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Keywords: Äspö, Geology, Borehole, Rock unit, Deformation zone, Interpretation, SHI.

Abstract

This report presents the outcome from a simplified geological single-hole interpretation (SHI) of 20 boreholes from the Äspö area, which is one of the activities performed as part of the work for Äspö Site descriptive model (SDM).

The performed *simplified* geological single-hole interpretation deviates from the established SHI methodology of SKB as was performed during the Laxemar site investigation (SKB 2009). These older boreholes have an incomplete set of available input parameters, but the work follows the current nomenclature and methodology as far as possible and includes the following activities:

1. Merging sections of similar geological character along the drill core into rock units on the basis of lithological mapping and, when available, with support from density logs obtained from geophysical logging.
2. Identification of possible deformation zones based on inspection of the drill cores including characterization according to the criteria applied during the established SHI.

The borehole radar measurements was performed with the first generation of radar equipment and the evaluation of radar data was at that time performed more or less manually by using different programs for the different steps of evaluation. Furthermore, the radar directional antenna was not available during the measurements in the boreholes. The correlation between radar reflectors and geological structures has been studied elsewhere (see for example Carlsten et al. 1995).

Most of the defined rock units are dominated by Äspö diorite (501037) or, less frequently, by Ävrö granodiorite (501056). Fine-grained granite (511058) and gabbroid-dioritoid (508107) typically occur as subordinate rock units. The vast majority of the rock units have been interpreted with a high degree of confidence. Rock units with a lower degree of confidence are restricted to two boreholes, KAS09 and KAS14, where the density log suggests that the registered rock type is incorrect or erroneously translated into the current SKB nomenclature

In total, 52 possible deformation zones have been identified in the drill cores from the 20 boreholes, 5 with a low degree of confidence, 8 with a medium degree of confidence and 39 with a high degree of confidence. Possible deformation zones have been identified in all of the boreholes. Twenty of the possible deformation zones exceed 10 m in drill core length and the most intensive possible deformation zone occurs in KAS14 in the section 88–211 m. In addition to brittle deformation, 30 of the possible deformation zones include sections of ductile and/or brittle-ductile deformation. The brittle component of the brittle-ductile deformation is typically characterized by epidote-sealed fracture networks.

Sammanfattning

Denna rapport presenterar resultaten från förenklade geologiska enhålstolkningar (SHI) genomförd på 20 borrhål från Äspölaboratoriet. Den geologiska enhålstolkningen (SHI) utgör, en del av arbetet med Äspö platsbeskrivande modell Äspö (SDM).

Den förenklade geologiska enhålstolkningen avviker från etablerad geologisk enhålstolkning (SHI) metodik vilken användes för platsundersökningarna i Laxemar (SKB 2009). Dokumentationen av de äldre borrhålen är generellt bristfällig med avseende på ingående parametrar. Däremot tillämpas i arbetet en aktuell nomenklatur och en etablerad metodik i möjligaste mån och inkluderar följande aktiviteter:

1. Sammanslagning av sektioner med likartad geologisk karaktär till bergenheter baserat på bergartskartering av borrkärnan, och i förekommande fall, med stöd av densitetsdata från geofysisk borrhålsloggning
2. Identifiering av möjliga deformationszoner baserat på granskning av borrkärnorna och karaktärisering enligt kriterier som tillämpas vid etablerad geologisk enhålstolkning (SHI).

Borrhålsradar genomfördes med den första generationen av radarantenner och utvärderingen och tolkningen av radardata genomfördes manuellt med fristående program och i olika steg. Radar riktantenn var inte heller tillgänglig vid tiden för undersökningarna. Korrelationen mellan orienteringen av radarreflektorer och geologiska strukturer har utvärderats tidigare av Carlsten et al. (se Carlsten et al. 1995).

De flesta definierade bergenheterna domineras av Äspödiorit (501037) eller, mer sällan, Ävrögranodiorit (501056). Underordnade bergenheter utgörs företrädelsevis av finkornig granit (511058) och gabbroid-dioritoid (508107). De flesta av bergenheterna har tolkats med en hög konfidensgrad. Bergenheter med en lägre konfidensgrad är begränsade till två borrhål, KAS09 och KAS14, där densitetsdata indikerar att de karterade bergartstyperna är inkorrekta eller felaktigt översatta till aktuell SKB nomenklatur.

Totalt 52 möjliga deformationszoner har identifierats i borrkärnorna från de 20 borrhålen, fem med en låg konfidensgrad, åtta med en intermediär konfidensgrad och 39 med en hög konfidensgrad. Möjliga deformationszoner har identifierats i alla borrhål. Tjugo av de möjliga deformationszonerna överskrider 10 m i borrkärnslängd och den mest intensiva möjliga deformationszonen uppträder i KAS14 i intervallet 88–211 m. Utöver spröd deformation inkluderar 30 av de möjliga deformationszonerna sektioner med plastisk och/eller spröd-plastisk deformation. Den spröda komponenten av den spröd-plastiska deformationen karaktäriseras generellt av epidotläkta spricknätverk.

Contents

1 Introduction

1.1 Background

To support predictions and planning of experiments performed in the Äspö Hard Rock Laboratory (Äspö HRL), a site descriptive model (SDM) is under development, Äspö SDM. The purpose is to present an integrated understanding of the Äspö area based on available information from the fields of geology, hydrogeology, hydrogeochemistry, rock mechanics and thermal properties. An essential part in the Äspö SDM project is to incorporate existing borehole data from the earlier investigations, as well from construction and operational phases of the Äspö HRL.

A key input to the geological modelling during the site investigations at Forsmark and Laxemar-Simpevarp has been the geological single-hole interpretation (SHI) of borehole data. The established methodology provides an integrated synthesis of the geological and geophysical information in a borehole (SKB MD 810.003). Currently, borehole documentation from the older boreholes at Äspö is too incomplete to allow the full application of the established SHI methodology, due to the lack of BIPS-images, inconclusiveness in the geological documentation or lack of certain parameters such as fracture frequency, along with the fact that geophysical logs only exist for some of the boreholes.

During the modelling phase of the SFR extension project (Curtis et al. 2011), similar deficiencies in the borehole data were solved by the application of a *simplified* geological single-hole interpretation, which departs from the established complete SHI methodology, but follows the nomenclature and methodology of the current SHI procedure as far as possible (Petersson et al. 2011). In this methodology, rock units consisting of sections of similar geological character were defined on the basis of available lithological mapping, which were translated into current established SKB nomenclature for different rock types as presented in Table 1-2. Possible deformation zones, on the other hand, were identified by visual inspection of the drill cores and characterized according to the criteria applied during the established complete SHI.

In order to maximize the use of older borehole data from the Äspö HRL in the Äspö SDM work, it was decided to implement a similar methodology for 20 boreholes drilled during the period 1988–2002. Nine of the boreholes start at the surface, whereas the other 11 boreholes have a start elevation of approximately –490 m to –250 m in the Äspö HRL tunnel. The prime criterion for the selection of these boreholes is the expected crosscutting relationship with inferred deformation zones in the current geological model of Äspö (Berglund et al. 2003). Drill cores are available for all 20 boreholes and the majority have been mapped before the introduction of the current established rock nomenclature (SKB MD 132.004) by the use of the Petrocore system.

The selected boreholes have a total length of approximately 4470 m, Table 1-3. One of the boreholes, KAS03, is c. 1000 m in length, whereas the others range between 34 and 550 m in length. Table 1-3 displays the drill core length, orientation and available geological and geophysical documentation of the boreholes. The work included photographing of drill cores in a wet condition in those cases where no earlier photographs existed.

This report outlines the results from the *simplified* geological single-hole interpretation of 20 boreholes located at Äspö on surface and within the tunnel (Figure 1-1 and Figure 1-2), which is one of the activities performed within the work of upgrading the geological model of the Äspö Site Descriptive Model (SDM). The report also presents a simplified overview lithological mapping of the borehole KAS16.

The work was carried out in accordance with activity plan AP TD PRAS1002-12-023. The controlling documents for performing this activity are listed in Table 1-1. Rock type nomenclature (Table 1-2) that has been used is in accordance with method instruction SKB MD 132.004. Activity plan, method description and method instruction are SKB's internal controlling documents.

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

Activity plan	Number	Version
Förenklad SHI för Äspö SDM	AP TD PRAS1002-12-023	1.0
Method descriptions	**Number**	**Version**
Regler för bergarters benämningar för Laxemar-Simpevarpsområdet och för Äspölaboratoriet	SKB MD 132.004	3.0
Metodbeskrivning för Boremap-kartering	SKB MD 143.006	2.0
Instruktion för hantering och provtagning av borrkärna	SKB MD 143.007	3.0
Metodbeskrivning för geologisk enhålstolkning	SKB MD 810.003	3.0

Table 1-2. Rock type nomenclature for different rock types applied for Äspö SDM.

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
Ävrö granodiorite	501056	Granite to granodiorite, sparsely porphyritic to porphyritic
Ävrö quartz monzodiorite	501046	Quartz monzonite to quartz monzodiorite, generally porphyritic
Äspö diorite	501037	Quartz monzodiorite to granodiorite, 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
Gabbroid-dioritoid	508107	Mafic rock undifferentiated
Mylonite	508004	Mylonite
Sulphide mineralization	509010	Sulphide mineralization
Sandstone	506007	Sandstone
Quartz-dominated hydrothermal vein/segregation	508021	Quartz-dominated hydrothermal vein/segregation
Hybrid rock	505105	Hybrid rock
Breccia	508002	Breccia
Felsic volcanic rock	503076	Felsic volcanic rock

Table 1-3. Technical information for 20 boreholes at Äspö HRL and available geological/geophysical data are included in the *simplified* geological single-hole interpretation. The boreholes that have been drilled from the ground surface are denoted KASxx, whereas the other boreholes which have been drilled from tunnels in the Äspö HRL are denoted with KAnnnnA, or KFnnnnA01, where nnnn represent the length from the tunnel entrance in m.

Borehole ID	Drill core length (m) Sec_up	Sec_low	Bearing (°)	Inclination (°)	Mapping	BIPS	Geo-physics	New photos Drill core length (m)
KAS03	1.21	1002.14	326.7	–82.9	Petrocore	X/TV	X	1.20–1002.06
KAS05	1.14	549.59	151.8	–84.9	Petrocore	TV	X	1.05–549.59
KAS09	0.42	450.61	169.8	–59.9	Petrocore	X	X	0.40–186.58
KAS11	1.28	248.82	022.8	–88.7	Petrocore	–	X	1.28–248.82
KAS12	0.79	380.48	149.8	–69.9	Petrocore	–	X	–
KAS13	3.08	405.99	268.8	–62.2	Petrocore	–	X	–
KAS14	0.44	211.85	136.8	–61.3	Petrocore	–	X	0.44–211.82
KAS16	0.00	548.46	127.0	–84.5	Overview	–	X[1]	–
KAS17	0.47	352.73	315.0	–60.0	Overview	X	–	0.47–352.73
KA1751A	3.80	149.91	262.4	05.2	Petrocore	–	–	–
KA1754A	3.30	159.88	288.1	–26.2	Petrocore	–	X[1]	–
KA2048B	2.70	184.45	179.1	–10.6	Petrocore	–	X	151.17–184.45
KA2858A	0.00	59.70	275.2	–04.3	Petrocore	X	–	0.00–59.70
KA3105A	0.00	69.02	102.5	–4.7	Petrocore	X	X[1]	0.00–68.95
KA3385A	0.00	34.18	164.4	–04.1	Petrocore	X	X[1]	0.00–34.18
KA3510A	0.00	149.91	255.3	–30.2	Petrocore	X	X[1]	0.00–150.06
KF0066A01	0.00	60.11	004.2	00.5	Boremap	X	X[2]	0.00–60.11
KF0069A01	0.00	70.09	017.0	–01.8	Boremap	X	X[2]	0.00–70.09
KI0023B	0.00	200.71	202.8	–20.7	Petrocore Boremap	X	X[1]	0.00–200.71
KI0025F02	0.00	204.18	188.1	–25.4	Boremap	X	X[1]	0.00–204.18

[1] Only radar. [2] Only density.

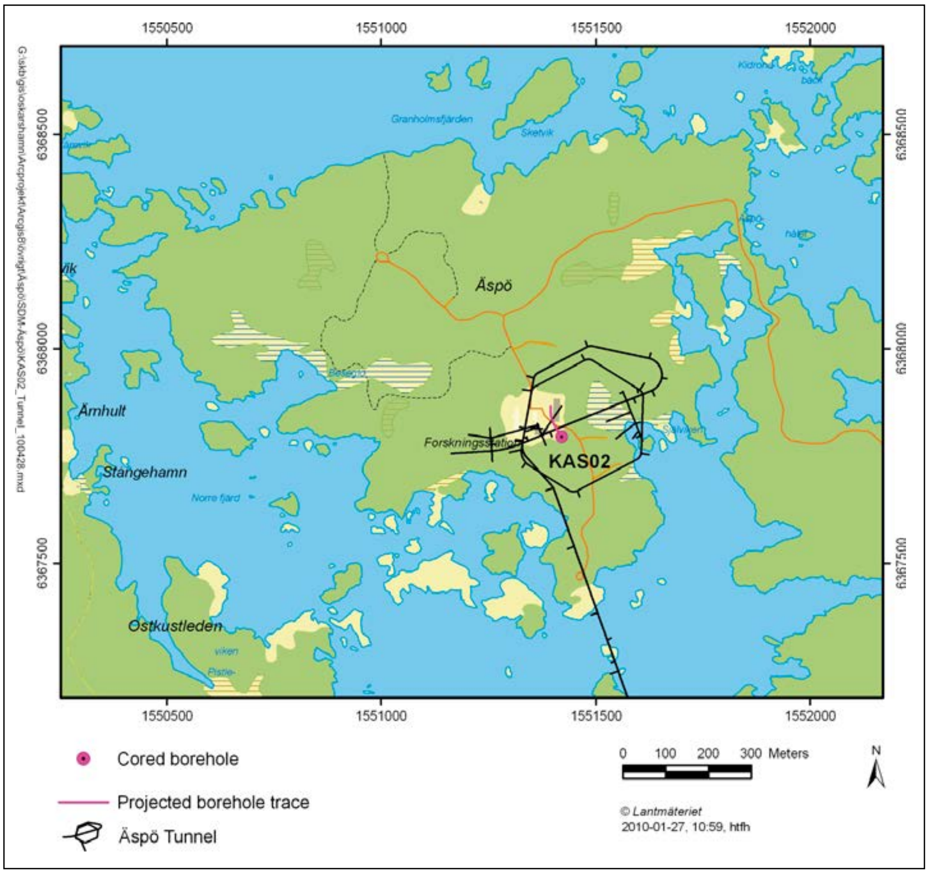


***Figure 1-1.** Äspö HRL tunnel view from above together with the surface drilled borehole KAS02 (Carlsten et al. 2017) .*

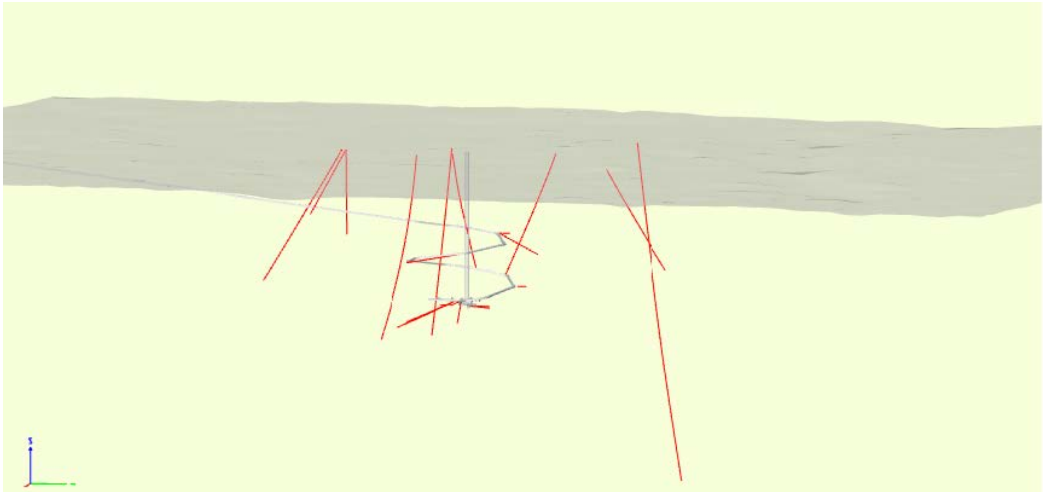


Figure 1-2. Äspö HRL tunnel view from east. Location of all boreholes in this study. Shaded area is the ground surface.

1.2 Objectives

In order to facilitate the use of older borehole data in the development of a site descriptive model Äspö SDM for the Äspö HRL, 20 boreholes drilled during the period 1988–2002 have been subjected to a *simplified* geological single-hole interpretation according to the methodology used by Petersson et al. (2011). This activity includes:

1. Merging sections of similar geological character into rock units on the basis of lithological mapping and, when available, with support from density logs obtained from geophysical logging
2. Identification of possible deformation zones based on inspection of the drill cores including characterization according to the SHI criteria applied during the site investigations at Forsmark (SKB 2008) and Laxemar (SKB 2009).

In those cases where borehole geophysical data are available, details have generally been included in the description of individual possible deformation zones. The result from the simplified geological single-hole interpretation is presented in WellCAD plots (Appendices 1 to 20) and is described in this report.

2 Methodology for *simplified* geological single-hole interpretation

2.1 Data used for the geological single-hole interpretation

Table 2-1 presents the data limitations and deviations from SKB's methodology for complete geological single-hole interpretation and the data that has been used in the single-hole interpretation of 20 cored drilled boreholes on surface and in the tunnel at Äspö. As a basis for the geological single-hole interpretation a combined WellCAD plot consisting of the above mentioned data sets were used, see Appendices 1–20.

Table 2-1. Data limitations and deviations from SKB´s complete geological single-hole interpretation.

Included in *simplified* geological single-hole interpretation (SHI)	Not included or specifically documented
Rock units (RU)	
Geological data with translated rock type nomenclature from Petrocore mapping (14 boreholes), overview mapping (2 boreholes) and detailed Boremap mapping (4 boreholes).	BIPS (TV)- or TV-images are available for 12 of the boreholes, but were only inspected during the SHI of KAS03.
Available geophysical logs: density (9 boreholes), resistivity, magnetic susceptibility and sonic (8 boreholes).	A complete suite of geophysical logging data has not been available. Radar data have not been used fully in the cointerpretation.
Possible deformation zones (PDZ)	
Identification was made based on direct drill core observations.	Identification of possible deformation zones was performed despite lack of relevant data.
Inspection of digital drill core images subsequent to the primary identification.	No group inspection of a WellCAD log.
Lithological overview mapping	
Rock types (> 1 m in borehole lengths).	Rock occurrences (< 1 m borehole length).
–	Ductile deformation (type and intensity).
–	Open fractures and crushes.
–	Bedrock alteration (type and intensity).
Photography of drill cores in wet condition.	Photography of drill cores in dry condition.

Information from geophysical borehole logging and radar measurements was attached after identification of possible deformation zones. The geophysical borehole logging data were interpreted without any post-processing, such as length adjustment, filtering or calibration. Moreover, it should be noted that the density curves presented in the logs of Appendices 1–20 are slightly displaced relative to the scale, and consequently, appear to indicate too low values.

The data used for the geological single-hole interpretation is summarized in Figure 2-1.

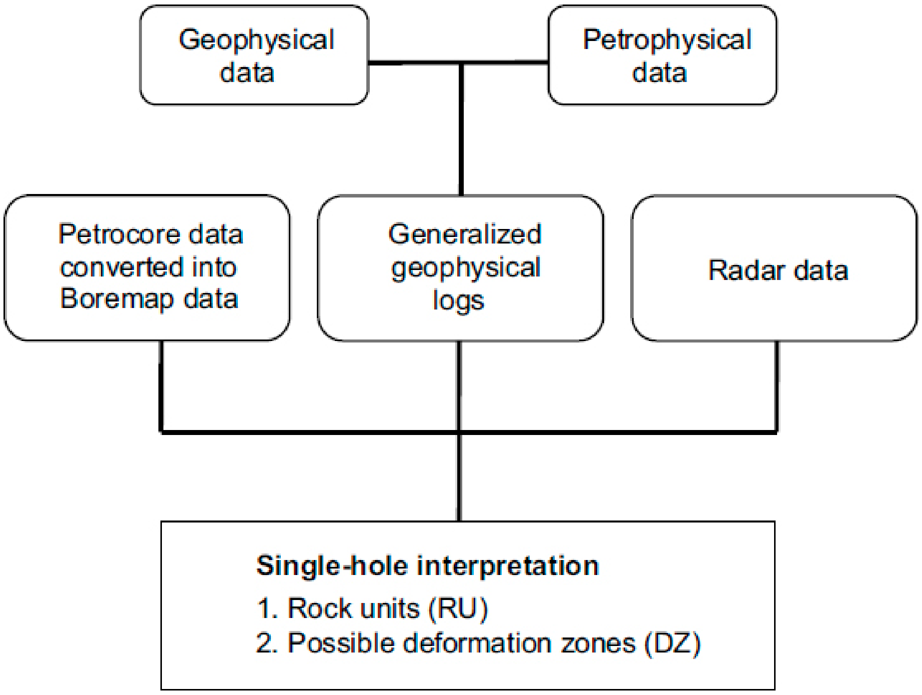


Figure 2-1. *Schematic block-scheme for data used in the geological single-hole interpretation.*

2.2 *Simplified* geological single-hole interpretation

The available geological documentation does not comply with the complete SHI requirements of SKB MD 810.003, and therefore strict application of methodology has not been possible to obtain. However, it was decided to follow the nomenclature and methodology for the geological single-hole interpretation (SHI) procedure as far as possible and record all necessary deviations. Due to the deviations from the established methodology, the current activity described in this report has not been classified as a complete geological single-hole interpretation, but rather as a '*simplified* geological single-hole interpretation'. The methodology has previously been applied at older boreholes from the construction of SFR in Forsmark (Petersson et al. 2011), but there is no specific method description available. The results are stored in the primary database Sicada.

The working procedure is to study all available types of data related to the character of the rock types and to merge sections of similar geological character into rock units. All data to be used are presented side by side in a borehole document extracted from the software WellCAD.

Methodology for simplified geological single-hole interpretation established during the site investigations at Forsmark (SKB 2008, Petersson et al. 2011) and Laxemar (SKB 2009) has not been fully applied for the simplified geological single-hole interpretation in this work for the 20 boreholes presented in Table 1-3.

Geophysical density logs, which represent important input for the work, are available for ten of the boreholes (Table 1-3). A minimum length of about 5 m was used for rock units in the geological single-hole interpretations during the site investigations at Forsmark (SKB 2008) and Laxemar (SKB 2009). This minimum length was generally also applied during the current work. The division into rock units was carried out by 2–3 geologists. Each rock unit is defined in terms of the borehole length interval and provided with a brief description. The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The rock units with a lower degree of confidence are restricted to two boreholes, KAS09 and KAS14, where the geophysical density logs suggest that the rock type registered during the Petrocore mapping is incorrect or erroneously translated into the current established SKB nomenclature.

The procedure to identify possible deformation zones is primarily based on inspection of the drill cores. Each identified possible deformation zone is defined in terms of the borehole length interval and provided with a brief description, which includes information of the rock types affected by the possible deformation zone, fracture character and frequency in general terms, as well as the existence of breccias, mylonites, cataclasites and bedrock alteration. A reassessment of each interval was done at the basis of the digital drill core images during the data compilation for this report. If judged necessary, the descriptions are adjusted. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

Possible deformation zones may be brittle, ductile or combined brittle-ductile in character. In the latter case, the ductile or brittle-ductile component is typically concentrated to subsections of possible deformation zones with an overall brittle character. Possible deformation zones that are brittle in character have been identified primarily on the basis of the frequency of fractures, according to the strategy presented in Munier et al. (2003). Brittle deformation zones defined by an increased frequency of extensional fractures (joints) or shear fractures (faults) are not distinguished. Both the damage zone (transition zone) and the core part of the deformation zone, with e.g. crushes, breccias and/or cataclasites, have been included in each deformation zone (Figure 2-2). Core sections are generally identified wherever it has been possible. The presence of bedrock alteration has assisted in the identification procedure.

The borehole radar measurements in the surface boreholes were performed with the first generation of radar equipment and evaluation of radar data was at that time performed more or less manually by using different programs for the different steps in the evaluation. The interpretation of radar reflectors in KAS05 was focused on association with major deformation zones, i.e. interpretation presented in the radar report comprises data for selected sections of the borehole. Directional radar antenna was not available at the time for measuring the surface boreholes KAS03, KAS05, KAS09 and KAS11. However, directional radar antenna was available at the time for measuring the surface boreholes KAS12, KAS13, KAS14, KAS16 and the tunnel boreholes. Radar data have mostly been collected from Sicada and in some cases from radar reports. Orientations from radar data presented in this report are related to RT90. Generally, two alternatives for radar orientation are given, firstly the radar directional (primary) and secondly the radar directional (alternative). The direct radar amplitude can be used as an indicator of the fracturing along the borehole wall, i.e. reduced direct radar amplitude generally indicates increased fracturing.

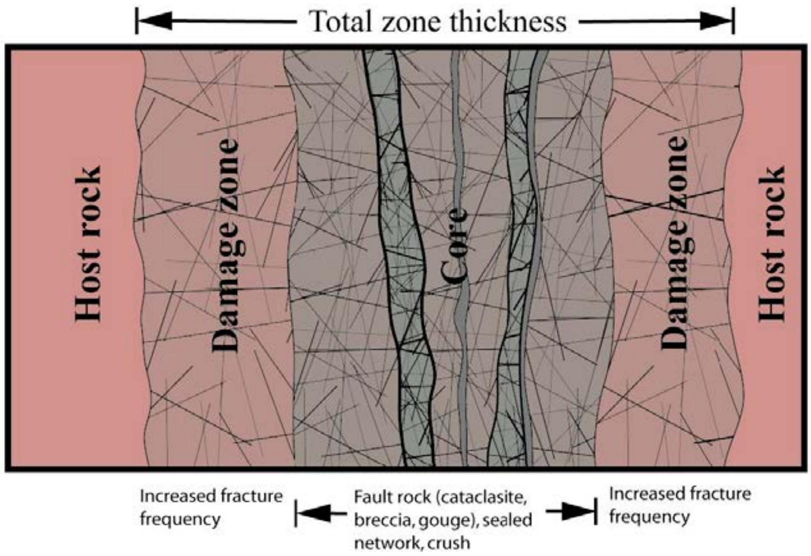


Figure 2-2. *Schematic illustration of the structure of a brittle deformation zone. Modified after Munier et al. (2003).*

Methodology established during the preceding site investigations at Forsmark and Laxemar-Simpevarp has not been fully applied for the overview mapping of KAS16 nor for the simplified geological single-hole interpretation. Table 2-1 presents the data limitations and deviations from SKB's method descriptions. Information from geophysical borehole logging and radar measurements was attached after identification of possible deformation zones. The geophysical borehole logging data were interpreted without any post-processing, such as length adjustment, filtering or calibration. Moreover, it should be noted that the density curves presented in the logs of Appendix 1 are slightly displaced relative to the scale, and consequently, appear to indicate too low values.

3 Results

The results of the *simplified* geological single-hole interpretation of rock units and possible deformation zones for 20 core-drilled boreholes in Äspö HRL are presented below and as print-outs from the software WellCAD in Appendices 1–20.

3.1 KAS03

The results of the identification of rock units and possible deformation zones in KAS03 are presented below and as print-outs from WellCAD in Appendix 1 and the location of KAS03 is shown in Figure 3-1.

3.1.1 Rock units

The borehole can be divided into six different rock units, RU1–RU6. Rock unit 1 occurs in four separate intervals, RU1a–RU1d, and RU3 in three separate intervals, RU3a–RU3c. The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. All rock units have been interpreted with a high degree of confidence.

RU1a (1.21–328.04 m)

Ävrö granodiorite (501056) with several minor occurrences of fine-grained granite (511058) and a few of gabbroid-dioritoid (508107). Confidence level = 3.

RU2 (328.04–347.23 m)

Gabbroid-dioritoid (508107). Confidence level = 3.

RU1b (347.23–561.79 m)

Ävrö granodiorite (501056) with several minor occurrences of fine-grained granite (511058) and a few of gabbroid-dioritoid (508107). Confidence level = 3.

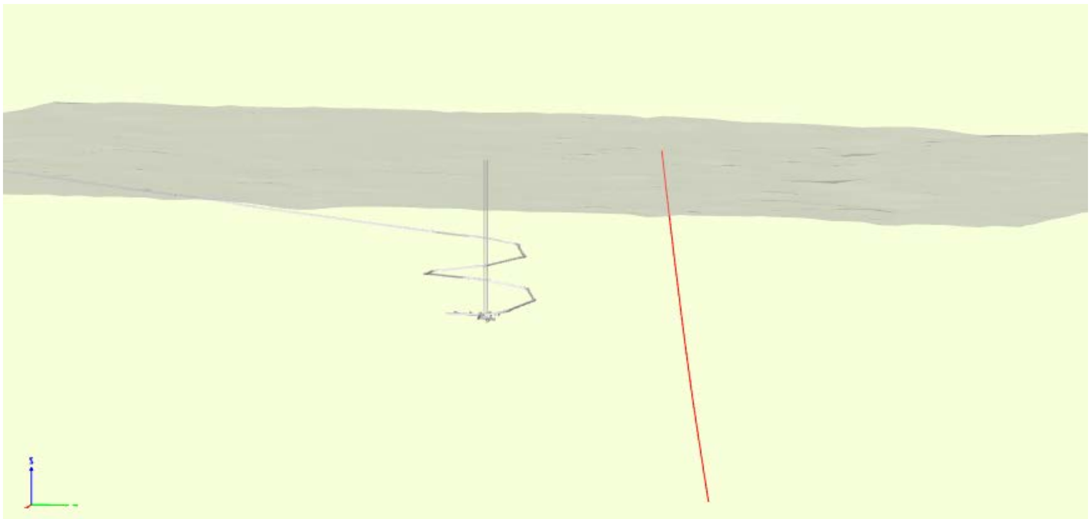


Figure 3-1. *Äspö HRL tunnel view from east. Location of surface drilled borehole KAS03. Shaded area is the ground surface.*

RU3a (561.79–599.83 m)

Gabbroid-dioritoid (508107) with minor occurrences of Ävrö granodiorite (501056). Confidence level = 3.

RU1c (599.83–632.79 m)

Ävrö granodiorite (501056) with minor occurrences of fine-grained granite (511058) and gabbroid-dioritoid (508107). Confidence level = 3.

RU4 (632.79–780.85 m)

Fine-grained granite (511058). Confidence level = 3.

RU3b (780.85–839.18 m)

Gabbroid-dioritoid (508107) with minor occurrences of Ävrö granodiorite (501056), fine-grained granite (511058) and Äspö diorite (501037). Confidence level = 3.

RU5 (839.18–891.10 m)

Fine-grained granite (511058) with subordinate amounts of Ävrö granodiorite (501056) and a section of Äspö diorite (501037) in the upper part of the rock unit. Confidence level = 3.

RU3c (891.10–945.46 m)

Gabbroid-dioritoid (508107) with minor occurrences of Ävrö granodiorite (501056). Confidence level = 3.

RU1d (945.46–966.00 m)

Ävrö granodiorite (501056). Confidence level = 3.

RU6 (966.00–1 002.14 m)

Äspö diorite (501037) with subordinate gabbroid-dioritoid (508107) in the lower part. Confidence level = 3.

3.1.2 Possible deformation zones

Seven possible deformation zones of brittle and, in some cases, brittle-ductile character have been identified in KAS03. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low. In KAS03 six has been classified with a high degree of confidence and one with a medium degree of confidence. Orientation of certain geological structures was made by using available BIPS-images.

DZ1 (217.50–223.20 m), brittle and brittle-ductile character

Increased frequency of broken (open) fractures and three 2–3 dm long crushed sections, which largely coincide with an occurrence of foliated gabbroid-dioritoid (508107). Locally, an increased frequency of unbroken (sealed) fractures and short sections of brittle-ductile deformation with the development of mylonite occur. Fractures are preferentially oriented parallel with the tectonic foliation in the gabbroid-dioritoid (508107). Predominant minerals in broken (open) fractures are chlorite, laumontite, calcite and more rarely adularia, and in unbroken (sealed) fractures, epidote, laumontite, chlorite and calcite. The gabbroid-dioritoid (508107) exhibits generally faint to weak chloritization and epidotization, whereas the associated Ävrö granodiorite (501056) is moderately oxidized. There is a major decrease in the bulk resistivity; there is also decreased p-wave velocity and magnetic susceptibility, a caliper anomaly and also an anomaly in the vertical fluid temperature gradient. In conclusion, all the geophysical logging data indicate increased fracture frequency, alteration and in- or outflow of water. Two non-oriented weak radar reflectors occur at 218 m and 220 m with the α-angle 33° and 23°, respectively. Rock types: Gabbroid-dioritoid (508107) with a distinct tectonic foliation (218°/53° and 234°/58°) and subordinate Ävrö granodiorite (501056). Contacts between the two rock types are parallel with the foliation and measurements yielded orientations at 212°/39° and 226°/66°. Confidence level = 3.

DZ2 (283.80–291.80 m), brittle character

Increased frequency of broken (open) fractures and several crushed sections, especially in the interval 286.0–288.8 m. Sealed fracture network with slightly brecciated sections at 288.0–288.2 m, sealed by chlorite, hematite and minor epidote and adularia. Generally α-angles are > 45°. Predominant minerals in broken (open) fractures are clay minerals, chlorite and hematite. Some fractures are slickensided. There is a major decrease in the bulk resistivity; there is also decreased p-wave velocity and magnetic susceptibility, a caliper anomaly and also a minor anomaly in the vertical fluid temperature gradient. In conclusion, all the geophysical logging data indicate increased fracture frequency, alteration and a minor in- or outflow of water. Two non-oriented strong radar reflectors occur at 286 m and 288 m with the α-angle 44° and 55°, respectively. In addition, one non-oriented weak radar reflector occurs at 289 m with the α-angle 24°. Rock type: Ävrö granodiorite (501056). Confidence level = 3.

DZ3 (343.90–347.30 m), brittle and ductile character

Increased frequency of broken (open) and, to some extent, unbroken (sealed) fractures along with a strongly developed foliation in the gabbroid-dioritoid (508107). Predominant minerals in broken (open) fractures are chlorite, calcite and hematite, and in unbroken (sealed) fractures, epidote. A few fractures are weakly slickensided. Weak chloritization and epidotization throughout the interval. There are no significant anomalies in the geophysical borehole logging data. One non-oriented radar reflector of medium strength occurs at 344 m with the α-angle 30°. Rock type: Gabbroid-dioritoid (508107). Confidence level = 3.

DZ4 (370.30–436.00 m), brittle and brittle-ductile character

Complex deformation of variable character. Three sections with increased frequency of broken (open) fractures and minor crush zones at 370.3–381.9 m, 395.0–418.6 m and 429.5–436.0 m, which correspond to a general decrease in the resistivity log. Ductile to brittle-ductile deformation at 396.0–418.4 m, mainly restricted to an occurrence of fine-grained granite (511058) at 403.1–418.4 m. Fracture networks sealed by chlorite, calcite and epidote are conspicuous in the fine-grained granite (511058). Predominant minerals in broken (open) fractures are chlorite, calcite, hematite and, more rarely laumontite and clay minerals. The α-angles vary and the locally well-developed foliation exerts only marginal control on the fracture orientation. Generally faint to moderate oxidation and more limited sections of faint to weak chloritization and epidotization. Conspicuous features: (1) argillization associated with thick calcite sealed fractures at 370.91–371.15 m, (2) strong argillization and hematization associated with the occurrence of fault gouge at 397.60–397.76 m (oriented 221°/60°), and (3) a few fractures with apertures at 1–3 cm (oriented 203°/49° and 218°/37°). The sub-sections 370.3–381.9 m, 395.0–418.6 m are geophysically characterized by caliper anomalies, decreased resistivity, p-wave velocity and magnetic susceptibility. There is also a distinct anomaly in the vertical fluid temperature gradient in the section 370.3–381.9 m. Six non-oriented weak radar reflectors occur at 370 m, 391 m, 393 m, 401 m, 420 m and 427 m with the α-angles of 60°, 45°, 43°, 30°, 35° and 35°, towards the borehole axis, respectively. In addition, one non-oriented radar reflector of medium strength occurs at 434 m with the α-angle 22°. Rock types: Ävrö granodiorite (501056) and fine-grained granite (511058). Confidence level = 3.

DZ5 (509.70–510.50 m), brittle character

Moderate oxidation, along with an increased frequency of broken (open) fractures and sealed fracture networks. Minor breccias occur. Predominant fracture minerals are chlorite, calcite and subordinate adularia. A corresponding decrease in the resistivity log occurs together with decreased p-wave velocity. Rock types: Ävrö granodiorite (501056). Confidence level = 3.

DZ6 (621.00–624.00 m), brittle character

Increased frequency of broken (open) and unbroken (sealed) fractures, and especially sealed fracture networks. Most fractures have α-angles > 45°. Predominant fracture minerals are chlorite, calcite and subordinate hematite, pyrite and clay minerals. Minor sections affected by argillization. The entire section is characterized by significantly decreased resistivity, p-wave velocity and magnetic susceptibility. There is also a major anomaly in the vertical fluid temperature gradient. Rock types: Ävrö granodiorite (501056) and in the lower part gabbroid-dioritoid (508107). Confidence level = 3.

DZ7 (713.70–734.20 m), brittle character

Increased frequency of broken (open) fractures and several minor crushes. The occurrence of a number of fractures with low α-angles and fresh condition of the fracture surfaces suggest that at least some fractures/crushes are drill induced. No obvious increase in the frequency of unbroken (sealed) fractures. Predominant fracture minerals are chlorite and calcite, and subordinate occurrence of pyrite and fluorite. Weak oxidation occurs. The section is characterized by decreased bulk resistivity, p-wave velocity and partly decreased magnetic susceptibility. There is also a major anomaly in the vertical fluid temperature gradient. One non-oriented strong radar reflector occurs at 721 m with the α-angle 13–25° and one non-oriented weak radar reflector occurs at 722 m with the α-angle 44°. Rock types: Fine-grained granite (511058). Confidence level = 2.

3.2 KAS05

The results of the identification of rock units and possible deformation zones in KAS05 are presented below and as print-outs from WellCAD in Appendix 2 and the location of KAS05 is shown in Figure 3-2.

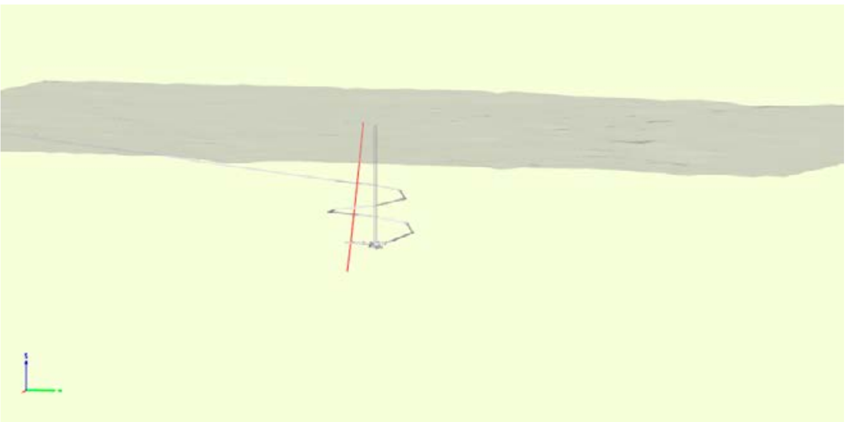


Figure 3-2. *Äspö HRL tunnel view from east. Location of surface drilled borehole KAS05. Shaded area is the ground surface.*

3.2.1 Rock units

The borehole can be divided into three different rock units, RU1–RU3. Rock unit 1 occurs in three separate intervals, RU1a–RU1c. The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. All rock units have been interpreted with a high degree of confidence. All rock units have been interpreted with a high degree of confidence.

RU1a (1.14–46.70 m)

Äspö diorite (501037). Confidence level = 3.

RU2 (46.70–127.26 m)

Ävrö granodiorite (501056) with a few minor occurrences of fine-grained granite (511058). Confidence level = 3.

RU1b (127.26–200.39 m)

Äspö diorite (501037) with minor occurrences of fine-grained granite (511058) and a section of Ävrö granodiorite (501056) at 146.11–152.26 m. Confidence level = 3.

RU3 (200.39–228.06 m)

Gabbroid-dioritoid (508107) with minor occurrences of Ävrö granodiorite (501056). Confidence level = 3.

RU1c (228.06–549.59 m)

Äspö diorite (501037) with minor occurrences of fine-grained granite (511058) and gabbroid-dioritoid (508107). Confidence level = 3.

3.2.2 Possible deformation zones

The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low. Three possible deformation zones of brittle character and one of brittle-ductile character have been identified in KAS05. The possible deformation zones with brittle character have been identified with a low or medium degree of confidence and the one with brittle-ductile character have been identified with a high degree of confidence. In addition to the geophysical anomalies associated with possible deformation zones, as described below, there is a general decrease in the single point resistance at 435–485 m borehole length with three well-defined anomalies at 442.5, 466.0 and 479.5 m length, which also coincide with anomalies in the p-wave velocity. The vertical temperature gradient data show a significant anomaly at 466 m, which indicates a major in- or outflow of water.

DZ1 (211.20–217.40 m), brittle character

Increased frequency of broken (open) fractures, especially with low α-angles to the borehole axis. One crushed section at 213.94–215.45 m. No obvious alteration or increase in the frequency of unbroken (sealed) fractures. Predominant fracture minerals are chlorite and calcite, and subordinate occurrence of clay minerals. There is a decrease in the single point resistance and partly decreased magnetic susceptibility. One non-oriented weak radar reflector occurs at 215 m with the α-angle 25°. Rock types: Gabbroid-dioritoid (508107). Confidence level = 2.

DZ2 (309.80–334.20 m), brittle-ductile character

Brittle-ductile deformation of weak to moderate intensity, where the brittle component is characterized by the presence of fracture networks sealed by epidote, chlorite, calcite and minor fluorite. Two crushed sections at 320.62–321.12 and 327.31–329.50 m. Generally weak oxidation along with moderate chloritization and epidotization. A deformation zone core has been identified at 327.0–329.1 m. This section exhibits brittle-ductile deformation of strong intensity (Figure 3-3a), extensive alteration, including chloritization, oxidation and argillization (Figure 3-3b) of varying intensity, as well as minor brecciation. In the sub section c. 320–330 m there is significantly decreased single point resistance, magnetic susceptibility and partly decreased p-wave velocity. Two non-oriented weak radar reflectors occur at 316 m and 330 m with the α-angle 28° and 30°, respectively. Rock types: Äspö diorite (501037) and subordinate gabbroid-dioritoid (508107). Confidence level = 3.

DZ3 (361.20–364.50 m), brittle character

Increased frequency of heterogeneously distributed sealed fracture networks and to some extent broken (open) fractures. Predominant fracture minerals are epidote and chlorite, and subordinate occurrence of hematite and clay minerals. Weak to moderate oxidation and epidotization throughout the interval. At c. 362.5 m there is a distinct decrease in the single point resistance. There are also several caliper anomalies along the section. Rock types: Fine-grained granite (511058), Ävrö granodiorite (501056), gabbroid-dioritoid (508107) and Äspö diorite (501037). Confidence level = 1.

DZ4 (400.00–400.60 m), brittle character

Increased frequency of broken (open) fractures with low α-angles to the borehole axis. Predominant fracture minerals are chlorite and clay minerals. A few fractures are weakly slickensided. No distinguishable alteration. At c. 400.0 m there is a distinct decrease in the single point resistance Two non-oriented weak radar reflectors occur at 400 m with the α-angles 25° and 60°, to the borehole axis respectively. Rock types: Äspö diorite (501037). Confidence level = 2.

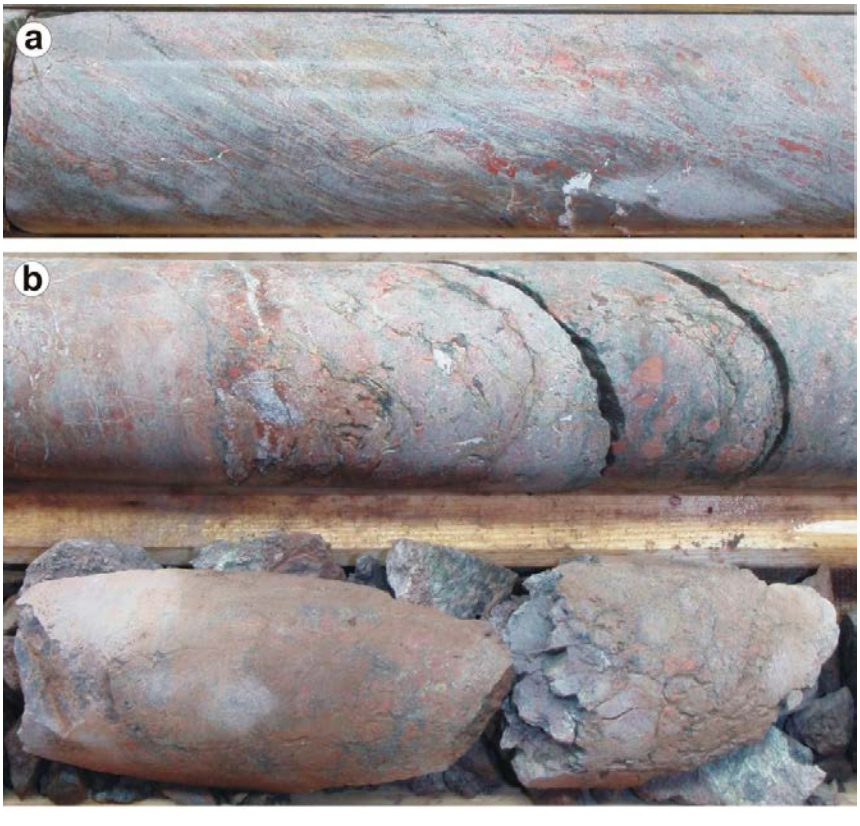


Figure 3-3. *Photographs of selected drill core sections from the deformation zone core of DZ2 in KAS05. (a) Intense brittle-ductile deformation at 327.75–327.92 m. (b) Sections affected by argillization of weak (327.11–327.28 m) and strong (328.00–328.17 m) intensity.*

3.3 KAS09

The results of the identification of rock units and possible deformation zones in KAS09 are presented below and as print-outs from WellCAD in Appendix 3 and the location of KAS09 is shown in Figure 3-4.

3.3.1 Rock units

The borehole can be divided into two different rock units, RU1 and RU2, primarily on the basis of density obtained from geophysical logging and visual inspection of the drill core. The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. All rock units have been interpreted with a high degree of confidence.

RU1 (0.42–252.62 m)

Äspö diorite (501037) with subordinate occurrences of fine-grained granite (511058). Confidence level = 3.

RU2 (252.62–450.61 m)

Ävrö granodiorite (501056), primarily identified on the basis of density obtained from geophysical logging and visual inspection of the drill core. Stored as Äspö diorite (501037) in Sicada. Subordinate occurrences of fine-grained granite (511058) and gabbroid-dioritoid (508107). Confidence level = 2.

3.3.2 Possible deformation zones

Two possible deformation zones of brittle character and three of brittle-ductile character have been identified in KAS09, all with a high degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (49.50–58.80 m), brittle character

Highly increased frequency of broken (open) fractures that coincides with the extent of a fine-grained granite (511058). Slightly increased frequency of unbroken (sealed) fractures that locally form networks. An extensive crushed section at 50.02–58.79 m. Virtually all fractures have α-angles > 45° against the borehole axis. Predominant fracture minerals are chlorite and calcite and subordinate occurrence of clay minerals and fluorite. No geophysical logs available for this section. Rock types: Fine-grained granite (511058) that exhibits a faint foliation with α-angle of approximately 80–90° to the borehole axis. Confidence level = 3.

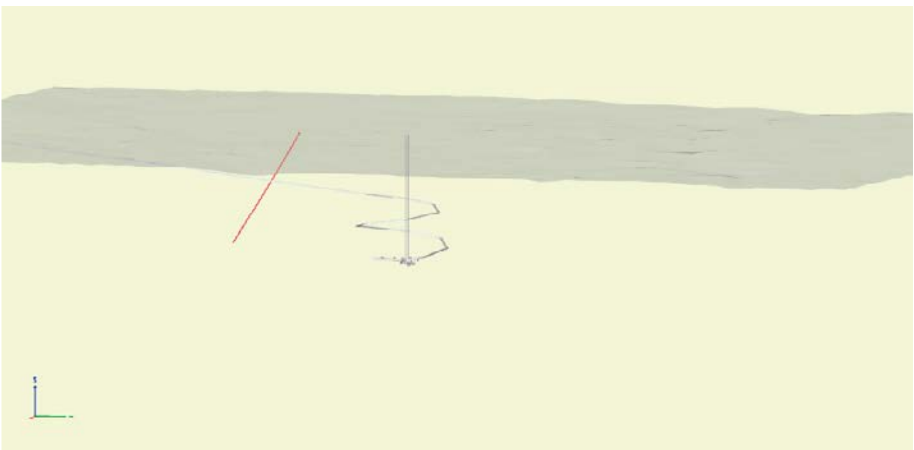


Figure 3-4. *Äspö HRL tunnel view from east. Location of surface drilled borehole KAS09. Shaded area is the ground surface.*

DZ2 (77.00–147.90 m), brittle and brittle-ductile character

Complex deformation of variable character. Generally increased frequency of broken (open) fractures, but highly increased frequency along with several crushes in the intervals 102.0–107.9 m and 129.0–149.9 m. Brittle-ductile deformation is concentrated to the interval 77.0–119.0 m, where epidote sealed fracture networks and minor mylonites frequently occur. A more extensive mylonitized section occurs at 137.85–138.02 m (Figure 3-5a). Predominant minerals in broken (open) fractures are chlorite, calcite, laumontite and clay minerals. Unbroken (sealed) fractures related to the brittle-ductile deformation are generally sealed by epidote. The structural trend of both the brittle and brittle-ductile deformation is more or less perpendicular to the length axis of the drill core (i.e. α-angles at > 75°). Generally weak to moderate oxidation throughout the possible deformation zone. A section of argillization and partly open fractures at 77.03–77.20 m (Figure 3-5b). Geophysical logging data starts at 100 m. There are two sections, 103–109 m and 130–146 m, which are characterized by significantly decreased single point resistance and p-wave velocity. The magnetic susceptibility is decreased and at c. 137 m there is an anomaly in the fluid temperature gradient indicating in- or outflow of water. One non-oriented weak radar reflector occurs at 100 m with the angle 60° to the borehole axis. The direct radar pulse is reduced from 100 m to 110 m. Rock types: Äspö diorite (501037) and subordinate fine-grained granite (511058) and gabbroid-dioritoid (508107) in the lower part. Confidence level = 3.

DZ3 (248.40–254.70 m), brittle and brittle-ductile character

Increased frequency of broken (open) fractures and one crush at 249.36–251.48 m. Intense brittle-ductile deformation is restricted to the section 250.1–252.7 m and has generally α-angles at 50–60° against the borehole axis. Predominant fracture minerals are chlorite, calcite and clay minerals. The section c. 243–253 m is characterized by significantly decreased single point resistance and p-wave velocity. There are also several caliper anomalies and the magnetic susceptibility is decreased along the interval 246.5–250.5 m. The vertical temperature gradient data show a significant anomaly, which indicates a major in- or outflow of water. One non-oriented strong radar reflector occurs at 249 m with the α-angle 38° to the borehole axis and one non-oriented radar reflector of medium strength occurs at 254 m with the α-angle 45° to the borehole axis. The direct radar pulse is reduced from 249 m to 255 m. Rock types: Äspö diorite (501037) and subordinate Ävrö granodiorite (501056). Confidence level = 3.

DZ4 (390.80–399.00 m), brittle and brittle-ductile character

Increased frequency of broken (open) fractures and several crushes, along with minor occurrences of brittle-ductile deformation. Generally α-angles > 45° to the borehole axis. Predominant fracture minerals are chlorite, calcite and more rarely fluorite and clay minerals. Locally weak to moderate oxidation. The section is characterized by significantly decreased single point resistance and p-wave velocity, and there are also several caliper anomalies. One non-oriented radar reflector of medium strength occurs at 396 m with the α-angle 50° to the borehole axis. The direct radar pulse is reduced from 391 m to 420 m. Rock types: Ävrö granodiorite (501056) and fine-grained granite (511058) with tectonic foliation of faint to weak intensity. Confidence level = 3.

DZ5 (410.40–420.00 m), brittle character

Increased frequency of broken (open) fractures with the occurrence of several minor crushes. A deformation zone core, characterized by increased frequency of sealed fracture networks and brecciated sections (Figure 3-6), has been defined at 414.5–419.0 m. Predominant minerals in broken (open) fractures are chlorite, clay minerals, calcite and hematite, and in unbroken (sealed) fractures, calcite, chlorite, epidote and hematite. Fractures exhibit generally α-angles > 45° to the borehole axis. Faint oxidation throughout the possible deformation zone. There are no geophysical logging data along this section. The direct radar pulse is reduced from 391 m to 420 m. Rock types: Ävrö granodiorite (501056). Confidence level = 3.

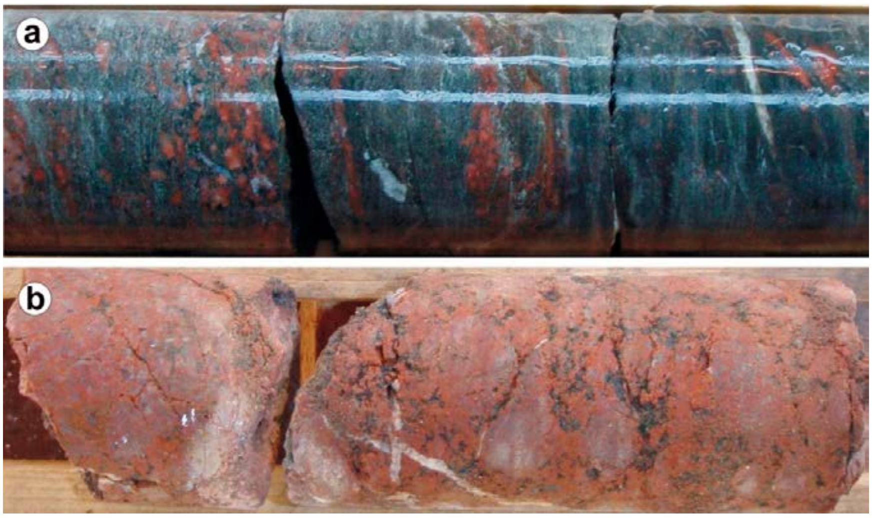


Figure 3-5. *Photographs of selected drill core sections of DZ2 in KAS09. (a) Mylonitized section at 137.85–138.02 m. (b) Weakly argillized section with partly open fractures at 77.03 – 77.20 m.*

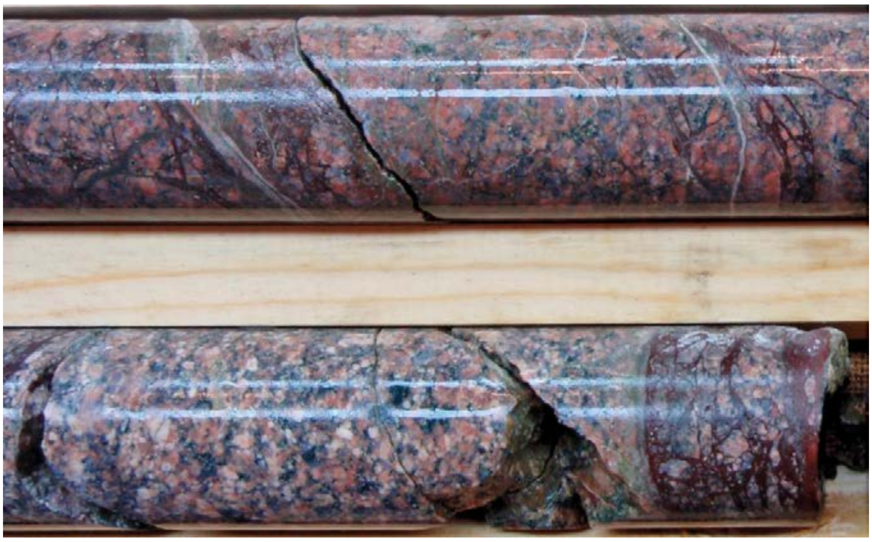


Figure 3-6. *Photograph of selected drill core sections from the zone core of DZ5 in KAS09, showing the character of sealed networks and associated breccias.*

3.4 KAS11

The results of the identification of rock units and possible deformation zones in KAS11 are presented below and as print-outs from WellCAD in Appendix 4 and the location of KAS11 is shown in Figure 3-7.

3.4.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. All rock units have been interpreted with a high degree of confidence. The borehole can be divided into three different rock units, RU1–RU3. Rock unit 2 occurs in two separate intervals, RU2a and RU2b.

RU1 (1.28–73.25 m)

Mixture of Äspö diorite (501037) and fine-grained granite (511058) in approximately equal proportions. Confidence level = 3.

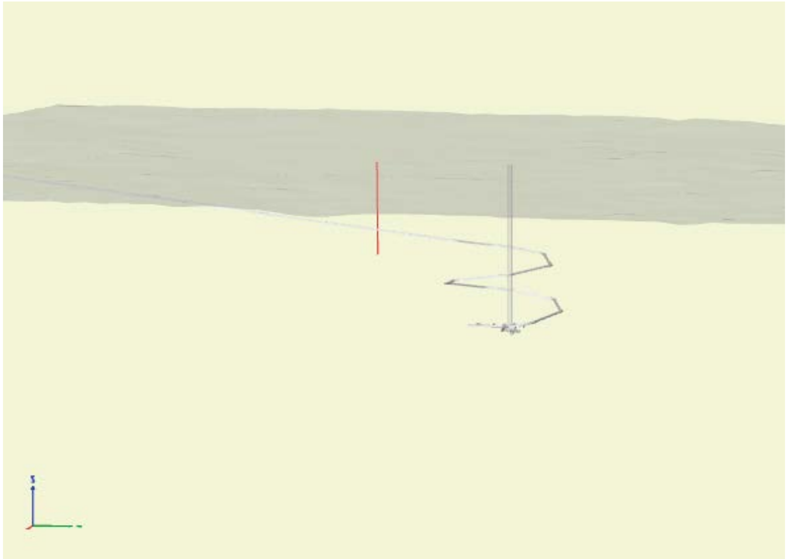


Figure 3-7. Äspö HRL tunnel view from east. Location of surface drilled borehole KAS11. Shaded area is the ground surface.

RU2a (73.25–157.57 m)

Äspö diorite (501037) with one minor occurrence of fine-grained granite (511058), one of gabbroid-dioritoid (508107) and one of pegmatite (501061) along the lower part of the rock unit. Confidence level = 3.

RU3 (157.57–181.58 m)

Fine-grained granite (511058). Confidence level = 3.

RU2b (181.58–248.82 m)

Äspö diorite (501037) with minor occurrences of fine-grained granite (511058). Confidence level = 3.

3.4.2 Possible deformation zones

Two possible deformation zones of brittle character and one of brittle-ductile character have been identified in KAS11, all with a high degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low. In addition to the geophysical anomalies associated with possible deformation zones, as described below, there is a significant decrease in single point resistance, p-wave velocity, magnetic susceptibility and density along the length interval 216–220 m.

DZ1 (32.50–41.30 m), brittle character

Highly increased frequency of broken (open) fractures and in the lowermost part sealed fracture networks. Predominant minerals in broken (open) fractures are chlorite, calcite and clay minerals, and in unbroken (sealed) fractures, epidote, chlorite and calcite. Variable fracture orientations occur, but generally α-angles are > 45° against the borehole axis. The section c. 36–41 m is characterized by decreased p-wave velocity and caliper anomalies. There is also a significant anomaly in the vertical temperature gradient data. At c. 41 m there is a change in the borehole diameter, and the increased diameter above 41 m affects the SPR-data in such a way that these data are not possible to interpret. Oxidation is of moderate to strong intensity. One non-oriented weak radar reflector occurs at 37 m with a α-angle of 60° against the borehole axis. Rock types: Fine-grained granite (511058) and in the lowermost part Äspö diorite (501037). Confidence level = 3.

DZ2 (59.50–61.70 m), brittle character

Increased frequency of broken (open) fractures and strong oxidation. Predominant fracture minerals are clay minerals, hematite, chlorite and calcite. Local argillization of faint to weak intensity. Possible hydraulic anomaly at 61.2–61.3 m. The section is characterized by significantly decreased single point resistance, p-wave velocity and magnetic susceptibility. Rock types: Äspö diorite (501037). Confidence level = 3.

DZ3 (154.20–181.80 m), brittle and brittle-ductile character

Increased frequency of broken (open) fractures, sealed fracture networks and several crushed sections. Brittle-ductile deformation along the intervals 155.5–156.6 m and 180.4–181.6 m. Also outside the possible deformation zone distinct sections of unbroken (sealed) fracture networks occur. Minor breccias occur as well. Predominant minerals in broken (open) fractures are chlorite, calcite and clay minerals, and minor hematite and fluorite, and in unbroken (sealed) fractures, epidote and quartz. There is a general faint oxidation. The section is characterized by significantly decreased single point resistance, p-wave velocity and magnetic susceptibility. There are also numerous caliper anomalies and a clear anomaly in the vertical temperature gradient. Two non-oriented weak radar reflectors occur at 155 m and 181 m with α-angles of 30° and 27°, against the borehole axis, respectively. The direct radar amplitude is reduced from 142 m to 162 m. Rock types: Fine-grained granite (511058) and along the upper and lower parts Äspö diorite (501037) as well as gabbroid-dioritoid (508107) in the uppermost part. Confidence level = 3.

3.5 KAS12

The results of the identification of rock units and possible deformation zones in KAS12 are presented below and as print-outs from WellCAD in Appendix 5 and the location of KAS12 is shown in Figure 3-8.

3.5.1 Rock units

The borehole can be divided into two different rock units, RU1 and RU2. Both rock units have been interpreted with a high degree of confidence. The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. All rock units have been interpreted with a high degree of confidence.

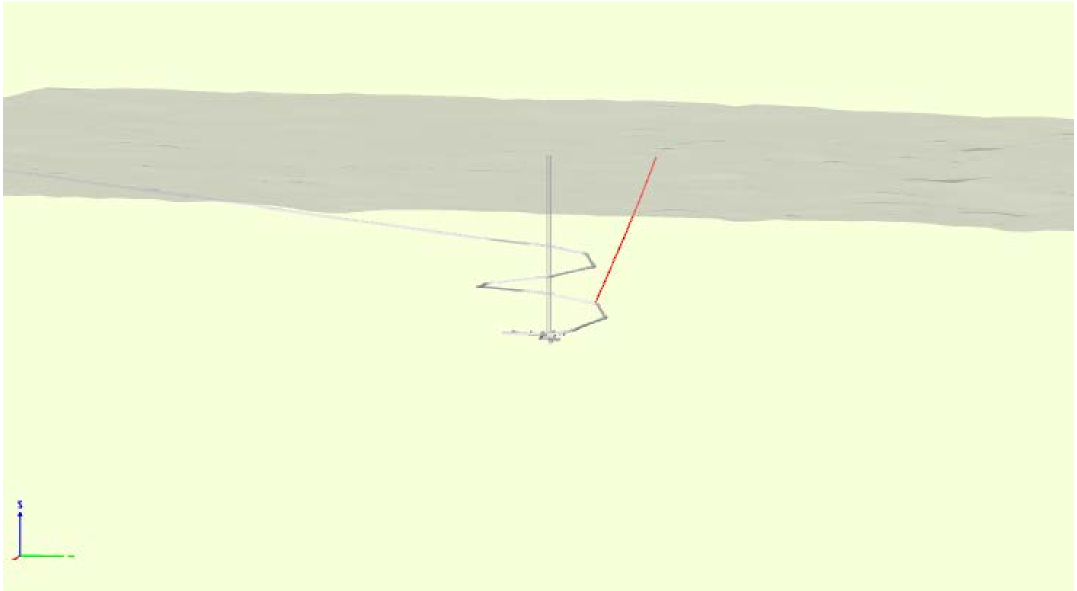


Figure 3-8. *Äspö HRL tunnel view from east. Location of surface drilled borehole KAS12. Shaded area is the ground surface.*

RU1 (0.79–348.06 m)

Äspö diorite (501037) with relatively frequent occurrences of particularly fine-grained granite (511058), but intervals of gabbroid-dioritoid (508107) also occur. Confidence level = 3.

RU2 (348.06–380.48 m)

Ävrö granodiorite (501056). Confidence level = 3.

3.5.2 Possible deformation zones

Three possible deformation zones of brittle-ductile character have been identified in KAS12, one with a medium degree of confidence and two with a high degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (25.20–41.55 m), brittle and brittle-ductile character

Heterogeneous character with brittle-ductile deformation and both broken (open) and unbroken (sealed) fractures that run more or less parallel with the drill core axis. Predominant fracture minerals are chlorite, hematite, calcite and, especially in sealed fractures, epidote. Scattered grains of pyrite occur as well. Epidotization of faint to moderate intensity and locally, oxidation of moderate intensity. The single point resistance and the p-wave velocity are partly decreased; there are also some caliper anomalies. However, the increased borehole diameter at c. 0–100 m, affects the logging data by decreased amplitudes, making them more difficult to interpret. The direct radar amplitude is reduced from 10 m to 40 m. Rock types: Äspö diorite (501037), fine-grained granite (511058) and gabbroid-dioritoid (508107). Confidence level = 2.

DZ2 (58.00–82.50 m), brittle and brittle-ductile character

Complex deformation of variable character, which reminds highly of DZ1, with brittle-ductile deformation and irregularly distributed epidote-sealed fracture networks and a faint to weak epidotization. A deformation zone core, mainly restricted to the occurrence of fine-grained granite (511058), has been identified at 74.4–81.7 m. It is characterized by intense brittle-ductile deformation (Figure 3-9a), epidotization and oxidation of moderate to strong intensity, minor occurrences of fault gouge and a short argillized section (Figure 3-9b). The structural trend of the brittle-ductile deformation, expressed as α-angles against the borehole axis, respectively, is approximately 60–70°. Predominant fracture minerals are epidote, chlorite, calcite, along with minor occurrences of laumontite and hematite. The single point resistance and the p-wave velocity are partly decreased; there are also some caliper anomalies. However, the increased borehole diameter at c. 0–100 m, affects the logging data by decreased amplitudes, making them more difficult to interpret. One oriented weak radar reflector occurs at 65 m with the α-angle 9° against the borehole axis, respectively and the orientation 327°/82°or 153°/82°. Rock types: Äspö diorite (501037) and in the deformation zone core, fine-grained granite (511058). Confidence level =3.

DZ3 (247.00–333.50 m), brittle and brittle-ductile character

Complex deformation of variable character, with brittle-ductile deformation, epidote sealed fracture networks and increased frequency of broken (open) fractures. Intervals with several crushes at 252–261 m and 299–317 m. Predominant fracture minerals are chlorite, calcite, and especially in sealed fracture networks, epidote. Oxidation of faint to moderate intensity and locally epidotization of variable intensity. Variable α-angles of fractures compared to core axis occur. Two deformation zone cores have been defined at 251.5–254.2 m and 300.6–305.5 m. They are characterized by highly increased frequency of broken (open) fractures, intense brittle-ductile deformation, epidote-sealed fracture networks, breccias and cataclasites (Figure 3-10), along with sections of argillization. The geophysical logging data show four sub-sections at c. 251–257 m, 281–285 m, 300–303 m and 314–319 m

Figure 3-9. Photographs of selected drill core sections from the zone core of DZ2 in KAS12 showing (a) the intense brittle-ductile deformation and (b) strong argillic alteration.

Figure 3-10. Photograph of a brecciated drill core section from the deformation zone core at 300.6–305.5 m of DZ3 in KAS12.

with significantly decreased single point resistance and p-wave velocity. Along all sections apart for the 300–303 m section, the magnetic susceptibility is decreased and there are significant caliper anomalies. One oriented strong radar reflector occurs at 254 m with the α-angle of 13° to the borehole axis and the orientation 016°/87° or 009°/62°. In addition, two oriented radar reflectors of medium strength occur at 252 m and 262 m with the α-angle of 35° and 30° to the borehole axis occur The orientation is 265°/75° or 103°/37° and 240°/82° or 060°/38°, respectively. Also, four oriented weak or uncertain radar reflectors occur at 278 m, 298 m, 300 m and 308 m with the α-angle of 30°, 30°, 27° and 34° to the borehole axis occur . Orientation is 266°/80° or 100°/42°, 240°/82° or 060°/38°, 160°/65° or 319°/65°, and 240°/78° or 060°/34°, respectively. The direct radar amplitude is reduced from 248 m to 270 m. Rock types: Äspö diorite (501037) and subordinate fine-grained granite (511058) and gabbroid-dioritoid (508107). Confidence level = 3.

3.6 KAS13

The results of the identification of rock units and possible deformation zones in KAS13 are presented below and as print-outs from WellCAD in Appendix 6 and the location of KAS13 is shown in Figure 3-11.

3.6.1 Rock units

The borehole can be divided into four different rock units, RU1–RU4. Rock unit 1 occurs in four separate intervals, RU1a–RU1d. The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. All rock units have been interpreted with a high degree of confidence.

RU1a (3.08–27.34 m)

Äspö diorite (501037). Confidence level = 3.

RU2 (27.34–219.92 m)

Ävrö granodiorite (501056) with minor occurrences of fine-grained granite (511058) and Äspö diorite (501037). A few sections of gabbroid-dioritoid (508107) above 60.16 m borehole length. Confidence level = 3.

RU1b (219.92–233.57 m)

Äspö diorite (501037) with a minor occurrence of fine-grained granite (511058). Confidence level = 3.

RU3 (233.57–272.87 m)

Gabbroid-dioritoid (508107) with several minor occurrences of fine-grained granite (511058) and pegmatite (501061). Confidence level = 3.

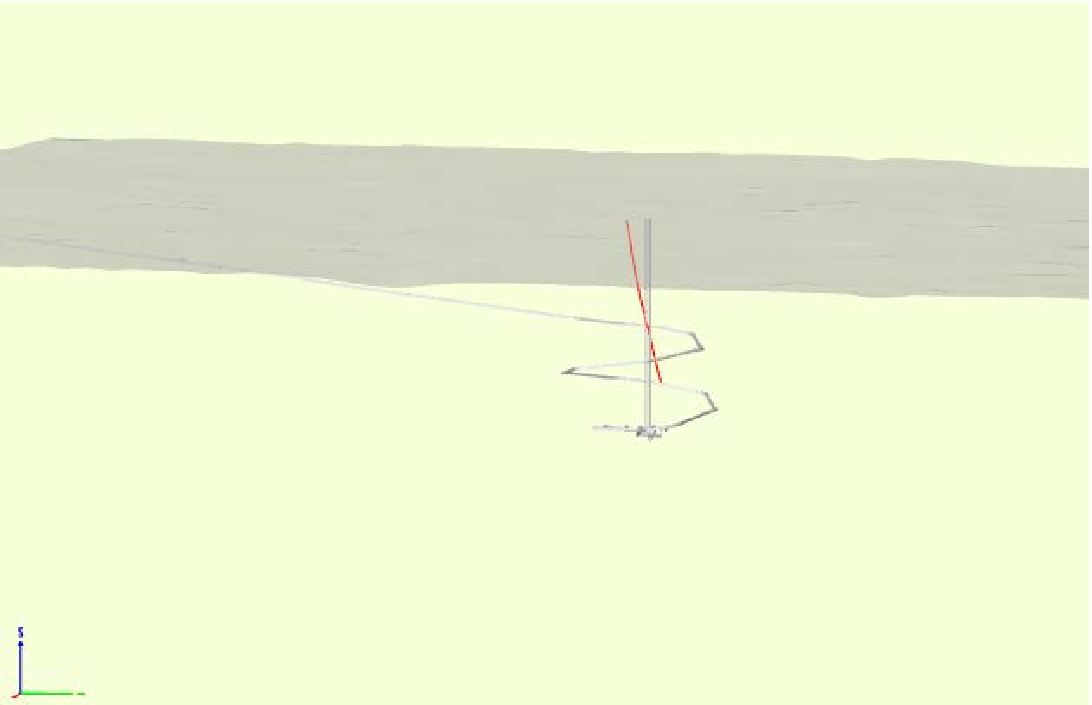


Figure 3-11. *Äspö HRL tunnel view from east. Location of surface drilled borehole KAS13. Shaded area is the ground surface.*

RU1c (272.87–370.73 m)

Äspö diorite (501037). Scattered, decimetre-wide zones of brittle-ductile deformation in the interval 347–370.7 m; the brittle component sealed by epidote. Confidence level = 3.

RU4 (370.73–389.01 m)

Fine-grained granite (511058). Confidence level = 3.

RU1d (389.01–405.99 m)

Äspö diorite (501037). Confidence level = 3.

3.6.2 Possible deformation zones

Two possible deformation zones of brittle character and four of ductile to brittle-ductile character have been identified in KAS13. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.The possible deformation zones with brittle character have been identified with a low and medium degree of confidence and the four with brittle-ductile character with a medium and high degree of confidence. In addition to the geophysical anomalies associated with possible deformation zones, as described below, there is a significant anomaly in the temperature gradient data at 81–85 m length, which indicates a major in- or outflow of water.

DZ1 (59.20–60.10 m), brittle-ductile character

Ductile to brittle-ductile deformation (Figure 3-12), with epidote-sealed fractures and minor fracture networks. No distinguishable alteration or increased frequency of broken (open) fractures. There are no significant anomalies in the geophysical logging data apart from decreased magnetic susceptibility. However, the increased borehole diameter at c. 0–100 m, affects the logging data by decreased amplitudes, making them more difficult to interpret. Rock types: Gabbroid-dioritoid (508107) with tectonic foliation of strong intensity. Confidence level = 3.

DZ2 (132.00–136.20 m), brittle character

Slightly increased frequency of broken (open) fractures and two crushed sections at 132.09–132.95 and 135.25–135.82 m. Predominant minerals in broken (open) fractures are chlorite and calcite, and in unbroken (sealed), epidote and calcite. Fractures exhibit variable orientations. General oxidation of faint to moderate intensity. There is a decrease in the single point resistance, magnetic susceptibility and also a minor p-wave velocity anomaly. One oriented strong radar reflector occurs at 133 m with α-angle of 30° to the borehole axis and the orientation 014°/88° or 206°/33°. In addition, one oriented radar reflector of medium strength occurs at 136 m with the α-angle 30° to the borehole axis and the orientation is 348°/88° or 156°/33°. Rock types: Ävrö granodiorite (501056). Confidence level = 1.

Figure 3-12. *Photograph of the intense brittle-ductile deformation at approximately 59.2 m length in KAS13.*

DZ3 (157.20–163.10 m), brittle and subordinate brittle-ductile character

Increased frequency of broken (open) and unbroken (sealed) fractures. Crushed section at 157.88–160.29 m with several broken (open) fractures that exhibit low α-angles to the borehole axis and fresh fracture surfaces, suggesting that the crush at least to some extent is drilling induced. Centimetre-wide sections with brittle-ductile deformation. Predominant minerals in broken (open) fractures are chlorite and calcite, and in unbroken (sealed), epidote and quartz. Oxidation of weak to moderate intensity occur. There is a decrease in the single point resistance, the magnetic susceptibility and the p-wave velocity. An anomaly in the vertical temperature gradient indicates in- or outflow of water. One oriented weak radar reflector occurs at 160 m with the α-angle of 23° to the borehole axis and the orientation 320°/89° or 121°/49°. Rock types: Ävrö granodiorite (501056). Confidence level = 1.

DZ4 (200.30–218.70 m), brittle and brittle-ductile character

Increased frequency of broken (open) fractures and one major crush at 208.89–215.32 m. Local epidote-sealed fracture networks. Brittle-ductile deformation in the section 209–214 m. Predominant minerals in broken (open) fractures are chlorite, calcite and more rarely clay minerals. Oxidation of faint to moderate intensity. The section is characterized by significantly decreased single point resistance and p-wave velocity. The magnetic susceptibility is partly decreased and there are some minor caliper anomalies. A clear anomaly in the vertical temperature gradient indicates in- or outflow of water. Two oriented strong radar reflectors occur at 209 m and 214 m with α-angles of 27° and 30° to the borehole axis respectively. The orientation is 040°/85° or 243°/45° and 039°/82° or 245°/43°, respectively. The direct radar amplitude is reduced from 208 m to 220 m. Rock types: Ävrö granodiorite (501056) and in the lower part Äspö diorite (501037). Confidence level = 3.

DZ5 (300.00–301.30 m), brittle-ductile character

Strongly foliated Äspö diorite (501037) with brittle-ductile deformation, minor epidote-sealed fracture networks and, to some extent, increased frequency of broken (open) fractures parallel with the foliation (α-angles at 25–30° to the borehole axis). The character reminds highly of DZ1. No distinguishable alteration. There are no geophysical anomalies along the section. Rock types: Strongly foliated Äspö diorite (501037). Confidence level = 3.

DZ6 (379.30–386.70 m), brittle character

Increased frequency of broken (open) fractures and several minor crushed sections. Predominant fracture minerals are chlorite, calcite and more rarely clay minerals. Oxidation is in general of moderate intensity. The section is characterized by significantly decreased single point resistance and p-wave velocity. The magnetic susceptibility is partly decreased. One oriented radar reflector of medium strength occurs at 386 m with the α-angle of 40° to the borehole axis and the orientation of 024°/76° or 236°/28°. Rock types: Fine-grained granite (511058) with tectonic foliation of faint to weak intensity. Confidence level = 2.

3.7 KAS14

The results of the identification of rock units and possible deformation zones in KAS14 are presented below and as print-outs from WellCAD in Appendix 7 and the location of KAS14 is shown in Figure 3-13.

3.7.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be divided into three different rock units, RU1–RU3. Rock units 1 and 3 have been interpreted with a low degree of confidence, since the density log and visual inspection of the drill core suggest that the proportion of Äspö diorite (501037) should be higher in favor of Ävrö granodiorite (501056). Rock unit 2 has been interpreted with a high degree of confidence.

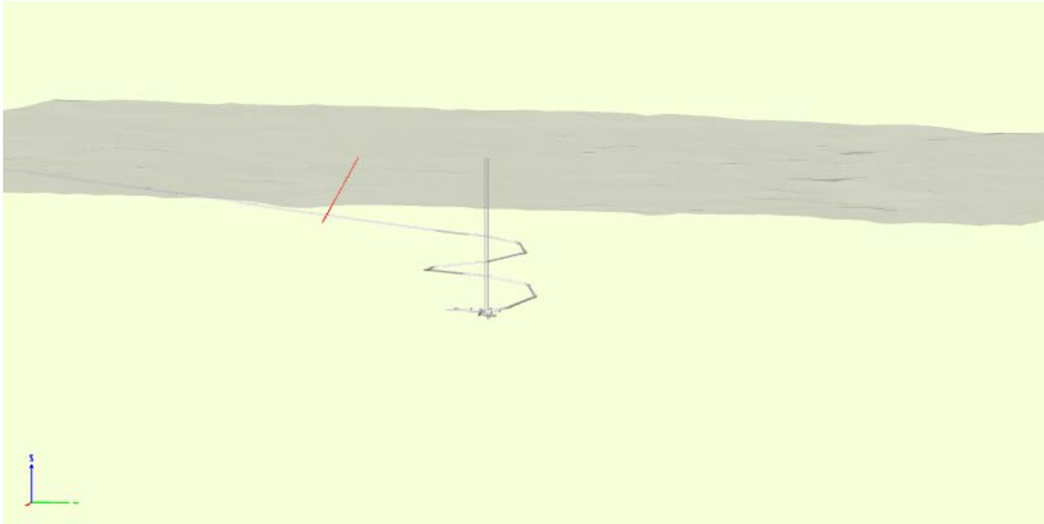


Figure 3-13. Äspö HRL tunnel view from east. Location of surface drilled borehole KAS14. Shaded area is the ground surface.

RU1 (0.44–36.59 m)

Ävrö granodiorite (501056) with subordinate occurrences of fine-grained granite (511058). Confidence level = 1.

RU2 (36.59–57.59 m)

Fine-grained granite (511058). Confidence level = 3.

RU3 (57.59–211.85 m)

Ävrö granodiorite (501056) with subordinate Äspö diorite (501037) and minor occurrences of fine-grained granite (511058). Confidence level = 1.

3.7.2 Possible deformation zones

Two possible deformation zones of brittle character and one of brittle-ductile character have been identified in KAS14. The possible deformation zones with brittle character have been identified with a low and medium degree of confidence and the one with brittle-ductile character with a high degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (16.60–21.70 m), brittle character

Increased frequency of broken (open) fractures associated with a section of fine-grained granite (511058). Predominant fracture minerals are chlorite, calcite, clay minerals and hematite. Fractures exhibit variable orientations, but generally α-angles of > 45° against the borehole axis occur. Oxidation is in general of moderate intensity. The magnetic susceptibility is partly decreased and there is a major anomaly in the vertical temperature gradient, which indicates an in- or outflow of water. The increased borehole diameter at c. 0–100 m, affects the logging data by decreased amplitudes, making them more uncertain and difficult to interpret. Rock types: Fine-grained granite (511058) and subordinate Ävrö granodiorite (501056). Confidence level = 1.

DZ2 (36.60–62.80 m), brittle character

Increased frequency of broken (open) fractures associated with an occurrence of moderately oxidized fine-grained granite (511058). Local occurrence of chlorite-sealed fracture networks. Predominant fracture minerals are chlorite and calcite. Fractures exhibit variable orientations, but generally α-angles of > 45° against the borehole axis occur. The geophysical data indicate the occurrence of fine-grained granite (decreased density and increased natural gamma radiation), but there are no significant anomalies in the SPR or sonic data. However, the increased borehole diameter at c. 0–100 m, affects the logging data by decreased amplitudes, making them more uncertain and difficult to interpret. Three oriented weak radar reflectors occur at 37 m, 44 m and 61 m with the α-angles of 40°, 40° and 50° against the borehole axis respectively. The orientation is 158°/56° or 292°/56°, 281°/63° or 146°/49°, and 195°/64° or 316°/27°, respectively. In addition, a non-oriented weak radar reflector occurs at 51 m with the α-angle of 60° against the borehole axis. The direct radar amplitude is reduced from 53 m to 54 m. Rock types: Fine-grained granite (511058) and subordinate Ävrö granodiorite (501056). Confidence level = 2.

DZ3 (88.40–211.85 m, end of drill core), brittle and subordinate brittle-ductile character

Increased frequency of broken (open) fractures and the occurrence of several minor crushes, especially in the intervals 88.4–135.5 m, 153.8–166.0 m and 182.7–211.85 m. Local occurrence of increased frequency of unbroken (sealed) fractures. Section with minor occurrences of brittle-ductile deformation at 182.80–192.0 m. Predominant fracture minerals are chlorite, calcite, clay minerals, minor fluorite and especially in unbroken (sealed) fractures, epidote and calcite. Fractures exhibit variable orientations, but generally α-angles of > 45° against the borehole axis occur. Oxidation is in general of faint to moderate intensity. Strong oxidation at 180.8–186.5 m, moderate epidotization at 183.0–193.0 m and weak epidotization at 193.0–205.0 m. One oriented strong radar reflector occurs at 190 m with the angle of 37° against the borehole axis. The three sections c. 110–135 m, 150–166 m and 192–202 m show a concentration of caliper anomalies, decreased p-wave velocity, decreased single point resistance and partly decreased magnetic susceptibility. In the section interval c. 148–162 m there is a significant anomaly in the vertical temperature gradient, suggesting in- or outflow of water. The orientation is 201°/80° or 352°/30°. Four oriented radar reflectors of medium or weak strength occur at 100 m, 117 m, 142 m and 158 m with α-angle of 70°, 25°, 30° and 40° against the borehole axis, respectively. The orientation is 225°/50° or 225°/10°, 173°/82° or 328°/54°, 212°/89° or 019°/32°, and 237°/79° or 077°/22°, respectively. In addition, four non-oriented radar reflectors occur at 131 m, 135 m, 174 m, and 185 m with α-angle of 90°, 90°, 90°, and 90° against the borehole axis, respectively. The direct radar amplitude is reduced from 113 m to 124 m and from 153 m to 165 m. Rock types: Äspö diorite (501037) and Ävrö granodiorite (501056) together with fine-grained granite (511058). Confidence level = 3.

3.8 KAS16

The results of the identification of rock units and possible deformation zones in KAS16 are presented below and as print-outs in WellCAD in Appendix 8 and the location of KAS16 is shown in Figure 3-14. As no original geological mapping was available for KAS16 a simplified lithological overview mapping was performed, see Table 3-1. Only rock types exceeding 1 m in drill core length were registered and no alterations, fracture frequencies or crushes were documented.

3.8.1 Rock units

The borehole can be divided into three different rock units, RU1–RU3. Rock unit 1 occurs in three separate intervals, RU1a–RU1c, and RU2 in four separate intervals, RU2a–RU2d. All rock units have been interpreted with a high degree of confidence. The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

RU1a (0.0–17.00 m)

Fine-grained granite (511058) and gabbroid-dioritoid (508107) in approximately equal proportions. Confidence level = 3.

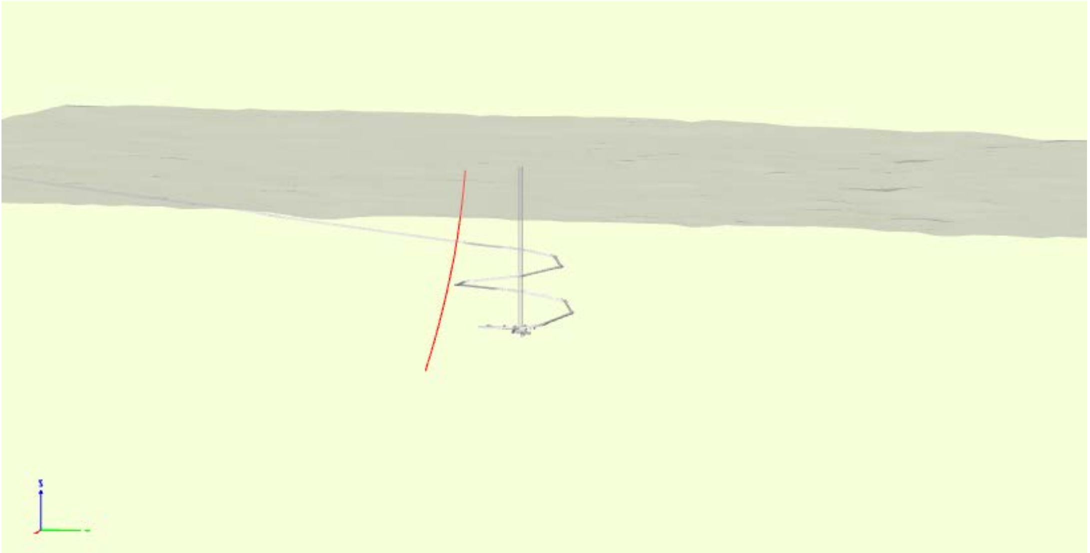


Figure 3-14. *Äspö HRL tunnel view from east. Location of surface drilled borehole KAS16. Shaded area is the ground surface.*

Tabell 3-1. Overview lithological mapping of KAS16.

Drill core length (m)		Rock type	
Sec_up	Sec_low	ID code	Name
0.0	8.0	511058	Fine-grained granite
8.0	15.0	508107	Gabbroid-dioritoid
15.0	17.0	511058	Fine-grained granite
17.0	177.8	501037	Äspö diorite
177.8	186.8	511058	Fine-grained granite
186.8	188.9	501037	Äspö diorite
188.9	191.5	511058	Fine-grained granite
191.5	293.2	501037	Äspö diorite
293.2	306.0	511058	Fine-grained granite
306.0	311.0	508107	Gabbroid-dioritoid
311.0	312.8	501037	Äspö diorite
312.8	338.6	511058	Fine-grained granite
338.6	390.6	501037	Äspö diorite
390.6	454.0	511058	Fine-grained granite
454.0	462.3	508107	Gabbroid-dioritoid
462.3	548.46	501037	Äspö diorite

RU2a (17.00–177.80 m)

Äspö diorite (501037). Confidence level = 3.

RU3 (177.80–191.50 m)

Fine-grained granite (511058) with subordinate Äspö diorite (501037). Confidence level = 3.

RU2b (191.50–293.20 m)

Äspö diorite (501037). Confidence level = 3.

RU1b (293.20–338.60 m)

Fine-grained granite (511058) and subordinate gabbroid-dioritoid (508107) and Äspö diorite (501037). Confidence level = 3.

RU2c (338.60–390.60 m)

Äspö diorite (501037). Confidence level = 3.

RU1c (390.06–462.30 m)

Fine-grained granite (511058) and subordinate gabbroid-dioritoid (508107). Confidence level = 3.

RU2d (462.30–548.46 m)

Äspö diorite (501037). Confidence level = 3.

3.8.2 Possible deformation zones

Two possible deformation zones of brittle character and one of brittle-ductile character have been identified in KAS16, all with a high degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (8.00–14.90 m), brittle and brittle-ductile character

Increased frequency of broken (open) fractures, minor crushes and brittle-ductile deformation that coincides with an interval of gabbroid-dioritoid (508107). Fractures exhibit generally α-angles of > 45° against the borehole axis. Predominant fracture minerals are chlorite, calcite, and more rarely hematite and clay minerals occur. Faint to weak chloritization of the gabbroid-dioritoid (508107) and weak to moderate oxidation of the fine-grained granite (511058). Rock types: Gabbroid-dioritoid (508107) with subordinate fine-grained granite (511058). Confidence level = 3.

DZ2 (390.60–456.30 m), brittle character

Increased frequency of broken (open) fractures that largely coincides with an interval of fine-grained granite (511058); locally highly increased frequency and sections with crushes. Intervals with increased frequency of unbroken (sealed and partly open) fractures that typically form networks. Minor cataclasites occur in a few sections. Predominant fracture minerals are chlorite, calcite, clay minerals, hematite and more rarely pyrite and fluorite occur. Oxidation is in general of moderate intensity throughout the interval. A well-defined section of porous granite (episyenite) occurs at 448.1–454.0 m, which appears less fractured than the remaining parts of the possible deformation zone (Figure 3-15). Two oriented strong radar reflectors and one oriented radar reflector of medium strength occur at 400 m, 449 m and 456 m with α-angles of 25°, 33° and 29° against the borehole axis, respectively. The orientations are 228°/71° or 048°/60°, 355°/54° or 181°/61°, and 199°/66° or 016°/56°, respectively. In addition, two non-oriented radar reflectors occur at 424 m and 432 m with α-angles of 30° and 32° against the borehole axis, respectively. Rock types: Fine-grained granite (511058) with distinct tectonic foliation of moderate to strong intensity and well-developed sealed spaced cleavage and subordinate gabbroid-dioritoid (508107). Confidence level = 3.

Figure 3-15. Photograph of a 1 dm core section of porous granite or episyenite from the interval 448.1–454.0 m in KAS16.

DZ3 (525.20–528.60 m), brittle character

Increased frequency of broken (open) fractures and crushed intervals. Locally sealed to partly open fracture networks occur. Predominant fracture minerals are chlorite and calcite, and epidote in unbroken (sealed) fractures. The oxidation is weak to moderate. Rock type: Äspö diorite (501037). Confidence level = 3.

3.9 KAS17

The results of the identification of rock units and possible deformation zones in KAS17 are presented below and as print-outs from WellCAD in Appendix 9 and the location of KAS17 is shown in Figure 3-16.

3.9.1 Rock units

The borehole can be defined as one rock unit, RU1, interpreted with a high degree of confidence. The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

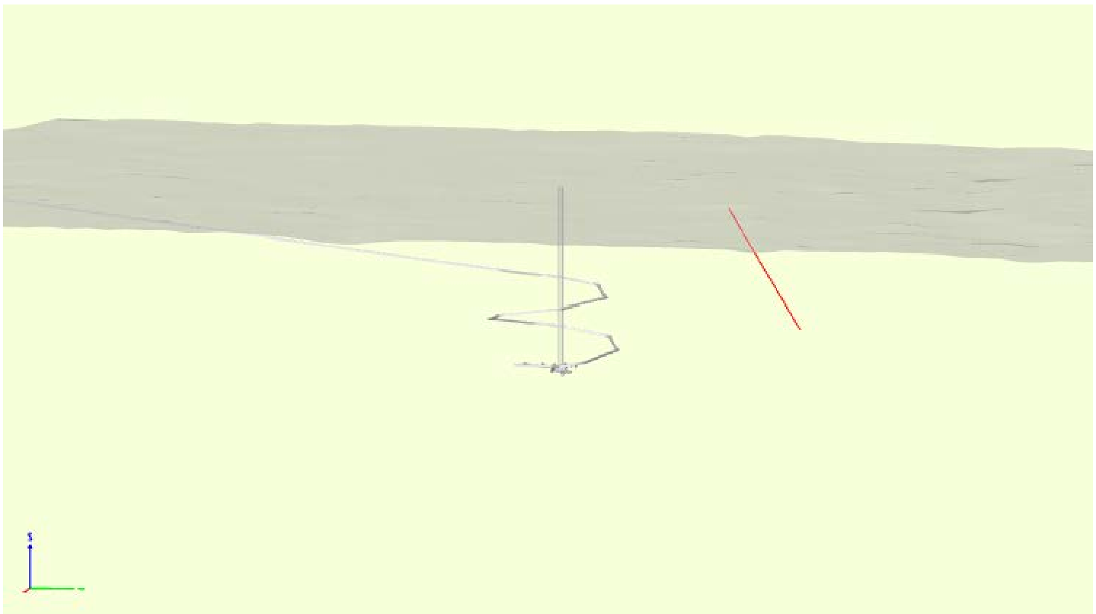


Figure 3-16. Äspö HRL tunnel view from east. Location of surface drilled borehole KAS17. Shaded area is the ground surface.

RU1 (0.47–352.73 m)

Dominated by Äspö diorite (501037) with subordinate occurrences of fine-grained granite (511058). Both rock types exhibit tectonic foliation of weak to moderate intensity. However, the euhedral to subhedral K-feldspar phenocrysts in the Äspö diorite (501037) are generally randomly oriented. Confidence level = 3.

3.9.2 Possible deformation zones

One possible deformation zone of brittle character and three of brittle-ductile character have been identified in KAS17, all with a high degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (18.20–27.30 m), brittle and brittle-ductile character

Brittle-ductile deformation, increased frequency of broken (open) fractures and occurrence of epidote-sealed fracture networks. Deformation zone core occur at 18.2–21.5 m, defined on the basis of intense brittle-ductile deformation and epidotization of variable intensity. Predominant minerals in broken (open) fractures are clay minerals, hematite, chlorite and calcite, and in unbroken (sealed) fractures, epidote. Locally faint to moderate oxidation and weak chloritization. Rock types: Äspö diorite (501037) and subordinate occurrences of fine-grained granite (511058). Confidence level = 3.

DZ2 (102.50–109.80 m), brittle character

Increased frequency of broken (open) fractures. Predominant fracture minerals are clay minerals, hematite, chlorite and calcite. Variable α-angles against the core axis occur. Oxidation is in general of weak to strong intensity and very locally weak argillization occurs. Rock type: Äspö diorite (501037). Confidence level = 3.

DZ3 (148.50–229.30 m), brittle and brittle-ductile character

Complex deformation of variable character, with brittle-ductile deformation and in the interval 176.7–221.1 m highly increased frequency of broken (open) fractures and occurrence of several crushed intervals. The brittle-ductile deformation occurs sporadically along the drill core and the brittle component is typically characterized by epidote sealed fracture networks. Mylonitization in the section 227.0–227.2 m. Predominant minerals in broken (open) fractures are chlorite, clay minerals, hematite, calcite and laumontite, and in unbroken (sealed) fractures, epidote, laumontite and calcite. Generally, faint to weak oxidation and chloritization occurs. Strong laumontization associated with accumulations of calcite occur in the section 153.3–158.0 m; protolith cannot be distinguished. Rock types: Äspö diorite (501037) and fine-grained granite (511058) with distinct tectonic foliation oriented approximately 45° towards the axis of the drill core. Confidence level = 3.

DZ4 (264.80–308.60 m), brittle and brittle-ductile character

Brittle-ductile deformation, fracture networks sealed by predominantly epidote and, to some extent, increased frequency of broken (open) fractures. Predominant fracture minerals are clay minerals, laumontite, calcite, chlorite and hematite. Strong alteration and/or dense networks sealed by quartz-epidote at 274.3–274.9 m and 279.6–282.1 m. Local oxidation and chloritization of faint to weak intensity occur, and very locally faint argillization occur. Rock types: Äspö diorite (501037). Confidence level = 3.

3.10 KA1751A

The results of the identification of rock units and possible deformation zones in KA1751A are presented below and as print-outs from WellCAD in Appendix 10 and the location of KA1751A is shown in Figure 3-17.

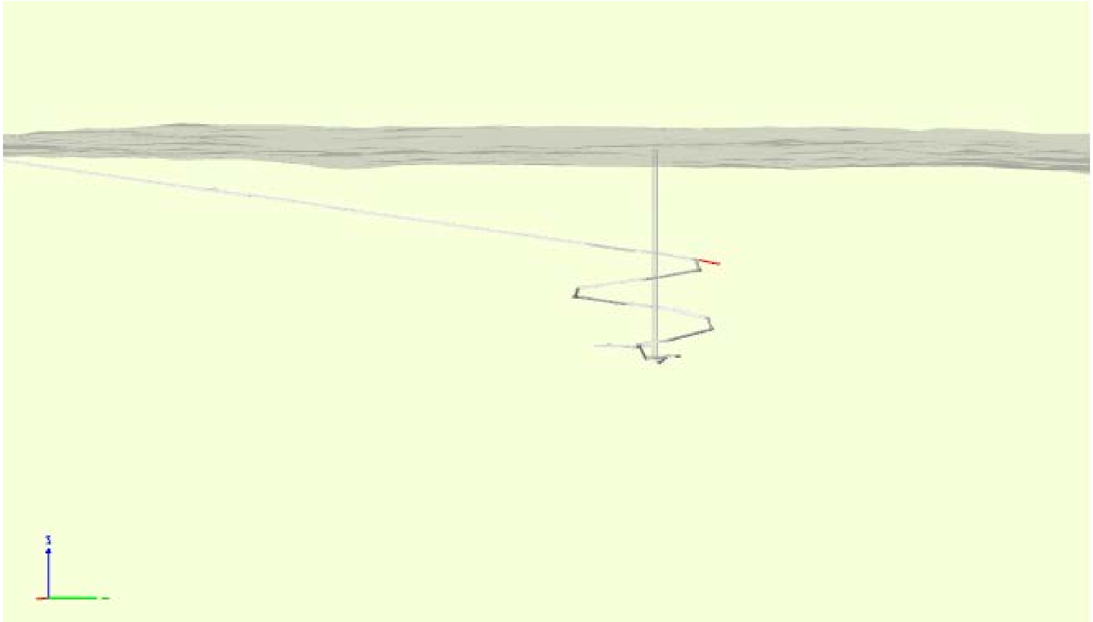


Figure 3-17. Äspö HRL tunnel view from east. Location of surface drilled borehole KA1751A. Shaded area is the ground surface.

3.10.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be divided into four different rock units, RU1–RU4. Rock unit 1 occurs in four separate intervals, RU1a–RU1d, and RU2 in two separate intervals, RU2a–RU2b. All rock units have been interpreted with a high degree of confidence.

RU1a (3.80–12.10 m)

Äspö diorite (501037). Confidence level = 3.

RU2a (12.10–44.70 m)

Ävrö granodiorite (501056) with one occurrence of fine-grained granite (511058) at 41.70–44.70 m. Confidence level = 3.

RU1b (44.70–58.42 m)

Äspö diorite (501037) with minor occurrences of fine-grained granite (511058). Confidence level = 3.

RU2b (58.42–81.68 m)

Ävrö granodiorite (501056) with one occurrence of fine-grained granite (511058) at 58.42–60.10 m. Confidence level = 3.

RU1c (81.68–103.30 m)

Äspö diorite (501037). Confidence level = 3.

RU3 (103.30–128.96 m)

Gabbroid-dioritoid (508107) with one occurrence of fine-grained granite (511058) at 109.90–113.77 m and a minor occurrence of pegmatite (501061) in the lower part of the rock unit. Confidence level = 3.

RU1d (128.96–145.37 m)

Äspö diorite (501037). Confidence level = 3.

RU4 (145.37–149.91 m)

Fine-grained granite (511058). Confidence level = 3.

3.10.2 Possible deformation zones

The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low. Two possible deformation zones of brittle-ductile character have been identified in KA1751A, both with a medium degree of confidence.

DZ1 (104.30–118.00 m), brittle and ductile character

Increased frequency of broken (open) fractures, locally with ductile deformation of moderate to strong intensity. No alteration or increased frequency of unbroken (sealed) fractures. Predominant fracture minerals are chlorite and calcite. Rock types: Gabbroid-dioritoid (508107) with subordinate fine-grained granite (511058). Confidence level = 2.

DZ2 (134.60–149.91 m, end of drill core), brittle and brittle-ductile character

Composite character with scattered occurrences of epidote-sealed fracture networks and weak to moderate epidotization in the interval 134.6–145.1 m, increased frequency of broken (open) fractures in the interval 145.1–149.91 m, and brittle-ductile deformation in the interval 143.2–144.7 m. Predominant minerals in broken (open) fractures are chlorite and calcite, with minor fluorite. Rock types: Äspö diorite (501037) and in the lowermost part of the drill core, fine-grained granite (511058) with weak tectonic foliation. Confidence level = 2.

3.11 KA1754A

The results of the identification of rock units and possible deformation zones in KA1754A are presented below and as print-outs from WellCAD in Appendix 11 and the location of KA1754A is shown in Figure 3-18.

3.11.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be divided into three different rock units, RU1–RU3. All rock units have been interpreted with a high degree of confidence.

RU1 (3.30–83.71 m)

Äspö diorite (501037) with minor occurrences of fine-grained granite (511058). Confidence level = 3.

RU2 (83.71–100.22 m)

Gabbroid-dioritoid (508107) with subordinate fine-grained granite (511058) restricted to the upper part of the rock unit. Confidence level = 3.

RU3 (100.22–159.88 m)

Fine-grained granite (511058). Confidence level = 3.

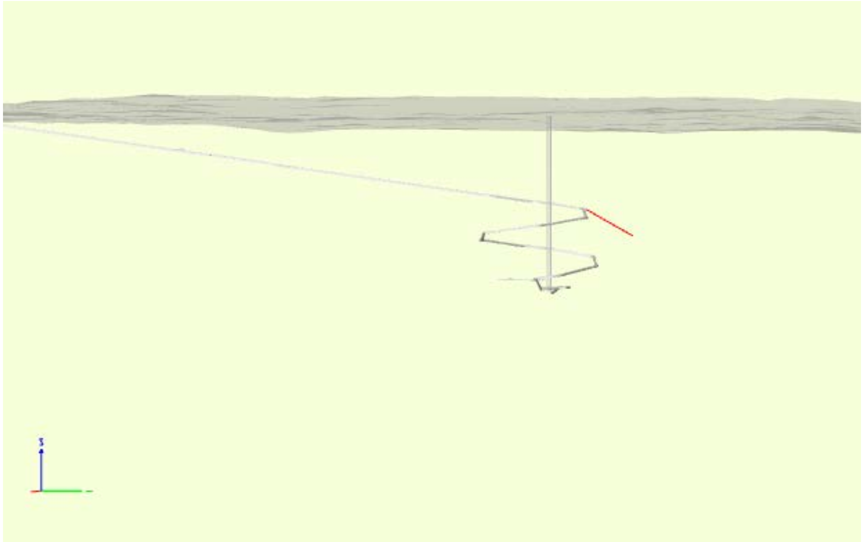


Figure 3-18. Äspö HRL tunnel view from east. Location of surface drilled borehole KA1754A. Shaded area is the ground surface.

3.11.2 Possible deformation zones

One possible deformation zone of brittle-ductile character has been identified in KA1754A with a high degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (83.40–140.60 m), brittle and brittle-ductile character

Increased frequency of broken (open) fractures with several crushes, especially in the interval 83.4–115 m. Occurrences of brittle-ductile deformation in the interval 83.4–103 m and slightly increased frequency of unbroken (sealed) fractures and sealed fracture networks throughout the possible deformation zone. Fractures generally exhibit α-angles of > 45° against the borehole axis. Predominant minerals in broken (open) fractures are chlorite and calcite, with a local occurrence of clay minerals; and in unbroken (sealed) fractures, epidote and calcite dominates. Weak oxidation of fine-grained granite (511058) and minor sections of complete silicification and epidotization. Five oriented weak radar reflectors occur at 85 m, 95 m, 101 m, 125 m and 134 m with α-angles of 72°, 20°, 54°, 52° and 41° against the borehole axis, respectively. The orientation is 045°/76° or 014°/54°, 111°/63° or 148°/81°, 053°/31° or 200°/82°, 074°/63° or 353°/76° and 086°/65° or 086°/35°, respectively. The direct radar amplitude is reduced from 90 m to 100 m. Rock types: Gabbroid-dioritoid (508107) predominates in the upper part and fine-grained granite (511058) in the lower part of the drill core within the possible deformation zone unit. The tectonic foliation is in general of weak to moderate in intensity. Confidence level = 3.

3.12 KA2048B

The results of the identification of rock units and possible deformation zones in KA2048B are presented below and as print-outs from WellCAD in Appendix 12 and the location of KA2048B is shown in Figure 3-19.

3.12.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be divided into three different rock units, RU1–RU3. Rock unit 2 occurs in two separate intervals, RU2a–RU2b. All rock units have been interpreted with a high degree of confidence.

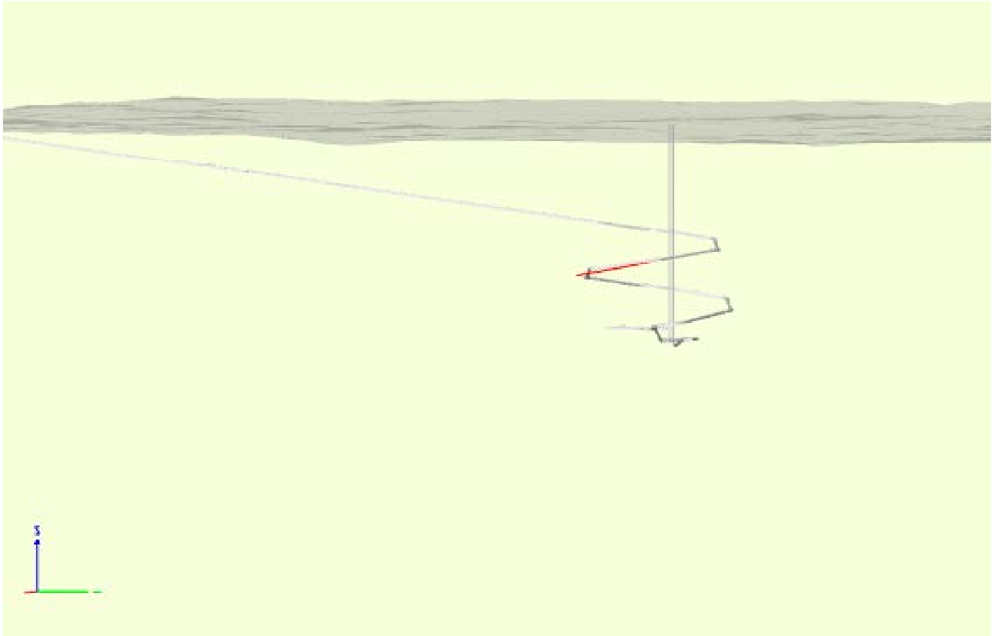


Figure 3-19. Äspö HRL tunnel view from east. Location of surface drilled borehole KA2048B. The borehole KA2048B is drilled parallel with the entrance tunnel (red line). Shaded area is the ground surface.

RU1 (2.70–85.92 m)

Ävrö granodiorite (501056) dominates with subordinate fine-grained granite (511058) and Äspö diorite (501037) in the uppermost part of the rock unit, at 2.70–4.99 m. Confidence level = 3.

RU2a (85.92–156.24 m)

Äspö diorite (501037) dominates with minor occurrences of fine-grained granite (511058). A minor occurrence of gabbroid-dioritoid (508107) occur at 143.51–145.29 m. Confidence level = 3.

RU3 (156.24–174.35 m)

Fine-grained granite (511058) dominates. Confidence level = 3.

RU2b (174.35–184.45 m)

Äspö diorite (501037) dominates with minor occurrences of fine-grained granite (511058). Confidence level = 3.

3.12.2 Possible deformation zones

One possible deformation zone of brittle character has been identified in KA2048B with a high degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (26.80–45.70 m), brittle and brittle-ductile character

Increased frequency of broken (open) fractures and to some extent unbroken (sealed) fractures. A few epidote-sealed fracture networks and breccias occur. Fractures generally exhibit α-angles of > 40° against the borehole axis. Predominant fracture minerals are calcite and chlorite, and minor fluorite occurs as well. Generally a weak to moderate oxidation and locally faint epidotization occur. The geophysical logging show significantly decreased bulk resistivity, decreased p-wave velocity and partly decreased magnetic susceptibility along the entire section. One weak oriented radar reflector occurs at 29 m with the α-angle of 30° against the borehole axis and the orientation of the reflector is 208°/59° or 142°/71°. Two oriented strong radar reflectors occur at 38 m and 41 m with α-angles of 10° and 21° against the borehole axis, respectively. The orientation is 189°/88° or 349°/88° and 341°/58° or 027°/67°, respectively. The direct radar amplitude is reduced from 25 m to 45 m. Rock types: Ävrö granodiorite (501056) and fine-grained granite (511058). Confidence level = 3.

3.13 KA2858A

The results of the identification of rock units and possible deformation zones in KA2858A are presented below and as print-outs from WellCAD in Appendix 13 and the location of KA2858A is shown in Figure 3-20.

3.13.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be divided into three different rock units, RU1–RU3. All rock units have been interpreted with a high degree of confidence.

RU1 (0.00–19.52 m)

Mixed rock unit, which consists of Äspö diorite (501037), Ävrö granodiorite (501056) and fine-grained granite (511058). Confidence level = 3.

RU2 (19.52–43.08 m)

Äspö diorite (501037) dominates. Confidence level = 3.

RU3 (43.08–59.70 m)

Fine-grained granite (511058) dominates the section and is mixed with subordinate Äspö diorite (501037). Confidence level = 3.

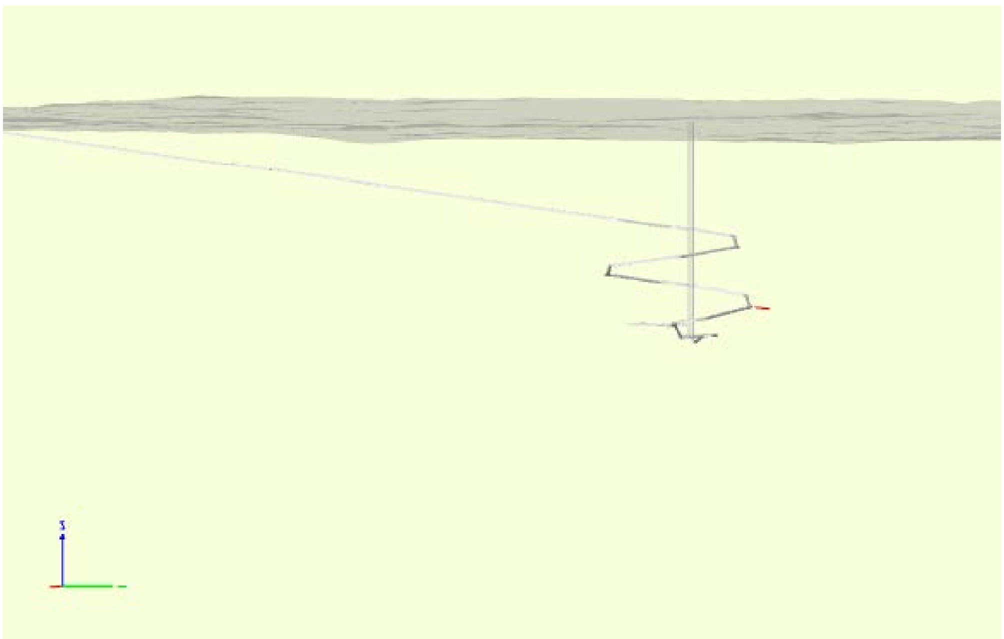


Figure 3-20. *Äspö HRL tunnel view from east. Location of surface drilled borehole KA2858A. Shaded area is the ground surface.*

3.13.2 Possible deformation zones

One possible deformation zone of brittle-ductile character has been identified in KA2858A with a high degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (0.40–7.90 m), brittle-ductile character

Ductile to brittle-ductile deformation with epidote-sealed fractures that locally form minor networks. No increased frequency of broken (open) fractures. Predominant minerals in unbroken (sealed) fractures are epidote and in addition laumontite and calcite. Generally oxidation of weak to moderate intensity occur. Rock type: Äspö diorite (501037). Confidence level = 3.

3.14 KA3105A

The results of the identification of rock units and possible deformation zones in KA3105A are presented below and as print-outs from WellCAD in Appendix 14 and the location of KA3105A is shown in Figure 3-21.

3.14.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be divided into two different rock units, RU1 and RU2. All rock units have been interpreted with a high degree of confidence.

RU1 (0.00–65.55 m)

Äspö diorite (501037) dominates. Confidence level = 3.

RU2 (65.55–68.95 m)

Gabbroid-dioritoid (508107) dominates. Confidence level = 3.

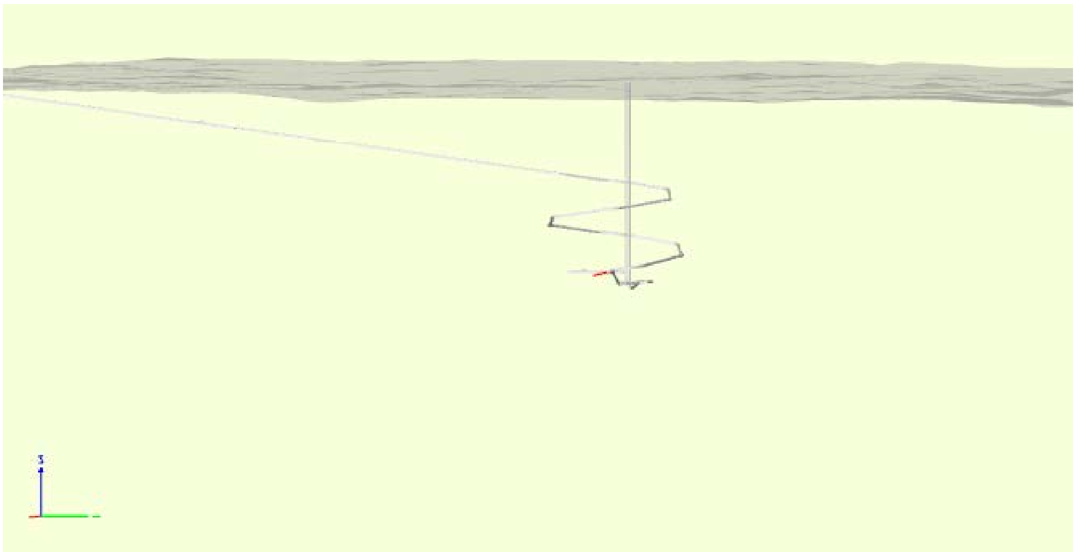


Figure 3-21. *Äspö HRL tunnel view from east. Location of surface drilled borehole KA3105A. Shaded area is the ground surface.*

3.14.2 Possible deformation zones

The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low. One possible deformation zone of brittle character has been identified in KA3105A with a high degree of confidence.

DZ1 (60.40–68.95 m, end of drill core), brittle character

Highly increased frequency of broken (open) fractures, crushes and epidote-sealed fracture networks, especially in the interval 60.4–63.8 m, which also includes several minor breccias/cataclasites. Predominant fracture minerals are chlorite, quartz, calcite, epidote and minor pyrite. Generally a weak oxidation and epidotization occur. Rock types: Äspö diorite (501037) and gabbroid-dioritoid (508107). Confidence level = 3.

3.15 KA3385A

The results of the identification of rock units and possible deformation zones in KA3385A are presented below and as print-outs from WellCAD in Appendix 15 and the location of KA3385A is shown in Figure 3-22.

3.15.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be defined as one rock unit, RU1, interpreted with a high degree of confidence.

RU1 (0.00–34.18 m)

Äspö diorite (501037) dominates with subordinate occurrences of fine-grained granite (511058) and gabbroid-dioritoid (508107). Confidence level = 3.

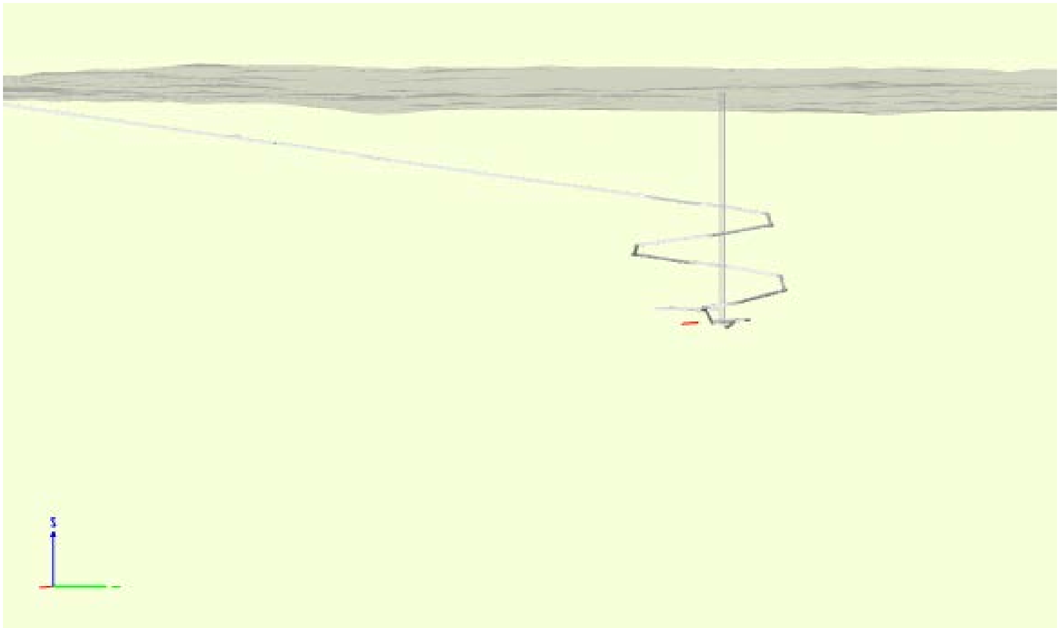


Figure 3-22. *Äspö HRL tunnel view from east. Location of surface drilled borehole KA3385A. Shaded area is the ground surface.*

3.15.2 Possible deformation zones

One possible deformation zone of brittle-ductile character has been identified in KA3385A with a low degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (0.00–34.18 m, entire drill core), brittle and subordinate brittle-ductile character

Slightly increased frequency of broken (open) fractures and locally epidote-sealed fracture networks. A few, centimetre- to decimetre wide sections of brittle-ductile deformation. Predominant minerals in broken (open) fractures are chlorite and calcite. Generally faint to weak epidotization throughout the drill core and a weak oxidation of fine-grained granite (511058) occur. Five oriented weak or uncertain radar reflectors occur at 0 m, 3 m, 7 m, 7 m and 21 m with an α-angle of 52°, 54°, 15°, 43° and 28° against the borehole axis, respectively. The orientation of the radar reflectors are 189°/86° or 265°/86°, 191°/86° or 183°/86°, 158°/31° or 103°/36°, 180°/87° or 274°/87° and 285°/53° or 354°/58°, respectively. Rock types: Äspö diorite (501037) and subordinate fine-grained granite (511058) and gabbroid-dioritoid (508107). Confidence level = 1.

3.16 KA3510A

The results of the identification of rock units and possible deformation zones in KA3510A are presented below and as print-outs from WellCAD in Appendix 16 and the location of KA3510A is shown in Figure 3-23.

3.16.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be divided into two different rock units, RU1 and RU2. Rock unit 1 occurs in two separate intervals, RU1a and RU1b. All rock units have been interpreted with a high degree of confidence.

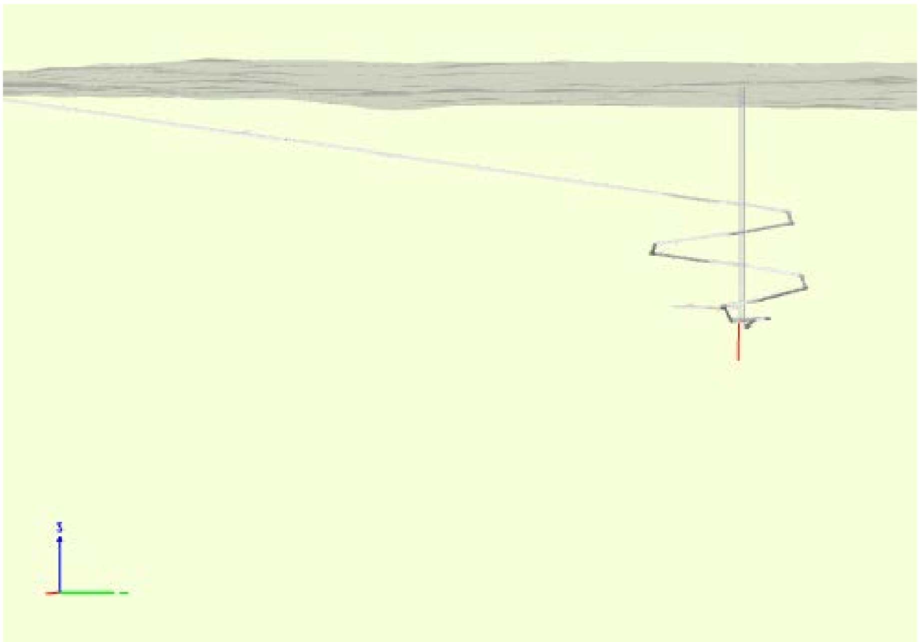


Figure 3-23. *Äspö HRL tunnel view from east. Location of surface drilled borehole KA3510A. Shaded area is the ground surface.*

RU1a (0.00–112.02 m)

Äspö diorite (501037) dominates with minor occurrences of fine-grained granite (511058). One occurrence of Ävrö granodiorite (501056) at 25.00–28.05 m. Confidence level = 3.

RU2 (112.02–122.20 m)

Fine-grained granite (511058) dominates. Confidence level = 3.

RU1b (122.20–149.91 m)

Äspö diorite (501037) dominates with minor occurrences of fine-grained granite (511058). Confidence level = 3.

3.16.2 Possible deformation zones

One possible deformation zone of brittle character and one of brittle to brittle-ductile character have been identified in KA3510A with a medium and a high degree of confidence, respectively. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (12.8–33.4 m), brittle and subordinate brittle-ductile character

Scattered occurrences of epidote-sealed fracture networks (Figure 3-24a) and locally increased frequency of broken (open) fractures. Ductile to brittle-ductile deformation occur in the interval 16–23 m (Figure 3-24b). Generally a faint epidotization and in the section 22.9–23.6 m a strong epidotization occur. There are three oriented weak or uncertain radar reflectors at 13 m, 19 m and 26 m with α-angles of 31°, 36° and 38° against the borehole axis, respectively. The orientation of the radar reflectors are 280°/90° or 044°/59°, 109°/87° or 040°/50° and 111°/88° or 038°/50°, respectively. The direct radar amplitude is reduced from 10 m to 16 m. Rock types: Äspö diorite (501037). Confidence level = 3.

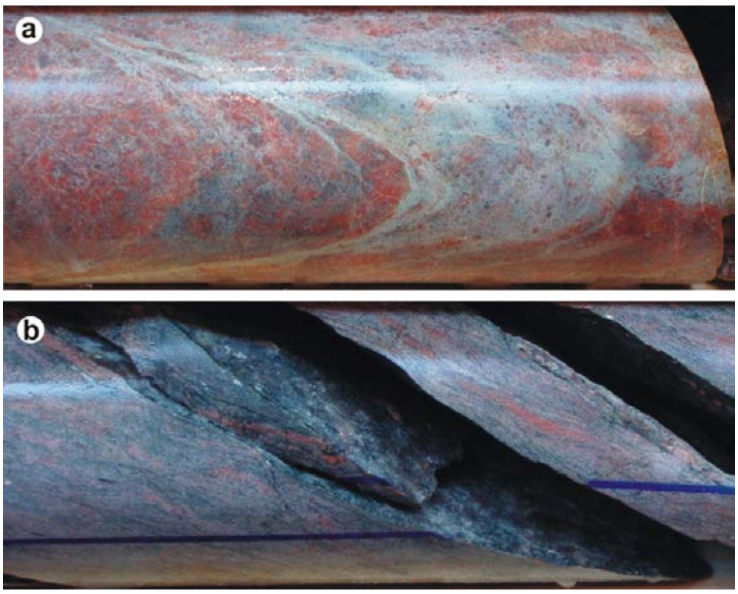


Figure 3-24. *Photographs of selected drill core sections from DZ1 in KA3510A, showing (a) a network of hairline fractures sealed by epidote and (b) intense ductile to brittle-ductile deformation at approximately 22.7 m length.*

DZ2 (112.4–122.2 m), brittle character

Increased frequency of broken (open) fractures that generally coincides with an interval of fine-grained granite (511058). Most fractures are parallel with the foliation in the granite. Predominant fracture minerals in the broken (open) fractures are calcite, chlorite and subordinately, fluorite and hematite. One oriented strong radar reflector occurs at 117 m with α-angle of 20° against the borehole axis and an orientation of 47°/80° or 262°/80°. One oriented weak radar reflector occurs at 119 m with α-angle of 30° against the borehole axis and an orientation of 267°/68° or 033°/83°. In addition, a non-oriented weak radar reflector occurs at 117 m with α-angle of 46° against the borehole axis. The direct radar amplitude is reduced from 118 m to 120 m. Rock types: Foliated fine-grained granite (511058), with a spaced cleavage defined by hairline fractures sealed by epidote, especially in the interval 117.4–120.7 m. Confidence level = 2.

3.17 KF0066A01

The results of the identification of rock units and possible deformation zones in KF0066A01 are presented below and as print-outs from WellCAD in Appendix 17 and the location of KF0066A01 is shown in Figure 3-25.

3.17.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be defined as one rock unit, RU1, interpreted with a high degree of confidence.

RU1 (0.00–60.11 m)

Äspö diorite (501037) dominates with subordinate occurrences of fine-grained granite (511058) and a short interval of hybrid rock (505105). Note that Äspö diorite (501037) previously has been registered as diorite-gabbro (501033) in the Petrocore mapping. Confidence level = 3.

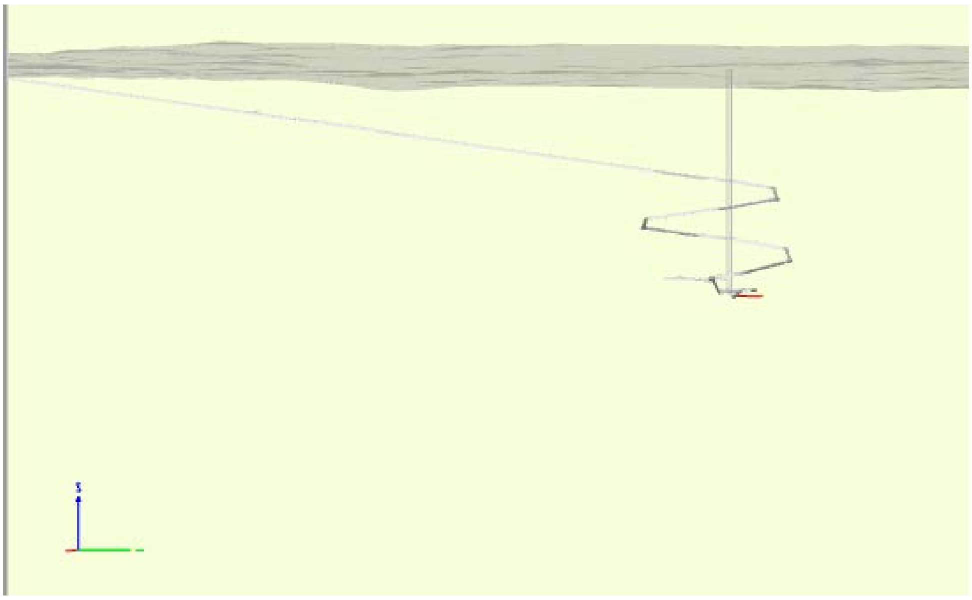


Figure 3-25. *Äspö HRL tunnel view from east. Location of surface drilled borehole KF0066A01. Shaded area is the ground surface.*

3.17.2 Possible deformation zones

One possible deformation zone of brittle-ductile character has been identified in KF0066A01 with a high degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (42.70–44.30 m), brittle and brittle-ductile character

Increased frequency of broken (open) fractures and brittle-ductile deformation with epidote-sealed fracture networks including 0.36 m of core loss. Predominant fracture mineral is chlorite. Oxidation with weak intensity occurs in the section. Rock types: Äspö diorite (501037) and a small interval of hybrid rock (505105). Confidence level = 3.

3.18 KF0069A01

The results of the identification of rock units and possible deformation zones in KF0069A01 are presented below and as print-outs from WellCAD in Appendix 18 and the location of KF0069A01 is shown in Figure 3-26.

3.18.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be defined as one rock unit, RU1, interpreted with a high degree of confidence.

RU1 (0.0–70.09 m)

Äspö diorite (501037) dominates with subordinate occurrences of fine-grained granite (511058) and short intervals of hybrid rock (505105). Note that Äspö diorite (501037) previously has been registered as diorite-gabbro (501033) in the Petrocore mapping. Confidence level = 3.

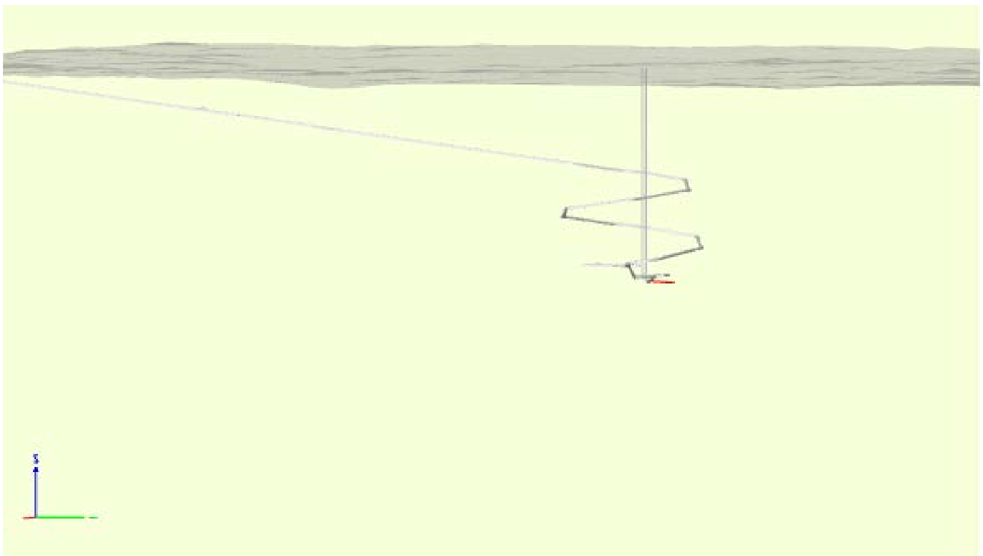


Figure 3-26. *Äspö HRL tunnel view from east. Location of surface drilled borehole KF0069A01. Shaded area is the ground surface.*

3.18.2 Possible deformation zones

The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low. One possible deformation zone of brittle-ductile character has been identified in KF0069A01 with a high degree of confidence.

DZ1 (58.60–61.00 m), brittle-ductile character

Brittle-ductile deformation with epidote-sealed fracture networks and slightly increased frequency of broken (open) fractures. No alteration occur. Rock types: Äspö diorite (501037 and a short interval of hybrid rock (505105). Confidence level = 3.

3.19 KI0023B

The results of the identification of rock units and possible deformation zones in KI0023B are presented below and as print-outs from WellCAD in Appendix 19 and the location of KI0023B is shown in Figure 3-27.

3.19.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be divided into two different rock units, RU1–RU2. Rock unit 1 occurs in three separate intervals, RU1a–RU1c, and RU 2 occurs in two separate intervals, RU2a and RU2b. All rock units have been interpreted with a high degree of confidence.

RU1a (0.00–113.24 m)

Äspö diorite (501037) dominates with a few minor occurrences of fine-grained granite (511058). Confidence level = 3.

RU2a (113.24–118.27 m)

Gabbroid-dioritoid (508107) with subordinate occurrences of fine-grained granite (511058). Note that Gabbroid-dioritoid (508107) is presented as Fine-grained diorite-gabbro (505102) in Appendix 19. Confidence level = 3.

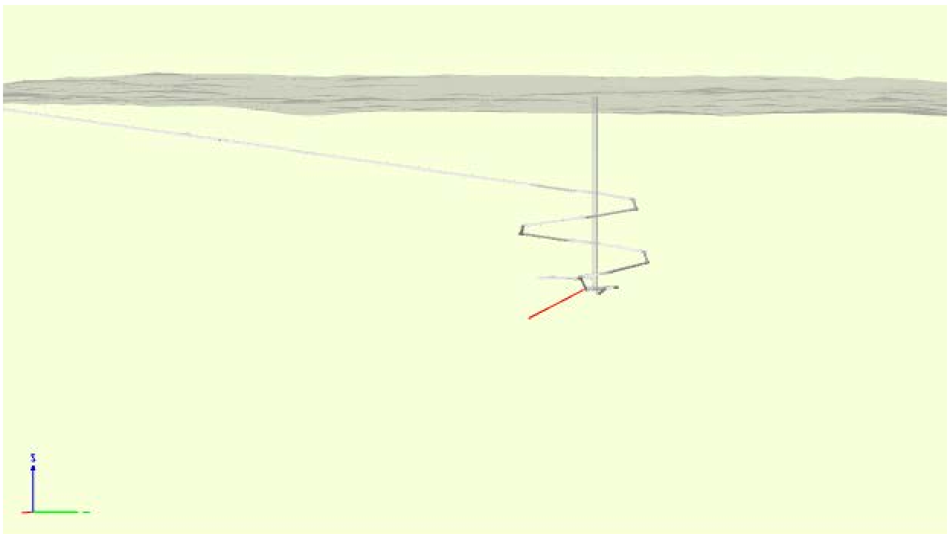


Figure 3-27. *Äspö HRL tunnel view from east. Location of surface drilled borehole KI0023B. Shaded area is the ground surface.*

RU1b (118.27–154.30 m)

Äspö diorite (501037) dominates. Confidence level = 3.

RU2b (154.30–159.53 m)

Gabbroid-dioritoid (508107) with subordinate occurrences of fine-grained granite (511058). Note that Gabbroid-dioritoid (508107) is presented as Fine-grained diorite-gabbro (505102) in Appendix 19. Confidence level = 3.

RU1c (159.53–200.71 m)

Äspö diorite (501037) dominates with a few minor occurrences of fine-grained granite (511058). Confidence level = 3.

3.19.2 Possible deformation zones

One possible deformation zone of brittle-ductile character has been identified in KI0023B with a high degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

DZ1 (165.00–170.90 m), brittle and brittle-ductile character

Brittle-ductile deformation with epidote-sealed fracture networks and slightly increased frequency of broken (open) fractures. A decimeter-wide brecciated section sealed by chlorite and epidote at the lower boundary of the possible deformation zone. Predominant minerals in broken (open) fractures are chlorite, calcite, and more rarely clay minerals, epidote and quartz. Locally a weak to moderate oxidation and faint epidotization occur. One oriented radar reflector of medium strength occurs at 166 m with α-angle of 33° against the borehole axis and an orientation of 142°/57° or 239°/31°. Two oriented weak radar reflectors occur at 168 m and 170 m with α-angle of 34° and 90°, respectively. The orientation of the radar reflectors are 235°/40° or 149°/63°and 292°/73°, respectively. The direct radar amplitude is reduced from 162 m to 168 m. Rock types: Äspö diorite (501037). Confidence level = 3.

3.20 KI0025F02

The results of the identification of rock units and possible deformation zones in KI0025F02 are presented below and as print-outs from WellCAD in Appendix 20 and the location of KI0025F02 is shown in Figure 3-28.

3.20.1 Rock units

The confidence in the interpretation of a rock unit is assigned according to three classes: 3 = high, 2 = medium and 1 = low. The borehole can be defined as one rock unit, RU1, interpreted with a high degree of confidence.

RU1 (0.00–204.18 m)

Äspö diorite (501037) dominates with an occurrence of fine-grained diorite-gabbro (505102) at 89.10–93.95 m and fine-grained granite (511058) in the lowermost part of the borehole. Confidence level = 3.

3.20.2 Possible deformation zones

One possible deformation zone of brittle-ductile character has been identified in KI0025F02 with a high degree of confidence. One additional possible deformation zone, mainly defined by moderate oxidation, has been identified with a low degree of confidence. The confidence in the interpretation of a possible deformation zone is assigned according to three classes: 3 = high, 2 = medium and 1 = low.

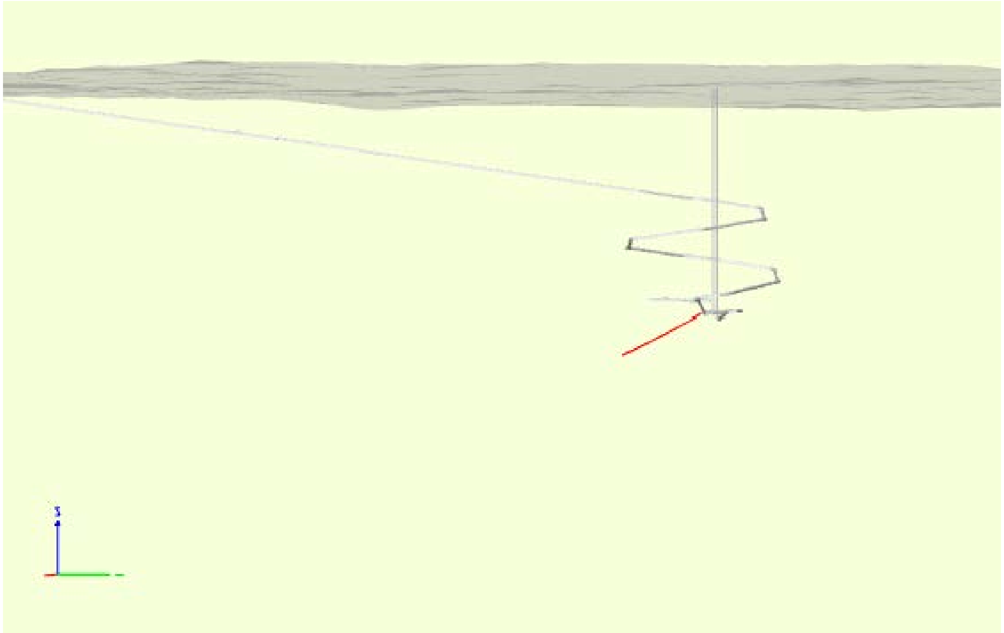


Figure 3-28. *Äspö HRL tunnel view from east. Location of surface drilled borehole KI0025F02. Shaded area is the ground surface.*

DZ1 (131.00–134.00 m), brittle and brittle-ductile character

Brittle-ductile deformation with epidote-sealed fracture networks and slightly increased frequency of broken (open) fractures. The sealed networks generally occur as a spaced cleavage. Predominant minerals in broken (open) fractures are chlorite and calcite. Rock alteration is characterized by an oxidation of weak intensity. Rock types: Äspö diorite (501037). Confidence level = 3.

DZ2 (199.30–204.18 m)

The deformation zone is primarily defined by intense alteration characterized by oxidation of moderate intensity, typically along with epidotization of faint to weak intensity. There is a sporadic occurrence of fractures and fracture networks sealed by epidote, calcite and chlorite, but generally no increased frequency of open fractures in the interval. Rock types: Äspö diorite (501037) and in the lowermost part, fine-grained granite (511058). Confidence level = 1. Note that the confidence level of DZ2 is marked as confidence level 3 in Appendix 20.

4 Discussion

During traditional geological single-hole interpretation input data from the borehole TV (BIPS) investigation of core drilled boreholes are essential. However, for the older Äspö boreholes BIPS (borehole TV) data is missing. Hence, possible location and true orientation (strike and dip) of fractures intersecting the borehole is missing. There is thus incompleteness in the geological documentation and lack of certain parameters such as fracture frequency, along with the fact that geophysical logging data only exist for some or in some parts of the older boreholes on Äspö. The borehole documentation from the older surface based boreholes and tunnel boreholes were too sparse to allow the full application of the established and complete SHI methodology. When BIPS (borehole TV) was not available the geological mapping was only based on inspection of the drill core.

Therefore *simplified* geological single-hole interpretation was performed on 20 core drilled boreholes from Äspö HRL in a similar way as for the traditional geological single-hole interpretation performed during the Laxemar site investigation (SKB 2009). The work followed the current nomenclature and methodology as far as possible and includes the following activities:

1. Merging sections of similar geological character along the drill core into rock units on the basis of lithological mapping and, when available, with support from density logs obtained from geophysical logging.
2. Identification of possible deformation zones based on inspection of the drill cores including characterization according to the criteria applied during the established SHI.

Most of the defined rock units are dominated by Äspö diorite (501037) or, less frequently, by Ävrö granodiorite (501056). Fine-grained granite (511058) and gabbroid-dioritoid (508107) typically occur as subordinate rock units. The vast majority of the rock units have been interpreted with a high degree of confidence. Rock units with a lower degree of confidence are restricted to two boreholes, KAS09 and KAS14, where the density log suggests that the registered rock type is incorrect or erroneously translated into the current SKB nomenclature.

In total, 52 possible deformation zones have been identified in the drill cores from the 20 boreholes, 5 with a low degree of confidence, 8 with a medium degree of confidence and 39 with a high degree of confidence. Possible deformation zones have been identified in all of the boreholes. Twenty of the possible deformation zones exceed 10 m in drill core length and the most intensive possible deformation zone occurs in KAS14 in the section 88–211 m. In addition to brittle deformation, 30 of the possible deformation zones include sections of ductile and/or brittle-ductile deformation. The brittle component of the brittle-ductile deformation is typically characterized by epidote-sealed fracture networks.

References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.com/publications.

Berglund J, Curtis P, Eliasson T, Olsson T, Starzec P, Tullborg E-L, 2003. Äspö Hard Rock Laboratory. Update of the geological model 2002. SKB IPR-03-34, Svensk Kärnbränslehantering AB.

Carlsten S, Stanfors R, Askling P, Annertz K, 1995. Comparison between borehole radar data and geological parameters from tunnel mapping. SKB HRL Progress Report 25-95-22, Svensk Kärnbränslehantering AB.

Carlsten S, Stråhle A, Wahlgren C-H, Hultgren P, Stenberg L, Mattsson H, 2017. Äspö Site Descriptive Model. Geological single-hole interpretation of KAS02. SKB P-14-14, Svensk Kärnbränslehantering AB.

Curtis P, Markström I, Petersson J, Triumf C-A, Isaksson H, Mattsson H, 2011. Site investigation SFR. Bedrock geology. SKB R-10-49, Svensk Kärnbränslehantering AB.

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.

Petersson J, Curtis P, Bockgård N, Mattsson H, 2011. Site investigation SFR. Rock type coding, overview geological mapping and identification of rock units and possible deformation zones in drill cores from the construction of SFR. SKB P-10-07, Svensk Kärnbränslehantering AB.

SKB, 2008. Site description of Forsmark at completion of the site investigation phase. SDM-Site Forsmark. SKB TR-08-05, Svensk Kärnbränslehantering AB.

SKB, 2009. Site description of Laxemar at completion of the site investigation phase. SDM-Site Laxemar. SKB TR-09-01, Svensk Kärnbränslehantering AB.

Appendix 1

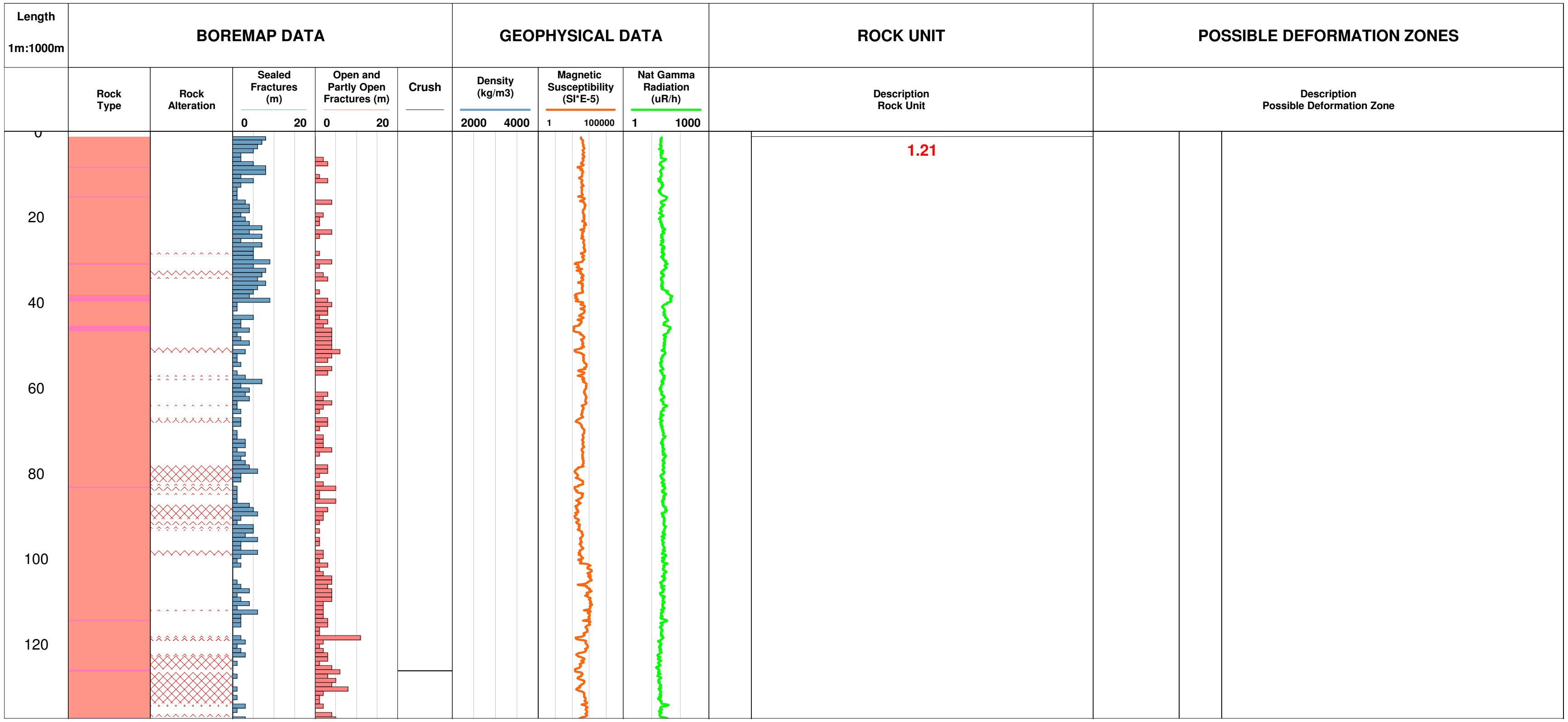
Geological single-hole interpretation of KAS03

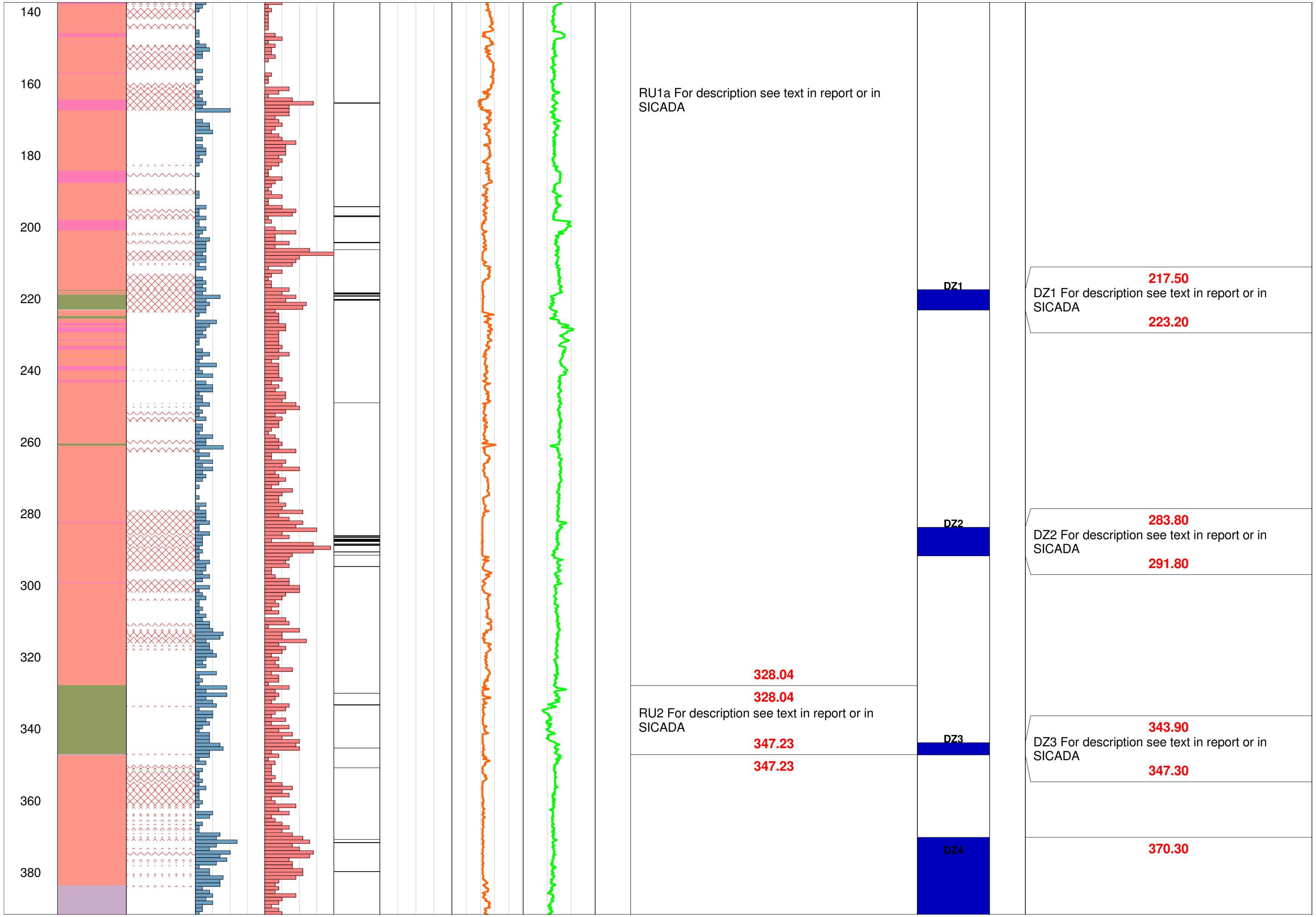
Title	SINGLE HOLE INTERPRETATION KAS03					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	-82.89	Elevation [m.a.s.l.]	8.79	Strike Reference	ÄSPÖ96
Borehole	KAS03	Date of mapping	1988-04-10 00:00:00	Drilling Start Date	1988-01-04 06:00:00	Made By	PKM
Diameter [mm]	56	Coordinate System	ÄSPÖ96	Drilling Stop Date	1988-02-01 00:00:00	SHI Light GE299	
Length [m]	1002.260	Northing [m]	7758.23	Surveying Date	1988-04-12 00:00:00	Mapping Type	GE037
Bearing [°]	338.53	Easting [m]	1805.21	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained Götemar granite 531058
- Fine-grained granite 511058
- Pegmatite 501061
- Ävrö granodiorite 501056
- Äspö diorite 501037
- Gabbroid-dioritoid 508107
- Mylonite 508004
- Quartz-dominated hydrothermal vein/segregation 508021
- Hybrid rock 505105
- Breccia 508002

ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized
- Sericitisized

DZ CONFIDENCE LEVEL
- Confidence 2
- Confidence 3

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220
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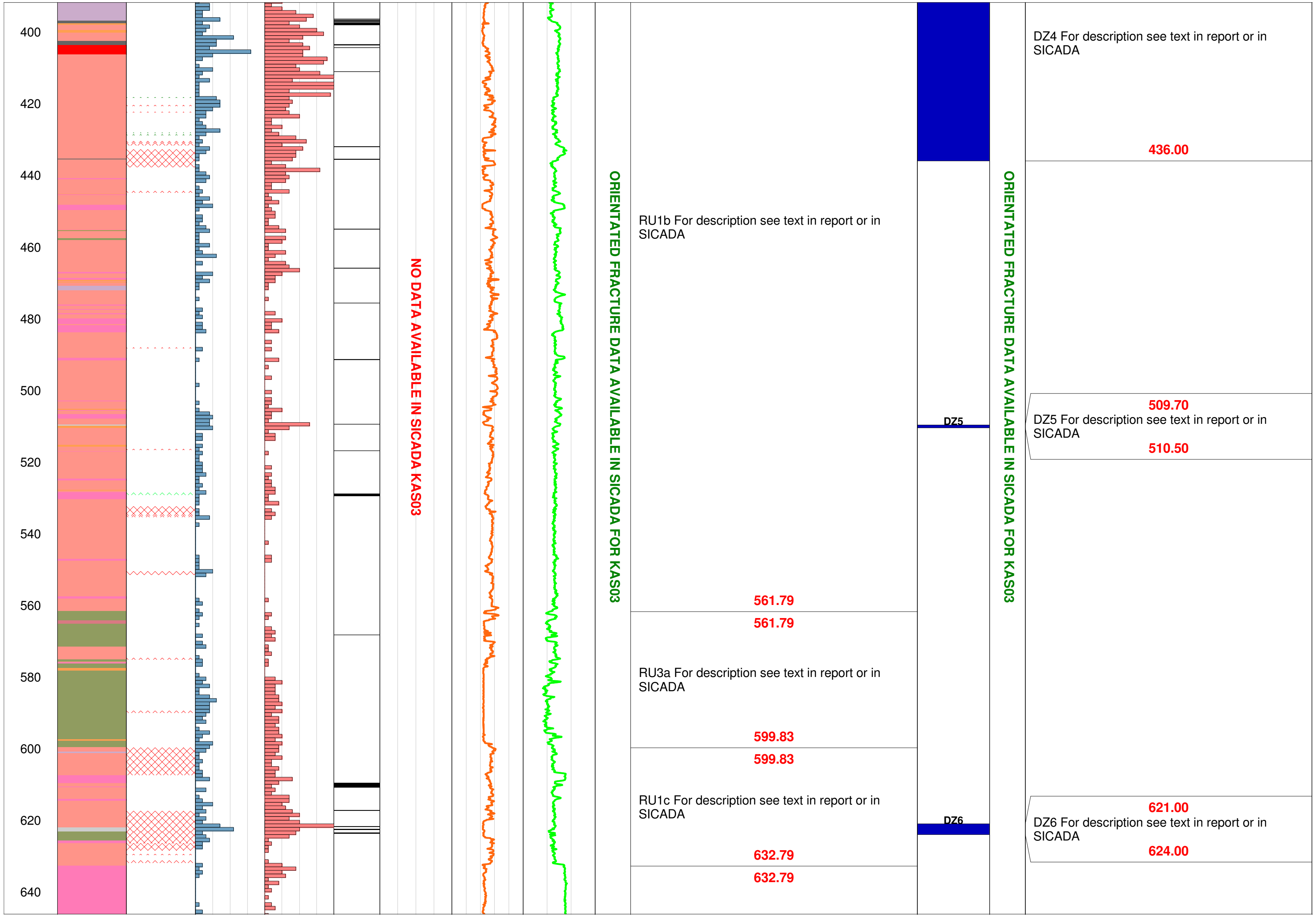
260
280
300
320
340
360
380
RU1a For description see text in report or in SICADA
328.04
328.04
RU2 For description see text in report or in SICADA
347.23
347.23
DZ1
DZ2
DZ3
DZ4
217.50
DZ1 For description see text in report or in SICADA
223.20
283.80
DZ2 For description see text in report or in SICADA
291.80
343.90
DZ3 For description see text in report or in SICADA
347.30
370.30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420
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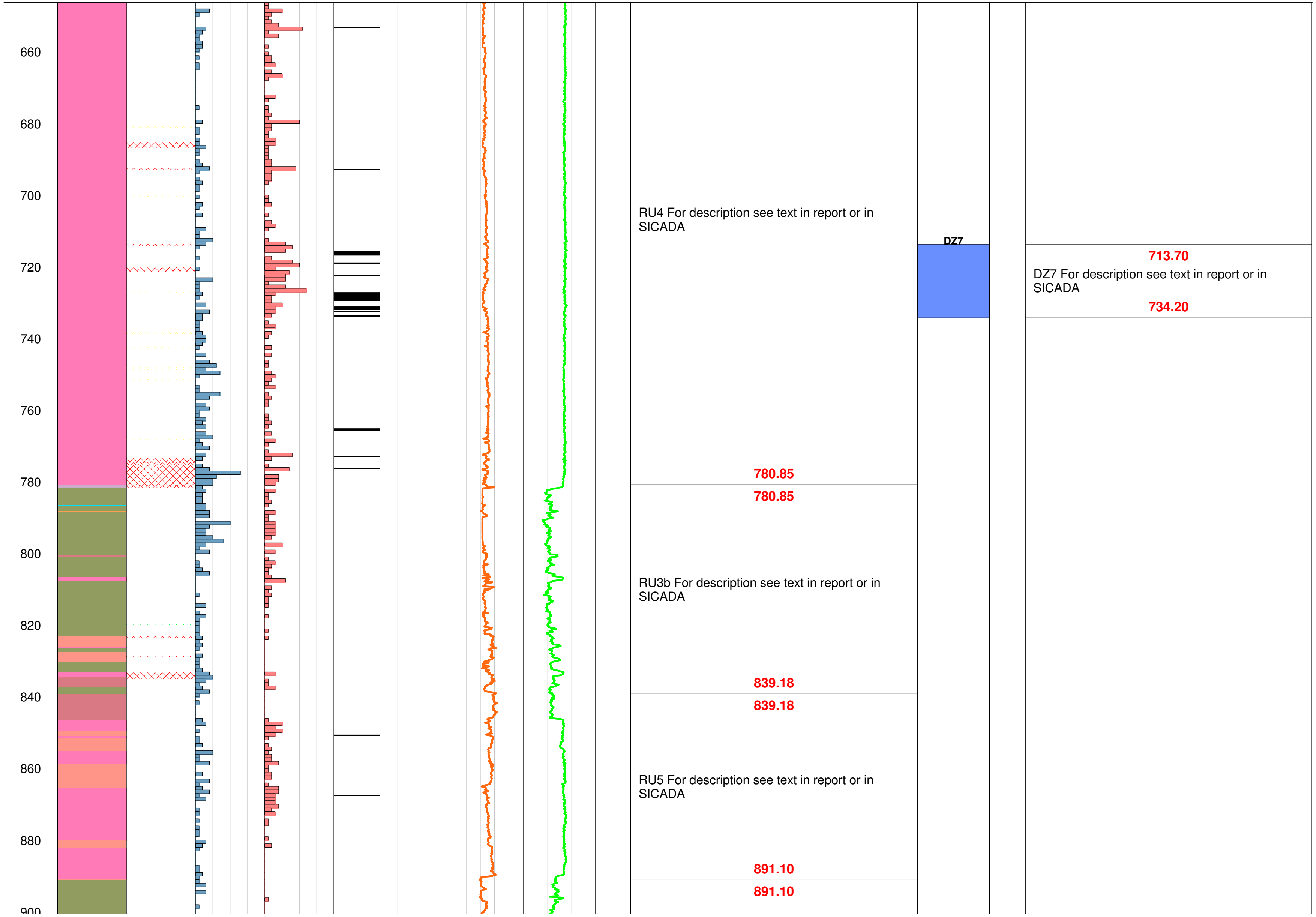
460
480
500
520
540
560
580
600
620
640
NO DATA AVAILABLE IN SICADA KAS03
ORIENTATED FRACTURE DATA AVAILABLE IN SICADA FOR KAS03
RU1b For description see text in report or in SICADA
561.79
561.79
RU3a For description see text in report or in SICADA
599.83
599.83
RU1c For description see text in report or in SICADA
632.79
632.79
DZ5
DZ6
ORIENTATED FRACTURE DATA AVAILABLE IN SICADA FOR KAS03
DZ4 For description see text in report or in SICADA
436.00
509.70
DZ5 For description see text in report or in SICADA
510.50
621.00
DZ6 For description see text in report or in SICADA
624.00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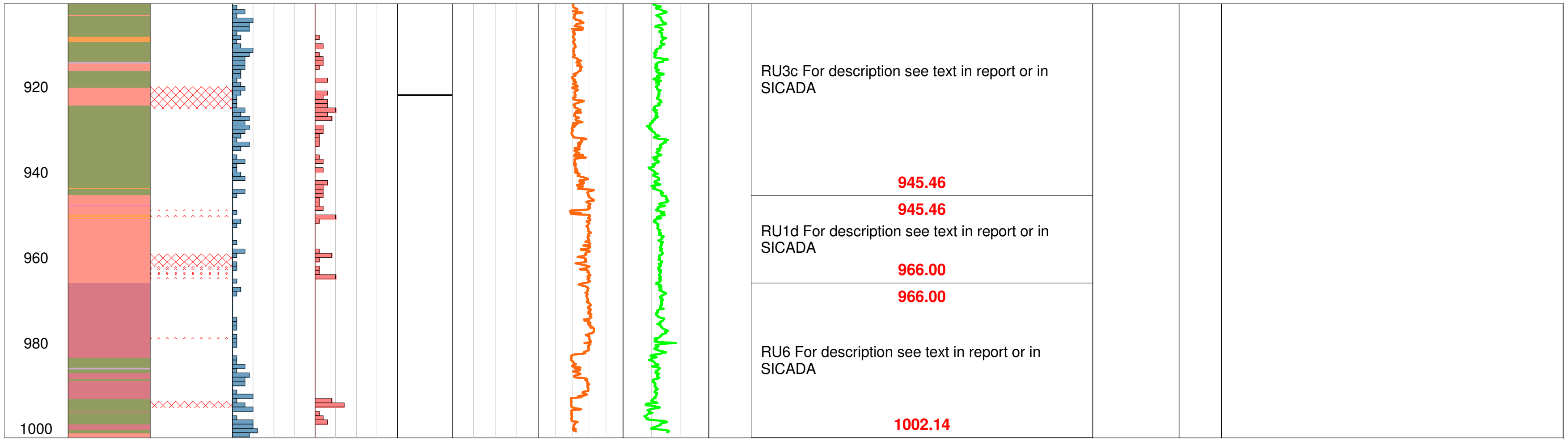
680
700
720
740
760
780
800
820
840
860
880
900
RU4 For description see text in report or in SICADA
780.85
780.85
RU3b For description see text in report or in SICADA
839.18
839.18
RU5 For description see text in report or in SICADA
891.10
891.10
DZ7
713.70
DZ7 For description see text in report or in SICADA
734.20


920
940
960
980
1000
RU3c For description see text in report or in SICADA
945.46
945.46
RU1d For description see text in report or in SICADA
966.00
966.00
RU6 For description see text in report or in SICADA
1002.14

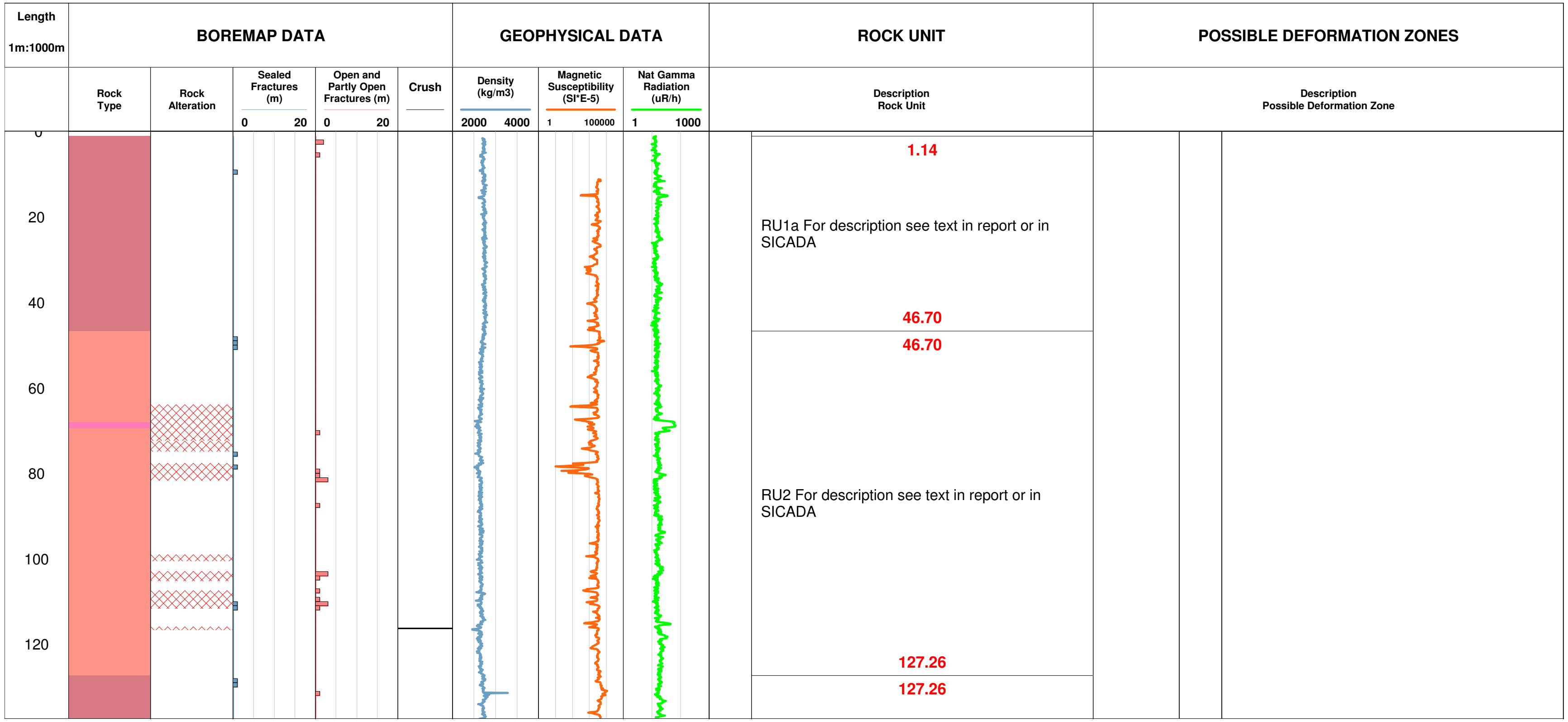
Geological single-hole interpretation of KAS05

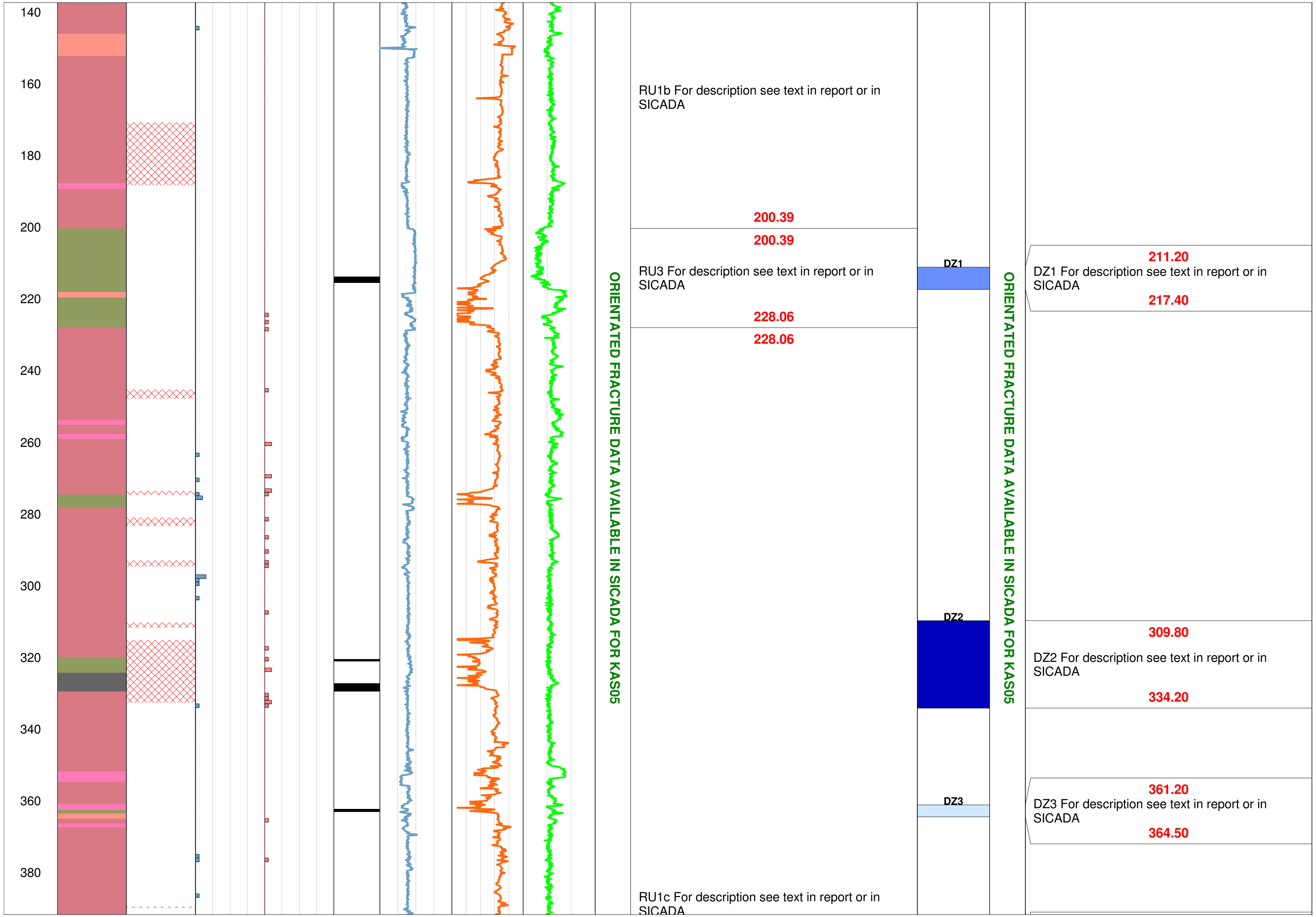
Title	SINGLE HOLE INTERPRETATION KAS05					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	-84.89	Elevation [m.a.s.l.]	8.68	Strike Reference	ÄSPÖ96
Borehole	KAS05	Date of mapping	1989-03-15 00:00:00	Drilling Start Date	1988-12-05 23:00:00	Made By	PKM
Diameter [mm]	76	Coordinate System	ÄSPÖ96	Drilling Stop Date	1988-12-11 23:00:00	SHI Light GE299	
Length [m]	549.600	Northing [m]	7247.97	Surveying Date	1989-03-10 00:00:00	Mapping Type	GE040
Bearing [°]	163.60	Easting [m]	2059.62	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Ävrö granodiorite 501056
- Äspö diorite 501037
- Gabbroid-dioritoid 508107
- Mylonite 508004

ROCK ALTERATION
- Oxidized
- Epidotized

DZ CONFIDENCE LEVEL
- Confidence 1
- Confidence 2
- Confidence 3

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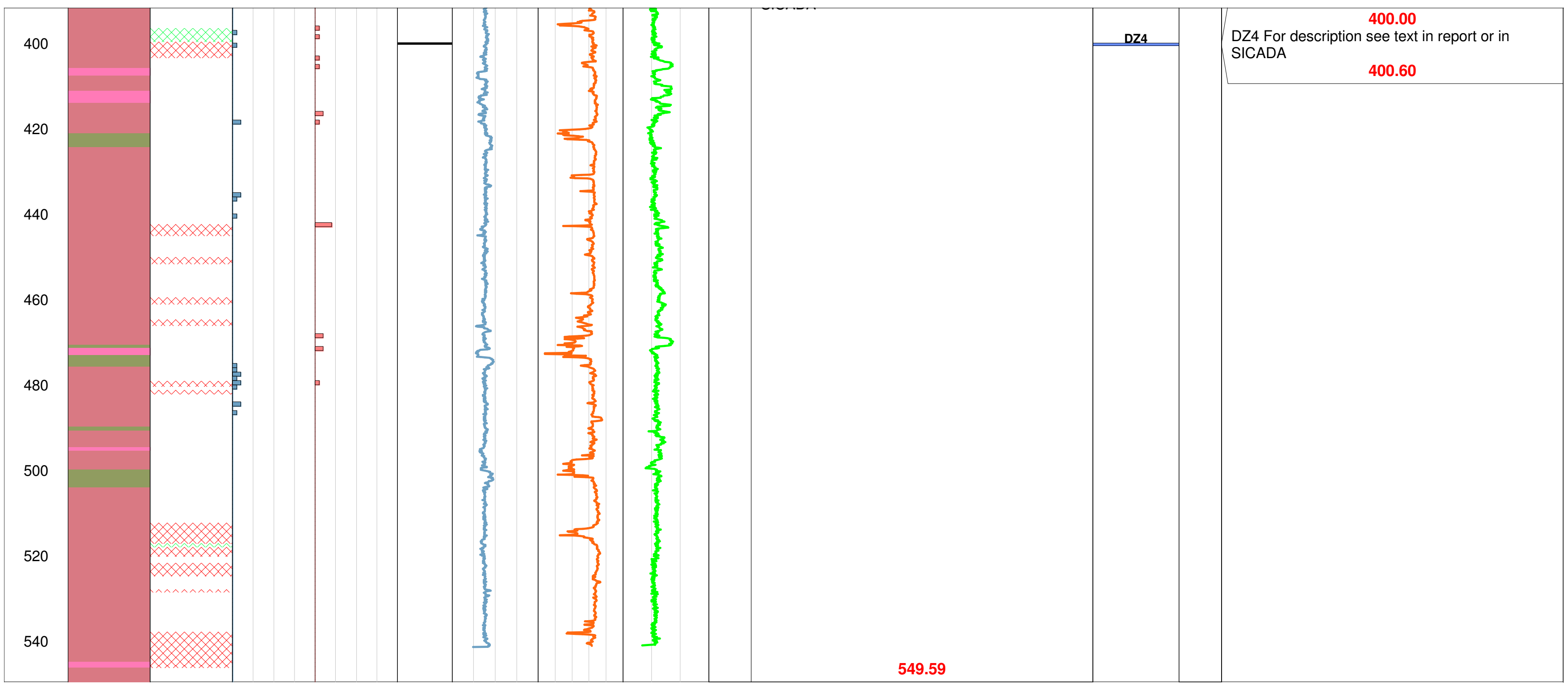
160
180
200
220
240
260
280
300
320
340
360
380
RU1b For description see text in report or in SICADA
200.39
200.39
RU3 For description see text in report or in SICADA
228.06
228.06
RU1c For description see text in report or in SICADA
ORIENTATED FRACTURE DATA AVAILABLE IN SICADA FOR KAS05
DZ1
DZ2
DZ3
ORIENTATED FRACTURE DATA AVAILABLE IN SICADA FOR KAS05
211.20
DZ1 For description see text in report or in SICADA
217.40
309.80
DZ2 For description see text in report or in SICADA
334.20
361.20
DZ3 For description see text in report or in SICADA
364.50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420
440
460
480
500
520
540
549.59
DZ4
400.00
DZ4 For description see text in report or in SICADA
400.60

Appendix 3

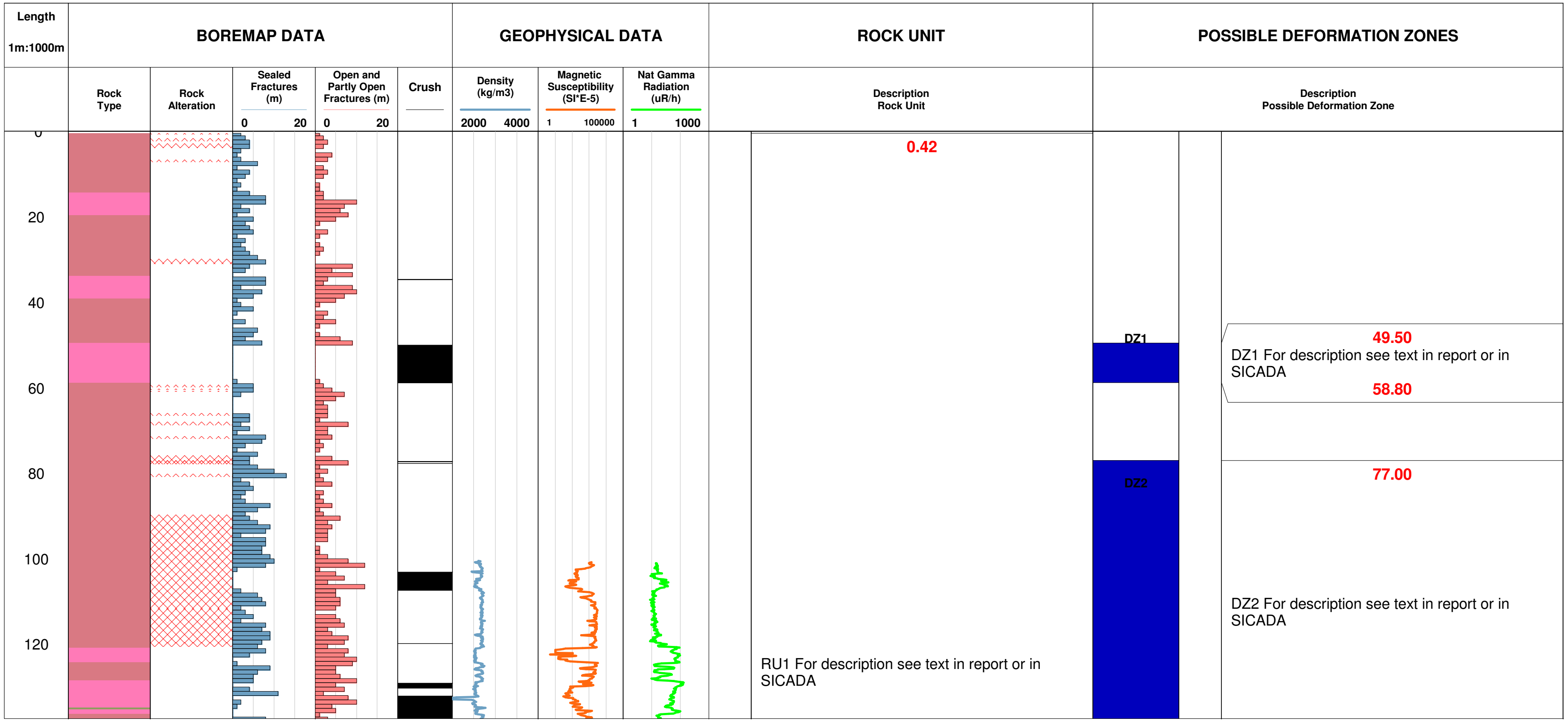
Geological single-hole interpretation of KAS09

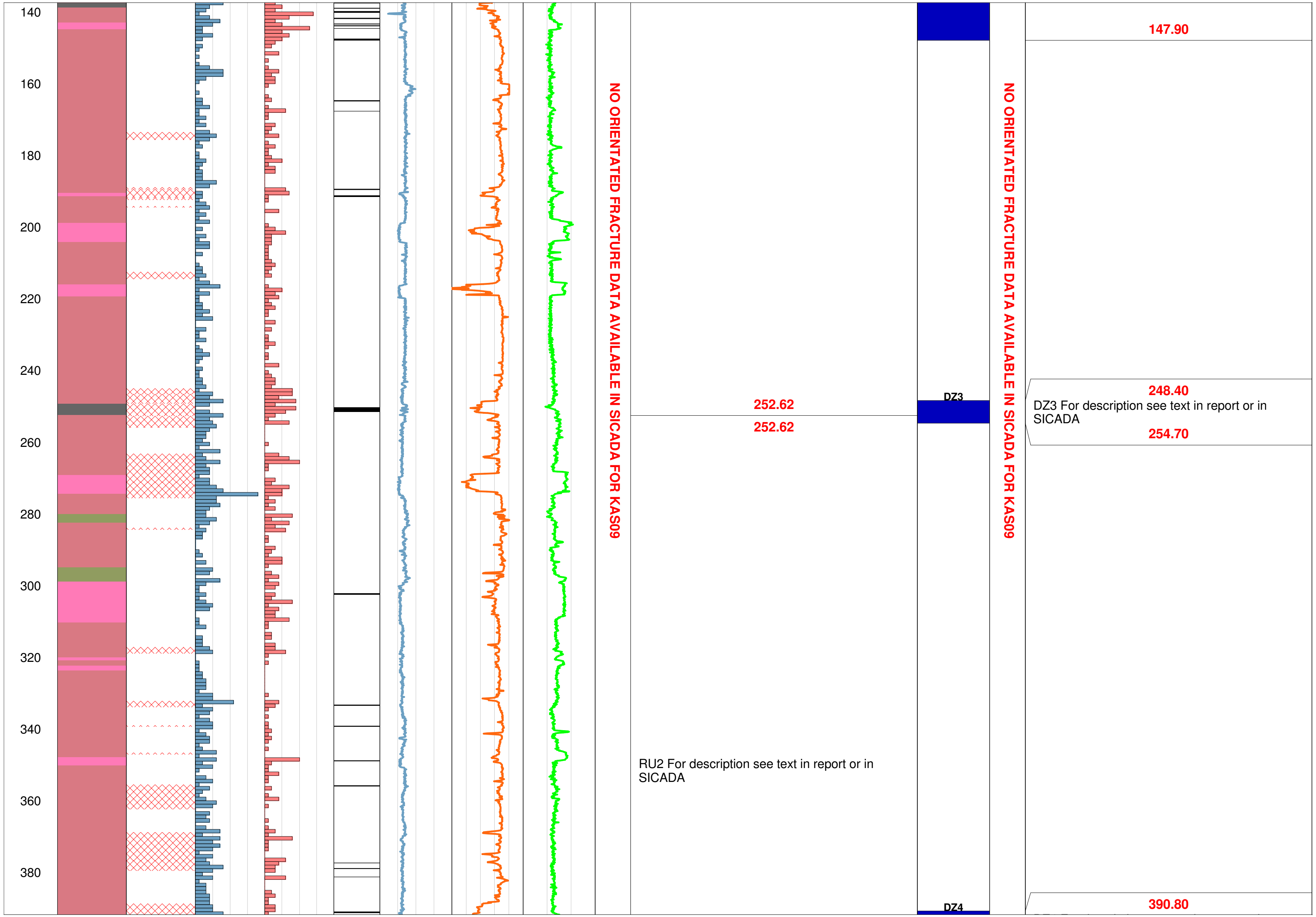
Title	**SINGLE HOLE INTERPRETATION KAS09**							**SIGNED DATA**	YES
Site	ÄSPÖ	**Inclination [°]**	-59.89	**Elevation [m.a.s.l.]**	4.08			**Strike Reference**	ÄSPÖ96
Borehole	KAS09	**Date of mapping**	1990-04-03 00:00:00	**Drilling Start Date**	1989-10-09 23:00:00			**Made By**	PKM
Diameter [mm]	56	**Coordinate System**	ÄSPÖ96	**Drilling Stop Date**	1989-10-15 23:00:00			**SHI Light GE299**	
Length [m]	450.620	**Northing [m]**	6925.19	**Surveying Date**	1990-03-27 00:00:00			**Mapping Type**	GE037
Bearing [°]	181.60	**Easting [m]**	2091.11	**Plot Date**	2015-06-08 02:01:34				

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Äspö diorite 501037
- Gabbroid-dioritoid 508107
- Mylonite 508004
- Breccia 508002

ROCK ALTERATION
- Oxidized

DZ CONFIDENCE LEVEL
- Confidence 3

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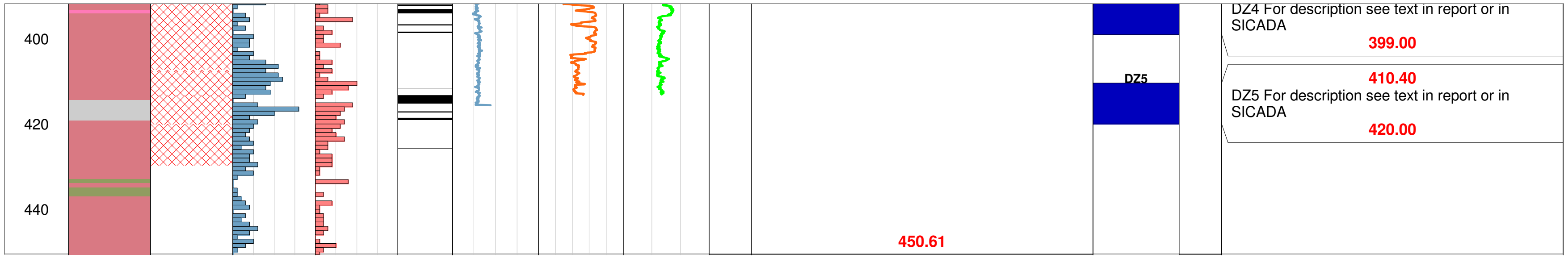
160
180
200
220
240
260
280
300
320
340
360
380
NO ORIENTATED FRACTURE DATA AVAILABLE IN SICADA FOR KAS09
252.62
252.62
RU2 For description see text in report or in SICADA
DZ3
DZ4
NO ORIENTATED FRACTURE DATA AVAILABLE IN SICADA FOR KAS09
147.90
248.40
DZ3 For description see text in report or in SICADA
254.70
390.80


400
420
440
450.61
DZ5
DZ4 For description see text in report or in SICADA
399.00
410.40
DZ5 For description see text in report or in SICADA
420.00

Appendix 4

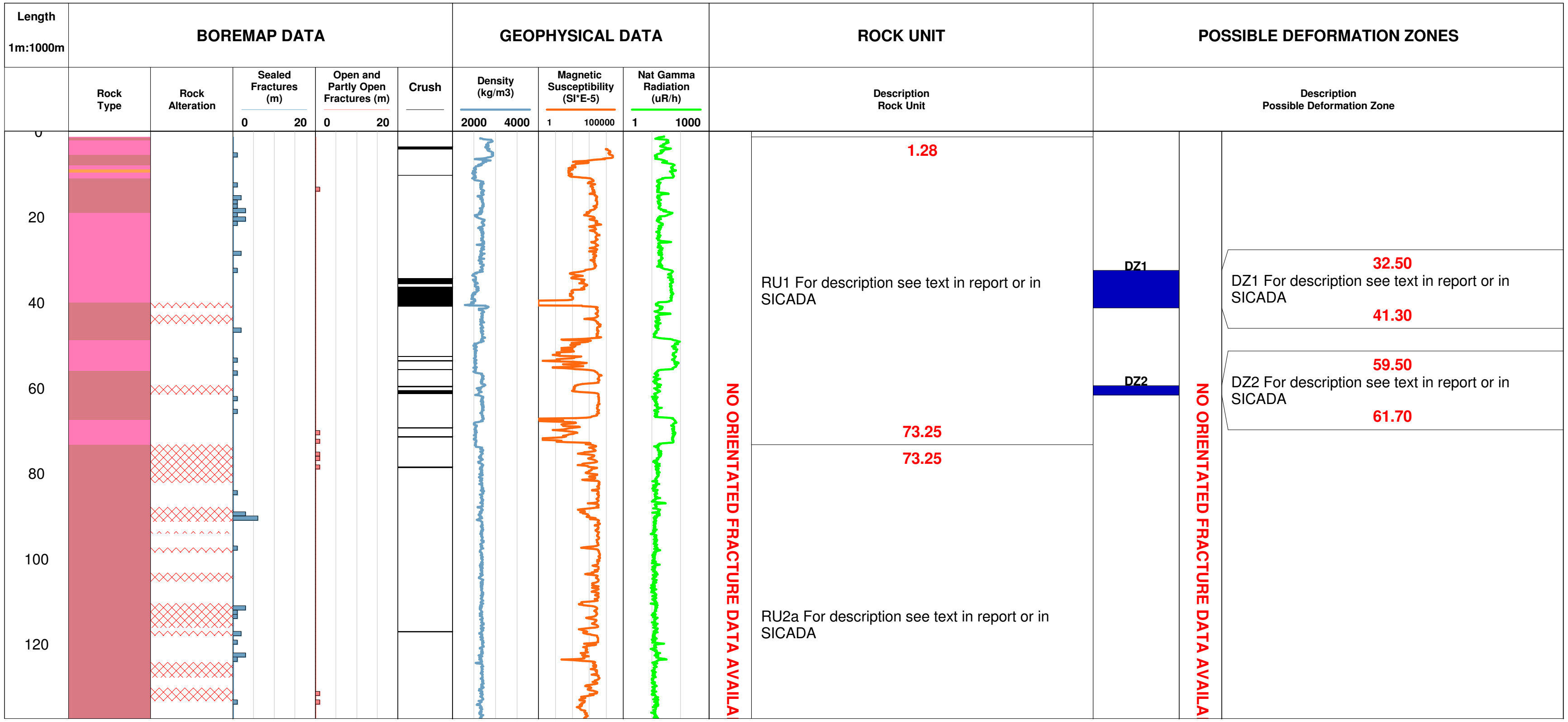
Geological single-hole interpretation of KAS11

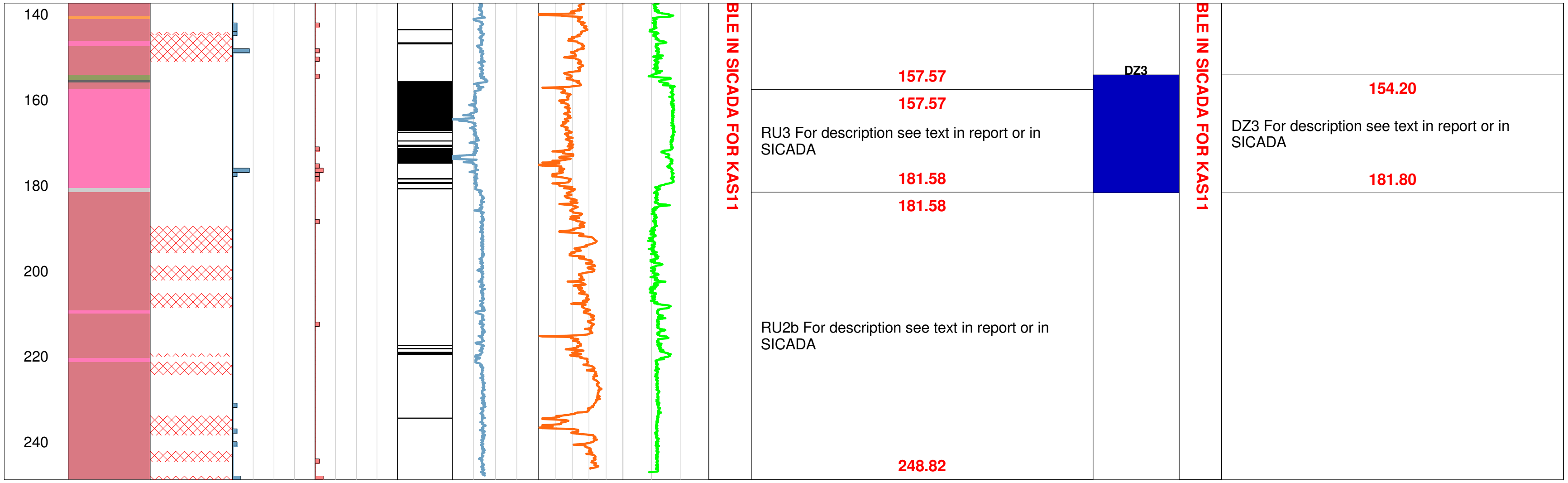
Title	SINGLE HOLE INTERPRETATION KAS11					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	-88.69	Elevation [m.a.s.l.]	4.22	Strike Reference	ÄSPÖ96
Borehole	KAS11	Date of mapping	1990-04-21 00:00:00	Drilling Start Date	1989-10-23 23:00:00	Made By	PKM
Diameter [mm]	56	Coordinate System	ÄSPÖ96	Drilling Stop Date	1989-10-27 00:00:00	SHI Light GE299	
						Mapping Type	GE040
Length [m]	248.900	Northing [m]	6937.03	Surveying Date	2001-05-11 00:00:00		
Bearing [°]	34.67	Easting [m]	2090.46	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Pegmatite 501061
- Äspö diorite 501037
- Gabbroid-dioritoid 508107
- Mylonite 508004
- Breccia 508002

ROCK ALTERATION
- Oxidized

DZ CONFIDENCE LEVEL
- Confidence 3





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160
180
200
220
240
BLE IN SICADA FOR KAS11
157.57
157.57
RU3 For description see text in report or in SICADA
181.58
181.58
RU2b For description see text in report or in SICADA
248.82
DZ3
BLE IN SICADA FOR KAS11
154.20
DZ3 For description see text in report or in SICADA
181.80

Appendix 5

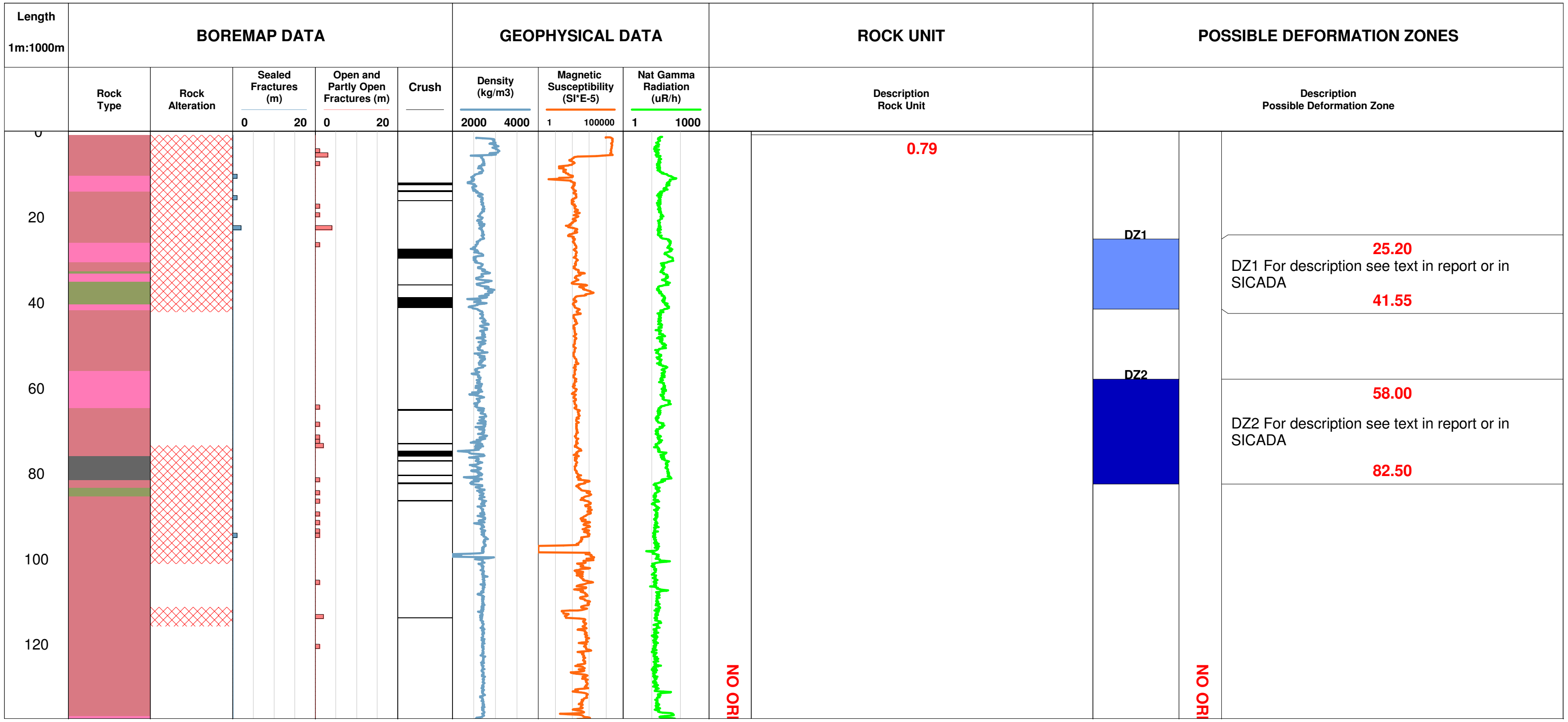
Geological single-hole interpretation of KAS12

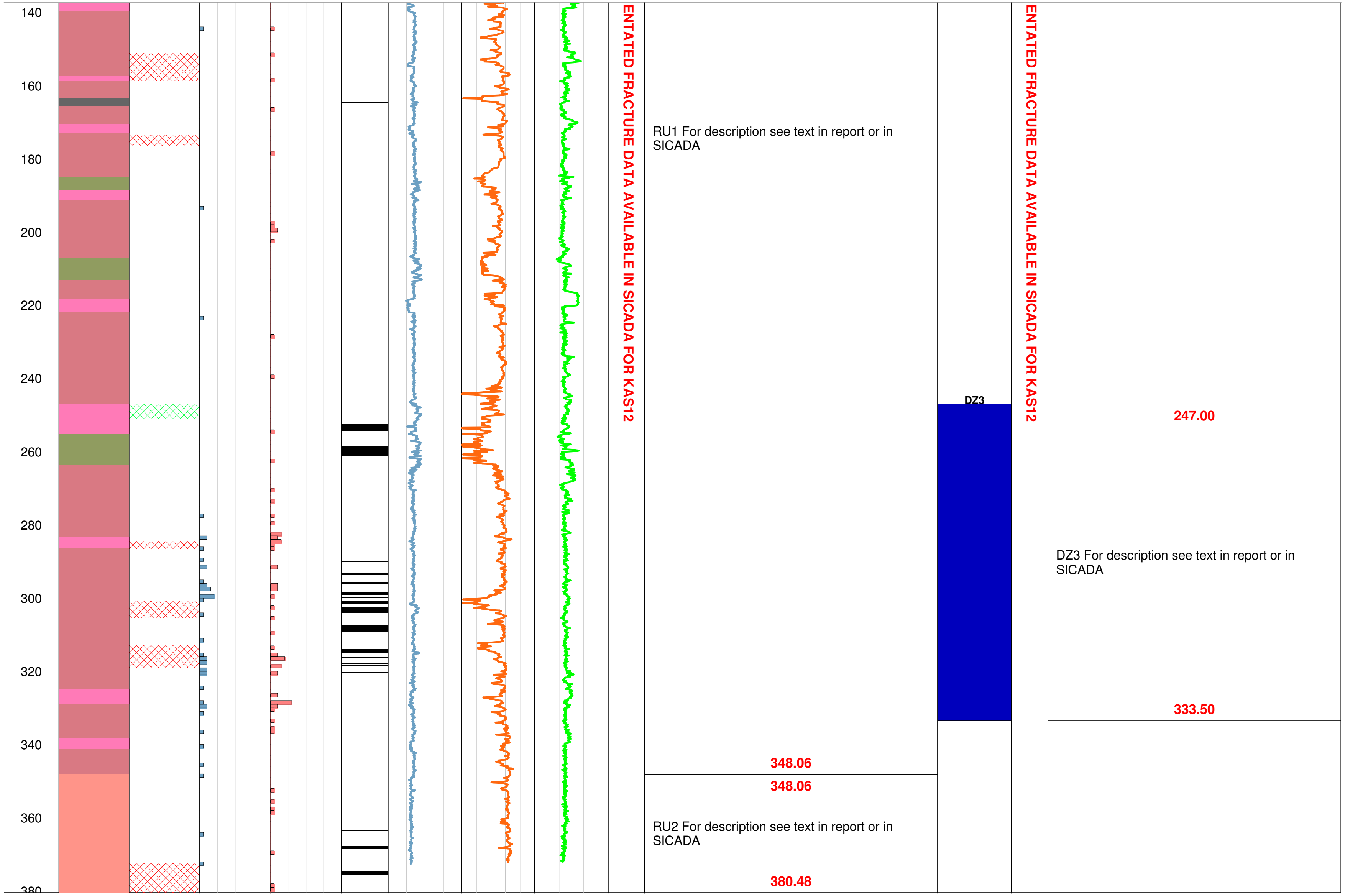
Title	SINGLE HOLE INTERPRETATION KAS12					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	-69.89	Elevation [m.a.s.l.]	4.83	Strike Reference	ÄSPÖ96
Borehole	KAS12	Date of mapping	1990-05-03 00:00:00	Drilling Start Date	1990-02-08 23:00:00	Made By	PKM
Diameter [mm]	56	Coordinate System	ÄSPÖ96	Drilling Stop Date	1990-02-18 23:00:00	SHI Light GE299	
Length [m]	380.480	Northing [m]	7568.80	Surveying Date	1990-04-23 00:00:00	Mapping Type	GE040
Bearing [°]	161.67	Easting [m]	2156.60	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Ävrö granodiorite 501056
- Äspö diorite 501037
- Gabbroid-dioritoid 508107
- Mylonite 508004

ROCK ALTERATION
- Oxidized
- Epidotisized

DZ CONFIDENCE LEVEL
- Confidence 2
- Confidence 3

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180
200
220
240
260
280
300
320
340
360
380
ENTATED FRACTURE DATA AVAILABLE IN SICADA FOR KAS12
RU1 For description see text in report or in SICADA
348.06
348.06
RU2 For description see text in report or in SICADA
380.48
DZ3
ENTATED FRACTURE DATA AVAILABLE IN SICADA FOR KAS12
247.00
DZ3 For description see text in report or in SICADA
333.50

Appendix 6

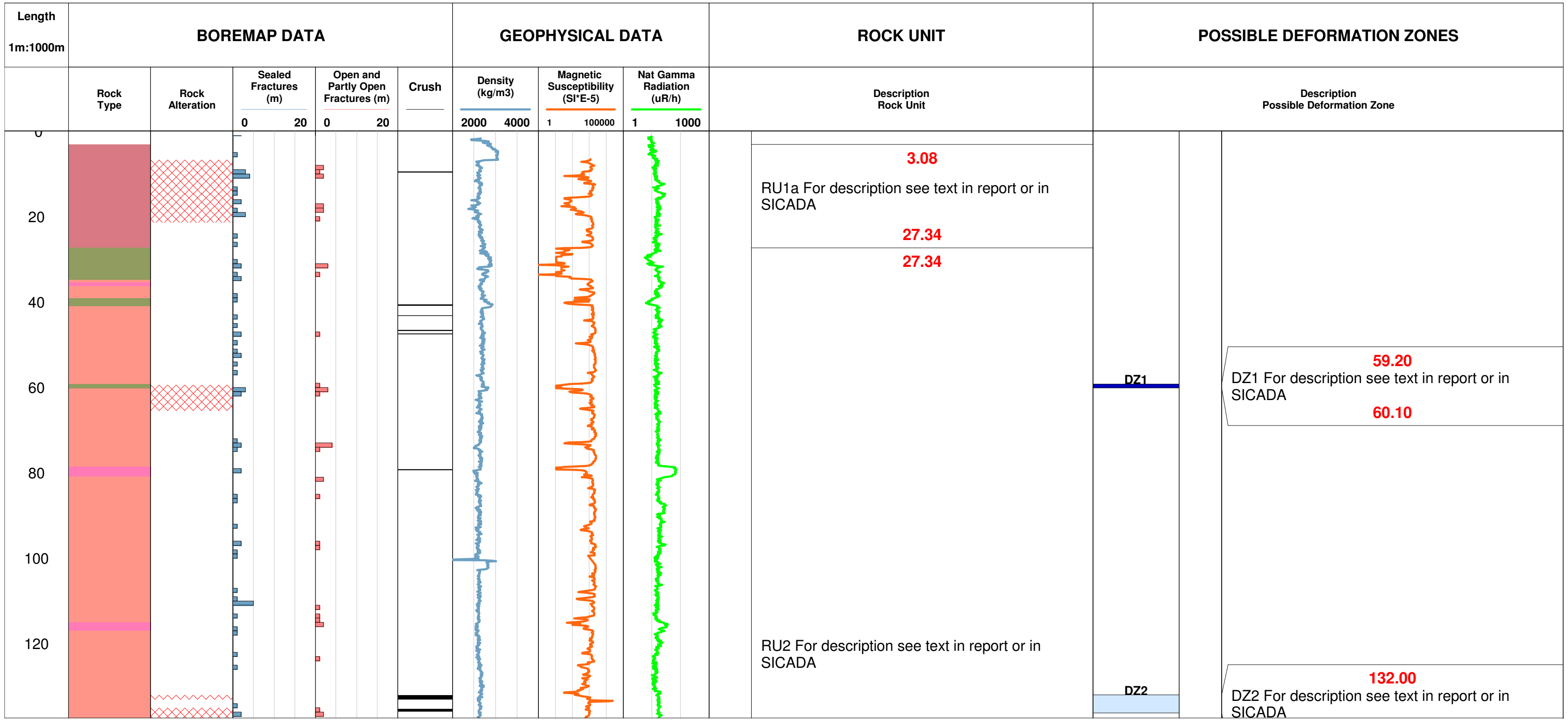
Geological single-hole interpretation of KAS13

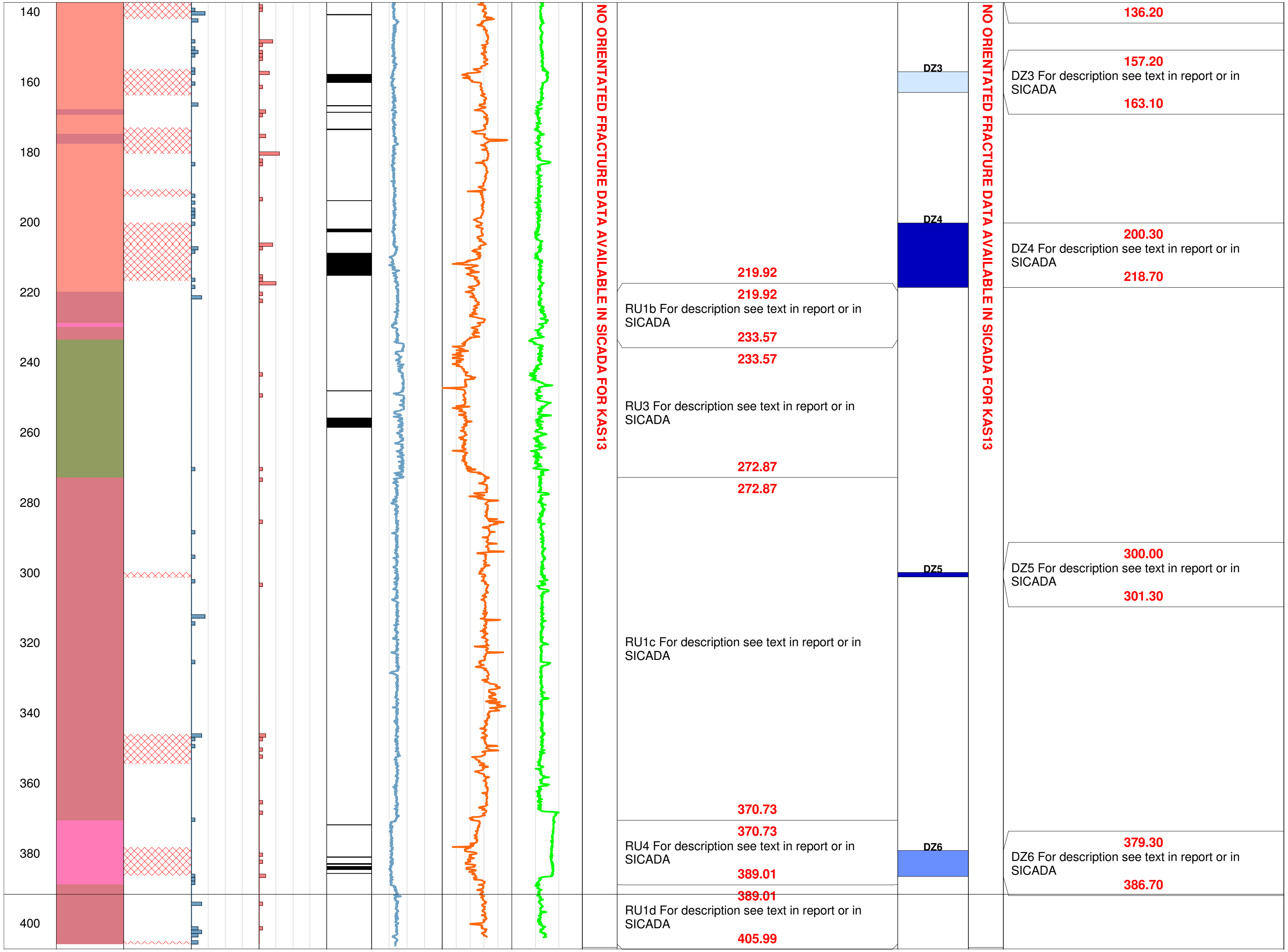
Title	**SINGLE HOLE INTERPRETATION KAS13**					**SIGNED DATA**	YES
Site	ÄSPÖ	**Inclination [°]**	-62.19	**Elevation [m.a.s.l.]**	3.84	**Strike Reference**	ÄSPÖ96
Borehole	KAS13	**Date of mapping**	1990-06-30 00:00:00	**Drilling Start Date**	1990-01-31 23:00:00	**Made By**	PKM
Diameter [mm]	56	**Coordinate System**	ÄSPÖ96	**Drilling Stop Date**	1990-02-09 23:00:00	**SHI Light GE299**	
Length [m]	406.950	**Northing [m]**	7264.76	**Surveying Date**	2002-08-01 14:00:00	**Mapping Type**	GE040
Bearing [°]	280.67	**Easting [m]**	2168.59	**Plot Date**	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Ävrö granodiorite 501056
- Äspö diorite 501037
- Gabbroid-dioritoid 508107

ROCK ALTERATION
- Oxidized

DZ CONFIDENCE LEVEL
- Confidence 1
- Confidence 2
- Confidence 3





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160
180
200
220
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260
280
300
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340
360
380
400
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219.92
219.92
RU1b For description see text in report or in SICADA
233.57
233.57
RU3 For description see text in report or in SICADA
272.87
272.87
RU1c For description see text in report or in SICADA
370.73
370.73
RU4 For description see text in report or in SICADA
389.01
389.01
RU1d For description see text in report or in SICADA
405.99
DZ3
DZ4
DZ5
DZ6
NO ORIENTATED FRACTURE DATA AVAILABLE IN SICADA FOR KAS13
136.20
157.20
DZ3 For description see text in report or in SICADA
163.10
200.30
DZ4 For description see text in report or in SICADA
218.70
300.00
DZ5 For description see text in report or in SICADA
301.30
379.30
DZ6 For description see text in report or in SICADA
386.70

Appendix 7

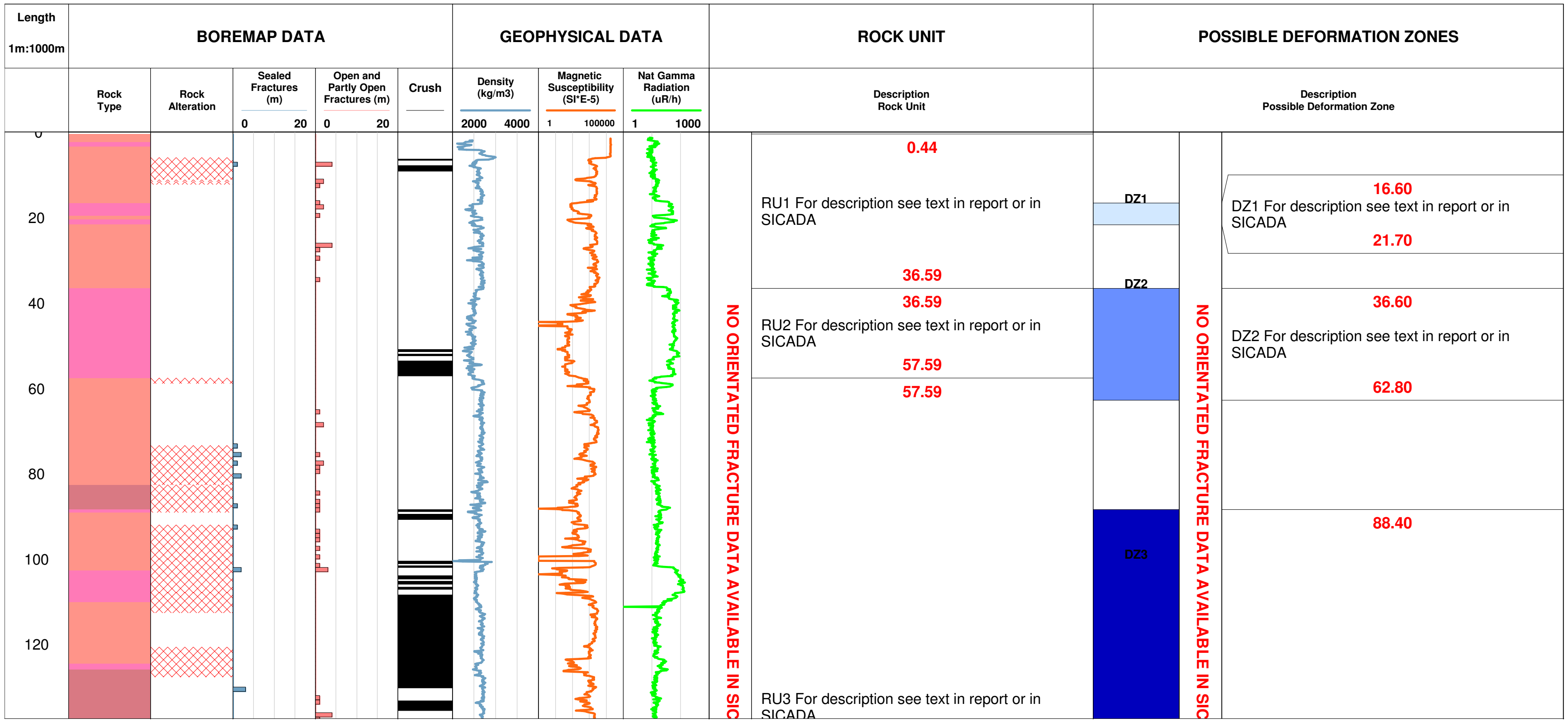
Geological single-hole interpretation of KAS14

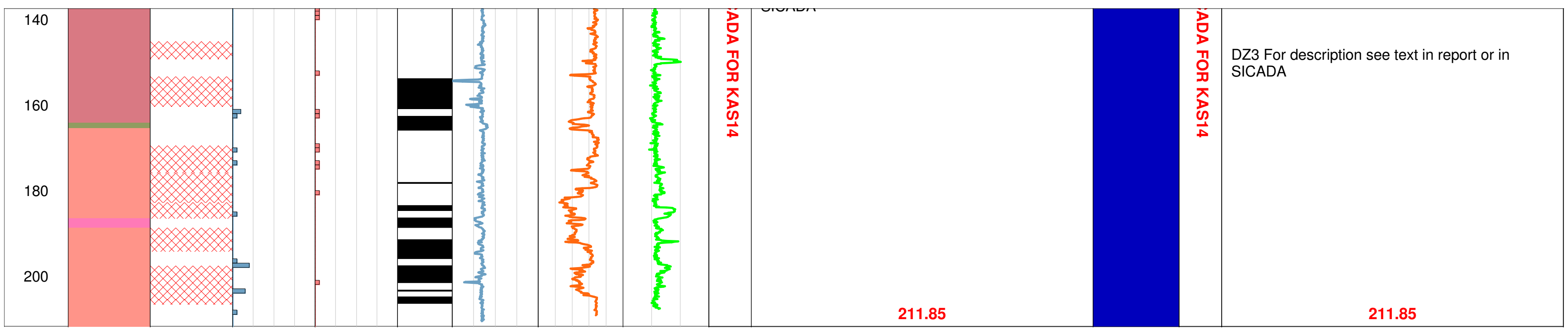
Title	SINGLE HOLE INTERPRETATION KAS14					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	-61.29	Elevation [m.a.s.l.]	3.35	Strike Reference	ÄSPÖ96
Borehole	KAS14	Date of mapping	1990-06-13 00:00:00	Drilling Start Date	1990-03-16 23:00:00	Made By	PKM
Diameter [mm]	56	Coordinate System	ÄSPÖ96	Drilling Stop Date	1990-03-21 23:00:00	SHI Light GE299	
Length [m]	211.850	Northing [m]	6939.28	Surveying Date	1994-02-01 00:00:00	Mapping Type	GE040
Bearing [°]	148.67	Easting [m]	2127.32	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Ävrö granodiorite 501056
- Äspö diorite 501037
- Gabbroid-dioritoid 508107

ROCK ALTERATION
- Oxidized

DZ CONFIDENCE LEVEL
- Confidence 1
- Confidence 2
- Confidence 3




140
160
180
200
ADA FOR KAS14
SICADA
211.85
ADA FOR KAS14
DZ3 For description see text in report or in SICADA
211.85

Appendix 8

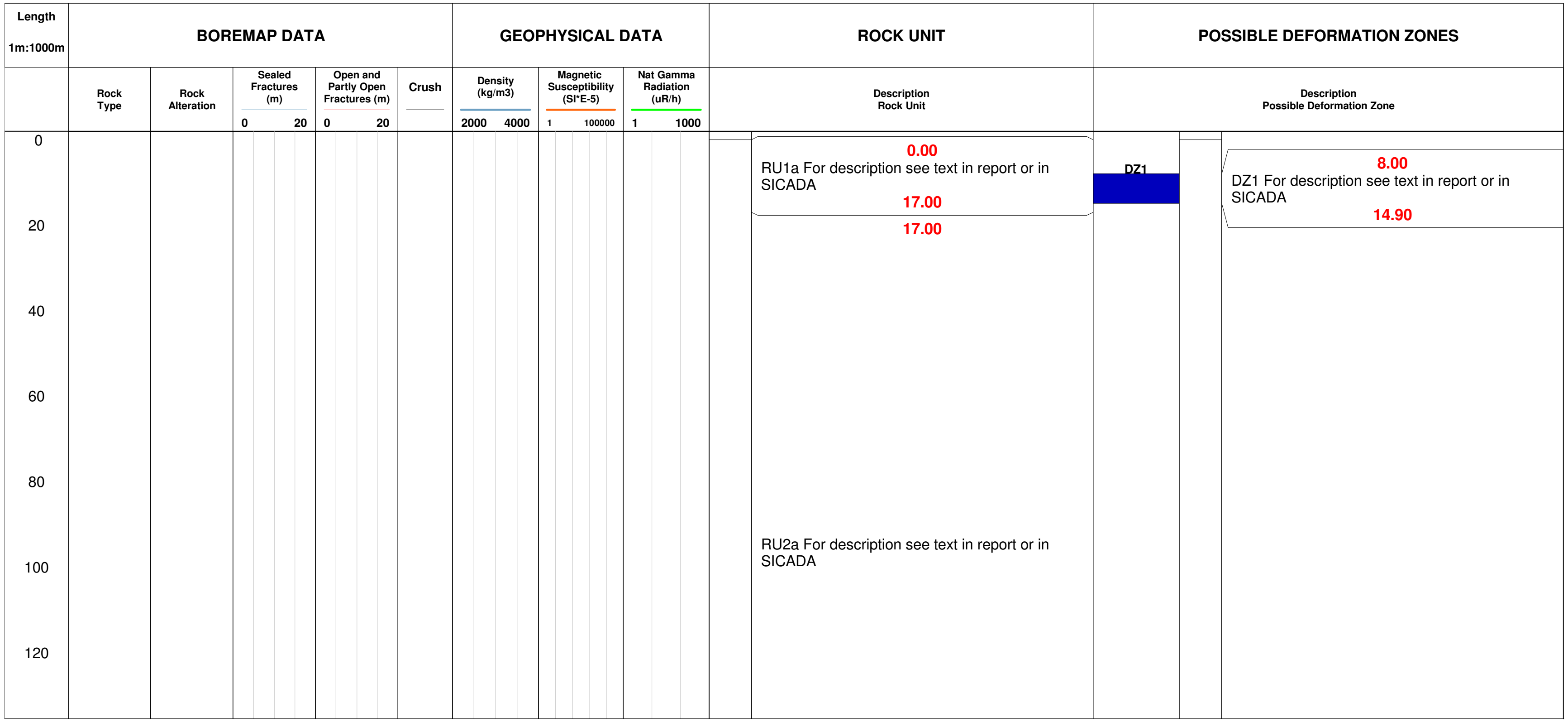
Geological single-hole interpretation of KAS16

Title	**SINGLE HOLE INTERPRETATION KAS16**					**SIGNED DATA**	YES
Site	ÄSPÖ	**Inclination [°]**	-84.49	**Elevation [m.a.s.l.]**	3.66	**Strike Reference**	ÄSPÖ96
Borehole	KAS16	**Date of mapping**	1992-09-30 00:00:00	**Drilling Start Date**	1992-08-01 00:00:00	**Made By**	PKM
Diameter [mm]	56	**Coordinate System**	ÄSPÖ96	**Drilling Stop Date**	1992-09-02 00:00:00	**SHI Light GE299**	
						Mapping Type	GE055
Length [m]	548.460	**Northing [m]**	7171.77	**Surveying Date**	1992-09-02 01:00:00		
Bearing [°]	138.82	**Easting [m]**	2250.20	**Plot Date**	2015-06-08 02:01:34		

ROCK TYPE **ÄSPÖ**

ROCK ALTERATION

DZ CONFIDENCE LEVEL
Confidence 3



140
160
180
200
220
240
260
280
300
320
340
360
380

NO DATA AVAILABLE IN SICADA KAS16

NO DATA AVAILABLE IN SICADA KAS16

NO DATA AVAILABLE IN SICADA KAS16

NO DATA AVAILABLE IN SICADA KAS16

NO DATA AVAILABLE IN SICADA KAS16

NO DATA AVAILABLE IN SICADA KAS16

NO ORIENTATED FRACTURE DATA AVAILABLE IN SICADA FOR KAS16

177.80

177.80
RU3 For description see text in report or in SICADA
191.50

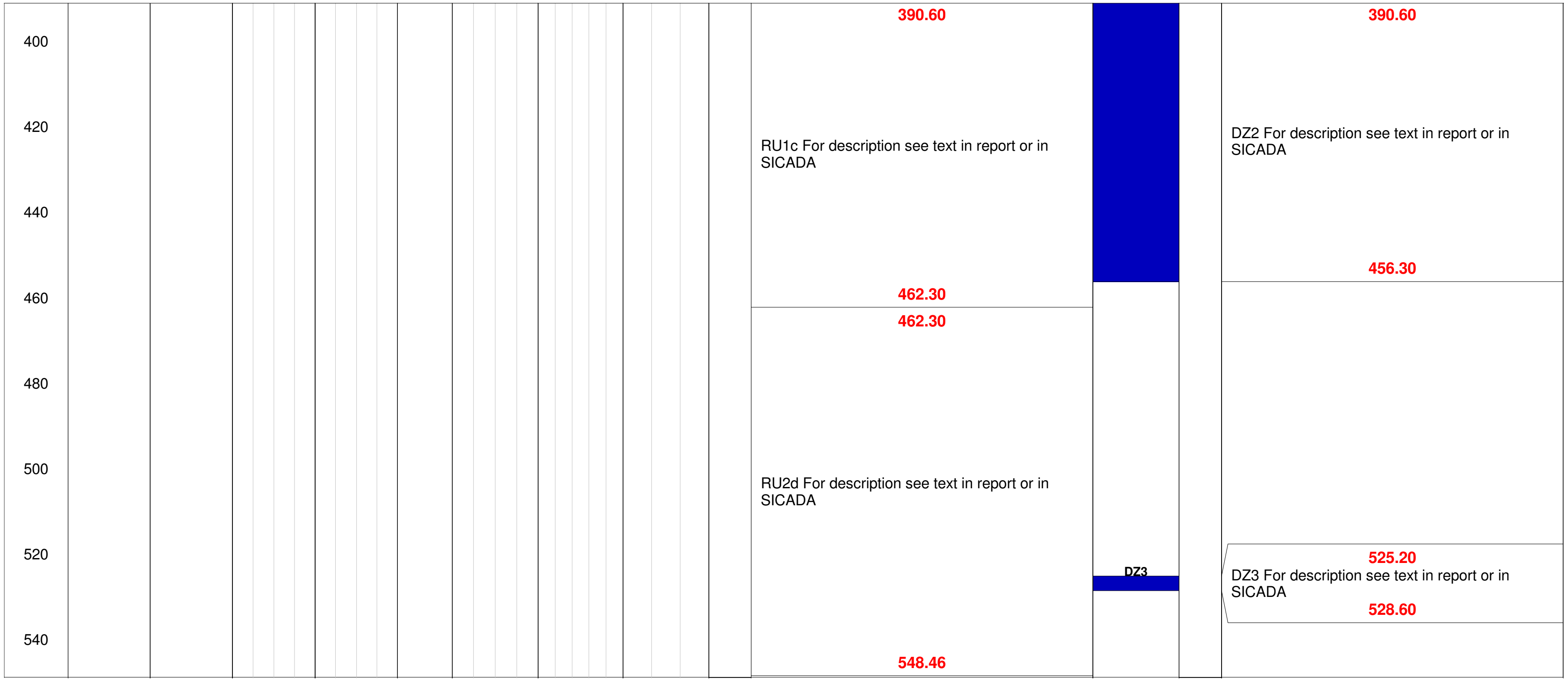
191.50
RU2b For description see text in report or in SICADA
293.20

293.20
RU1b For description see text in report or in SICADA
338.60

338.60
RU2c For description see text in report or in SICADA
390.60

DZ2

NO ORIENTATED FRACTURE DATA AVAILABLE IN SICADA FOR KAS16


400
420
440
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500
520
540
390.60
RU1c For description see text in report or in SICADA
462.30
462.30
RU2d For description see text in report or in SICADA
548.46
DZ3
390.60
DZ2 For description see text in report or in SICADA
456.30
525.20
DZ3 For description see text in report or in SICADA
528.60

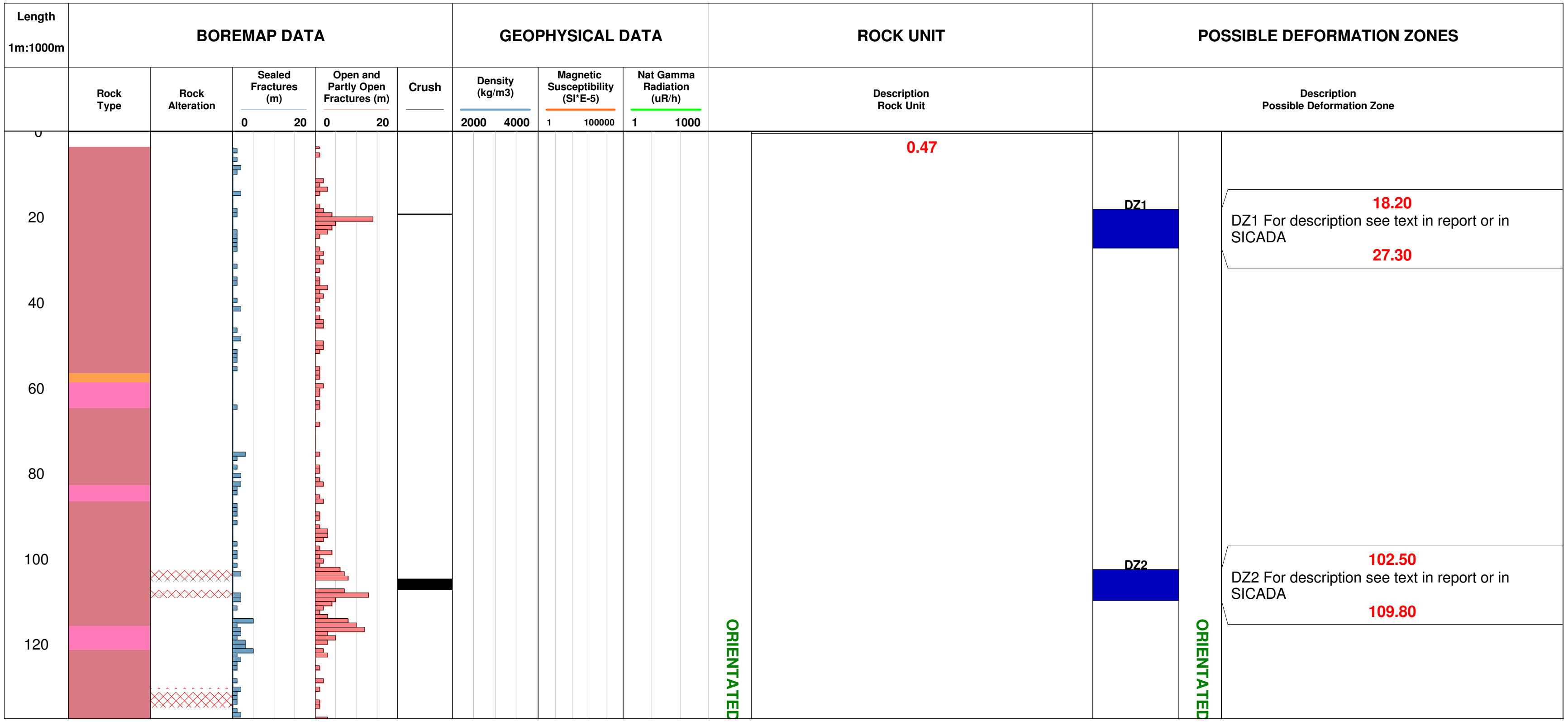
Geological single-hole interpretation of KAS17

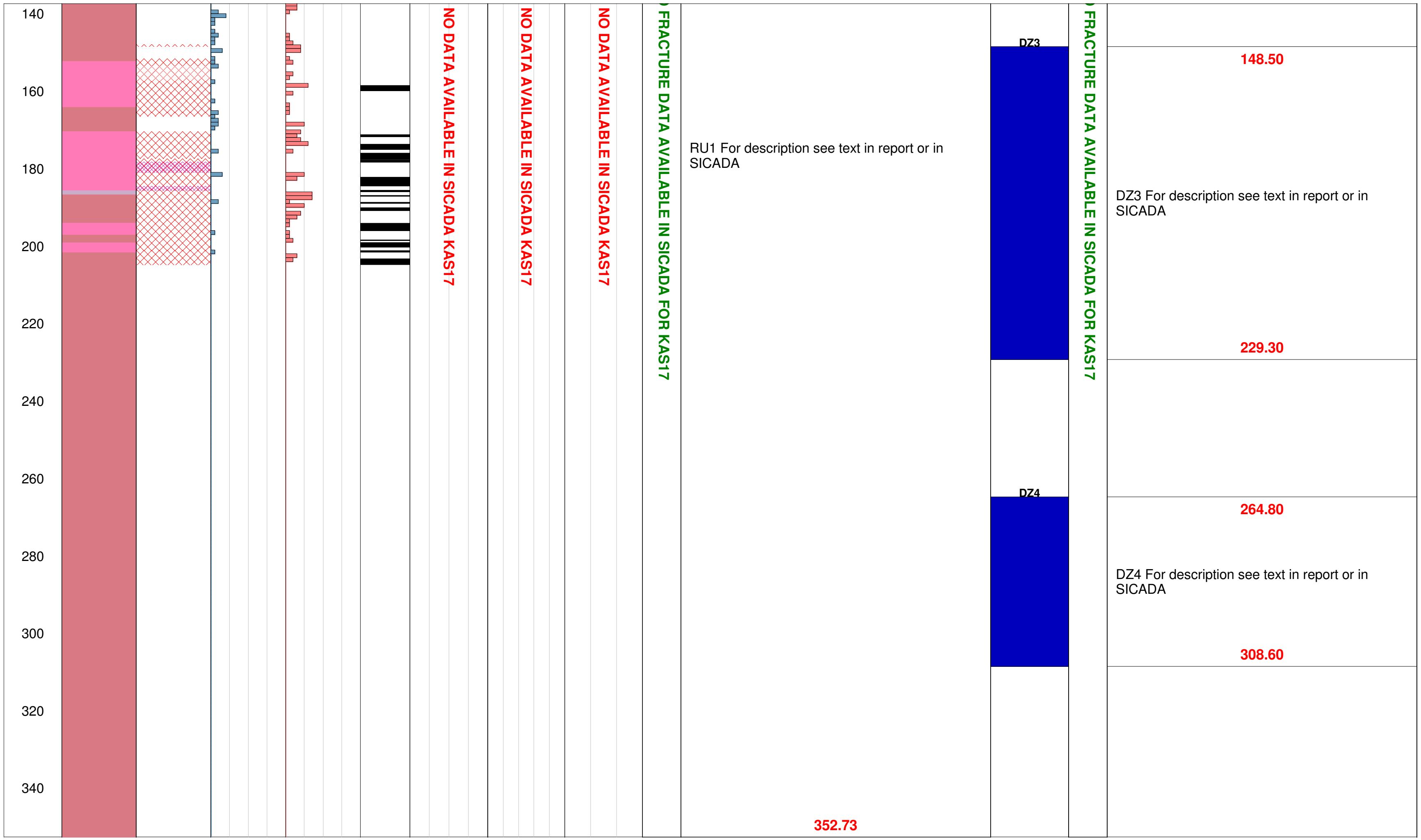
Title	**SINGLE HOLE INTERPRETATION KAS17**							**SIGNED DATA**	YES
	Site	ÄSPÖ	**Inclination [°]**	-59.33	**Elevation [m.a.s.l.]**	2.87		**Strike Reference**	ÄSPÖ96
	Borehole	KAS17	**Date of mapping**	2012-08-23 14:54:00	**Drilling Start Date**	2004-06-03 15:30:00		**Made By**	PKM
	Diameter [mm]	76	**Coordinate System**	ÄSPÖ96	**Drilling Stop Date**	2004-12-22 13:00:00		**SHI Light GE299**	
	Length [m]	352.730	**Northing [m]**	7790.16	**Surveying Date**	2004-09-08 13:20:00		**Mapping Type**	GE043
	Bearing [°]	327.19	**Easting [m]**	2647.21	**Plot Date**	2015-06-08 02:01:34			

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Pegmatite 501061
- Äspö diorite 501037
- Hybrid rock 505105

ROCK ALTERATION
- Oxidized
- Argillization
- Laumontitization
- Fract zone alteration

DZ CONFIDENCE LEVEL
- Confidence 3

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340
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NO DATA AVAILABLE IN SICADA KAS17
NO DATA AVAILABLE IN SICADA KAS17
FRACTURE DATA AVAILABLE IN SICADA FOR KAS17
RU1 For description see text in report or in SICADA
352.73
DZ3
DZ4
FRACTURE DATA AVAILABLE IN SICADA FOR KAS17
148.50
DZ3 For description see text in report or in SICADA
229.30
264.80
DZ4 For description see text in report or in SICADA
308.60

Appendix 10

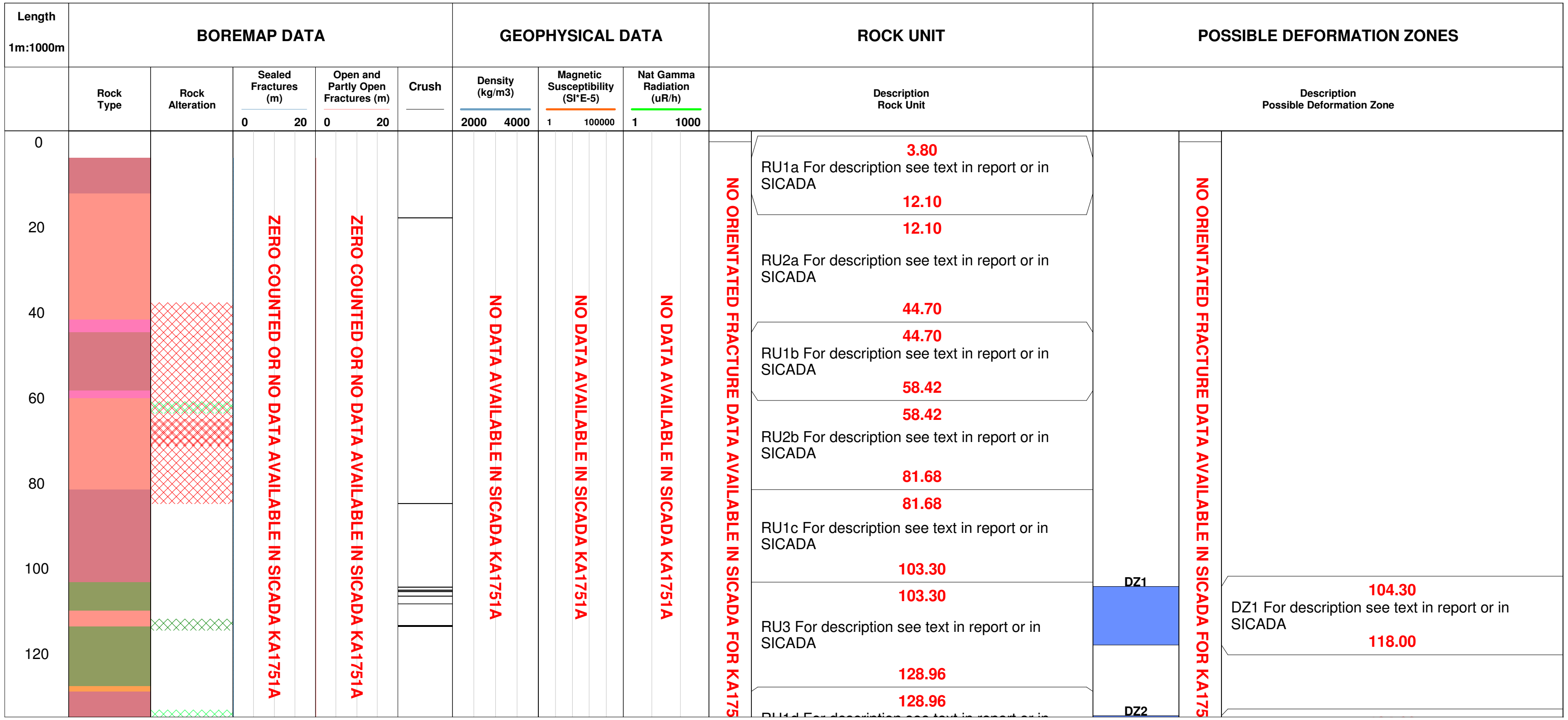
Geological single-hole interpretation of KA1751A

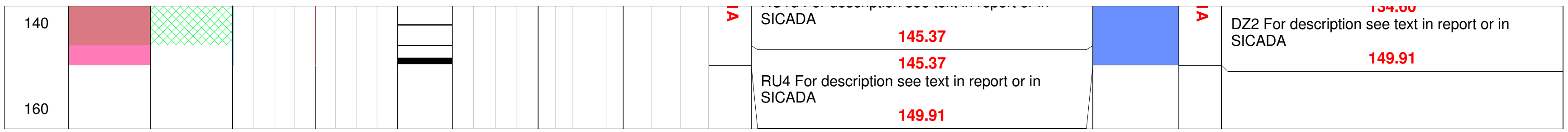
Title	SINGLE HOLE INTERPRETATION KA1751A					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	5.20	Elevation [m.a.s.l.]	-237.55	Strike Reference	ÄSPÖ96
Borehole	KA1751A	Date of mapping	1995-04-07 01:00:00	Drilling Start Date	1993-04-21 16:52:00	Made By	PKM
Diameter [mm]	56	Coordinate System	ÄSPÖ96	Drilling Stop Date	1993-05-04 19:01:00	SHI Light GE299	
Length [m]	149.910	Northing [m]	7385.83	Surveying Date	1993-05-04 20:00:00	Mapping Type	GE040
Bearing [°]	274.23	Easting [m]	2059.70	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Pegmatite 501061
- Ävrö granodiorite 501056
- Äspö diorite 501037
- Gabbroid-dioritoid 508107

ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized

DZ CONFIDENCE LEVEL
- Confidence 2




140
160
SICADA
145.37
145.37
RU4 For description see text in report or in SICADA
149.91
DZ2 For description see text in report or in SICADA
149.91

Appendix 11

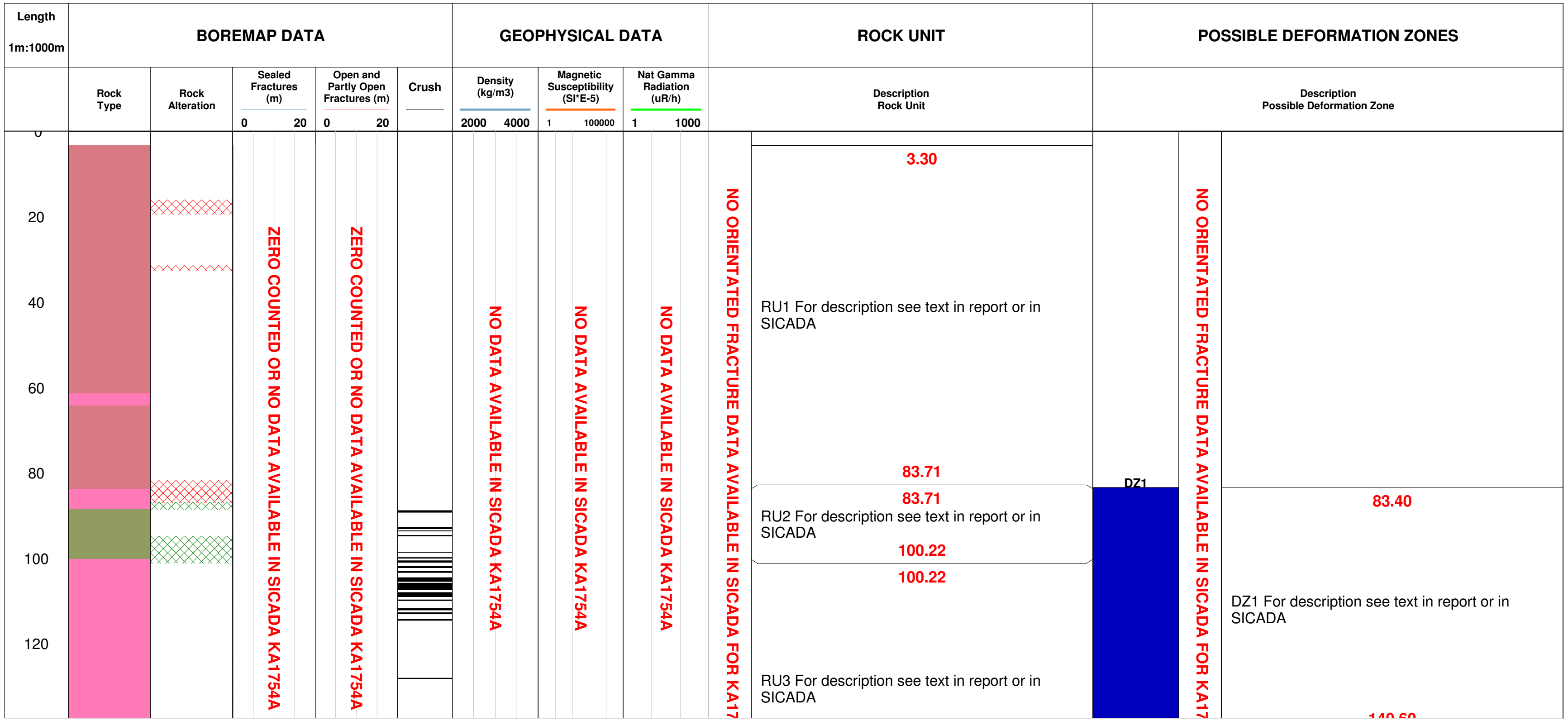
Geological single-hole interpretation of KA1754A

Title	SINGLE HOLE INTERPRETATION KA1754A					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	-26.19	Elevation [m.a.s.l.]	-237.83	Strike Reference	ÄSPÖ96
Borehole	KA1754A	Date of mapping	1995-04-09 01:00:00	Drilling Start Date	1993-05-10 11:00:00	Made By	PKM
Diameter [mm]	56	Coordinate System	ÄSPÖ96	Drilling Stop Date	1993-05-19 09:08:00	SHI Light GE299	
						Mapping Type	GE040
Length [m]	159.880	Northing [m]	7388.96	Surveying Date	1993-05-19 09:08:00		
Bearing [°]	299.90	Easting [m]	2060.76	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Äspö diorite 501037
- Gabbroid-dioritoid 508107

ROCK ALTERATION
- Oxidized
- Chloritisized

DZ CONFIDENCE LEVEL
- Confidence 3



Appendix 12

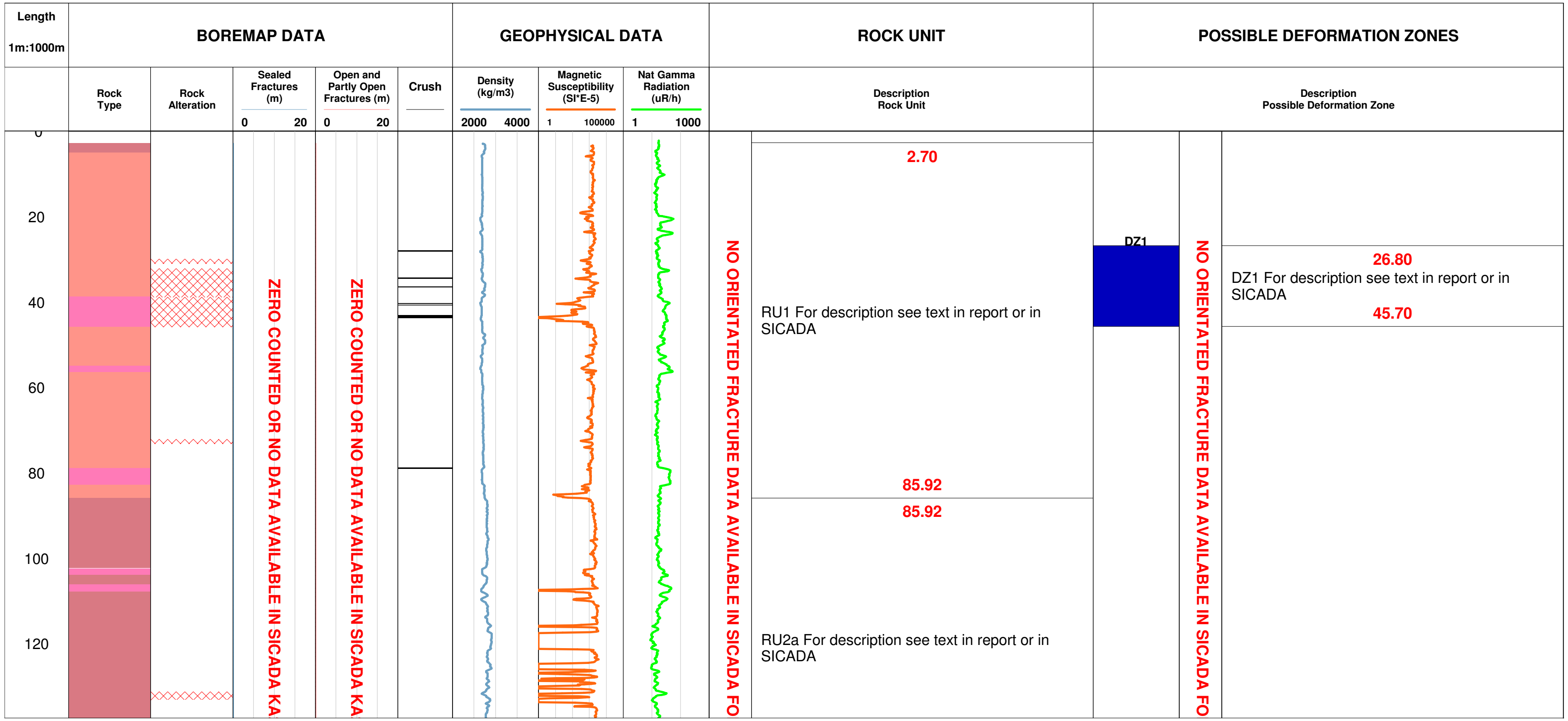
Geological single-hole interpretation of KA2048B

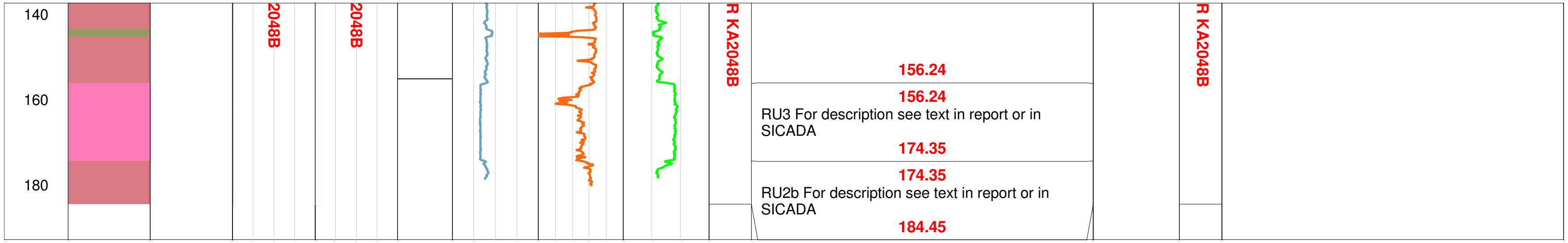
Title	SINGLE HOLE INTERPRETATION KA2048B					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	-10.59	Elevation [m.a.s.l.]	-275.42	Strike Reference	ÄSPÖ96
Borehole	KA2048B	Date of mapping	1995-01-11 00:00:00	Drilling Start Date	1993-02-06 01:15:00	Made By	PKM
Diameter [mm]	56	Coordinate System	ÄSPÖ96	Drilling Stop Date	1993-02-16 08:12:00	SHI Light GE299 Mapping Type	GE040
Length [m]	184.450	Northing [m]	7325.03	Surveying Date	1993-02-16 21:15:00		
Bearing [°]	190.90	Easting [m]	2320.01	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Ävrö granodiorite 501056
- Äspö diorite 501037
- Gabbroid-dioritoid 508107

ROCK ALTERATION
- Oxidized

DZ CONFIDENCE LEVEL
- Confidence 3

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160
180
2048B
2048B
R KA2048B
156.24
156.24
RU3 For description see text in report or in SICADA
174.35
174.35
RU2b For description see text in report or in SICADA
184.45
R KA2048B

Appendix 13

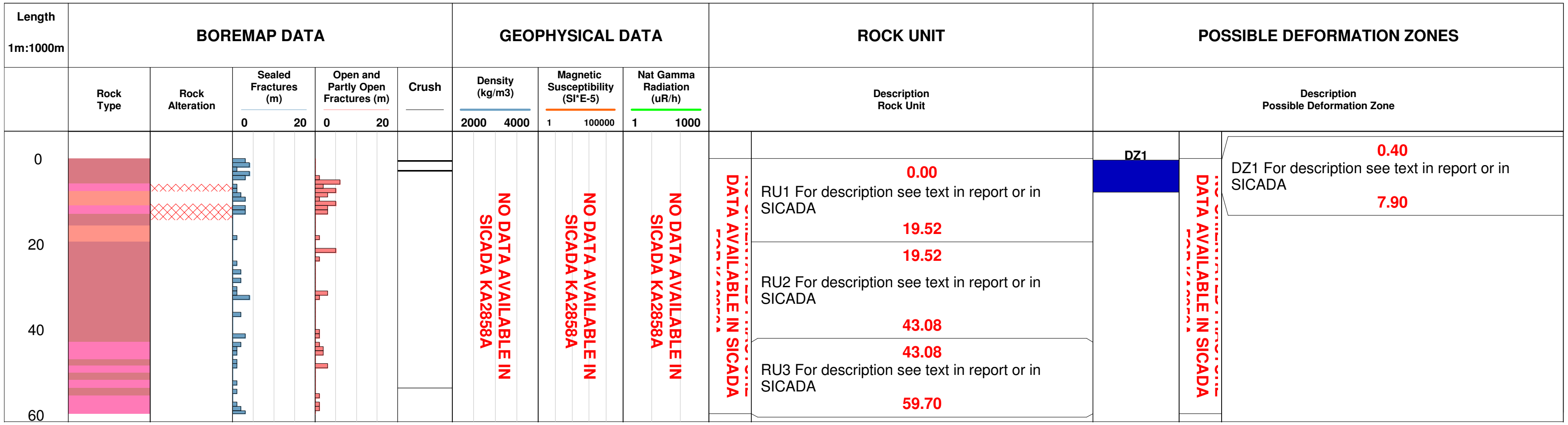
Geological single-hole interpretation of KA2858A

Title	**SINGLE HOLE INTERPRETATION KA2858A**					**SIGNED DATA**	YES
Site	ÄSPÖ	**Inclination [°]**	-4.28	**Elevation [m.a.s.l.]**	-379.37	**Strike Reference**	ÄSPÖ96
Borehole	KA2858A	**Date of mapping**	1995-01-14 00:00:00	**Drilling Start Date**	1995-01-13 12:08:00	**Made By**	PKM
Diameter [mm]	56	**Coordinate System**	ÄSPÖ96	**Drilling Stop Date**	1995-01-15 14:00:00	**SHI Light GE299**	
						Mapping Type	GE037
Length [m]	59.700	**Northing [m]**	7465.22	**Surveying Date**	1996-01-16 00:00:00		
Bearing [°]	287.00	**Easting [m]**	2221.98	**Plot Date**	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Ävrö granodiorite 501056
- Äspö diorite 501037

ROCK ALTERATION
- Oxidized

DZ CONFIDENCE LEVEL
- Confidence 3



Appendix 14

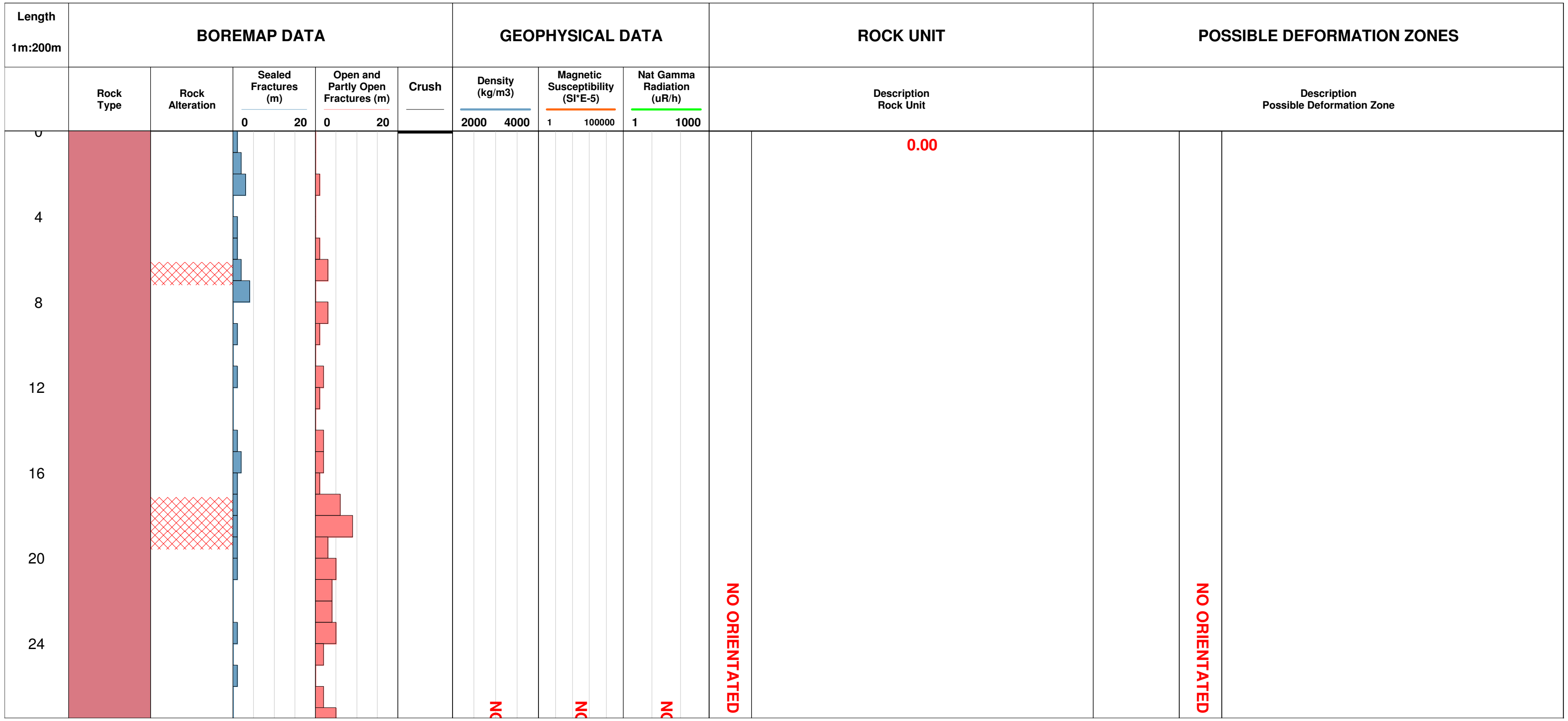
Geological single-hole interpretation of KA3105A

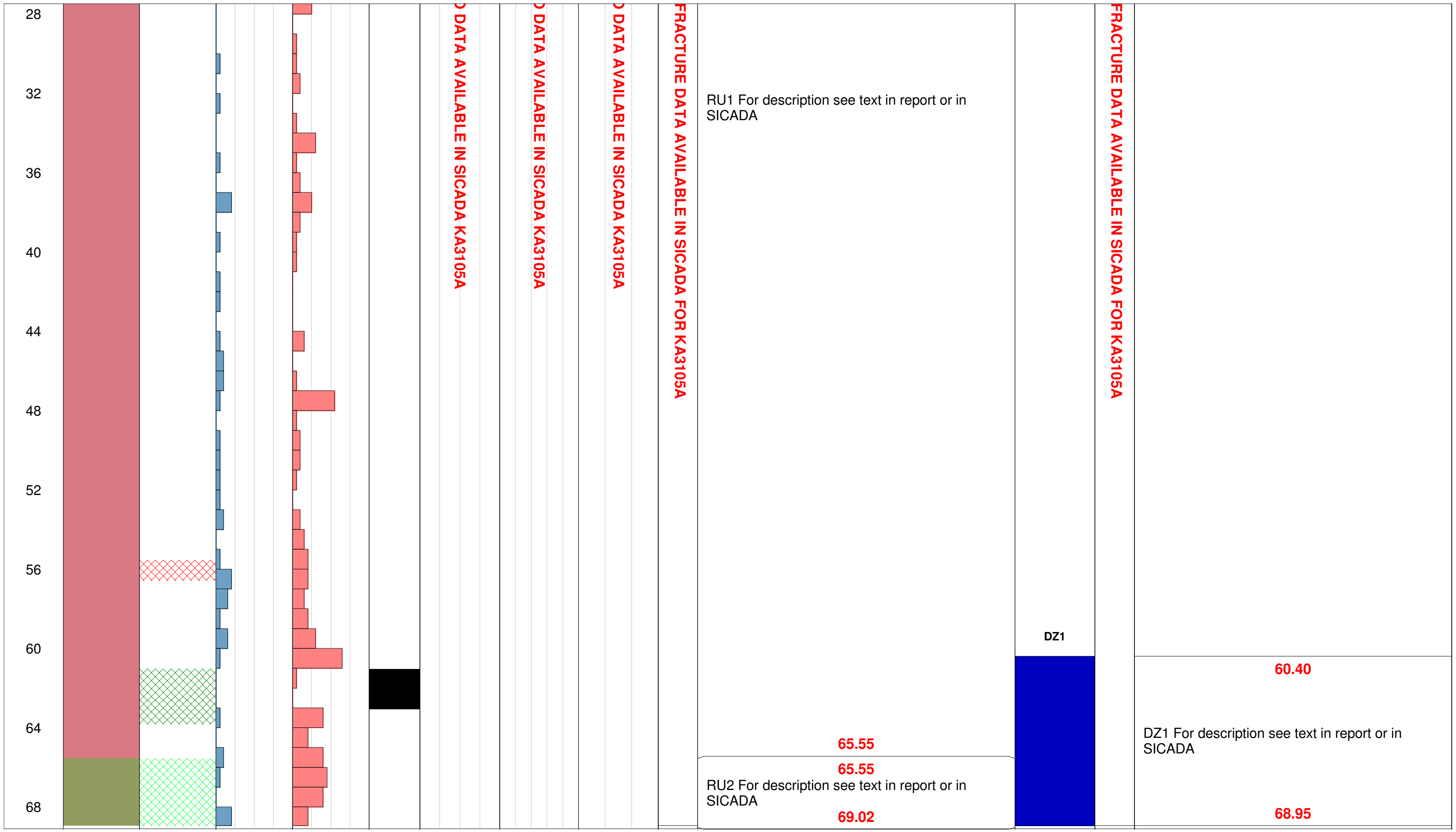
Title	SINGLE HOLE INTERPRETATION KA3105A					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	-4.77	Elevation [m.a.s.l.]	-413.67	Strike Reference	ÄSPÖ96
Borehole	KA3105A	Date of mapping	1994-12-16 00:00:00	Drilling Start Date	1994-12-13 13:10:00	Made By	PKM
Diameter [mm]	56	Coordinate System	ÄSPÖ96	Drilling Stop Date	1994-12-15 16:17:00	SHI Light GE299	
Length [m]	68.950	Northing [m]	7314.52	Surveying Date	1996-01-16 00:00:00	Mapping Type	GE037
Bearing [°]	102.55	Easting [m]	2358.45	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Äspö diorite 501037
- Gabbroid-dioritoid 508107

ROCK ALTERATION
- Oxidized
- Chloritisized
- Epidotisized

DZ CONFIDENCE LEVEL
- Confidence 3

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32
36
40
44
48
52
56
60
64
68
D DATA AVAILABLE IN SICADA KA3105A
D DATA AVAILABLE IN SICADA KA3105A
D DATA AVAILABLE IN SICADA KA3105A
FRACTURE DATA AVAILABLE IN SICADA FOR KA3105A
RU1 For description see text in report or in SICADA
65.55
65.55
RU2 For description see text in report or in SICADA
69.02
DZ1
FRACTURE DATA AVAILABLE IN SICADA FOR KA3105A
60.40
DZ1 For description see text in report or in SICADA
68.95

Appendix 15

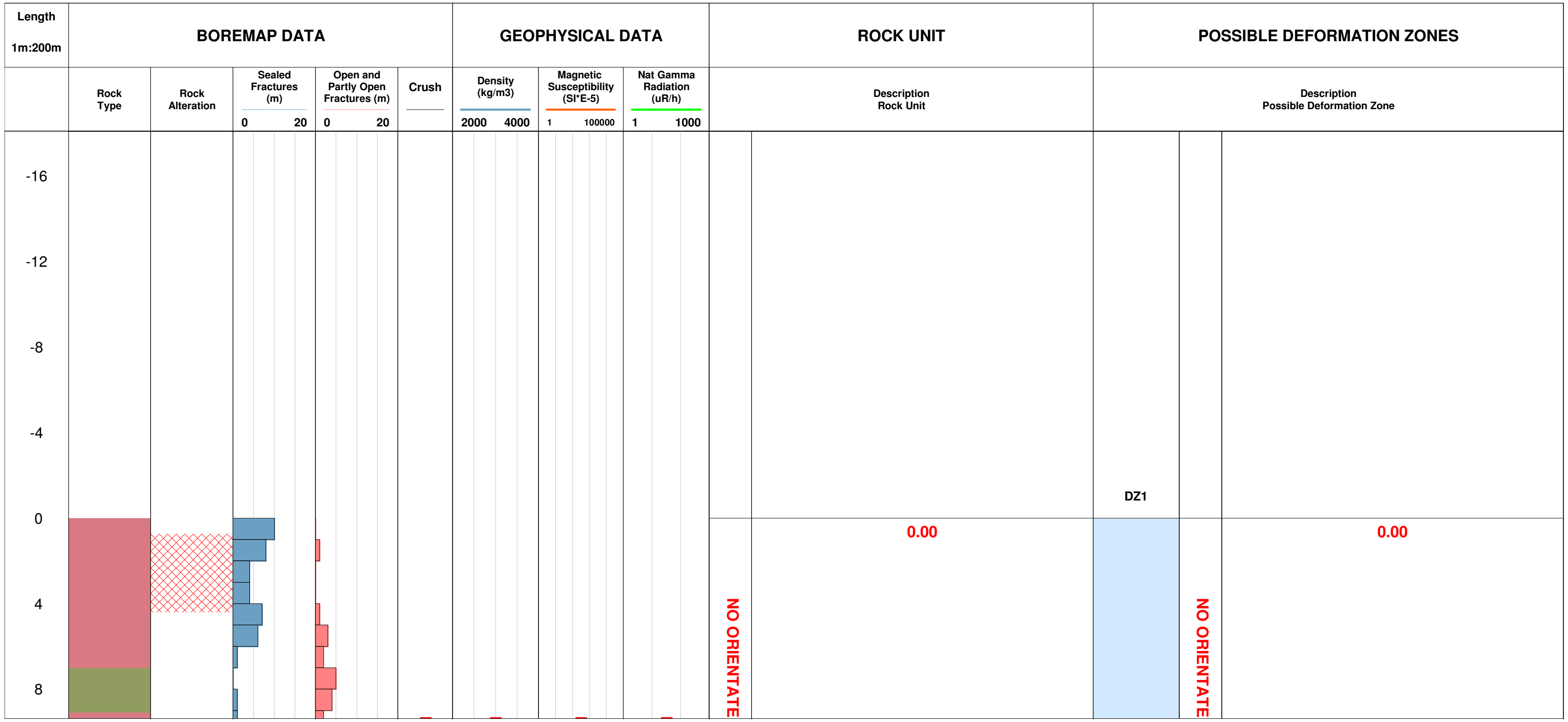
Geological single-hole interpretation of KA3385A

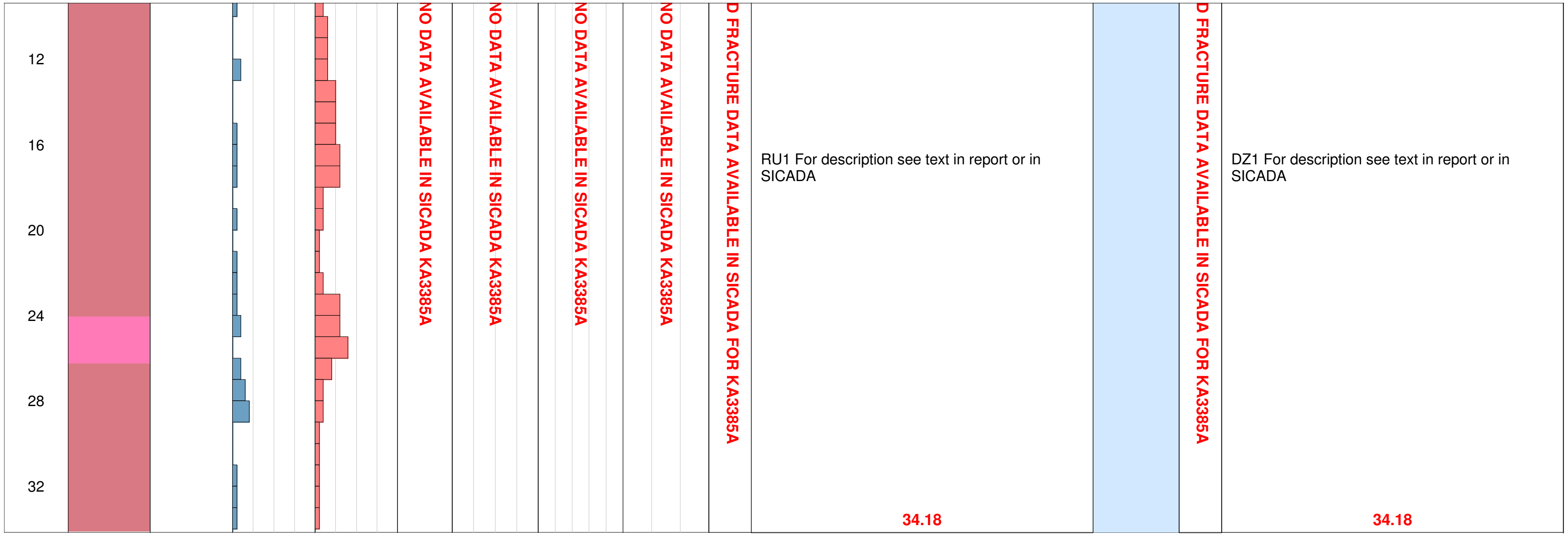
Title	**SINGLE HOLE INTERPRETATION KA3385A**					**SIGNED DATA**	YES
Site	ÄSPÖ	**Inclination [°]**	-4.09	**Elevation [m.a.s.l.]**	-445.98	**Strike Reference**	ÄSPÖ96
Borehole	KA3385A	**Date of mapping**	1995-01-10 00:00:00	**Drilling Start Date**	1995-01-05 12:20:00	**Made By**	PKM
Diameter [mm]	56	**Coordinate System**	ÄSPÖ96	**Drilling Stop Date**	1995-01-10 12:15:00	**SHI Light GE299**	
Length [m]	34.180	**Northing [m]**	7250.73	**Surveying Date**	2006-10-10 15:20:00	**Mapping Type**	GE037
Bearing [°]	176.20	**Easting [m]**	2084.42	**Plot Date**	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Äspö diorite 501037
- Gabbroid-dioritoid 508107

ROCK ALTERATION
- Oxidized

DZ CONFIDENCE LEVEL
- Confidence 1

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16
20
24
28
32
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NO DATA AVAILABLE IN SICADA KA3385A
NO DATA AVAILABLE IN SICADA KA3385A
NO DATA AVAILABLE IN SICADA KA3385A
D FRACTURE DATA AVAILABLE IN SICADA FOR KA3385A
RU1 For description see text in report or in SICADA
34.18
D FRACTURE DATA AVAILABLE IN SICADA FOR KA3385A
DZ1 For description see text in report or in SICADA
34.18

Appendix 16

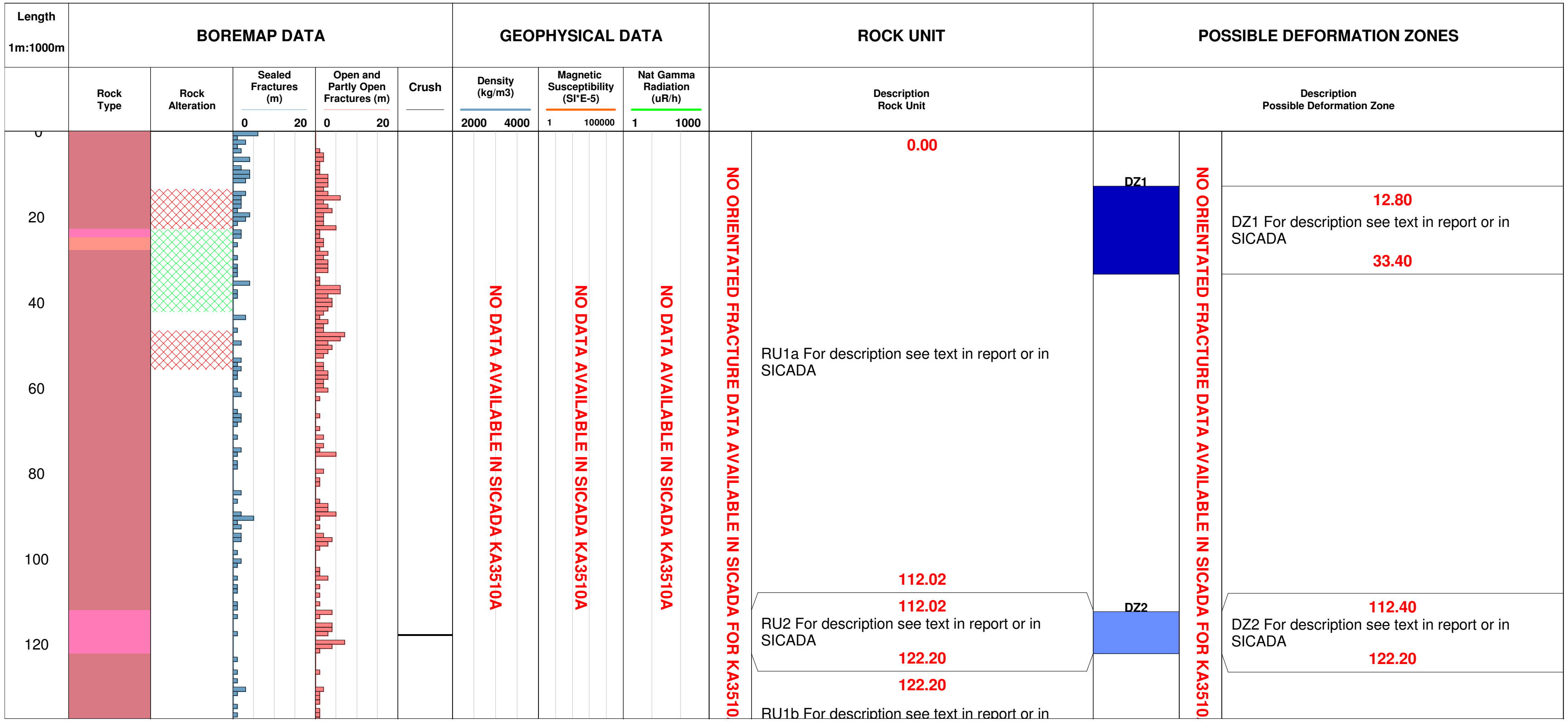
Geological single-hole interpretation of KA3510A

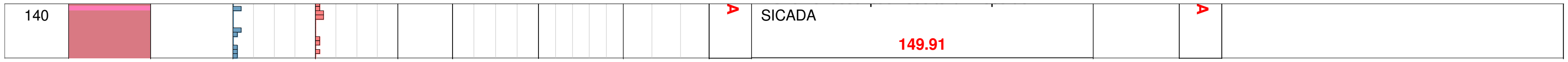
Title	SINGLE HOLE INTERPRETATION KA3510A					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	-30.14	Elevation [m.a.s.l.]	-448.69	Strike Reference	ÄSPÖ96
Borehole	KA3510A	Date of mapping	1996-10-06 01:00:00	Drilling Start Date	1996-08-26 13:44:00	Made By	PKM
Diameter [mm]	76	Coordinate System	ÄSPÖ96	Drilling Stop Date	1996-09-09 10:17:00	SHI Light GE299	
						Mapping Type	GE037
Length [m]	150.060	Northing [m]	7260.89	Surveying Date	1996-10-10 01:00:00		
Bearing [°]	255.33	Easting [m]	1953.80	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Ävrö granodiorite 501056
- Äspö diorite 501037

ROCK ALTERATION
- Oxidized
- Epidotisized

DZ CONFIDENCE LEVEL
- Confidence 2
- Confidence 3




140
A
SICADA
149.91
A

Appendix 17

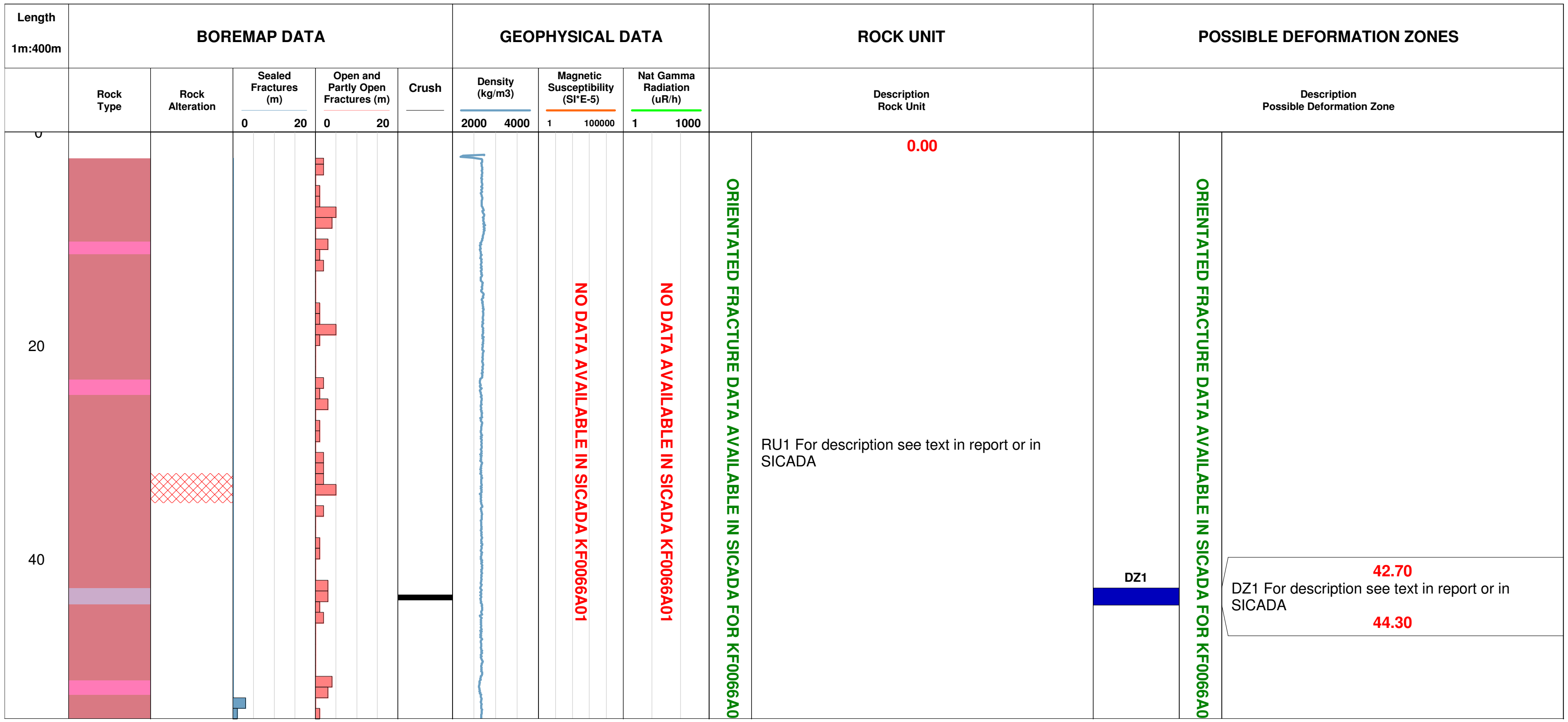
Geological single-hole interpretation of KF0066A01

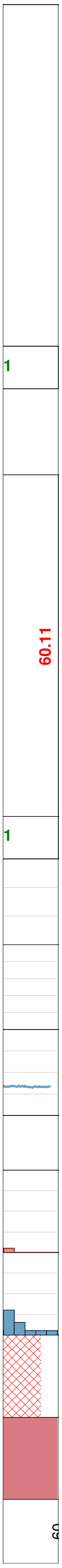
Title	SINGLE HOLE INTERPRETATION KF0066A01					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	0.51	Elevation [m.a.s.l.]	-454.34	Strike Reference	ÄSPÖ96
Borehole	KF0066A01	Date of mapping	2002-06-28 16:51:00	Drilling Start Date	2002-05-28 15:31:00	Made By	PKM
Diameter [mm]	76	Coordinate System	ÄSPÖ96	Drilling Stop Date	2002-06-01 15:29:00	SHI Light GE299	
						Mapping Type	GE041
Length [m]	60.110	Northing [m]	7299.13	Surveying Date	2002-05-30 10:00:00		
Bearing [°]	15.98	Easting [m]	2027.93	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Äspö diorite 501037
- Hybrid rock 505105

ROCK ALTERATION
- Oxidized

DZ CONFIDENCE LEVEL
- Confidence 3




1
60.11
1

Appendix 18

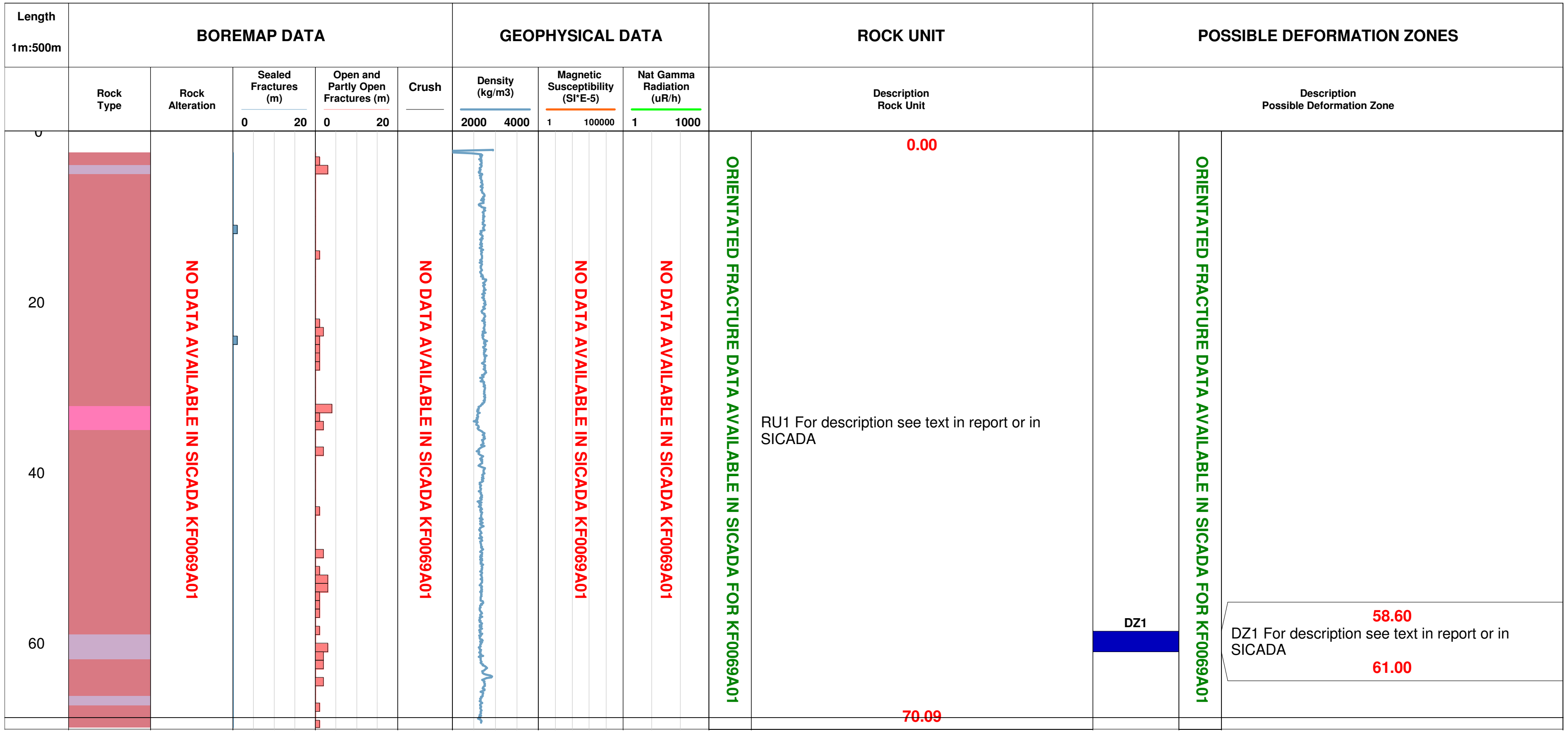
Geological single-hole interpretation of KF0069A01

Title	SINGLE HOLE INTERPRETATION KF0069A01					**SIGNED DATA**	YES
Site	ÄSPÖ	**Inclination [°]**	-1.75	**Elevation [m.a.s.l.]**	-454.81	**Strike Reference**	ÄSPÖ96
Borehole	KF0069A01	**Date of mapping**	2002-07-01 09:02:00	**Drilling Start Date**	2002-05-15 09:37:00	**Made By**	PKM
Diameter [mm]	76	**Coordinate System**	ÄSPÖ96	**Drilling Stop Date**	2002-05-21 14:07:00	**SHI Light GE299**	
Length [m]	70.090	**Northing [m]**	7299.40	**Surveying Date**	2002-05-17 10:15:00	**Mapping Type**	GE041
Bearing [°]	28.87	**Easting [m]**	2030.90	**Plot Date**	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Äspö diorite 501037
- Hybrid rock 505105

ROCK ALTERATION

DZ CONFIDENCE LEVEL
- Confidence 3



Appendix 19

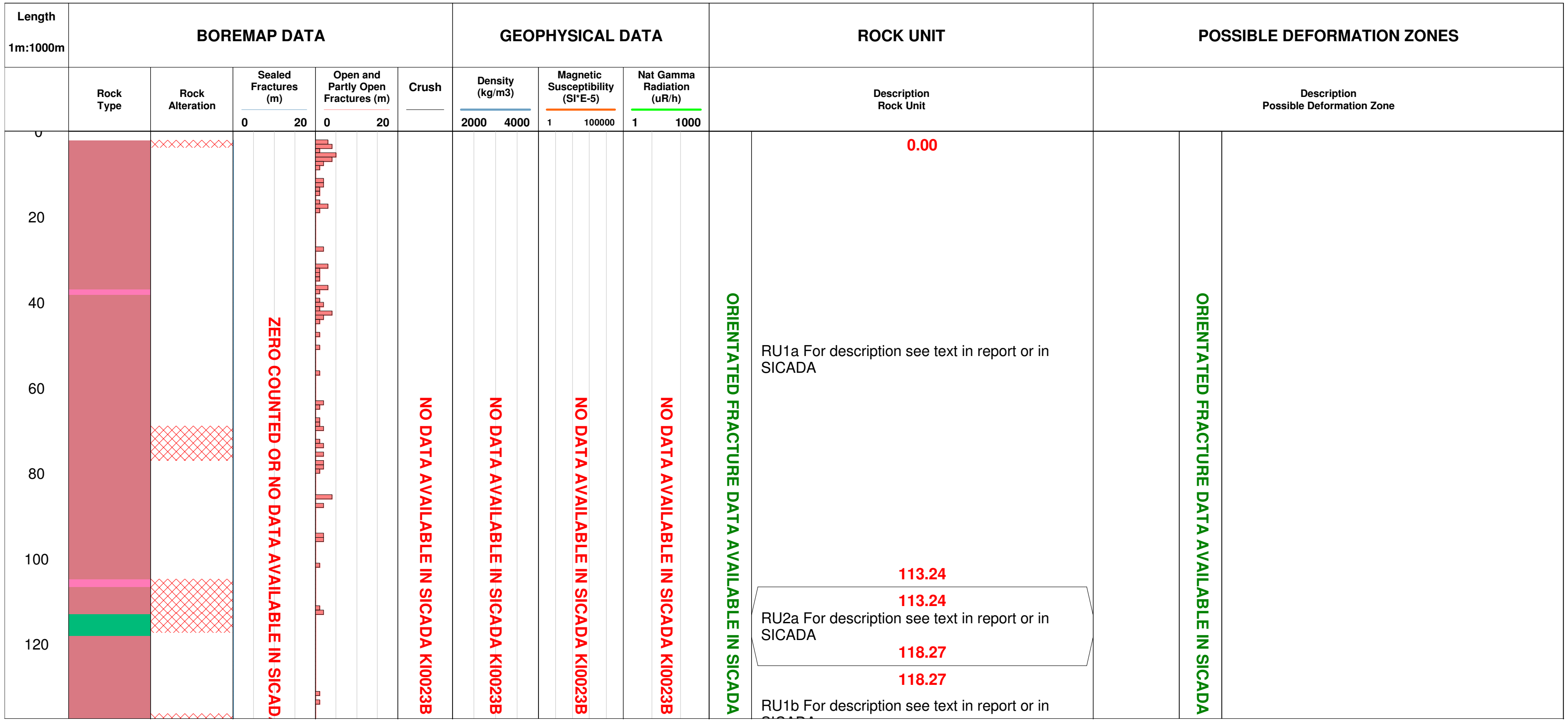
Geological single-hole interpretation of KI0023B

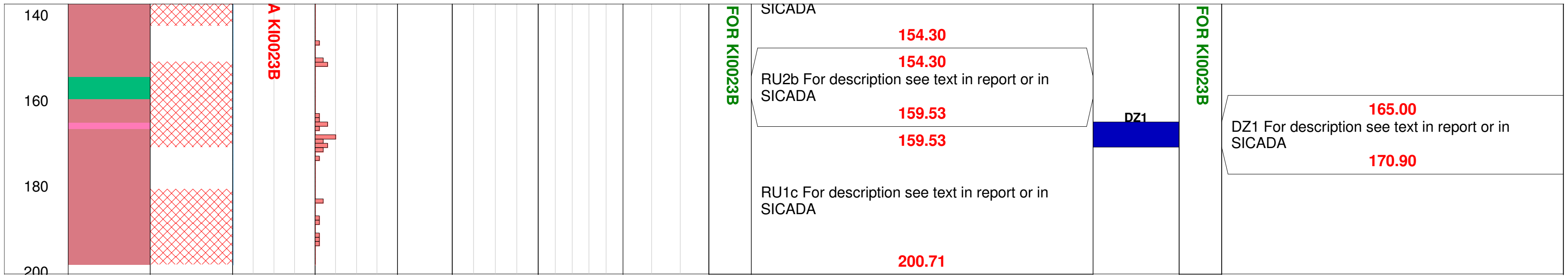
Title	**SINGLE HOLE INTERPRETATION KI0023B**						**SIGNED DATA**	YES
Site	ÄSPÖ	**Inclination [°]**	-20.72	**Elevation [m.a.s.l.]**	-447.68		**Strike Reference**	ÄSPÖ96
Borehole	KI0023B	**Date of mapping**	1998-01-27 10:58:00	**Drilling Start Date**	1997-10-19 11:00:00		**Made By**	PKM
Diameter [mm]	76	**Coordinate System**	ÄSPÖ96	**Drilling Stop Date**	1997-11-20 16:18:00		**SHI Light GE299**	
Length [m]	200.710	**Northing [m]**	7241.26	**Surveying Date**	1997-11-26 12:20:00		**Mapping Type**	GE036
Bearing [°]	214.61	**Easting [m]**	1951.91	**Plot Date**	2015-06-08 02:01:34			

ROCK TYPE ÄSPÖ
- Fine-grained granite 511058
- Äspö diorite 501037
- Fine-grained diorite-gabbro 505102

ROCK ALTERATION
- Oxidized

DZ CONFIDENCE LEVEL
- Confidence 3

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FOR KI0023B
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154.30
154.30
RU2b For description see text in report or in SICADA
159.53
159.53
RU1c For description see text in report or in SICADA
200.71
DZ1
FOR KI0023B
165.00
DZ1 For description see text in report or in SICADA
170.90

Appendix 20

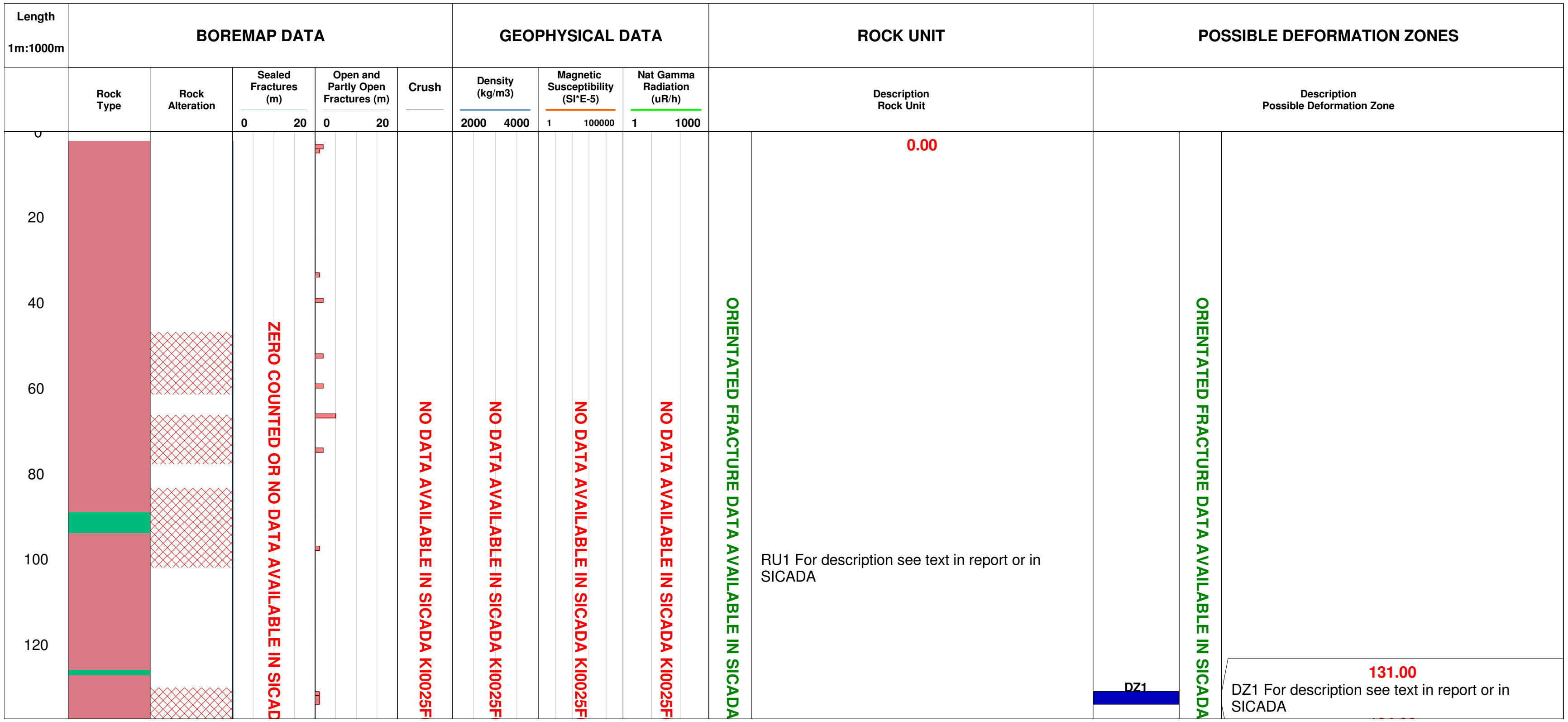
Geological single-hole interpretation of KI0025F02

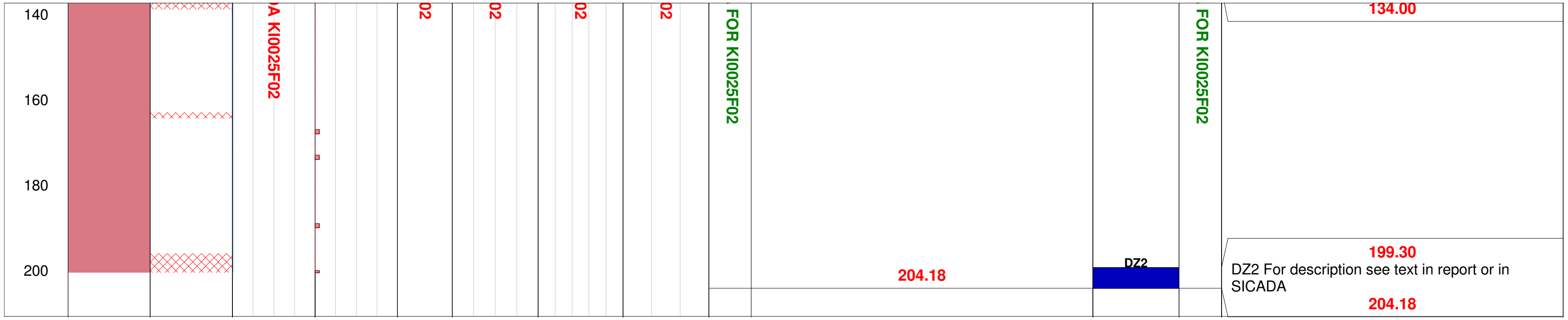
Title	SINGLE HOLE INTERPRETATION KI0025F02					SIGNED DATA	YES
Site	ÄSPÖ	Inclination [°]	-25.47	Elevation [m.a.s.l.]	-448.52	Strike Reference	ÄSPÖ96
Borehole	KI0025F02	Date of mapping	1998-09-30 16:18:00	Drilling Start Date	1998-08-10 09:14:00	Made By	PKM
Diameter [mm]	76	Coordinate System	ÄSPÖ96	Drilling Stop Date	1998-08-25 10:20:00	SHI Light GE299	
						Mapping Type	GE036
Length [m]	204.180	Northing [m]	7238.49	Surveying Date	1998-09-04 14:00:00		
Bearing [°]	199.97	Easting [m]	1952.75	Plot Date	2015-06-08 02:01:34		

ROCK TYPE ÄSPÖ
- Äspö diorite 501037
- Fine-grained diorite-gabbro 505102

ROCK ALTERATION
- Oxidized

DZ CONFIDENCE LEVEL
- Confidence 3

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160
180
200
A KI0025F02
02
02
02
02
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204.18
DZ2
FOR KI0025F02
134.00
199.30
DZ2 For description see text in report or in SICADA
204.18