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Geological single-hole interpretation of HFM42–HFM47 and KFM25–KFM27

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Keywords: Geology, Rock units, Possible deformations zone, Borehole.

Abstract

This report presents the geological single-hole interpretation (SHI) of percussion drilled boreholes HFM42–HFM47 and core drilled boreholes KFM25–KFM27.

The core drilled boreholes KFM25–KFM27 were drilled close to the nuclear power plant in Forsmark to monitor the ground water level and the potential for subsidence along sub-horizontal fractures with aperture and sediment fillings.

HFM42 was drilled to install geophones and fibre optic cable for seismic monitoring, whereas HFM43–HFM47 were drilled mainly to perform hydraulic tests, including flow logging and water sampling.

The interpretation to identify rock units (RU) and possible deformation zones (PDZ) along individual boreholes is based on the geological mapping with support from single point resistivity (SPR). Hydrogeological data from the flow logging were included for comparative purposes.

The number of rock units in the individual boreholes varies from one to four and in some cases the rock units are divided into subunits. Possible deformations zones are recognised with low to medium confidence level in HFM44, HFM46 and KFM27.

Sammanfattning

Denna rapport redovisar resultat från geologisk enhålstolkning (SHI) av hammarhålen HFM42–HFM47 och kärnborrhålen KFM25–KFM27.

Kärnborhålen KFM25–KFM27 borrades i nära anslutning till kärnkraftverket i Forsmark för att övervaka grundvattennivån och potentiell risk för sättningar i bergmassan kopplat till bankningsplan med apertur och sedimentfyllning.

HFM42 borrades för att installera geofoner och fiberoptisk kabel för seismisk övervakning, medan HFM43–HFM47 i huvudsak borrades för att genomföra hydrauliska tester, så som flödesloggning och vattenprovtagning.

Tolkningar för att identifiera bergenheter och möjliga deformationszoner längs enskilda borrhål har gjorts baserat på geologisk kartering med stöd från resistivitetsmätningar (SPR). Hydrogeologisk data från flödesloggningen av borrhålen inkluderades i jämförande syfte.

Antalet bergenheter i enskilda borrhål varierar från en till fyra, och i vissa fall har bergenheterna delats in i delenheter.

Möjliga deformationszoner har identifierats med låg till medelhög konfidensgrad i HFM44, HFM46 och KFM27.

Contents

1 Introduction

Primary geological and geophysical borehole data stored in the SKB database SICADA need to be integrated and synthesized before they can be used for deterministic, 3D geological modelling. The integrated synthesis is provided by the SKB method of geological single-hole interpretation (SKB MD 810.003), which aims to document all the rock units (RU) that exceed a minimum length of 5–10 m along the borehole, as well as the possible deformation zones (PDZ) that are intersected by the borehole. The identification of these geological features is carried out independently for each borehole, in connection with an analysis of base data and, for cored boreholes, an inspection of the drill core. The end result of this procedure is an integrated series of different logs and accompanying descriptive documents.

This document reports the geological single-hole interpretations of the cored boreholes KFM25–HFM27 and the percussion drilled boreholes HFM42–HFM47 in the Forsmark area.The three cored borholes are located in close proximity to the nuclear power plant, Forsmark 1, whereas HFM42 and HFM43 are located in the Söderviken area and HFM44–HFM47 are located in the Stora Asphällan area. For borehole location see Figure 1-1.

The work was carried out in accordance with activity plan AP SFK-20-008 (in Swedish). The controlling documents for performing this activity are listed in Table 1-1. Both the activity plan and method description are SKB's internal controlling documents.

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

Activity plan	Number	Version
Geologisk enhålstolkning (SHI) av borrhål HFM42–HFM47 och KFM25–KFM27	AP SFK-20-008	1.0
Method description	**Number**	**Version**
Metodbeskrivning för geologisk enhålstolkning	SKB MD 810.003	3.0

Figure 1-1. *Location of the boreholes KFM25–KFM27 and HFM42–HFM47 relative to the coastline and the Forsmark nuclear power plant.*

2 Objectives and scope

A geological single-hole interpretation is carried out in order to merge sections of similar geological character into rock units (RU) and identify all possible deformation zones (PDZ) within a borehole. The work involves an integrated interpretation of data from the geological borehole mapping and different borehole geophysical logs. The end result is an integrated series of different logs and a brief description the gelogical characteristics of each unit and possible zone.

The geological mapping of the cored boreholes involves a documentation of the character of the bedrock with the Boremap system, which combines drill core mapping with inspection of an oriented image obtained by optical televiewer (OPTV) of the borehole wall.

Borehole logs used as basis for the geological single-hole interpretation are presented in a composite WellCad plot. A more detailed description of the technique is provided in the method description for geological single-hole interpretation (SKB MD 810.003). The work reported here concerns stage 1 in the single-hole interpretation, as defined in the method description.

3 Data used for the geological single-hole interpretation (SHI)

KFM25–KFM27

The following data and interpretations have been used for the single-hole interpretation:

- Boremap data, including OPTV, mapping data and results presented by Winell (2020).
- Single-point resistivity (SPR) measurements from the PFL flow logging presented by Komulainen et al. (2020).

The material used as a basis for the geological single-hole interpretation was a WellCad plot consisting of parameters from the geological mapping and the SPR measurements. Additional hydraulic data were included strictly for comparative purposes and were not used in the actual interpretation procedure. The plot consists of seven main columns and several subordinate columns. These include:

1. Length along the borehole
2. Elevation (meter below sea level; RH2000)
3. Rock type
   – Rock type
   – Rock occurrence (< 1 m)
   – Rock type structure
   – Rock type texture
   – Rock type grain size
   – Structure orientation
   – Rock alteration
   – Rock alteration intensity
4. Fracture frequency
   – Open total
   – Sealed total
   – Fracture, open frac, orientation
   – Fracture, broken frac, orientation
   – Total fractures
   – Open aperture
   – Open width
   – Sealed width
5. Fracture alteration orientation
   – Open alteration
   – Sealed alteration
   – Surface
6. Sealed network
7. Crush zones and core loss
   – Crush zone
   – Piece length
   – Core loss
8. Hydrology
   – Electric conductivity, EC
   – Transmissivity
   – Flow
   – SPR
   – Transmissivity flow anomalies, 5 m sections

HFM42–HFM47

The following data and interpretations have been used for the single-hole interpretation:

- Boremap data, including OPTV and mapping data and results presented by Rauséus (2020).

The material used as a basis for the geological single-hole interpretation was a WellCad plot consisting of parameters from the geological mapping. Additional hydraulic data were included strictly for comparative purposes and were not used in the actual interpretation.

The plot consists of six main columns and several subordinate columns. These include:

1. Borehole length and elevation
   – Length
   – Elevation, meter below sea level (RH2000)
2. Rock type
   – Rock type
   – Rock occurrence (< 1 m)
   – Rock type structure
   – Rock type texture
   – Rock type grain size
   – Structure orientation
   – Alteration
   – Alteration Intensity
3. Fracture frequency
   – Open fractures
   – Sealed fractures
   – Open total factures
   – Sealed total fractures
   – Total fractures
   – Crush zone
   – Sealed network
   – RQD reversed
4. Fracture character
   – Open fracture orientation
   – Sealed fracture orientation
   – Open width
   – Open aperture
   – Sealed width
   – Clay Mineral
   – Surface Slickensided
5. Hydro flow
   – Hydraulic flow measurements – impeller
6. Core
   – Core loss

4 Execution of the geological single-hole interpretation

The geological single-hole interpretation has been carried out by a group of geoscientists consisting of geologists, a geophysicist and a hydrogeologist. Several of these geoscientists previously participated in the development of the source material for the single-hole interpretation. All data to be used (see Chapter 3) are visualized side by side in a borehole document extracted from the software WellCad. The working procedure is summarized in Figure 4-1 and in the text below.

4.1 General

The SHI is initiated by a study of all types of primary data (rock type, rock alteration, natural gamma radiation, etc) related to the character of the rock type to merge sections of similar rock types, or sections where one rock type is very dominant, into rock units (minimum length of c 5 m). Each rock unit is defined in terms of the borehole length interval and provided with a brief description for inclusion in the WellCad plot. The confidence in the interpretation of a rock unit is made on the following basis: 3 = high, 2 = medium and 1 = low. The use of low or medium degree of confidence is generally restricted to percussion drilled boreholes, where no drill core is available.

The working procedure proceeds with identification of PDZs by visual inspection of the results of the geological mapping (fracture frequency, fracture mineral, aperture, alteration, etc) in combination with the SPR data. The section of each identified PDZ is defined in terms of the borehole length interval and provided with a brief description for inclusion in the WellCad plot. This includes a brief description of the rock types affected by the PDZ. The confidence in the interpretation of a PDZ is made on the following basis: 3 = high, 2 = medium and 1 = low.

Inspection of the OPTV image is carried out wherever it is judged necessary during the working procedure. Furthermore, following the definitions of rock units and PDZs, with their respective confidence estimates, the drill cores are inspected in order to check the selection of the boundaries between these geological entities. If judged necessary, the location of these boundaries is adjusted. Potential candidates for PDZs as identified on the basis of the WellCad compilation, may be omitted/rejected if the interpretation lacks sufficient support in the drill core. In addition, the estimated confidence level may be revised based on the ocular inspection.

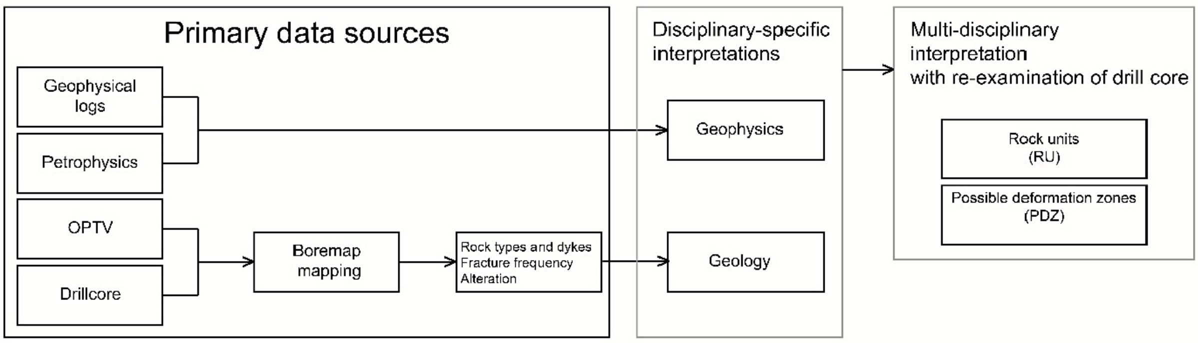


Figure 4-1. *Schematic flow chart showing the procedure for the development of a geological single-hole interpretation. Modified from SKB MD 810.003.*

Brittle PDZs have been identified primarily on the basis of the frequency of fractures, according to the concept presented in Figure 4-2. Tensional fractures (joints) or shear fractures (faults) are not distinguished. Both the damage zone, with a fracture frequency in the range 4–9 fractures/m, and the core part, with a fracture frequency > 9 fractures/m, have been included in each zone (Figure 4-2). It should be emphasized that the identification of a PDZ is not limited to the absolute fracture frequency; the basis is the *relative* fracture frequency along with other indications. The frequencies of open and sealed fractures have been assessed in the identification procedure, and the character of the zone has been described accordingly. Partly open fractures are included together with open fractures in the brief description of each zone.

Single point resisitence, SPR, is used to support identification of water bearing fractures, characterize deformation zones and in some cases the occurence of bedrock alteration.

4.2 Nonconformities

Except for the SPR obtained during the PFL-logging, no geophysical information was available for any of the borholes included in this report.

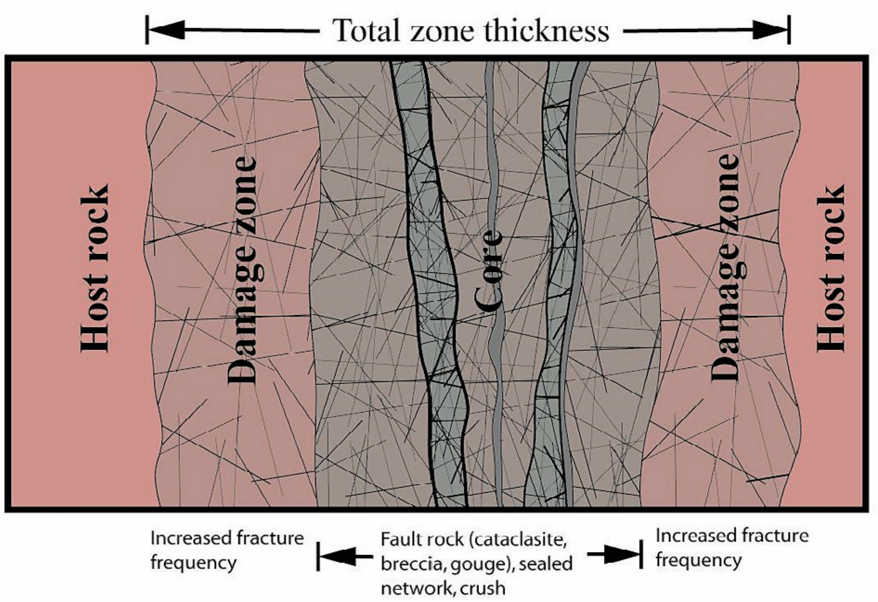


***Figure 4-2.** Terminology for brittle deformation zones (modified after Munier et al. 2003).*

5 Results

5.1 HFM42

Rock units

One rock unit (RU1) occurs in the borehole.

6.03–195.03 m

RU1: Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061), amphibolite (102017) and fine- to medium-grained metagranitoid (101051). The metagranite-granodiorite exhibits foliation of weak to medium intensity, dipping steeply towards the SW. Confidence level = 3.

Possible deformation zones

No possible deformations zones have been recognised in HFM42.

5.2 HFM43

Rock units

One rock unit (RU1) occurs in the borehole.

6.20–200.07 m

RU1: Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061) and amphibolite (102017). The metagranite-granodiorite exhibits foliation of weak intensity, dipping steeply towards the SW. Confidence level = 3.

Possible deformation zones

No possible deformations zones have been recognised in HFM43.

5.3 HFM44

Rock units

The borehole has been divided into four rock units, RU1–RU4.

9.12–23.17 m

RU1: Medium-grained metagranite-granodiortite (101057) with two subordinate occurrences of amphibolite (102017) in the lowermost part of the rock unit. The metagranite-granodiortite exhibits foliation, weak to medium intensity, dipping steeply towards the NE. Confidence level = 2.

23.17–82.25 m

RU2: Fine-grained felsic to intermediate metavolcanic rock (103076) with a few subordinate occurrences of pegmatitic granite (101061), amphibolite (102017) and fine- to medium-grained metagranitoid (101051). Confidence level = 2.

82.25–153.44 m

RU3: Medium-grained metagranite-granodiortite (101057) with undulating foliation of weak to medium intensity, dipping vertically to steeply towards the NE–SW. Subordinate occurrences of fine-grained felsic to intermediate metavolcanic rock (103076) and pegmatitic granite (101061) ranging up to 5 m in borehole length in the lower half of the rock unit. Several minor occurrences of fine- to medium-grained metagranitoid in the interval 105–125 m. Confidence level = 2.

153.44–199.72 m

RU4: Fine-grained felsic to intermediate metavolcanic rock (103076) with one section of medium-grained metagranite-granodiortite (101057) at 164–170 m borehole length. The metavolcanic rock exhibits foliation of weak to medium intensity, dipping steeply towards the northeast. Subordinate occurrence of pegmatitic granite (101061). Confidence level = 2.

Possible deformation zones

161.88–167.65 m

PDZ1: Increased frequency of fractures registered as sealed networks. The possible zone is situated in fine-grained metavolcanic rock (103076) and medium-grained metagranite-granodiorite (101057). Confidence level = 1.

5.4 HFM45

Rock units

The borehole can be divided into four rock units and some of them are repeated as totally eight subunits.

6.31–78.28 m

RU1a: Medium-grained metagranite-granodiortite (101057) with several subordinate occurrences of pegmatitic granite (101061) and two minor occurrences of amphibolite (102017). The metagranite-granodiortite exhibits foliation of medium intensity, dipping sub-vertically towards the northeast. Confidence level = 2.

78.28–88.80 m

RU2a: Pegmatitic granite (101061). Confidence level = 2.

88.80–108.17 m

RU3a: Fine-grained felsic to intermediate metavolcanic rock (103076) with foliation of weak intensity, dipping steeply towards the SSW. Confidence level = 2.

108.17–119.66 m

RU1b: Medium-grained metagranite-granodiortite (101057) with one occurrence of pegmatitic granite (101061) at 111–114 m borehole length. The extent of the rock unit is limited by subordinate occurrences of amphibolite (102017), 1–2 m in borehole length. Confidence level = 2.

119.66–139.81 m

RU3b: Fine-grained felsic to intermediate metavolcanic rock (103076) with weak foliation, dipping steeply to sub-vertically towards the SSW. Confidence level = 2.

139.81–165.70 m

RU4: Medium-grained metagranite-granodiortite (101057) with a subordinate occurrence of amphibolite (102017) along the upper limit of the unit and one of pegmatitic granite (101061) along the lower limit. The metagranite-granodiortite exhibits foliations of fain to weak intensity, dipping sub-vertically towards the southwest. Confidence level = 2.

165.70–185.31 m

RU2b: Pegmatitic granite (101061) with faint foliation, dipping steeply towards the northeast. Confidence level = 2.

185.31–200.45 m

RU3c: Fine-grained felsic to intermediate metavolcanic rock (103076) with a few subordinate occurrences of amphibolite (102017) and pegmatitic granite (101061). The metavolcanic rock exhibits foliation of weak intensity, dipping steeply towards the south. Confidence level = 2.

Possible deformation zones

No possible deformations zones have been recognised in HFM45.

5.5 HFM46

Rock units

The borehole consists of two rock units, RU1–RU2.

6.11–55.92 m

RU1: Medium-grained metagranite-granodiorite (101057) with several subordinate occurrences of pegmatitic granite (101061). The two most extensive occur at 11–15 m and 50–56 m borehole length. Confidence level = 2.

55.92–200.00 m

RU2: Fine-grained felsic to intermediate metavolcanic rock (103076) with subordinate occurrences of medium-grained metagranite-granodiorite (101057), amphibolite (102017) and pegmatitic granite (101061). The metavolcanic rock exhibits foliation of medium intensity, dipping steeply towards the southwest. Confidence level = 2.

Possible deformation zones

Three possible deformations zones have been recognised in HFM46 with confidence level = 1.

81.41–87.20 m

PDZ1: Increased frequency of fractures with one crush at 81.42–81.63 m borehole length. Fracture aperture generally 1 mm with a few fractures ranging up to 5 mm. The possible zone is situated in felsic to intermediate meta volcanic rock (103076). Confidence level = 1.

136.91–143.96 m

PDZ2: Increased frequency of fractures with three crushes at 138.44–139.72, 140.68–140.75 and 142.90–143.32 m borehole length. The possible zone is situated in felsic to intermediate metavolcanic rock (103076). Confidence level = 1.

164.07–187.91 m

PDZ3: Increased frequency of fractures with five minor crushes at 164.38–164.43, 165.89–166.26, 172.82–173.03, 185.08–185.21 and 187.02–187.15 m borehole length. General fracture apertures at 1–2 m with one aperture at 40 mm. The possible zone is situated in section with felsic to intermediate metavolcanic rock (103076) and medium-grained metagranite-granodiorite (101057). Confidence level = 1.

5.6 HFM47

Rock units

The borehole consists of two rock units, RU1–RU2.

12.09–101.16 m

RU1a: Medium-grained metagranite-granodiorite (101057) with subordinate occurrence of pegmatitic granite (101061). Single minor occurrences of fine-grained felsic to intermediate metavolcanic rock (103076) and amphibolite (102017). The metagranite-granodiorite exhibits undulating foliation of faint to weak intensity, with subvertical dip towards the northeast and southwest. Confidence level = 2.

101.16–172.68 m

RU2a: Fine-grained felsic to intermediate metavolcanic rock (103076) with subordinate occurrences of medium-grained metagranite-granodiorite (101057), amphibolite (102017) and pegmatitic granite (101061). The metavolcanic rock exhibits undulating foliation of weak to medium intensity, with subvertical dip towards the northeast and southwest. Confidence level = 2.

172.68–192.60 m

RU1b Medium-grained metagranite-granodiorite (101057) with subordinate occurrences of pegmatitic granite (101061) in the lower part of the unit. Confidence level = 2.

192.60–200.70 m

RU2b: Fine-grained felsic to intermediate metavolcanic rock (103076) with a few subordinate occurrences of pegmatitic granite (101061) and amphibolite (102017). The metavolcanic rock exhibits foliation of weak to medium intensity, dipping steeply towards the southwest. Confidence level = 2.

Possible deformation zones

No possible deformations zones have been recognised in HFM47.

5.7 KFM25

Rock units

The borehole consists of one rock unit, RU1.

6.06–100.59 m

RU1: Medium-grained metagranite-granodiorite (101057) with several minor occurrences of pegmatitic granite (101061). One amphibolite (102017) occurs at 47.1–48.6 m borehole length and one occurrence of fine- to medium-grained metagranitoid (101051) at 37.8–38.6 m borehole length. The metagranite-granodiorite exhibits foliation of medium intensity, dipping steeply to sub-vertically towards to WSW. Confidence level = 3.

Possible deformation zones

According to the geological interpretation, none of the structures intersected by KFM24 fulfil the criteria of being a possible deformations zone.

5.8 KFM26

Rock units

The borehole consists of two rock units, RU1–RU2.

6.03–54.22 m

RU1: Medium-grained metagranite-granodiortite (101057) with several minor occurrences of pegmatitic granite (101061). Confidence level = 3.

54.22–100.63 m

RU2: Medium-grained metagranite-granodiortite (101057 with three subordinate occurrences of amphibolite (102017) at 54.21–60.05, 72.52–75.85 and 83.73–85.51 m borehole length. Local chloritization and oxidation of the amphibolite at 54.21–60.05 m borehole length. Several minor occurrences (< 1 dm) of pegmatitic granite (101061). The metagranite-granodiortite exhibits undulating foliation of medium intensity, dipping vertically to sub-vertically towards the east and west. Confidence level = 3.

Possible deformation zones

No possible deformations zones have been recognised in KFM26.

5.9 KFM27

The borehole consists of three rock units, RU1–RU3.

9.03–56.24 m

RU1: Weakly albitized medium-grained metagranite-granodiortite (101057) with subordinate occurrences of pegmatitic granite (101061). One occurrence at fine- to medium-grained granite (111058) at 40.35–42.96 m borehole length. The metagranite-granodiortite exhibits foliation of medium intensity, dipping sub-vertically towards the west. Confidence level = 3.

56.24–66.44

RU2: Pegmatitic granite (101061) and one minor occurrence of medium-grained metagranite-granodiortite (101057). Confidence level = 3.

66.44–100.64

RU3: Weakly albitized medium-grained metagranite-granodiortite (101057) with subordinate occurrences of pegmatitic granite (101061). The metagranite-granodiortite exhibits foliation of medium intensity, dipping sub-vertically towards the west. Confidence level =3.

Possible deformation zones

One possible deformations zone has been recognised in HFM27 with confidence level = 2.

30.00–92.00 m

PDZ1: Increased frequency of both open and sealed fractures, and between 56 and 73 m borehole length especially sealed fracture networks. One crush at 66.45–67.03 m borehole length and three minor sections at 86.70–88.36 m borehole length. Fracture width and apertures up to 1.5 mm, with one exception reaching a width of 5 mm. Predominant minerals in both open and sealed fractures are calcite, chlorite, oxidized walls and no detectable minerals. Confidence level = 2.

References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.com/publications.
SKBdoc documents will be submitted upon request to document@skb.se.

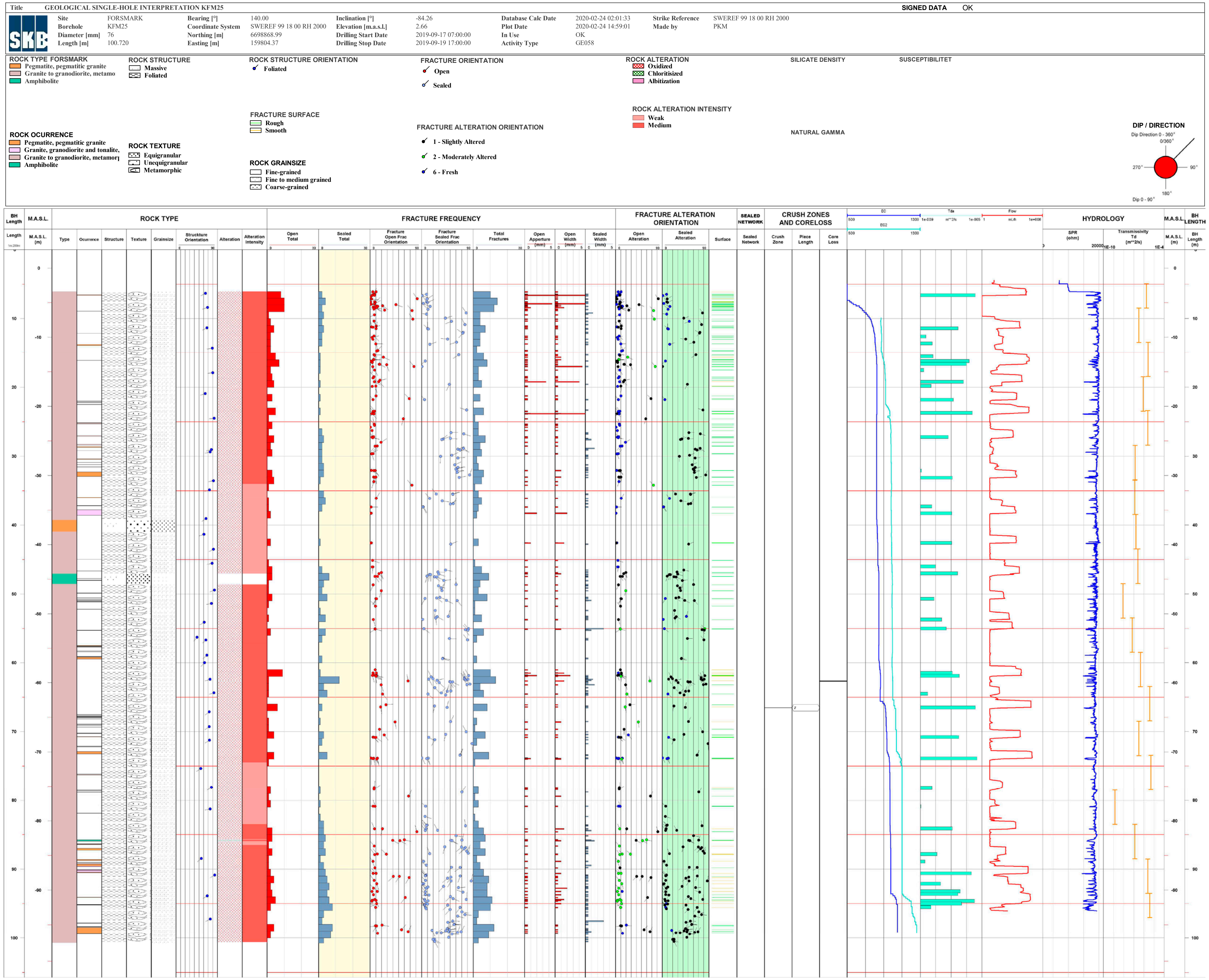
Komulainen J, Pekkanen J, Hurmerinta E, Ripatti K, 2020. Difference flow logging in boreholes KFM25, KFM26 and KFM27. SKB P-20-17, Svensk Kärnbränslehantering AB.

Munier R, Stenberg L, Stanfors R, Miles A G, Hermanson J, Triumf C-A, 2003. Geological site descriptive model. A strategy for the model development during site investigations. SKB R-03-07, Svensk Kärnbränslehantering AB.

Rauséus G, 2020. Boremapkartering av HFM42 – HFM47. SKBdoc 1678353 ver 1.0, Svensk Kärnbränslehantering AB. (In Swedish.)

Winell S, 2020. Boremap mapping of core drilled borehole KFM25, KFM26 and KFM27. SKB P-19-26, Svensk Kärnbränslehantering AB.

WellCad images KFM25–KFM27 and HFM42–HFM47




Title GEOLOGICAL SINGLE-HOLE INTERPRETATION KFM26
SIGNED DATA OK
Site FORSMARK
Borehole KFM26
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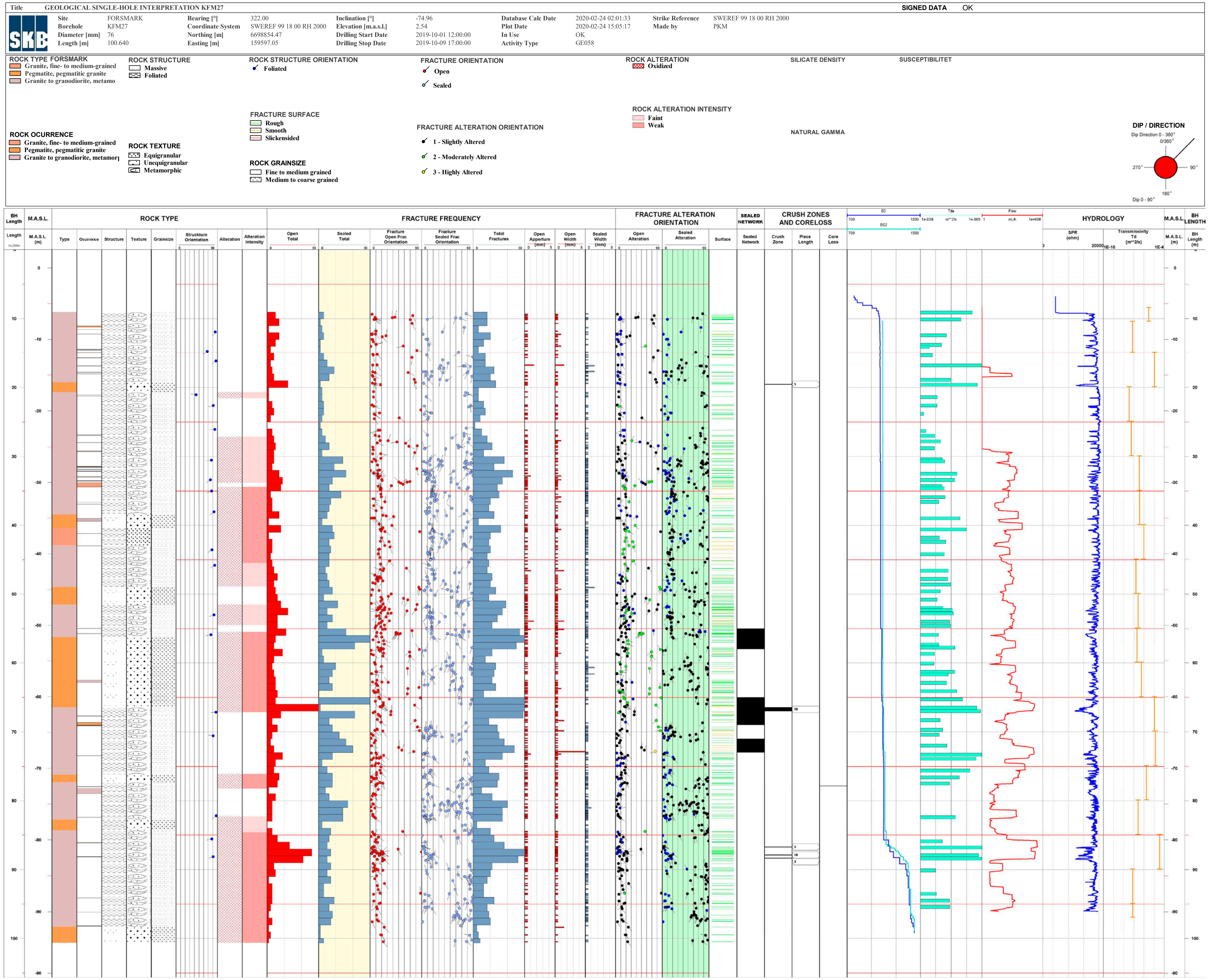
Length [m] 100.740
Bearing [°] 17.00
Coordinate System SWEREF 99 18 00 RH 2000
Northing [m] 6698941.42
Easting [m] 159726.47
Inclination [°] -84.87
Elevation [m.a.s.l.] 3.00
Drilling Start Date 2019-10-01 07:00:00
Drilling Stop Date 2019-10-03 15:00:00
Database Calc Date 2020-02-24 02:01:33
Plot Date 2020-02-24 14:27:49
In Use OK
Activity Type GE058
Strike Reference SWEREF 99 18 00 RH 2000
Made by PKM
ROCK TYPE FORSMARK
Granite to granodiorite, metamo
Amphibolite
ROCK STRUCTURE
Foliated
ROCK STRUCTURE ORIENTATION
Foliated
FRACTURE ORIENTATION
Open
Sealed
ROCK ALTERATION
Oxidized
Chloritisized
Albitization
SILICATE DENSITY
SUSCEPTIBILITET
FRACTURE SURFACE
Rough
Smooth
ROCK ALTERATION INTENSITY
Faint
Weak
Medium
Strong
ROCK OCURRENCE
Granite, fine- to medium-grained
Pegmatite, pegmatitic granite
Granite, granodiorite and tonalite,
Granite to granodiorite, metamor
Amphibolite
ROCK TEXTURE
Equigranular
Metamorphic
FRACTURE ALTERATION ORIENTATION
1 - Slightly Altered
2 - Moderately Altered
3 - Highly Altered
ROCK GRAINSIZE
Fine-grained
Fine to medium grained
NATURAL GAMMA
DIP / DIRECTION
BH Length
M.A.S.L.
ROCK TYPE
FRACTURE FREQUENCY
FRACTURE ALTERATION ORIENTATION
SEALED NETWORK
CRUSH ZONES AND CORELOSS
HYDROLOGY
NO DATA IN SICADA FOR THIS IN KFM26



Title GEOLOGICAL SINGLE-HOLE INTERPRETATION KFM27
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Borehole KFM27
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Length [m] 100.640
Bearing [°] 322.00
Coordinate System SWEREF 99 18 00 RH 2000
Northing [m] 6698854.47
Easting [m] 159597.05
Inclination [°] -74.96
Elevation [m.a.s.l.] 2.54
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Drilling Stop Date 2019-10-09 17:00:00
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Plot Date 2020-02-24 15:05:17
In Use OK
Activity Type GE058
Strike Reference SWEREF 99 18 00 RH 2000
Made by PKM
ROCK TYPE FORSMARK
Granite, fine- to medium-grained
Pegmatite, pegmatitic granite
Granite to granodiorite, metamo
ROCK STRUCTURE
Massive
Foliated
ROCK STRUCTURE ORIENTATION
Foliated
FRACTURE ORIENTATION
Open
Sealed
ROCK ALTERATION
Oxidized
SILICATE DENSITY
SUSCEPTIBILITET
FRACTURE SURFACE
Rough
Smooth
Slickensided
ROCK ALTERATION INTENSITY
Faint
Weak
FRACTURE ALTERATION ORIENTATION
1 - Slightly Altered
2 - Moderately Altered
3 - Highly Altered
NATURAL GAMMA
ROCK OCURRENCE
Granite, fine- to medium-grained
Pegmatite, pegmatitic granite
Granite to granodiorite, metamor
ROCK TEXTURE
Equigranular
Unequigranular
Metamorphic
ROCK GRAINSIZE
Fine to medium grained
Medium to coarse grained
DIP / DIRECTION
ROCK TYPE
FRACTURE FREQUENCY
FRACTURE ALTERATION ORIENTATION
SEALED NETWORK
CRUSH ZONES AND CORELOSS
HYDROLOGY

Title	GEOLOGICAL SINGLE-HOLE INTERPRETATION HFM42					SIGNED DATA	SICADA
Site	FORSMARK	Bearing [°]	176.19	Inclination [°]	-89.11	Surveying Date	2020-02-24 02:01:33
Borehole	HFM42	Coordinate System	SWEREF 99 18 00 RH 2000	Elevation [m.a.s.l.]	4.21	Plot Date	2020-02-24 15:12:47
Diameter [mm]	138	Northing [m]	6698418.32	Drilling Start Date	2018-04-10 08:00:00	In Use	OK
Length [m]	195.300	Easting [m]	160094.17	Drilling Stop Date	2018-04-11 14:00:00	Activity Type	GE063

Strike Reference: SWEREF 99 18 00 RH 2000
Made by: PKM

ROCK TYPE FORSMARK
- Pegmatite, pegmatitic granite
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite

ROCK STRUCTURE
- Massive
- Foliated

ROCK STRUCTURE ORIENTATION
- Foliated

ROCK ALTERATION INTENSITY

ROCK OCURRENCE
- Pegmatite, pegmatitic granite
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Amphibolite

ROCK TEXTURE
- Metamorphic

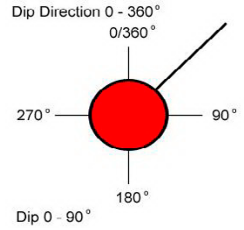
ROCK ALTERATION

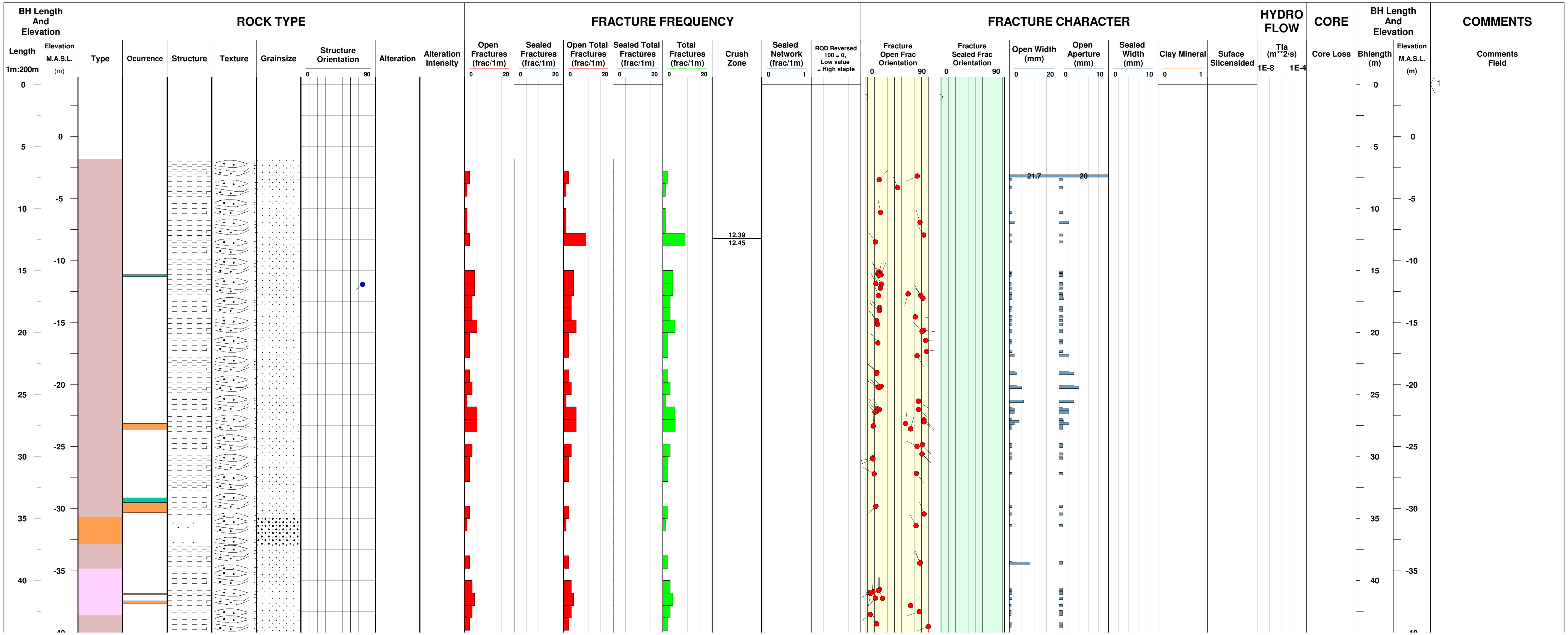
OPEN FRACTURE ORIENTATION
- Open fracture orientation

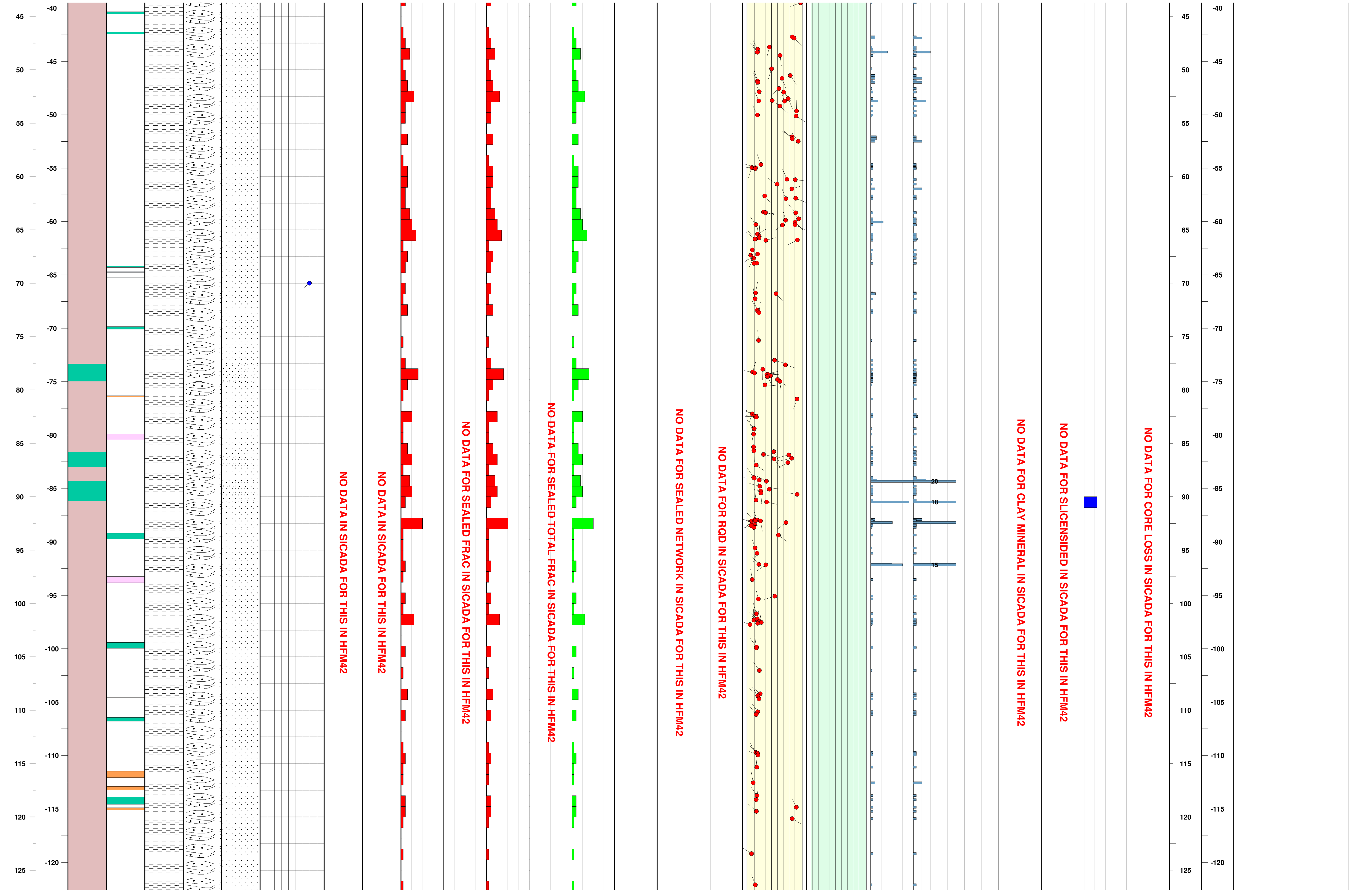
SEALED FRACTURE ORIENTATION

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

DIP / DIRECTION



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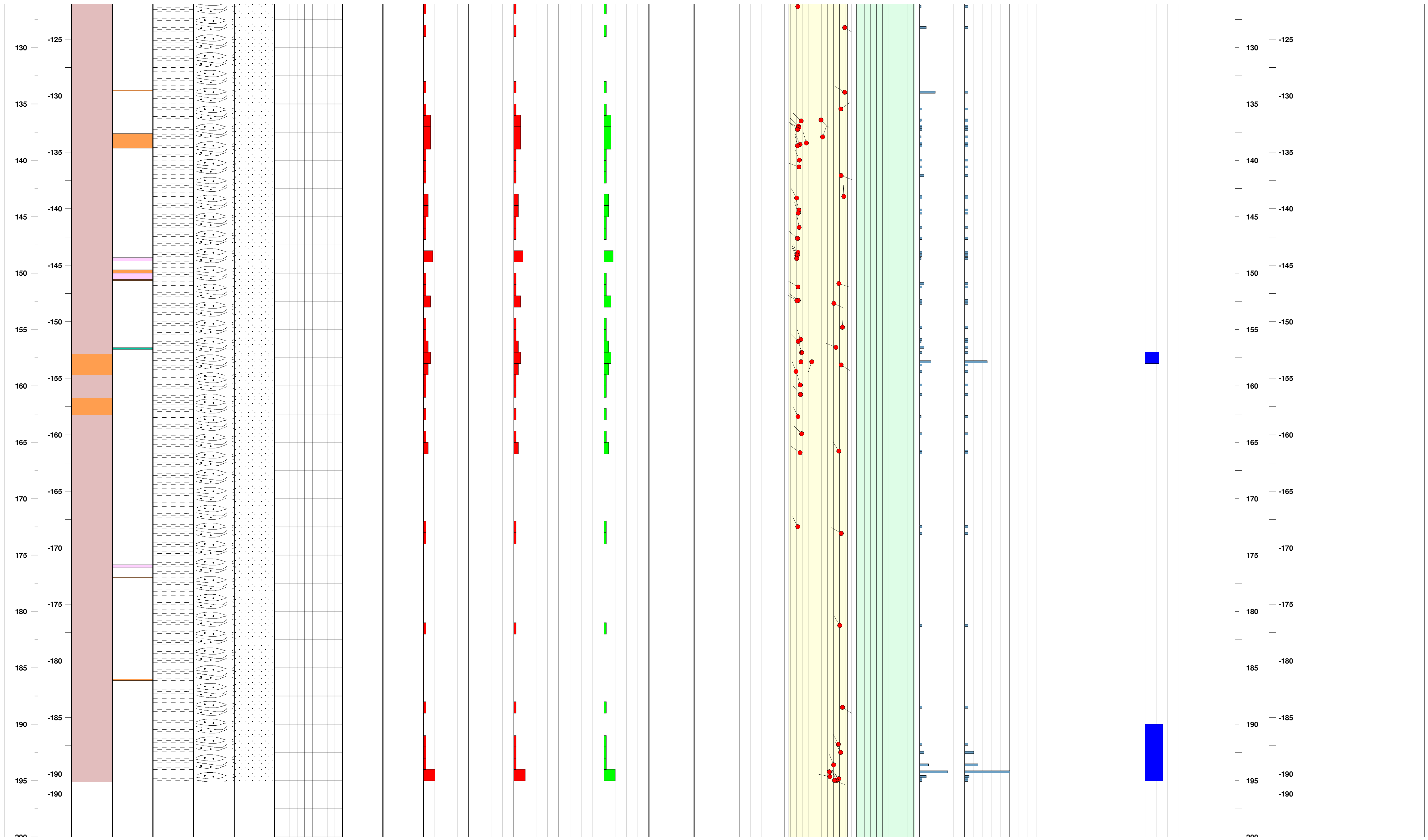
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Title GEOLOGICAL SINGLE-HOLE INTERPRETATION HFM43 **SIGNED DATA** SICADA

Site	FORSMARK	**Bearing [°]**	303.79	**Inclination [°]**	-85.20	**Surveying Date**	2020-02-25 02:01:33	**Strike Reference**	SWEREF 99 18 00 RH 2000
Borehole	HFM43	**Coordinate System**	SWEREF 99 18 00 RH 2000	**Elevation [m.a.s.l.]**	4.33	**Plot Date**	2020-02-25 16:31:06	**Made by**	PKM
Diameter [mm]	137	**Northing [m]**	6698537.92	**Drilling Start Date**	2018-04-12 08:00:00	**In Use**	OK		
Length [m]	200.000	**Easting [m]**	160064.53	**Drilling Stop Date**	2018-04-23 20:30:00	**Activity Type**	GE063		

ROCK TYPE FORSMARK
- **Pegmatite, pegmatitic granite**
- **Granite to granodiorite, metamorphic, medium-grained**
- **Amphibolite**

ROCK OCURRENCE
- **Pegmatite, pegmatitic granite**
- **Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained**
- **Amphibolite**

ROCK STRUCTURE
- **Massive**
- **Lineated**

ROCK TEXTURE
- **Metamorphic**

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

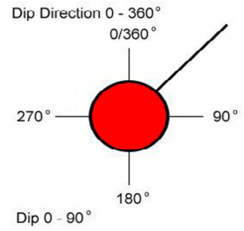
ROCK STRUCTURE ORIENTATION
- **Foliated**

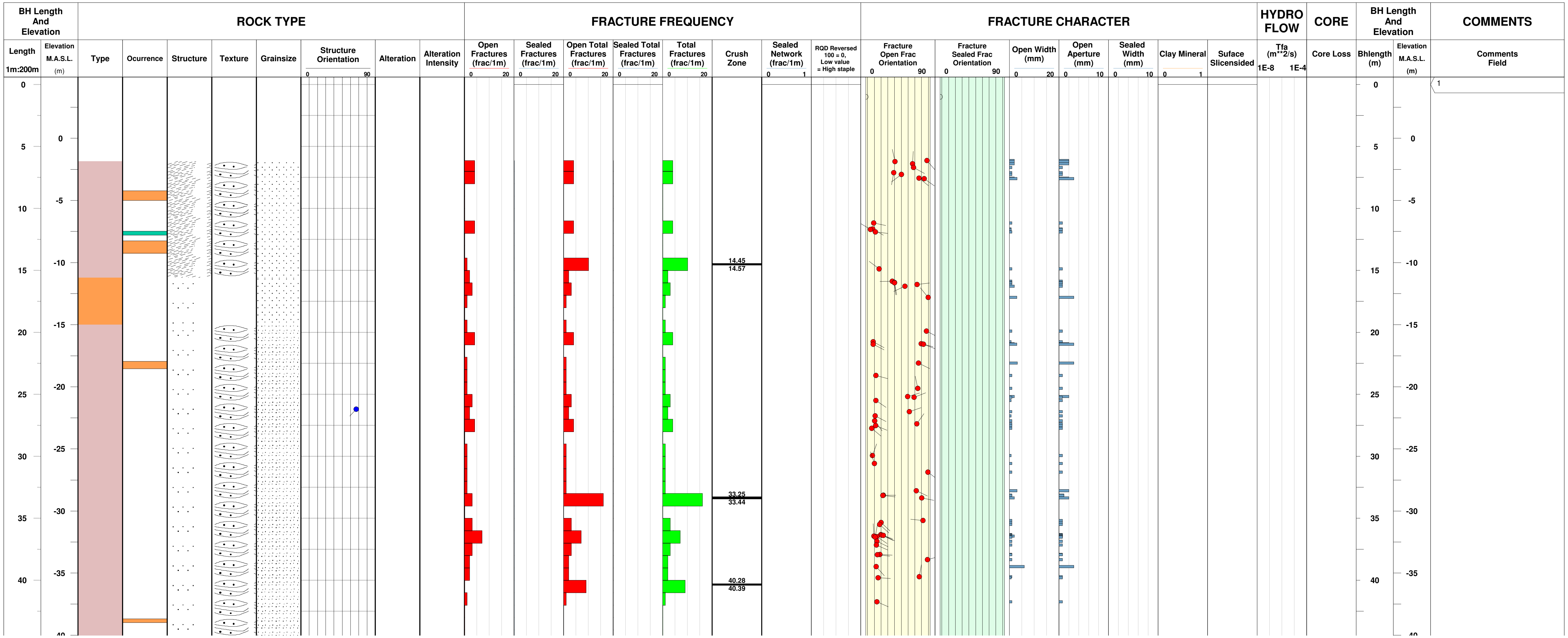
ROCK ALTERATION

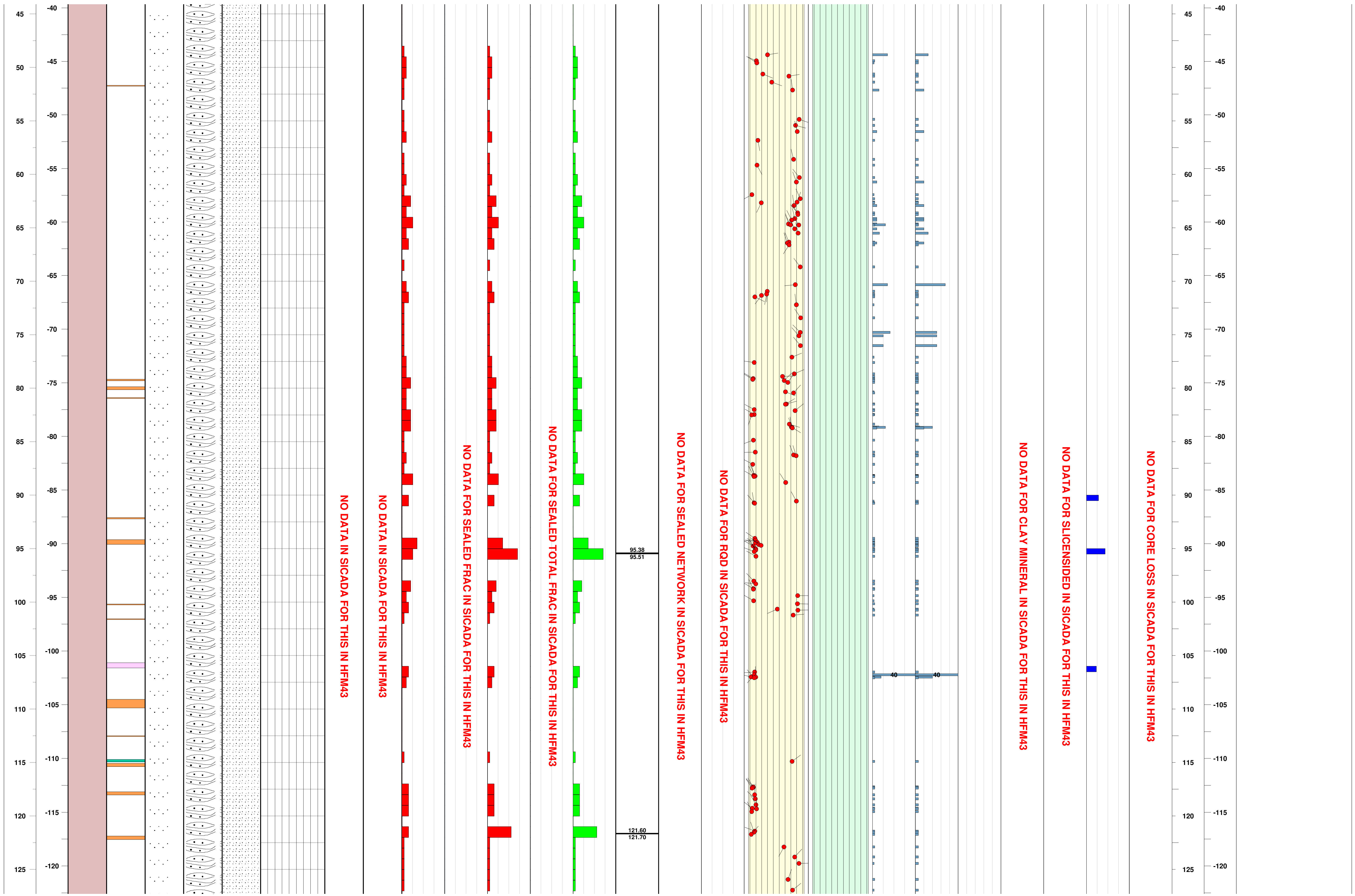
ROCK ALTERATION INTENSITY

OPEN FRACTURE ORIENTATION
- **Open fracture orientation**

SEALED FRACTURE ORIENTATION



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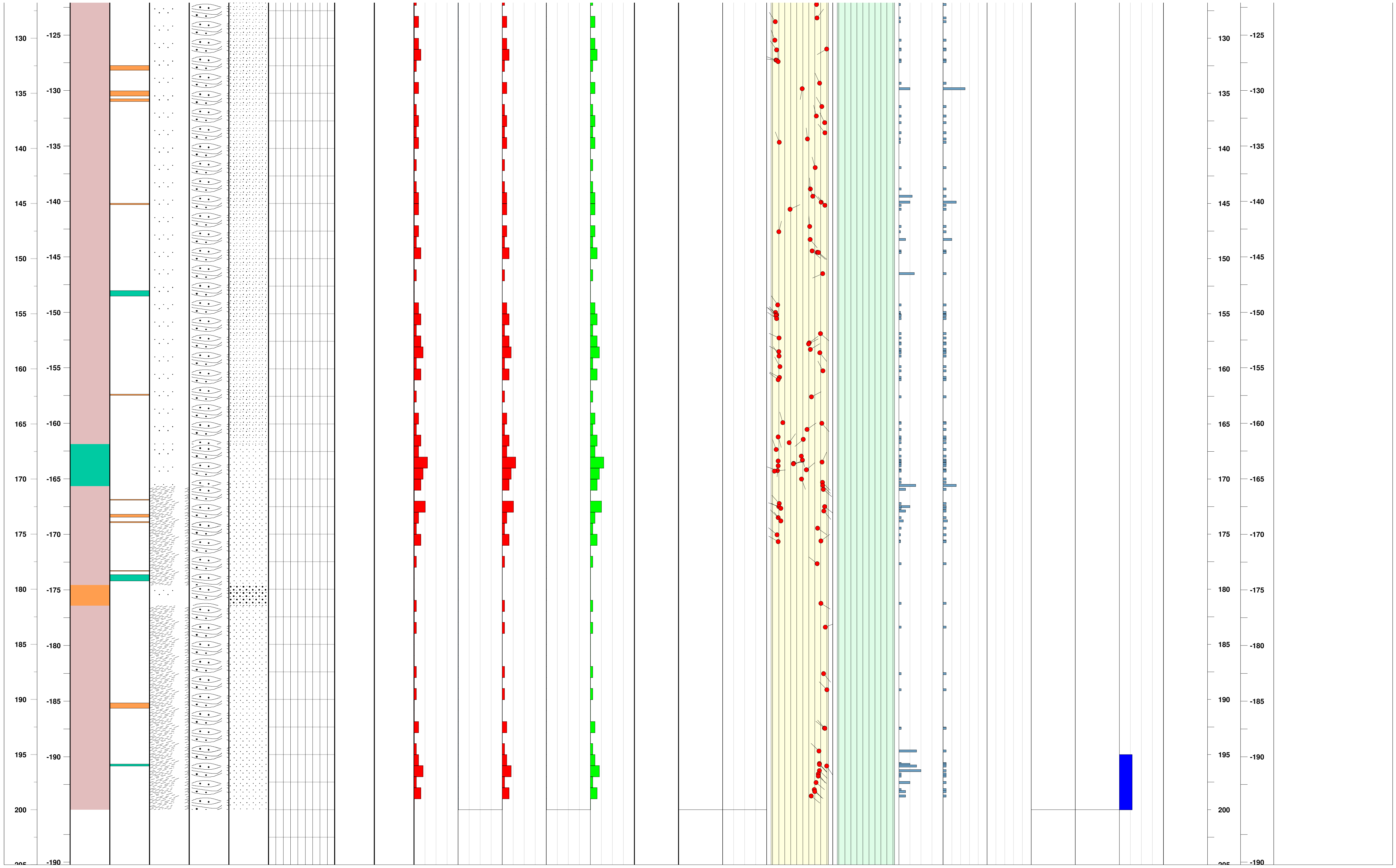
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Title	GEOLOGICAL SINGLE-HOLE INTERPRETATION HFM44					SIGNED DATA	SICADA
Site	FORSMARK	Bearing [°]	255.72	Inclination [°]	-83.18	Surveying Date	2020-02-25 02:01:33
Borehole	HFM44	Coordinate System	SWEREF 99 18 00 RH 2000	Elevation [m.a.s.l.]	2.94	Plot Date	2020-02-25 16:35:27
Diameter [mm]	134	Northing [m]	6699322.21	Drilling Start Date	2018-04-23 07:00:00	In Use	OK
Length [m]	199.600	Easting [m]	161395.20	Drilling Stop Date	2018-04-26 12:00:00	Activity Type	GE063

Strike Reference	SWEREF 99 18 00 RH 2000
Made by	PKM

ROCK TYPE FORSMARK

- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained
- Felsic to intermediate volcanic rock, metamorphic

ROCK STRUCTURE

- Gneissic
- Massive
- Foliated

ROCK STRUCTURE ORIENTATION

- Foliated

ROCK ALTERATION INTENSITY

ROCK OCURRENCE

- Pegmatite, pegmatitic granite
- Granite, granodiorite and tonalite, metamorphic, fine- to medium-grained
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite
- Felsic to intermediate volcanic rock, metamorphic

ROCK TEXTURE

- Metamorphic

ROCK ALTERATION

ROCK GRAINSIZE

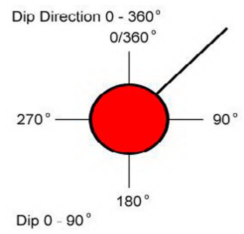
- Fine to medium grained
- Medium to coarse grained
- Medium-grained

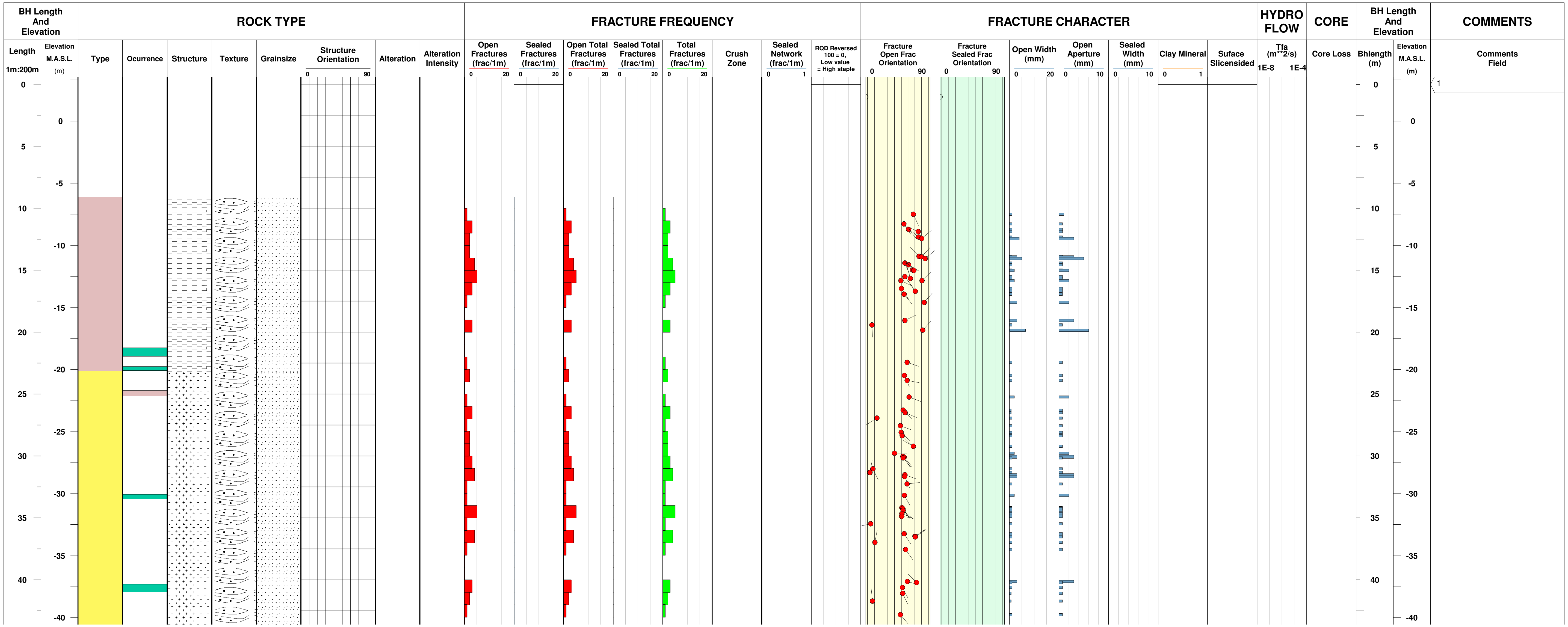
OPEN FRACTURE ORIENTATION

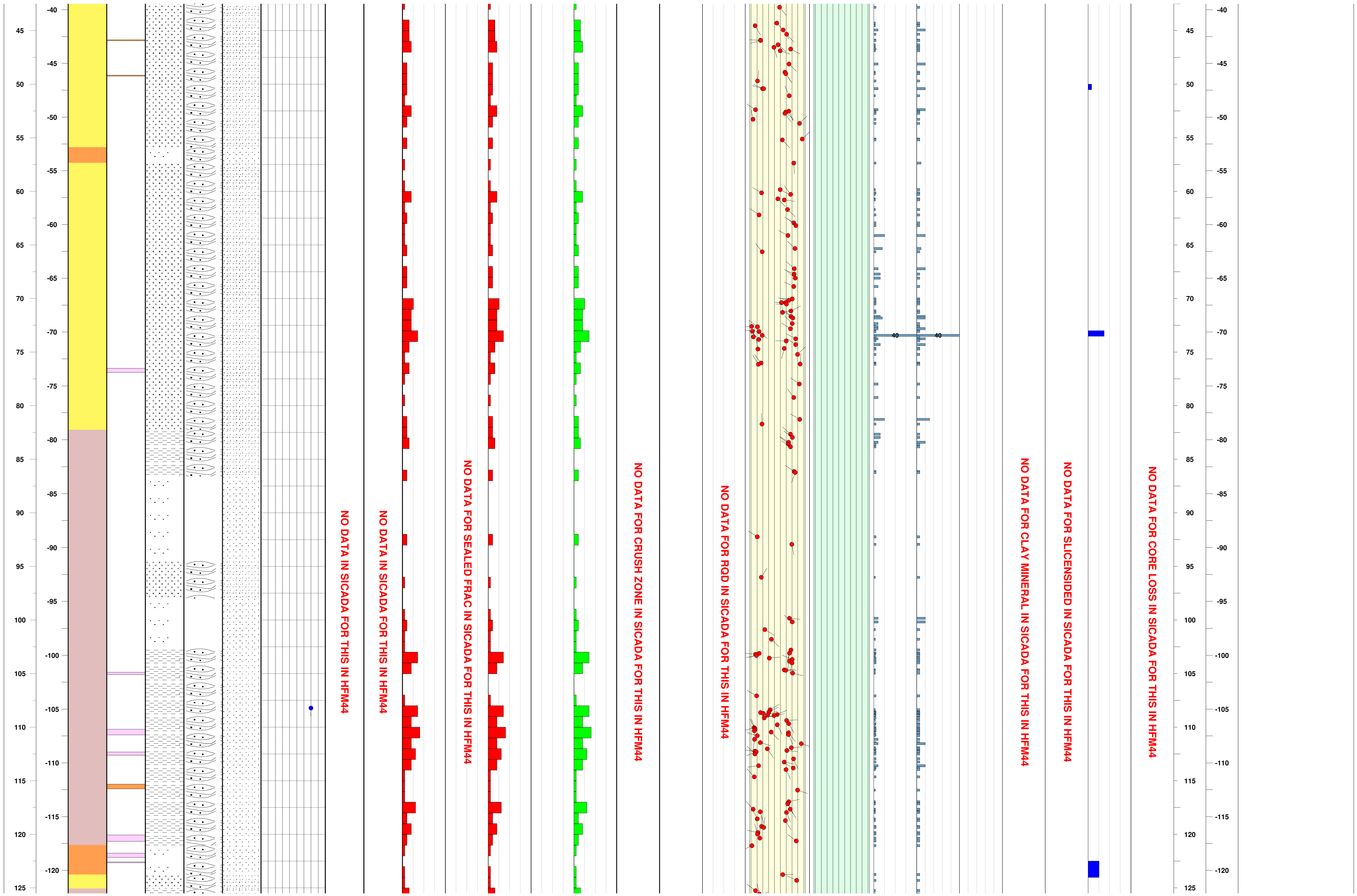
- Open fracture orientation

SEALED FRACTURE ORIENTATION

DIP / DIRECTION



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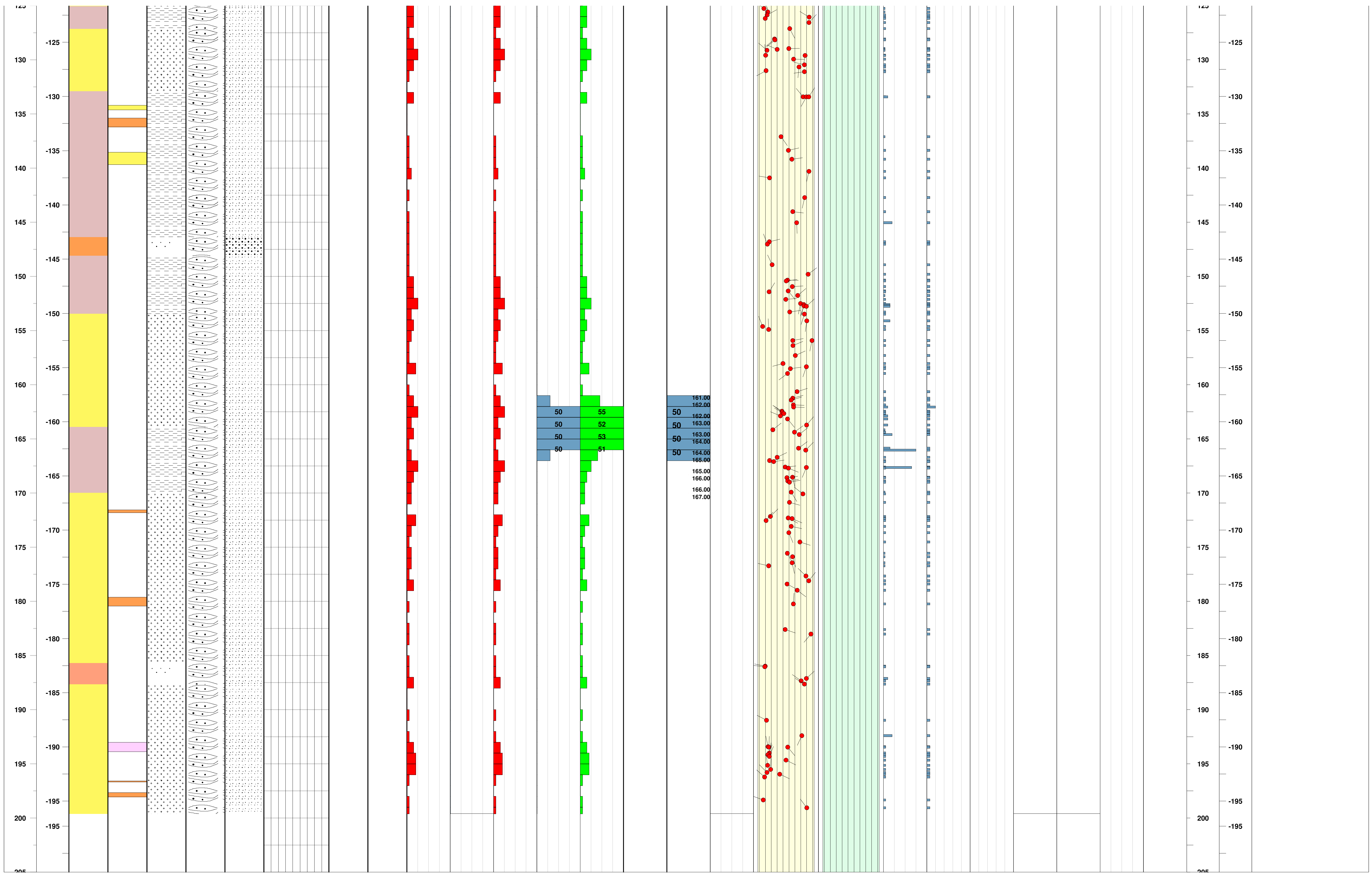

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Title	GEOLOGICAL SINGLE-HOLE INTERPRETATION HFM45					SIGNED DATA	SICADA		
Site	FORSMARK	Bearing [°]	291.20	Inclination [°]	-84.97	Surveying Date	2020-02-25 02:01:33	Strike Reference	SWEREF 99 18 00 RH 2000
Borehole	HFM45	Coordinate System	SWEREF 99 18 00 RH 2000	Elevation [m.a.s.l.]	3.86	Plot Date	2020-02-25 16:37:50	Made by	PKM
Diameter [mm]	139	Northing [m]	6699603.14	Drilling Start Date	2018-05-02 08:00:00	In Use	OK		
Length [m]	200.300	Easting [m]	161117.22	Drilling Stop Date	2018-05-04 08:00:00	Activity Type	GE063		

ROCK TYPE FORSMARK
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite
- Felsic to intermediate volcanic rock, metamorphic

ROCK OCURRENCE
- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Amphibolite

ROCK STRUCTURE
- Gneissic
- Massive
- Foliated

ROCK TEXTURE
- Metamorphic

ROCK GRAINSIZE
- Fine to medium grained
- Medium-grained

ROCK STRUCTURE ORIENTATION

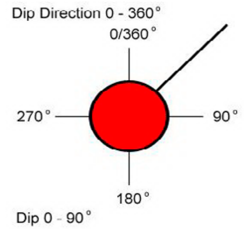
ROCK ALTERATION

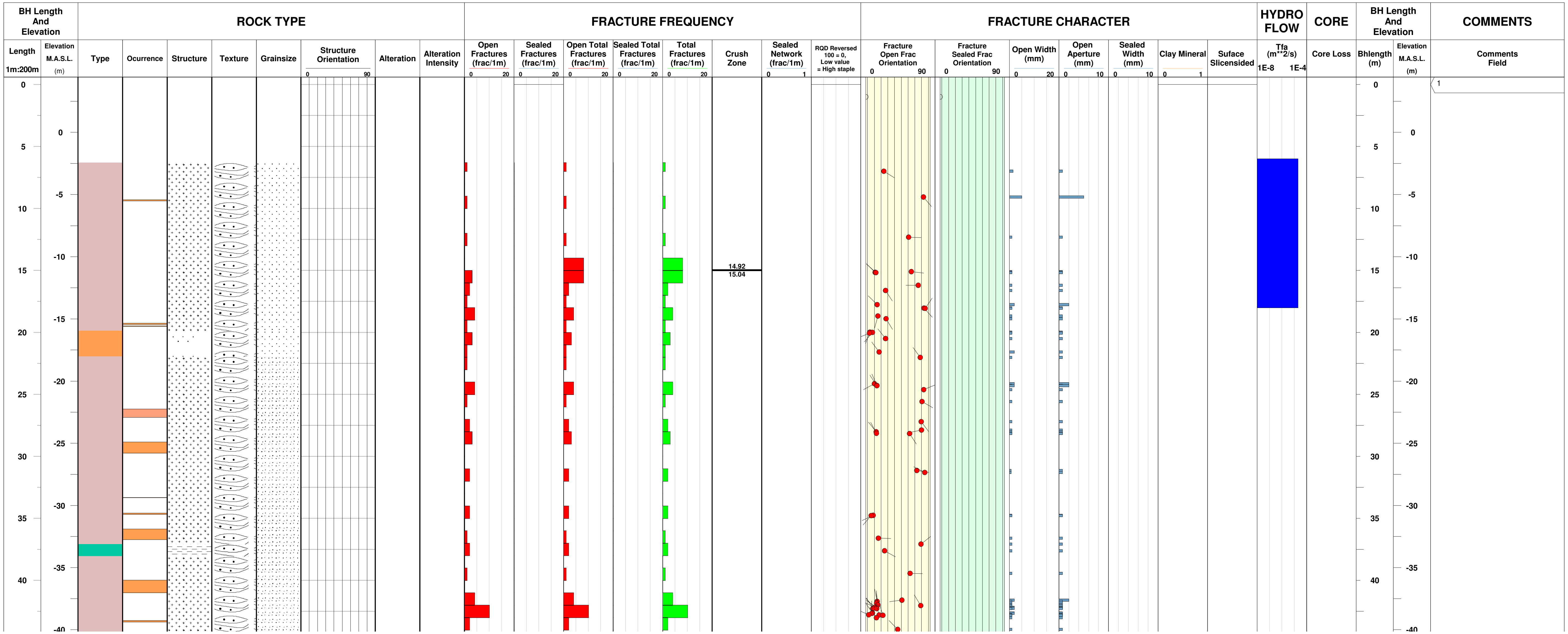
ROCK ALTERATION INTENSITY

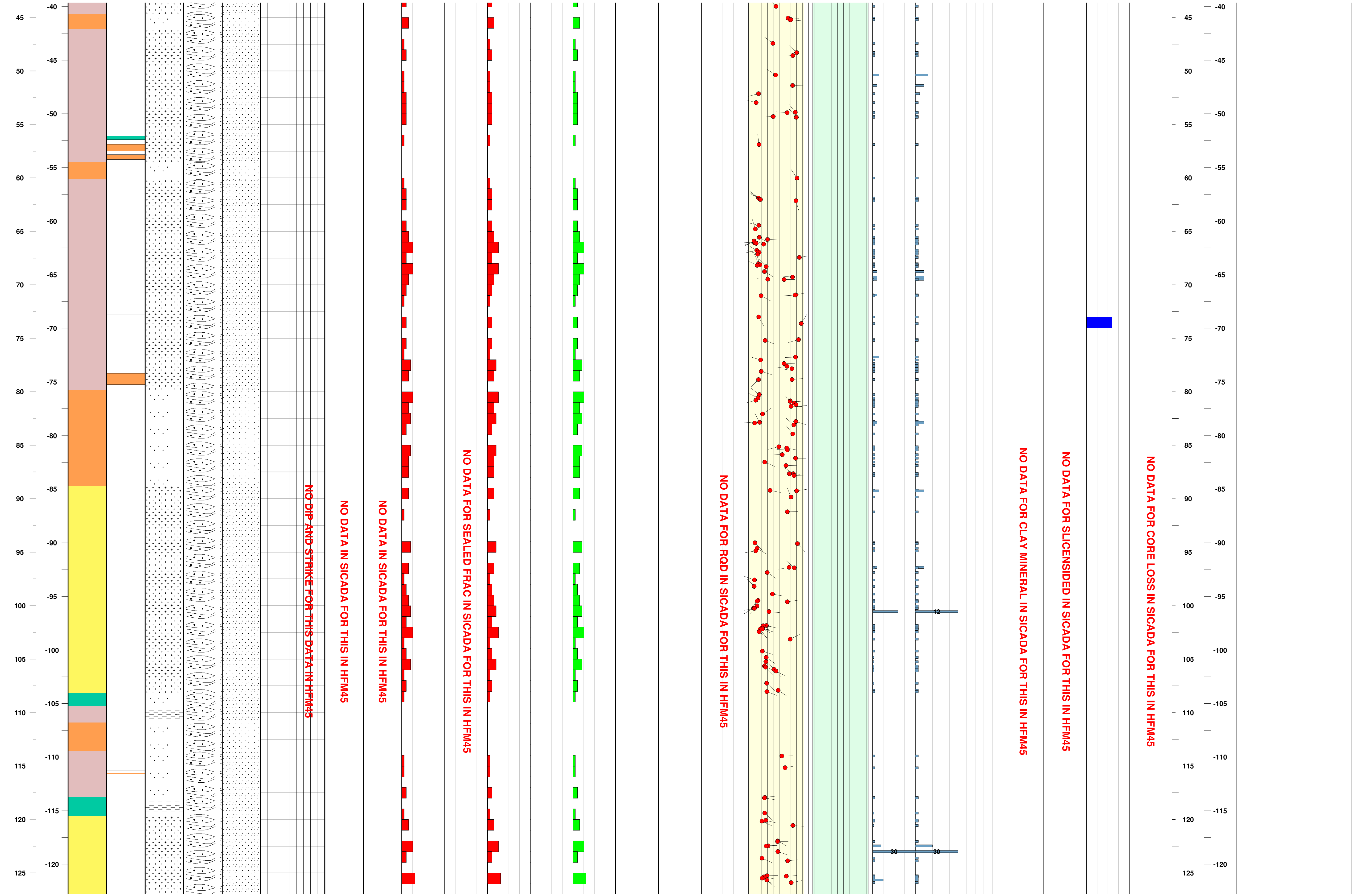
OPEN FRACTURE ORIENTATION
- Open fracture orientation

SEALED FRACTURE ORIENTATION

DIP / DIRECTION



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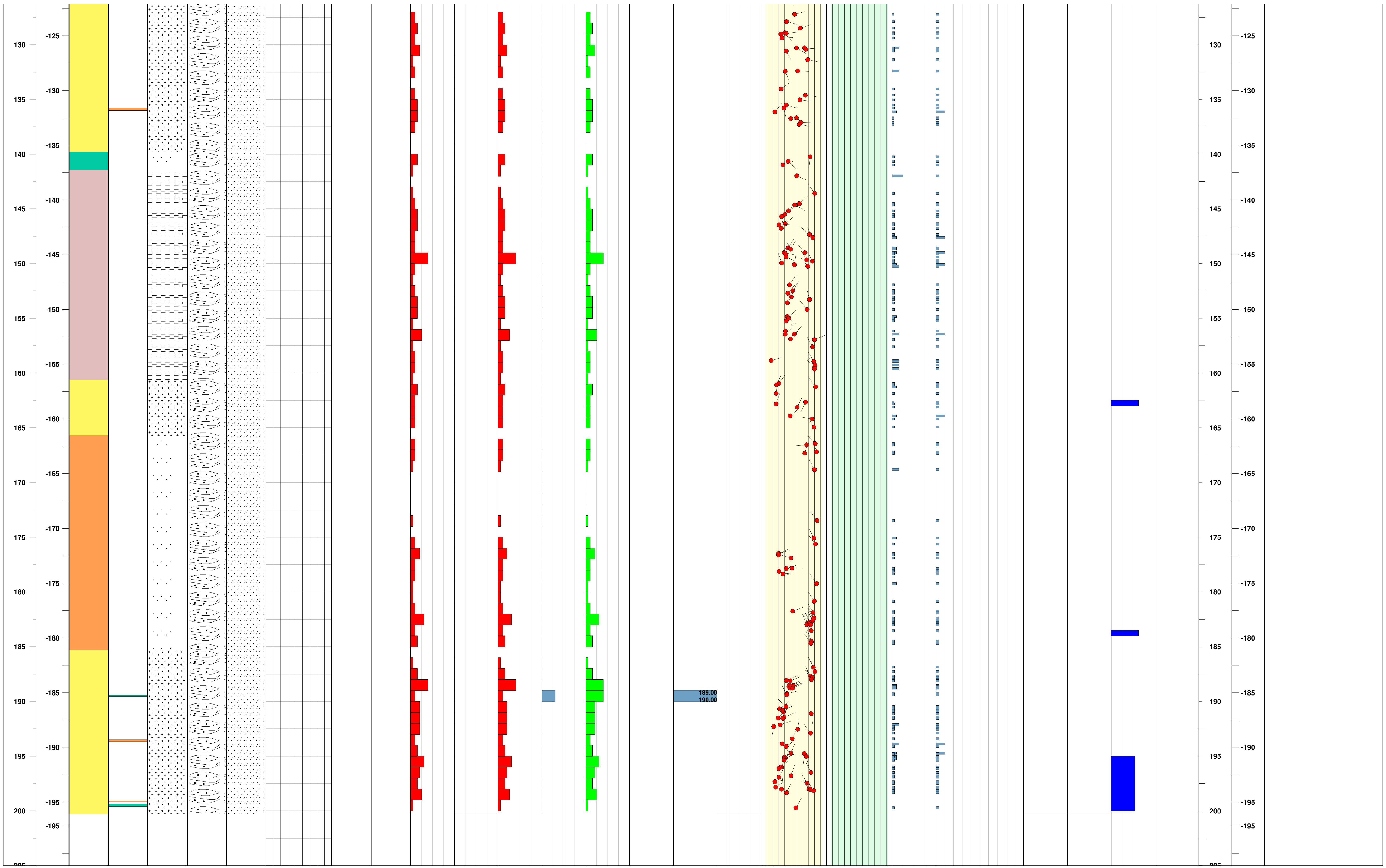


Title GEOLOGICAL SINGLE-HOLE INTERPRETATION HFM46 — **SIGNED DATA** SICADA

Site	FORSMARK	Bearing [°]	108.14	Inclination [°]	-85.40	Surveying Date	2020-02-25 02:01:33
Borehole	HFM46	Coordinate System	SWEREF 99 18 00 RH 2000	Elevation [m.a.s.l.]	1.70	Plot Date	2020-02-25 16:40:49
Diameter [mm]	138	Northing [m]	6699951.07	Drilling Start Date	2018-05-07 07:00:00	In Use	OK
Length [m]	200.000	Easting [m]	161324.55	Drilling Stop Date	2018-05-09 08:00:00	Activity Type	GE063

Strike Reference: SWEREF 99 18 00 RH 2000
Made by: PKM

ROCK TYPE FORSMARK
- Granite, fine- to medium-grained
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite
- Felsic to intermediate volcanic rock, metamorphic

ROCK OCURRENCE
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite

ROCK STRUCTURE
- Gneissic
- Massive

ROCK TEXTURE
- Metamorphic

ROCK GRAINSIZE
- Fine to medium grained
- Medium-grained

ROCK STRUCTURE ORIENTATION
- Gneissic
- Banded

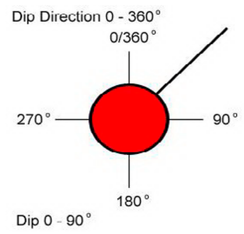
ROCK ALTERATION

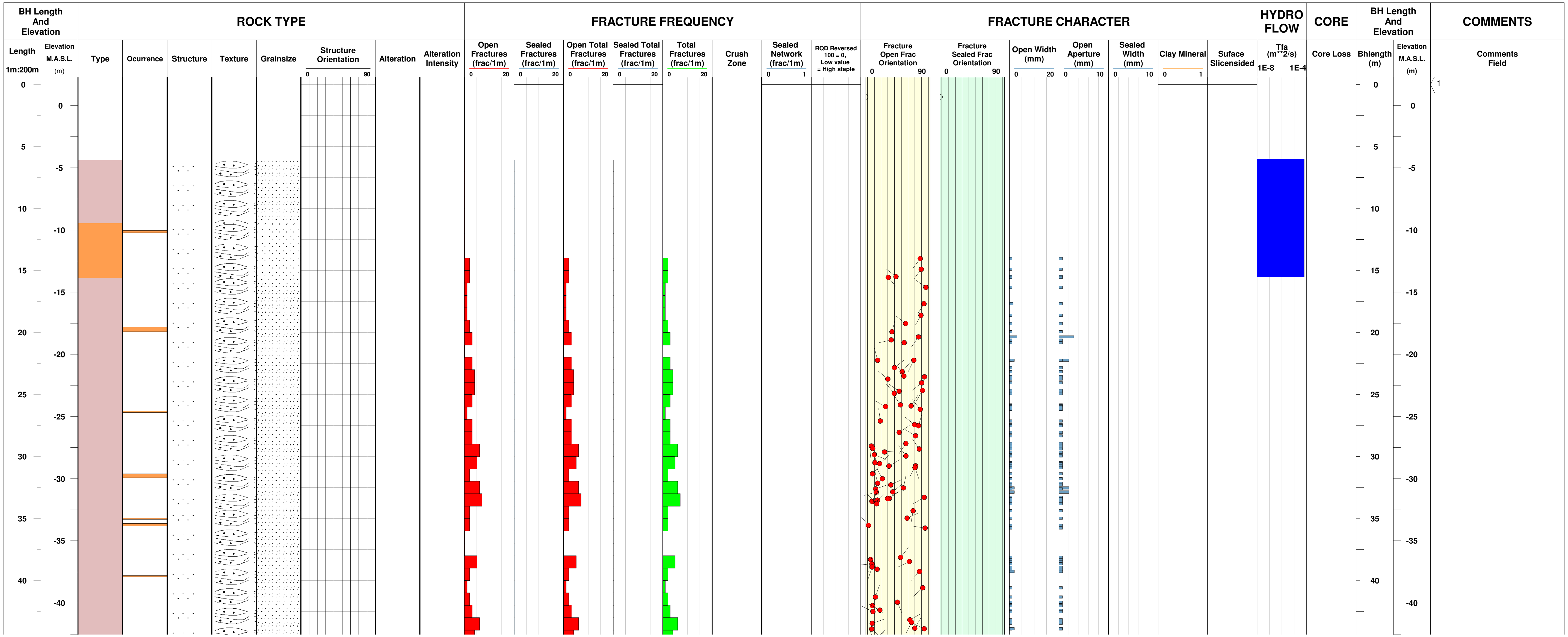
ROCK ALTERATION INTENSITY

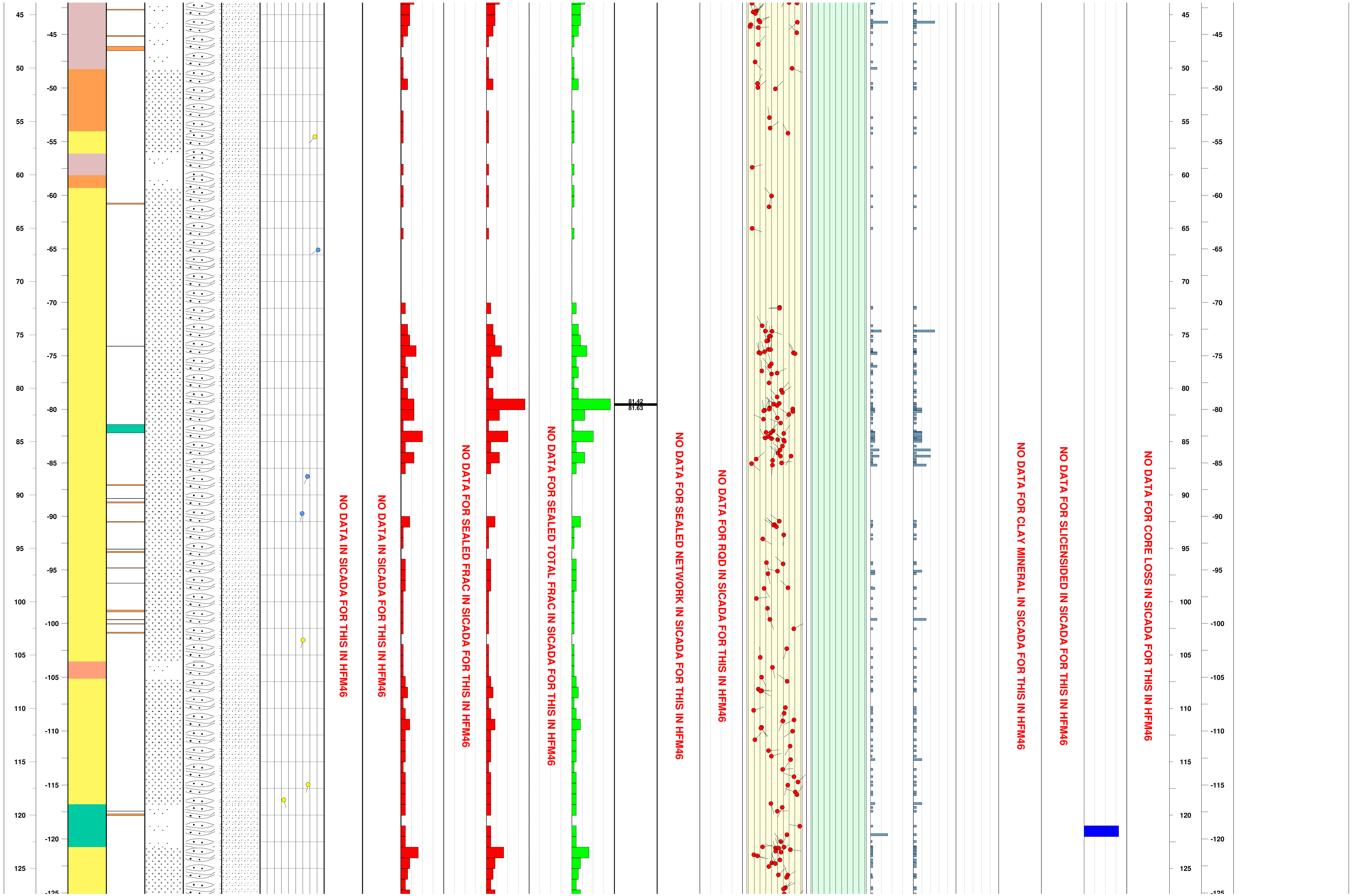
OPEN FRACTURE ORIENTATION
- Open fracture orientation

SEALED FRACTURE ORIENTATION

DIP / DIRECTION



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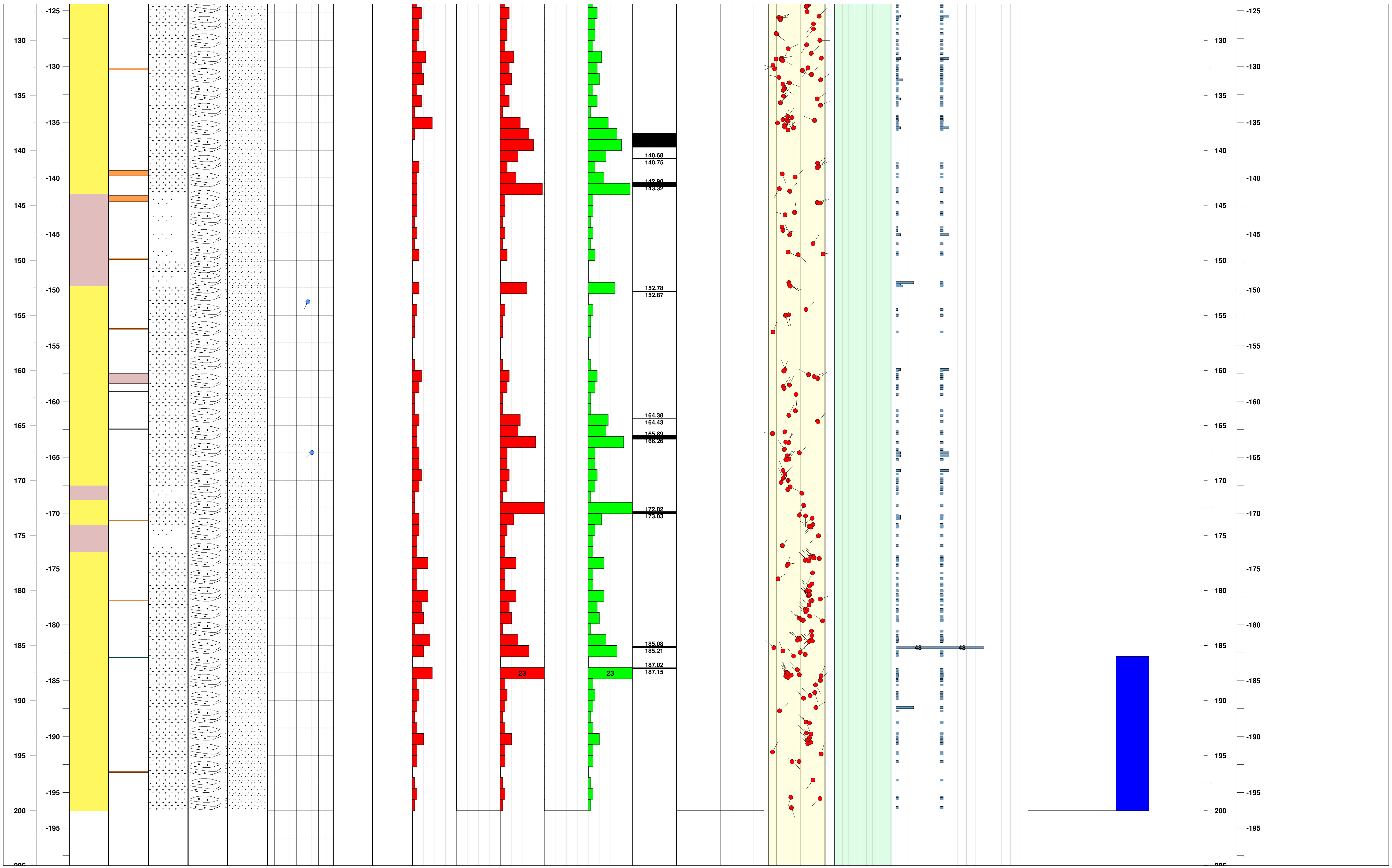

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Title	GEOLOGICAL SINGLE-HOLE INTERPRETATION HFM47					SIGNED DATA	SICADA
Site	FORSMARK	Bearing [°]	150.00	Inclination [°]	-84.41	Surveying Date	2020-02-25 02:01:33
Borehole	HFM47	Coordinate System	SWEREF 99 18 00 RH 2000	Elevation [m.a.s.l.]	3.52	Plot Date	2020-02-25 16:43:17
Diameter [mm]	138	Northing [m]	6699398.78	Drilling Start Date	2019-09-04 15:00:00	In Use	OK
Length [m]	200.400	Easting [m]	161283.41	Drilling Stop Date	2019-09-05 19:00:00	Activity Type	GE063

Strike Reference: SWEREF 99 18 00 RH 2000
Made by: PKM

ROCK TYPE FORSMARK
- Pegmatite, pegmatitic granite
- Granite to granodiorite, metamorphic, medium-grained
- Amphibolite
- Felsic to intermediate volcanic rock, metamorphic

ROCK STRUCTURE
- Massive
- Foliated

ROCK STRUCTURE ORIENTATION
- Foliated

ROCK ALTERATION INTENSITY

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

ROCK TEXTURE
- Metamorphic

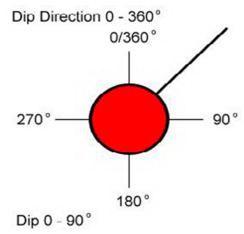
ROCK ALTERATION

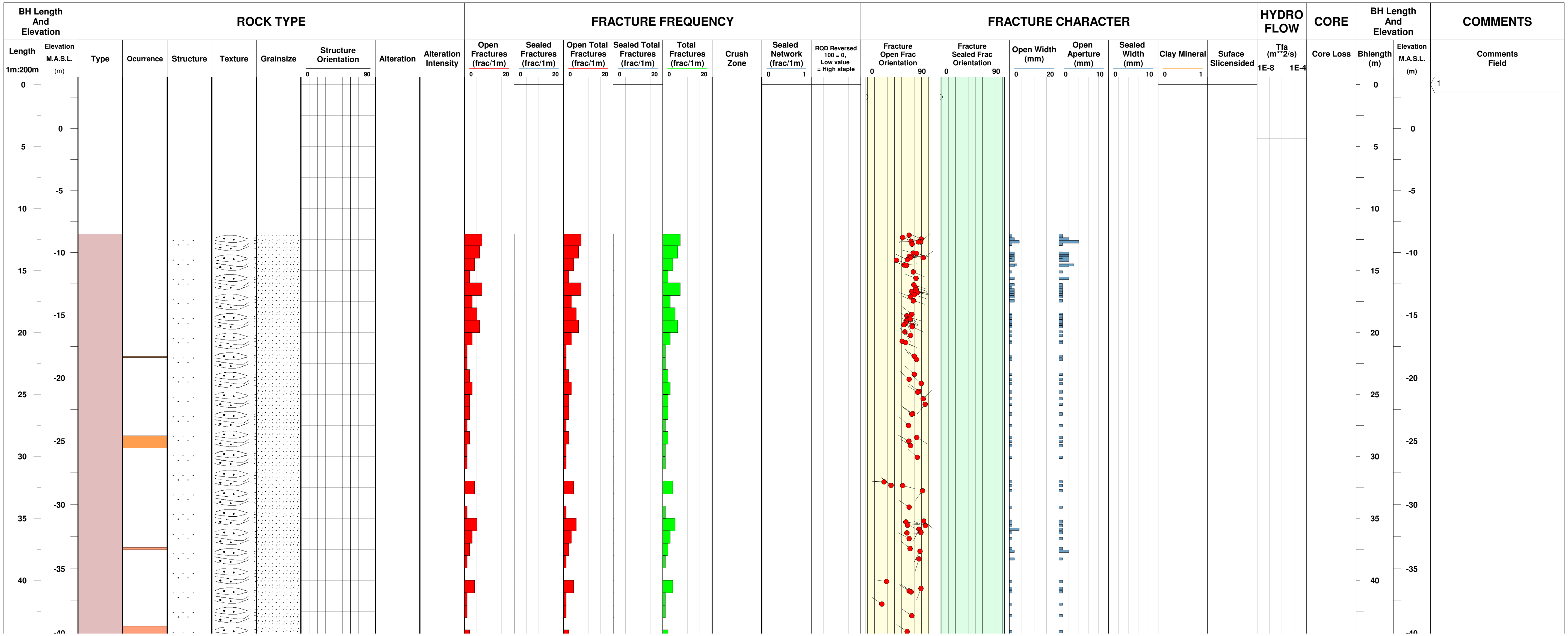
OPEN FRACTURE ORIENTATION
- Open fracture orientation

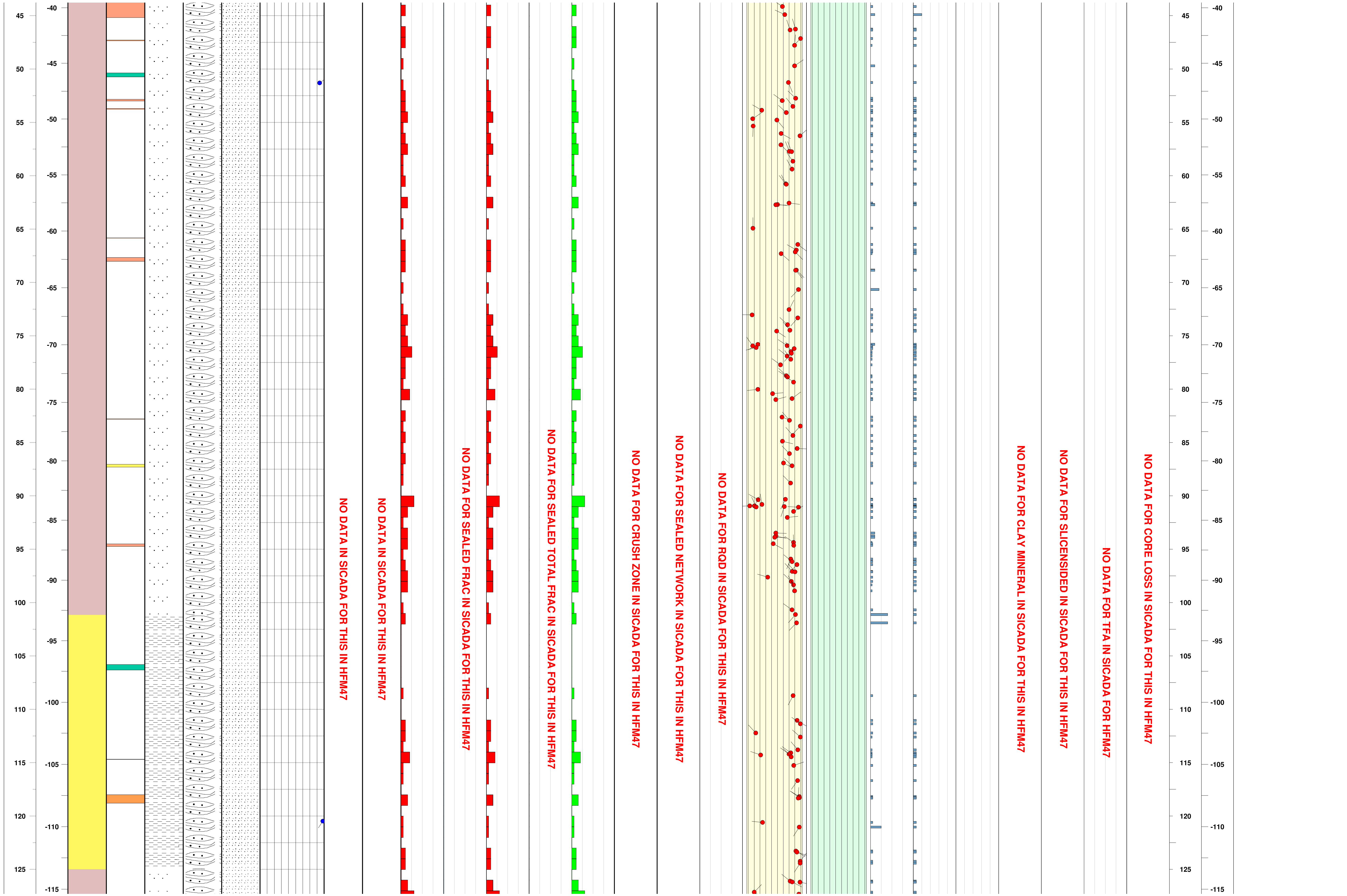
SEALED FRACTURE ORIENTATION

ROCK GRAINSIZE
- Fine to medium grained
- Medium-grained

DIP / DIRECTION



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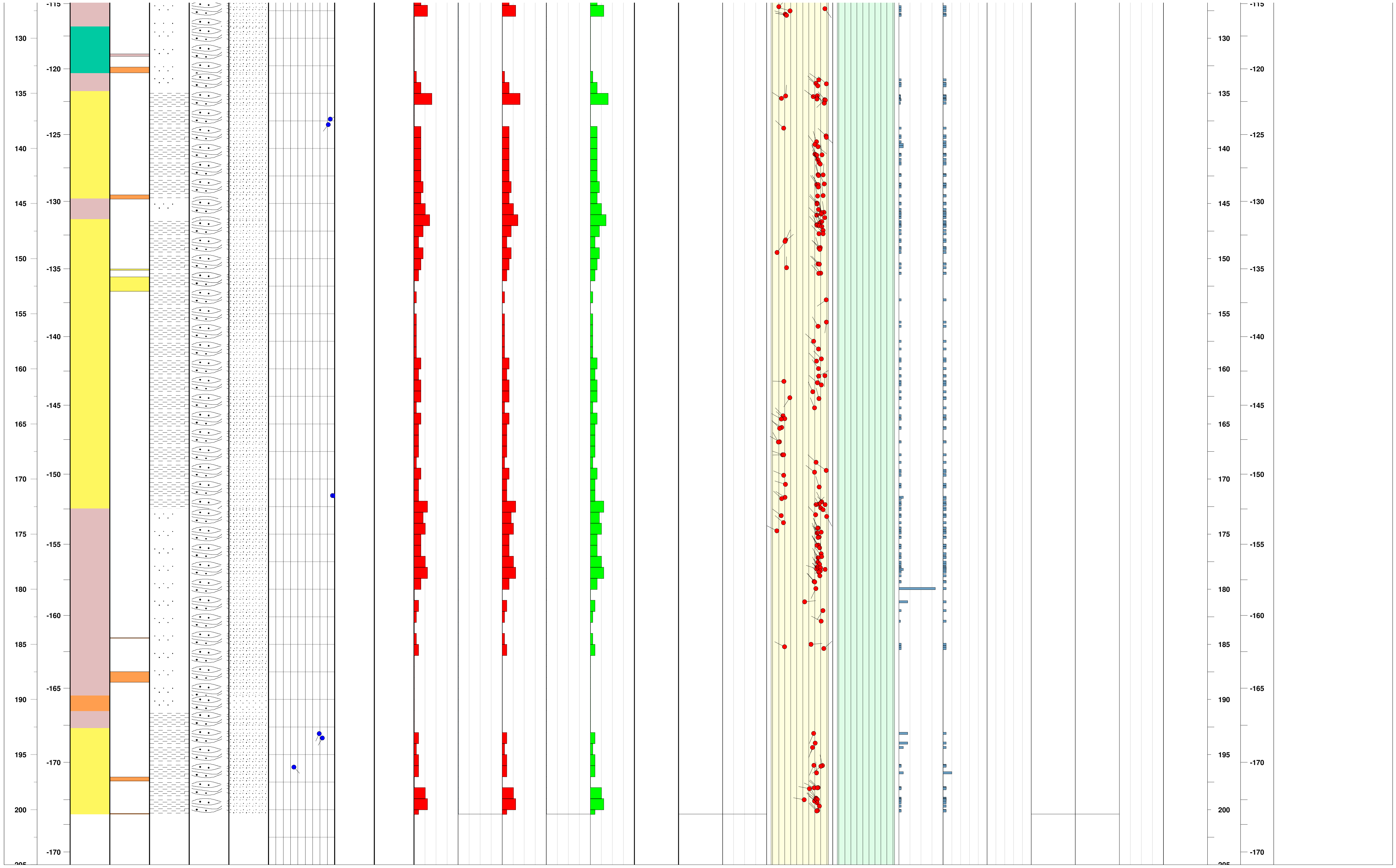
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Arkitektkopia AB, Bromma, 2020

SKB is responsible for managing spent nuclear fuel and radioactive waste produced by the Swedish nuclear power plants such that man and the environment are protected in the near and distant future.

skb.se