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Keywords: Geophysics, Rock unit, Borehole, Deformation zone, Fractures, Alteration.

Abstract

This report contains geological single-hole interpretation of the cored boreholes KLX07A and KLX07B and the percussion drilled boreholes HLX34 and HLX35 at Laxemar. The interpretation combines the geological core mapping, interpreted geophysical logs and borehole radar measurements to identify rock units and possible deformation zones in the borehole.

The geological single-hole interpretation shows that two rock units (RU1–RU2) occur in KLX07A. However, the borehole can be divided into three separate sections due to the repetition of rock unit RU1. The borehole is totally dominated by Ävrö granite (501044). Subordinate rock types are fine-grained diorite-gabbro (505102), fine-grained granite (511058) and pegmatite (501061). Thirteen possible deformation zones have been identified in KLX07A (DZ1–DZ13).

The geological single-hole interpretation shows that borehole KLX07B is dominated by Ävrö granite (501044), which constitutes one rock unit (RU1). Fine-grained granite (511058), fine-grained diorite-gabbro (505102), fine-grained dioritoid (501030) and quartz monzodiorite (501036) occur in shorter sections. Three possible deformation zones have been identified in KLX07B (DZ1–DZ3).

The percussion borehole HLX34 is dominated by Ävrö granite (501044), which constitutes one rock unit (RU1). Fine-grained diorite-gabbro (505102), fine-grained granite (511058), diorite/gabbro (501033) and granite (501058) occur in shorter sections. Five possible deformation zones have been identified in HLX34 (DZ1–DZ5).

The percussion borehole HLX35 is dominated by Ävrö granite (501044), which constitutes one rock unit (RU1). Fine-grained granite (511058), pegmatite (501061) and diorite/gabbro (501033) occur in scattered minor sections. One possible deformation zone has been identified in HLX35 (DZ1).

Sammanfattning

Denna rapport behandlar geologisk enhålstolkning av kärnborrhålen KLX07A och KLX07B samt hammarborrhålen HLX34 och HLX35 i Laxemar. Den geologiska enhålstolkningen syftar till att utifrån den geologiska karteringen, tolkade geofysiska loggar och borrhålsradarmätningar identifiera olika litologiska enheters fördelning i borrhålen samt möjliga deformationszoners läge och utbredning.

Två litologiska enheter (RU1–RU2) har identifierats i KLX07A. Baserat på upprepning av RU1 kan borrhålet delas in i tre sektioner. Generellt sett domineras borrhålet av Ävrö granit (501044). Finkornig diorit-gabbro (505102), finkornig granit (511058) och pegmatit (501061) förekommer i mindre omfattning. Tretton möjliga deformationszoner har identifierats i KLX07A (DZ1–DZ13).

Den geologiska enhålstolkningen visar att borrhål KLX07B domineras av Ävrö granit (501044), vilken utgör en litologisk enhet (RU1). Finkornig granit (511058), finkornig diorit-gabbro (505102) och kvartsmonzodiorit (501036) förekommer i mindre omfattning. Tre möjliga deformationszoner har identifierats i KLX07B (DZ1–DZ3).

Hammarborrhål HLX34 domineras av Ävrö granit (501044), vilken utgör en litologisk enhet (RU1). Finkornig diorit-gabbro (505102), finkornig granit (511058), diorit/gabbro (501033) och granit (501058) förekommer i mindre omfattning. Fem möjliga deformationszoner har identifierats i HLX34 (DZ1–DZ5).

Hammarborrhål HLX35 domineras av Ävrö granit (501044), vilken utgör en litologisk enhet (RU1). Finkornig granit (511058), pegmatit (501061) och diorit/gabbro (501033) förekommer i mindre omfattning. En möjlig deformationszon har identifierats i HLX35 (DZ1).

Contents

1 Introduction

Much of the primary geological and geophysical borehole data stored in the SKB database SICADA need to be integrated and synthesized before they can be used for modeling in the 3D-CAD system Rock Visualization System (RVS). The end result of this procedure is a geological single-hole interpretation, which consists of integrated series of different loggings and accompanying descriptive documents (SKB MD 810.003, SKB internal controlling document).

This document reports the results gained by the geological single-hole interpretation of the cored boreholes KLX07A and KLX07B, and the percussion drilled boreholes HLX34 and HLX35 at Laxemar (Figure 1-1), which is one of the activities performed within the site investigation at Oskarshamn. The work was carried out in accordance with Activity Plan AP PS 400-05-068. The controlling documents for performing this activity are listed in Table 1-1. Both Activity Plan and Method Description are SKB's internal controlling documents. Rock type nomenclature that has been used is shown in Table 1-2.

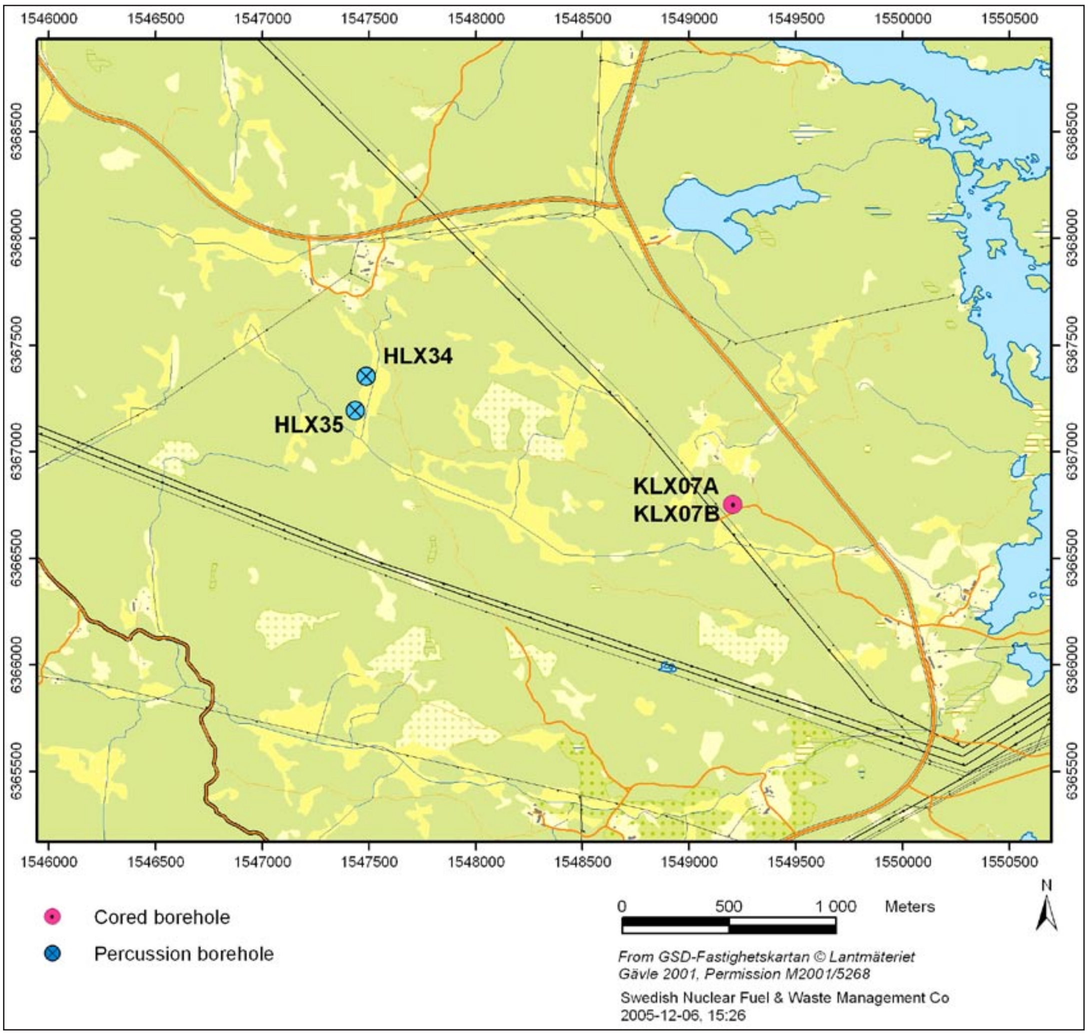


Figure 1-1. *Map showing the position of the cored boreholes KLX07A and KLX07B and the percussion drilled boreholes HLX34 and HLX35.*

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

Activity Plan	Number	Version
Geologisk enhålstolkning av KLX07A, KLX07B, HLX34 och HLX35	AP PS 400-05-068	1.0
Method Description	**Number**	**Version**
Metodbeskrivning för geologisk enhålstolkning	SKB MD 810.003	3.0

Table 1-2. Rock type nomenclature for the site investigation at Oskarshamn.

Rock type	Rock code	Rock description
Dolerite	501027	Dolerite
Fine-grained Götemar granite	531058	Granite, fine- to medium-grained, ("Götemar granite")
Coarse-grained Götemar granite	521058	Granite, coarse-grained, ("Götemar granite")
Fine-grained granite	511058	Granite, fine- to medium-grained
Pegmatite	501061	Pegmatite
Granite	501058	Granite, medium- to coarse-grained
Ävrö granite	501044	Granite to quartz monzodiorite, generally porphyritic
Quartz monzodiorite	501036	Quartz monzonite to monzodiorite, equigranular to weakly porphyritic
Diorite/gabbro	501033	Diorite to gabbro
Fine-grained dioritoid	501030	Intermediate magmatic rock
Fine-grained diorite-gabbro	505102	Mafic rock, fine-grained
Sulphide mineralization	509010	Sulphide mineralization
Sandstone	506007	Sandstone

2 Objective and scope

A geological single-hole interpretation is carried out in order to identify and to describe briefly the characteristics of major rock units and possible deformation zones within a borehole. The work involves an integrated interpretation of data from the geological mapping of the borehole (Boremap), different borehole geophysical logs and borehole radar data. The geological mapping of the cored boreholes involves a documentation of the character of the bedrock in the drill core. This work component is carried out in combination with an inspection of the oriented image of the borehole walls that is obtained with the help of the *B*orehole *I*mage *P*rocessing *S*ystem (BIPS). The geological mapping of the percussion boreholes focuses more attention on an integrated interpretation of the information from the geophysical logs and the BIPS images. For this reason, the results from the percussion borehole mapping are more uncertain. The interpretations of the borehole geophysical and radar logs are available when the single-hole interpretation is performed. The result from the geological single-hole interpretation is presented in a WellCad plot.

3 Data used for the single-hole interpretation

The following data have been used in the single-hole interpretation of the boreholes KLX07A, KLX07B, HLX34 and HLX35:

- Boremap data (including BIPS and geological mapping data) /1, 2/.
- Generalized geophysical logs and their interpretation /3/.
- Radar data and their interpretation /4/.

As a basis for the geological single-hole interpretation a combined WellCad plot consisting of the above mentioned data sets were used. An example of a WellCad plot used during the geological single-hole interpretation is shown in Figure 3-1. The plot consists of nine main columns and several subordinate columns. These include nine main:

1: Length along the borehole

2: Boremap data

  2.1: Rock type

  2.2: Rock type < 1 m

  2.3: Rock type structure

  2.4: Rock structure intensity

  2.5: Rock type texture

  2.6: Rock type grain size

  2.7: Structure orientation

  2.8: Rock alteration

  2.9: Rock alteration intensity

  2.10: Crush

3: Generalized geophysical data

  3.1: Silicate density

  3.2: Magnetic susceptibility

  3.3: Natural gamma radiation

  3.4: Estimated fracture frequency

4: Unbroken fractures

  4.1: Primary mineral

  4.2: Secondary mineral

  4.3: Third mineral

  4.4: Fourth mineral

  4.5: Alteration, dip direction

5: Broken fractures

  5.1: Primary mineral

  5.2: Secondary mineral

  5.3: Third mineral

5.4: Fourth mineral

5.5: Aperture (mm)

5.6: Roughness

5.7: Surface

5.8: Slickenside

5.9: Alteration, dip direction

6: Crush zones

6.1: Piece (mm)

6.2: Sealed network

6.3: Core loss

7: Fracture frequency

7.1: Sealed fractures

7.2: Open fractures

8: BIPS

9: Length along the borehole

The geophysical logs are described below:

Magnetic susceptibility: The rock has been classified into sections of low, medium, high, and very high magnetic susceptibility. The susceptibility is strongly connected to the magnetite content in the different rock types.

Natural gamma radiation: The rock has been classified into sections of low, medium, and high natural gamma radiation. Low radiation may indicate mafic rock types and high radiation may indicate younger, fine- to medium-grained granite or pegmatite.

Possible alteration: This parameter has not been used in the geological single-hole interpretation in the area.

Silicate density: This parameter indicates the density of the rock after subtraction of the magnetic component. It provides general information on the mineral composition of the rock types, and serves as a support during classification of rock types.

Estimated fracture frequency: This parameter provides an estimate of the fracture frequency along 5 m sections, calculated from short and long normal resistivity, SPR, P-wave velocity as well as focused resistivity 140 and 300. The estimated fracture frequency is based on a statistical connection after a comparison has been made between the geophysical logs and the mapped fracture frequency. The log provides an indication of sections with low and high fracture frequencies.

Close inspection of the borehole radar data was carried out during the interpretation process, especially during the identification of possible deformation zones. The occurrence and orientation of radar anomalies within the possible deformation zones are commented upon in the text that describes these zones.

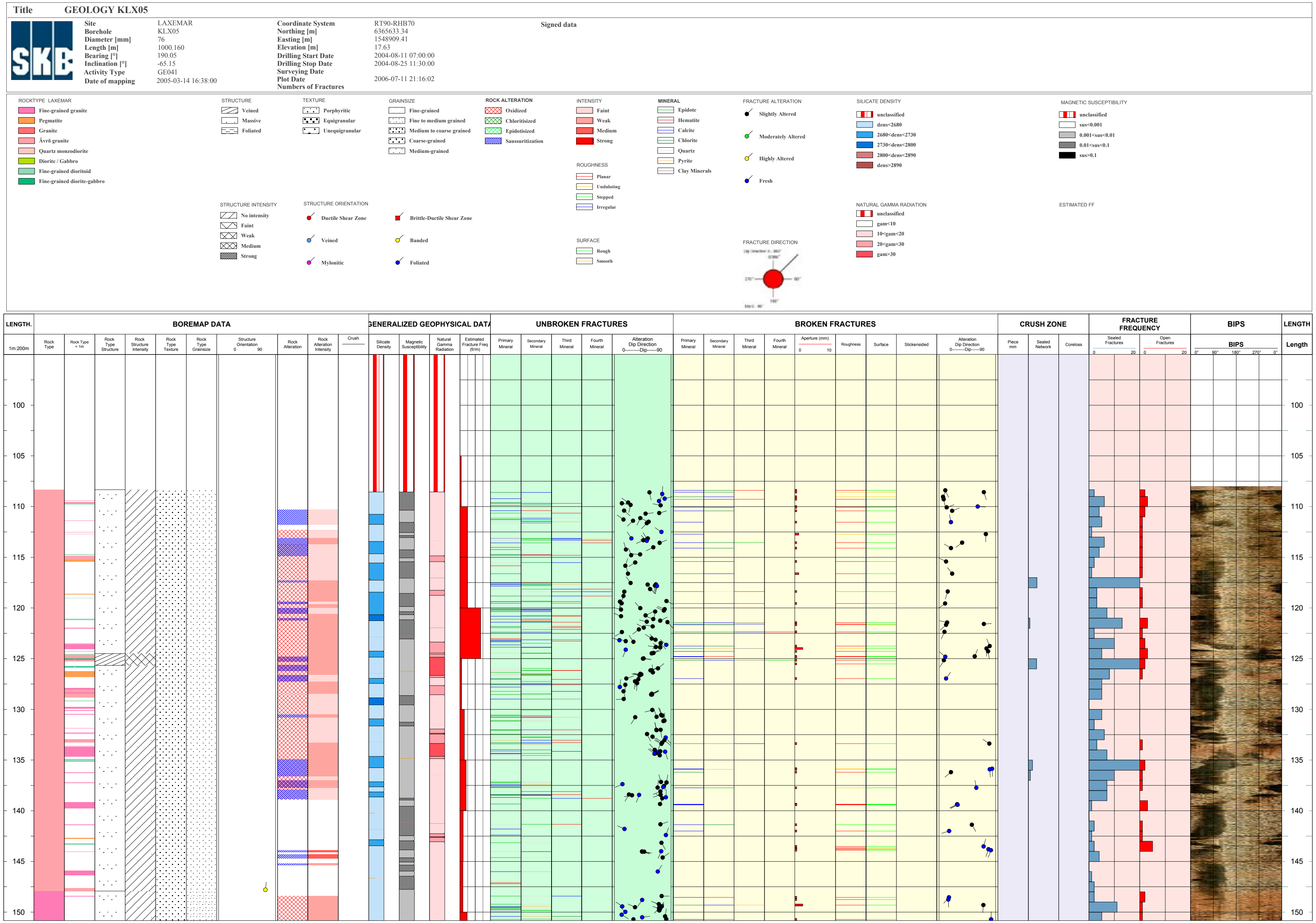


Figure 3-1. *Example of WellCad plot (from borehole KLX05 in Laxemar) used as a basis for the single-hole interpretation.*

4 Execution

4.1 General

The geological single-hole interpretation has been carried out by a group of geoscientists consisting of both geologists and geophysicists. All data to be used (see above) 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.

The first step in the working procedure is to study all types of data (rock type, rock alteration, silicate density, natural gamma radiation, etc) related to the character of the rock type and 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 level in the interpretation of a rock unit is made on the following basis: 3 = high, 2 = medium, and 1 = low.

The second step in the working procedure is to identify possible deformation zones by visual inspection of the results of the geological mapping (fracture frequency, fracture mineral, aperture, alteration, etc) in combination with the geophysical logging and radar data. The section of each identified possible deformation zone is defined in terms of the borehole length interval and provided with a brief description for inclusion in the WellCad plot. The confidence level in the interpretation of a possible deformation zone is made on the following basis: 3 = high, 2 = medium and 1 = low.

Inspection of BIPS images is carried out wherever it is judged necessary during the working procedure. Furthermore, following definition of rock units and deformation zones, 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.

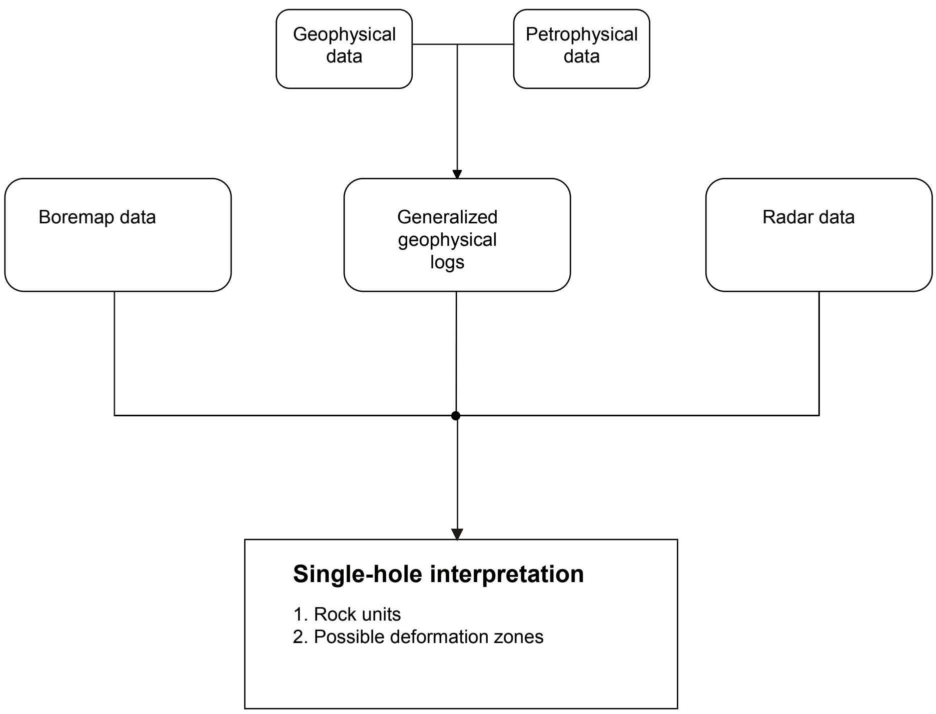


Figure 4-1. *Schematic block-scheme of single-hole interpretation.*

Deformation zones that are brittle in character have been identified primarily on the basis of the frequency of fractures, according to the recommendations in /5/. Both the transitional part, with a fracture frequency in the range 4–9 fractures/m, and the cored part, with a fracture frequency > 9 fractures/m, have been included in each zone (Figure 4-2). 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. The presence of bedrock alteration, the occurrence and, locally, inferred orientation of radar reflectors, the resistivity, SPR, P-wave velocity, caliper and magnetic susceptibility logs have all assisted in the identification of the zones.

Since the frequency of fractures is of key importance for the definition of the possible deformation zones, a moving average plot for this parameter is shown for the cored boreholes KLX07A and KLX07B (Figure 4-3 and 4-4). A 5 m window and 1 m steps have been used in the calculation procedure. The moving averages for open fractures alone, the total number of open fractures (open, partly open and crush), the sealed fractures alone, and the total number of sealed fractures (sealed and sealed fracture network) are shown in this diagram.

The occurrence and orientation of radar anomalies within the possible deformation zones are used during the identification of possible deformation zones. Overviews of the borehole radar measurement in KLX07A, KLX07B, HLX34 and HLX35 are shown in Figures 4-5 to 4-8.

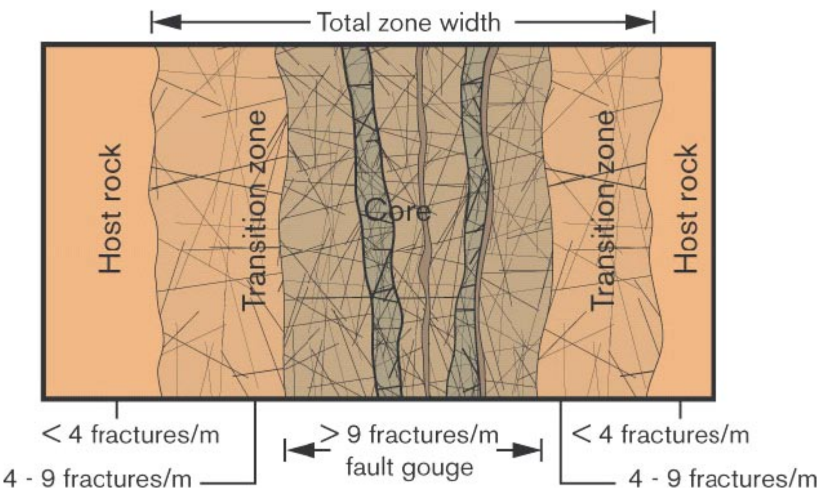


Figure 4-2. Terminology for brittle deformation zones (after /5/).

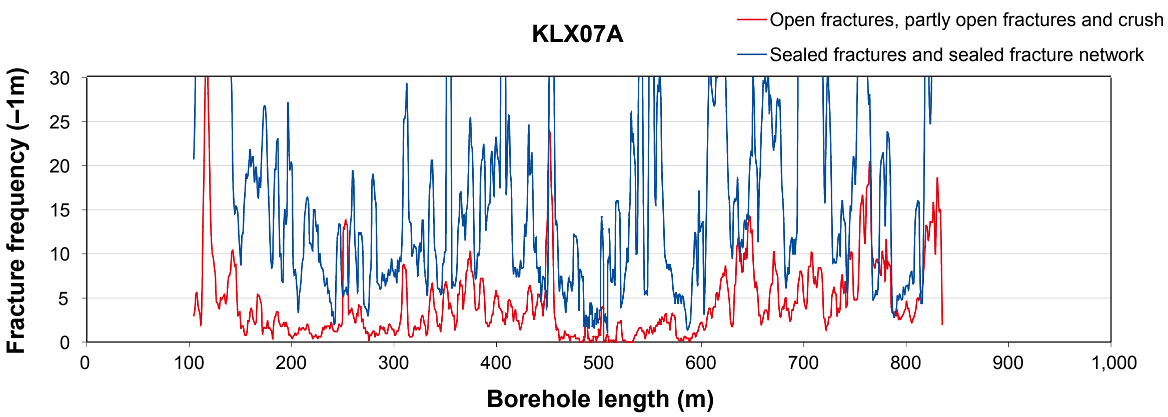


Figure 4-3. Fracture frequency plot for KLX07A. Moving average with a 5 m window and 1 m steps.

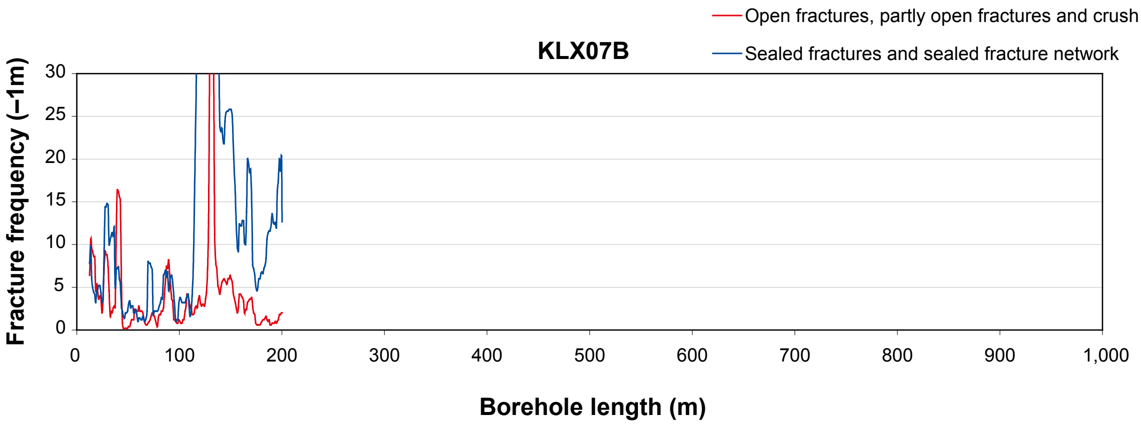


Figure 4-4. *Fracture frequency plot for KLX07B. Moving average with a 5 m window and 1 m steps.*

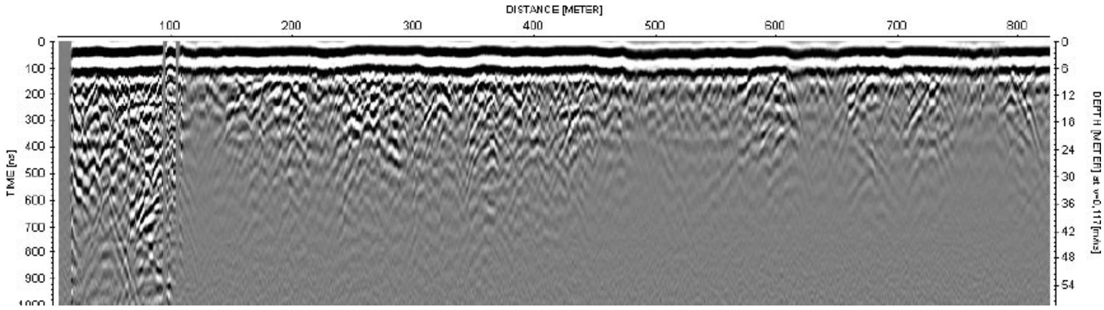


Figure 4-5. *Overview (20 MHz data) of the borehole radar measurement in KLX07A.*

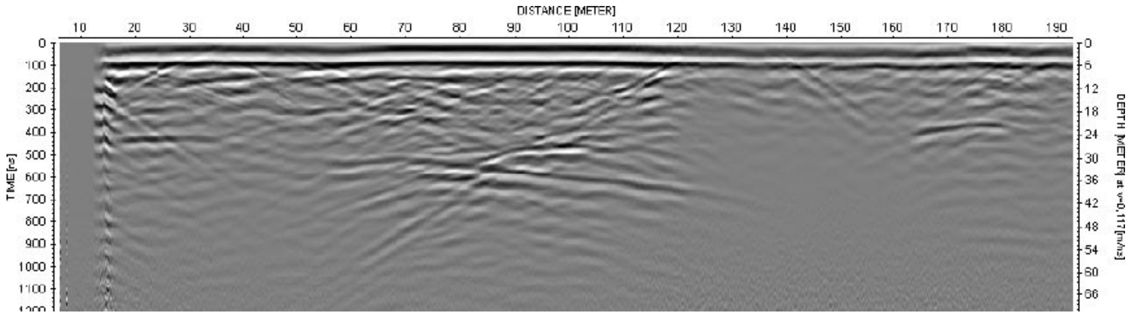


Figure 4-6. *Overview (20 MHz data) of the borehole radar measurement in KLX07B.*

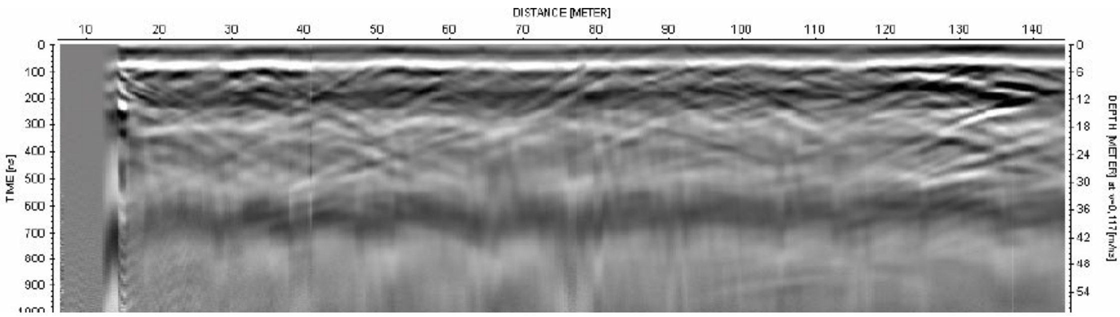


Figure 4-7. *Overview (20 MHz data) of the borehole radar measurement in HLX34.*

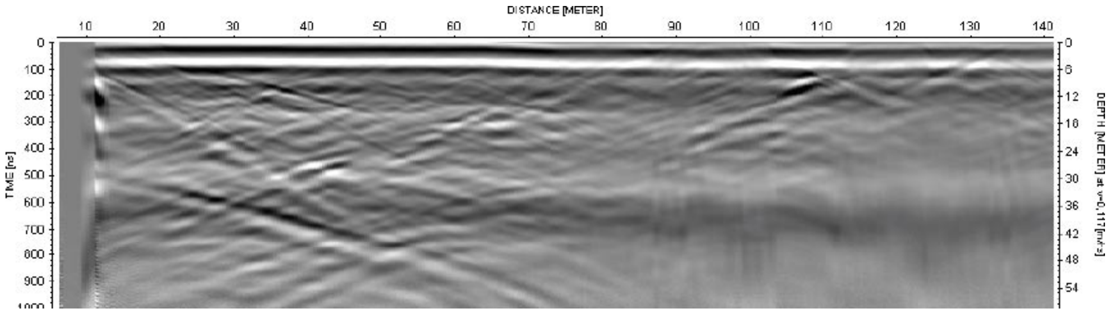


Figure 4-8. *Overview (20 MHz data) of the borehole radar measurement in HLX35.*

4.2 Nonconformities

In some cases alternative orientations for oriented radar reflectors are presented. One of the alternatives is considered to be correct, but due to uncertainty in the interpretation of radar data, a decision concerning which of the alternatives that represent the true orientation cannot be made.

Orientations from directional radar are presented as strike/dip using the right-hand rule.

5 Results

The detailed results of the single-hole interpretation are presented as print-outs from the software WellCad (Appendix 1 for KLX07A, Appendix 2 for KLX07B, Appendix 3 for HLX34 and Appendix 4 for HLX35).

5.1 KLX07A

Rock units

The borehole can be divided into two rock units (RU1–RU2), one of which is recurrent in the borehole (RU1a and RU1b). For this reason, the borehole is divided into three rock sections:

RU1a: 101.98–453.0 m

Totally dominated by Ävrö granite (501044). Subordinate rock types comprise sparse occurrences of fine-grained diorite-gabbro (505102), fine-grained granite (511058) and pegmatite (501061). The sections of fine-grained diorite-gabbro are concentrated in the section 198–250 m. The Ävrö granite has a density in the range 2,650–2,680 kg/m^3 and the natural gamma radiation is in the range of 20–30 µR/h. Sealed fracture network is characteristic along the whole rock unit. Furthermore, scattered minor sections are foliated. Confidence level = 3.

RU2: 453.0–589.50 m

Totally dominated by Ävrö granite (501044). Subordinate rock types comprise sparse occurrences of fine-grained diorite-gabbro (505102) and fine-grained granite (511058). The Ävrö granite in the rock unit is characterized by a density in the range 2,720–2,760 kg/m^3, the natural gamma radiation is in the range of 15–20 µR/h and there is a lower intensity of open fractures as compared to RU1. Sealed fracture network is characteristic along the whole rock unit. Scattered sections are foliated. Confidence level = 3.

RU1b: 589.50–841.51 m

Totally dominated by Ävrö granite (501044). Subordinate rock types comprise sparse occurrences of fine-grained diorite-gabbro (505102), fine-grained granite (511058) and pegmatite (501061). The Ävrö granite has a density in the range 2,650–2,680 kg/m^3 and the natural gamma radiation is in the range of 20–30 µR/h. Sealed fracture network is characteristic along the whole rock unit. Foliation is characteristic, particularly in the sections 589.50–647.92 m and 724.21–841.51 m. Confidence level = 3.

Possible deformation zones

Thirteen deformation zones have been recognised in KLX07A:

DZ1: 105–147 m

Inhomogeneous deformation zone characterized by high frequency of sealed and open fractures with chlorite, epidote and iron hydroxide. Alteration mainly comprises red staining and subordinate sections of epidotization and saussuritization. Ten radar reflectors are identified, two of them are oriented. The oriented reflectors are at 115.5 m with the orientation 53/227 and at 134.8 m with the orientation 71/230 or 24/314. The angle to borehole axis of non-oriented reflectors is in the interval 40–62°. Decreased radar amplitude at 115 m, 130 m and 140 m. The section 114.75–117.86 is characterized by crush and core loss, and also by significant caliper anomalies and low p-wave velocity. The entire DZ1 is characterized by a general decrease in the bulk resistivity and magnetic susceptibility, and there are also numerous p-wave velocity anomalies. Confidence level = 3.

DZ2: 167.90–168.30 m

Minor deformation zone characterized by cataclasite with calcite, epidote and clay. Two non-oriented radar reflectors are identified, with the angle 22 and 32° to borehole axis. Geophysical loggings indicate decreased resistivity, decreased p-wave velocity and positive caliper anomalies. Confidence level = 3.

DZ3: 184.80–185.40 m

Minor deformation zone characterized by cataclasite sealed with epidote and chlorite, and fractures sealed with calcite. One non-oriented radar reflector with the angle 47° to borehole axis. Decreased radar amplitude at 185 m. Minor anomalies in p-wave velocity and resistivity loggings. Confidence level = 3.

DZ4: 252.5–253.10 m

Minor deformation zone characterized by crush. Chlorite and epidote sealed fractures. Two non-oriented radar reflectors with the angle 40 and 68° to borehole axis. Low resistivity, low p-wave velocity and high caliper anomalies indicate open fractures. Confidence level = 3.

DZ5: 308–313 m

Minor deformation zone characterized by red staining with a central part at 311–312 m comprising epidote sealed cataclasite. Four radar reflectors, two of them oriented. The oriented reflectors are at 311.6 m with the orientation 218/03 and at 311.9 m with the orientation 278/27. The angle to borehole axis is in the interval 48–71°. Geophysical loggings indicate distinct low resistivity, low p-wave velocity and positive caliper anomalies. Confidence level = 3.

DZ6: 335.60–340 m

Minor deformation zone characterized by inhomogeneous red staining, cataclasite with epidote, chlorite, alternating with more well preserved parts. Three non-oriented radar reflectors are identified. The angle to borehole axis is 12°, 70° and 39°. Decreased radar amplitude in the interval 335–340 m, and continues to 340 m. A number of minor low resistivity and low p-wave anomalies occur along the section. Confidence level = 3.

DZ7: 347–387.5 m

Slightly increased sealed fracture frequency. The section 386.30–386.70 m is characterized by a section of epidote sealed cataclasite. 14 radar reflectors have been identified, two of them are oriented. The oriented reflectors are at 348.6 m with the orientation 195/50 and at 375.3 m with the orientation 267/83. The angle to borehole axis of non-oriented reflectors is in the interval 24–64°. Decreased radar amplitude in the intervals 347–350 m and 375–387.5 m. Several p-wave velocity anomalies and a few low resistivity anomalies occur in the section. Confidence level = 2.

DZ8: 432.60–434.50 m

Increased fracture frequency particularly of sealed fractures. Scattered sections of chlorite and epidote sealed cataclasite (1–3 cm wide). Two radar reflectors are identified, one of them is oriented. The angle to borehole axis of the non-oriented reflector is 58° and the reflector at 434.3 m has the orientation 252/78. Low resistivity, low p-wave velocity and positive caliper anomalies. Confidence level = 3.

DZ9: 448–459 m

Increased frequency of open and sealed fractures. The section 453.8–454.40 m is intensely foliated (protomylonitic) including sections of cataclasite. Four radar reflectors, one of them oriented. The orientation is 210/44 at 455.9 m. Angle to borehole axis of non-oriented reflectors is 46, 62 and 56°. Decreased radar amplitude in the interval 450–459 m, and continues to 465 m. At c. 453 m there are distinct coincident anomalies in the resistivity, p-wave velocity and caliper logs. Confidence level = 3.

DZ10: 604–654.70 m

Increased frequency of open and sealed fractures. The section is characterized by scattered cataclasite and clay altered fracture fillings. 15 non-oriented radar reflectors and two oriented. The oriented reflectors occur at 623.4 m with the orientation 085/82 and at 650.1 m with the orientation 143/07. Angle to borehole axis of non-oriented is in the interval 21–76°. Decreased radar amplitude in the intervals 610–630 m and 645–655 m. Major decrease in bulk resistivity and magnetic susceptibility. Numerous low p-wave velocity anomalies and partly also caliper anomalies. Confidence level = 3.

DZ11: 693–724.20 m

Increased red staining and frequency of open and sealed fractures. Scattered sections of chlorite and epidote sealed cataclasite. Four non-oriented and five oriented radar reflectors are identified. The angle to borehole axis of non-oriented reflectors is in the interval 34–48°. The oriented reflectors occur at 697.0 m with orientation 154/43, at 697.6 m with orientation 145/42, at 707.8 m with orientation 230/61, at 713.9 m with orientation 228/76, and at 717.3 m with orientation 269/78. Decreased radar amplitude in the interval 690–700 m, i.e. it starts outside DZ11. The geophysical logs indicate two subsections 694–699 m and 709–717 m with low resistivity and decreased p-wave velocity. There is a large decrease in the magnetic susceptibility along the major part of the section of DZ11. Confidence level = 3.

DZ12: 737.90–785 m

Oxidized section and increased frequency of sealed fractures. Scattered sections of chlorite and epidote sealed cataclasite. 16 non-oriented radar reflectors with the angle to borehole axis between 35–61° to borehole axis, and 6 oriented radar reflectors. The oriented reflectors occur at 747.8 m with orientation 264/87, at 751.2 m with orientation 092/84, at 753.7 m with orientation 005/43, at 758.9 m with orientation 085/79, at 772.2 m with orientation 300/05 or 256/72, and at 782.9 m with orientation 121/14. Decreased radar amplitude at 745 m, at the section 755–765 m and at 785 m. There is a general decrease in the magnetic susceptibility in the section 740–760 m. The entire DZ12 is characterized by numerous low resistivity and low p-wave velocity anomalies, and a few caliper anomalies. Confidence level = 3.

DZ13: 816.8–835.5 m

Increased frequency of open fractures and crush at 820.83–821.04, 821.50–821.55, 825.49–825.72, 826.13–826.28, 828.60–828.65 and 831.39–832.27 m. Data on alteration is missing. Four radar reflectors are identified, two of them are oriented. Angle to borehole axis of non-oriented is 60 and 27°. The oriented reflectors occur at 820.9 m with orientation 033/85 and at 832.8 m with orientation 209/89. The section is characterized by several distinct anomalies in the p-wave velocity log data and only minor low resistivity and caliper anomalies. Confidence level = 3.

5.2 KLX07B

Rock units

The borehole is composed of one rock unit:

RU1: 9.64–199.70 m

Totally dominated by Ävrö granite (501044). Subordinate rock types comprise fine-grained granite (511058), fine-grained diorite-gabbro (505102), fine-grained dioritoid (501030) and quartz monzodiorite (501036). The fine-grained diorite-gabbro (505102) is concentrated in the section 128–153 m, the latter of which also display high density of 2,770–2,940 kg/m^3, low natural gamma radiation of 7–18 μR/h and partly very low magnetic susceptibility. Confidence level = 3.

Possible deformation zones

Three possible deformation zones are indicated in KLX07B:

DZ1: 27–30 m

Characterized by increased frequency of open fractures and crush at 28.77–28.89 m and 29.01–29.12 m. Weak red staining. One oriented radar reflector at 28.7 m with the orientation 033/19 or 213/19. Decreased radar amplitude in the interval 25–30 m. There is distinct coincident low resistivity and low p-wave velocity anomalies at the section coordinate ca 28.5 m. There is also a slight increase of the borehole diameter (caliper). Confidence level = 3.

DZ2: 39.7–42 m

Characterized by a crush at 40.52–41.17 m and weak to medium red staining. Two radar reflectors are identified, one of them is oriented. Angle to borehole axis of the nonoriented is 37° and the orientation at 40.9 m is 048/50. Decreased radar amplitude in the interval 40–45 m. There is distinct coincident low resistivity and low p-wave velocity anomalies at the section coordinate ca 40.0 m. There is also a slight increase of the borehole diameter (caliper). Confidence level = 3.

DZ3: 124–172 m

Characterized by increased frequency of sealed network and increased frequency of sealed fractures, and by increased frequency of open fractures between 128 and 155 m. Crush at 130.15–130.17 m, 130.89–131.66 m and 132.78–132.87 m. There are 14 non-oriented radar reflectors and one oriented. A very strong and persistent radar reflector intersects the borehole at 130 m with the angle 61° to borehole axis. The reflector can be traced at least 60 m away from the borehole. The angle to borehole axis is generally between 46 and 80°. The orientation of the reflector at 130.2 m is 246/30. Decreased radar amplitude at 130 m and in the interval

165–170 m. The section is characterized by a general decrease in the bulk resistivity. At ca 129–131 m there is a major decrease in the p-wave velocity and in the resistivity. Also note that the DZ3 coincides with a section of increased density. Confidence level = 3.

5.3 HLX34

Rock units

The borehole is composed of one rock unit:

RU1: 9.10–151.80 m
Totally dominated by Ävrö granite (501044). Subordinate rock types comprise in particular fine-grained diorite-gabbro (505102). Furthermore, sections of fine-grained granite (511058), diorite/gabbro (501033) and granite (501058) occur. The rock unit is characterized by fairly constant density in the range 2,640–2,740 kg/m^3. Confidence level = 2.

Possible deformation zones

Five possible deformation zones are indicated in HLX34:

DZ1: 33–35 m

Crush zone. Two non-oriented radar reflectors with the angle 26 and 56° to borehole axis. Decreased radar amplitude at 35 m. Geophysical loggings indicate low density, low magnetic susceptibility, low resistivity and caliper anomalies. Confidence level = 2.

DZ2: 52–55 m

Minor deformation zone characterized by increased frequency of open fractures. Two non-oriented radar reflectors with the angle 54 and 56° to borehole axis. Geophysical loggings indicate low density, low magnetic susceptibility, low resistivity and caliper anomalies. Confidence level = 2.

DZ3: 68–73 m

Major increase of open fractures. Four non-oriented radar reflectors with the angle 70, 60, 48 and 53° to borehole axis. Decreased radar amplitude in the interval 65–75 m. Geophysical loggings indicate low resistivity and caliper anomalies, low density, low susceptibility. Confidence level = 2.

DZ4: 85–87 m

Minor deformation zone characterized by increase of open fractures, which are spatially related to a fine-grained diorite-gabbro (505102). One non-oriented radar reflector with the angle 57° to borehole axis. Decreased radar amplitude at 85 m. Geophysical loggings indicate narrow distinct low p-wave velocity anomalies, low susceptibility and low resistivity anomalies. Confidence level = 2.

DZ5: 111–113 m

Minor deformation zone characterized by major increase of open fractures, which are spatially related to a fine-grained diorite-gabbro (505102). One non-oriented radar reflector with the angle 31° to borehole axis. Decreased radar amplitude in the interval 105–115 m. Geophysical loggings indicate narrow distinct low p-wave velocity anomalies, low susceptibility, low resistivity anomalies, low density and caliper anomalies. Confidence level = 2.

5.4 HLX35

Rock units

The borehole is composed of one rock unit:

RU1: 6.10–151.80

Totally dominated by Ävrö granite (501044). Subordinate rock types comprise in particular fine-grained diorite-gabbro (505102). Furthermore, subordinate scattered minor sections of fine-grained granite (511058), pegmatite (501061) and diorite/gabbro (501033) occur. Based on the density log, the borehole can be divided into two subsections. Subsection 1 (c. 7–67 m) is characterized by density in the range 2,630–2,670 kg/m^3 and subsection 2 (c. 67–147 m) is characterized by density in the range 2,690–2,750 kg/m^3. Subsection 1 has a natural gamma radiation in the range 20–25 µR/h and subsection 2 has a natural gamma radiation in the range 10–15 µR/h. Confidence level = 2.

Possible deformation zones

One possible deformation zone is indicated in HLX35:

DZ1: 116–142 m

Deformation zone characterized by major increase of open fractures in the interval 116–127 m, and a moderate increase in the interval 127–142 m. Crush zone at 141.68–141.82 m. Twelve non-oriented radar reflectors with the angle in the interval 30–61° to borehole axis. A very strong and persistent radar reflector intersects the borehole at 132 m with the angle 43° to borehole axis. The reflector can be traced at least 40 m away from the borehole. Decreased radar amplitude in the interval 115–125 m, at 135 m and at 140 m. Significant low resistivity anomalies, some caliper and p-wave velocity anomalies, and partly anomalously low magnetic susceptibility. Confidence level = 2.

6 Comments

The result from the geological single-hole interpretation of KLX07A, KLX07B, HLX34 and HLX35 are presented in WellCad plots (Appendix 1–4). The WellCad plots consist of the following columns:

In data Boremap	1:	Depth (Length along the borehole)
	2:	Rock type
	3:	Rock alteration
	4:	Frequency of sealed fractures
	5:	Frequency of open and partly open fractures
	6:	Crush zones
In data Geophysics	7:	Silicate density
	8:	Magnetic susceptibility
	9:	Natural gamma radiation
	10:	Estimated fracture frequency
Interpretations	11:	Description: Rock unit
	12:	Stereogram for sealed fractures in rock unit (blue symbols)
	13:	Stereogram for open and partly open fractures in rock unit (red symbols)
	14:	Description: Possible deformation zone
	15:	Stereogram for sealed fractures in possible deformation zone (blue symbols)
	16:	Stereogram for open and partly open fractures in possible deformation zone (red symbols)

7 References

/1/ **Dahlin P, Ehrenborg J, 2005.** Oskarshamn site investigation. Boremap mapping of core drilled borehole KLX07A and KLX07B. SKB P-05-263, Svensk Kärnbränslehantering AB.

/2/ **Sigurdsson O, 2005.** Oskarshamn site investigation. Simplified boremap mapping of percussion boreholes HLX34 and HLX35. SKB P-05-279, Svensk Kärnbränslehantering AB.

/3/ **Mattsson H, Keisu M, 2005.** Oskarshamn site investigation. Interpretation of geophysical borehole measurements from KLX07A, KLX07B, HLX20, HLX32; HLX34 and HLX35. SKB P-05-259, Svensk Kärnbränslehantering AB.

/4/ **Gustafsson J, Gustafsson C, 2005.** Oskarshamn site investigation. RAMAC and BIPS logging in boreholes KLX07A, KLX07B, HLX34 and HLX35 and deviation logging in boreholes KLX07B, HLX34 and HLX35. SKB P-05-231, Svensk Kärnbränslehantering AB.

/5/ **Munier R, Stenberg L, Stanfors R, Milnes 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.

Geological single-hole interpretation of KLX07A

Title	**SINGLE HOLE INTERPRETATION KLX07A**						
Site	LAXEMAR	**Inclination [°]**	-60.03	**Elevation [m.a.s.l.]**	18.40	**Signed data**	
Borehole	KLX07A	**Date of mapping**	2005-07-07 15:06:00	**Drilling Start Date**	2004-11-23 07:00:00		
Diameter [mm]	76	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2004-12-07 09:00:00		
Length [m]	844.730	**Northing [m]**	6366751.28	**Surveying Date**			
Bearing [°]	174.18	**Easting [m]**	1549206.90	**Plot Date**	2007-10-14 22:03:05		

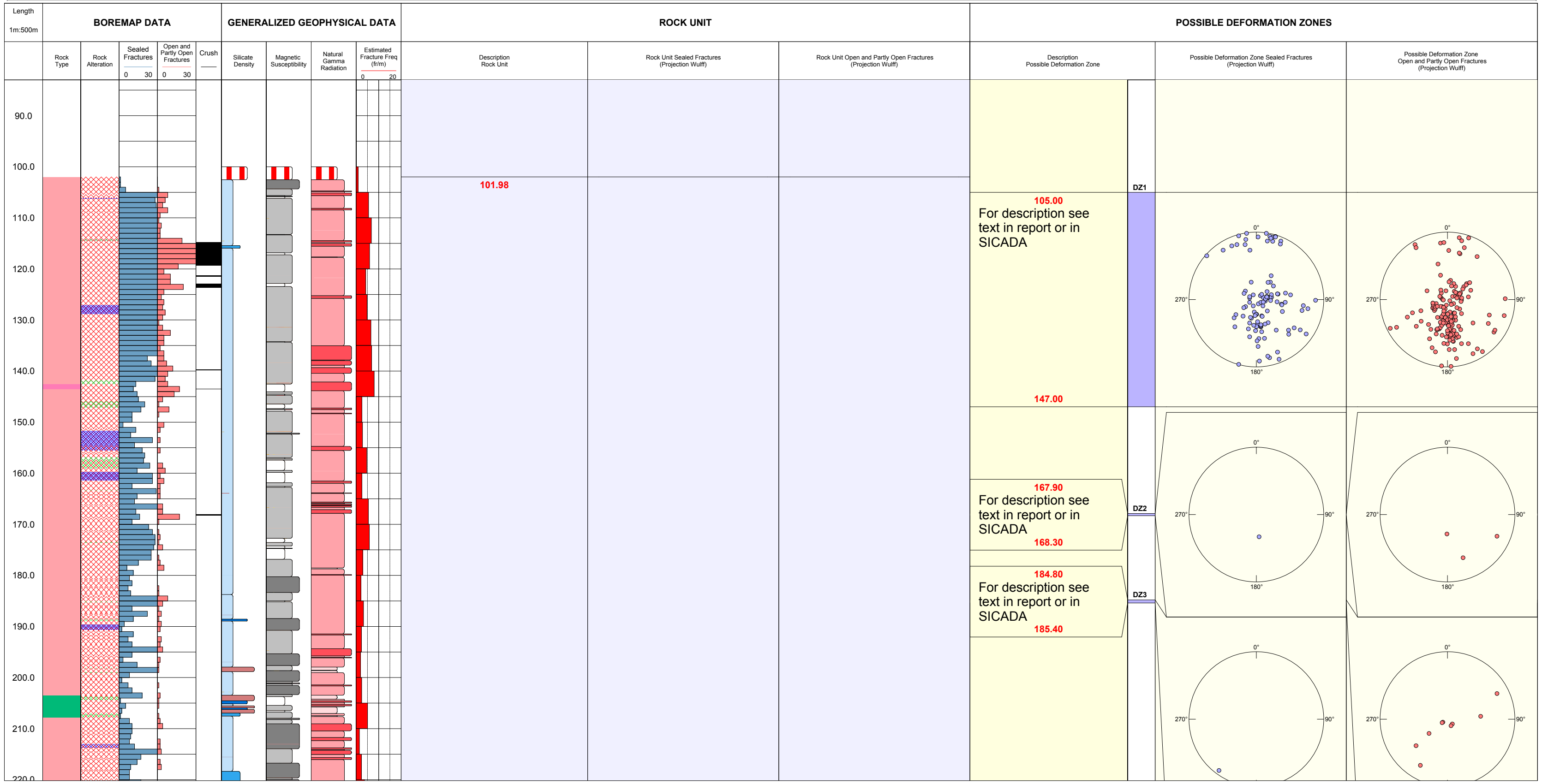
ROCKTYPE LAXEMAR
- Fine-grained granite
- Ävrö granite
- Fine-grained diorite-gabbro

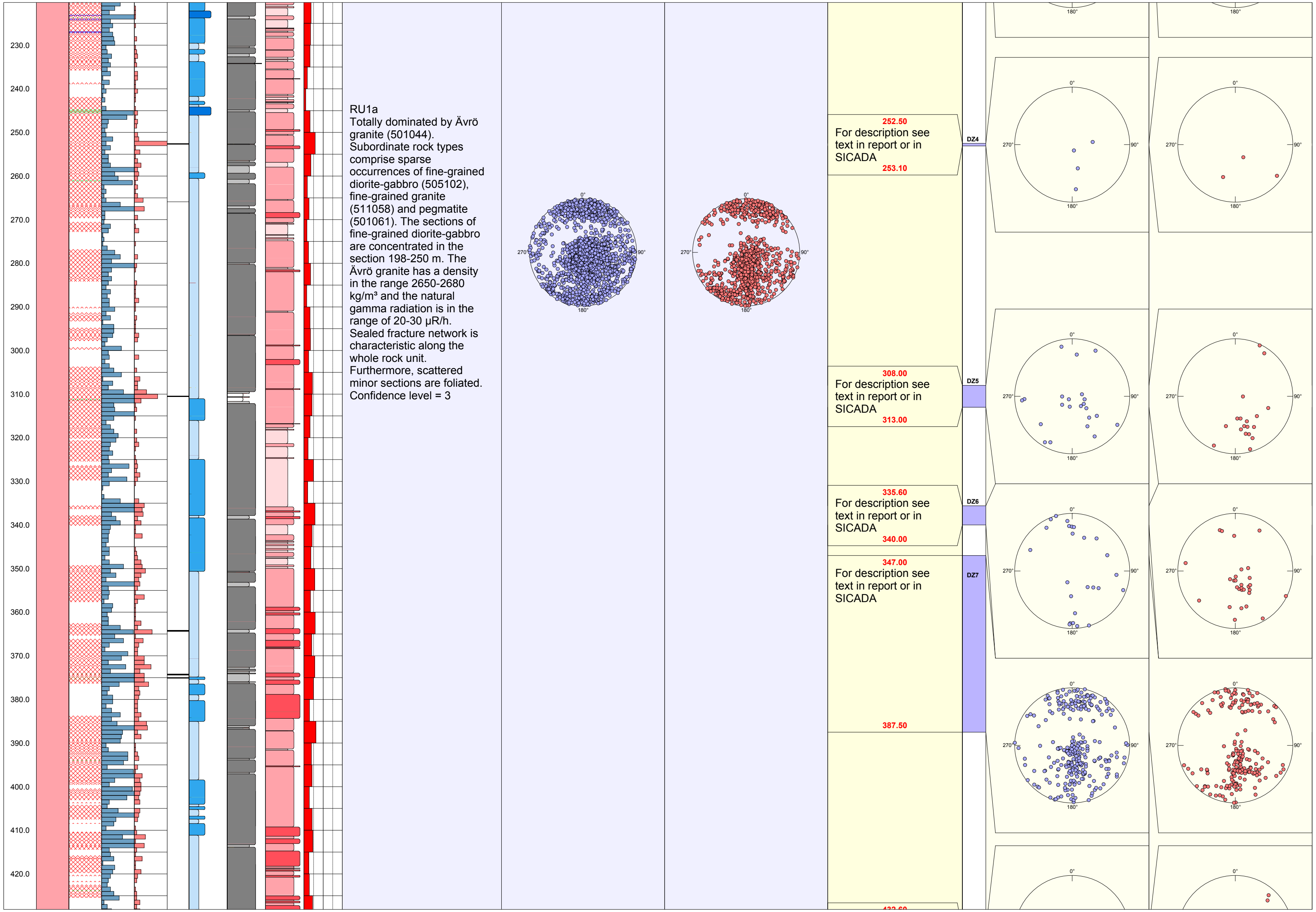
ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Quartz dissolution
- Albitization
- Saussuritization

SILICATE DENSITY
- unclassified
- dens<2680
- 2680<dens<2730
- 2730<dens<2800
- 2800<dens<2890

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1
- sus>0.1

NATURAL GAMMA
- unclassified
- gam<10
- 10<gam<20
- 20<gam<30
- gam>30

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320.0
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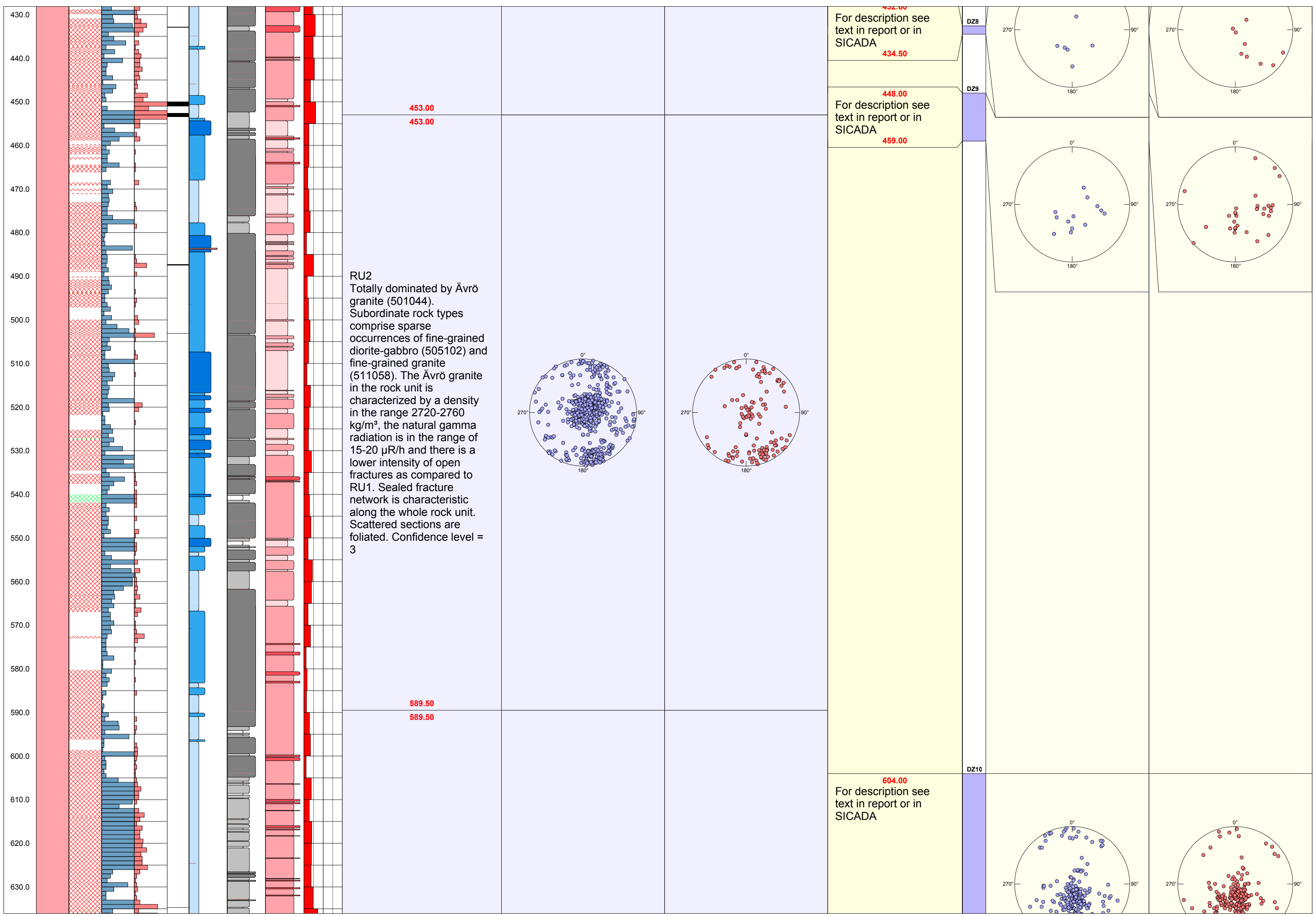
360.0
370.0
380.0
390.0
400.0
410.0
420.0
RU1a
Totally dominated by Ävrö granite (501044). Subordinate rock types comprise sparse occurrences of fine-grained diorite-gabbro (505102), fine-grained granite (511058) and pegmatite (501061). The sections of fine-grained diorite-gabbro are concentrated in the section 198-250 m. The Ävrö granite has a density in the range 2650-2680 kg/m³ and the natural gamma radiation is in the range of 20-30 μR/h. Sealed fracture network is characteristic along the whole rock unit. Furthermore, scattered minor sections are foliated.
Confidence level = 3
252.50
For description see text in report or in SICADA
253.10
DZ4
308.00
For description see text in report or in SICADA
313.00
DZ5
335.60
For description see text in report or in SICADA
340.00
DZ6
347.00
For description see text in report or in SICADA
DZ7
387.50
0°
90°
180°
270°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450.0
460.0
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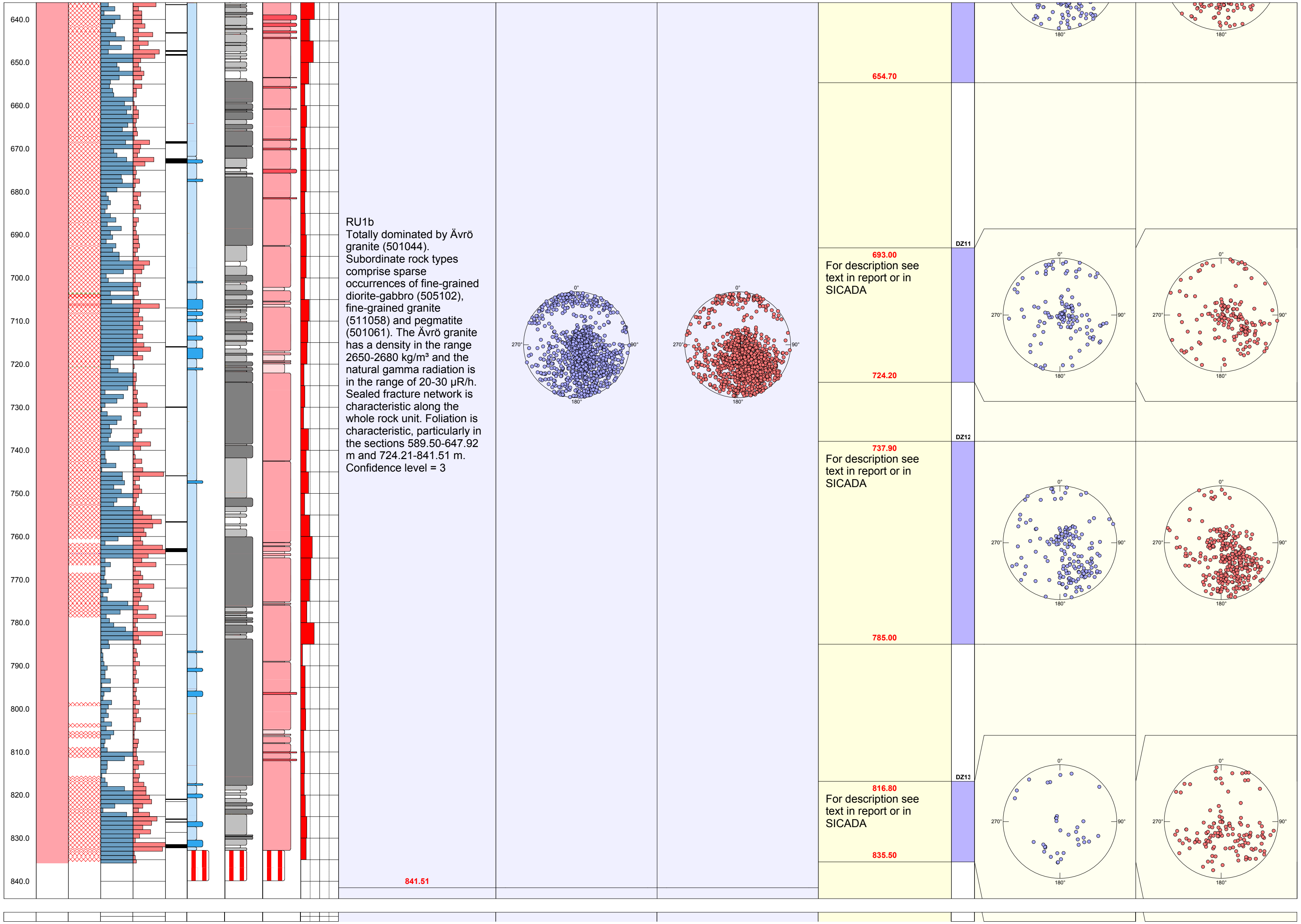
480.0
490.0
500.0
510.0
520.0
530.0
540.0
550.0
560.0
570.0
580.0
590.0
600.0
610.0
620.0
630.0
453.00
453.00
RU2
Totally dominated by Ävrö granite (501044). Subordinate rock types comprise sparse occurrences of fine-grained diorite-gabbro (505102) and fine-grained granite (511058). The Ävrö granite in the rock unit is characterized by a density in the range 2720-2760 kg/m³, the natural gamma radiation is in the range of 15-20 µR/h and there is a lower intensity of open fractures as compared to RU1. Sealed fracture network is characteristic along the whole rock unit. Scattered sections are foliated. Confidence level = 3
589.50
589.50
For description see text in report or in SICADA
434.50
DZ8
448.00
For description see text in report or in SICADA
459.00
DZ9
604.00
For description see text in report or in SICADA
DZ10
0°
90°
180°
270°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690.0
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720.0
730.0
740.0
750.0
760.0
770.0
780.0
790.0
800.0
810.0
820.0
830.0
840.0
RU1b
Totally dominated by Ävrö granite (501044). Subordinate rock types comprise sparse occurrences of fine-grained diorite-gabbro (505102), fine-grained granite (511058) and pegmatite (501061). The Ävrö granite has a density in the range 2650-2680 kg/m³ and the natural gamma radiation is in the range of 20-30 μR/h. Sealed fracture network is characteristic along the whole rock unit. Foliation is characteristic, particularly in the sections 589.50-647.92 m and 724.21-841.51 m. Confidence level = 3
841.51
654.70
DZ11
693.00
For description see text in report or in SICADA
724.20
DZ12
737.90
For description see text in report or in SICADA
785.00
DZ13
816.80
For description see text in report or in SICADA
835.50
0°
90°
180°
270°

Geological single-hole interpretation of KLX07B

Title SINGLE HOLE INTERPRETATION KLX07B

Site	LAXEMAR	Inclination [°]	-85.14	Elevation [m.a.s.l.]	18.31	Signed data	
Borehole	KLX07B	Date of mapping	2005-09-13 08:00:00	Drilling Start Date	2005-05-23 18:00:00		
Diameter [mm]	76	Coordinate System	RT90-RHB70	Drilling Stop Date	2005-06-03 08:00:00		
Length [m]	200.130	Northing [m]	6366752.32	Surveying Date			
Bearing [°]	174.33	Easting [m]	1549206.80	Plot Date	2007-10-14 22:03:05		

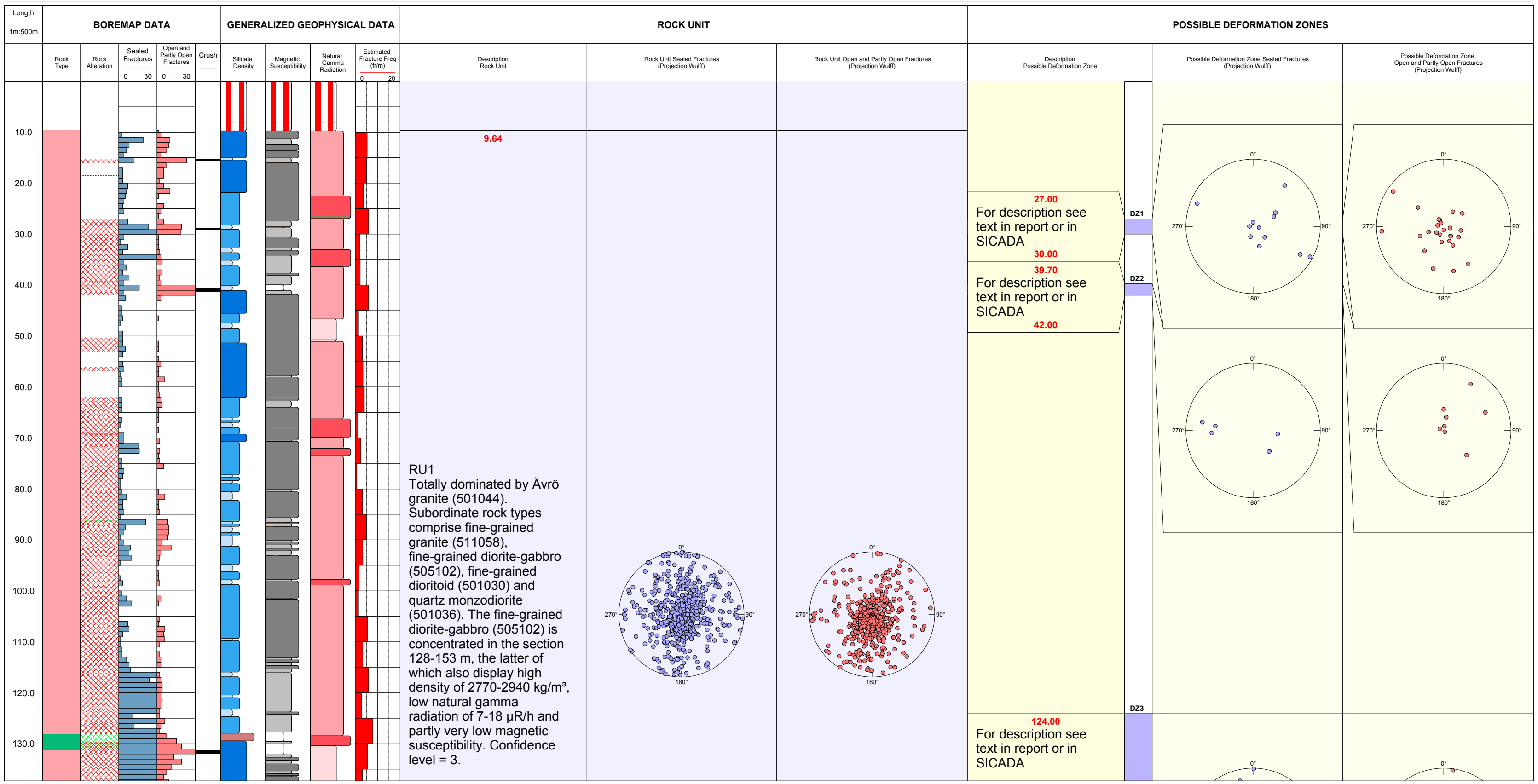
ROCKTYPE LAXEMAR
- Ävrö granite
- Fine-grained diorite-gabbro

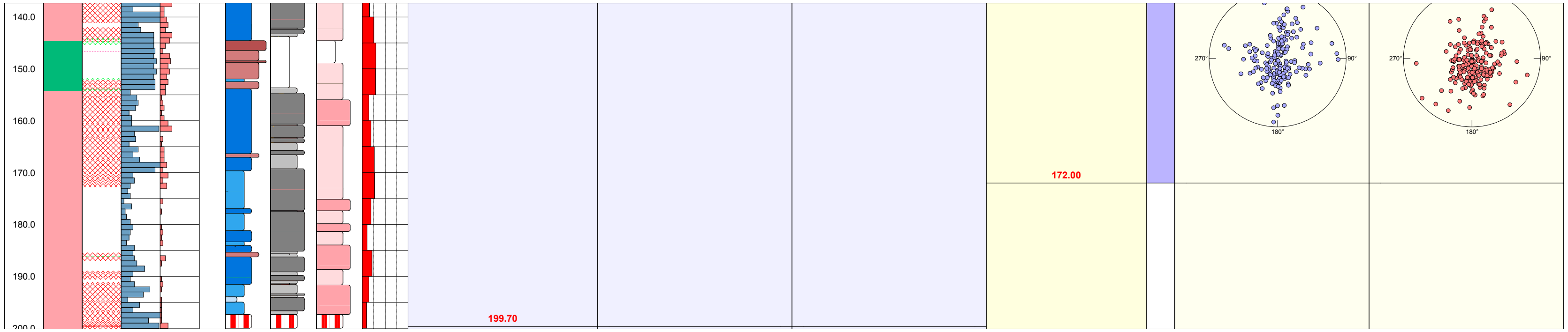
ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Argillization
- Albitization
- Saussuritization

SILICATE DENSITY
- unclassified
- dens<2680
- 2680<dens<2730
- 2730<dens<2800
- 2800<dens<2890
- dens>2890

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1

NATURAL GAMMA
- unclassified
- gam<10
- 10<gam<20
- 20<gam<30
- gam>30

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200.0
199.70
172.00
270°
90°
180°
270°
90°
180°

Geological single-hole interpretation of HLX34

Title	SINGLE HOLE INTERPRETATION HLX34					
Site	LAXEMAR	Inclination [°]	-59.72	Elevation [m.a.s.l.]	14.29	Signed data
Borehole	HLX34	Date of mapping	2005-09-01 15:42:00	Drilling Start Date	2005-05-09 13:00:00	
Diameter [mm]	137	Coordinate System	RT90-RHB70	Drilling Stop Date	2005-06-14 19:30:00	
Length [m]	151.800	Northing [m]	6367355.13	Surveying Date		
Bearing [°]	101.07	Easting [m]	1547489.56	Plot Date	2007-10-15 22:03:14	

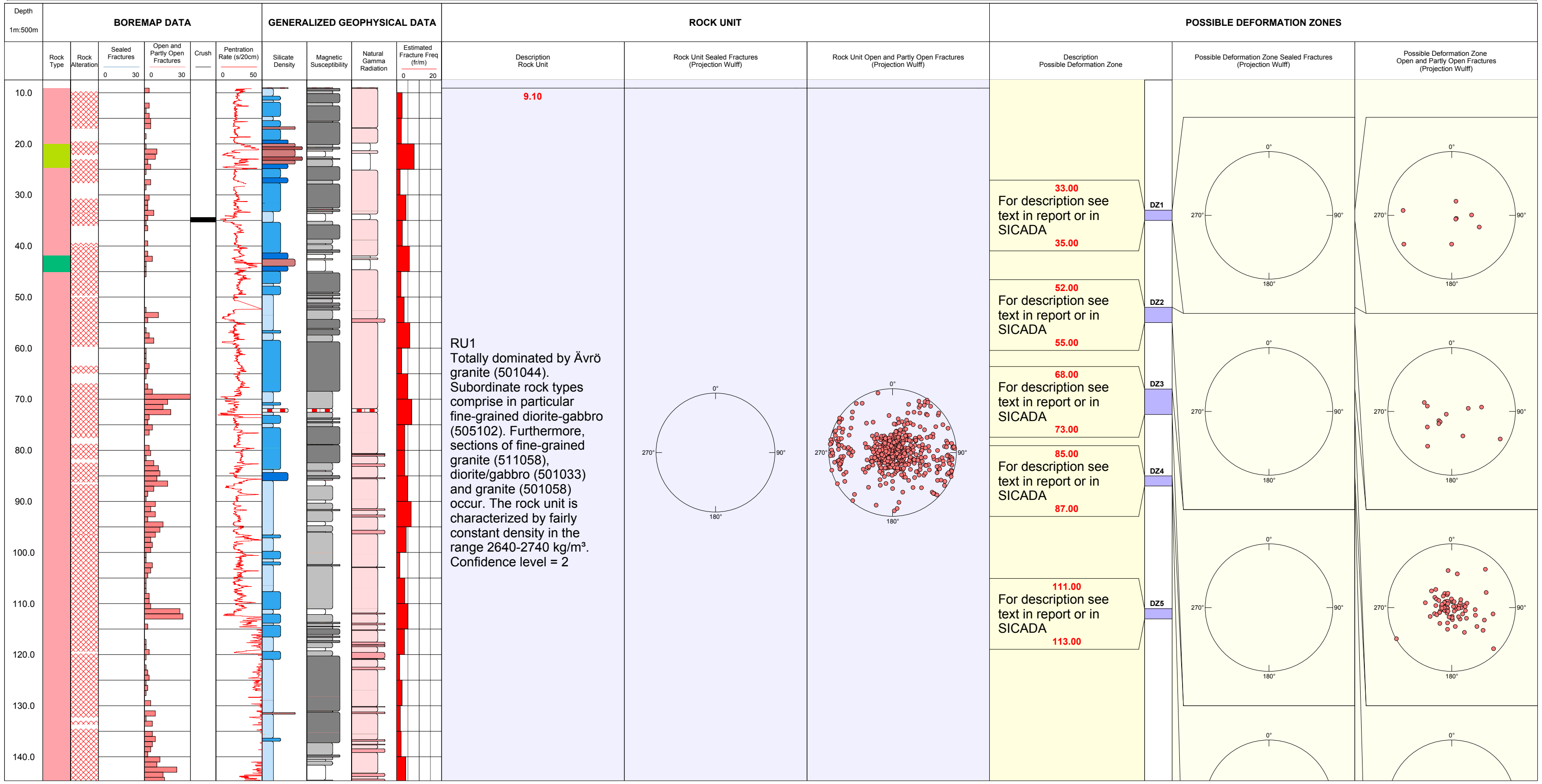
ROCKTYPE LAXEMAR
- Ävrö granite
- Diorite / Gabbro
- Fine-grained diorite-gabbro

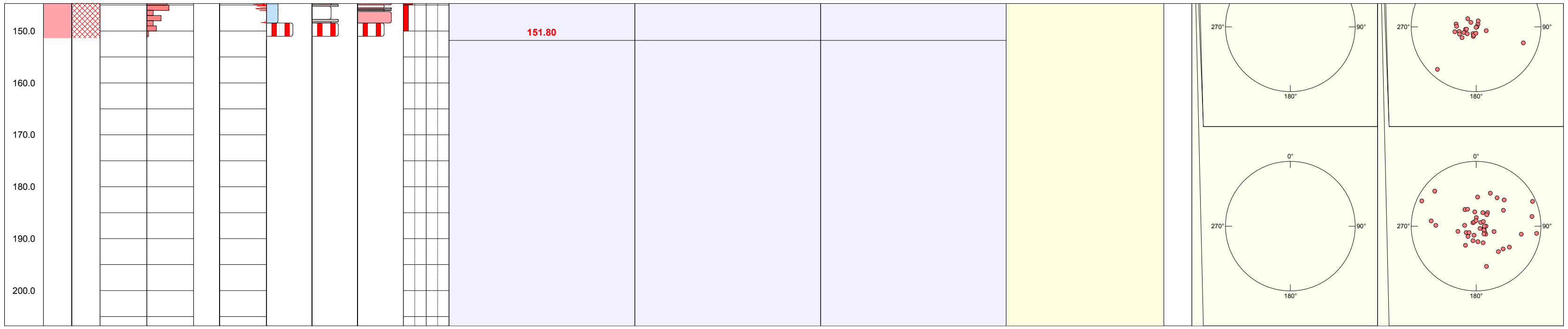
ROCK ALTERATION
- Oxidized

SILICATE DENSITY
- unclassified
- dens<2680
- 2680<dens<2730
- 2730<dens<2800
- 2800<dens<2890
- dens>2890

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1

NATURAL GAMMA
- unclassified
- gam<10
- 10<gam<20
- 20<gam<30

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200.0
151.80
0°
270°
90°
180°

Appendix 4

Geological single-hole interpretation of HLX35

Title SINGLE HOLE INTERPRETATION HLX35

Site	LAXEMAR	**Inclination [°]**	-60.12	**Elevation [m.a.s.l.]**	14.44	**Signed data**
Borehole	HLX35	**Date of mapping**	2005-09-08 08:51:00	**Drilling Start Date**	2005-05-28 07:00:00	
Diameter [mm]	140	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2005-06-02 20:00:00	
Length [m]	151.800	**Northing [m]**	6367194.79	**Surveying Date**		
Bearing [°]	102.22	**Easting [m]**	1547437.79	**Plot Date**	2007-10-15 22:03:14	

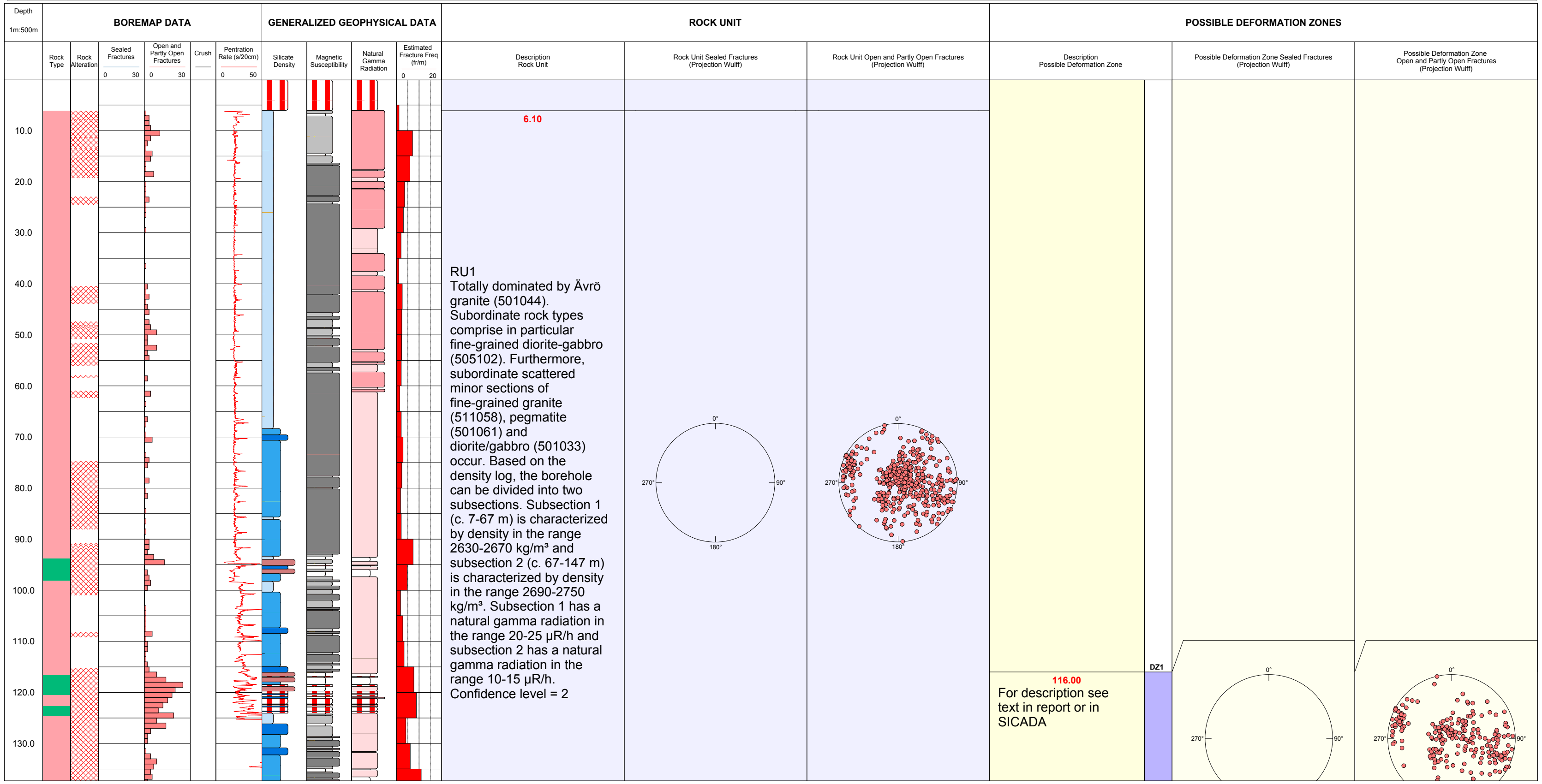
ROCKTYPE LAXEMAR
- Ävrö granite
- Fine-grained diorite-gabbro

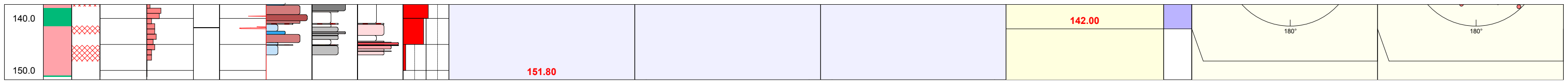
ROCK ALTERATION
- Oxidized

SILICATE DENSITY
- unclassified
- dens<2680
- 2680<dens<2730
- 2730<dens<2800
- 2800<dens<2890
- dens>2890

SUSCEPTIBILITET
- unclassified
- sus<0.001
- 0.001<sus<0.01
- 0.01<sus<0.1

NATURAL GAMMA
- unclassified
- gam<10
- 10<gam<20
- 20<gam<30
- gam>30

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150.0
151.80
142.00
180°
180°