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Data in SKB's database can be changed for different reasons. Minor changes in SKB's database will not necessarily result in a revised report. Data revisions may also be presented as supplements, available at www.skb.se.

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Abstract

This report contains geological single-hole interpretation of the cored borehole KLX15A and the percussion boreholes HLX30, HLX31 and HLX33 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 boreholes.

The geological single-hole interpretation shows that the borehole KLX15A is dominated by quartz monzodiorite (501036) which constitutes one rock unit (RU1). The rock unit can be divided into two separate sections (RU1a and RU1b). Between the two separate sections occurs a rock unit (RU2) which is dominated by Ävrö granite (501044). Subordinate rock types comprise occurrences of fine-grained diorite-gabbro (505102), pegmatite (501061), fine-grained granite (511058) and granite (501058). Twenty possible deformation zones are identified in KLX15A (DZ1–DZ20).

One rock unit (RU1) occurs in percussion borehole HLX30. The borehole is dominated by Ävrö granite (501044). Subordinate rock types comprise occurrences of fine-grained diorite-gabbro (505102) and sparse occurrence of fine-grained granite (511058). Five possible deformation zones are identified in HLX30 (DZ1–DZ5).

Percussion borehole HLX31 is totally dominated by Ävrö granite (501044) which constitutes one rock unit (RU1). Subordinate rock type comprises fine-grained diorite-gabbro (505102). Three possible deformation zones are identified in HLX31 (DZ1–DZ3).

One rock unit (RU1) occurs in percussion borehole HLX33. The borehole is totally dominated by Ävrö granite (501044). Subordinate rock types comprise occurrences of fine-grained diorite-gabbro (505102) and sparse occurrence of fine-grained granite (511058). One possible deformation zone is identified in HLX33 (DZ1).

Sammanfattning

Denna rapport behandlar geologisk enhålstolkning av kärnborrhålet KLX15A och hammarborrhålen HLX30, HLX31 och HLX33 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.

Den geologiska enhålstolkningen visar att kärnborrhålet KLX15A domineras av kvartsmonzodiorit (501036) vilken utgör en litologisk enhet (RU1). Denna litologiska enhet förekommer i två sektioner (RU1a och RU1b). Mellan de två sektionerna finns en litologisk enhet (RU2) vilken domineras av Ävrögranit (501044). Underordnade bergarter utgörs av finkornig dioritgabbro (505102), pegmatit (501061), finkornig granit (511058) och granit (501058). Tjugo möjliga deformationszoner har identifierats i KLX15A (DZ1–DZ20).

En litologisk enhet (RU1) förekommer i hammarborrhålet HLX30. Borrhålet domineras av Ävrögranit (501044). Finkornig diorit-gabbro (505102) och smärre förekomster av finkornig granit (511058) förekommer som underordnade bergarter. Fem möjliga deformationszoner har identifierats i HLX30 (DZ1–DZ5).

Hammarborrhålet HLX31 domineras fullständigt av Ävrögranit (501044) vilken utgör en litologisk enhet (RU1). Finkornig diorit-gabbro (505102) förekommer som underordnad bergart. Tre möjliga deformationszoner har identifierats i HLX31 (DZ1–DZ3).

En litologisk enhet (RU1) förekommer i hammarborrhålet HLX33. Borrhålet domineras av Ävrögranit (501044). Finkornig diorit-gabbro (505102) och smärre förekomster av finkornig granit (511058) förekommer som underordnade bergarter. En möjlig deformationszon har identifierats i HLX33 (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 v.3.0, SKB internal controlling document).

This document reports the results gained by the geological single-hole interpretation of boreholes KLX15A, HLX30, HLX31 and HLX33 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 400-07-049. 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.

Original data from the reported activity are stored in the primary database Sicada, where they are traceable by the Activity Plan number (AP PS 400-07-049). Only data in SKB's databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the databases may be revised, if needed. Such revisions will not necessarily result in a revision of the P-report, although the normal procedure is that major data revisions entail a revision of the P-report. Minor data revisions are normally presented as supplements, available at www.skb.se.

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

Activity plan	Number	Version
Geologisk enhålstolkning av KLX15A, HLX30, HLX31 och HLX33	AP PS 400-07-049	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

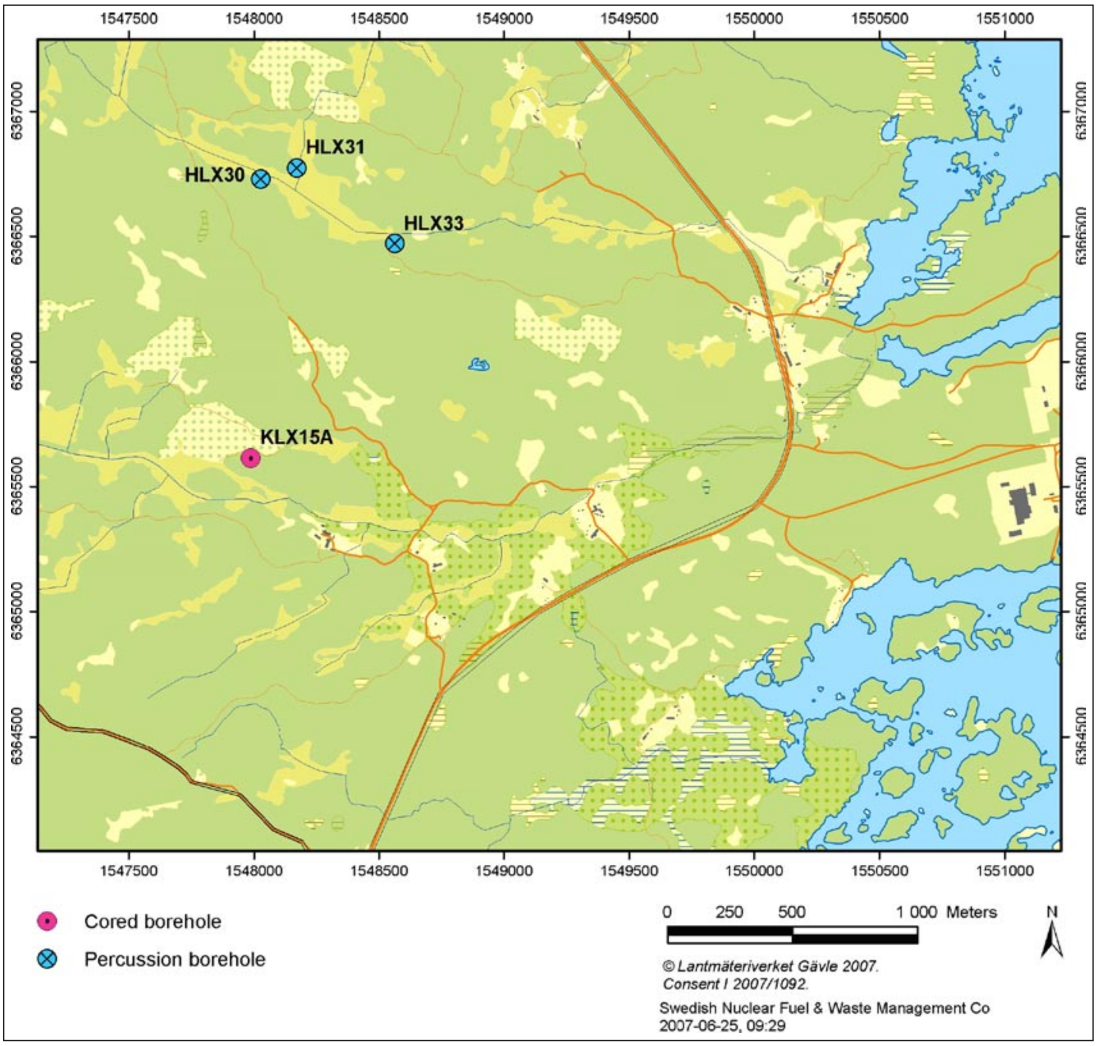


***Figure 1-1.** Map showing the position of the cored borehole KLX15A and the percussion boreholes HLX30, HLX31 and HLX33.*

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 Borehole Image Processing *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. 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

The following data have been used in the single-hole interpretation of boreholes KLX15A, HLX30, HLX31 and HLX33:

- Boremap data (including BIPS and geological mapping data) /2, 3/.
- Generalized geophysical logs and their interpretation /4, 5/.
- Radar data and their interpretation /6, 7, 8/.

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 ten main columns and several subordinate columns. These include:

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 fine-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.

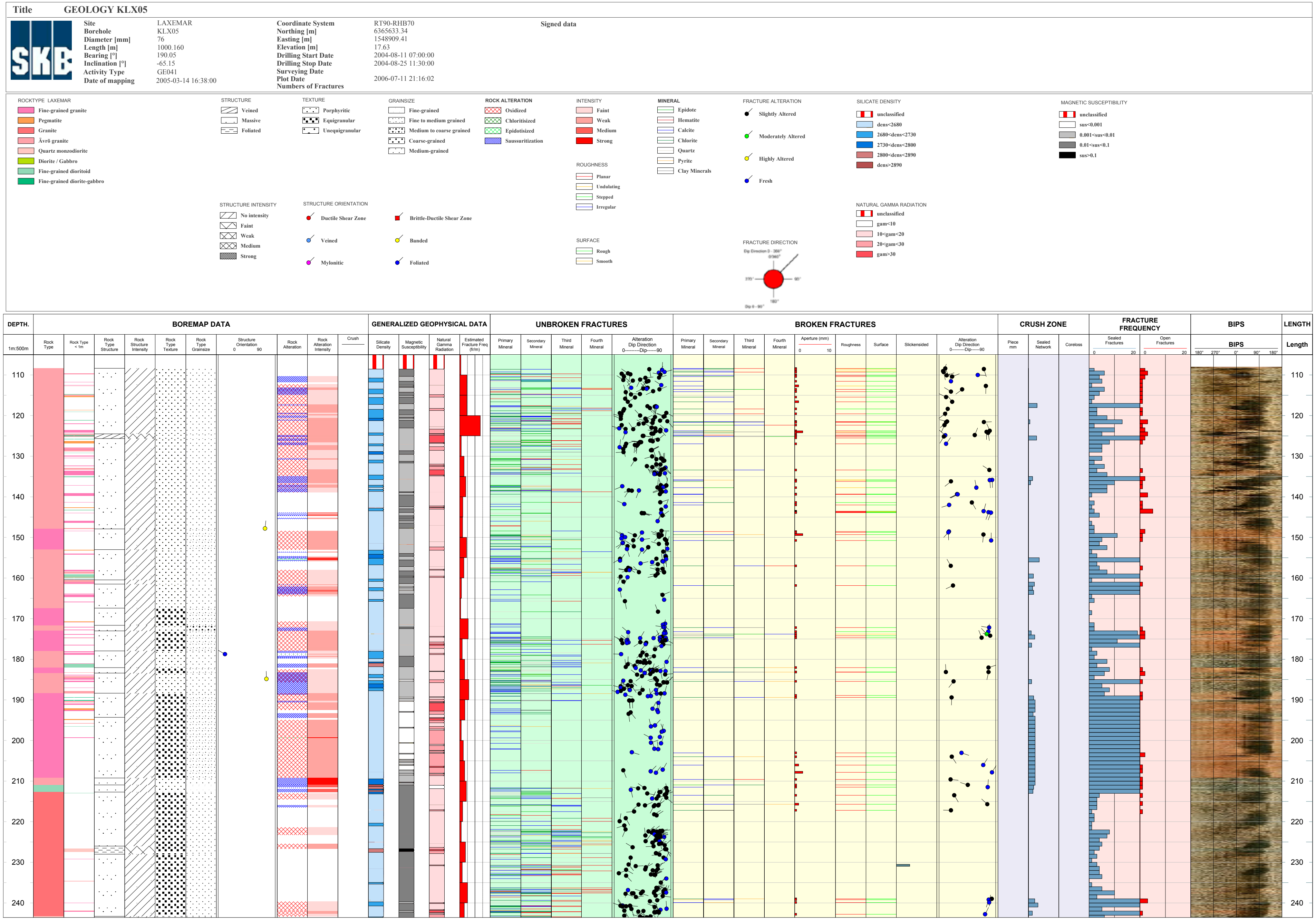


Figure 3-1. Example of WellCad plot (from borehole KLX05 in Laxemar) used as a basis for the single-hole interpretation.

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 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.

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. This includes a brief description of the rock types affected by the possible deformation zone. The confidence 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 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 whenever 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.

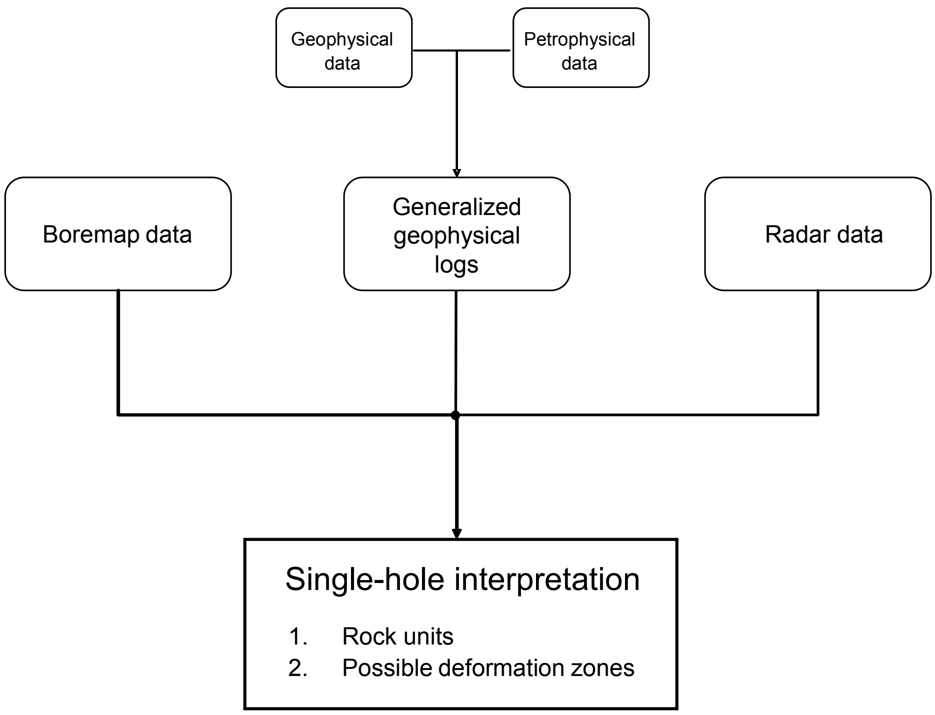
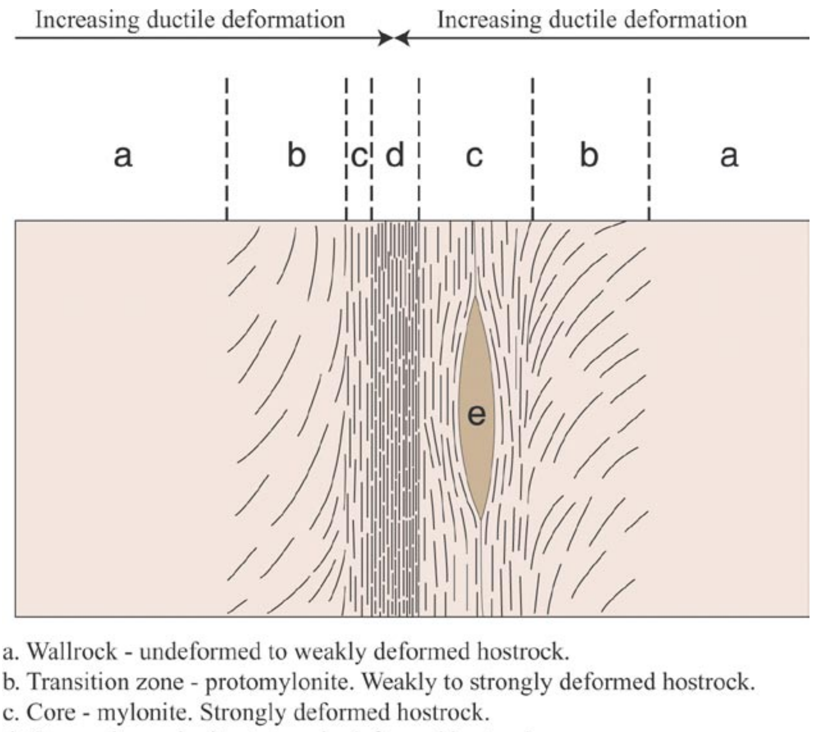


Figure 4-1. *Schematic block-scheme of single-hole interpretation.*

Possible deformation zones that are ductile or brittle in character have been identified primarily on the basis of occurrence of protomylonitic to mylonitic foliation and the frequency of fractures, respectively, according to the recommendations in /1/. Both the transitional parts and the core part have been included in each zone (Figures 4-2 to 4-4). The fracture/m values in Figure 4-4 may serve only as examples. 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 primarily the brittle structures.

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 borehole KLX15A (Figure 4-5). 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 a diagram.

The occurrence and orientation of radar anomalies within these possible deformation zones are used during the identification of zones. Overviews of the borehole radar measurement in KLX15A, HLX30, HLX31 and HLX33 are shown in Figures 4-6 to 4-9. A conductive environment causes attenuation of the radar wave, which in turn decreases the penetration. The effect of attenuation can be observed in boreholes HLX30, HLX31 and HLX33 (Figure 4-7 to 4-9). The effect of attenuation varies between the different antenna frequencies (20 MHz, 100 MHz, 250 MHz and 60 MHz directional antenna). 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 method, e.g. 040/80 corresponds to a strike of N40°E and a dip of 80° to the SE.



a. Wallrock - undeformed to weakly deformed hostrock.
b. Transition zone - protomylonite. Weakly to strongly deformed hostrock.
c. Core - mylonite. Strongly deformed hostrock.
d. Core - ultramylonite. Intensely deformed hostrock.
e. Tectonic lens - rock with minor deformation within the shearzone

Figure 4-2. *Schematic example of a ductile shear zone. Homogeneous rock which is deformed under low- to medium-grade metamorphic conditions (after /1/).*

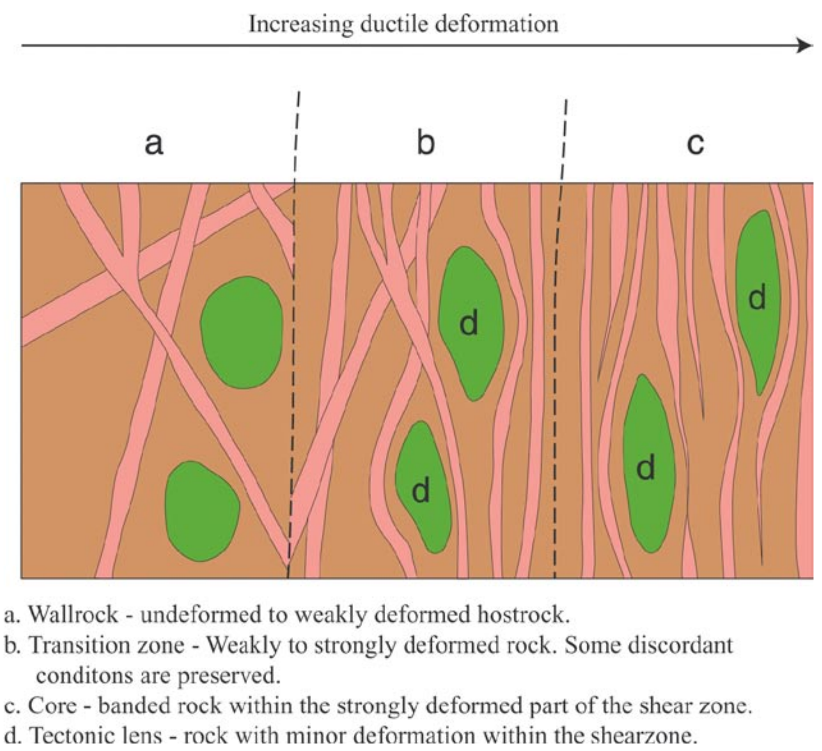


Figure 4-3. *Schematic example of a ductile shear zone. Heterogeneous rock which is deformed under low- to high-grade metamorphic conditions (after /1/).*

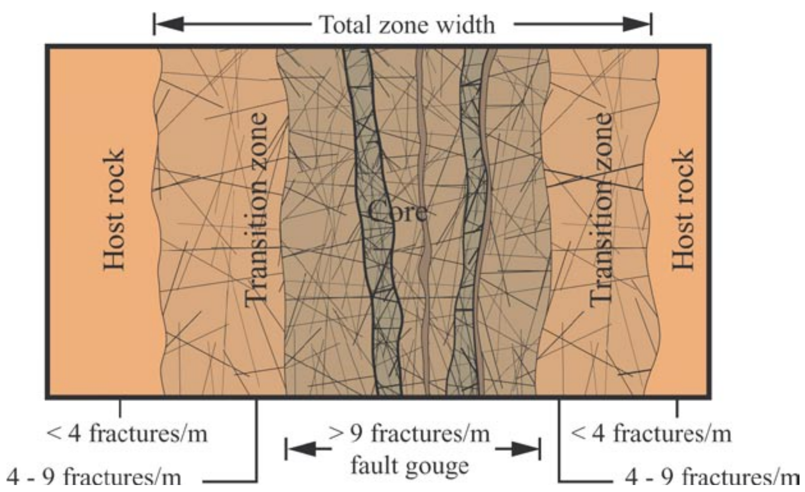


Figure 4-4. *Schematic example of a brittle deformation zone (after /1/).*

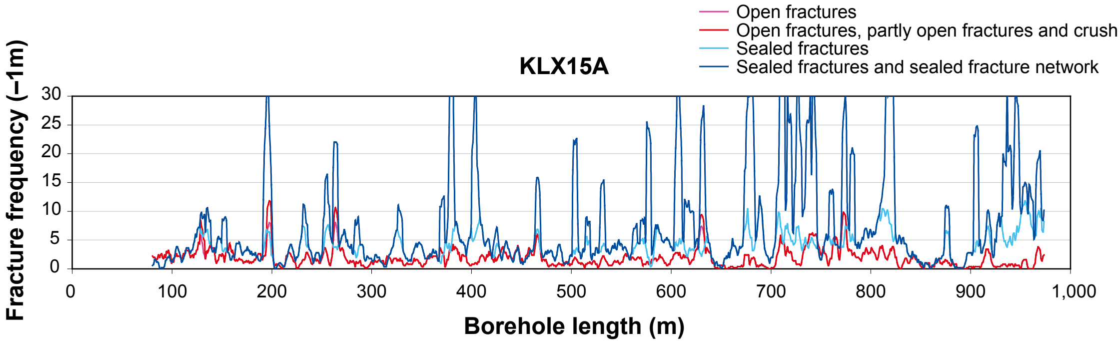


Figure 4-5. *Fracture frequency plot for KLX15A. Moving average with a 5 m window and 1 m steps.*

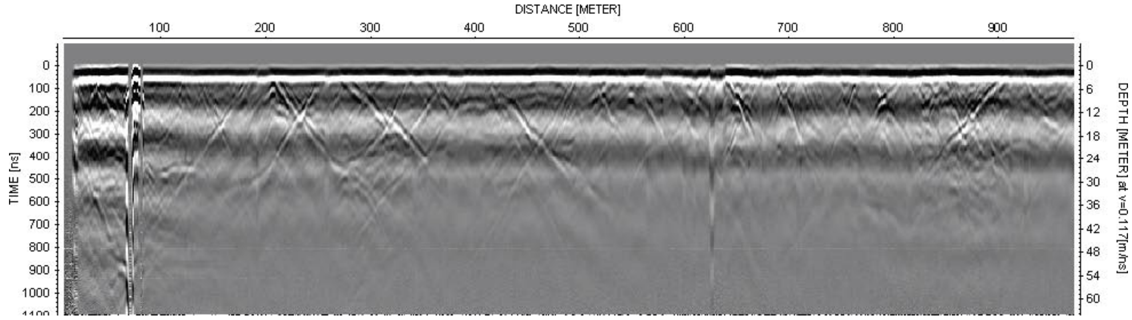


Figure 4-6. *Overview (20 MHz data) of the borehole radar measurement in KLX15A.*

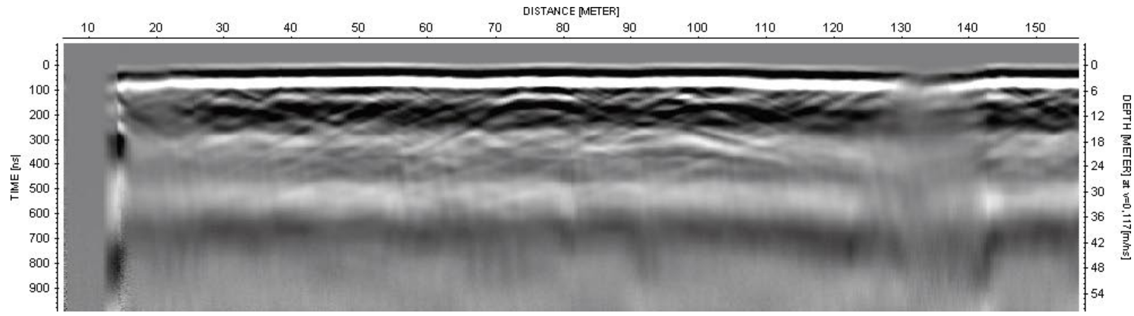


Figure 4-7. *Overview (20 MHz data) of the borehole radar measurement in HLX30.*

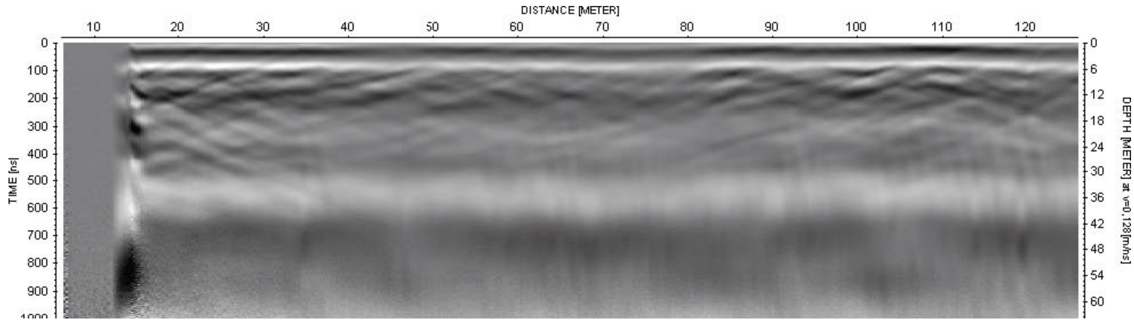


Figure 4-8. *Overview (20 MHz data) of the borehole radar measurement in HLX31.*

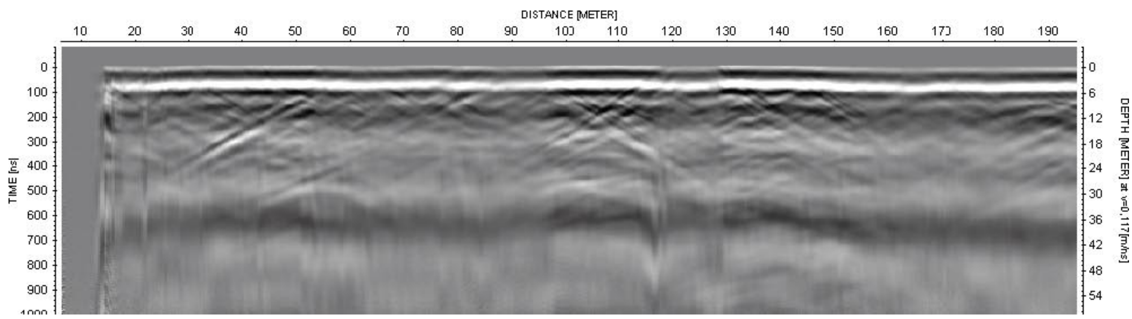


Figure 4-9. *Overview (20 MHz data) of the borehole radar measurement in HLX33.*

5 Results

The detailed result of the single-hole interpretation is presented as print-out from the software WellCad (Appendix 1 for KLX15A, Appendix 2 for HLX30, Appendix 3 for HLX31 and Appendix 4 for HLX33).

5.1 KLX15A

Rock units

The borehole can be divided into two different rock units, RU1–RU2. However, rock unit 1 occurs in two separate length intervals (RU1a and RU1b). The rock units have been recognized with a high degree of confidence.

77.59–658.99 m

RU1a: Totally dominated by quartz monzodiorite (501036). Subordinate rock types comprise fine-grained diorite-gabbro (505102), fine-grained granite (511058), pegmatite (501061) and granite (501058). The last c. 10 m of the rock unit is weakly foliated. The quartz monzodiorite (501036) has a density in the range 2,750–2,800 kg/m^3 along the entire rock unit. Confidence level = 3.

658.99–682.89

RU2: Dominated by Ävrö granite (501044). Subordinate rock types comprise quartz monzodiorite (501036) in the section 663.413–666.864 m, pegmatite (501061), fine-grained granite (511058) and very sparse occurrence of granite (501058). The upper part of the rock unit is faintly foliated. The Ävrö granite (501044) has a density in the range 2,650–2,750 kg/m^3 with a dominance for lower density. Confidence level = 3.

682.89–1,000.43 m

RU1b: Totally dominated by quartz monzodiorite (501036). Subordinate rock types comprise fine-grained granite (511058), pegmatite (501061), fine-grained diorite-gabbro (505102), and granite (501058).). Scattered ≤ c. 15 m long sections are faintly to weakly foliated. The quartz monzodiorite (501036) has a density in the range 2,750–2,800 kg/m^3 along the entire rock unit. Confidence level = 3.

Possible deformation zones

Twenty possible deformation zones have been recognised with a high degree of confidence in KLX15A (DZ1–DZ20).

130.15–130.36 m

DZ1: Minor brittle-ductile shear zone in composite intrusion, including increased frequency of sealed fractures, one crush and faint saussuritization. Significantly decreased P-wave velocity, resistivity and magnetic susceptibility. The caliper mean data indicates decreased borehole diameter in the section. One strong radar reflector occurs at 129.2 m, which is just outside the deformation zone, with the angle 31° to borehole axis. Low radar amplitude occurs in the section 129–131 m. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock type comprises fine-grained diorite-gabbro (505102). Confidence level = 3.

193.14–199.70 m

DZ2: Brittle-ductile shear zone in composite intrusion. Increased frequency of open and sealed fractures, sealed network, two slickensides, two crush and partly weak saussuritization and partly faint epidotization. Significantly decreased resistivity and magnetic susceptibility and partly decreased P-wave velocity along the entire section. The caliper mean data indicates slightly increased borehole diameter. One oriented and two non-oriented radar reflectors occur. The oriented reflector occurs at 195.9 m with the orientation 071/29. The reflector is strong and can be observed to a distance of 30 m outside the borehole. The non-oriented reflectors occur at 196.8 m and 198.7 m with the angle 51° and 46° to borehole axis, respectively. The host rock is dominated by fine-grained diorite-gabbro (505102). Subordinate rock types comprise quartz monzodiorite (501036) and pegmatite (501061). Confidence level = 3.

253.69–254.37 m

DZ3: Minor brittle-ductile shear zone characterized by slightly increased frequency of open and sealed fractures. Significantly decreased resistivity and magnetic susceptibility and partly decreased P-wave velocity. One oriented radar reflector occurs at 253.6 m with the orientation 339/38 or 250/59. The reflector is prominent and can be observed to a distance of 15 m outside the borehole. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock type comprises fine-grained granite (511058). Confidence level = 3.

262.35–265.79 m

DZ4: Brittle deformation zone characterized by increased frequency of open and sealed fractures, sealed network, two crush, apertures 3–10 mm, two slickensides, faint to weak red staining and saussuritization and partly medium epidotization. Significantly decreased resistivity and magnetic susceptibility and partly decreased P-wave velocity. The caliper mean data indicates a significant anomaly at c. 264.6 m. One of the most prominent radar reflectors in the borehole (reflector 66) occurs at 261.3 m, which is immediately above DZ4. The orientation of the reflector is 094/31, and the reflector can be observed to a distance of 30 m outside the borehole. Parts of the reflector (reflector 66xx at 264.2 m, reflector 66xxxx at 264.7 m and reflector 66x at 265.0 m) have been interpreted to intersect within DZ4. Also, one non-oriented radar reflector occurs at 263.0 m with the angle 55° to borehole axis. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock types comprise fine-grained granite (511058) and fine-grained diorite-gabbro (505102). Confidence level = 3.

346.65–347.00 m

DZ5: Minor brittle-ductile shear zone in composite intrusion. Weakly red staining. Significantly decreased resistivity and magnetic susceptibility and partly decreased P-wave velocity. Low radar amplitude occurs in the section 346–348 m. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock type comprises fine-grained diorite-gabbro (505102). Confidence level = 3.

350.16–350.34 m

DZ6: Minor ductile shear zone in composite intrusion. One slickenside and faint saussuritization. There is a minor decrease in magnetic susceptibility and resistivity. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock type comprises fine-grained diorite-gabbro (505102). Confidence level = 3.

362.75–362.95 m

DZ7: Minor deformation zone characterized by brecciation. Partly decreased magnetic susceptibility and resistivity. The host rock is dominated Ävrö granite (501044). Confidence level = 3.

377.84–386.00 m

DZ8: Inhomogeneous brittle-ductile shear zone. Increased frequency of sealed fractures, slight increase in open fractures, sealed network, cataclasites, breccias, weak to strong red staining and partly weak epidotization. Significant decrease in bulk resistivity and bulk magnetic susceptibility and a minor decrease in P-wave velocity. Three non-oriented radar reflectors occur at 379.5 m, 383.1 m and 385.9 m with the angle 36°, 10° and 34° to borehole axis, respectively. Low radar amplitude occurs in the section 376–383 m. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock types comprise pegmatite (501061) and fine-grained granite. Confidence level = 3.

401.90–409.10 m

DZ9: Brittle-ductile shear zone. Increased frequency of sealed fractures and sealed network, weak to medium red staining and partly weak saussuritization. Significantly decreased resistivity and magnetic susceptibility in the section c. 402.5–403.5 m. Partly decreased P-wave velocity along the entire section of the possible deformation zone. One non-oriented radar reflector occurs at 405.6 m with the angle 63° to borehole axis. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock type comprises fine-grained granite (511058). Confidence level = 3.

502.50–505.60 m

DZ10: Brittle-ductile shear zone. Increased frequency of sealed fractures and sealed network, weak to medium red staining and one slickenside. Significant decrease in resistivity and magnetic susceptibility and a minor decrease in P-wave velocity. Two oriented and two non-oriented radar reflectors occur within DZ10. The oriented reflectors occur at 504.0 m with the orientation 309/33 or 265/29 and at 504.6 m with the orientation 093/14 or 101/86. Both reflectors are strong and can be observed to a distance of 24 m outside the borehole. The non-oriented reflectors occur at 503.8 m and 504.9 m with the angle 56° and 59° to borehole axis, respectively. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock types comprise fine-grained granite (511058) and very sparse occurrence of granite (501058). Confidence level = 3.

602.24–608.72 m

DZ11: Brittle deformation zone characterized by increased frequency of sealed fractures, weak to strong red staining, partly faint epidotization, one cataclasite (2 cm) and one breccia (20 cm). Significant decrease in resistivity and magnetic susceptibility and a minor decrease in P-wave velocity. Three non-oriented radar reflectors occur at 603.0 m, 604.8 m and 605.4 m with the angle 58°, 34° and 50° to borehole axis, respectively. Low radar amplitude occurs in the section 602–608 m. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock types are granite (501058) and pegmatite (501061). Confidence level = 3.

629.10–634.94 m

DZ12: Brittle deformation zone characterized by increased frequency of open and sealed fractures, sealed network, two crush, weak to medium red staining, partly weak chloritization, weak epidotization and vuggy character in the lower part of the section. Significant decrease in bulk resistivity and bulk magnetic susceptibility and also a major decrease in P-wave velocity. One oriented and two non-oriented radar reflectors occur within the deformation zone. The oriented reflector occurs at 631.1 m with the orientation 004/56 or 225/78. The non-oriented reflectors occur at 630.0 m and 630.5 m with the angle 49° and 37° to borehole axis, respectively. Very low radar amplitude occurs in the section 628–635 m, which is partly above DZ12. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock types comprise granite (501058) and very sparse occurrence of fine-grained granite (511058). Confidence level = 3.

658.91–659.80 m

DZ13: Brittle-ductile deformation zone. Faint red staining. There is a minor decrease in magnetic susceptibility and resistivity. One non-oriented radar reflector occurs at 658.9 m with the angle 38° to borehole axis. The host rock is dominated by Ävrö granite (501044) (501036). Subordinate rock types comprise quartz monzodiorite (501036) and very sparse occurrence of granite (501058). Confidence level = 3.

675.05–682.68 m

DZ14: Brittle deformation zone characterized by increased frequency of sealed fractures and sealed network. Three slickensides, faint to strong red staining and partly faint epidotization. Significantly decreased resistivity and magnetic susceptibility at the two section coordinates 675.5 m and 682.0 m. One strong radar reflector occurs at 681.2 m with the orientation 278/89 or 066/07. The reflector can be observed to a distance of 20 m outside the borehole. Low radar amplitude occurs in the section 680–683 m. The host rock is dominated by Ävrö granite (501044). Subordinate rock types comprise pegmatite (501061), fine-grained granite (511058) and quartz monzodiorite (501036). Confidence level = 3.

688.00–688.50 m

DZ15: Minor brittle-ductile shear zone. Moderate increase in sealed fractures. Significantly decreased magnetic susceptibility. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock type comprises pegmatite (501061). Confidence level = 3.

711.36–743.76 m

DZ16: Inhomogeneous deformation zone characterized by brittle and brittle-ductile deformation. Increased frequency of sealed fractures, sealed fracture network and slight increase in open fractures, eight slickensides, partly weak to medium red staining. The most intensely deformed sections (cores) are: 711.36–711.60 m, 714.08–714.23 m, 717.85–718.60 m, 731.68–732.55 m and 743.10–743.76 m. Significant decrease in magnetic susceptibility along the major part of the section. Decreased resistivity at the section coordinates 711.7 m, 714.2 m, 716.4 m, 718.5 m, 725.5–726.5 m, 732.0 m, 734.2 m and 738.0–747.0 m. There is also decreased P-wave velocity in the section 717.5–719.0 m. Four oriented and sixteen non-oriented radar reflectors occur within DZ16. The oriented reflectors occur at 718.1 m (256/65 or 333/31), at 714.9 m (248/76 or 358/34), at 737.8 m (247/62 or 337/40) and at 743.4 m (225/75). The non-oriented reflectors occur with angles between 3° and 63° to borehole axis. Low radar amplitude occurs in the section 711–719 m. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock types comprise pegmatite (501061), granite (501058), fine-grained granite (511058) and fine-grained diorite-gabbro (505102). Confidence level = 3.

772.70–774.15 m

DZ17: Brittle-ductile shear zone in composite intrusion. Increased frequency of open and sealed fractures, sealed fracture network and two slickensides. Significantly decreased resistivity and magnetic susceptibility and partly decreased P-wave velocity. One oriented radar reflector occurs at 773.8 m with the orientation 184/06 or 288/84. The reflector is prominent and can be observed to a distance of 25 m outside the borehole. The host rock is dominated by fine-grained diorite-gabbro (505102). Subordinate rock type comprises quartz monzodiorite (501036). Confidence level = 3.

821.63–821.94 m

DZ18: Brittle-ductile shear zone. Increased frequency of sealed fractures and sealed network, and slight increase of open fractures and faint epidotization. Significantly decreased resistivity and magnetic susceptibility and partly decreased P-wave velocity. One non-oriented radar reflector occurs at 822.0 m with the angle 69° to borehole axis. The host rock is dominated by quartz monzodiorite (501036). Confidence level = 3.

917.75–918.46 m

DZ19: Ductile shear zone in composite intrusion. Increased frequency of sealed fractures and sealed fracture network and one slickenside. Significantly decreased resistivity and magnetic susceptibility and partly decreased P-wave velocity. One of the most prominent radar reflectors in the borehole (reflector 209) occurs at 921.5 m, which is immediately below DZ19. The orientation of the reflector is 088/68 or 077/29, and the reflector can be observed to a distance of 30 m outside the borehole. Parts of the reflector (reflector 209x at 915.6 m, reflector 209xx at 918.9 m and reflector 209xxx at 911.7 m) have been interpreted to intersect close to DZ19. Low radar amplitude occurs in the section 915–920 m, which is partly above and partly below the deformation zone. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock type comprises fine-grained diorite-gabbro (505102). Confidence level = 3.

978.43–1,000.430 m

DZ20: Inhomogeneous deformation zone characterized by brittle and brittle-ductile deformation. Increased frequency of sealed fractures and sealed fracture network and slight increase in open fractures, faint to strong red staining and partly faint to weak saussuritization, one core loss and ten slickensides. The most intensely deformed sections (cores) are: 994.71–997.50 m (brittle-ductile deformation) and 997.50–1,000.43 m (brittle deformation; some fractures subparallel to core). No geophysical data. The geophysical logging was interrupted at c. 978 m. Two non-orinted radar reflectors occur at 980.4 m and 987.5 m, both with the angle 52° to borehole axis. The host rock is dominated by quartz monzodiorite (501036). Subordinate rock types comprise pegmatite (501061) and fine-grained granite (511058). Confidence level = 3.

5.2 HLX30

Rock units

One rock unit (RU1) occurs in the borehole. The rock unit has been recognized with a medium degree of confidence.

9.11–162.84 m

RU1: Totally dominated by Ävrö granite (501044). Subordinate rock types comprise in particular fine-grained diorite-gabbro (505102) and sparse occurrence of fine-grained granite (511058). Confidence level = 2.

Possible deformation zones

Five possible deformation zones have been recognised with a medium degree of confidence in HLX30 (DZ1–DZ5).

10–42 m

DZ1: Brittle deformation zone characterized by increased frequency of open fractures, crush at c. 20.5 m and medium red staining. Significantly decreased bulk resistivity and magnetic susceptibility. Nine non-oriented radar reflectors occur at the section, and the angle to borehole axis is from 54° to 80°. Low radar amplitude occurs in the section 10–22 m. Host rock is totally dominated by Ävrö granite (501044), and very subordinate occurrence of fine-grained granite (511058), the latter of which coincides with the crush. Confidence level = 2.

60–68 m

DZ2: Brittle deformation zone characterized by increased frequency of open fractures, crush at c. 62 m and medium red staining. High frequency of negative resistivity anomalies and decreased bulk magnetic susceptibility. Five non-oriented radar reflectors occur with an angle from 52° to 80° to borehole axis. Host rock is totally dominated by Ävrö granite (501044). Confidence level = 2.

85.5–88 m

DZ3: Brittle deformation zone characterized by increased frequency of open fractures and weak red staining. Significantly decreased resistivity and magnetic susceptibility. Four non-oriented radar reflectors occur with an angle from 58° to 70° to borehole axis. Low radar amplitude occurs in the section 84–90 m. Host rock is dominated by fine-grained diorite-gabbro (505102). Subordinate rock type is Ävrö granite (501044). Confidence level = 2.

127–137.5 m

DZ4: Brittle deformation zone characterized by increased frequency of open fractures and weak red staining. Significantly decreased bulk resistivity and magnetic susceptibility. Partly decreased P-wave velocity. Four non-oriented radar reflectors occur with an angle from 58° to 63° to borehole axis. Two of the reflectors are prominent (at 128.0 m and 134.6 m) and can be observed to a distance of c. 12 m outside the borehole. Very low radar amplitude occurs in the section 134–139 m, which is partly below the deformation zone. Host rock is dominated by Ävrö granite (501044) and fine-grained diorite-gabbro (505102). Confidence level = 2.

148.5–154 m

DZ5: Brittle deformation zone characterized by increased frequency of open fractures, crush at c. 153.5 m and weak red staining. Significantly decreased resistivity and magnetic susceptibility. Three non-oriented radar reflectors occur with an angle from 50° to 79° to borehole axis. Host rock is dominated by Ävrö granite (501044). Confidence level = 2.

5.3 HLX31

Rock units

One rock unit (RU1) occurs in the borehole. The rock unit has been recognized with a medium degree of confidence.

9.10–128.75 m

RU1: Totally dominated by Ävrö granite (501044). Subordinate rock type comprises fine-grained diorite-gabbro (505102). Confidence level = 2.

Possible deformation zones

Three possible deformation zones have been recognised with a medium degree of confidence in HLX31 (DZ1–DZ3).

60–67 m

DZ1: Brittle deformation zone characterized by increased frequency of open fractures and medium red staining. Significantly decreased resistivity and magnetic susceptibility and several caliper anomalies. One strong non-oriented radar reflector occurs at 66.1 m with the angle 31° to borehole axis. Host rock is totally dominated by Ävrö granite (501044). Confidence level = 2.

96–98.5 m

DZ2: Brittle deformation zone characterized by increased frequency of open fractures, crush at c. 97 m and weak red staining. Significantly decreased resistivity and magnetic susceptibility and several caliper anomalies. Two non-oriented radar reflectors occur at 96.5 m and 98.1 m with the angle 63° and 57° to borehole axis, respectively. The lower radar reflector is strong. Low radar amplitude occurs in the interval 96–102 m, which is partly below the deformation zone. Host rock is totally dominated by Ävrö granite (501044). Confidence level = 2.

126–127 m

DZ3: Brittle deformation zone characterized by increased frequency of open fractures, crush at c. 126.5 m and weak red staining. Significantly decreased resistivity and magnetic susceptibility and one major caliper anomaly. Host rock is totally dominated by Ävrö granite (501044). Confidence level = 2.

5.4 HLX33

Rock units

One rock unit (RU1) occurs in the borehole. The rock unit has been recognized with a medium degree of confidence.

9.11–201.77 m

RU1: Totally dominated by Ävrö granite (501044). Subordinate rock types comprise in particular fine-grained diorite-gabbro (505102) and sparse occurrence of fine-grained granite (511058). Confidence level = 2.

Possible deformation zones

One possible deformation zone has been recognised with a medium degree of confidence in HLX33 (DZ1).

12–28 m

DZ1: Brittle deformation zone characterized by increased frequency of open fractures, crush at c. 23 m and weak to medium red staining. Significantly decreased resistivity and magnetic susceptibility. Four non-oriented radar reflectors occur with an angle from 46° to 80° to borehole axis. Low radar amplitude occurs in the interval 10–30 m, which is partly above and below the deformation zone. Host rock is totally dominated by Ävrö granite (501044). Confidence level = 2.

6 Comments

The results from the geological single-hole interpretation of KLX15A, HLX30, HLX31 and HLX33 are presented in WellCad plots (Appendices 1–4). The WellCad plot consists 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/ **Munier R, Stenberg L, Stanfors R, Milnes A G, Hermanson J, Triumf CA, 2003.** Geological site descriptive model. A strategy for the model development during site investigations. SKB R-03-07, Svensk Kärnbränslehantering AB.

/2/ **Mattsson K-J, Dahlin P, 2007.** Oskarshamn site investigation. Boremap mapping of telescopic drilled borehole KLX15A. SKB P-07-xx (in prep.), Svensk Kärnbränslehantering AB.

/3/ **Sigurdsson, Oskar, 2005.** Oskarshamn site investigation. Simplified Boremap mapping of percussion boreholes HLX13, HLX21, HLX22, HLX23, HLX24, HLX25, HLX30, HLX31 and HLX33 on lineament EW007. SKB P-05-164, Svensk Kärnbränslehantering AB.

/4/ **Mattsson H, Keisu P, 2005.** Oskarshamn site investigation. Interpretation of geophysical borehole measurements from KLX08, HLX30, HLX31 and HLX33. SKB P-06-65, Svensk Kärnbränslehantering AB.

/5/ **Mattsson H, Keisu P, 2005.** Oskarshamn site investigation. Interpretation of geophysical borehole measurement from KLX15A. SKB P-07-114, Svensk Kärnbränslehantering AB.

/6/ **Gustafsson J, Gustafsson C, 2007.** Oskarshamn site investigation. RAMAC, BIPS and deviation logging in borehole KLX15A. SKB P-07-117, Svensk Kärnbränslehantering AB.

/7/ **Gustafsson J, Gustafsson C, 2006.** Oskarshamn site investigation. RAMAC and BIPS logging in boreholes KLX10 and HLX31. SKB P-06-50, Svensk Kärnbränslehantering AB.

/8/ **Gustafsson J, Gustafsson C, 2005.** Oskarshamn site investigation. RAMAC, BIPS and deviation logging in boreholes KLX08, HLX30 and HLX33. SKB P-05-240, Svensk Kärnbränslehantering AB.

Geological single-hole interpretation of KLX15A

Title	SINGLE HOLE INTERPRETATION KLX15A					
Site	LAXEMAR	Inclination [°]	-54.41	Elevation [m.a.s.l.]	14.52	Signed data
Borehole	KLX15A	Date of mapping	2007-04-04 16:08:00	Drilling Start Date	2006-12-21 08:30:00	
Diameter [mm]	76	Coordinate System	RT90-RHB70	Drilling Stop Date	2006-12-29 17:00:00	
Length [m]	1000.430	Northing [m]	6365613.35	Surveying Date		
Bearing [°]	198.83	Easting [m]	1547987.51	Plot Date	2007-10-14 22:03:05	

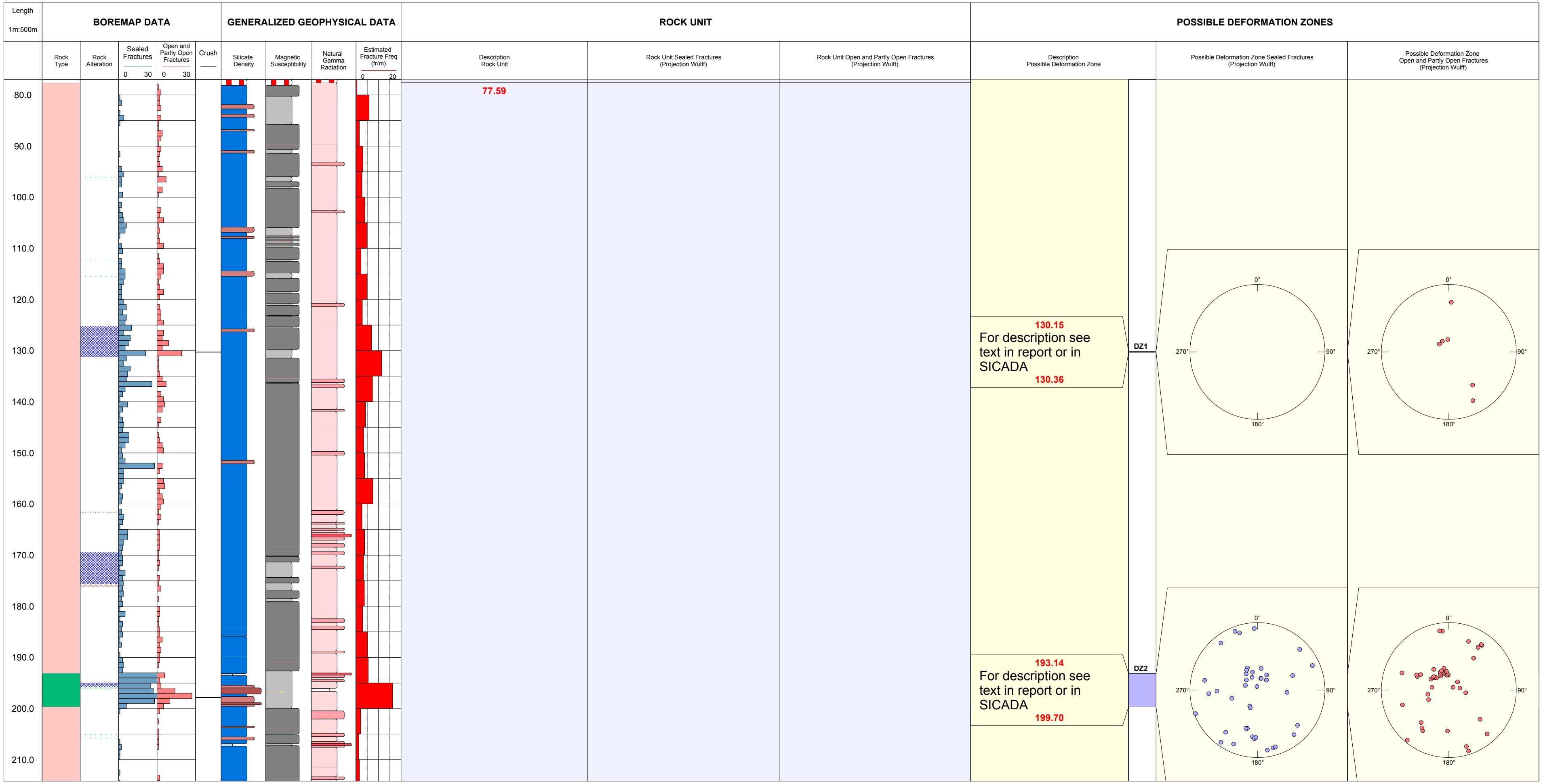
ROCKTYPE LAXEMAR
- Fine-grained granite
- Pegmatite
- Granite
- Ävrö granite
- Quartz monzodiorite
- Fine-grained diorite-gabbro

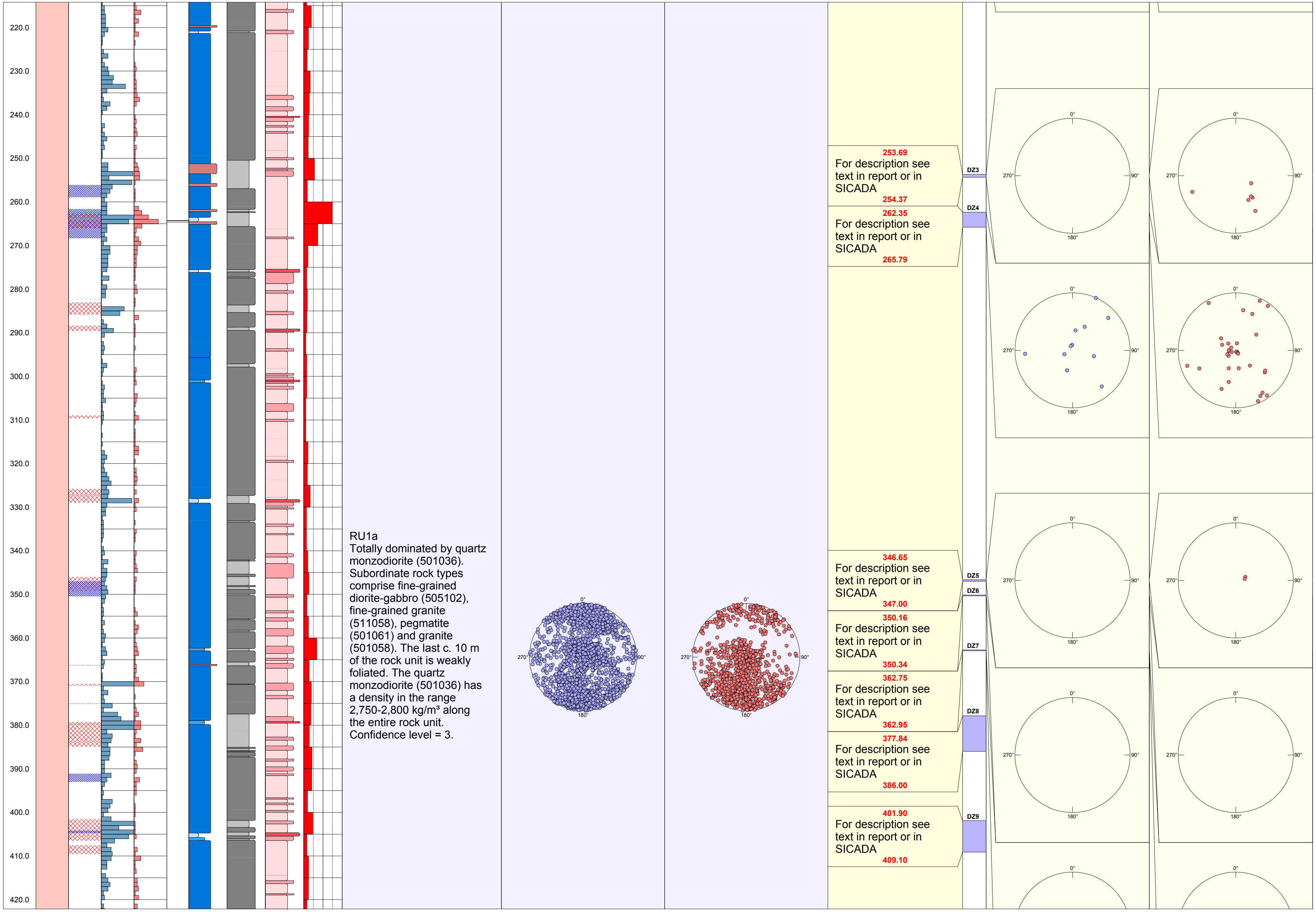
ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Saussuritization

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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350.0
360.0
370.0
380.0
390.0
400.0
410.0
420.0
RU1a
Totally dominated by quartz monzodiorite (501036). Subordinate rock types comprise fine-grained diorite-gabbro (505102), fine-grained granite (511058), pegmatite (501061) and granite (501058). The last c. 10 m of the rock unit is weakly foliated. The quartz monzodiorite (501036) has a density in the range 2,750-2,800 kg/m³ along the entire rock unit. Confidence level = 3.
0°
90°
180°
270°
253.69
For description see text in report or in SICADA
254.37
262.35
For description see text in report or in SICADA
265.79
346.65
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347.00
350.16
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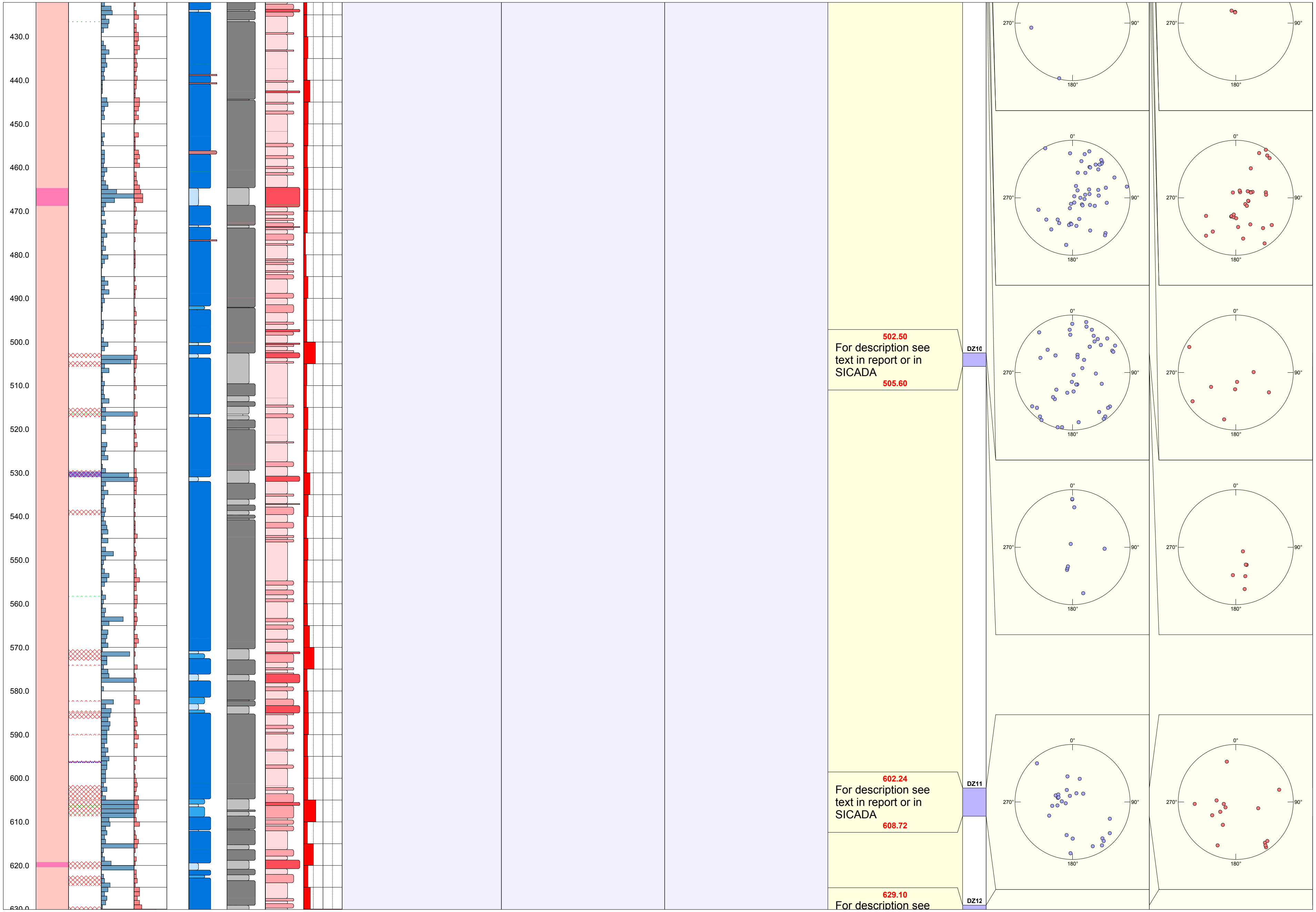
350.34
362.75
For description see text in report or in SICADA
362.95
377.84
For description see text in report or in SICADA
386.00
401.90
For description see text in report or in SICADA
409.10
DZ3
DZ4
DZ5
DZ6
DZ7
DZ8
DZ9



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560.0
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580.0
590.0
600.0
610.0
620.0
502.50
For description see text in report or in SICADA
505.60
DZ10
602.24
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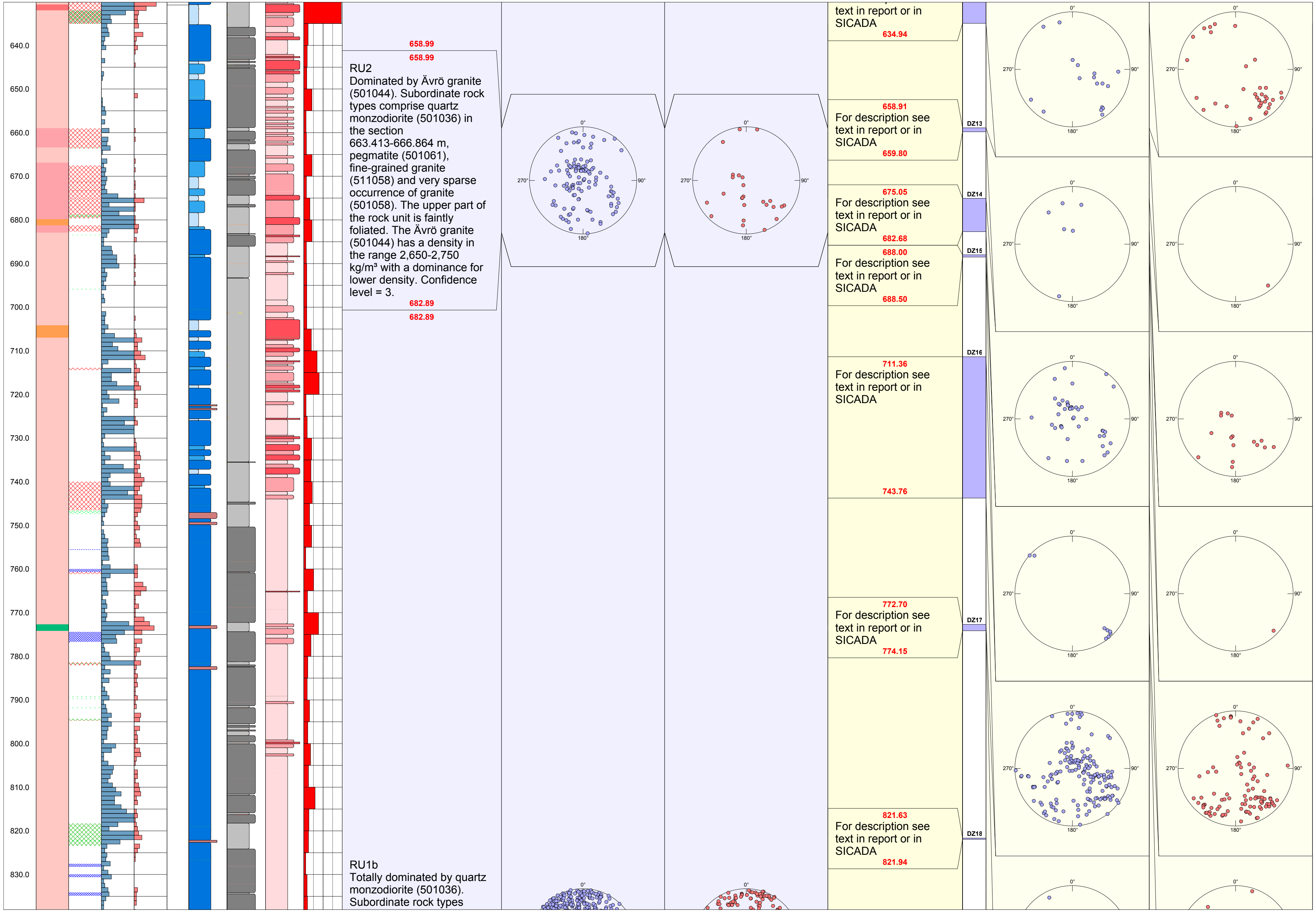
608.72
DZ11
629.10
For description see
DZ12



640.0
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670.0
680.0
690.0
700.0
710.0
720.0
730.0
740.0
750.0
760.0
770.0
780.0
790.0
800.0
810.0
820.0
830.0
658.99
658.99
RU2
Dominated by Ävrö granite (501044). Subordinate rock types comprise quartz monzodiorite (501036) in the section 663.413-666.864 m, pegmatite (501061), fine-grained granite (511058) and very sparse occurrence of granite (501058). The upper part of the rock unit is faintly foliated. The Ävrö granite (501044) has a density in the range 2,650-2,750 kg/m³ with a dominance for lower density. Confidence level = 3.
682.89
682.89
RU1b
Totally dominated by quartz monzodiorite (501036). Subordinate rock types
text in report or in SICADA
634.94
658.91
For description see text in report or in SICADA
659.80
675.05
For description see text in report or in SICADA
682.68
688.00
For description see text in report or in SICADA
688.50
711.36
For description see text in report or in SICADA
743.76
772.70
For description see text in report or in SICADA
774.15
821.63
For description see text in report or in SICADA
821.94
DZ13
DZ14
DZ15
DZ16
DZ17
DZ18
0°
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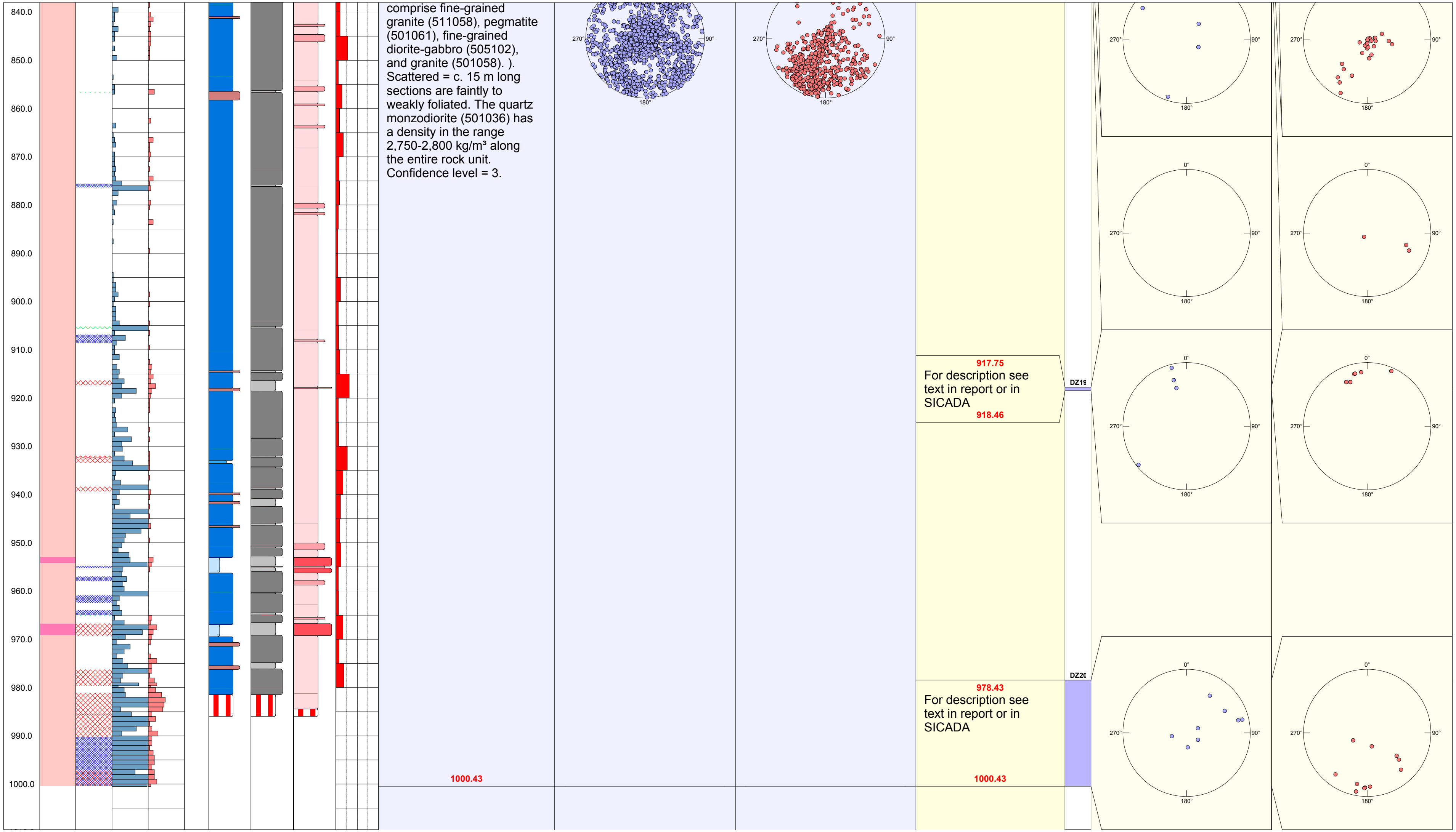
180°
270°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920.0
930.0
940.0
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960.0
970.0
980.0
990.0
1000.0
comprise fine-grained granite (511058), pegmatite (501061), fine-grained diorite-gabbro (505102), and granite (501058).). Scattered = c. 15 m long sections are faintly to weakly foliated. The quartz monzodiorite (501036) has a density in the range 2,750-2,800 kg/m³ along the entire rock unit. Confidence level = 3.
1000.43
917.75
For description see text in report or in SICADA
918.46
978.43
For description see text in report or in SICADA
1000.43
DZ19
DZ20
0°
90°
180°
270°

Geological single-hole interpretation of HLX30

Title	SINGLE HOLE INTERPRETATION HLX30					
Site	LAXEMAR	Inclination [°]	-61.03	Elevation [m.a.s.l.]	12.18	Signed data
Borehole	HLX30	Date of mapping	2005-09-14 14:01:00	Drilling Start Date	2004-11-26 07:00:00	
Diameter [mm]	139	Coordinate System	RT90-RHB70	Drilling Stop Date	2004-11-30 17:00:00	
Length [m]	163.400	Northing [m]	6366730.73	Surveying Date		
Bearing [°]	55.82	Easting [m]	1548026.73	Plot Date	2007-10-15 22:03:14	

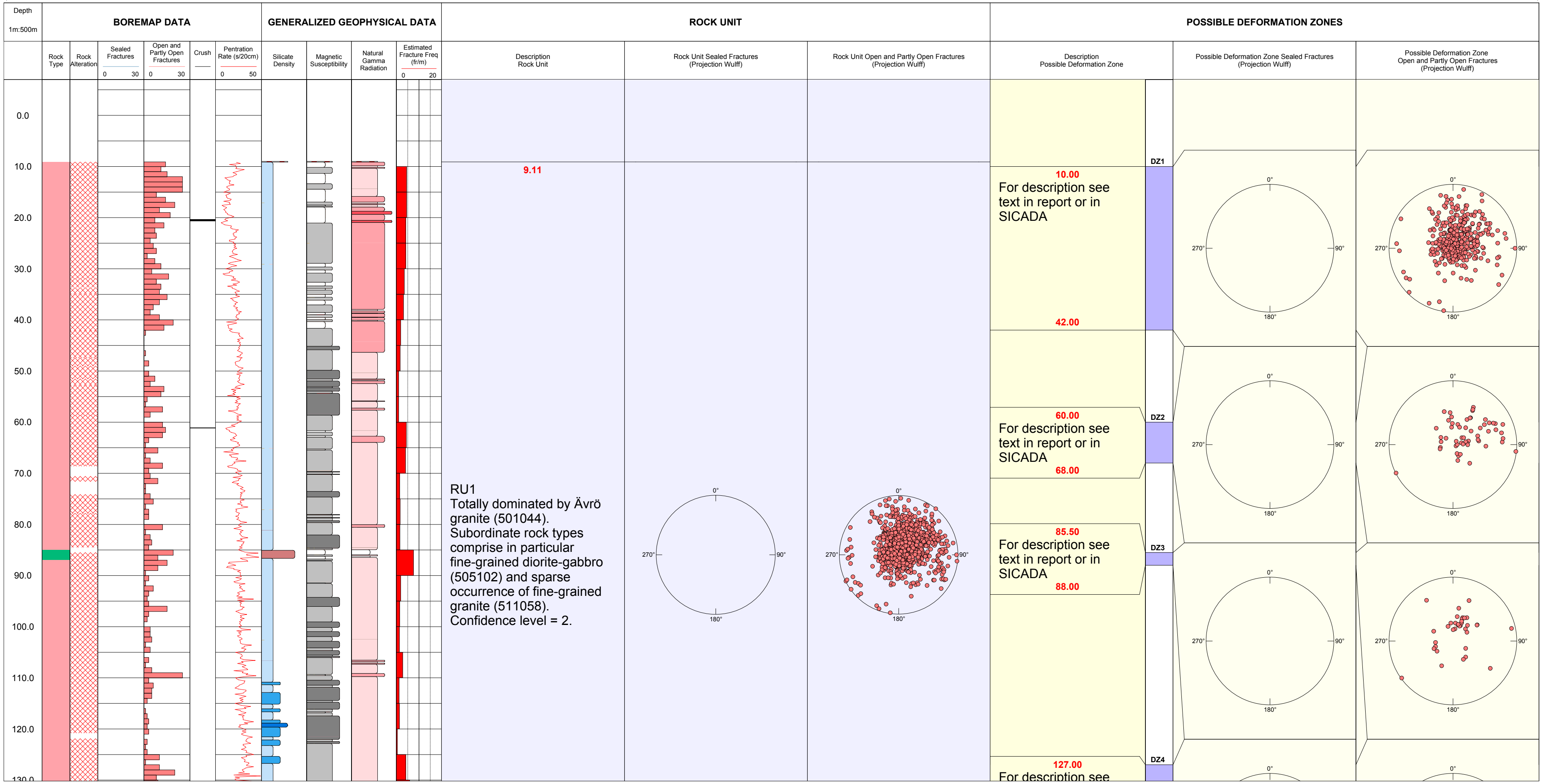
ROCKTYPE LAXEMAR
- Ävrö granite
- Fine-grained diorite-gabbro

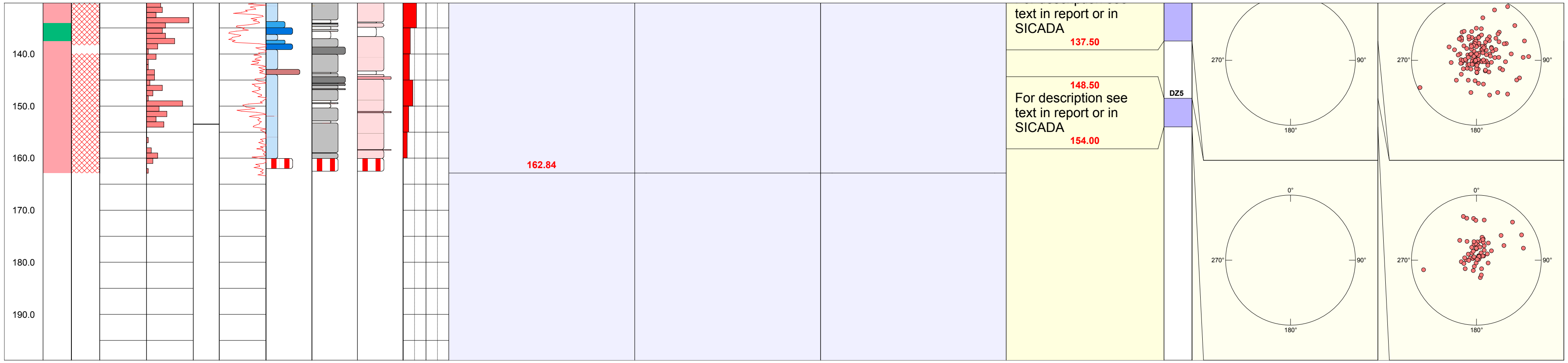
ROCK ALTERATION
- Oxidized

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

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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text in report or in
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137.50
148.50
For description see
text in report or in
SICADA
154.00
DZ5
0°
90°
180°
270°

Geological single-hole interpretation of HLX31

Title	SINGLE HOLE INTERPRETATION HLX31					
Site	LAXEMAR	Inclination [°]	-58.75	Elevation [m.a.s.l.]	12.16	Signed data
Borehole	HLX31	Date of mapping	2005-12-13 15:20:00	Drilling Start Date	2004-12-01 07:00:00	
Diameter [mm]	139	Coordinate System	RT90-RHB70	Drilling Stop Date	2004-12-03 12:00:00	
Length [m]	133.200	Northing [m]	6366774.51	Surveying Date		
Bearing [°]	231.77	Easting [m]	1548172.27	Plot Date	2007-10-15 22:03:14	

ROCKTYPE LAXEMAR
Ävrö granite

ROCK ALTERATION
Oxidized

SILICATE DENSITY
unclassified
dens<2680
2680<dens<2730

SUSCEPTIBILITET
unclassified
sus<0.001
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0.01<sus<0.1

NATURAL GAMMA
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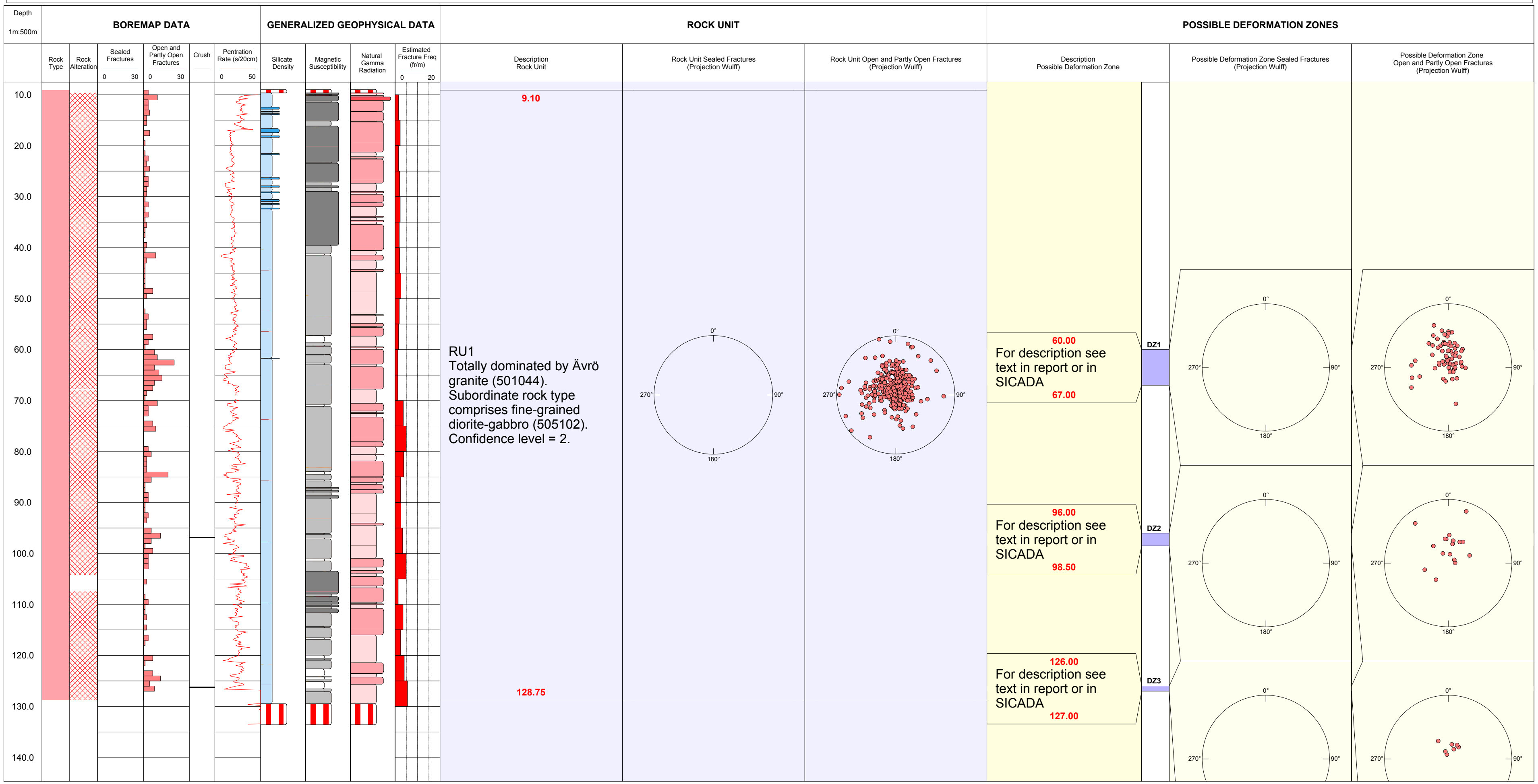
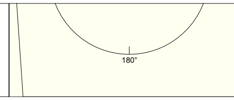
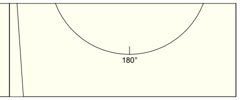
gam>30



150.0																	

Appendix 4

Geological single-hole interpretation of HLX33

Title	SINGLE HOLE INTERPRETATION HLX33							
Site	LAXEMAR	**Inclination [°]**	-58.80	**Elevation [m.a.s.l.]**	12.20	**Signed data**		
Borehole	HLX33	**Date of mapping**	2005-10-13 14:59:00	**Drilling Start Date**	2004-12-17 07:00:00			
Diameter [mm]	139	**Coordinate System**	RT90-RHB70	**Drilling Stop Date**	2004-12-20 19:15:00			
Length [m]	202.100	**Northing [m]**	6366471.74	**Surveying Date**				
Bearing [°]	21.77	**Easting [m]**	1548562.71	**Plot Date**	2007-10-15 22:03:14			

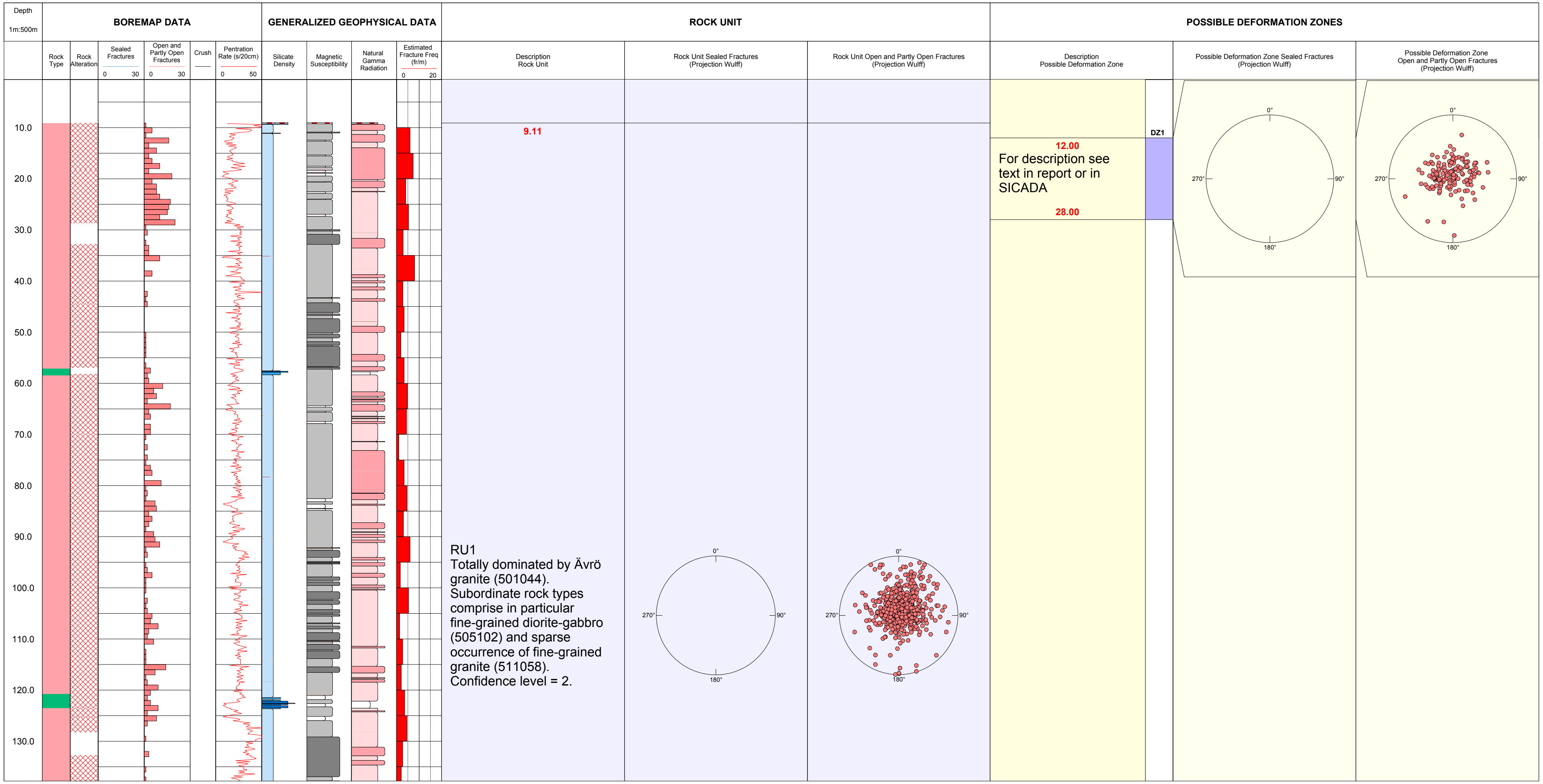
ROCKTYPE LAXEMAR
- Ävrö granite
- Fine-grained diorite-gabbro

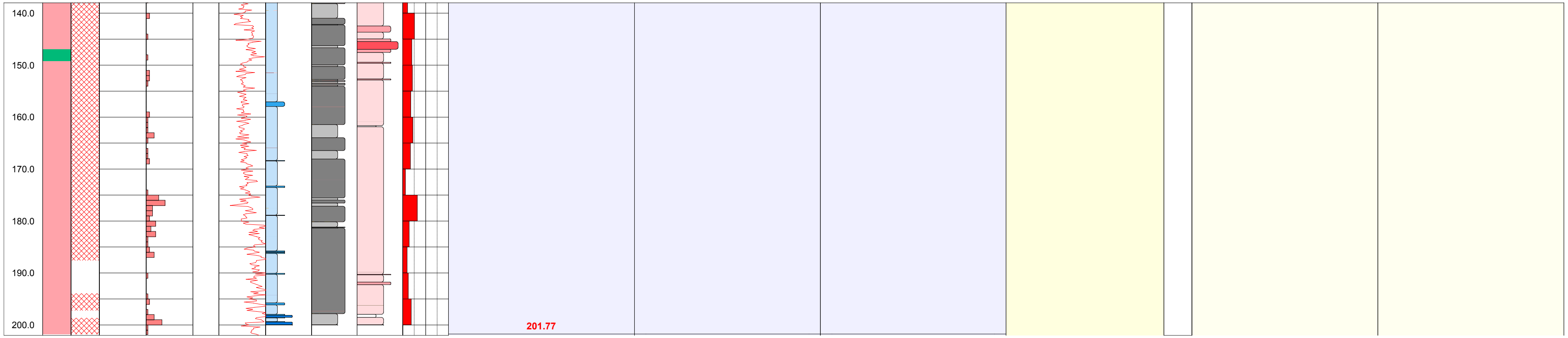
ROCK ALTERATION
- Oxidized

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

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




140.0
150.0
160.0
170.0
180.0
190.0
200.0
201.77