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Äspö Hard Rock Laboratory

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Abstract

Two boreholes KA2051A01 and KA3007A01 were core drilled in the Äspö Hard Rock Laboratory (Äspö HRL) in 2011 as a part of the pre-investigation for the project TUDP002 "Expansion of Äspö HRL 2011–2012". The result from the Boremap mapping of the two boreholes is presented in this report. Borehole KA2051A01 started in NASA2050A and has a length of 319.84 m, with bearing 86.62° and inclination –35.01°, while borehole KA3007A01 started in NASA3009A and has a length of 227.76 m, with bearing 22.16° and inclination –14.35°. The coordinate system used is ÄSPÖ96. The purpose of the location and orientation of the boreholes is to investigate the bedrock as part of the pre-investigation for the placement of the new tunnels at the Äspö HRL.

The geological mapping is done according to the Boremap method, which is based on simultaneous study of drill core and borehole image (BIPS). The section between 219.39–227.48 m of drill core KA3007A01 was mapped in Boremap without BIPS-image.

The dominating rock types of borehole KA2051A01 is porphyritic Äspö diorite and Ävrö granodiorite which make up approximately 47 and 27% of the mapped interval respectively. The third main rock type which is also frequent as rock occurrences (< 1 m wide, dykes and/or veins) cutting other rock types throughout the borehole is fine-grained granite making up approximately 16% of the rock volume. Lastly, approximately 8% consists of Diorite-gabbro. Subordinate rock types are Pegmatite, Gabbroid-dioritoid, Hybrid rock and Quartz-dominated hydrothermal vein/segregation.

Alteration in the form of red staining (oxidation) occurs in approximately 63% of the core and epidotization in approximately 37%. The total number of mapped fractures is 2,579. They are divided into open fractures (3.8 fractures/meter), sealed fractures (4.2 fractures/meter) and partly open fractures (approximately 0.05 fractures/meter).

Structural observations in borehole KA2051A01 include cataclastic structures, sealed networks, breccia, thin (< 1 cm wide) brittle-ductile shear zones and foliations.

KA3007A01 is dominated by Äspö diorite, constituting 55% of the rock in the core. Ävrö granodiorite is the second most common rock type occupying 27% of the mapped interval. The third main rock type is fine-grained granite making up approximately 16% of the borehole rock volume. Lastly, approximately 8% of the core consists of Gabbroid-dioritoid. Subordinate rock types are Pegmatite dykes and veins (slightly more than 1%) as well as Hybrid rock (just under 1%).

Alteration in the form of red staining (oxidation) occurs in approximately 59% of the core and epidotization in approximately 41%.

Structural observations in borehole KA3007A01 include crush zones, cataclastic structures, sealed networks, breccia, brittle-ductile shear zones, ductile shear zone and foliations.

Sammanfattning

SKB bestämde 2010 att sätta igång projektet TUDP002 ”Utbyggnad Äspölaboratoriet 2011–2012” Som en del i förundersökningen inför projektet borrades två kärnborrhål, KA2051A01 och KA3007A01. Denna rapport presenterar resultatet från en Boremap-kartering av de två borrhålen. Påslaget för borrhål KA2051A01 är i nischen NASA2050A. Längden är 319,84 m, den har riktning 86,62° och stupning –35,01°. Påslaget för borrhål KA3007A01 är i nischen NASA3009A. Hålet är 227,76 m långt, med riktning 22,16° och stupning –14,35°. Koordinatsystemet som används är ÄSPÖ96. Placering och orientering av borrhålen är ett led i förundersökningen inför placeringen av dom nya tunnlarna i Äspölaboratoriet.

Den geologiska karteringen äger rum enligt Boremap-metoden som bygger på en samtidig studie av borrkärnan samt en bild av borrhålsväggarna (BIPS), förutom i borrhål KA3007A01 där borrkärnan mellan 219,39–227,48 m karterades utan BIPS-bild.

I borrhål KA2051A01 är de dominerande bergarterna porfyrisk Äspödiorit (47 % av kärnan) och Ävrö granodiorit (27 % av kärnan). Den tredje vanligaste är en finkornig granit (16 % av kärnan) som ofta även förekommer som klippande gångar och/eller ådror (< 1 m breda) i hela borrhålet. Till slut kommer en diorit-gabbro, den utgör cirka 8 % av kärnan. De bergarter som förekommer i små mängder är pegmatit, gabbroid-dioritoid, hybrid bergart och kvarts dominerad hydrothermal ådra/segregation.

Omvandling i form av rödfärgning (oxidering) förekommer i cirka 63 % av kärnan och epidotisering utgör cirka 37 %. Det totala antalet karterade sprickor i borrhålet uppgår till 2 579, de är uppdelade i öppna sprickor (3,8 sprickor/meter), stängda sprickor (4,2 spr./m) och delvis öppna sprickor (cirka 0,05 spr./m).

Strukturobservationer i borrhål KA2051A01 inkluderar kataklastiska strukturer, stängda nätverk, breccia, tunna (< 1 cm breda) spröda till plastiska skjuvzoner och foliering.

KA3007A01 domineras (55 %) av porfyritisk Äspödiorit. Ävrögranodiorit utgör 27 %. Finkornig granit utgör cirka 16 % av borrkärnan. Slutligen, cirka 8 % av kärnan utgörs av gabbroid-dioritoid. De bergarter som förekommer i små mängder är pegmatitgångar och ådror (lite över 1 %) samt hybrid bergart (strax under 1 %).

Omvandling i form av rödfärgning (oxidering) förekommer i cirka 59 % av kärnan och epidotisering utgör cirka 41 %.

Strukturobservationer i borrhål KA3007A01 inkluderar krosszoner, kataklastiska strukturer, stängda nätverk, breccia, spröda till plastiska skjuvzoner, plastiska skjuvzoner och foliering.

Contents

1 Introduction

This report gives a brief presentation of the data gained from the mapping of boreholes KA2051A01 and KA3007A01, which is as a part of the project TUDP002 "Expansion of Äspö HRL 2011–2012". After completion both boreholes were BIPS-logged and mapped according to the Boremap method. This document reports data gained by the Boremap mapping. The work was carried out in accordance with activity plan AP TD TUDP002-11-012. Controlling documents for the execution of this activity are listed in Table 1-1. Both activity plan and method descriptions are SKB's internal controlling documents. Rock type nomenclature that has been used is shown in Table 1-2.

The bearing, inclination and length of each borehole, as well as the identification tag of the niches that they were drilled from can be seen in Table 1-3, while the location of the two boreholes can be seen in Figure 1-1.

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

Activity plan	Number	Version
Äspö utbyggnad, DP1-Karakterisering – Boremap-kartering av KA2051A01 och KA3007A01.	AP TD TUDP002-11-012	1.0
Method descriptions	**Number**	**Version**
Nomenklatur vid Boremap-kartering.	SKB MD 143.008	1.0
Method Description for Boremap mapping.	SKB MD 143.006	3.0
Mätsystembeskrivning för Boremap.	SKB MD 146.005	1.0
Instruktion: Regler för bergarters benämningar vid platsundersökning I Oskarshamn.	SKB MD 132.004	3.0
Instruktion för längdkalibrering vid undersökningar i kärnborrhål.	SKB MD 620.010	2.0

Table 1-2. The rock nomenclature (rock types and rock occurrences) used in the Boremap mapping.

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 monzodiorite to granodiorite, equigranular to sparsely porphyritic
Diorite-gabbro	501033	Diorite to gabbro
Fine-grained dioritoid	501030	Intermediate rock, fine-grained
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

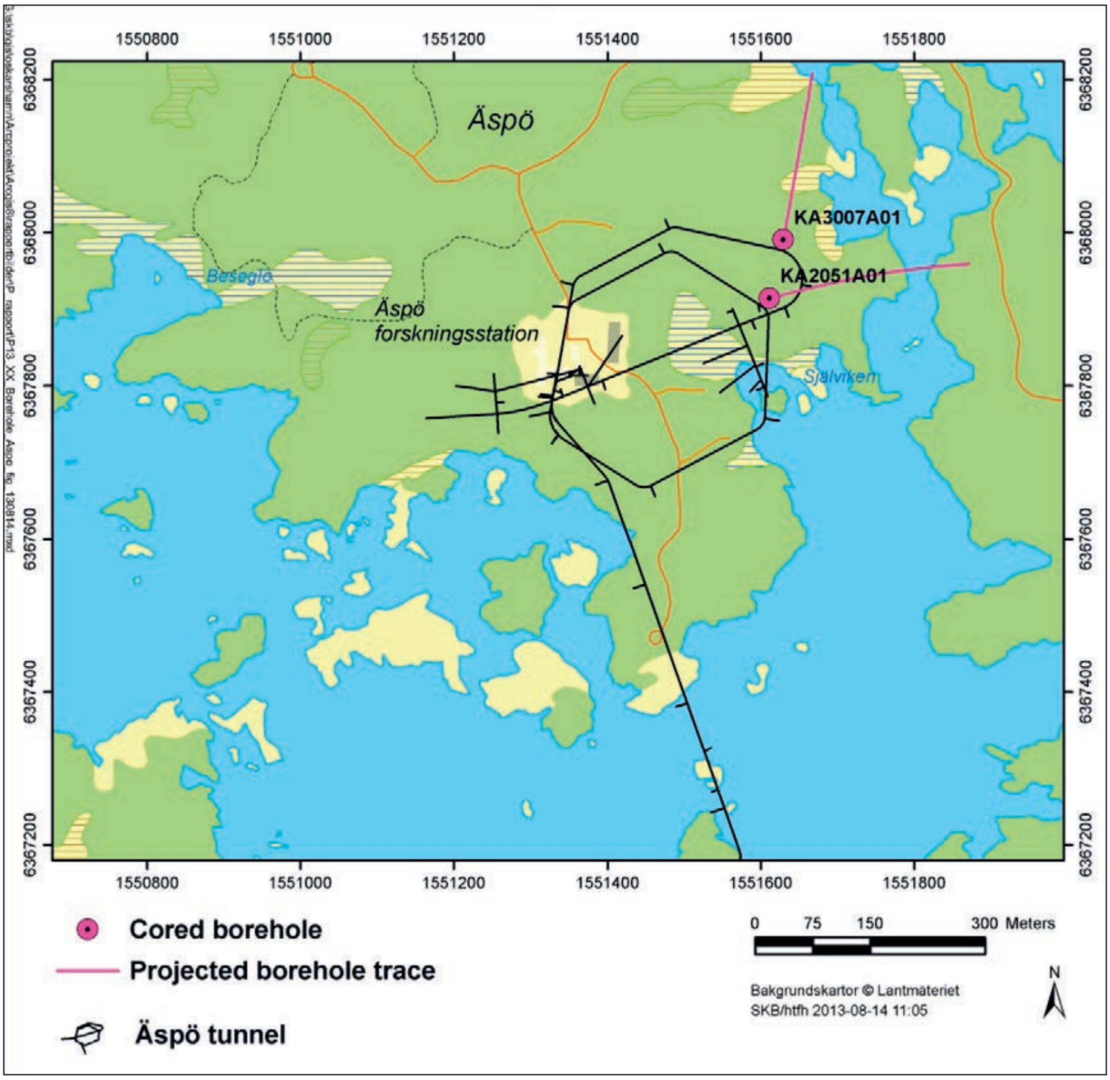


Figure 1-1. Map showing the position of the cored boreholes KA2051A01 and KA3007A01.

Table 1-3. Bearing, inclination, length as well as niche ID from where the collaring of the boreholes KA2051A01 and KA3007A01 took place. The coordinate system of the bearing is Äspö96.

	KA2051A01	KA3007A01
Bearing (ÄSPÖ 96)	86.62°	22.16°
Inclination	–35.01°	–14.35°
Length	319.84 m	227.76 m
Niche	NASA2050A	NASA3009A

The Boremap mapping method is based on combined information from detailed drill core logging and BIPS-image (Borehole Image Processing System) of the borehole wall. Petrographical (rock types, rock occurrences and alteration) and structural (fractures, crush zones and ductile deformation) information is obtained. In addition the Boremap mapping software calculates the orientation (strike and dip) of each marked planar feature in the borehole using information from the BIPS-image and borehole surveying. Aperture and widths of fractures are estimated, as well as the roughness of broken (open) fracture surfaces (ISRM 1978). In addition, all identified minerals that fill fractures are listed.

All data were stored in the primary SKB database Sicada (Site Characterisation Database) and are traceable by the activity plan number.

2 Objective and scope

The principal aim of the mapping activity presented in this report is to obtain a documentation of geological structures and lithologies intersecting boreholes KA2051A01 and KA3007A01. Geological structures will be correctly orientated in space along the borehole with the Boremap system. All orientations are related to Äspö96.

3 Equipment

3.1 Description of software

Mapping of drill core with BIPS-images according to the Boremap method is done on a desktop computer using the software Boremap (version 4.1.5.0), which shows the video image from BIPS (Borehole Image Processing System) and extracts the geometrical parameters: length, width, strike and dip from the image, as can be seen in Figure 3-1.

The length registered in the BIPS-image is adjusted using the core length of easily recognisable structures in both core and BIPS-image, in the upper and lower-parts of the BIPS-image. The diameter and orientation (bearing and inclination) of the borehole is the basis for calculating the strike and dip of the mapped planar structures. Data from deviation measurements (Maxibor and Flexit) are imported from Sicada and used by the Boremap software to correct for changes in direction of the boreholes with length.

The final data presentation was made using BIPS Image Print, Dips (version 5.1), Microsoft Access, Microsoft Excel and WellCAD (version 4.2).

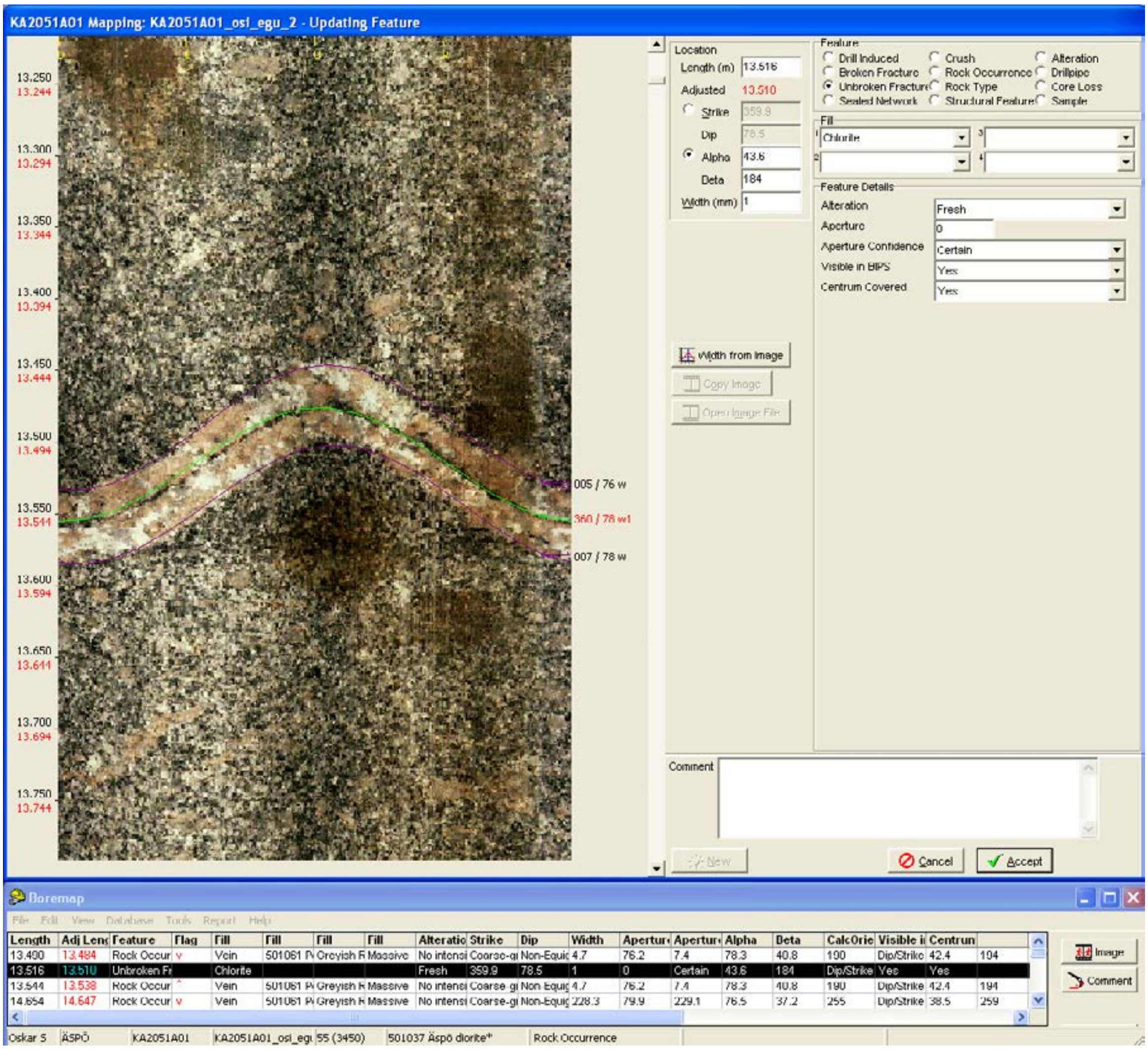


Figure 3-1. A good quality BIPS-image as it is seen in the Boremap software. Borehole KA2051A01, length 13.2–13.8 m adjusted length (red numbers), showing grey, medium grained, massive and porphyritic Äspö diorite, cut by a Pegmatite vein. The green line is logged by the geologist as a fresh, unbroken fracture filled with Chlorite.

3.2 Other equipment

For the careful mapping of the core, normal geological field equipment was used, such as a folding rule, water-filled atomizer, hand held lens, streak plate (a piece of white, unglazed porcelain), small magnet, hydrochloric acid (HCl 10% solution), knife and a pencil. When needed a Zeiss Stemi DV4 (magnification 8X-32X) stereomicroscope is available for studying minor fracture fillings, as well as a Susceptibility meter (SM20 from GF instruments) to measure the magnetic susceptibility of the rock types in the drill core.

3.3 BIPS-image video film sequences

The BIPS-image (Gustafsson 2013) of KA2051A01 covers the interval 4.0–319.6 m (adjusted length), while KA3007A01 covers the interval 3.6–218.5 m (adjusted length).

3.4 BIPS-image video film quality

The quality of the BIPS-image depends on several parameters.

- The clarity of the borehole water (i.e. the amount of material in suspension).
- The condition of the borehole walls (e.g. the amount of sedimentation and/or gauge on the borehole wall).
- The quality of the BIPS-image (i.e. the technical limitations of the image; resolution and contrast).

3.4.1 BIPS-image resolution

The BIPS-image resolution that depends on the BIPS video camera pixel size and illumination angle, will decide the minimum width of both fractures and apertures that can be seen in the BIPS-image.

3.4.2 BIPS-image contrast

The colour contrast between fractures and wall rock is important when visibility of fractures is discussed. A thinner fracture can be seen in the BIPS-image if it is of light colour in a darker rock, than if the colours of the fracture and wall rock are similar or the same. In rare cases, when the BIPS-image contrast is strong between a thin fracture and the surrounding rock, the fracture might be visible in the BIPS-image even if it is not visible in the drill core.

3.4.3 BIPS-image quality

The varying quality of the BIPS-images for boreholes KA2051A01 and KA3007A01 is caused by various disturbances, such as:

- Brownish to reddish-brown coatings on the borehole walls, probably rests of grout.
- Vertical bleached bands, probably a mixture of drill cuttings and water.
- Occasional vertical enlargements of pixels, due to stick-slip movement of the BIPS camera probe.

The image quality is divided into four classes:

- Good – the image is mainly clear and easy to interpret.
- Acceptable – the mapping can be performed without problems.
- Bad – image is somewhat difficult to interpret.
- Very bad – image cannot be interpreted and only very obvious and outstanding features can be mapped.

It should be remembered that even if only 10–20% of the image is visible it is normally enough for an acceptable interpretation. When the BIPS-image quality is so bad that fractures and structures cannot be identified in the BIPS-image, they can still be oriented using the guide-line method (Section 4.3.3). The BIPS-image quality for KA2051A01 and KA3007A01 is presented in Tables 3-1 and 3-2.

Table 3-1. BIPS-image quality of borehole KA2051A01 (lengths are not adjusted).

Sec Up (m)	Sec Low (m)	Interval (m)	Quality
4.00	5.40	1.40	Acceptable
5.40	63.00	57.60	Good
63.00	112.00	49.00	Acceptable – bad
112.00	212.00	100.00	Good – acceptable
212.00	280.00	68.00	Good
280.00	318.24	38.24	Good

Table 3-2. BIPS-image quality of borehole KA3007A01(lengths are not adjusted).

Sec Up (m)	Sec Low (m)	Interval (m)	Quality
3.59	84.40	80.81	Acceptable – bad
84.40	90.00	5.60	Good – acceptable
90.00	130.00	40.00	Acceptable
130.00	200.00	70.00	Good – acceptable
200.00	217.97	17.97	Good

4 Execution

4.1 General

The Boremap-BIPS mapping of the core drilled boreholes KA2051A01 and KA3007A01 is performed and documented in accordance with activity plan AP TD TUDP002-11-012 (SKB internal document). The mapping was performed in accordance with the current SKB method descriptions, as listed in Table 1-1.

Each drill core was displayed on inclined roller tables in its entire length and mapped with the Boremap system at the SKB core-logging facility in Oskarshamn. The core mapping was carried out with the support of generalized geophysical logs and rock samples.

The mapping was performed by Oskar Sigurdsson (H Ask Geokonsult AB), as well as Allan Stråhle, Eva Selnert and Eva Samuelsson (Geosigma AB).

4.2 Preparations

Any depth registered in the BIPS-image deviates from the true depth in the borehole, a deviation which increases with depth. This problem was minimized by adjusting the depth according to the core length to clearly visible rock contacts in the borehole as well as other clearly recognizable features in both BIPS-image and core.

The different orientations of the observations were adjusted to true space. Data necessary for this adjustment are borehole bearing, inclination, diameter; length and deviation, all collected from the Sicada database.

4.3 Execution of measurements

Concepts used during the mapping of the core, are defined in this chapter.

The first approximately 3 m of both KA2051A01 and KA3007A01 have casing and have therefore no BIPS-image. At the bottom of KA3007A1 approximately 9.3 m of the borehole are without BIPS-image. See Table 4-1 for lengths of core and BIPS-images.

The borehole lengths that are not BIPS-logged can be mapped with the Boremap system. But, without the BIPS-image, orientations for planar structures can only be obtained if the core outside the BIPS-image can be fitted together with the oriented part of the core. This is not possible for the first meters of core (the casing) in both boreholes KA2051A01 and KA3007A01. The core is too broken up to be fitted together. On the other hand the lowest part of both boreholes can to a varying degree be fitted together. Therefore, approximately 8 m of borehole KA3007A01 is mapped in Boremap without BIPS-image.

Table 4-1. Lengths of core with core diameter and lengths of BIPS-images with measured lengths and adjusted lengths, of boreholes KA2051A01 and KA3007A01.

	KA2051A01	KA3007A01
Core with diameter 0.08 m		0–3.04 m
Core with diameter 0.050 m		3.04–227.76 m
Core with diameter 0.1 m	0–3.1 m	
Core with diameter 0.0502 m	3.1–319.84 m	
BIPS-image measured length	4.0–318.15	3.58–217.979 m
BIPS-image adjusted length	4.0–319.6	3.58–218.5 m

4.3.1 Fracture definitions

Definition of different fracture types (broken and unbroken) as well as crush and sealed fracture networks are found in SKB MD 143.006 “Metodbeskrivning för Boremap-kartering” (Method description for Boremap mapping) and SKB MD 143.008 “Nomenklatur vid Boremap-kartering” (Boremap logging nomenclature). Both are internal SKB documents.

Fractures are mapped as broken if they split the core and unbroken if they do not. All fractures are described with width, mineral fillings and alteration. Broken fractures have in addition the attributes roughness and surface. The resolution of the BIPS-image allows fractures down to 1 mm wide to be measured in the image Thinner fractures are denoted a value of 0.5 mm. The same principle is used for measuring apertures of open fractures, the reliability or aperture confidence is estimated according to the following:

- Certain – aperture is visible in BIPS-image and measureable to 1 mm or larger.
- Probable – core bits do not fit perfectly, aperture is given the value 0.5 mm.
- Possible – altered fracture surface, aperture is given the value 0.5 mm.

Unbroken fractures that have visible apertures are categorised as partly open fractures.

Cataclastic structures are here mapped as structural parameters within the Boremap parameter rock occurrence, which has an upper and lower contact. Usually these rock occurrences are dominated by green Epidote matrix with various amounts of clasts, normally consisting of the same rock as the designated rock occurrence. Strike and dip of the cataclastic structure is obtained by setting it as a structural parameter within the rock occurrence.

4.3.2 Fracture alteration and joint alteration number

The joint alteration number for a fracture is mainly related to the width of the mineral fillings and their clay content. Thicker fractures rich in clay minerals get joint alteration numbers 2–3, while the majority of fractures which are very thin to extremely thin and seldom contain clay minerals receive joint alteration numbers between 1 and 2.

- **Joint alteration 1** – Fractures without wall rock alterations and with no mineral filings are considered fresh. The same goes for fractures that have wall rock alteration of e.g. oxidation (red colouring) or epidotization. The fracture filling minerals Calcite, Quartz, Fluorite, Zeolites (e.g. Laumontite) and sulphides are considered to be deposited in broken fractures by circulating water-rich solutions and not fracture alteration minerals. The joint alteration number is therefore set to 1 for these minerals.
- **Joint alteration 1.5** – The fracture filling minerals Epidote, Prehnite, Hematite, Chlorite and/or clay minerals are considered to be mainly resulting from altered wall rock material. A weak alteration is thus assumed and the joint alteration number is set to 1.5. The thickness of the clay minerals is important since their occurrence often results in a higher joint alteration number.
- **Joint alteration > 1.5** – If fracture filling minerals are a few mm wide bands of clay minerals often together with Epidote and Chlorite, the joint alteration number is set to 2. In rare cases, when a fracture contains 5–10 mm thick clay-rich bands, together with e.g. Chlorite, the joint alteration number is set to 3.

4.3.3 Mapping of fractures not visible in the BIPS-image

Fractures that are not visible in the BIPS-image are orientated by using the guide-line method (Ehrenborg and Dahlin 2005), based on the following data:

- Adjusted borehole length (depth).
- Amplitude (the interval from the uppermost to the lowermost extreme of a fracture measured along the drill core).
- The relation between the orientations of the fracture trace measured on the drill core and a well defined structure that is visible in both the BIPS-image and drill core.

The error in fracture orientations using the guide line method is unknown, but estimated to be negligible. It is considered better than the alternative, which is to mark all fractures not visible in the BIPS-image as planes perpendicular to the borehole. All fractures are marked as either visible in BIPS or not in the Boremap mapping, which makes it possible to separate the two.

Correction for the difference between the core and borehole wall diameter are made for each fracture, as the BIPS-image represents the borehole wall, with its larger diameter than the core. The difference in adjusted borehole length between core and borehole wall is zero for structures that cut the core at right angles. This difference increases as the orientation of the structure approximates the core axis.

The following steps describe mapping of structures with the guide line method:

- The structure is drawn on the BIPS-image as a structure trace (e.g. the green line in Figure 3-1) and the amplitude of the structure in the core is corrected to the higher value in the BIPS-image.
- The structure trace is rotated in the BIPS-image to the correct position relative to a feature with known orientation (strike and dip).
- The structure trace is moved to the adjusted length in the BIPS-image, in accordance with the length measured on the drill core.

This method is often used when two are Boremap-BIPS mapping, whether or not the structure is visible in the BIPS-image, as it clarifies exactly which structure is being mapped (amplitude, orientation compared to known structure and length).

4.3.4 Definition of veins and dykes

Rock occurrences that are less than 20 cm wide are defined as veins, while those between 20 and 100 cm are called dykes.

4.3.5 Fracture fillings and mineral codes

Fracture fillings are noted in order of decreasing abundance; if there are more than four minerals identified they are noted in the comment field. The identification and abundance of each mineral is subjective and is decided by ocular observations which could result in possible misrepresentation of certain minerals depending on their visibility and distribution in the fracture as well as whether the fracture is open or closed.

When mineral fillings that are not represented in the mineral list of Boremap occur in the drill core they are represented with an X and explanation in the comment. Only one such occasion occurred, it was in borehole KA3007A01 where the code X1 stands for grout (light grey).

4.3.6 Alteration intensity and intensity of structural type

The intensity of the alteration is estimated and varies from fresh to completely altered rock, where all the original minerals have been altered to secondary minerals. In this report intensities of oxidation (red colouring) vary from faint to medium, while epidotization has been mapped in all four alteration stages from faint to strong:

- Faint: Very weakly developed alteration, e.g. in the case of oxidation a slight red colouring of some mineral grains in an otherwise grey rock, and in the case of epidotization occasional mineral grains show green colouring.
- Weak: Clearly developed alteration, e.g. in the case of oxidation most of the mineral grains in the rock show red colouring and in the case of epidotization most mineral grains show green colouring.
- Medium: Strongly developed alteration, e.g. in the case of oxidation the rock has a strong red colour and in the case of epidotization the rock seems dominated by secondary minerals and has become greyish green in colour.
- Strong: Very strongly developed alteration, e.g. in the case of epidotization the whole rock seems to be made up of secondary minerals, usually mostly Epidote and Chlorite.

Structural intensity varies somewhat depending on the type of structure, but in general the estimations within marked areas containing the mapped structures foliation and/or ductile zones are made as follows:

- Weak: Clearly developed structure, usually as parallel orientation of many or most of the mineral grains.
- Medium: Strongly developed structure, most of the mineral grains very clearly show parallel orientation.
- Strong: Very strongly developed structure, all mineral grains show very strong parallel orientation.

4.4 Data handling

The Boremap mapping is performed on a desktop computer connected to the SKB network at SKB's core storage facility in Oskarshamn. Before every break (> 15 minutes) a back-up is saved on the local disk as well as at the end of each day after being checked by the mapping geologists.

The mapping is also checked by a computer routine in the Boremap program before it is exported to and archived in the Sicada database. Personnel from SKB also perform spot test controls and regular quality revisions.

All primary data is stored in SKB's database Sicada. Only these data are to be used for further interpretation and modelling.

5 Results

Below is a short summary of the results from the Boremap mapping for boreholes KA2051A01 and KA3007A01. More general information can be found in the Appendix 1 and Appendix 2. WellCad diagrams are shown in Appendix A1.1 and A2.1. BIPS-images of KA2051A01 and KA3007A01 (Gustafsson 2013) are shown in Appendix A1.2 and Appenix A2.2 and stereonets and rose-diagrams of all logged fractures, all open fractures, all closed fractures, sealed networks and cataclastic structures are shown in Appendix A1.3 and Appendix A2.3 for each borehole respectively.

Some screen dumps from the core logging using the Boremap software with BIPS-image are shown in Figures 5-1 through 5-4. The percentages of different lithologies are given in Tables 5-1 and 5-2.

Various portions of the rock show red staining (oxidation) as well as green staining (epidotization). Table 5-3 shows the distribution as well as the intensity of the staining. In this Boremap mapping the alteration intensity was defined as faint when the red- and/or green- staining could be observed in the core, weak when red- and/or green- staining was clear but did not dominate the original rock colour in the core and medium when the red- and/or green- staining dominated over the original rock colour.

Table 5-4 shows the number of fractures in the mapped boreholes (open, sealed and partly open fractures) and the average fracture frequency per meter. Crush zones mapped from the cores and BIPS-image are shown in Table 5-5. There the borehole length to the upper contact, width of each zone, the average piece length and the strike and dip of the upper contact are listed.

Table 5-6 lists the number and direction of the cataclastic structures mapped in the two boreholes. Also the average width of the rock occurrence that contains the cataclastic structure parameter is given as well as the average strike and dip of the designated cataclastic structure within each rock occurrence containing the cataclastic structure.

Table 5-7 shows the number of sealed networks mapped in the boreholes, along with the average width and orientation of upper contact.

Tables 5-8 and 5-9 list the mapped structures of the two boreholes. They are divided into foliation, brecciation, brittle-ductile shear zones and cataclastic structures. Their total number, intensity, average widths and average direction is also indicated.

Results from geophysical measurements made in boreholes KA2051A01 and KA3007A01 were used as support to the Boremap mapping of the cores, especially when it came to rock types (Mattsson 2013, Nielsen and Ringgaard 2013). The difference in density between Ävrö granodiorite and Äspö diorite is quite distinct when looking at Silicate density logs. This is also the case for Diorite-gabbro in borehole KA2051A01 and for Gabbroid-dioritoid in borehole KA3007A01. These mafic rock types are also noticeably lower in magnetic susceptibility, which is also the case for the fine grained Granites occurring in both boreholes. Natural gamma radiation is generally somewhat higher in the fine grained Granites.

5.1 KA2051A01

See Appendix A1.1 for a WellCAD graphic presentation of mapping results. The BIPS-image of the borehole is shown in Appendix A1.2 and the orientations of all the logged fractures, open and closed fractures (broken and unbroken fractures), sealed networks and cataclastic structures are illustrated in Appendix A1.3.

5.1.1 Lithology

The dominant rock type is Äspö diorite, often containing fragments (xenoliths) consisting of fine-grained Gabbroid-dioritoid. Other dominating rock types are Ävrö granodiorite, fine-grained granite and Diorite-gabbro. All rock types are cut by fine-grained granite as well as minor dykes and veins consisting of both fine-grained granite and Pegmatites. One approximately 0.5 m long occurrence of hybrid rock as well as an approximately 3 cm wide Quartz-dominated hydrothermal vein/segregation is also mapped in the Boremap mapping (Figure 5-1 and Table 5-1).

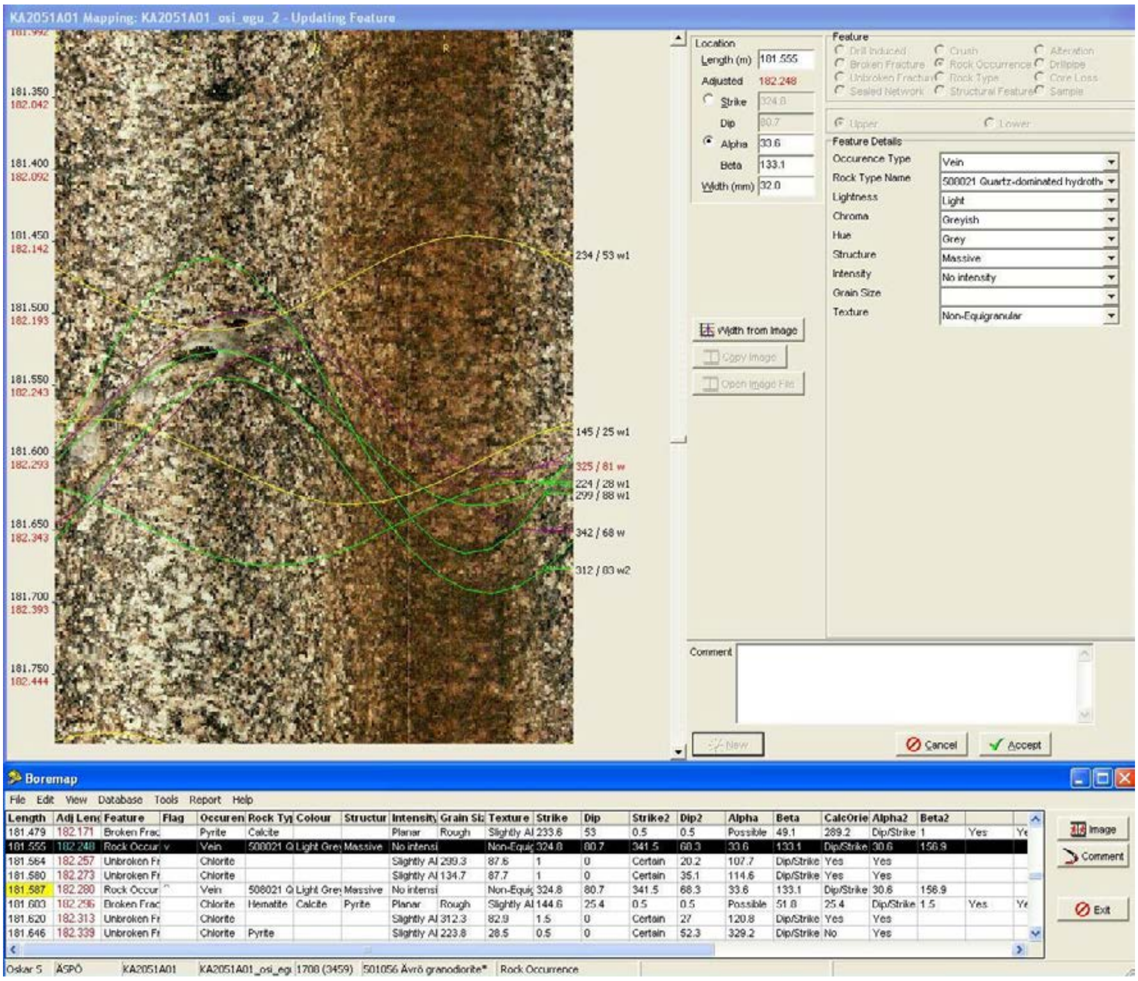


Figure 5-1. A good quality BIPS-image as it is seen in the Boremap software. Borehole KA2051A01, 182.042–182.444 m adjusted length (red numbers), showing light reddish grey, medium grained, massive and equigranular Ävrö granodiorite, cut by a Quartz-dominated hydrothermal vein/segregation. The green lines are logged by the geologist as a slightly altered, unbroken fractures filled with Chlorite. The yellow lines are on the other hand logged as planar, rough and slightly altered broken fractures filled with Chlorite, Hematite, Calcite and Pyrite.

Table 5-1. Lithology of KA2051A01, rock types and rock occurrences. Percents calculated from adjusted length of BIPS-image.

Rock name	SKB rock code	%
Äspö diorite	501037	46.55
Ävrö granodiorite	501056	27.84
Fine-grained granite	511058	15.72
Diorite-gabbro	501033	7.92
Pegmatite	501061	1.43
Gabbroid-dioritoid	508107	0.36
Hybrid rock	505105	0.16
Quartz-dominated hydrothermal vein/segregation	508021	0.01

5.1.2 Alteration

Alteration in the form of red staining (oxidation) occurs in ca 63% of the core (approximately 58% is weak and 5% is of medium intensity) and in the form of epidotization ca 37% (see Table 5-3 and Appendix A1.1). Approximately 16% of the epidotization is weak, 17% is of medium intensity and 4% is strong (see Appendix A1.1). The main concentration of the epidotization is in connection with the rock type Diorite-gabbro, Figure 5-2.

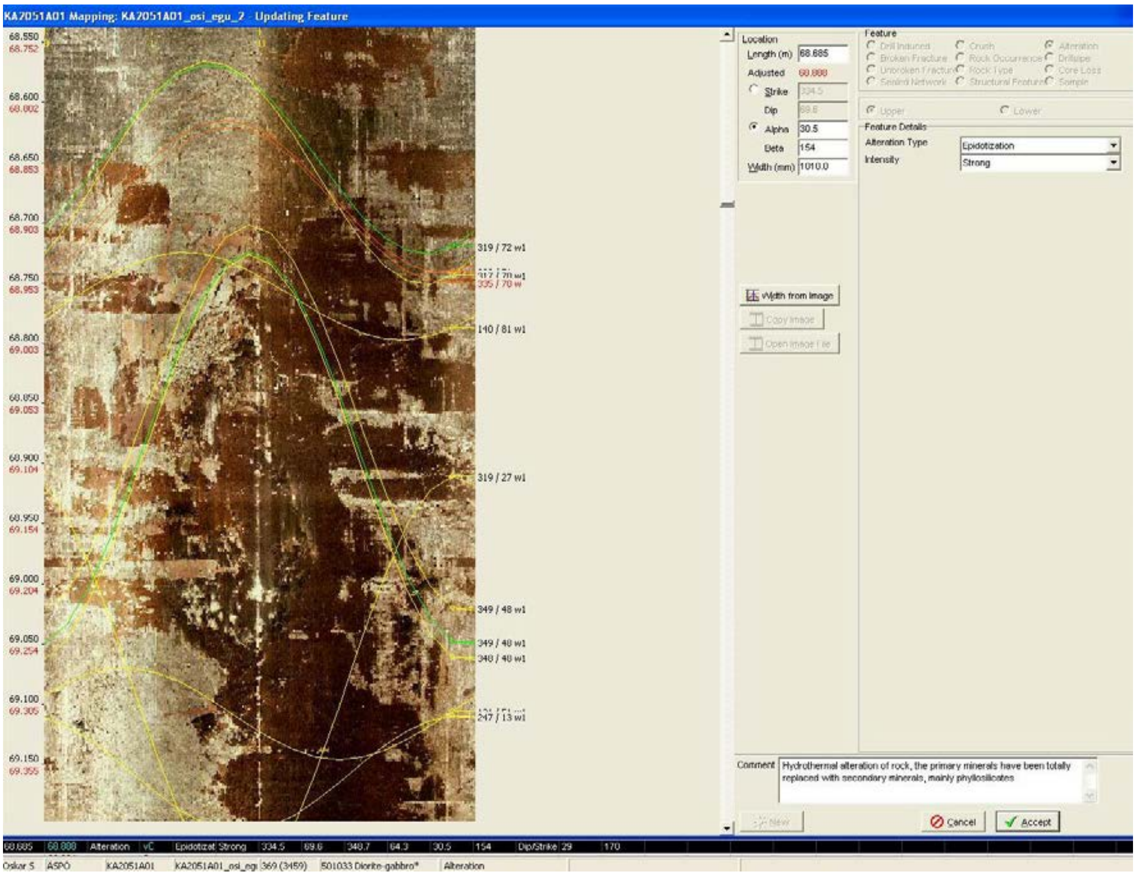


Figure 5-2. *An acceptable poor quality BIPS-image (because of grout on the borehole walls) as it is seen in the Boremap software. Borehole KA2051A01, 68.752–69.355 m adjusted length (red numbers), showing hydrothermally altered Diorite-gabbro. The alteration type chosen is epidotization with the intensity set to medium in the uppermost part (down to approximately 68.881 m, the uppermost red line), i.e. most of the primary minerals have been replaced with secondary minerals, mainly phyllosilicates. Below approximately 68.888 m the figure shows strong intensity, there the primary minerals have been totally replaced with secondary minerals. Green lines are logged by the geologist as unbroken fractures and yellow lines as broken fractures, both are filled with Calcite.*

5.1.3 Fractures

The total number of mapped fractures are 2,579, which can be divided into 1,229 broken fractures (average of 3.9 per meter) and 1,350 unbroken fractures (average of 4.3 per meter). The fractures can also be divided into 1,229 open fractures, resulting in an average of 3.9 per meter, 1,335 sealed fractures (4.2 per/meter) and 15 partly open fractures (approximately 0.05 per meter) see Table 5-4.

5.1.4 Structures

No crush zones were observed in borehole KA2051A01 (see Table 5-5). The numbers of mapped cataclastic structures are 61 with an average width of 4 cm (see Table 5-6), while the number of sealed networks are 55 with average width of 39 cm (see Table 5-7).

Other observed structures in the borehole are breccias, brittle-ductile shear zones and foliations, shown in Table 5-8.

Two of the breccias occur in the lower part of Diorite-gabbro that shows strong alteration (epidotization) as in Figure 5-2, with an average strike/dip of: 346/75. The following breccia observations occur at irregular intervals further down hole, the average strike/dip of five measurements is: 138/82. The two observations at approximately 228 and 245 m borehole length in Äspö diorite show an average strike/dip of: 212/70.

The uppermost of the three brittle-ductile shear zones is very thin (less than 1 cm wide) with strike/dip: 176/60 and the lower two are between 10 and 15 cm wide with an average strike/dip of: 136/59.

The uppermost mapped foliation is in close proximity to an open fracture with strike/dip: 134/58. The next two are in a foliated fine-grained granite dike cut by a thin Pegmatite (see Figure 5-3) with average strike/dip: 32/48. The foliation at approximately 68 m borehole length is in the upper part of Diorite-gabbro with strike/dip: 340/72. The foliation at approximately 265 m borehole length with strike/dip: 156/89 is within Äspö diorite. The foliation at 281 m is close to the contact of fine to medium grained granite affecting both the Äspö diorite as well as the granite. The three lowermost foliation observations are within the same fine to medium grained granite. All four have an average strike/dip of: 273/51.

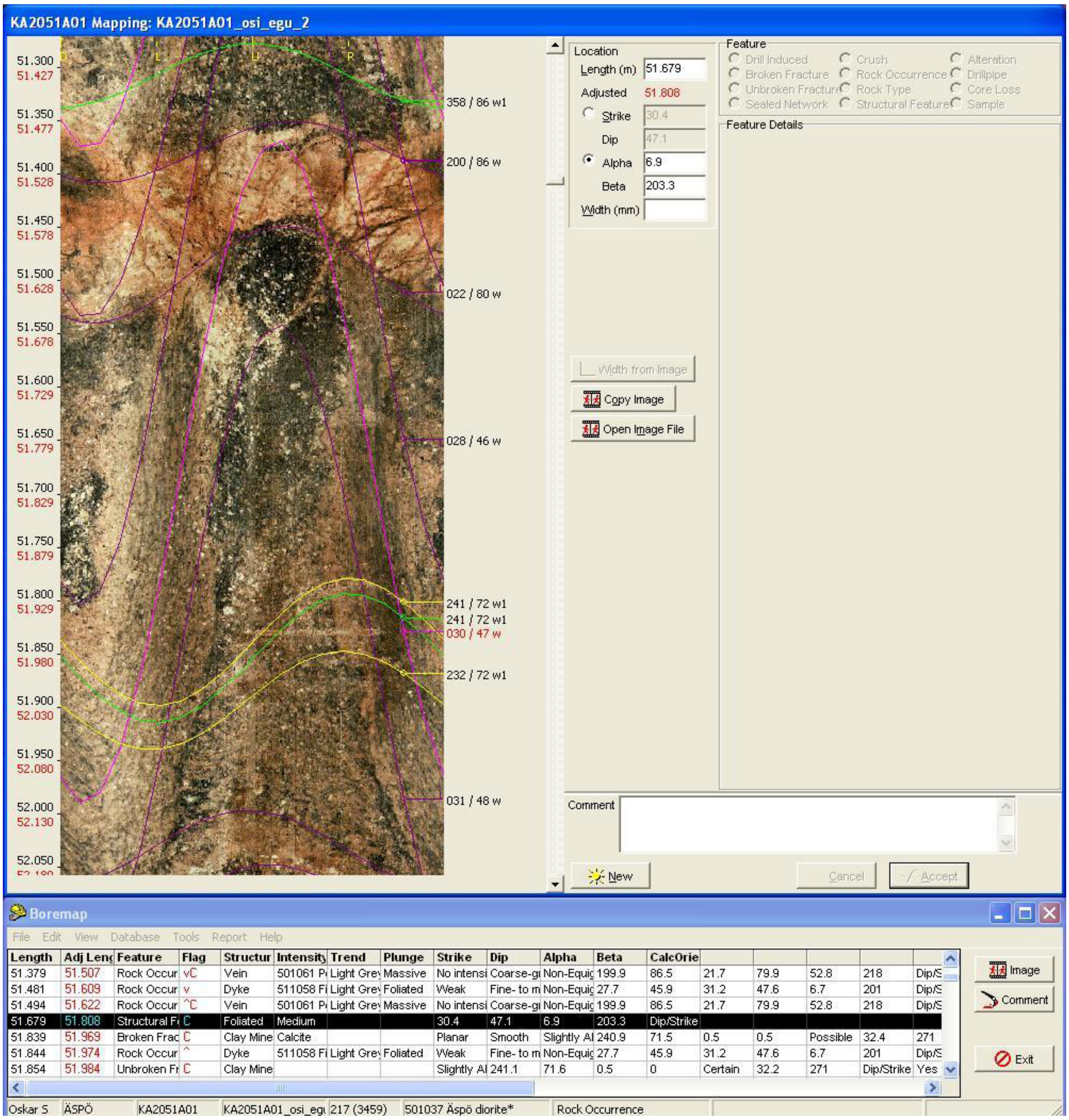


Figure 5-3. A BIPS-image of good quality as it is seen in the Boremap software. Borehole KA2051A01, 51.427–52.180 m adjusted length (red numbers), showing dark grey, medium grained, massive and porphyritic Äspö diorite, cut by a foliated fine-grained granite vein, which in turn is cut by a massive thin Pegmatite dike.

5.2 KA3007A01

See Appendix A2.1 for a WellCAD graphic presentation of mapping results. The BIPS-image of the borehole is shown in Appendix A2.2 and the orientations of all the logged fractures, open and closed fractures (broken and unbroken fractures), sealed networks and cataclastic structures are illustrated in Appendix A2.3.

5.2.1 Lithology

The dominant rock type is Äspö diorite (Figure 5-4) carrying varying minor amounts of fine-grained Gabbroid-dioritoid fragments (xenoliths). Ävrö granodiorite is also a dominating rock type, as well as fine-grained granite and to a lesser extent Gabbroid-dioritoid. All rock types are cut by fine-grained granite as well as minor dykes and veins consisting of both fine-grained granite and Pegmatites (Figure 5-2). A total of 1% hybrid rock is also mapped in the borehole (Table 5-2).

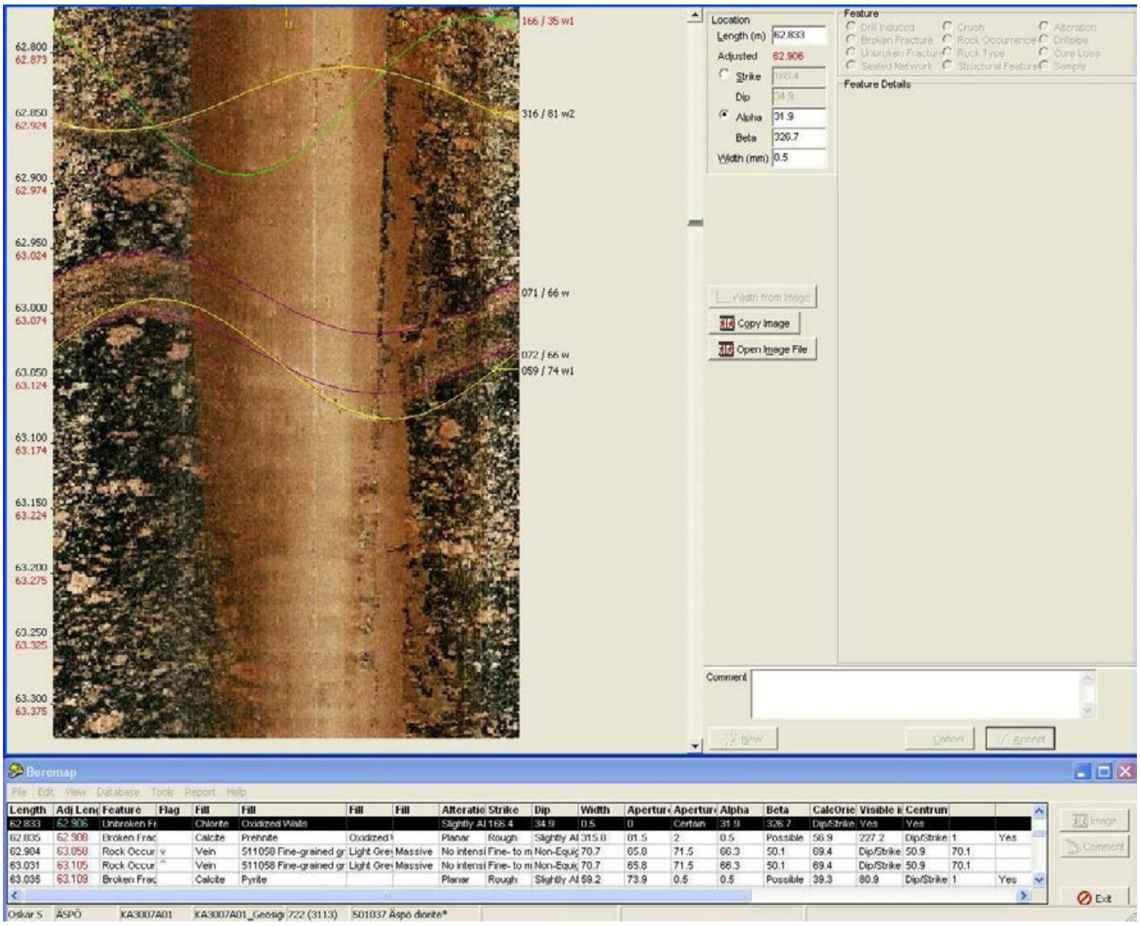


Figure 5-4. A BIPS-image of acceptable quality as it is seen in the Boremap software. Borehole KA3007A01, 62.873–63.375 m adjusted length (red numbers), showing dark reddish grey, medium grained, massive and porphyritic Äspö diorite, cut by a fine-grained granite vein. The green line is logged by the geologist as a slightly altered, unbroken fracture filled with Chlorite and with oxidized walls. The yellow lines are on the other hand logged as planar, rough and slightly altered broken fractures, the upper one is filled with Calcite and Prehnite with oxidized walls, while the lower contains Calcite and Pyrite.

Table 5-2. Lithology of KA3007A01, rock types and rock occurrences. Percents calculated from adjusted length of BIPS-image.

Rock name	SKB rock code	%
Äspö diorite	501037	51.08
Ävrö granodiorite	501056	22.54
Fine-grained granite	511058	16.94
Gabbroid-dioritoid	508107	7.36
Pegmatite	501061	1.35
Hybrid rock	505105	0.74

5.2.2 Alteration

Alteration in the form of red staining (oxidation) occurs in ca 59% of the core (approximately 45% is weak and 14% is of medium intensity) and in the form of epidotization ca 41% (see Table 5-3 and Appendix A2.1). Approximately 32% of the epidotization is weak, somewhat more than 7% is of medium intensity and less than 2% is strong (see Appendix A2.1).

5.2.3 Fractures

The total length of the mapped borehole is 223.9 m and the number of mapped fractures are 2,075, which can be divided into 1,045 broken fractures (average of 4.7 per meter) and 1,030 unbroken fractures (average of 4.6 per meter). The fractures can also be divided into 1,044 open fractures (4.4 fractures/meter), 998 sealed fractures (4.5 fractures/meter) and 33 partly open fractures (0.1 fractures/meter). In Table 5-4 the fracture count is divided into mapping with and mapping without BIPS-image. The borehole length with BIPS-image (215.8 m), have 981 mapped open fractures, resulting in an average of 4.5 per meter, 933 sealed fractures (4.3 per/meter) and 29 partly open fractures (ca 0.1 per/m). Approximately 8.1 m of the core was Boremap mapped without the BIPS-image and there the number of open fractures is 63 (7.8 per/meter), sealed fractures are 65 (8.0 per/meter) and partly open fractures 4 (0.5 per/meter), see Table 5-4.

5.2.4 Structures

Four thin crush zones were observed at core length 131.9, 151.8, 156.0 and 174.5 m. In total they are approximately 1.3 m wide, where the crush zones at 131.9 and 156.0 m make up approximately 77.7% of the total width; see Table 5-5. The number of cataclastic structures is 67 with an average width of 4 cm (see Table 5-6), while sealed networks are 47 with average width of 63 cm (see Table 5-7).

Other observed structures in the borehole are breccias, brittle-ductile shear zones, ductile shear zone and foliations, shown in Table 5-9.

There are two observations of medium intensity breccias in the borehole, one at 12.4 m borehole length with strike/dip: 117/89 and the other at 132.6 m borehole length with strike/dip: 44/48.

A brittle-ductile shear zone of strong intensity occurs at 74.5 m borehole length with strike/dip: 104/28. One medium intensity zone is located at 120,9 m borehole length with strike/dip: 58/27. It is situated just below a cataclastic band at 120.8 m and above an approximately 8 cm wide foliated band of medium intensity with strike/dip: 62/28 between 120.9–121.0 m. Within a fine grained granite between 131.6 to 131.8 m borehole length two weak intensity brittle-ductile shear zones occur at 131.7 m with strike/dip: 75/37 and at 131.8 m with strike/dip: 73/49 respectively.

One ductile shear zone is observed in borehole KA3007A07 at 131.7 m borehole length It is situated between the two brittle-ductile shear zones of weak intensity mentioned above. The ductile shear zone is of weak intensity with strike/dip: 72/52.

The foliation observations are more frequent in borehole KA3007A01 than in KA2051A01 with a dominating strike approximately 081/82, see Figure 5-5. Generally the foliation observations occur in proximity to other structural observations, as can be seen in the WellCAD presentation of Appendix A2.1. As an example the first four observed rock sections that show foliation occur between 76.5 m and 80 m borehole length include 6 measured foliations, see Table 5-9. At 77.8 m borehole length a cataclastic band is mapped with strike/dip: 271/70. Foliations can also be observed at borehole lengths between approximately 107.6 m down to 151 m, where cataclastic bands, brittle-ductile shear zones, ductile shear zone and breccia (at approximately 132.6 m borehole length) also are present.

Table 5-3. Total amount of alteration in boreholes KA2051A01 and KA3007A01. Percents calculated from adjusted length of BIPS-image. Altered length is length of borehole with altered rock and excluding length of borehole mapped as fresh rock.

Alteration	Intensity	KA2051A01 (total length) (%)	KA2051A01 (altered length) (%)	KA3007A01 (total length) (%)	KA3007A01 (altered length) (%)
Oxidation	Faint	1.22	3.92		
	Weak	16.78	53.93	26.52	45.32
	Medium	1.68	5.40	7.95	13.59
Epidotization	Faint	0.22	0.71		
	Weak	4.73	15.22	18.63	31.84
	Medium	5.22	16.78	4.42	7.56
	Strong	1.26	4.05	0.99	1.70

Table 5-4. Total number of fractures in boreholes KA2051A01 and KA3007A01. Total adjusted mapped length of borehole KA2051A01 is calculated as 316.000 m and of borehole KA3007A01 as 223.894 m, which is here divided into 215.8 m (core with BIPS-image) and 8.094 m for the borehole length without BIPS-image (for the calculations of fractures/meter).

Borehole ID	Tot nr of open fractures	Fractures/ meter	Tot nr of sealed fractures	Fractures/ meter	Tot nr of partly open fractures	Fractures/ meter
KA2051A01	1,229	3.889	1,335	4.225	15	0.047
KA3007A01	981	4.546	933	4.323	29	0.134
KA3007A01*	63	7.784	65	8.031	4	0.494

*Core only (no BIPS-image).

Table 5-5. Mapped crush zones in boreholes KA2051A01 and KA3007A01. Adjusted length and strike/dip from upper contact of crush zone.

Borehole ID	Adjusted length (m)	Total width of zone (m)	Piece length (m)	Strike/dip (degrees)
KA2051A01	–	–	–	–
KA3007A01	131.90	0.64	0.05	082/48
KA3007A01	151.81	0.19	0.01	126/76
KA3007A01	156.04	0.35	0.02	128/85
KA3007A01	174.52	0.10	0.02	340/80

Table 5-6. Mapped cataclastic structures in boreholes KA2051A01 and KA3007A01. Average width is the difference between upper and lower contact of the rock occurrences containing the cataclastic structure in each borehole. Strike/dip is an average from the approximate centre of each designated cataclastic structure.

Borehole ID	KA2051A01	KA3007A01
Total number	61 (69)	67 (68)
Average width (m)	0.04	0.05 (0.07)
Average direction, strike /dip (degrees)	208/89	307/67

Table 5-7. Mapped sealed networks in boreholes KA2051A01 and KA3007A01. Average width is the difference between upper and lower contact of the sealed network in the borehole. Strike/Dip is from upper contacts.

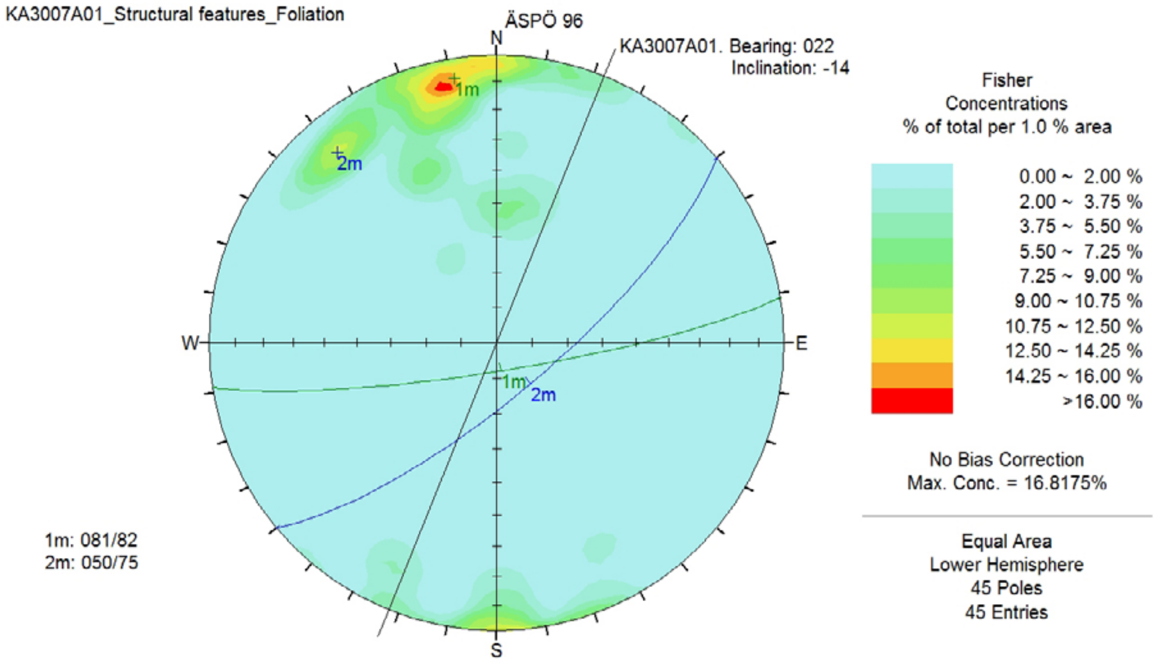
Borehole ID	KA2051A01	KA3007A01
Total number	55	47
Average width (m)	0.39	0.63
Average direction, strike/dip (degrees)	179/83	111/81

Table 5-8. Mapped structures in borehole KA2051A01. Upper and lower contacts are marked as Adj.sect.up (adjusted section up in m) and Adj.sect.low (adjusted section down in m) respectively. The measured structure is marked at a certain length along the borehole, here marked as Length. Width is the difference between the Adj.sect.up and Adj.sect.low. Strike is given in the coordinate system Äspö96 and the lithology can be found in Table 1-2.

KA2051A01	Adj. sect. up	Adj. sect. low	Length (m)	Width (m)	Intensity	Strike	Dip	Lithology
Breccia	88.43	88.44	88.44	0.02	Medium	348	81	Gab.id-dio.id
	88.63	88.64	88.63	0.01	Medium	343	68	Gab.id-dio.id
	136.87	136.89	136.88	0.02	Medium	132	81	Ävrö gr.dior.
	175.87	175.90	175.89	0.03	Medium	118	79	Ävrö gr.dior
	201.19	201.22	201.21	0.03	Medium	130	83	Ävrö gr.dior
	205.35	205.36	205.36	0.01	Medium	165	84	Ävrö gr.dior
	228.18	228.22	228.20	0.04	Medium	208	90	Äspö diorite
	245.32	245.36	245.34	0.04	Medium	216	49	Äspö diorite
	287.95	287.99	287.97	0.04	Medium	146	83	F.gr.granite
Brittle-duct. shear zones	218.45	218.46	218.46	0.01	Medium	176	60	Ävrö gr.dior
	255.90	256.05	255.97	0.15	Weak	127	50	?
	262.00	262.10	262.05	0.10	Weak	145	67	?
Foliated	36.30	36.70	36.52	0.40	Weak	134	58	?
	51.04	51.41	51.24	0.40	Medium	33	49	F.gr.granite
	51.61	51.97	51.81	0.40	Medium	30	47	F.gr.granite
	67.40	73.30	68.00	5.90	Weak	340	72	?
	264.80	265.80	265.00	1.00	Weak	156	89	?
	280.90	281.90	281.42	1.00	Weak	269	57	?
	298.20		301.22		Weak	276	56	
			302.51	11.10	Weak	280	46	?
		309.30	304.55		Weak	266	46	

Table 5-9. Mapped structures in borehole KA3007A01. Upper and lower contacts are marked as Adj.sect.up and Adj.sect.low respectively.

KA3007A01	Adj. sec. up	Adj. sec.low	Length (m)	Width (m)	Intensity	Strike	Dip	Lithology
Breccia	12.37	12.47	12.41	0.10	Medium	117	89	Äv.qtz.mond.
	132.52	132.67	132.63	0.15	Medium	44	48	F.gr. granite
Brittle-duct. shear zones	74.44	74.60	74.51	0.16	Strong	104	28	Äspö diorite
	120.86	120.93	120.89	0.07	Medium	58	27	Hybrid rock
	131.64		131.66	0.15	Weak	75	37	F.gr. granite
		131.78	131.77		Weak	73	49	
Ductile shear zone	131.68	131.76	131.72	0.08	Weak	72	52	F.gr. granite
Foliated	76.50		77.06	1.31	Weak	86	82	F.gr. granite
		77.81	77.76		Weak	270	82	
	77.81		77.82	0.39	Weak	269	72	Äspö diorite
		78.20	78.11		Weak	267	86	
	79.08	79.28	79.17	0.19	Weak	79	83	Äspö diorite
	79.84	79.98	79.88	0.14	Weak	295	79	Äspö diorite
	82.91	83.03	82.97	0.11	Weak	296	70	F.gr. granite
	87.48	87.56	87.52	0.08	Medium	100	85	Äspö diorite
	93.85	93.88	93.87	0.04	Medium	131	89	Äspö diorite
	100.28	102.15		1.87	Weak	271	87	F.gr. granite
	110.58	113.60	110.61	3.02	Weak	70	50	Äspö diorite
	115.17		115.38	1.01	Weak	90	87	Hybrid rock
		116.18	115.92		Weak	85	85	
	117.40		117.45	0.20	Weak	68	56	Ä-Dio border of Peg
		117.60	117.54		Weak	243	69	
	120.64	120.81	120.70	0.17	Weak	85	39	Pegmatite
	120.93	121.01	120.97	0.08	Medium	62	28	Hybrid rock
	121.28	121.33	121.30	0.04	Weak	107	45	Hybrid rock
	122.17	122.20	122.18	0.02	Weak	103	36	Hybrid rock
	122.24	122.27	122.25	0.03	Weak	93	42	Hybrid rock
	123.63		124.08	1.23	Weak	66	58	Hybrid rock
		124.86	124.53		Weak	64	86	
	129.26	129.48	129.33	0.22	Weak	272	90	Gab.-Dior.
	137.10	137.26	137.13	0.16	Weak	94	60	F.gr. granite
	165.03	165.22	165.17	0.18	Weak	80	73	F.gr. granite
	168.00	168.09	168.04	0.09	Medium	92	90	Äspö diorite
	171.10	171.41	171.25	0.31	Weak	98	88	Äv.granodio.
	171.72		171.84	0.38	Weak	112	89	?
		172.10	172.00		Weak	111	88	
	185.32		185.35	0.15	Weak	77	84	Äspö diorite
			185.40		Weak	84	82	
		185.47	185.45		Weak	77	73	
	187.68	187.75	187.71	0.07	Weak	59	80	F.gr. granite
	200.77		200.89	0.43	Weak	73	88	Äspö diorite
			201.05		Weak	75	81	
		201.20	201.15		Weak	73	86	
	204.51		204.59	0.39	Weak	77	70	Äv.granodio.
			204.71		Weak	67	70	
		204.90	204.87		Weak	75	74	
	205.34	205.91	205.52	0.57	Weak	248	84	Äv.granodio.
	215.00		215.30	0.50	Weak	54	79	?
		215.50	215.50		Weak	52	73	
	215.76		215.89	1.48	Medium	46	75	?
			216.02		Medium	47	77	
			216.46		Medium	38	76	
		217.25	217.08		Medium	52	76	



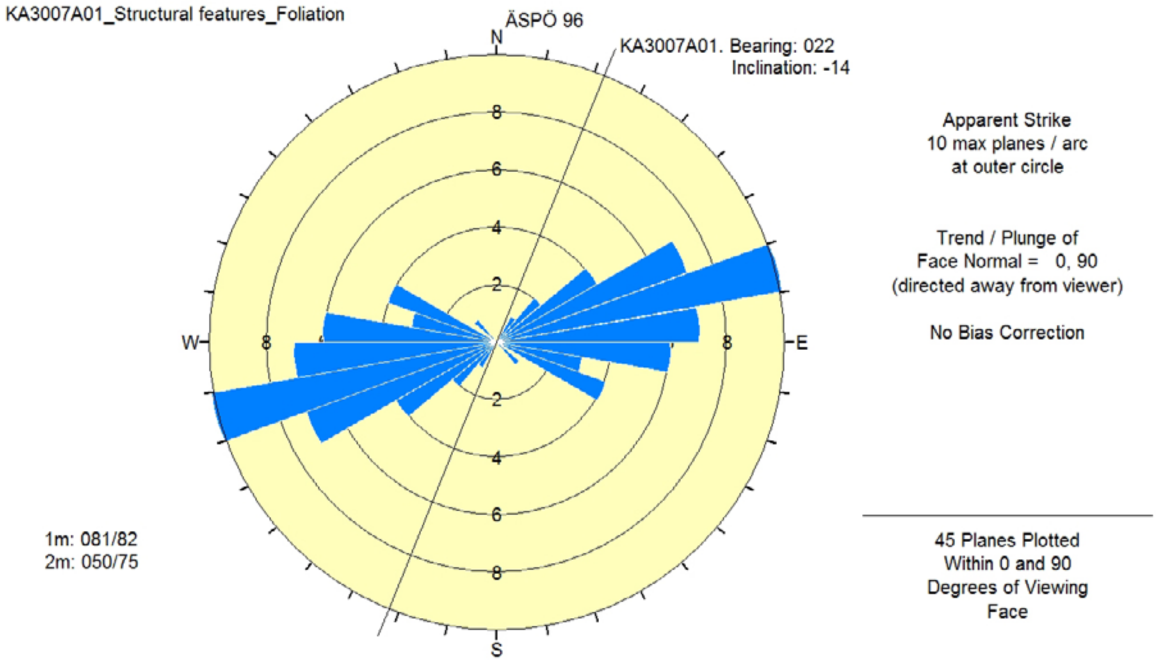


Figure 5-5. *Data from structural measurements in Boremap of foliations in the borehole KA3007A01. The coordinate system is Äspö96. Bearing of borehole KA3007A01 marked as a line. Top: Stereogram (strike/dip poles). Bottom: Rose diagram (strike). The diagrams have not been adjusted for borehole orientation bias.*

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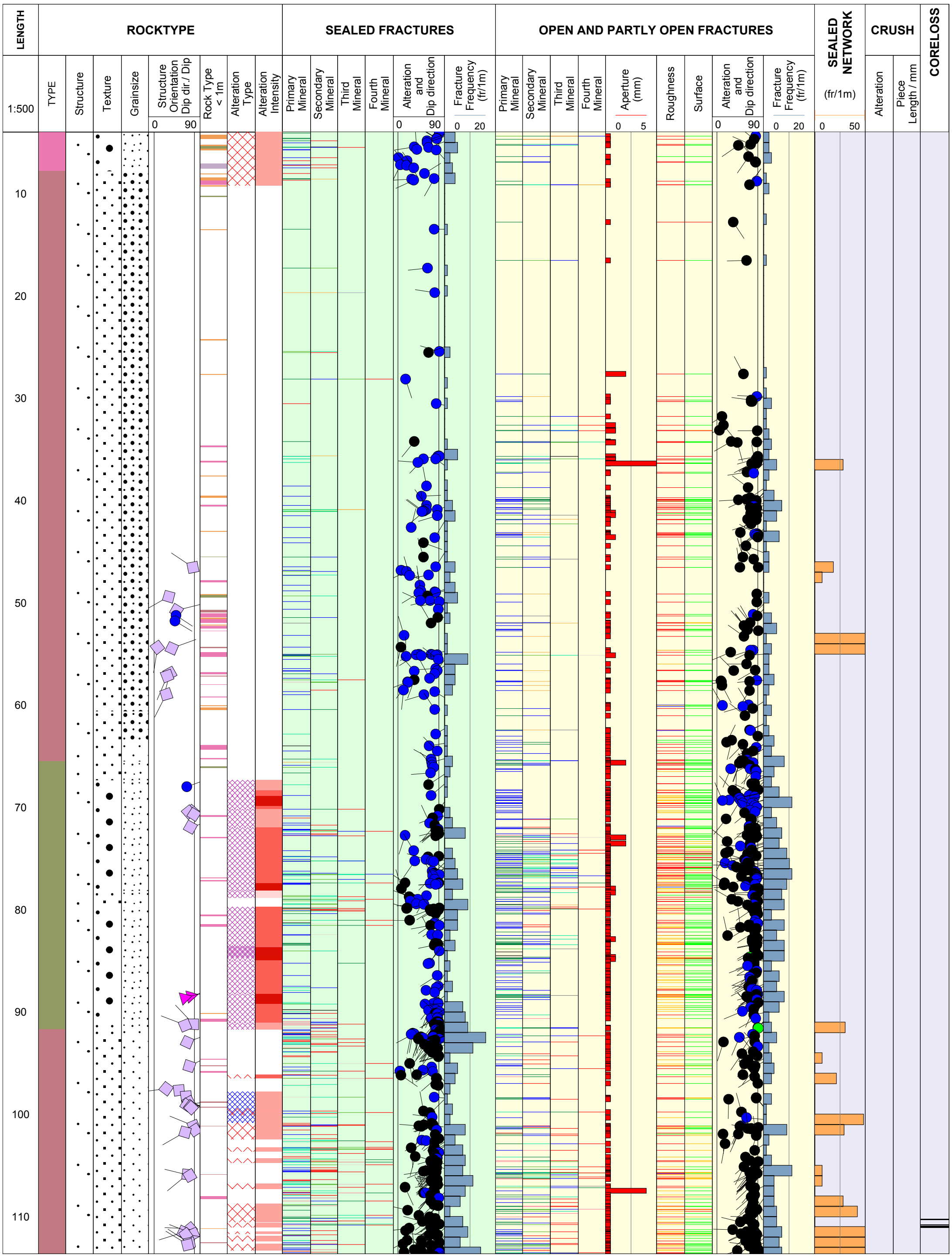
Appendix 1

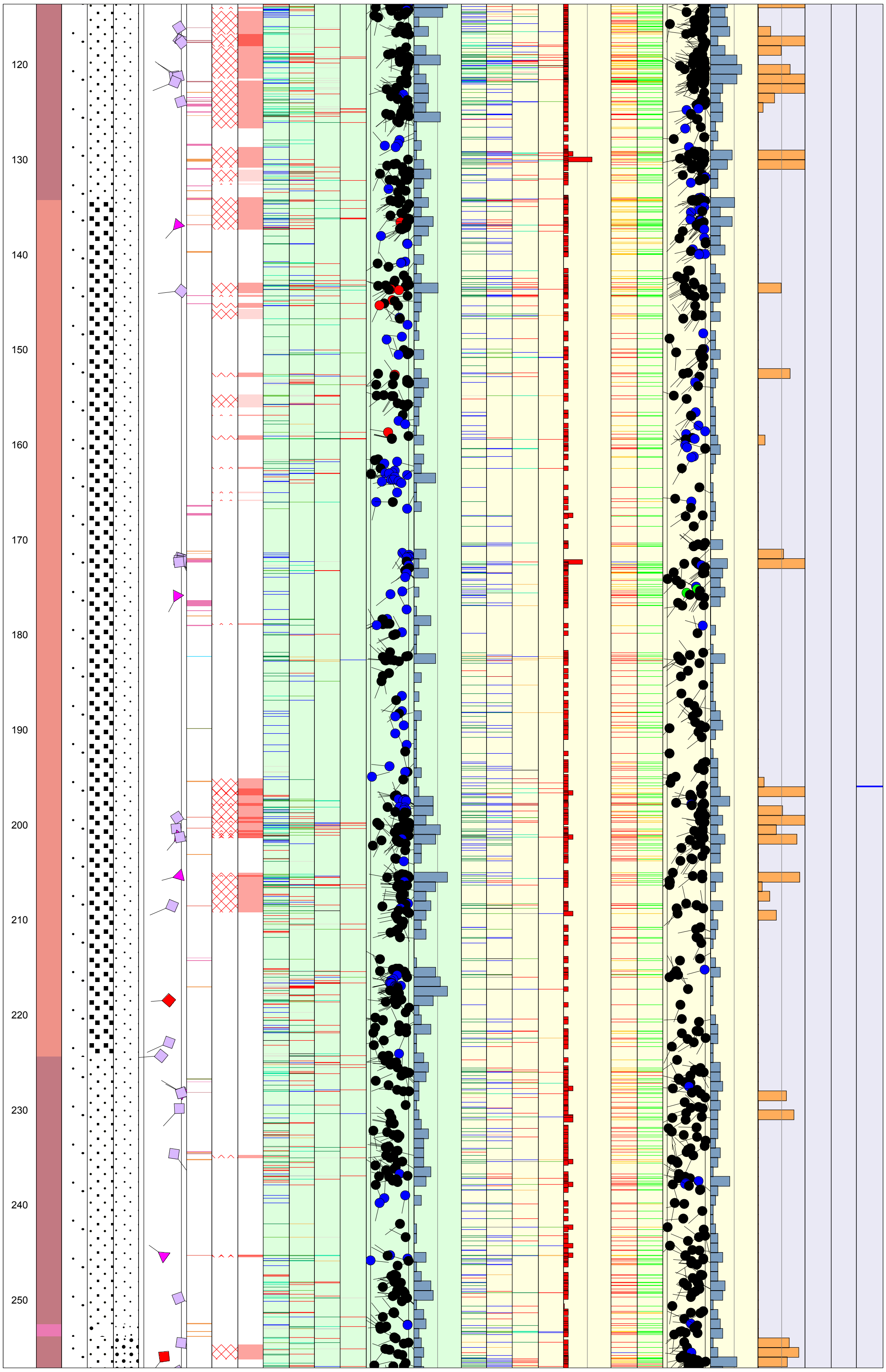
A1.1 WellCAD presentation of the mapping results for KA2051A01

Title	LEGEND FOR ÄSPÖ	KA2051A01
Site	ÄSPÖ	
Borehole	KA2051A01	
Plot Date	2012-02-02 23:01:44	
Signed data	2012-02-03	

Title GEOLOGY IN KA2051A01 Appendix: 1A

Site	ÄSPÖ	Coordinate System	ÄSPÖ96
Borehole	KA2051A01	Northing [m]	7339.25
Diameter [mm]	76	Easting [m]	2336.55
Length [m]	319.840	Elevation [m.a.s.l.]	-276.63
Bearing [°]	86.62	Drilling Start Date	2011-02-01 14:50:00
Inclination [°]	-34.79	Drilling Stop Date	2011-03-25 08:56:00
Date of coremapping	2011-06-13 14:18:00	Plot Date	2012-02-06 23:01:33
Rocktype data from	p_rock	Signed data	

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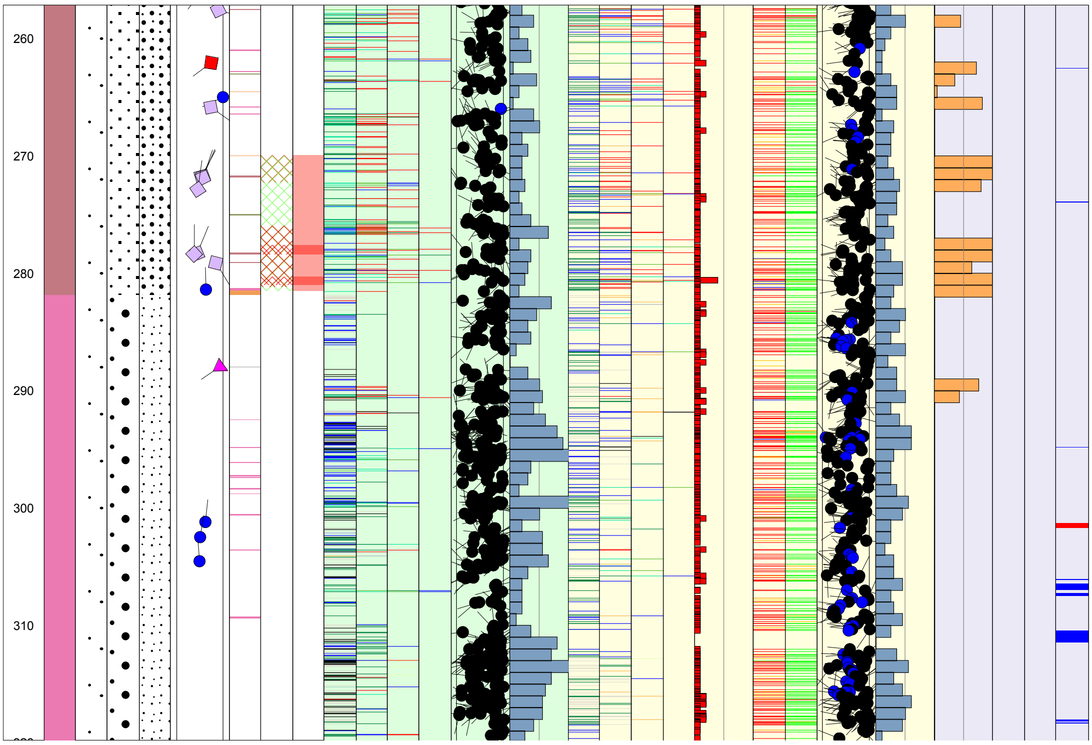

260
270
280
290
300
310

A1.2 BIPS-image of borehole KA2051A01

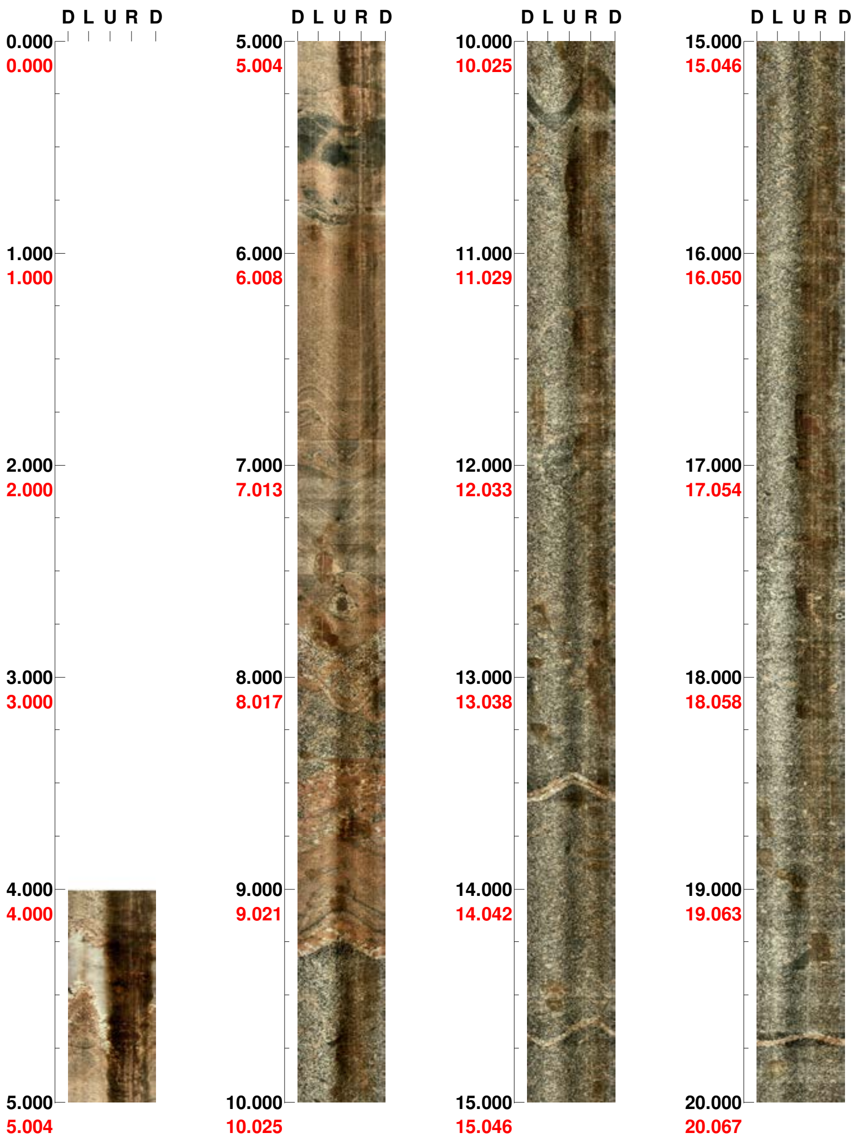
Project name: Äspö HRL

Image file	**: d:\work\r5911s~1\bips\ka2051~1.bip**
BDT file	**: d:\work\r5911s~1\bips\ka2051~1.bdt**
Locality	**: ASPO HRL**
Bore hole number	**: KA2051A1**
Date	**: 11/06/10**
Time	**: 10:46:00**
Depth range	**: 4.000 - 318.315 m**
Azimuth	**: 87**
Inclination	**: -35**
Diameter	**: 76.0 mm**
Magnetic declination	**: 0.0**
Span	**: 4**
Scan interval	**: 0.25**
Scan direction	**: To bottom**
Scale	**: 1/25**
Aspect ratio	**: 175 %**
Pages	**: 17**
Color	**: +0 +0 +0**

Project name: Äspö HRL

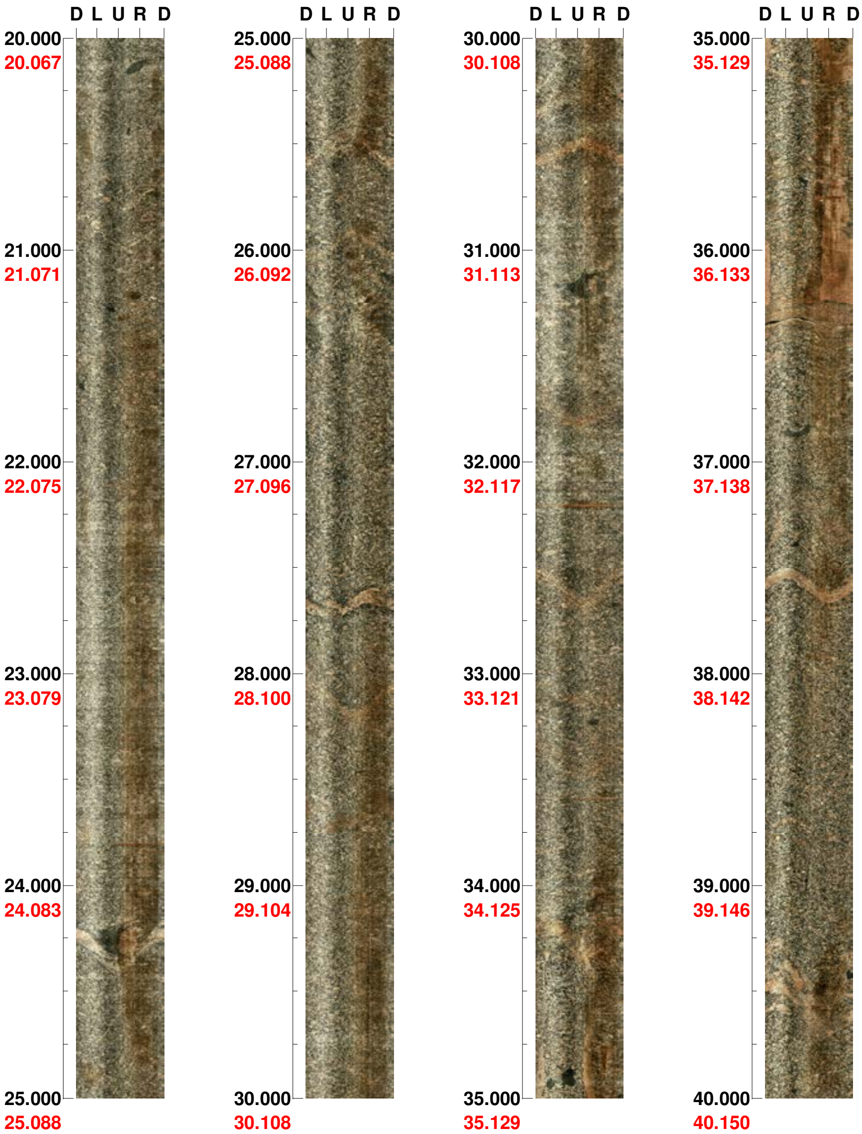
Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 0.000 - 20.000 m



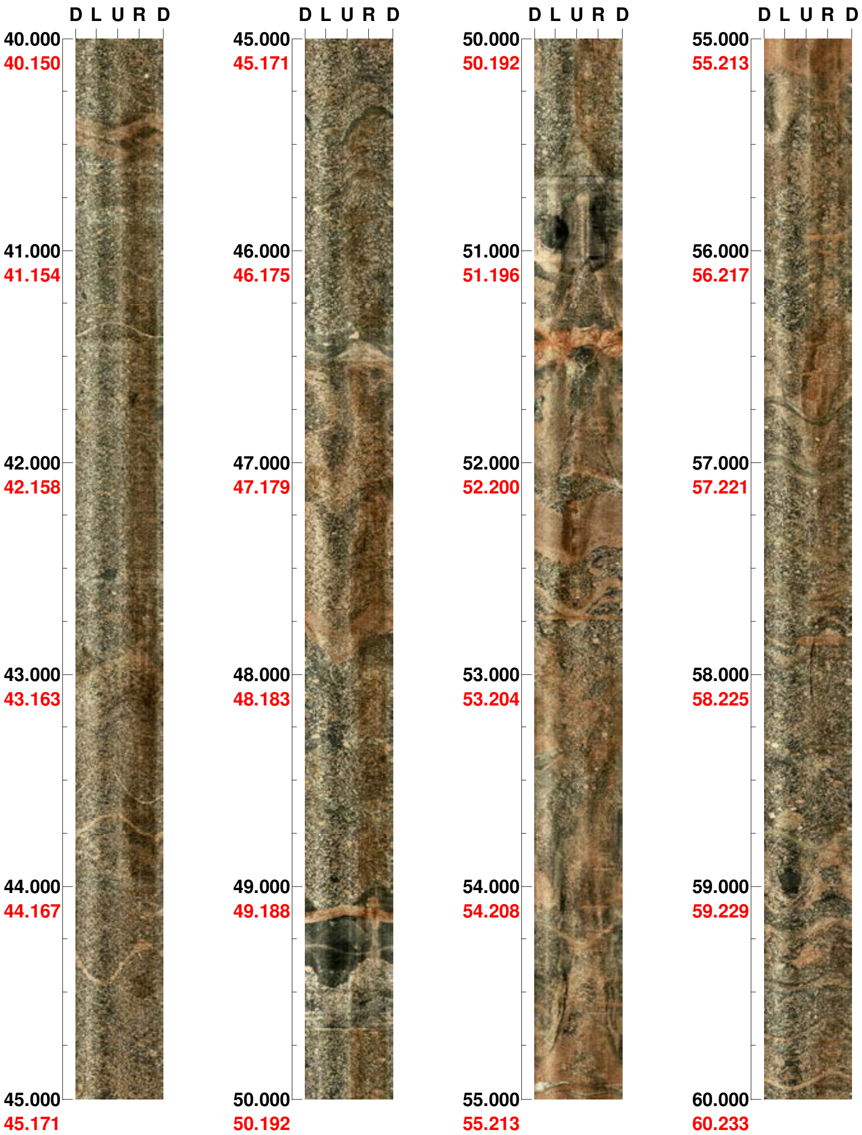
Project name: Äspö HRL
Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 20.000 - 40.000 m



Project name: Äspö HRL
Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

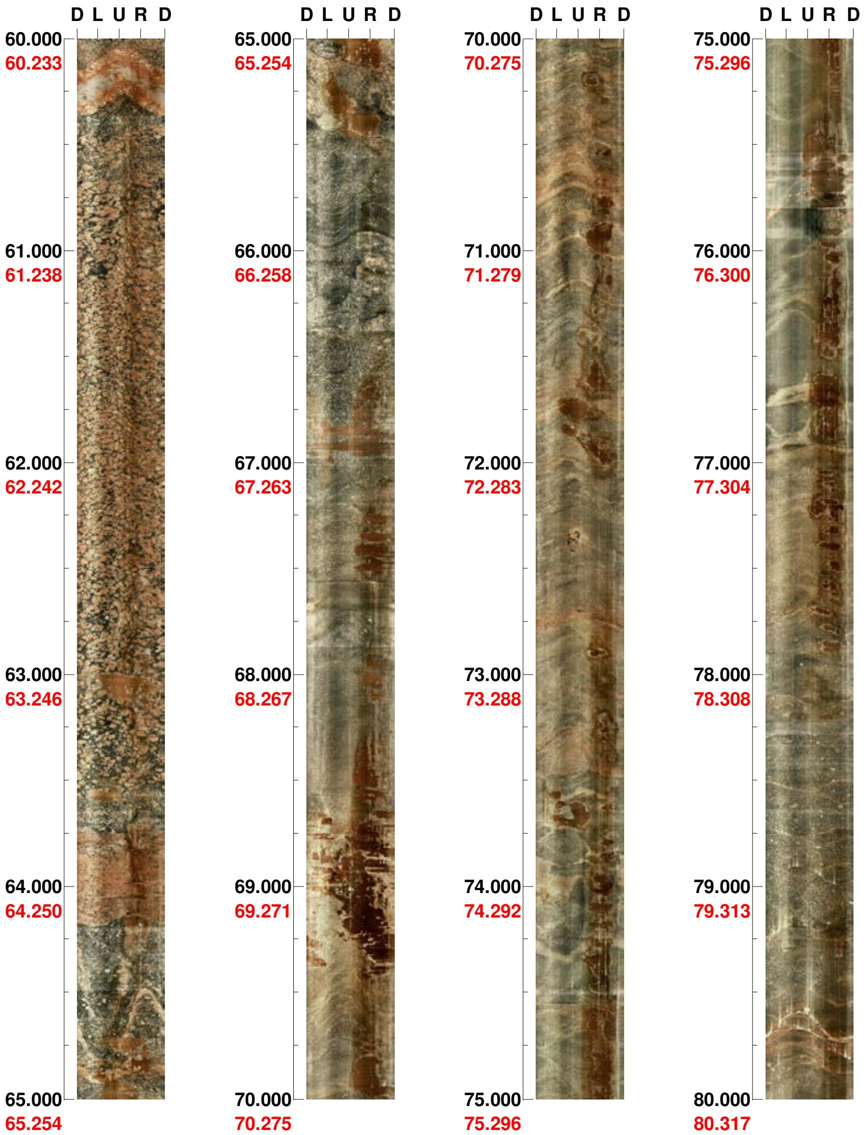
Depth range: 40.000 - 60.000 m



Project name: Äspö HRL

Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 60.000 - 80.000 m

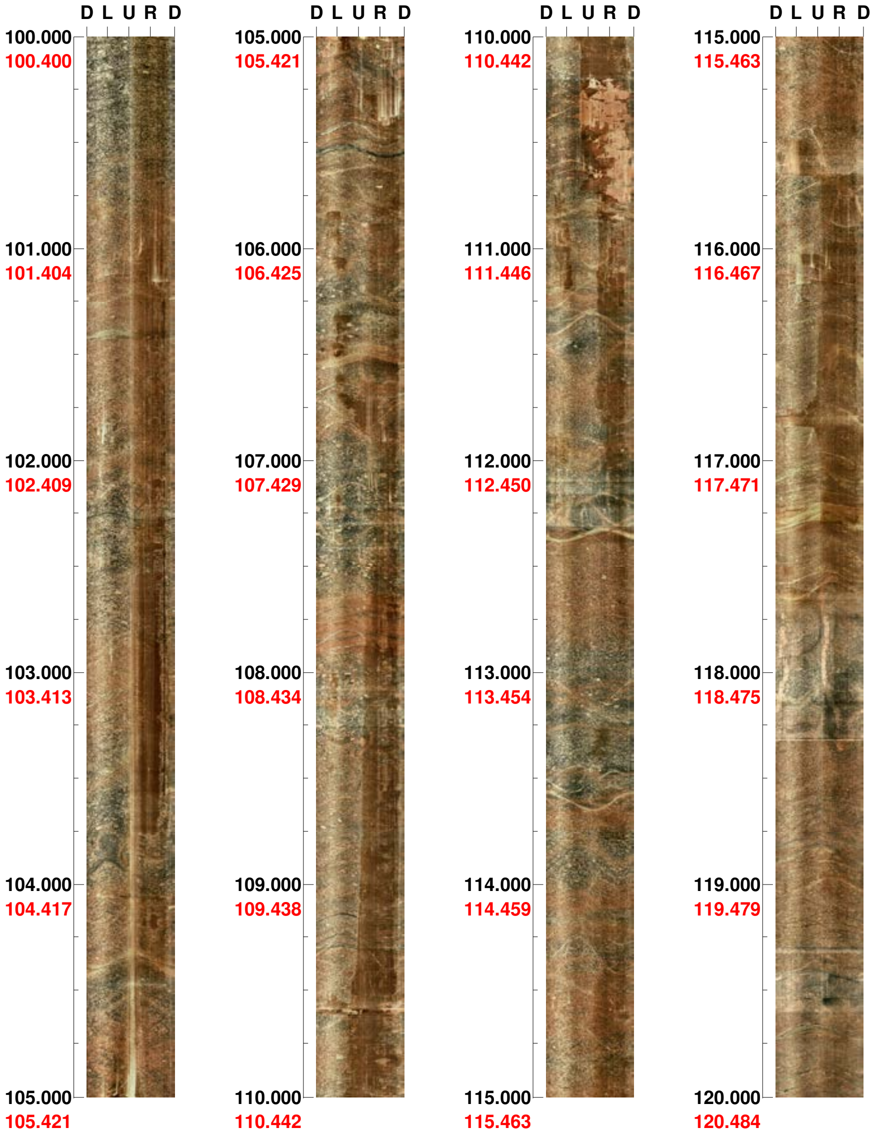


Project name: Äspö HRL
Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 80.000 - 100.000 m

Project name: Äspö HRL
Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

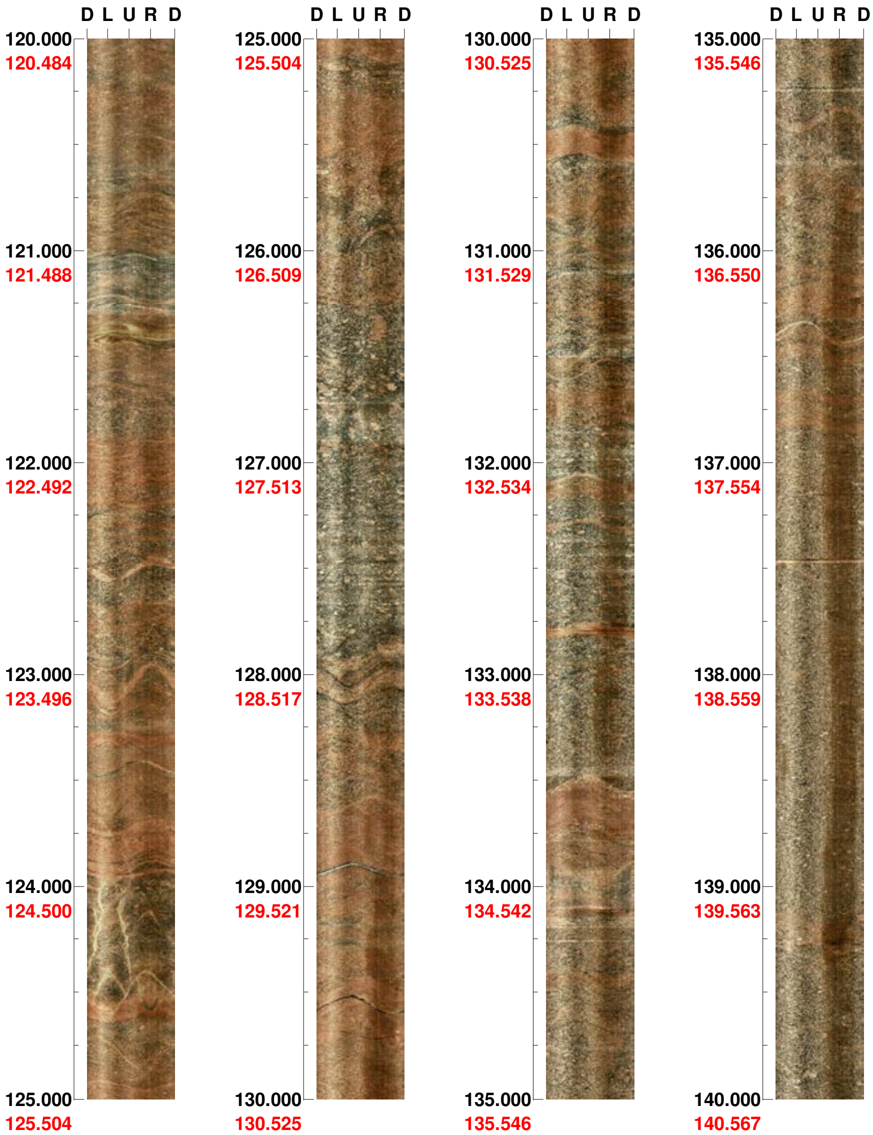
Depth range: 100.000 - 120.000 m



Project name: Äspö HRL

Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 120.000 - 140.000 m



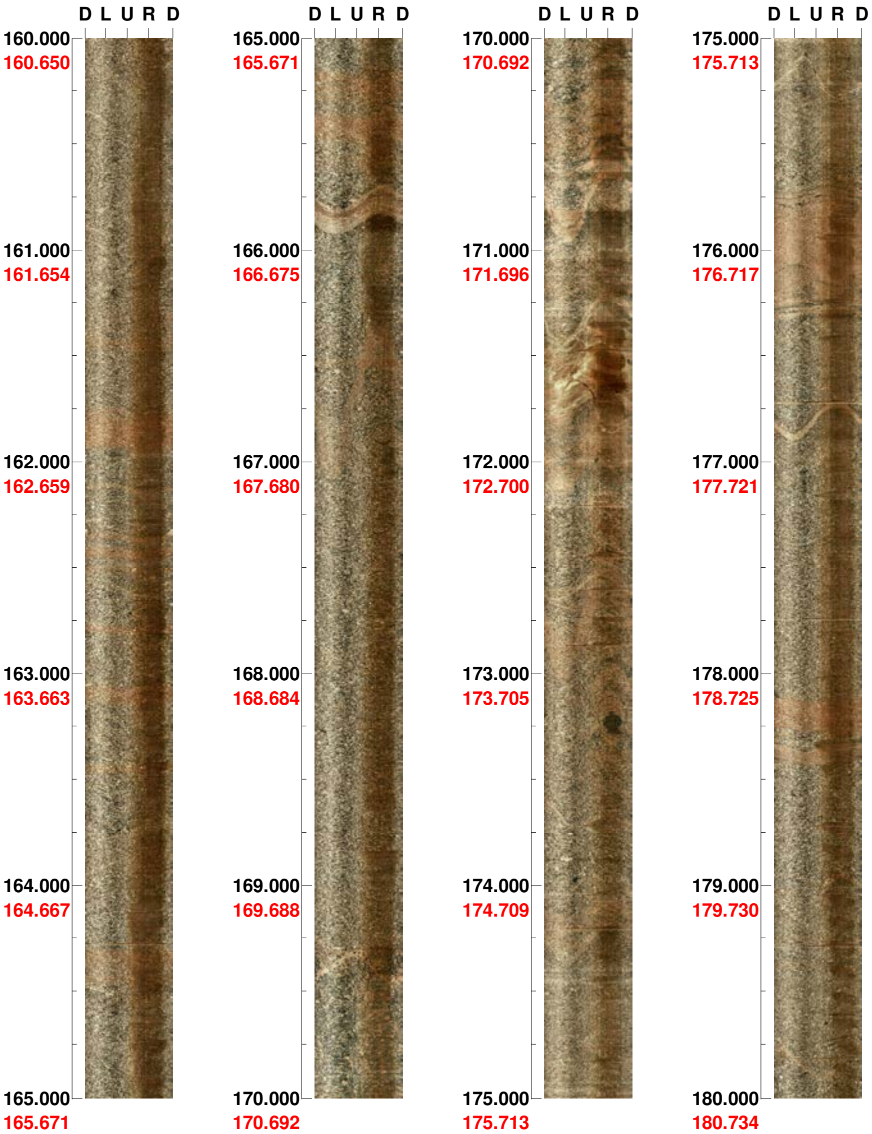
Project name: Äspö HRL

Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 140.000 - 160.000 m

Project name: Äspö HRL
Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

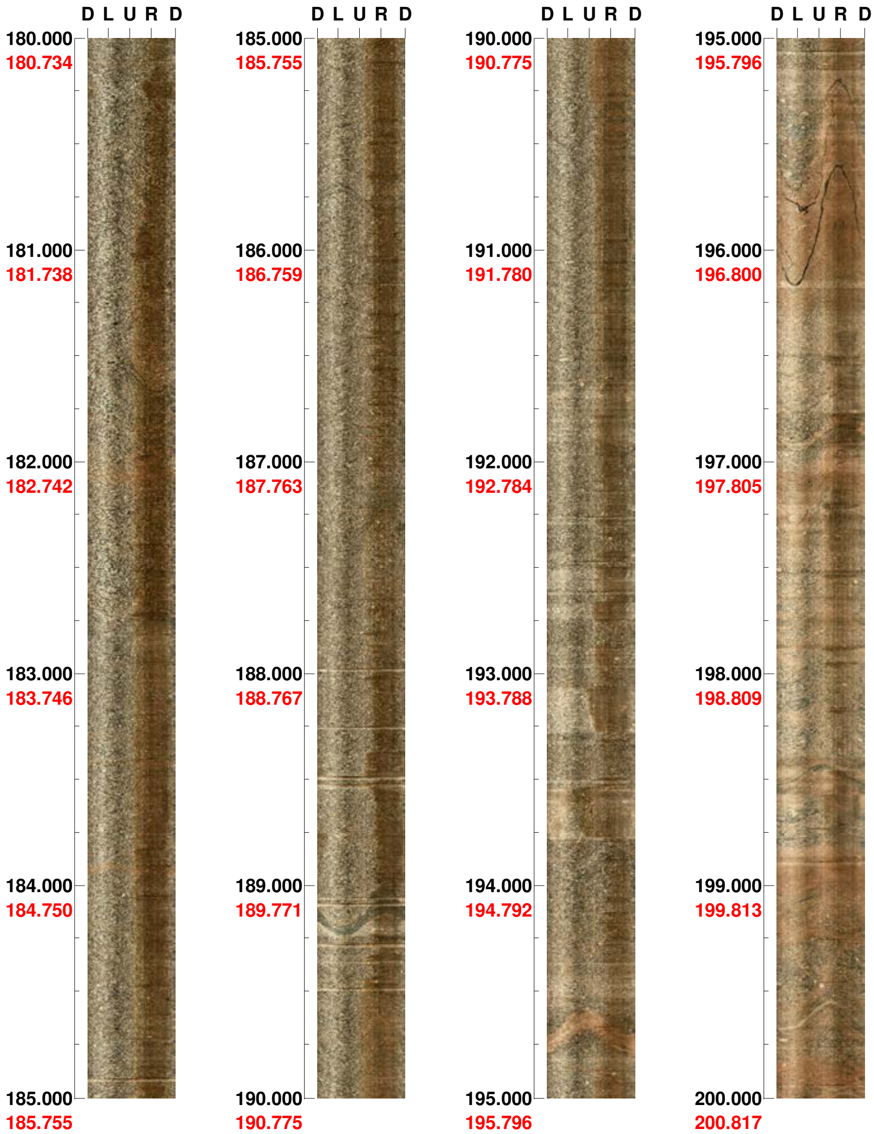
Depth range: 160.000 - 180.000 m



Project name: Äspö HRL

Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 180.000 - 200.000 m



Project name: Äspö HRL
Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 200.000 - 220.000 m

Project name: Äspö HRL

Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 220.000 - 240.000 m

Project name: Äspö HRL

Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 240.000 - 260.000 m

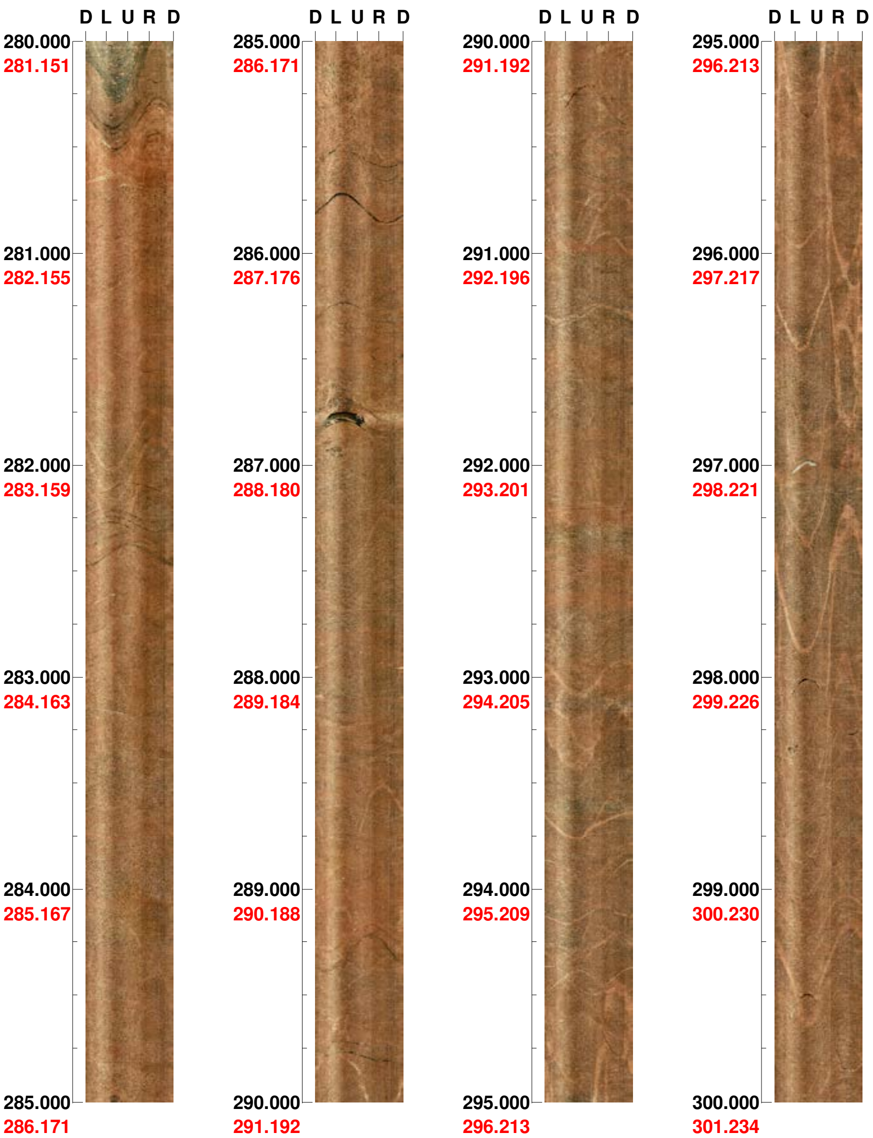
Project name: Äspö HRL

Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 260.000 - 280.000 m

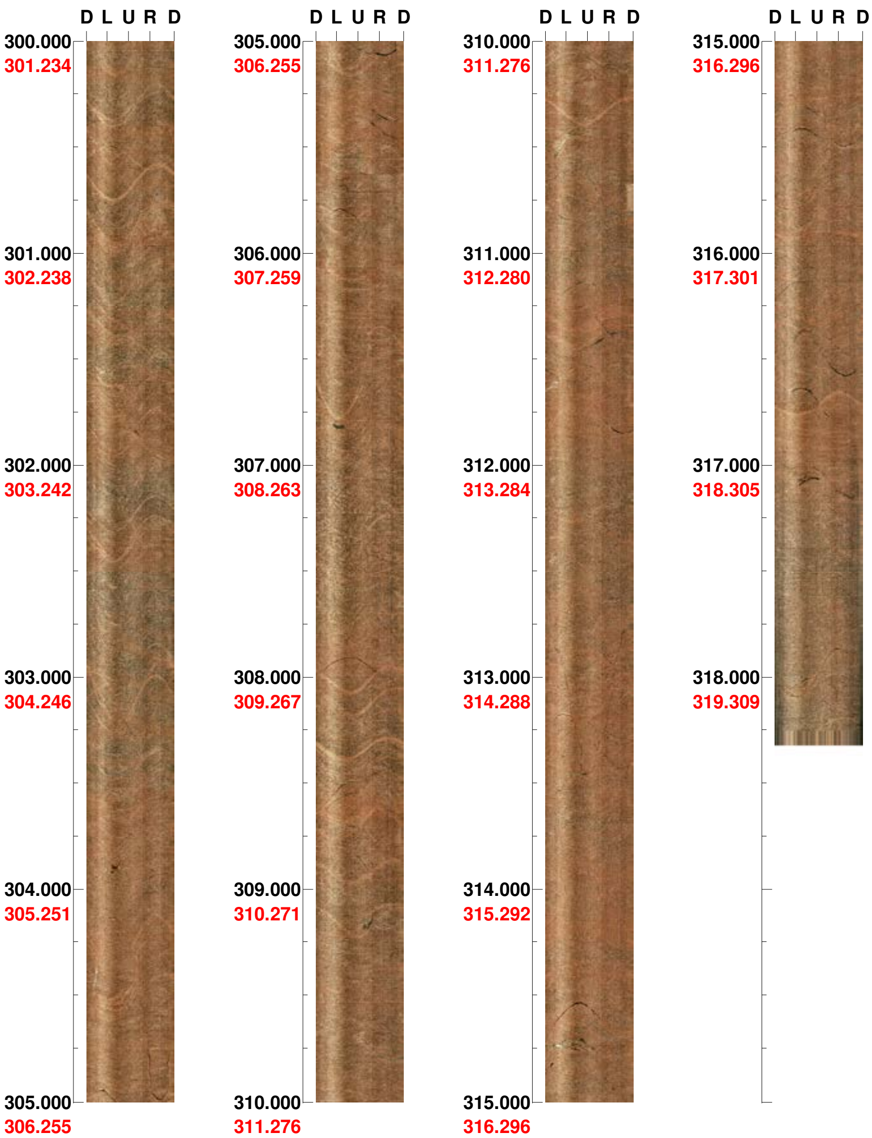
Project name: Äspö HRL
Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 280.000 - 300.000 m

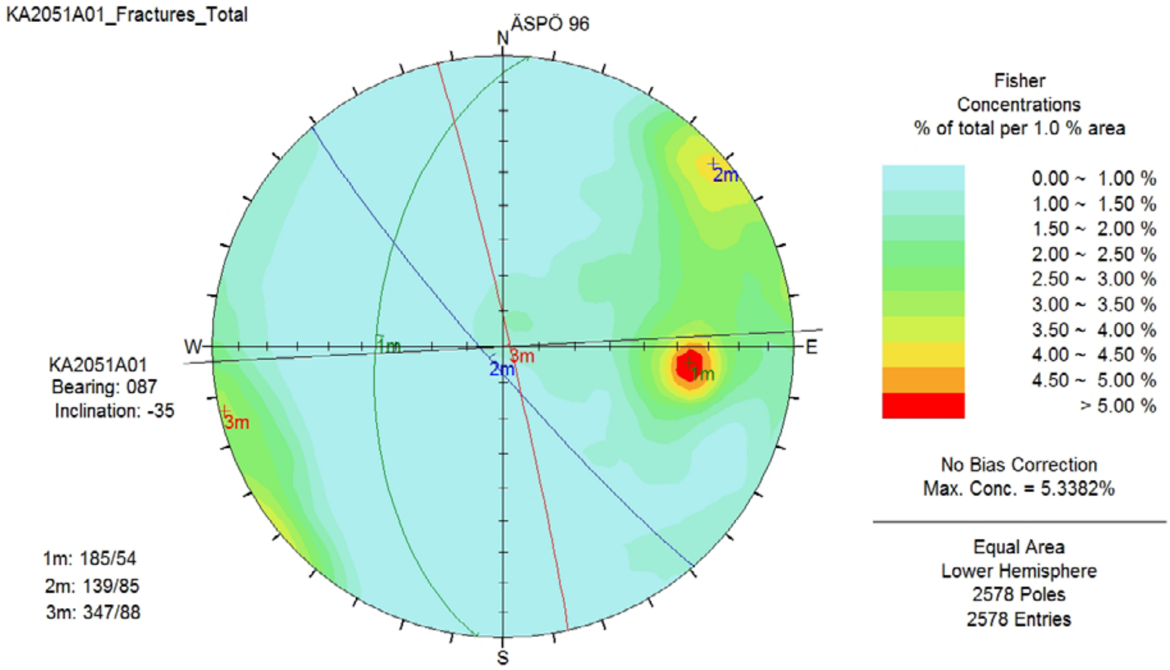


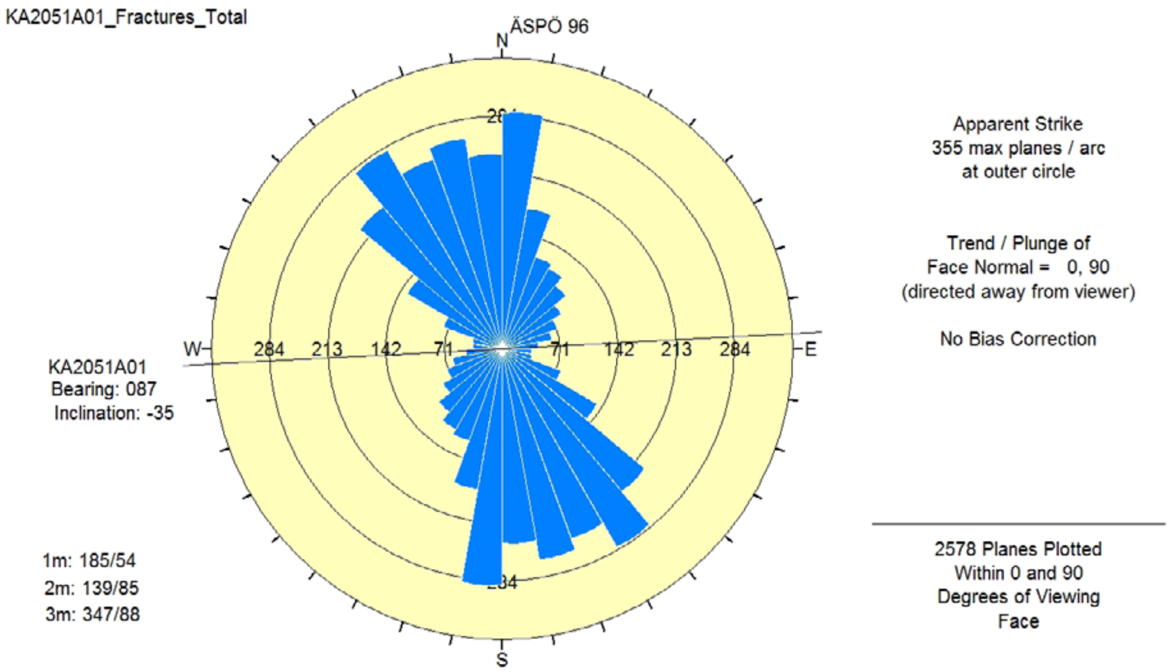
Project name: Äspö HRL
Bore hole No.: KA2051A1 **Azimuth: 87** **Inclination: -35**

Depth range: 300.000 - 318.315 m

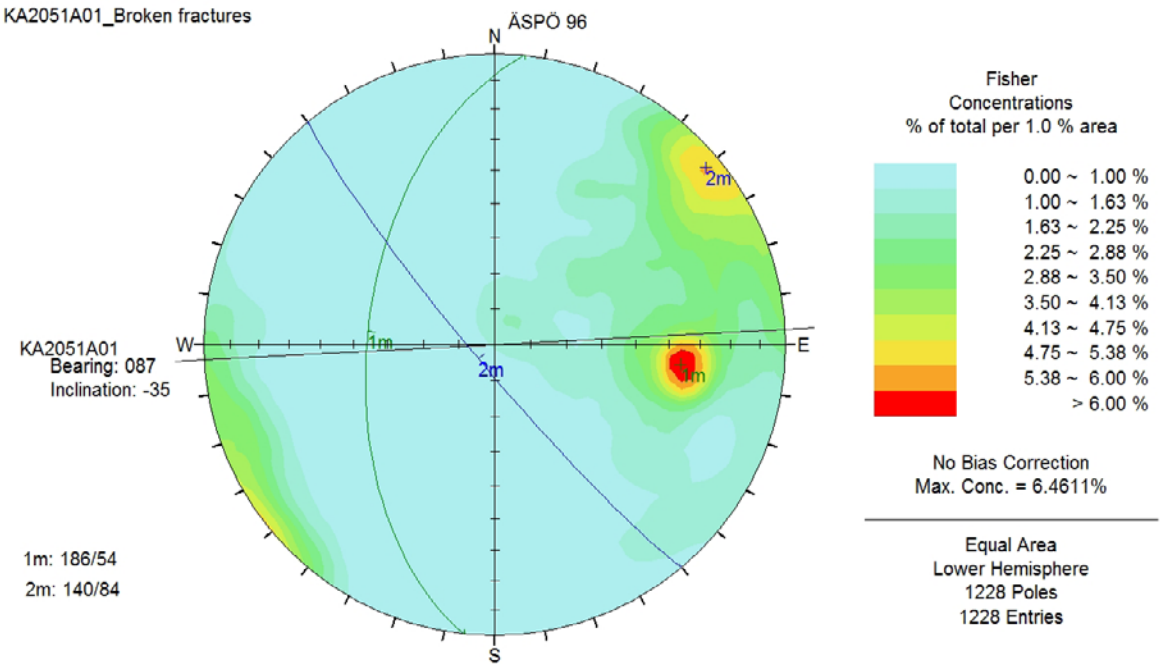


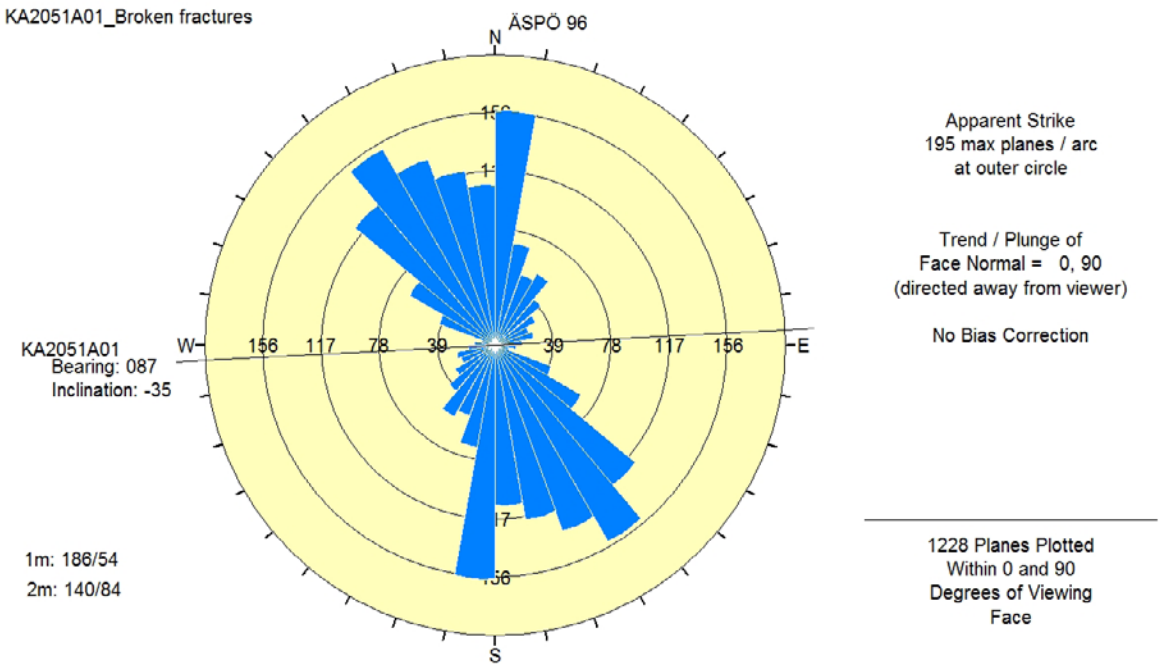
A1.3 Stereonets and rose-diagrams of all logged fractures, all open fractures, all closed fractures, sealed networks and cataclastic structures in borehole KA205101



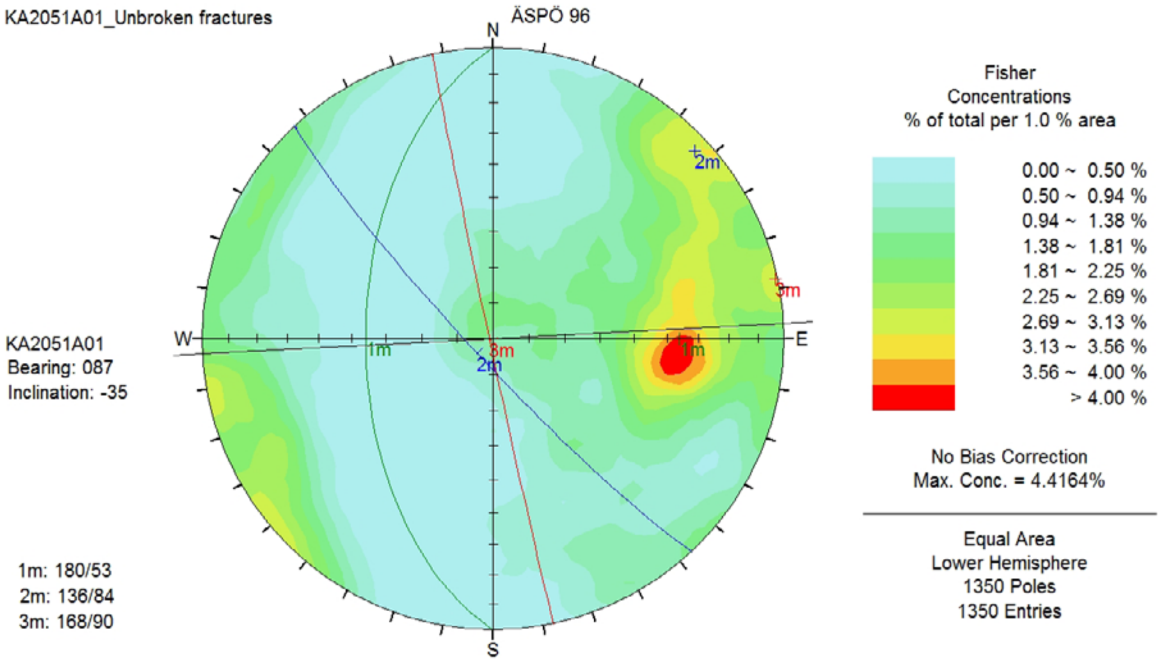


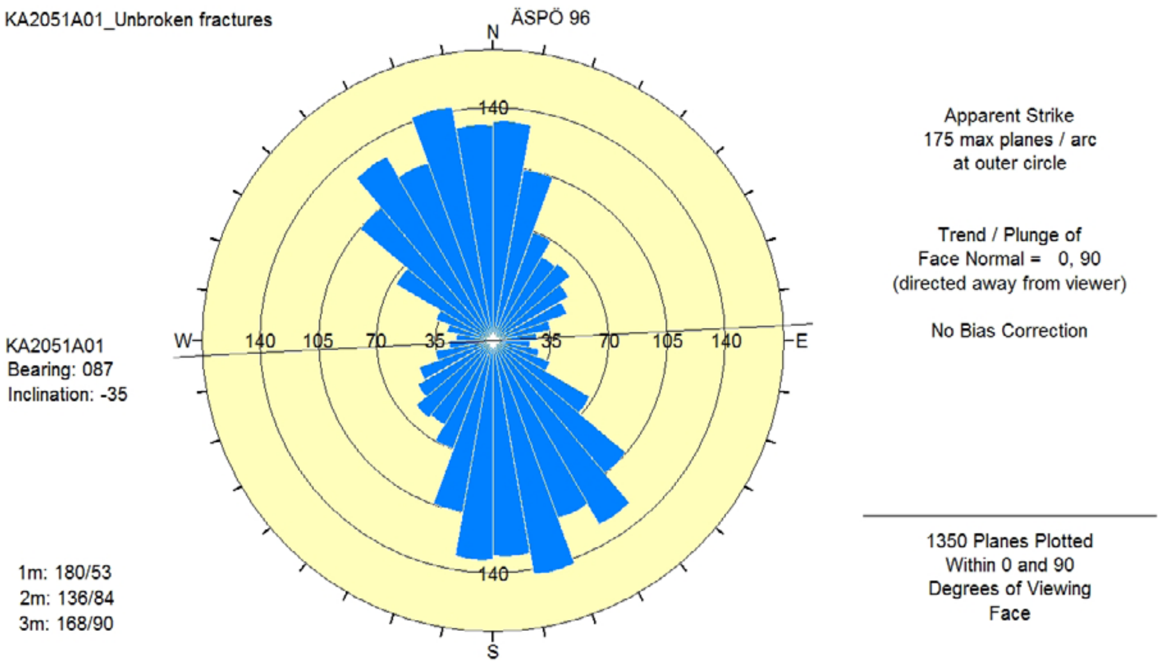
Data from structural measurements in Boremap of all logged fractures in borehole KA2051A01. The coordinate system is Äspö96. Bearing of borehole KA2051A01 marked as a line. Top: Stereogram (strike/dip poles). Bottom: Rose diagram (strike). One broken fracture at 280.3 m borehole length is missing since it has no measured strike/dip. The diagrams have not been adjusted for borehole orientation bias.



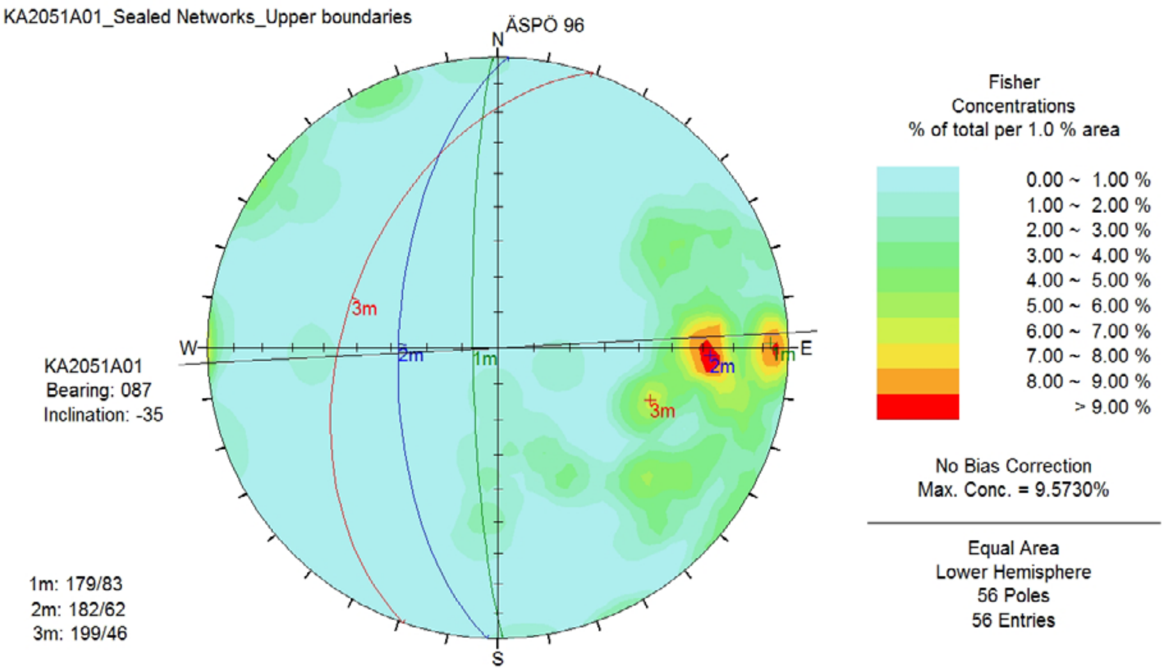


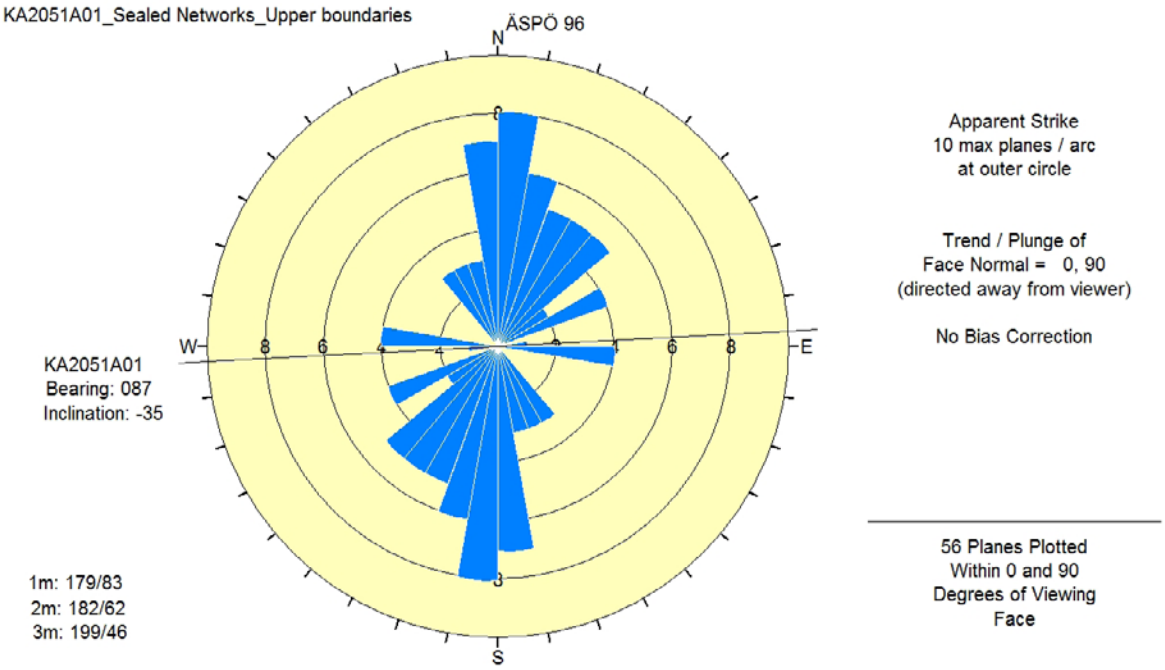
Data from structural measurements in Boremap of all open fractures in borehole KA2051A01. The coordinate system is Äspö96. Bearing of borehole KA2051A01 marked as a line. Top: Stereogram (strike/dip poles). Bottom: Rose diagram (strike). One broken fracture at 280.3 m borehole length is missing since it has no measured strike/dip. The diagrams have not been adjusted for borehole orientation bias.



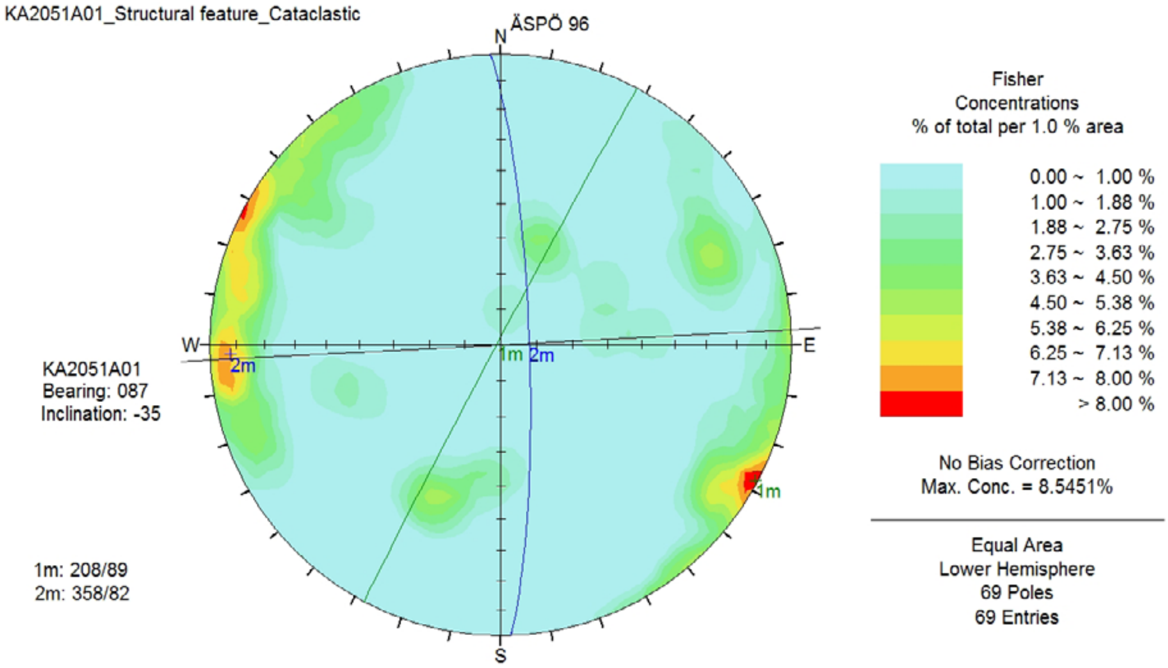


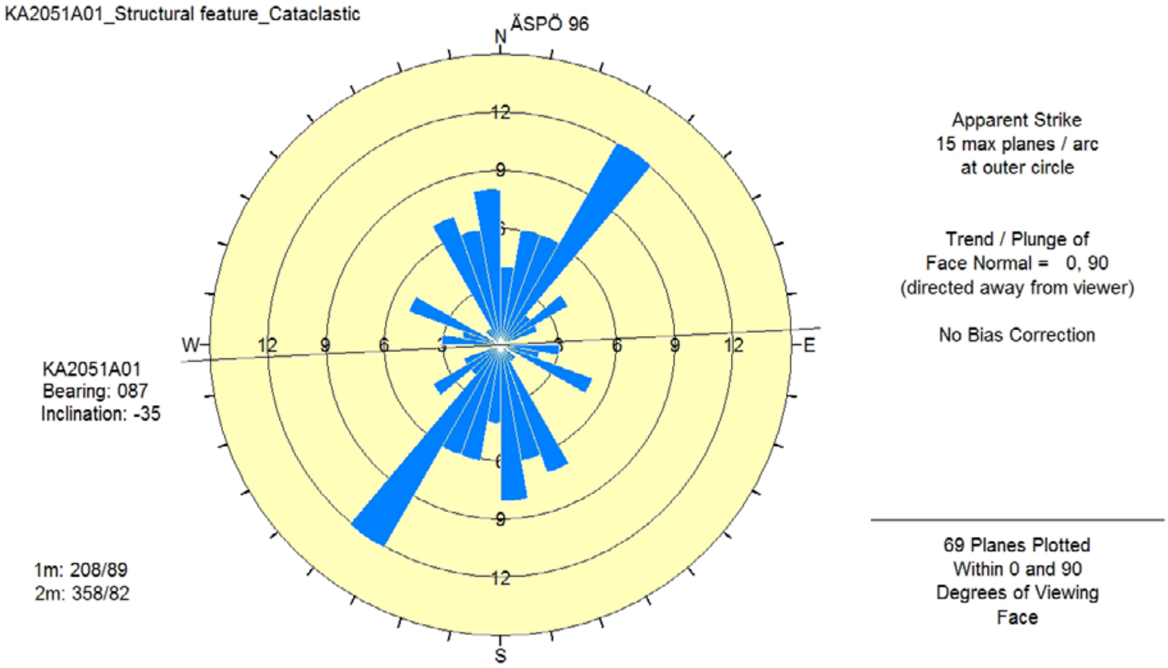
Data from structural measurements in Boremap of all closed fractures in borehole KA2051A01. The coordinate system is Äspö96. Bearing of borehole KA2051A01 marked as a line. Top: Stereogram (strike/dip poles). Bottom: Rose diagram (strike). The diagrams have not been adjusted for borehole orientation bias.





Data from structural measurements in Boremap showing upper contacts of sealed networks in borehole KA2051A01. The coordinate system is Äspö96. Bearing of borehole KA2051A01 marked as a line. Top: Stereogram (strike/dip poles). Bottom: Rose diagram (strike). The diagrams have not been adjusted for borehole orientation bias.





Data from structural measurements in Boremap showing cataclastic structures in borehole KA2051A01. The coordinate system is Äspö96. Bearing of borehole KA2051A01 marked as a line. Top: Stereogram (strike/dip poles). Bottom: Rose diagram (strike). The diagrams have not been adjusted for borehole orientation bias.

A2.1 WellCAD presentation of the mapping results for KA3007A01

Title	LEGEND FOR ÄSPÖ	KA3007A01

Site	ÄSPÖ
Borehole	KA3007A01
Plot Date	2012-02-02 23:01:44
Signed data	2012-02-03

ROCKTYPE ÄSPÖ

- Dolerite / Diabas
- Fine-grained Götemargranite
- Coarse-grained Götemargranite
- Fine-grained granite
- Pegmatite
- Granite
- Ävrö granite
- Ävrö granodiorite
- Ävrö quartz monzodiorite
- Äspö Diorite
- Quartz monzodiorite
- Diorite / Gabbro
- Fine-grained dioritoid
- Fine-grained diorite-gabbro
- Gabbroid-dioritoid
- Mylonite
- Sulphide mineralization
- Sandstone
- Quartz-dominated hydrothermal vien/segregation
- Hybrid rock
- Breccia
- Felsic volcanic rock
- Soil

STRUCTURE

- Cataclastic
- Schistose
- Gneissic
- Mylonitic
- Ductile Shear Zone
- Brittle-Ductile Zone
- Veined
- Banded
- Massive
- Foliated
- Brecciated
- Lineated

TEXTURE

- Hornfelsed
- Porphyritic
- Ophitic
- Equigranular
- Augen-Bearing
- Unequigranular
- Metamorphic

GRAINSIZE

- Aphanitic
- Fine-grained
- Fine to medium grained
- Medium to coarse grained
- Coarse-grained
- Medium-grained

STRUCTURE ORIENTATION

- Structure Orientation
- Cataclastic
- Represents all types
- Brecciated
- Bedded
- Schistose
- Mylonitic
- Foliated
- Lineated
- Ductile Shear Zone
- Veined
- Gneissic
- Brittle-Ductile Shear Zone
- Banded
- Sealed fracture orientation
- Open fracture orientation

ROCK ALTERATION TYPE

- Oxidized
- Chloritisized
- Epidotisized
- Weathered
- Tectonized
- Sericitisized
- Quartz dissolution
- Silicification
- Argillization
- Albitization
- Carbonatization
- Saussuritization
- Steatitization
- Uralitization
- Laumontitization
- Fract zone alteration

ROCK ALTERATION INTENSITY

- No intensity
- Faint
- Weak
- Medium
- Strong

ROUGHNESS

- Planar
- Undulating
- Stepped
- Irregular

SURFACE

- Rough
- Smooth
- Slickensided

CRUSH ALTERATION

- Slightly Altered
- Moderately Altered
- Highly Altered
- Completley Altered
- Gouge
- Fresh

MINERAL

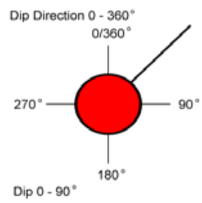
- Epidote
- White Feldspar
- Hematite
- Calcite
- Chlorite
- Quartz
- Unknown
- Pyrite
- Clay Minerals
- Prehnite
- Iron Hydroxide
- Oxidized Walls

FRACTURE ALTERATION

- Highly Altered
- Completely Altered
- Gouge
- Fresh
- Slightly Altered
- Moderately Altered

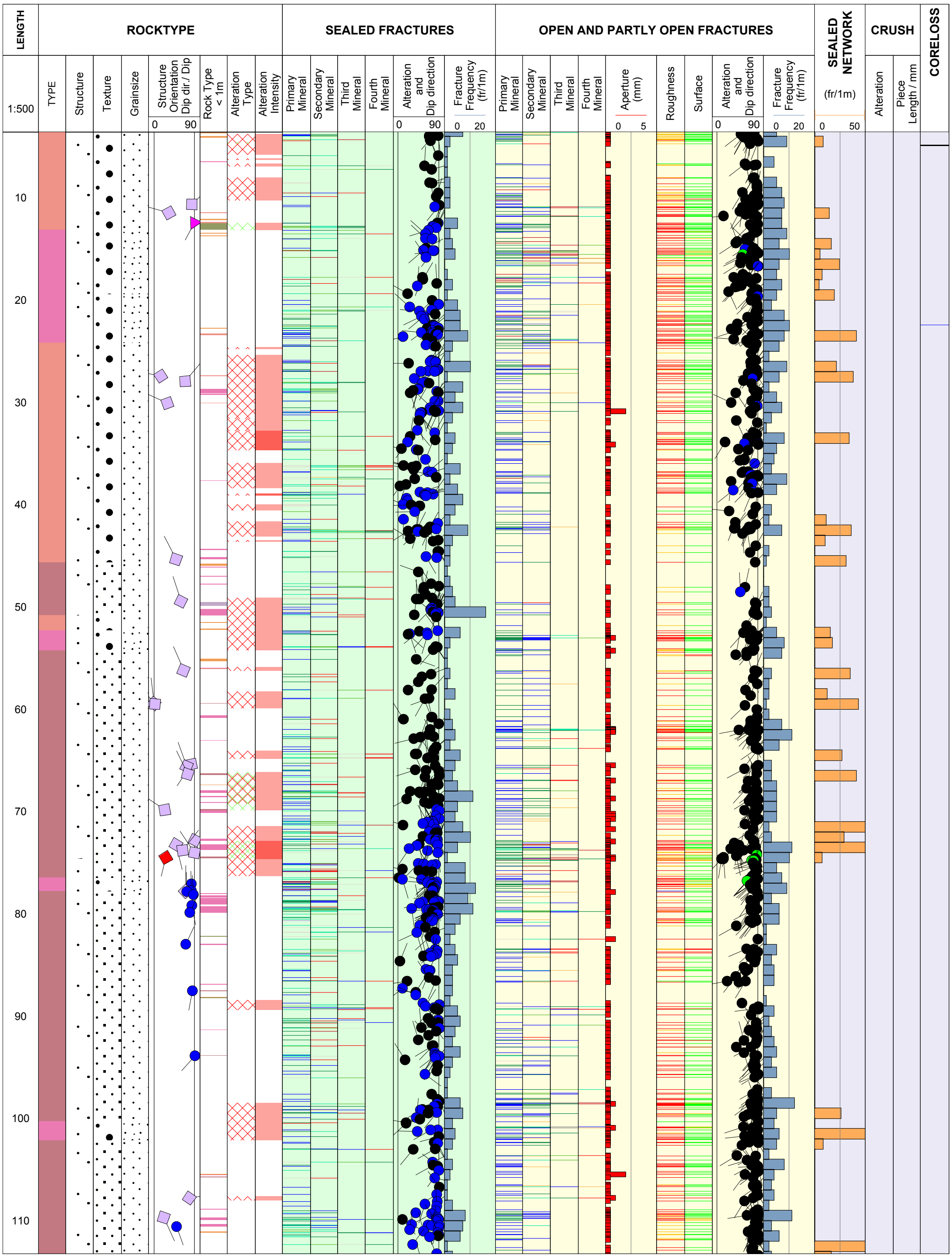
FRACTURE DIRECTION

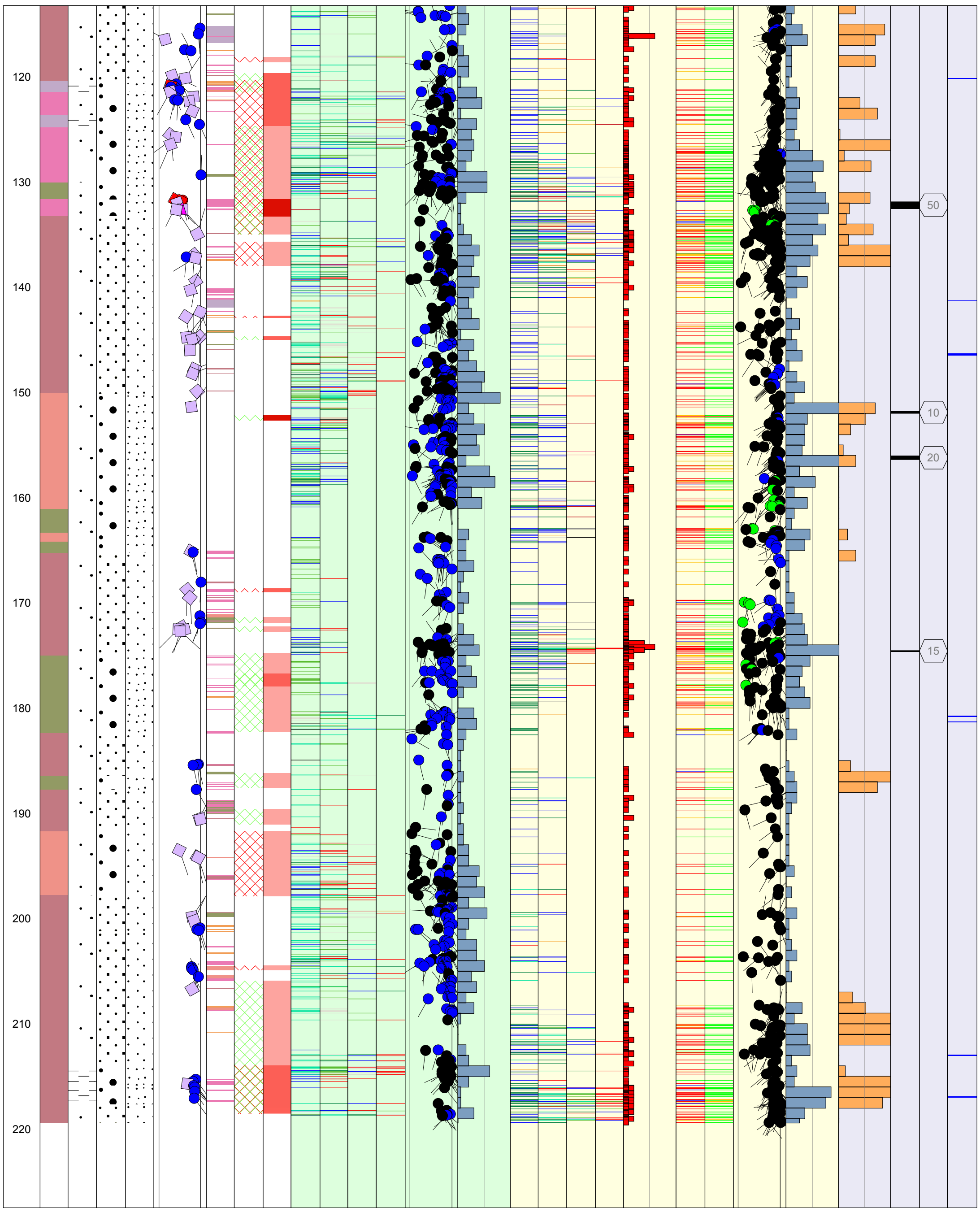
STRUKTURE ORIENTATION



Title **GEOLOGY IN KA3007A01** **Appendix: 2A**

Site	ÄSPÖ	**Coordinate System**	ÄSPÖ96
Borehole	KA3007A01	**Northing [m]**	7410.09
Diameter [mm]	76	**Easting [m]**	2369.57
Length [m]	227.760	**Elevation [m.a.s.l.]**	-400.63
Bearing [°]	22.16	**Drilling Start Date**	2011-04-13 10:00:00
Inclination [°]	-14.69	**Drilling Stop Date**	2011-05-17 07:52:00
Date of coremapping	2011-08-15 13:58:00	**Plot Date**	2012-02-06 23:01:33
Rocktype data from	p_rock	**Signed data**	





120
130
140
150
160
170
180
190
200
210
220
50
10
20
15

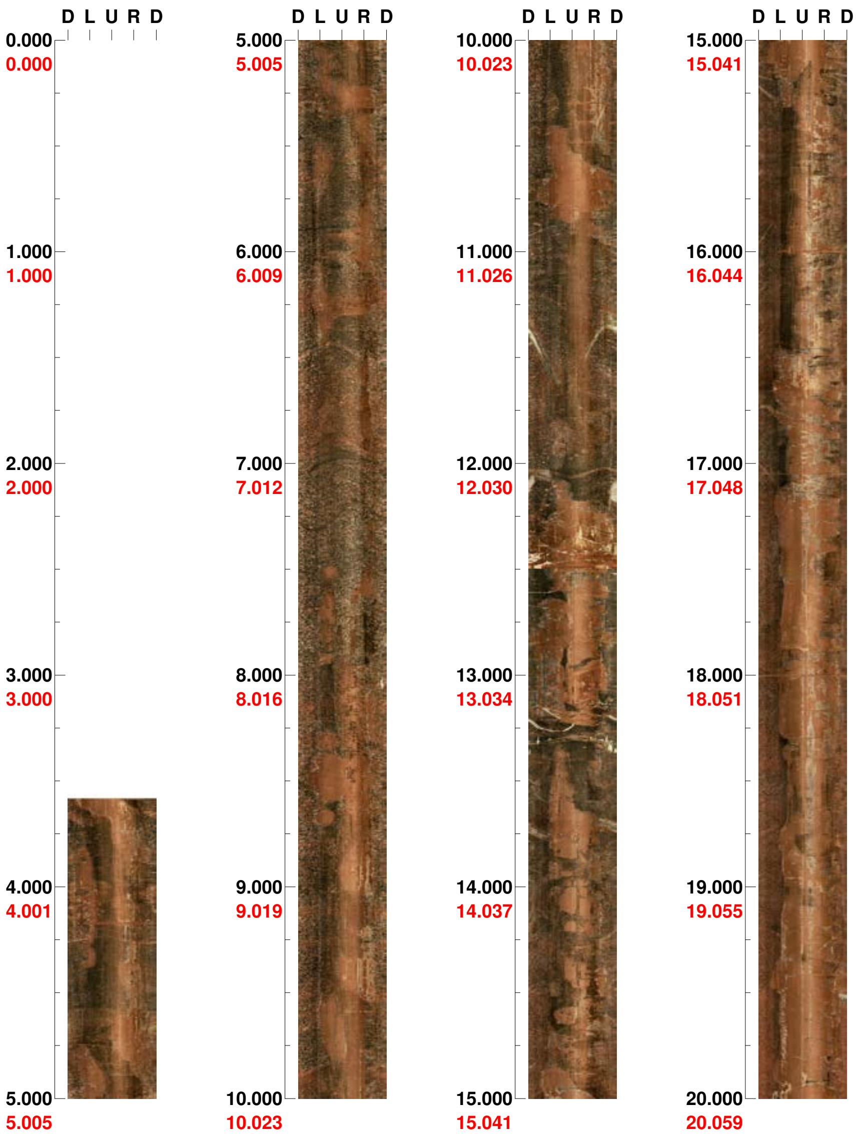
A2.2 BIPS-image of borehole KA3007A01

Project name: AP TDPRAS1004-11-022

Image file	**: d:\work\r5911s~1\bips\ka3007~1.bip**
BDT file	**: d:\work\r5911s~1\bips\ka3007~1.bdt**
Locality	**: ASPO HRL**
Bore hole number	**: KA307A01**
Date	**: 11/06/08**
Time	**: 10:23:00**
Depth range	**: 3.580 - 217.979 m**
Azimuth	**: 22**
Inclination	**: -14**
Diameter	**: 76.0 mm**
Magnetic declination	**: 0.0**
Span	**: 4**
Scan interval	**: 0.25**
Scan direction	**: To bottom**
Scale	**: 1/25**
Aspect ratio	**: 175 %**
Pages	**: 11**
Color	**: +0 +0 +0**

Project name: AP TDPRAS1004-11-022
Bore hole No.: KA307A01 **Azimuth: 22** **Inclination: -14**

Depth range: 0.000 - 20.000 m



Project name: AP TDPRAS1004-11-022
Bore hole No.: KA307A01 **Azimuth: 22** **Inclination: -14**

Depth range: 20.000 - 40.000 m

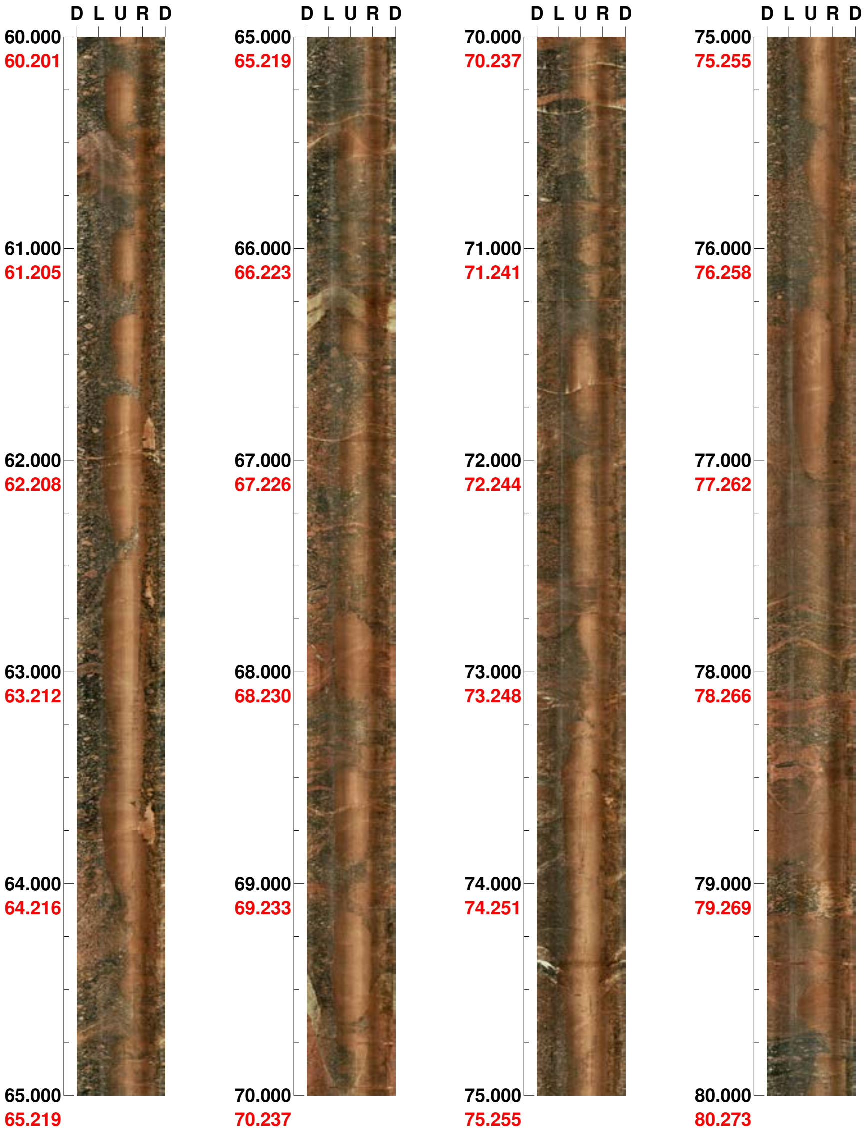
Project name: AP TDPRAS1004-11-022
Bore hole No.: KA307A01 **Azimuth: 22** **Inclination: -14**

Depth range: 40.000 - 60.000 m

Project name: AP TDPRAS1004-11-022

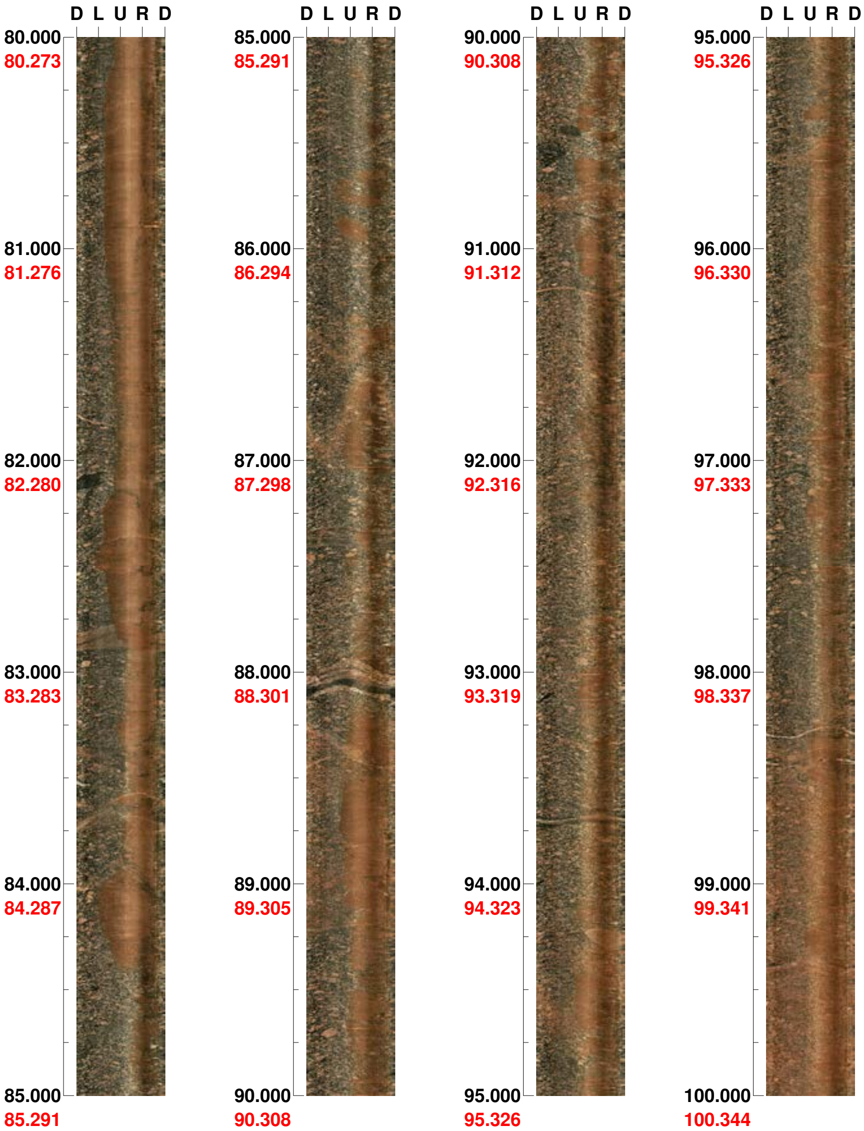
Bore hole No.: KA307A01 **Azimuth: 22** **Inclination: -14**

Depth range: 60.000 - 80.000 m



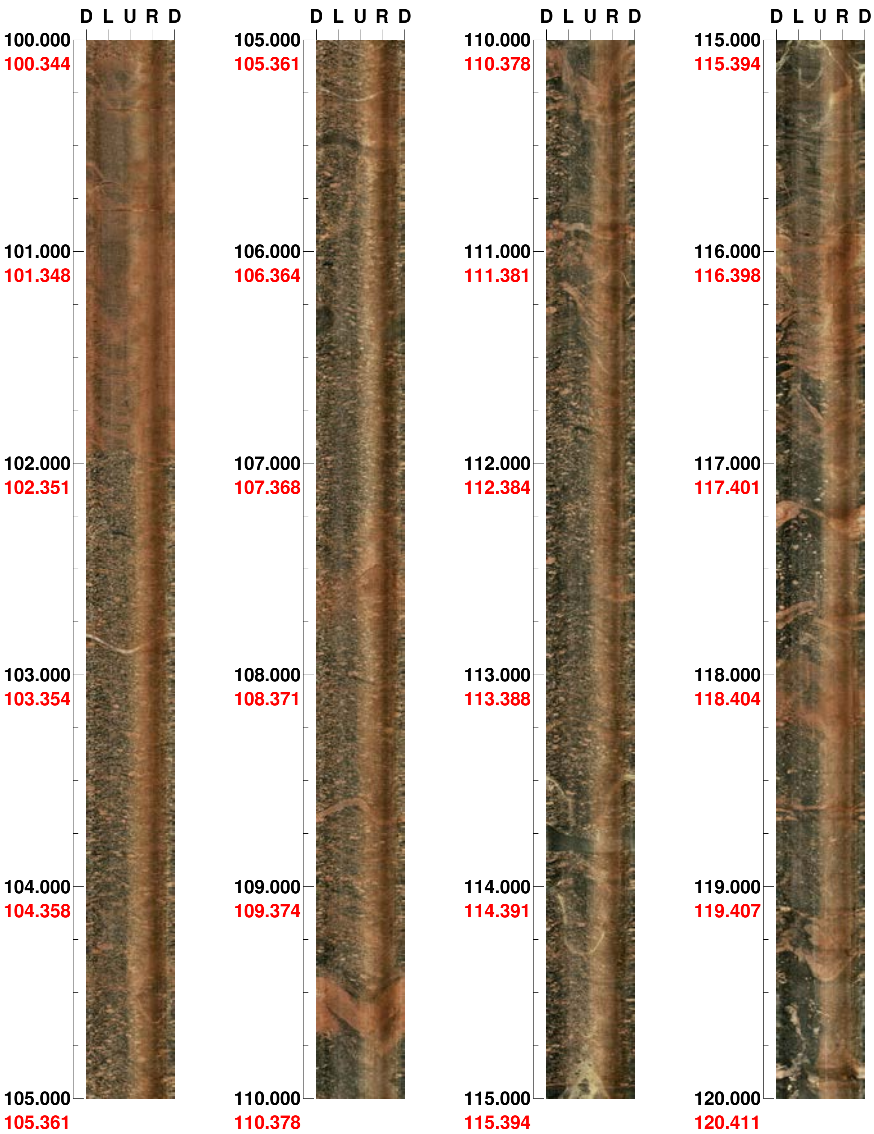
Project name: AP TDPRAS1004-11-022
Bore hole No.: KA307A01 **Azimuth: 22** **Inclination: -14**

Depth range: 80.000 - 100.000 m



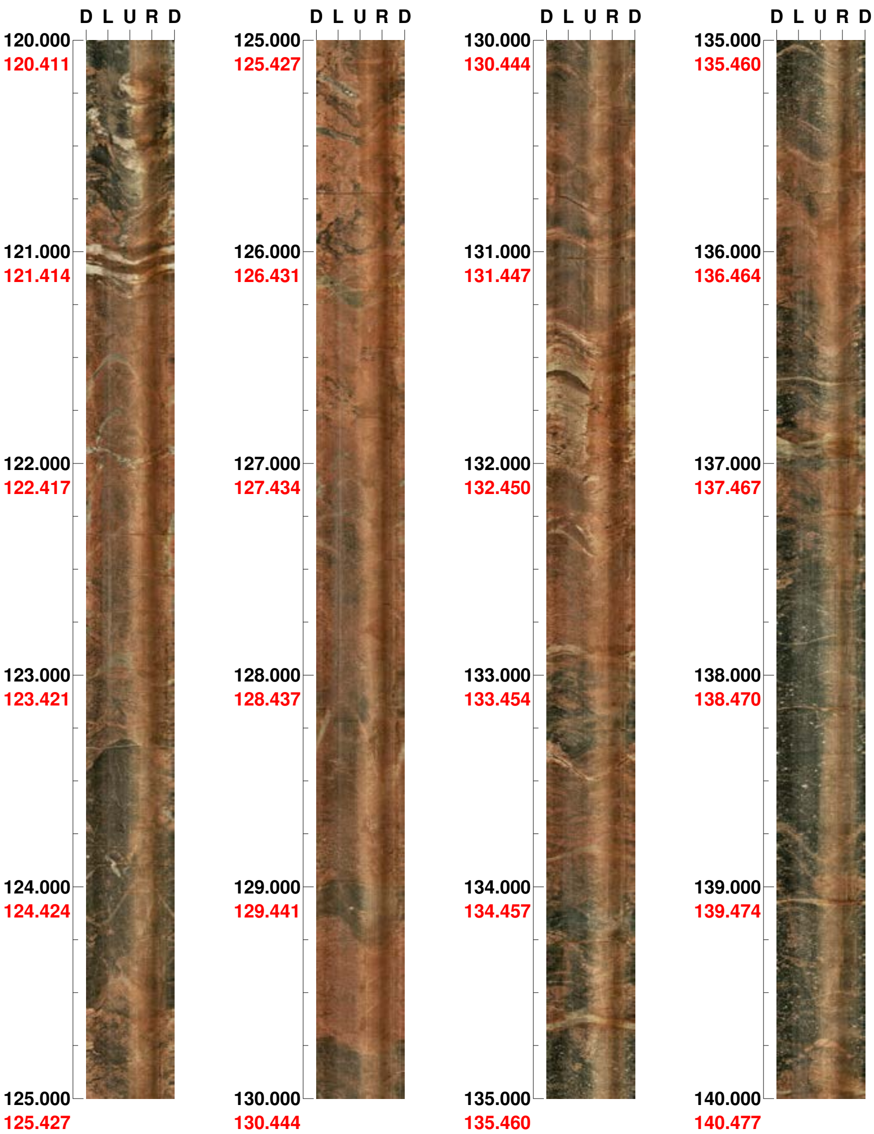
Project name: AP TDPRAS1004-11-022
Bore hole No.: KA307A01 **Azimuth: 22** **Inclination: -14**

Depth range: 100.000 - 120.000 m



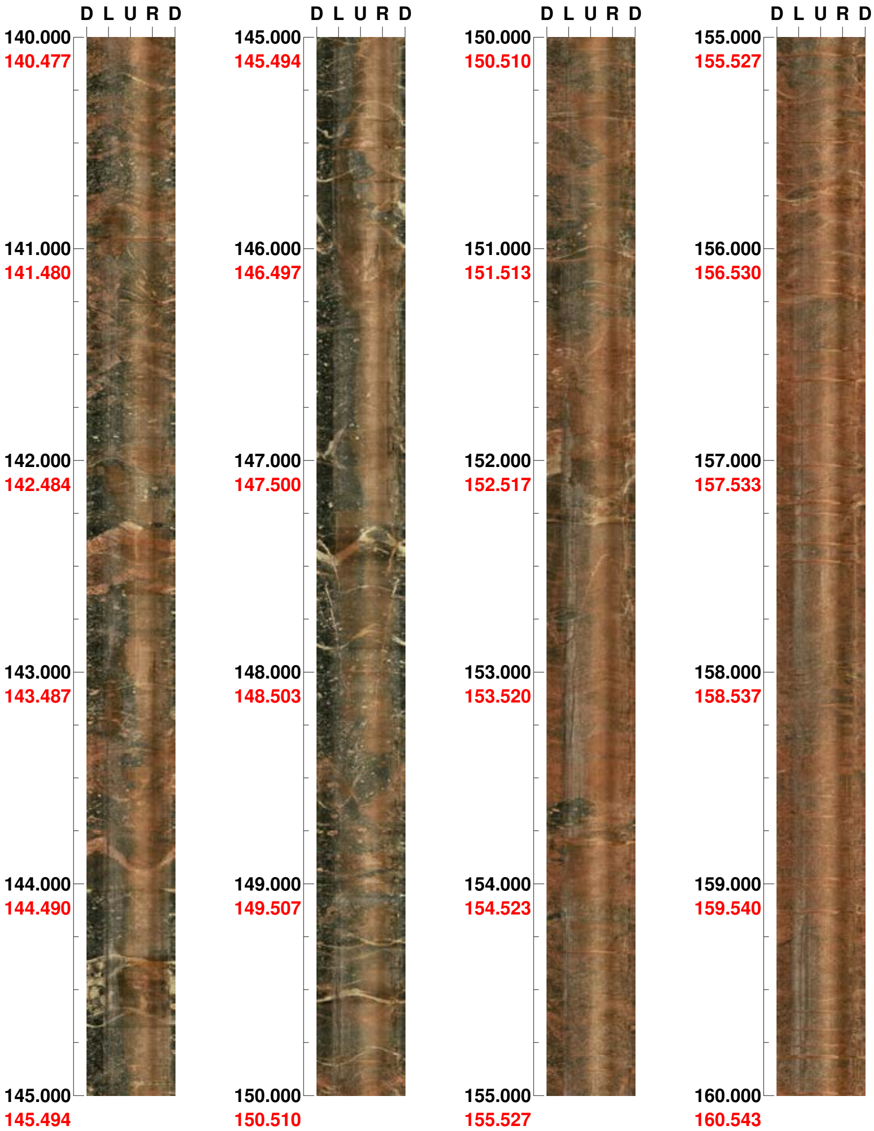
Project name: AP TDPRAS1004-11-022
Bore hole No.: KA307A01 **Azimuth: 22** **Inclination: -14**

Depth range: 120.000 - 140.000 m



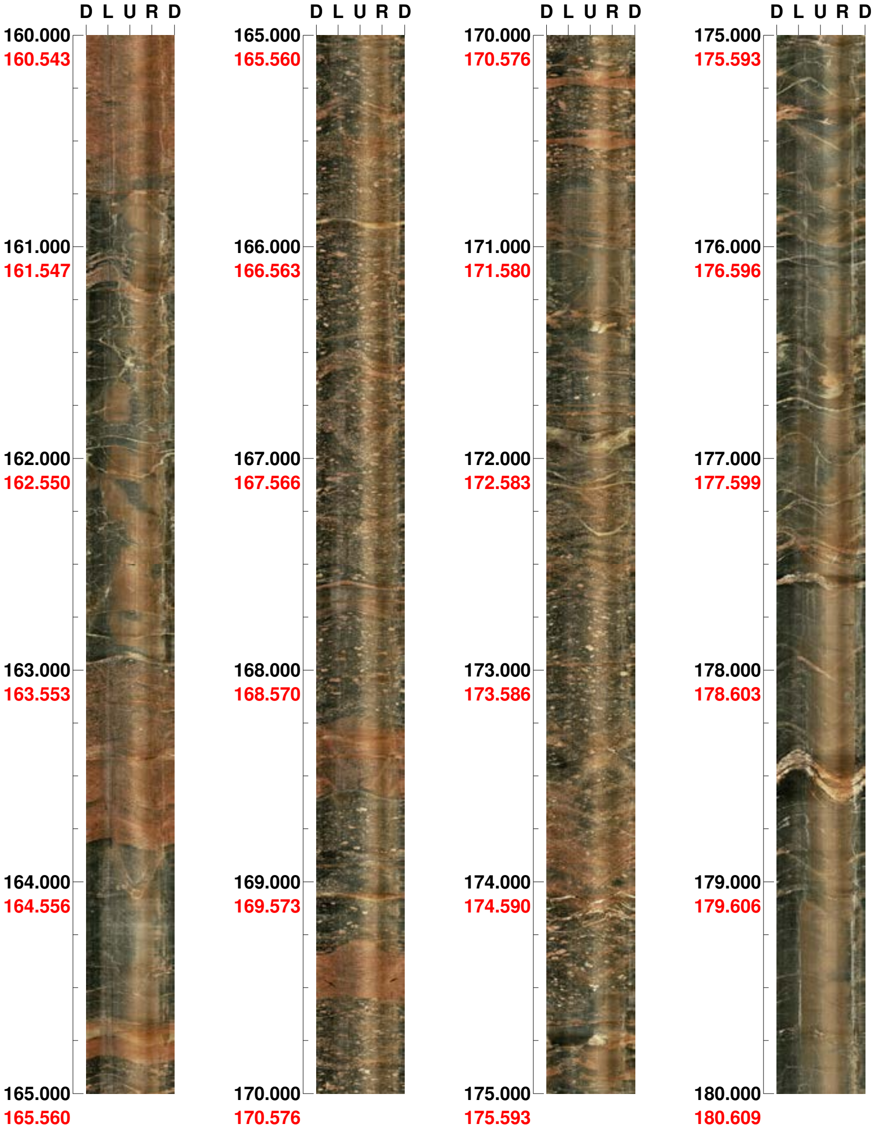
Project name: AP TDPRAS1004-11-022
Bore hole No.: KA307A01 **Azimuth: 22** **Inclination: -14**

Depth range: 140.000 - 160.000 m



Project name: AP TDPRAS1004-11-022
Bore hole No.: KA307A01 Azimuth: 22 Inclination: -14

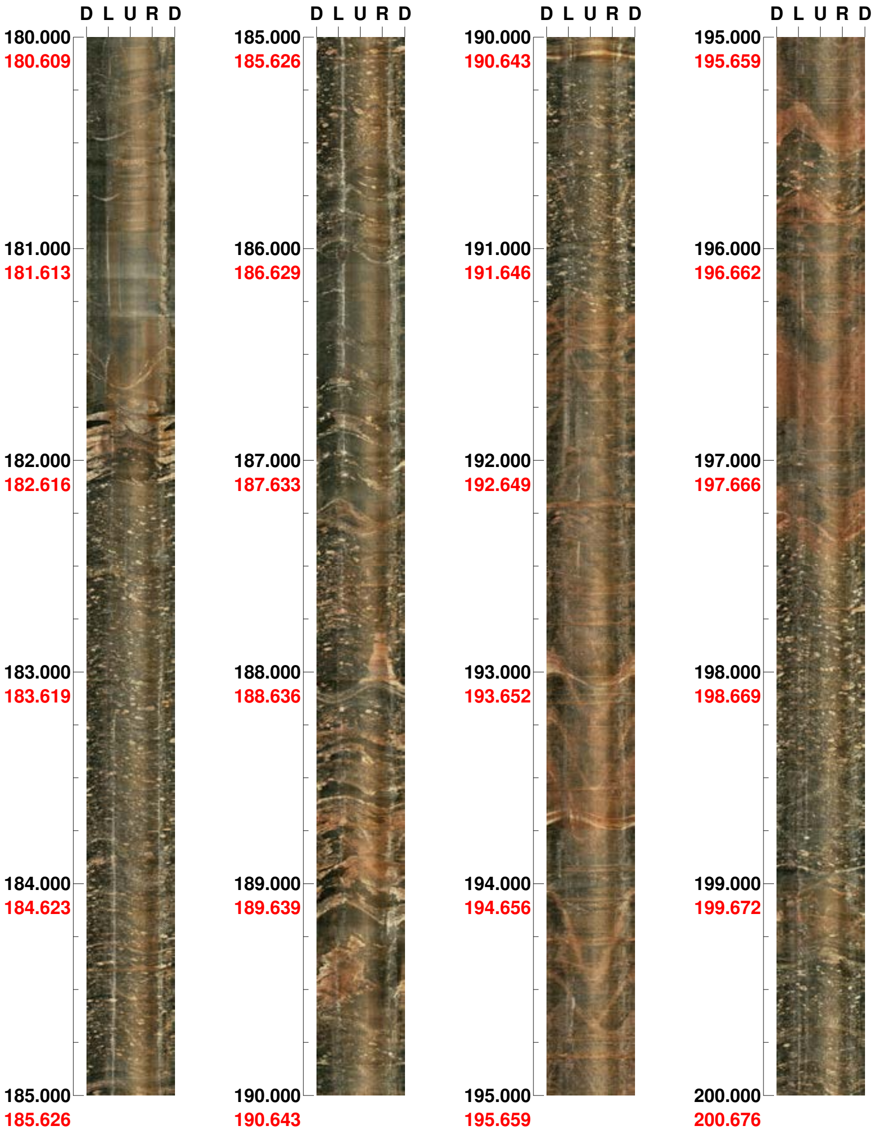
Depth range: 160.000 - 180.000 m



Project name: AP TDPRAS1004-11-022

Bore hole No.: KA307A01 **Azimuth: 22** **Inclination: -14**

Depth range: 180.000 - 200.000 m

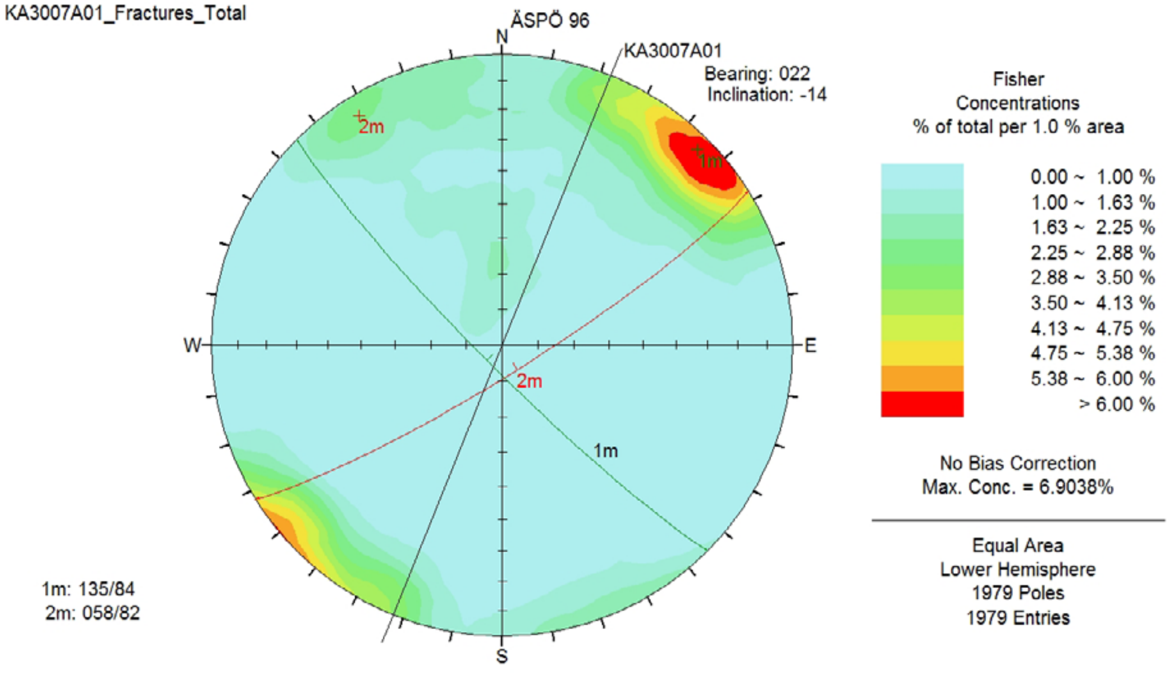


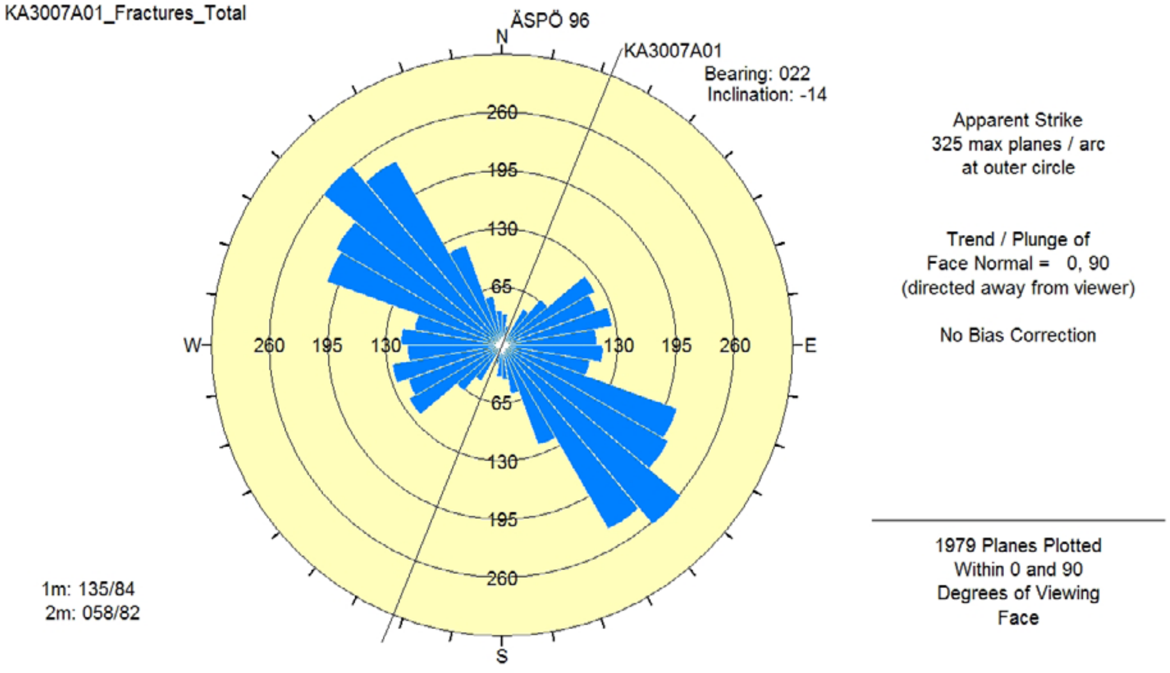
Project name: AP TDPRAS1004-11-022

Bore hole No.: KA307A01 **Azimuth: 22** **Inclination: -14**

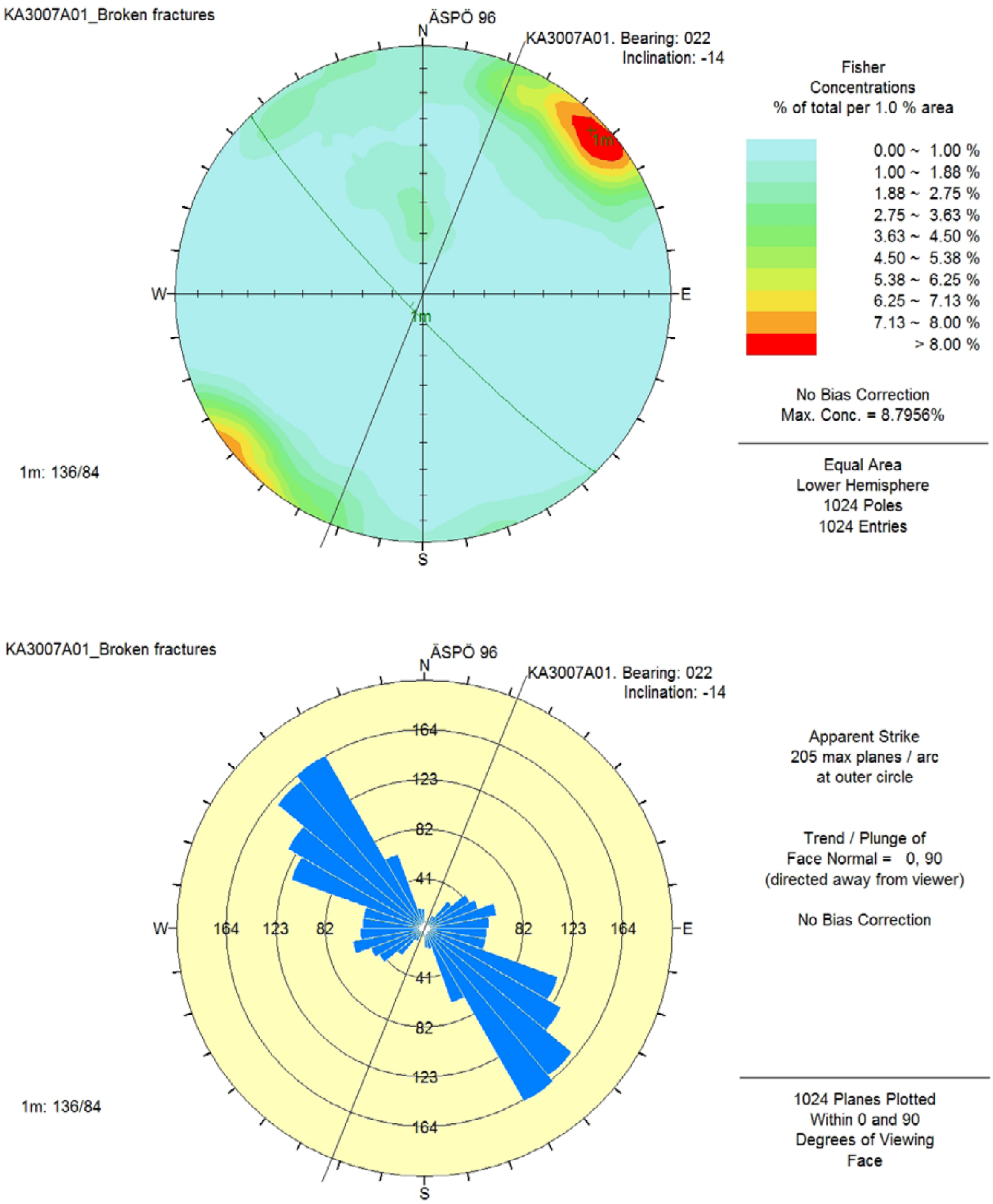
Depth range: 200.000 - 217.979 m

A2.3 Stereonets and rose-diagrams of all logged fractures, all open fractures, all closed fractures, sealed networks and cataclastic structures in borehole KA3007A01

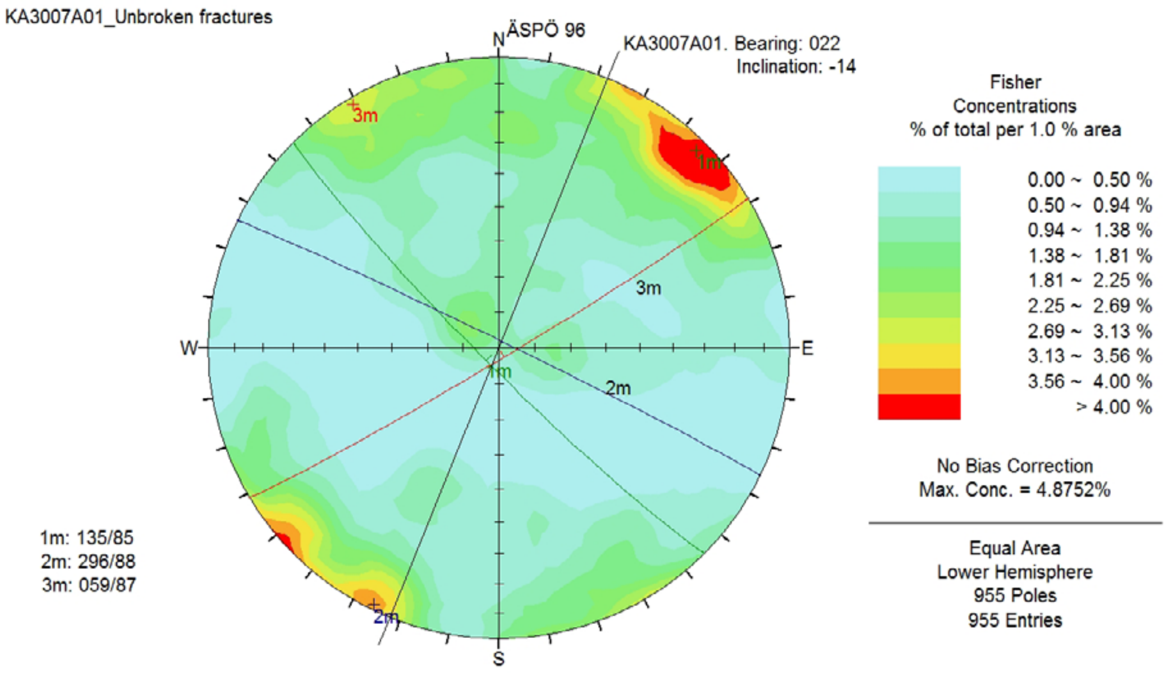


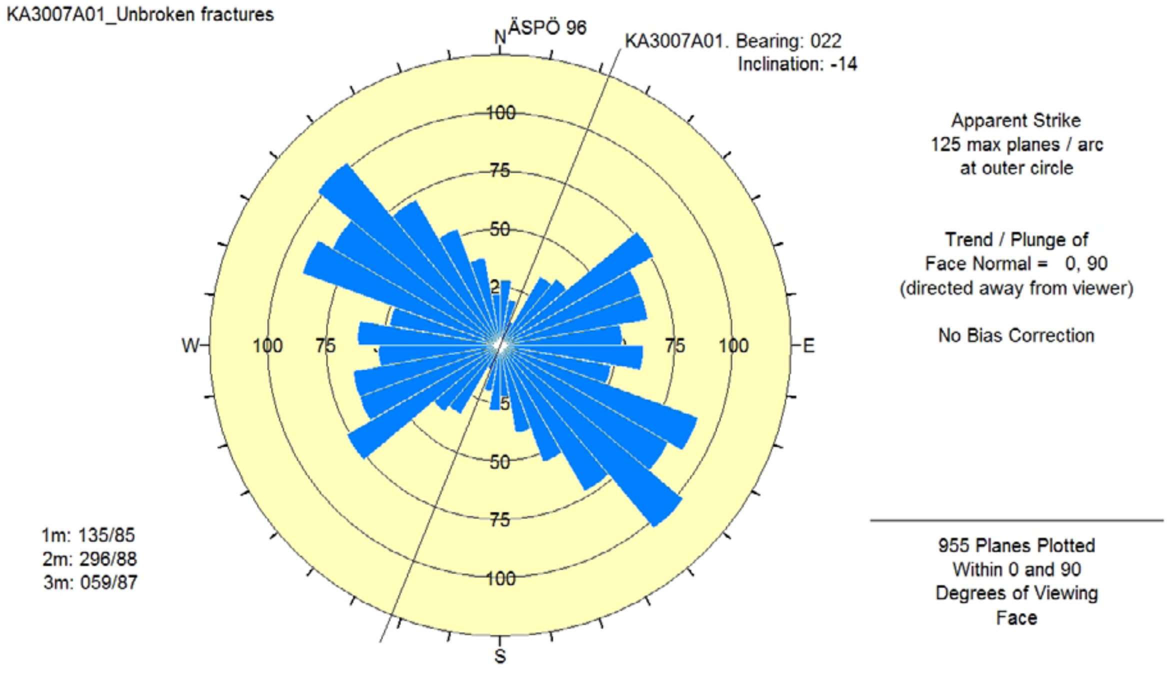


Data from structural measurements in Boremap of all logged fractures in borehole KA3007A01. The coordinate system is Äspö96. Bearing of borehole KA3007A01 marked as a line. Top: Stereogram (strike/dip poles). Bottom: Rose diagram (strike). In total 96 fractures have no measured strike/dip and are therefore excluded here.

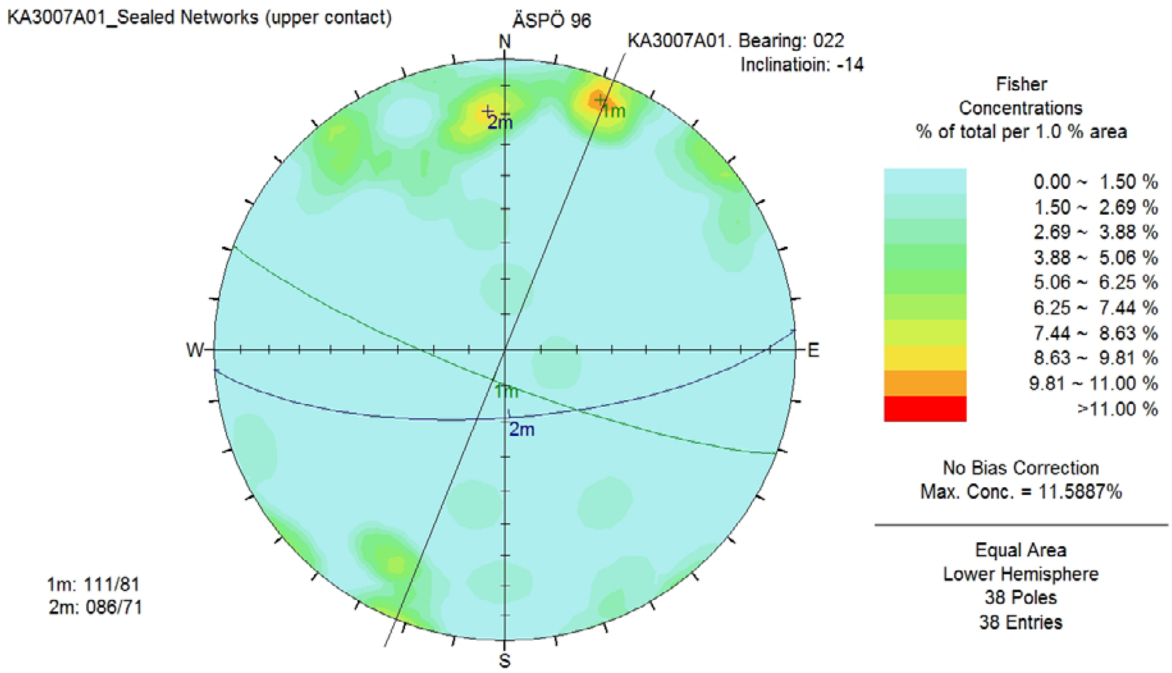


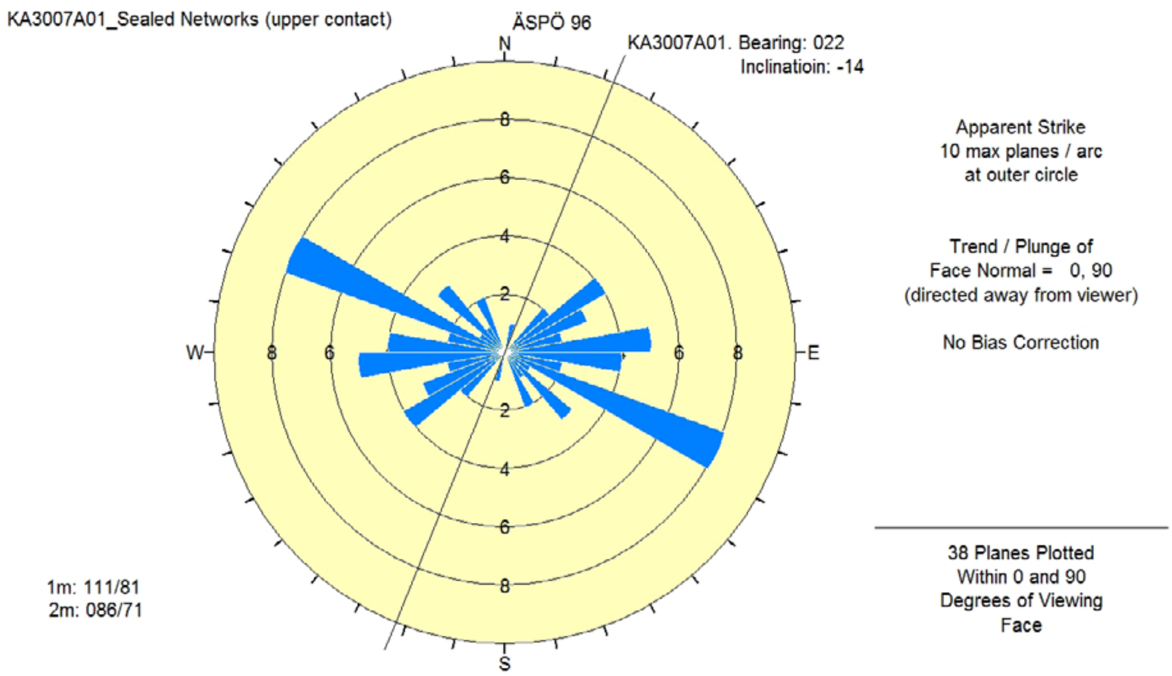
Data from structural measurements in Boremap of all open fractures in borehole KA3007A01. The coordinate system is Äspö96. Bearing of borehole KA3007A01 marked as a line. Top: Stereogram (strike/dip poles). Bottom: Rose diagram (strike). In total 20 open fractures have no measured strike/dip and are therefore excluded here.



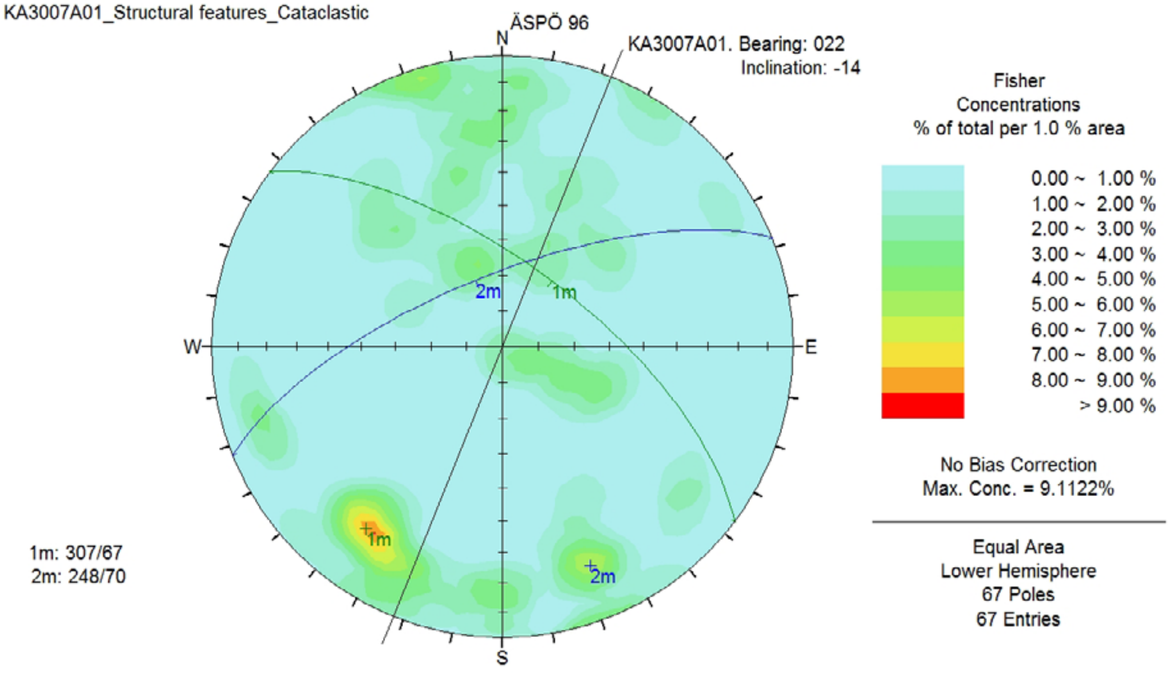


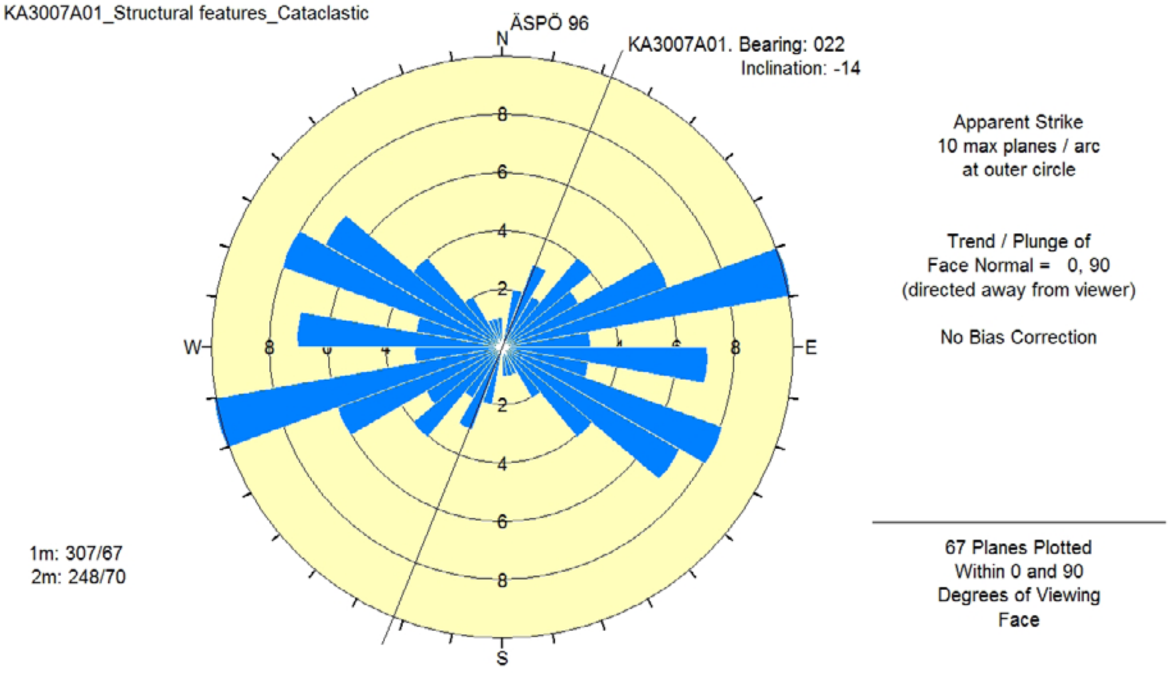
Data from structural measurements in Boremap of all closed fractures in borehole KA3007A01. The coordinate system is Äspö96. Bearing of borehole KA3007A01 marked as a line. Top: Stereogram (strike/dip poles). Bottom: Rose diagram (strike). In total 76 closed fractures have no measured strike/dip and are therefore excluded here.





Data from structural measurements in Boremap showing upper contacts of sealed networks in borehole KA3007A01. The coordinate system is Äspö96. Bearing of borehole KA3007A01 marked as a line. Top: Stereogram (strike/dip poles). Bottom: Rose diagram (strike).





Data from structural measurements in Boremap showing cataclastic structures in borehole KA3007A01. The coordinate system is Äspö96. Bearing of borehole KA3007A01 marked as a line. Top: Stereogram (strike/dip poles). Bottom: Rose diagram (strike).