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Geological single-hole interpretation of KSH03A, KSH03B, KLX02, HAV09 and HAV10

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September 2004

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

A pdf version of this document can be downloaded from www.skb.se

Reading instruction

For revision no. 1 of this report a recalculation of the directional radar data has been done. The strike and angel between the line of the plan’s cross-section with the surface and the Magnetic North direction was earlier counted counter-clockwise but it is now recalculated as such it counts clockwise. New values for strike and dip are therefore updated in Chapter 5.

Abstract

This document reports the geological single-hole interpretation, for the cored boreholes KSH03 A and B at the Simpevarp peninsula, KLX02 at Laxemar and HAV09 and HAV10 at the Ävrö Island.

The classification is performed manually by a combined interpretation of the logging data from the geological core mapping (Boremap), different geophysical loggings and borehole radar data. The results are presented as two logs, one indicating the lithological units (RU) and other possible deformation zones (DZ).

Tree rock units are indicated in KSH03A. In general KSH03A dominates by Ävrö granite. Sub ordinary rock types are fine- to medium grained granite and diorite/gabbro. One possible deformation zone has been identified in KSH03A. One rock unit is indicated in KSH03B which dominates by quartzmonzodiorite and Ävrö granite. No deformation zones have been identified in KSH03B.

Two rock units are indicated in KLX02 and one possible deformation zon has been identified in KLX02. RU1 is totally dominated by Ävrö granite, RU2 by fine-grained dioritoid and Ävrö granite.

One rock unit has been indicated in HAV09 which is dominated by Ävrö granite with some features of fine-grained dioritoid. Two possible deformations zones have been indicated

One rock unit has been indicated in HAV10 which is dominated by Ävrö granite with some features of fine grained dioritoid and fine grained granite. One deformation zone has been indicated.

Sammanfattning

Denna rapport behandlar geologisk enhålstolkning av kärnborrhålen KSH03A, KSH03B samt hammarborrhålen HAV09 och HAV10 på Simpevarpshalvön och Ävrö och kärnborrhålet KLX02 i Laxemar. Den geologiska enhålstolkningen syftar till att utifrån data från den geologiska kärnkarteringen, tolkade geofysiska loggar och borrhålsradarmätningar indikera olika litologiska enheters fördelning samt möjliga deformationszoners läge och utbredning längs hålet.

Undersökningar visar att det i KSH03A finns tre olika litologiska enheter. Generellt sett dominerar bergarten Ävrögranit. Fin- till medelkornig granit och diorit/gabbro förekommer i mindre omfattning. En möjlig större deformationszon identifieras i KSH03A. I KSH03B finns en litologisk enhet där kvartsmonzodiorit och Ävrögranit dominerar. Ingen deformationszon identifieras i KSH03B

För KLX02 indikeras två olika litologiska enheter och en möjlig större deformationszon. Dominerande bergarter i RU1 är Ävrögranit och i RU2 finkornig dioritoid och Ävrö granit.

I HAV09 finns en litologisk enhet, Ävrögranit med inslag av finkornig dioritoid. Två möjliga deformationszoner identifieras i HAV09.

I HAV10 finns en litologisk enhet, Ävrögranit med inslag agv finkornig dioritoid och finkornig granit. En större deformationszon identifieras i HAV10.

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 RVS. The end result of this procedure is a geological single-hole interpretation, which consist of integrated series of different loggings and accompanying descriptive documents (SKB MD 810.003, SKB internal controlling document).

This document reports the geological single-hole interpretation, for the cored boreholes KSH03 A and B at the Simpevarp peninsula, KLX02 at Laxemar and HAV09 and HAV10 at the Ävrö Island (Figure 1-1).

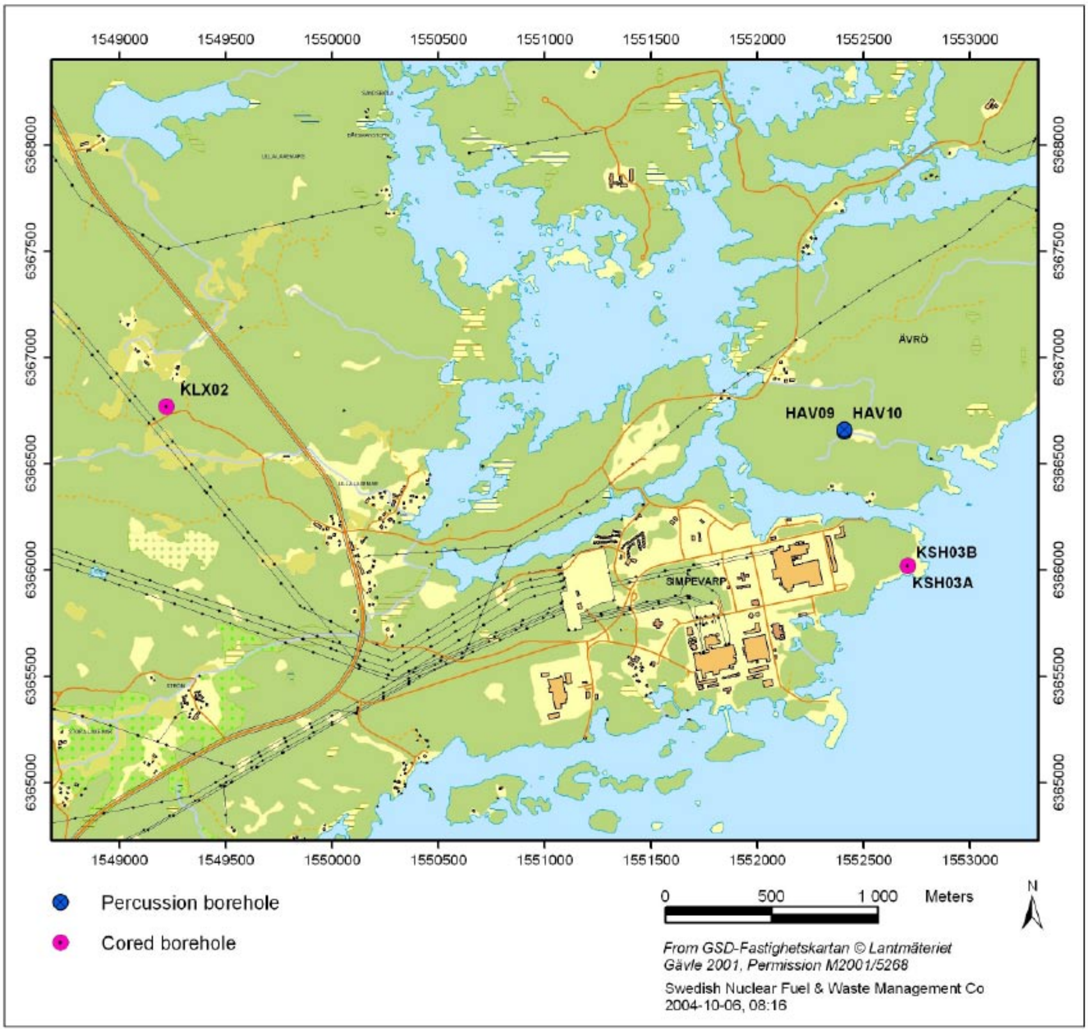


***Figure 1-1.** Map showing the position of the cored boreholes KSH03A and B, KLX02, HAV09 and HAV10.*

This document reports the results gained by the geological single-hole interpretation, 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 400-04-071. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

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

Activity plan	Number	Version
Geologisk enhålstolkning av KLX02, KSH03, HAV09 och HAV10	AP PS 400-04-071	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för geologisk enhålstolkning	SKB MD 810.003	1.0

Rock type nomenclature that has been used is displayed in Table 1-2.

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

Rock Name	Rock Description
Dolerite	Dolerite
Fine-grained Götemar granite	Granite, fine- to medium-grained, ("Götemar granite")
Coarse-grained Götemar granite	Granite, coarse-grained, ("Götemar granite")
Fine-grained granite	Granite, fine- to medium-grained
Pegmatite	Pegmatite
Granite	Granite, medium- to coarse-grained
Ävrö granite	Granite to quartz monzodiorite, generally porphyritic
Quartz monzodiorite	Quartz monzonite to monzodiorite, equigranular to weakly porphyritic
Diorite/gabbro	Diorite to gabbro
Fine-grained dioritoid	Intermediate magmatic rock
Fine-grained diorite-gabbro	Mafic rock, fine-grained
Sulphide mineralization	Sulphide mineralization
Sandstone	Sandstone

The reference to SICADA databases is listed in Table 1-3.

Table 1-3. Data references.

Subactivity	Database	Identity number
KSH03A and B	SICADA	Field note Simpevarp 494
KLX02	SICADA	Field note Simpevarp 495
HAV09	SICADA	Field note Simpevarp 493
HAV10	SICADA	Field note Simpevarp 493

2 Objective and scope

The single-hole interpretation is performed in order to make a generalized classification of major lithological units and possible major deformation zones within the borehole. The classification is performed manually by a combined interpretation of the logging data from the geological core mapping (Boremap), different geophysical loggings and borehole radar data. The results are presented as two logs, one indicating the lithological unit (RU) and other possible deformation zones (DZ).

3 Equipment

3.1 Description of interpretation tools

The data used for the single-hole interpretation are

- Boremap (including BIPS and core mapping data) /1, 2, 6/.
- Generalized geophysical loggings (interpretation of geophysical logging data) /3/.
- Interpreted radar data /4, 5/.

4 Execution

4.1 General

The single-hole interpretation method is an integrated interpretation of the information from three sources, and these are the boremap investigation, geophysical loggings and borehole radar data. The interpretation is performed by a group of experts consisting of geologist and one geophysicist (SKB MD 810.003 Metodbeskrivning för geologisk enhålstolkning, SKB internal document).

All data to be used (see above) are visualized side by side in a borehole document in the software WellCAD (see Appendices 1 and 2).

Step 1 is to manually (visually) go through the rock-type related logging data and merge sections of similar rock types, or sections where one rock type is very dominant, to major lithological units (minimum length of ca 5 m). Even so the fracture frequency and ductile deformation are included in the interpretation of rock units. All the interpretation is based on geophysical logging data, boremap data and BIPS.

Step 2 is to identify possible major deformation zones by visual inspection of the fracture frequency loggings, alteration loggings and radar loggings. The section of each identified possible deformation zone is indicated and shortly described in text.

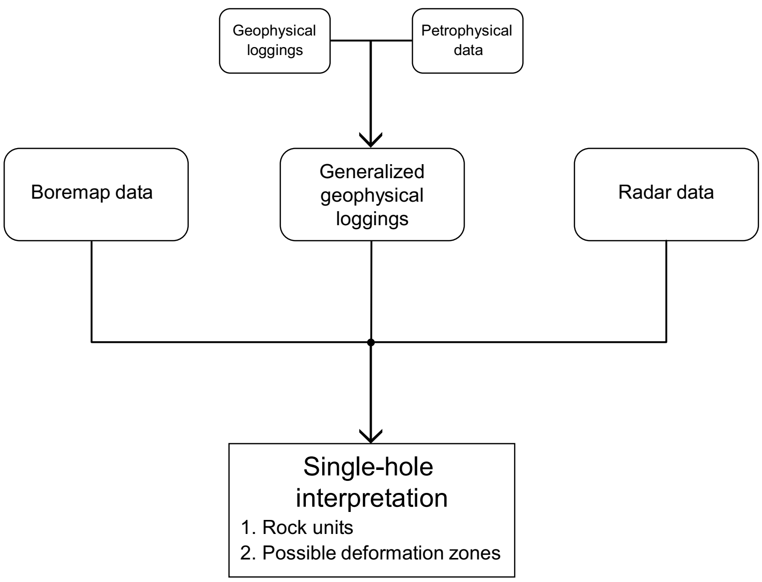


Figure 4-1. *Schematic block-scheme of single-hole interpretation.*

4.2 Nonconformities

For revision no. 1 of this report a recalculation of the directional radar data has been done. The strike and angel between the line of the plan's cross-section with the surface and the Magnetic North direction was earlier counted counter-clockwise but it is now recalculated as such it counts clockwise. New values for strike and dip are therefore updated in Chapter 5.

5 Results

The detailed results of the single-hole interpretation are presented as print-outs from the software WellCad (Appendix 1 for KSH03A, Appendix 2 for KSH03B, Appendix 3 for KLX02, Appendix 4 for HAV09 and Appendix 5 for HAV10. Orientations from directional radar are presented as dip/strike using the right-hand rule.

5.1 KSH03A

Three rock units are indicated

Rock unit 1: 100–270 m

Mixture of Ävrö granite and quartz monzodiorite. Silica density is lower than what is normal for the quartz monzodiorite. Some sections of fine- to medium-grained granite and pegmatite.

Rock unit 2: 270–440 m

Totally dominated by Ävrö granite. Certain sections of fine- to medium-grained granite and a few sections of diorite-gabbro. A c 10 cm long section of sandstone at c 271.5 m.

Rock unit 3: 440–575 m

Mixture of fine- to medium-grained granite (slightly dominating) and Ävrö granite. Higher degree of alteration and higher magnetic susceptibility than what is normal for fine- to medium-grained granite. Furthermore, the latter is texturally deviating by being unequigranular to megacryst-bearing (1–3 mm large feldspar grains).

Rock unit 2: 575–755 m

Totally dominated by Ävrö granite. The upper c 100 m of the section has a high resistivity, and higher density and lower natural gamma radiation than the lower 100 m of the section. 8 m long section of diorite to gabbro between c 647 and 655 m.

Rock unit 3: 755–864 m

Mixture of fine- to medium-grained granite (slightly dominating) and Ävrö granite. Higher degree of alteration and higher magnetic susceptibility than what is normal for fine- to medium-grained granite. Furthermore, the latter is texturally deviating by being unequigranular to megacryst-bearing (1–3 mm large feldspar grains). Certain sections (1–3 m long) of diorite to gabbro and medium-grained granite in the lower part.

Rock unit 2: 864–1,000 m

Totally dominated by Ävrö granite. Certain sections of fine- to medium-grained granite.

One possible major deformation zone has been identified in KSH03A.

Deformation zone 1: 162–275 m

Inhomogeneous, low-grade, ductile deformation. High frequency of open and sealed fractures and crush zones. Brecciation between 220–235 m and mylonitization between 270–275 m. Marked low resistivity and, where available, lower sonic. Sonic data are missing between 203.5–255.2 m). Distinct, major caliper anomaly. Generally low magnetic susceptibility. Dipole borehole radar shows several reflectors within the zone. Most of them are more or less perpendicular to the borehole axis. Oriented radar reflectors from directional antenna are found at 166.3 m with the orientation 21/352 (uncertain), 181.3 m with the orientation 32/249, at 244.6 m with the orientation 76/306, and at 254.8 m with the orientation 44/262 (uncertain). Uncertainty = 3.

A number of sections with increased fracturing may indicate minor deformation zones.

5.2 KSH03B

Rock unit 1: 0–100 m

Mixture of Ävrö granite and quartz monzodiorite.

No deformation zones have been identified in KSH03B.

5.3 KLX02

Two rock units are indicated.

Rock unit 1: 200–540 m

Totally dominated by Ävrö granite, with certain sections of fine-grained mafic rock (fine-grained diorite to gabbro) at c 358 and 388 m. Low fracture frequency with some sections with increased fracture frequency. Generally low silicate density (< 2,680 kg/m^3) and moderate to high natural gamma radiation.

Rock unit 2: 540–960 m

Mixture of Ävrö granite, slightly dominating, and fine-grained dioritoid. Certain < 10 m long sections of fine-grained diorite to gabbro between c 775 and 920 m and a few narrow sections of fine- to medium- grained granite. Low fracture frequency in the section c 540–770 m with certain sections with somewhat increased fracture frequency. Large variations in the silicate density, with high density corresponding to sections with fine-grained dioritoid and fine-grained diorite to gabbro, and low density corresponding to granite to quartz monzodiorite.

Rock unit 1: 960–1,000 m

Totally dominated by Ävrö granite, with certain sections of fine-grained diorite to gabbro at c 358 and 388 m. Low fracture frequency with some sections with increased fracture frequency. Generally low silicate density (< 2,680 kg/m^3) and moderate to high natural gamma radiation.

One possible deformation zone has been identified in KLX02.

Deformation zone 1: 770–960 m

Generally increased frequency of open fractures and higher oxidation. The most intensive part of the zone is located between 845–880 m, which is indicated by distinct low p-wave velocity and partly somewhat lower resistivity. Nine radar reflectors from directional antenna have been found within the zone. The orientation of the reflectors are 29–61°/047–086. Most of them are dipping around 50°. Uncertainty = 3.

A number of sections with increased fracturing may indicate minor deformation zones.

5.4 HAV09

One rock unit is indicated.

Rock unit 1: 0–200 m

Ävrö granite with < 15 m long sections of fine-grained dioritoid between 85 and 140 m, and fine- to medium-grained granite in the uppermost part. The section between c 76–96 m has a strongly increased gamma radiation.

Two possible deformation zones has been indicated in HAV09.

Deformation zone 1: 75–105 m

The zone is indicated by increased fracture frequency, high drill penetration rate, low resistivity, low magnetic susceptibility, low density, low p-wave velocity, distinct, marked caliper anomalies, and radar reflectors at 80.7 m 51° to borehole axis, 103.4 m and 80°, and at 104.7 m with the angle 46° to borehole axis. Uncertainty = 3.

Deformation zone 2: 149–155 m

High drill penetration rate, somewhat increased fracture frequency. Low resistivity, low magnetic susceptibility, low density, low p-wave velocity, distinct, marked caliper anomalies. Radar reflectors at 152.6 m with the angle 28° to borehole axis, 155.5 m with the angle 73°, and 155.2 m with the angle 25°. Uncertainty = 2.

5.5 HAV10

One rock unit is indicated.

Rock unit 1: 0–98 m

Ävrö granite with some sections of fine-grained dioritoid and fine- to medium-grained granite.

One possible deformation zone has been identified in HAV10.

Deformation zone 1: 0–38 m

Partly increased fracture frequency, indicated by caliper, low p-wave velocity, low resistivity, relatively high and uneven drill penetration rate. Four radar reflectors have been identified within the zone. There are one at 16.9 m with the angle 67° to borehole axis, 22.2 m with the angle 73°, 26.4 m with the angle 78°, and 36.1 m with the angle 58°. Uncertainty = 2.

References

/1/ **Ehrenborg J, Steiskal V, 2004.** Boremap mapping of the telescopic drilled borehole KSH03A and KSH03B.

/2/ **Ehrenborg J, Steiskal V, 2004.** Boremap mapping of the telescopic drilled borehole KLX02.

/3/ **Mattsson H, Thunehed H, 2004.** Interpretation of geofysical borehole data and compilation of petrophysical data from KSH03A (100–1,000 m), KSH03B, HAV09, HAV10 and KLX02 (200–1,000 m). SKB P-04-214, Svensk Kärnbränslehantering AB.

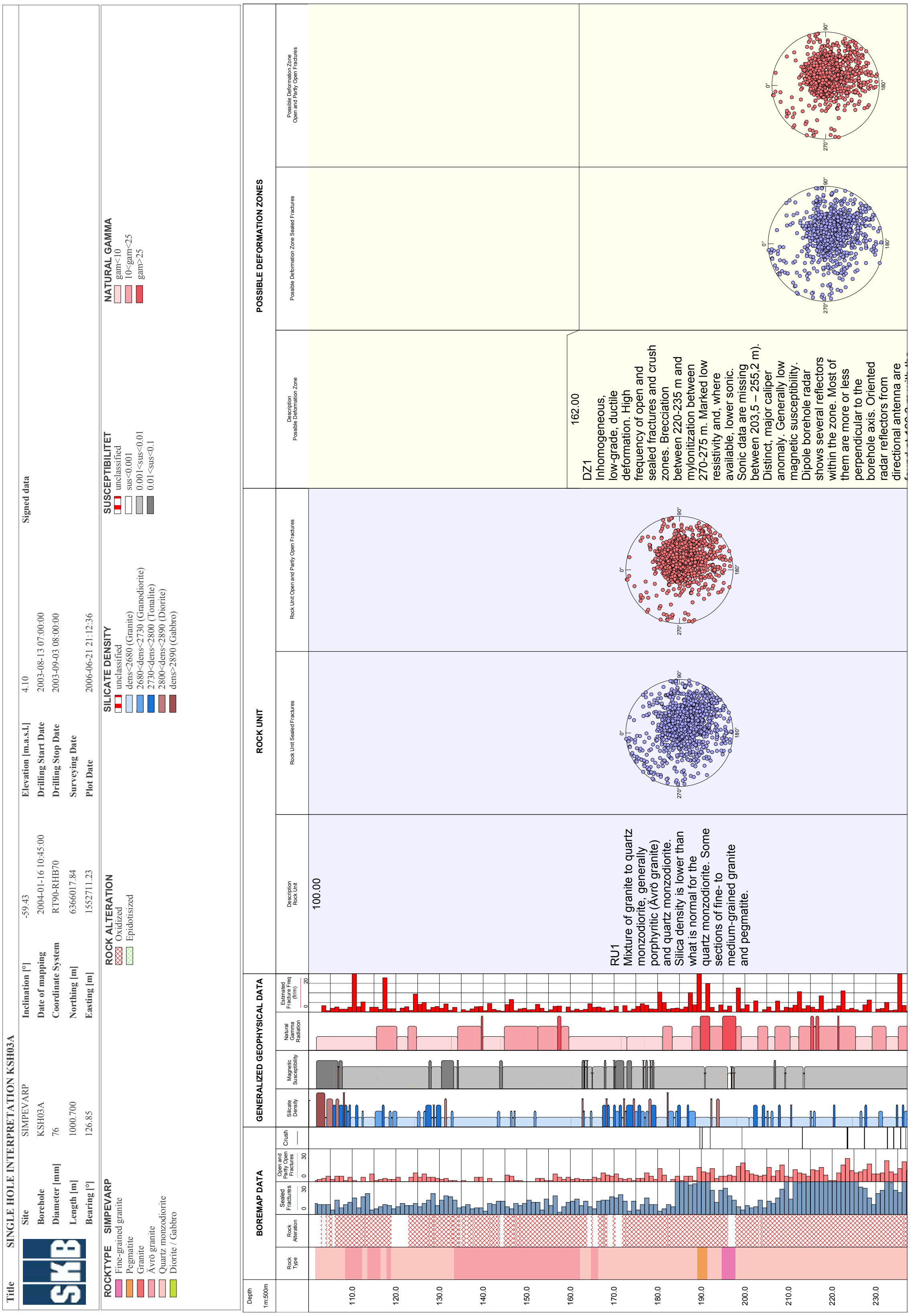
/4/ **Gustafsson J, Gustafsson C, 2004.** RAMAC and BIPS logging in boreholes KSH03A, KSH03B, HAV09, HAV10 and BIPS in KAV01. Oskarshamn site investigation. SKB P-04-48, Svensk Kärnbränslehantering AB.

/5/ **Aaltonen J, Gustafsson C, 2003.** RAMAC logging in boreholes KAV01 and KLX02. Oskarshamn site investigation. SKB P-03-120, Svensk Kärnbränslehantering AB.

/6/ **Sigurdsson O, 2005.** Oskarshamn site investigation. Simplified Boremap mapping of percussion boreholes HAV09 and HAV10. (in preparation)

Appendix 1

Geological single-hole interpretation for KSH03A



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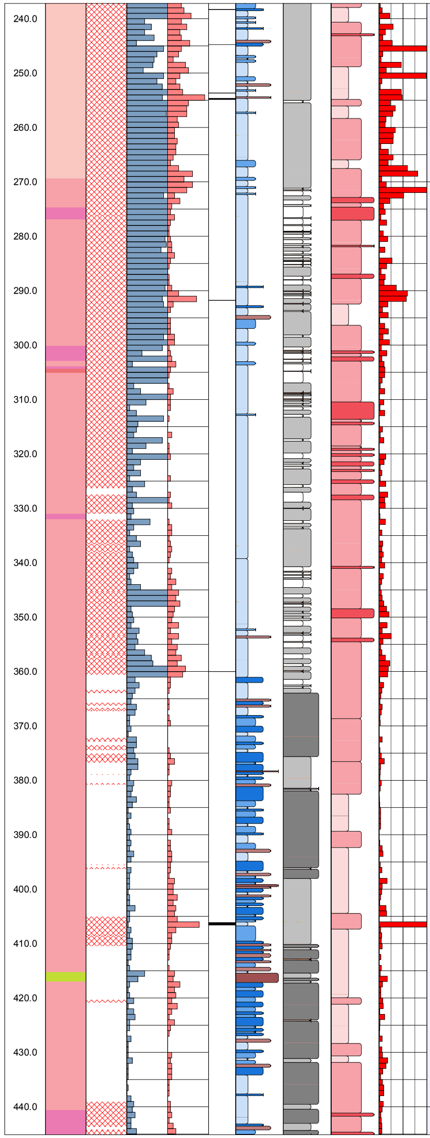
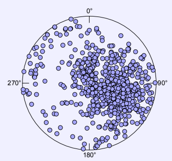
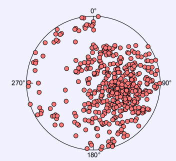


270.00
270.00

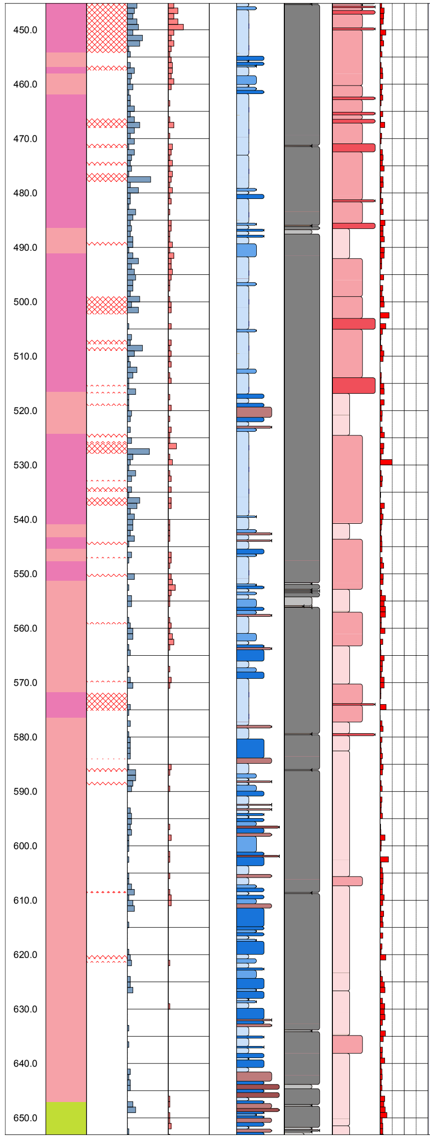
RU2
Totally dominated by granite to quartz monzodiorite, generally porphyritic (Ävrö granite) Certain sections of fine- to medium-grained granite and a few sections of diorite-gabbro. A c. 10 cm long section of sandstone at c. 271.5 m.

440.00
440.00





found at 166.3 m with the orientation 21/352 (uncertain), 181.3 m with the orientation 32/249, at 244.6 m with the orientation 76/306, and at 254.8 m with the orientation 44/262 (uncertain). Uncertainty = 3. A number of sections with increased fracturing may indicate minor deformation zones.
275.00

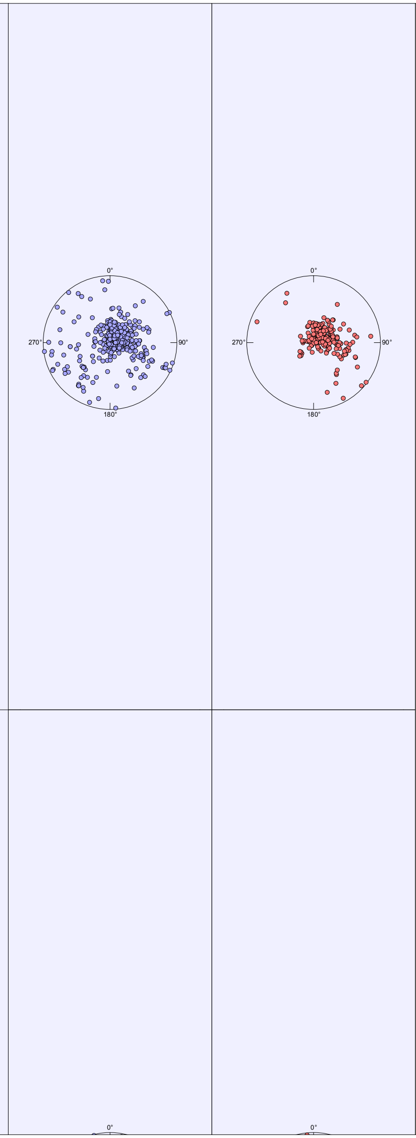


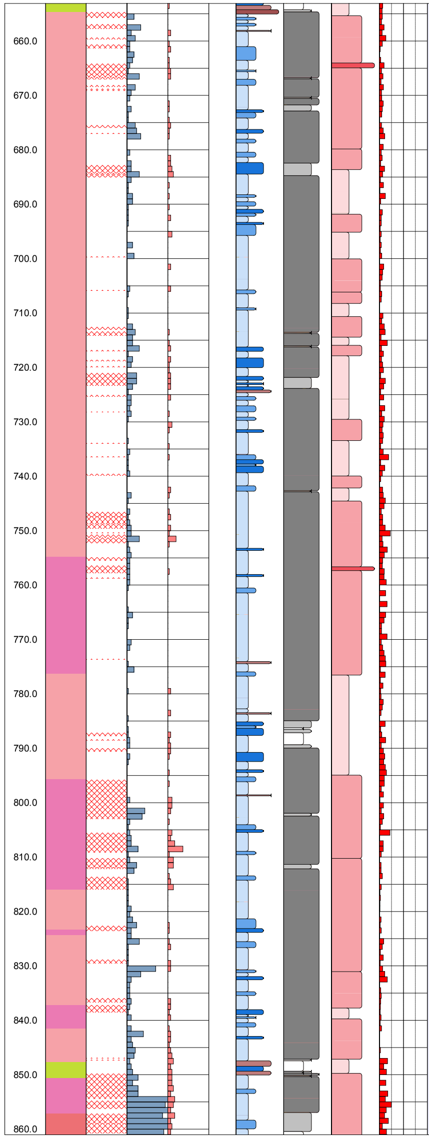
RU3
Mixture of fine- to medium-grained granite (slightly dominating) and granite to quartz monzodiorite, generally porphyritic (Ävrö granite). Higher degree of alteration and higher magnetic susceptibility than what is normal for fine- to medium-grained granite. Furthermore, the latter is texturally deviating by being unequigranular to megacryst-bearing (1-3 mm large feldspar grains).

575.00

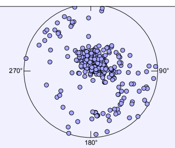
575.00

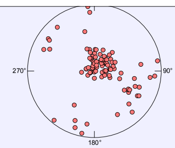
RU2
Totally dominated by granite to quartz





monzodiorite, generally porphyritic (Ävrö granite) The upper c. 100 m of the section has a high resistivity, and higher density and lower natural gamma radiation than the lower 100 m of the section. 8 m long section of diorite to gabbro between c. 647 and 655 m

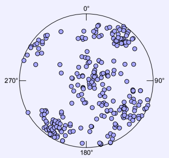


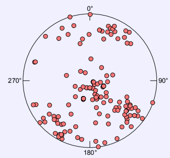


755.00

755.00

RU3
Mixture of fine- to medium-grained granite (slightly dominating) and granite to quartz monzodiorite, generally porphyritic (Ävrö granite). Higher degree of alteration and higher magnetic susceptibility than what is normal for fine- to medium-grained granite. Furthermore, the latter is texturally deviating by being unequigranular to megacryst-bearing (1-3 mm large feldspar grains). Certain sections (1-3 m long) of diorite to gabbro and medium-grained granite in the lower part.





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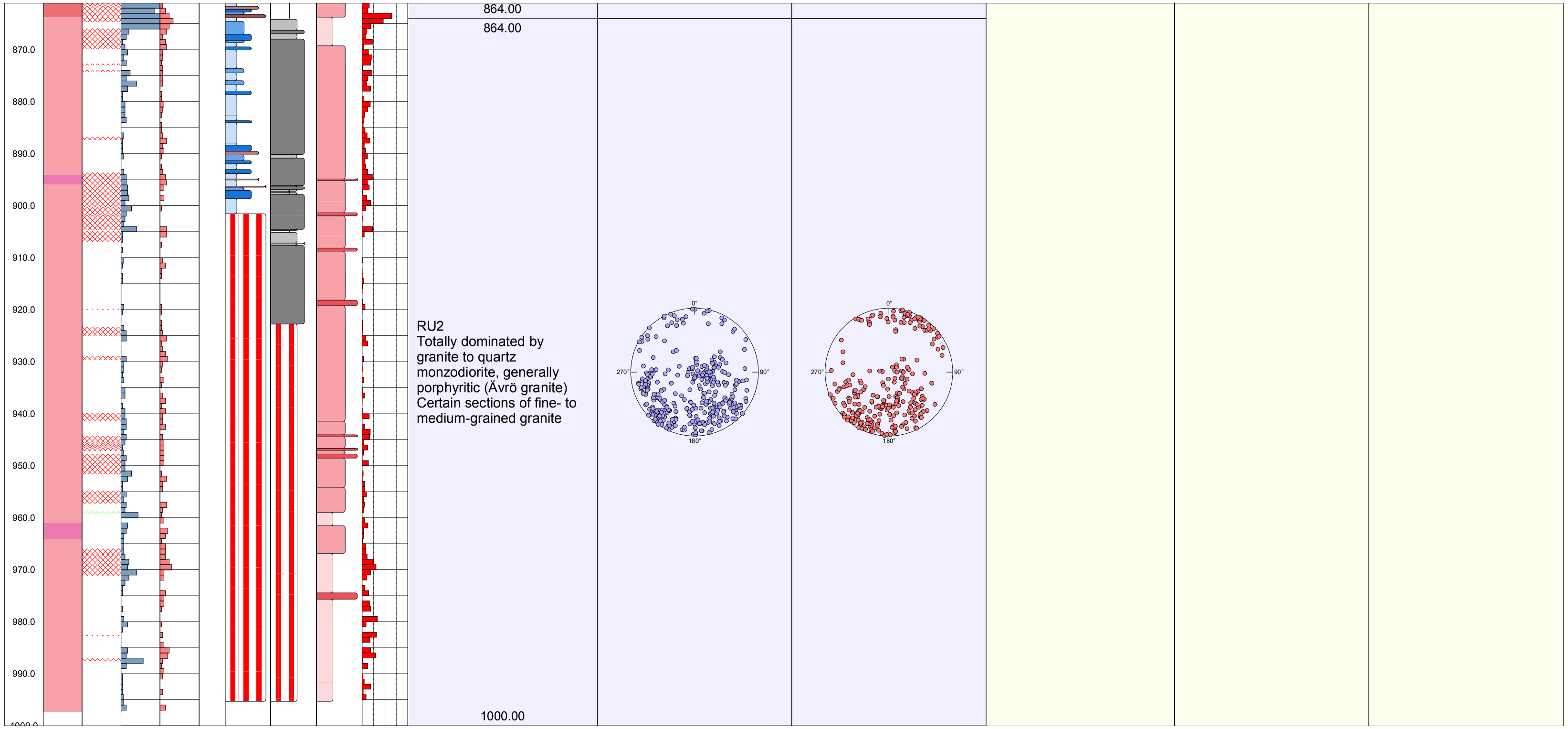
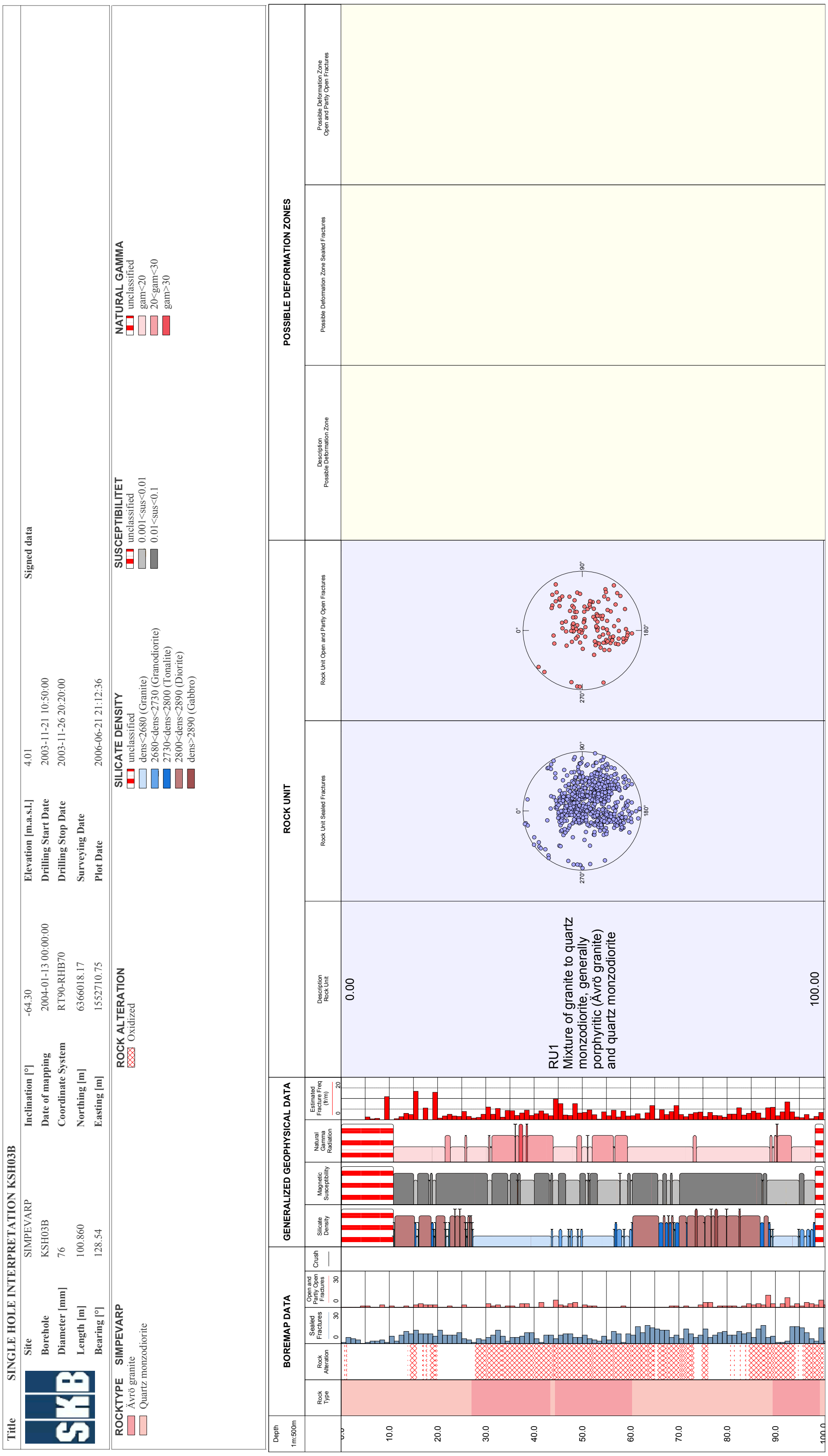
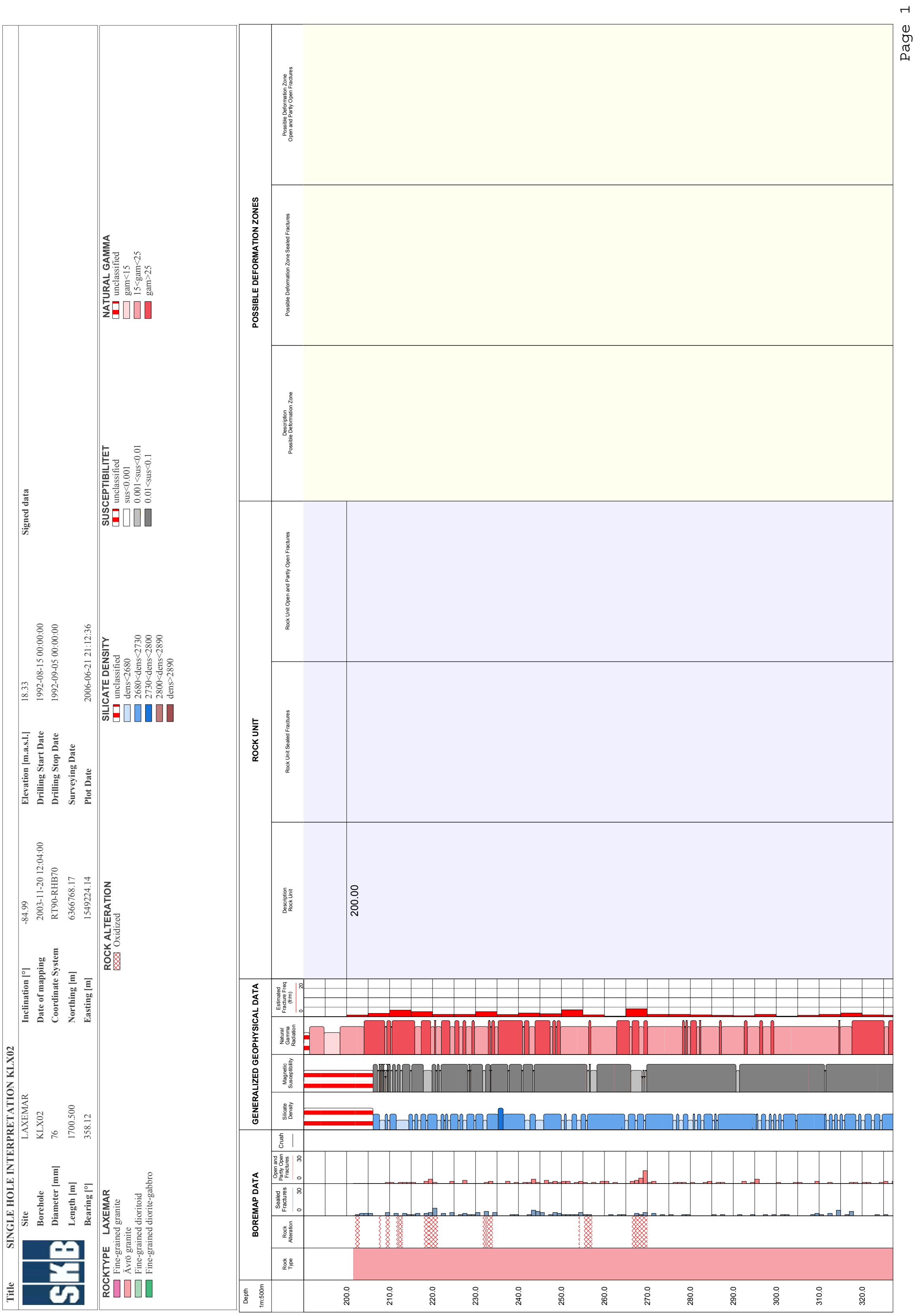

864.00
864.00
RU2
Totally dominated by
granite to quartz
monzodiorite, generally
porphyritic (Ävrö granite)
Certain sections of fine- to
medium-grained granite
1000.00
870.0
880.0
890.0
900.0
910.0
920.0
930.0
940.0
950.0
960.0
970.0
980.0
990.0
0°
90°
180°
270°

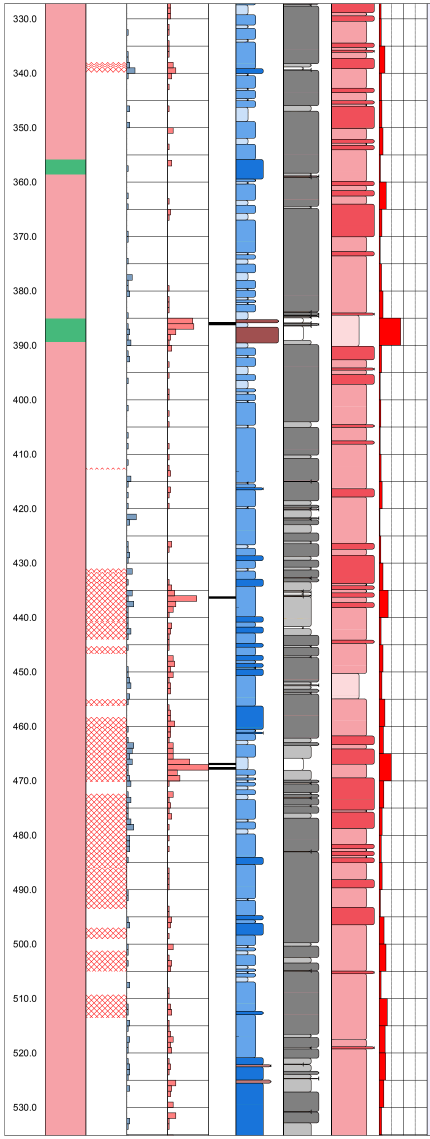
Geological single-hole interpretation for KSH03B



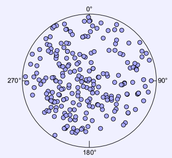
Appendix 3

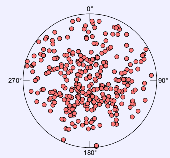
Geological single-hole interpretation for KLX02

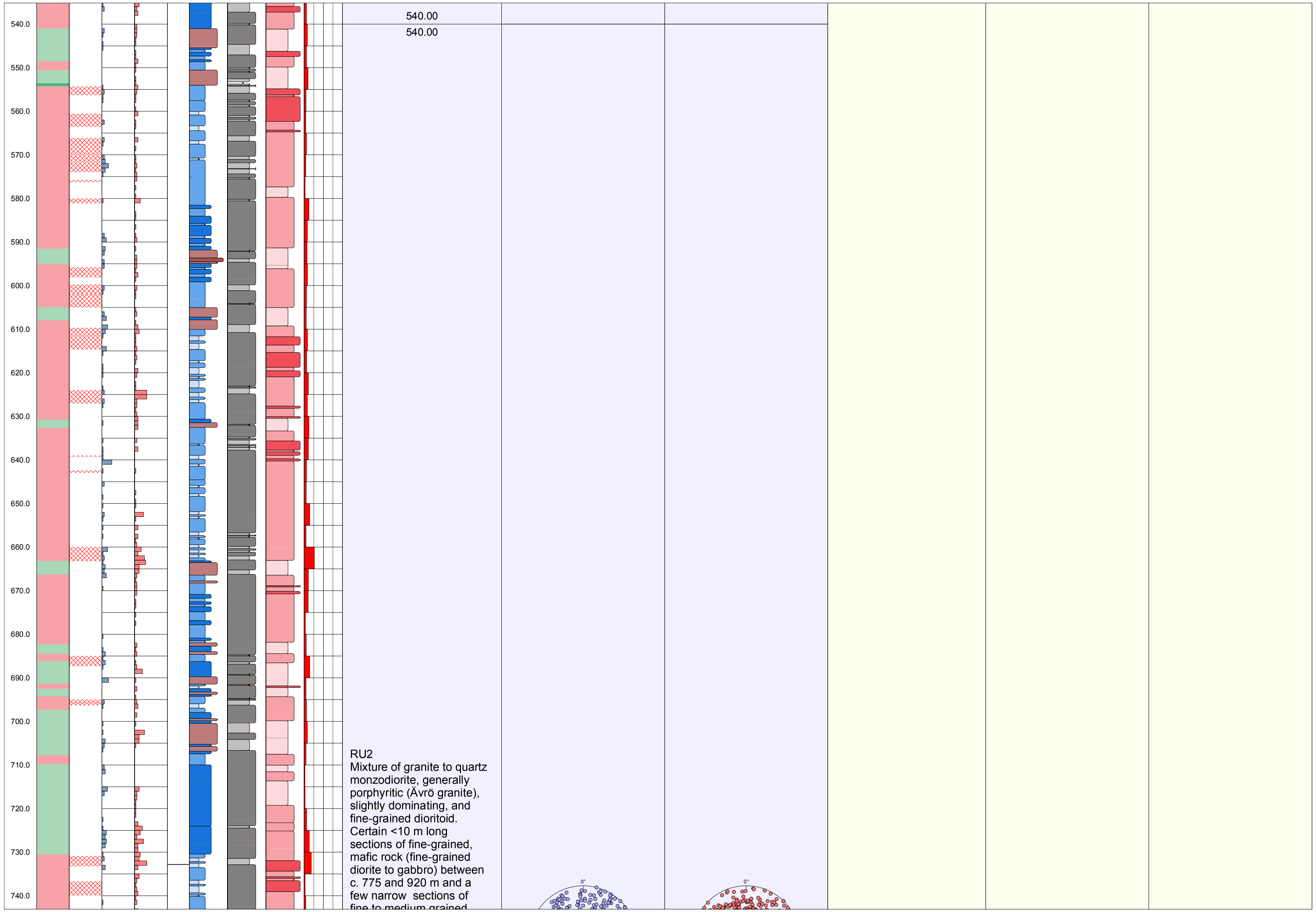




RU1
Totally dominated by granite to quartz monzodiorite, generally porphyritic (Ävrö granite), with certain sections of fine-grained mafic rock (fine-grained diorite to gabbro) at c. 358 and 388 m. Low fracture frequency with some sections with increased fracture frequency. Generally low silicate density (<2680 kg/m3) and moderate to high natural gamma radiation.






540.00
540.00
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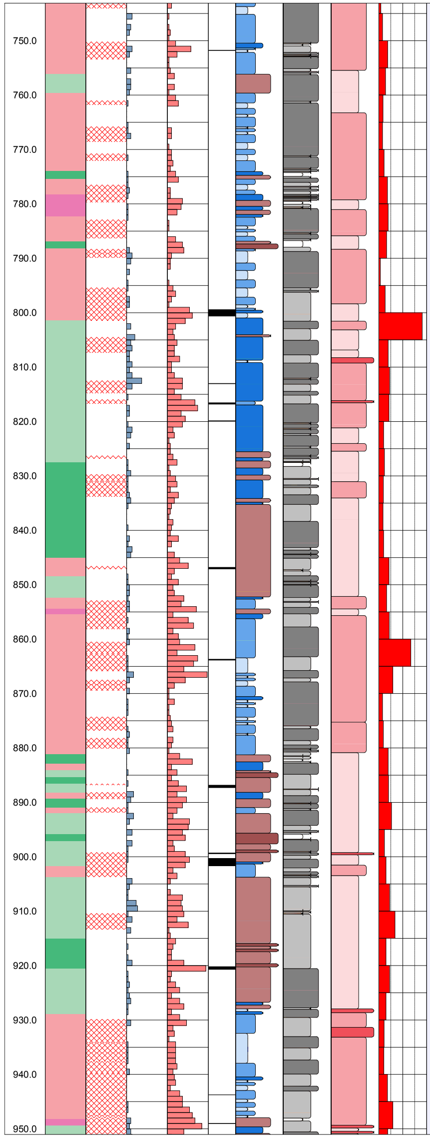
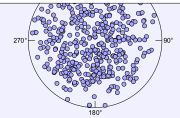
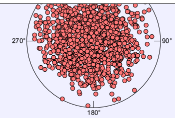
560.0
570.0
580.0
590.0
600.0
610.0
620.0
630.0
640.0
650.0
660.0
670.0
680.0
690.0
700.0
710.0
720.0
730.0
740.0
RU2
Mixture of granite to quartz monzodiorite, generally porphyritic (Ävrö granite), slightly dominating, and fine-grained dioritoid. Certain <10 m long sections of fine-grained, mafic rock (fine-grained diorite to gabbro) between c. 775 and 920 m and a few narrow sections of



fine to medium grained granite. Low fracture frequency in the section c. 540-770 m with certain sections with somewhat increased fracture frequency. Large variations in the silicate density, with high density corresponding to sections with fine-grained dioritoid and fine-grained mafic rock, and low density corresponding to granite to quartz monzodiorite.

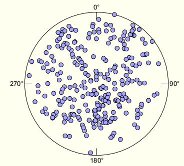
960.00

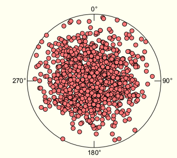


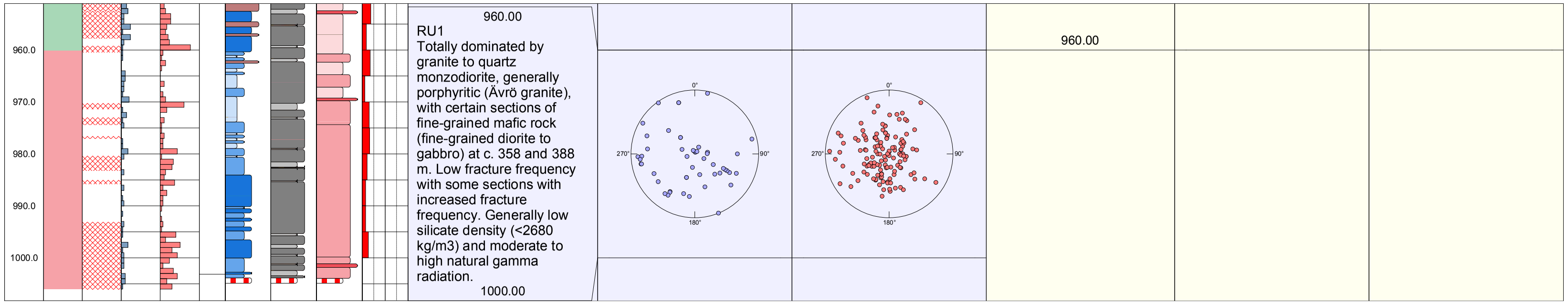


770.00

DZ1
Generally increased frequency of open fractures and higher oxidation. The most intensive part of the zone is located between 845-880 m, which is indicated by distinct low p-wave velocity and partly somewhat lower resistivity. Nine radar reflectors from directional antenna have been found within the zone. The orientations of the reflectors are 29-61°/047-086. Most of them are dipping around 50°. Uncertainty = 3. A number of sections with increased fracturing may indicate minor deformation zones.

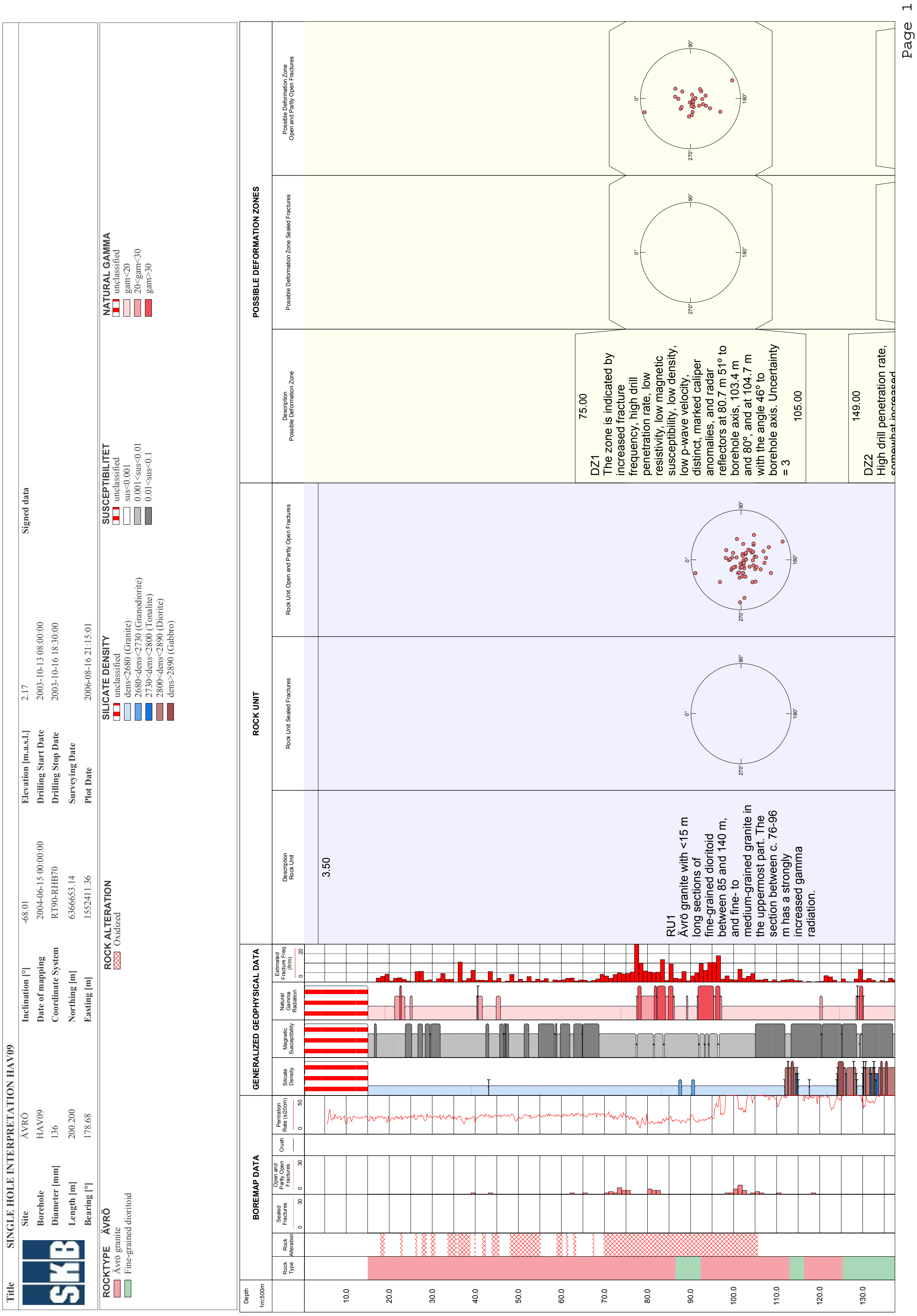


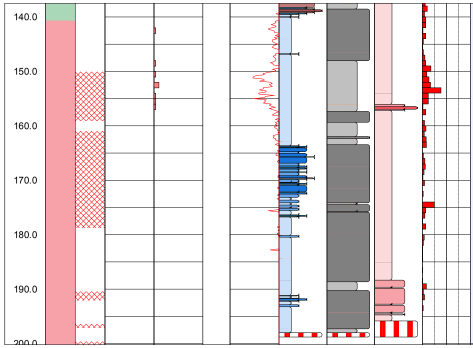



960.0
970.0
980.0
990.0
1000.0
960.00
RU1
Totally dominated by granite to quartz monzodiorite, generally porphyritic (Ävrö granite), with certain sections of fine-grained mafic rock (fine-grained diorite to gabbro) at c. 358 and 388 m. Low fracture frequency with some sections with increased fracture frequency. Generally low silicate density (<2680 kg/m3) and moderate to high natural gamma radiation.
1000.00
0°
90°
180°
270°
0°
90°
180°
270°
960.00

Appendix 4

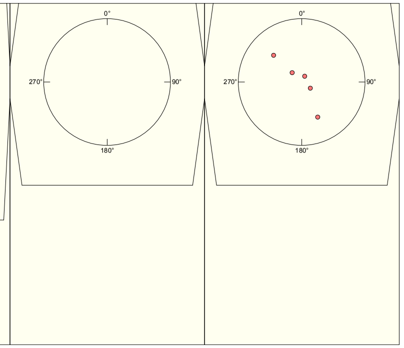
Geological single-hole interpretation for HAV09





200.00

somewhat increased fracture frequency. Low resistivity, low magnetic susceptibility, low density, low p-wave velocity, distinct, marked caliper anomalies. Radar reflectors at 152.6 m with the angle 28° to borehole axis, 155.5 m with the angle 73°, and 155.2 m with the angle 25°. Uncertainty =2.
155.00



Appendix 5

Geological single-hole interpretation for HAV10