0.3
Long normal resistivity (%)	0.2	0.4	0.4	2.0
Short normal resistivity (%)	0.1	0.3	0.3	2.0
Single point resistance (%)	0.13	0.48	0.34	No data
Caliper (meter)	0.0002	0.0002	0.0001	0.0005
Focused resistivity 300 (%)	9.3	10.5	12.5	No data
Focused resistivity 140 (%)	5.1	6.6	7.0	No data
Sonic (m/s)	46	49	33	20

5.2 Interpretation of the log data

The presentation of interpretation products presented below, in chapters 5.2.1 to 5.2.3, includes:

- Classification of silicate density.
- Classification of natural gamma radiation.
- Classification of magnetic susceptibility.
- Position of inferred fractures (0 = no method, 1 = all methods).
- Estimated fracture frequency in 5 meter sections.
- Classification of estimated fracture frequency (0 to 3, 3 to 6 and > 6 fractures/m).

5.2.1 Interpretation of HLX17

The results of the generalized log data and fracture estimations of HLX17 are presented in Figure 5-1 below.

Along the section c 10–110 m the silicate density varies greatly between 2,680–2,800 kg/m^3, which indicates rock with a mineral composition that corresponds to granodiorite to tonalite. Along this section the natural gamma radiation is generally low, but there are several thin positive anomalies in the natural gamma radiation log that most likely correspond to fine-grained granite or pegmatite dykes. At c 110 m depth there is a short high density anomaly that probably indicates the occurrence of a mafic dyke. Below 110 m depth and down to c 180 m depth, the silicate density decreases and the natural gamma radiation level is higher. This is a clear indication of the occurrence of rocks with a more acid (granitic) composition compared to the section above. Also the magnetic susceptibility is generally lower along section 110–180 m. Below c 180 m depth the density increases and the natural gamma radiation level decreases, indicating the same physical properties here as along the section 10–110 m.

The estimated fracture frequency is moderate or partly increased along the section c 10–100 m, which may correspond to a possible deformation zone. Below 100 m depth the frequency of fractures is generally low.

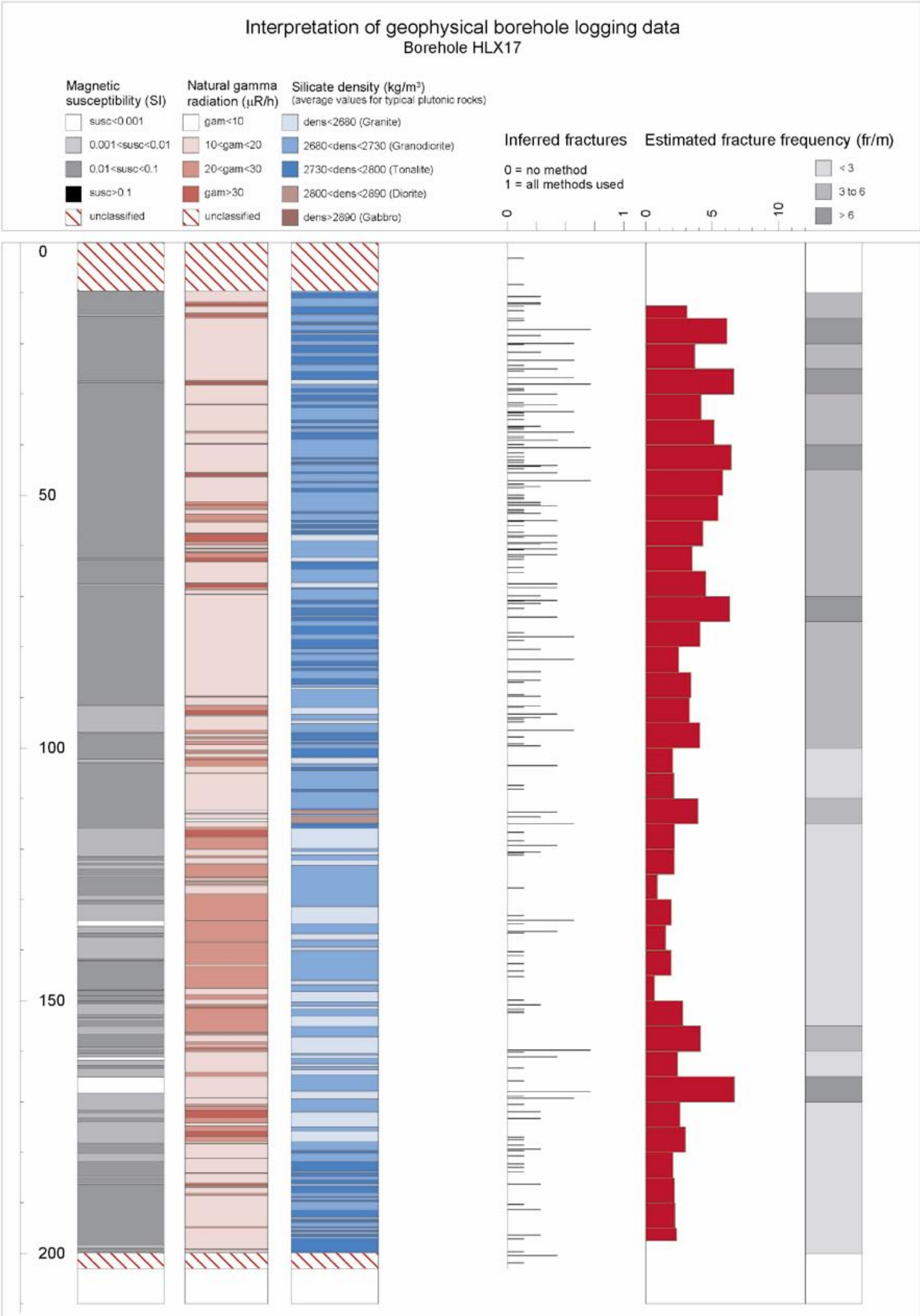

Figure 5-1. *Generalized geophysical logs and estimated fracture frequency for HLX17.*

5.2.2 Interpretation of HLX18

The results of the generalized log data and fracture estimations of HLX18 are presented in Figure 5-2 below.

Along the section 15–58 m the natural gamma radiation is low, the magnetic susceptibility is mainly low to moderate and the silicate density indicates rock with a mineral composition that corresponds to granodiorite. Between c 58 and 84 m depth there is a major increase of the silicate density and a corresponding decrease of the natural gamma radiation, which is a clear indication of the occurrence of mafic rock (diorite to gabbro or fine-grained mafic rock). At the lower part of this anomaly there are several narrow sub-sections with low density and high natural gamma radiation, which indicates the occurrence of fine-grained granite. From c 90 m depth and down to the bottom of the borehole (c 180 m) the silicate density varies between 2,680–2,800 kg/m^3, which indicates rock with a mineral composition that corresponds to granodiorite to tonalite, and the natural gamma radiation is generally low. Two minor high density anomalies occur at c 103 m and 127 m depth.

The estimated fracture frequency of HLX18 is generally moderate or low.

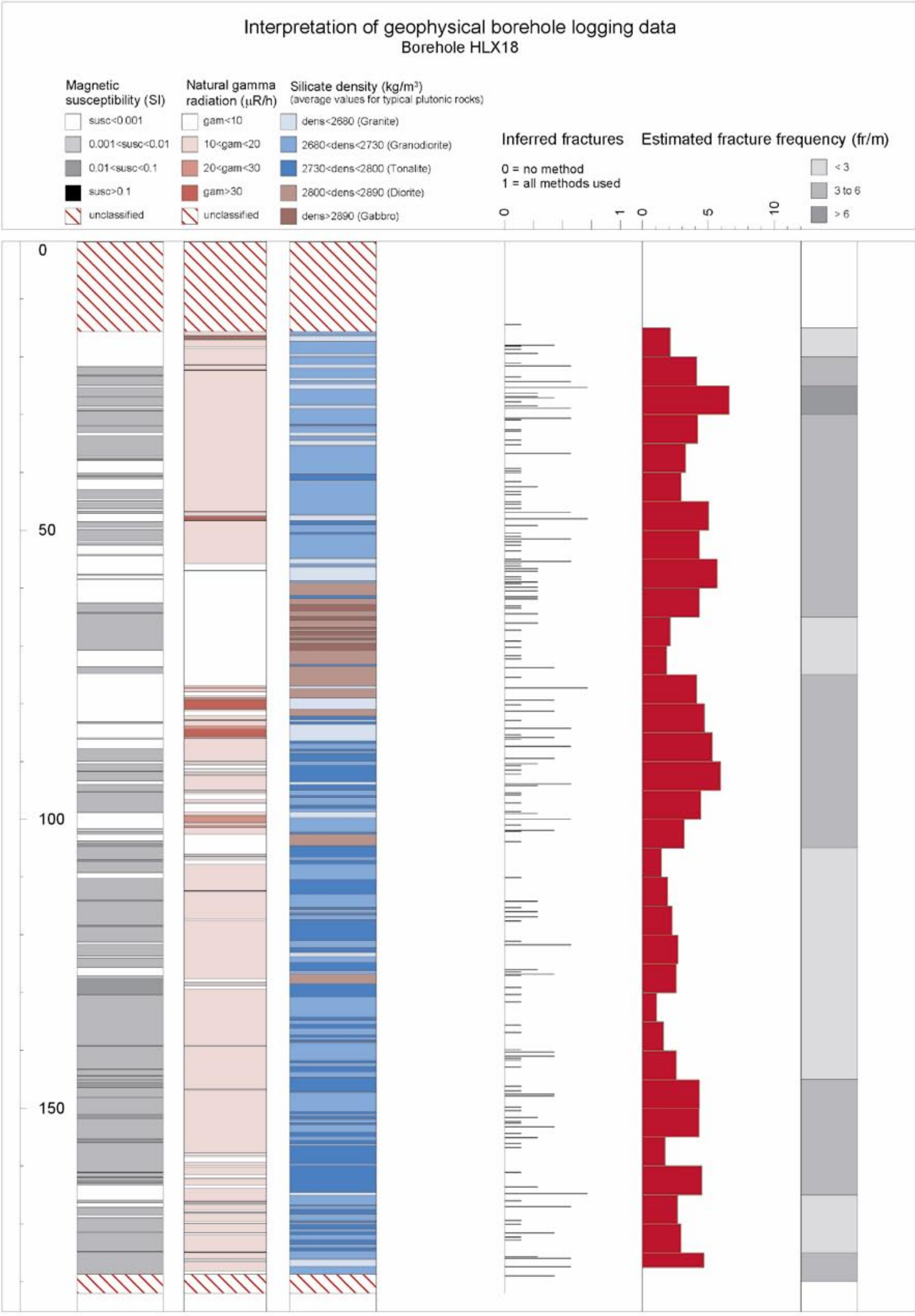

Figure 5-2. Generalized geophysical logs and estimated fracture frequency for HLX18.

5.2.3 Interpretation of HLX19

The results of the generalized log data and fracture estimations of HLX19 are presented in Figure 5-3 below.

Based on the physical properties, the borehole HLX19 can roughly be divided into two parts, section 12–120 m and section 120–202 m. The upper section is dominated by silicate densities indicating a mineral composition that corresponds mainly to granodiorite or tonalite rocks. Five c 1–4 m wide sections with low density, high natural gamma radiation and low magnetic susceptibility indicate fine-grained granite or pegmatite dykes. Two 2–4 m wide mafic dykes are also indicated along this part of the borehole. The lower part (section 120–202 m) is completely dominated by high silicate density (2,800–3,000 kg/m^3), low gamma radiation and moderate to high magnetic susceptibility. This combination of physical properties strongly indicates that the rock along this section is diorite to gabbro.

The estimated fracture frequency is mainly low or moderate, but three short intervals of high fracture frequency are indicated between 125 m and 165 m depth, which could indicate the occurrence of a deformation zone.

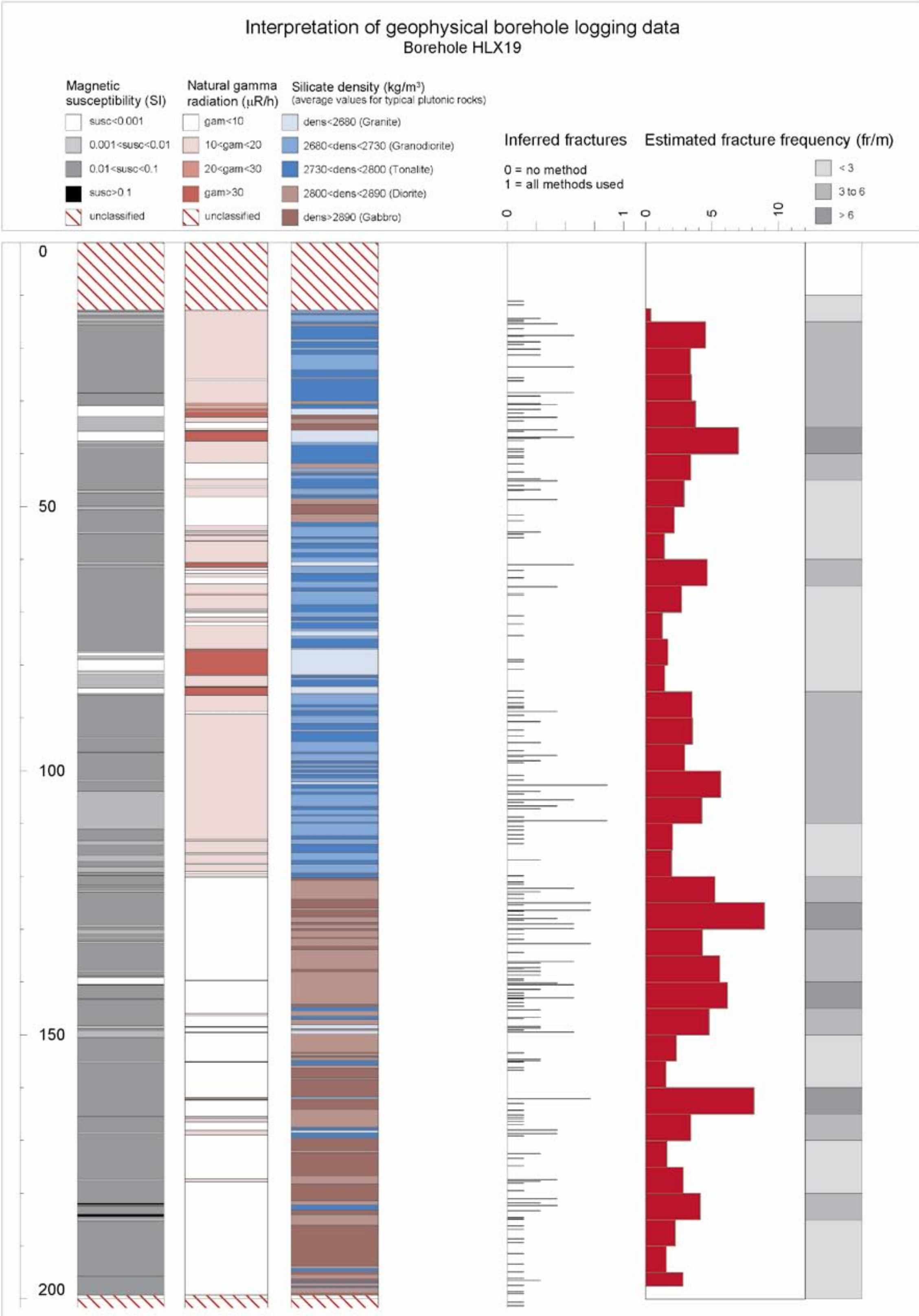

Figure 5-3. *Generalized geophysical logs and estimated fracture frequency for HLX19.*

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