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Oskarshamn site investigation

Simplified Boremap mapping of percussion boreholes HLX17, HLX18 and HLX19

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June 2005

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Keywords: Simplified Boremap mapping.

This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the author and do not necessarily coincide with those of the client.

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Abstract

Simplified Boremap mapping has been performed for percussion boreholes HLX17, HLX18 and HLX19 situated in the south-eastern part of the Laxemar subarea within the site investigation in Oskarshamn, Sweden.

The purpose of the activity reported here is to map the lithology and structural parameters in the percussion boreholes based on results from drilling in conjunction with digital BIPS-images (Borehole Image Processing System) of the borehole walls.

Borehole HLX17 is dominated by Ävrö granite with very low quantity of open fractures and relatively low alteration of the borehole walls, except for a slight increase below approximately 160 m. Boreholes HLX18 and HLX19 are different, they are still dominated by Ävrö granite but with more mafic rocks (especially HLX19) and with much higher number of open fractures (especially HLX18). Both HLX18 and HLX19 show more extensive alteration (red oxidation) of the borehole walls than HLX17.

This indicates that boreholes HLX18 and HLX19 cut through zones of deformation, while HLX17 does not. This is evident in HLX18 from the bottom of casing down to approximately 110 m and in HLX19 below approximately 80 m.

The present report comprises a description of the applied equipment and the performed activities, the observations, data delivery together with a presentation and discussion of the results.

Sammanfattning

Förenklad Boremap kartering är utförd på hammarborrhål HLX17, HLX18 och HLX19 i sydvästra delen av delområde Laxemar, vid platsundersökningen Oskarshamn.

Syftet med aktiviteten som rapporteras här är att kartera litologiska och strukturella parametrar i hammarborrhålen baserad på resultaten från borrhningen i förbindelse med digitala BIPS-bilder (Borehole Image Processing System) av borrhålsväggarna.

Borrhål HLX17 domineras av Ävrögranit med lågt antal öppna spricker och relativt liten omvandling av borrhålsväggarna ner till ca 160 m djup där en svag ökning kan märkas. Borrhål HLX18 och HLX19 skiljer sig markant från denna beskrivning, även om de är fortfarande dominerade av Ävrögranit innehåller de mera av mafiska bergarter (speciellt HLX19) och mycket fler öppna sprickor (speciellt HLX18). Både HLX18 och HLX19 visar mer extensiv och starkare omvandling (röd oxidering) av borrhålsväggarna än HLX17.

Detta indikerar att både borrhål HLX18 och HLX19 klipper deformationszoner, medan HLX17 gör det inte. Detta är tydligt i HLX18 från botten av foderrör ner till ca 110 m djup och i HLX19 nedan för ca 80 m djup.

Denna rapport beskriver använd utrustning och genomförd aktivitet, observationer, leverans av data samt en presentation och diskussion av resultaten.

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1 Introduction

To investigate the prerequisite for placing a tunnel between the Simpevarp-area (CLAB) and the Laxemar-area four percussion boreholes were drilled, HLX16, HLX17, HLX18 and HLX19, in June to August 2004, see Figure 1-1. The boreholes were drilled to investigate anomalies indicated by seismic refraction measurements /2/ (boreholes HLX16 and HLX17) and linked lineaments /3/ (boreholes HLX18 and HLX19).

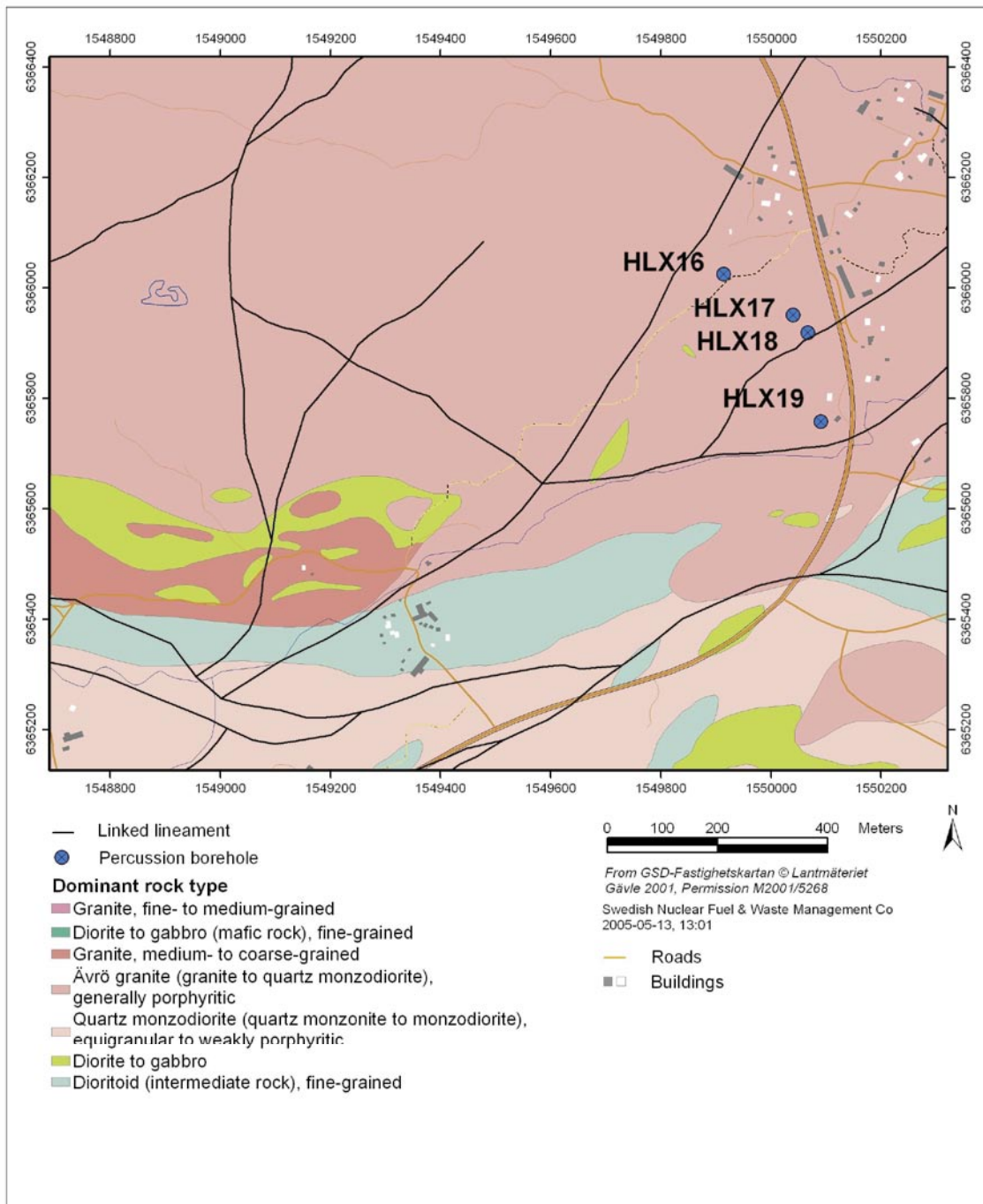


Figure 1-1. Location of boreholes HLX16, HLX17, HLX18 and HLX19 in the Laxemar sub area. The map shows the bedrock geology, linked lineaments, roads and buildings.

This document reports data gained by Simplified Boremap mapping of three of these percussion boreholes; HLX17, HLX18 and HLX19 during the later part of 2004 and the beginning of 2005. HLX16 is not included in this report since no BIPS-image was made of the borehole. The work was carried out in accordance with activity plan AP PS 400-04-053. Table 1-1 lists the controlling documents for this activity. Both activity plan and method description are SKB internal controlling documents.

After completing a percussion borehole it is logged with a digital colour TV-camera to produce images of the borehole wall called a BIPS-image (Borehole Image Processing System) /1/. Mapping of the percussion borehole is then done according to the Simplified Boremap method, in accordance with method description SKB MD 143.006 (SKB internal document). It is based on the BIPS-image and makes it possible to determine the quality of the bedrock that the borehole cuts through, both petrographical (rock types, rock occurrences and alteration) and structural (open fractures, crush zones and ductile deformation). In addition the software used for the mapping (Boremap) calculates the orientation (strike and dip) of each marked planar feature.

All data were stored in the primary data base SICADA for Oskarshamn and are traceable by the activity plan number.

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

Activity plan	Number	Version
Översiktlig kartering och förenklad Boremapkartering av hammarborrhål HLX16–HLX19. Förundersökning av tunnelpassage CLAB-Laxemar	AP PS 400-04-053	1.0
Method descriptions	Number	Version
Metodbeskrivning för BOREMAP kartering	SKB MD 143.006	1.0*

* A newer version of the method description considering in detail the activity discussed in this report (the Simplified Boremap mapping) is in preparation.

2 Objective and scope

The purpose of this investigation is to map the lithology and structural parameters of percussion holes HLX17, HLX18 and HLX19 in greater detail than the preliminary mapping of drill cuttings and results of measurements made while drilling the percussion holes, by using the Simplified Boremap mapping method.

The mapped parameters of the Simplified Boremap mapping are:

- Rock types (> 2 m wide).
- Rock occurrences (> 0.2 to < 2 m wide).
- Rock contacts.
- Alteration (mainly the intensity of red coloured oxidation).
- Open fractures (including crush zones).
- Ductile structures (e.g. foliation, shear zones etc).

3 Equipment

3.1 Description of equipment/interpretation tools

Mapping of BIPS-images according to the Simplified Boremap method is done on desktop computer using the software Boremap (version 3.4.5), which shows the BIPS-image as can be seen in Figure 3-1. Boremap is loaded with SKB rock and mineral standards, where the names and codes for rock types follow SKB standard in SKB DOC ID: 1018395 (“Regler för bergarters benämningar vid platsundersökningen i Oskarshamn”, SKB internal document).

The quality of the Simplified Boremap mapping 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 on the borehole wall).
- The quality of the BIPS-image (i.e. the technical limitations of the image).

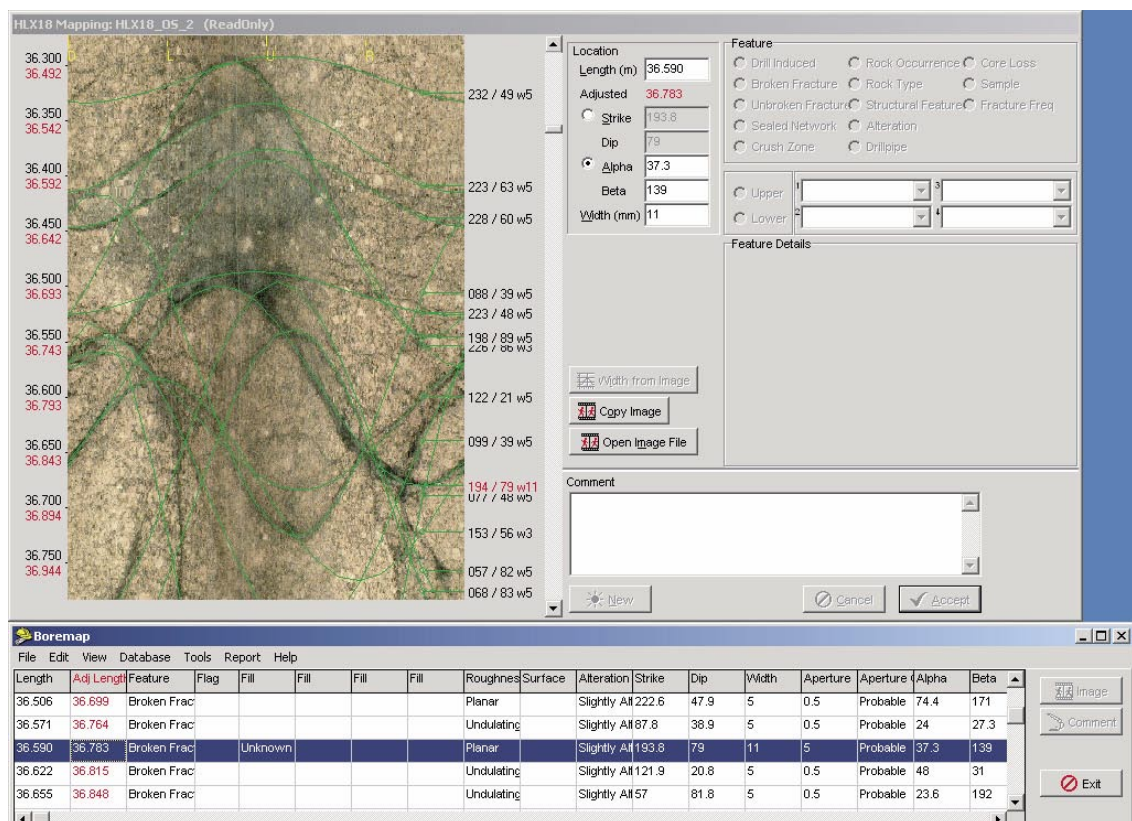


Figure 3-1. Good quality BIPS-image as it is seen in Boremap. Borehole HLX18 showing the borehole wall at 36.492–36.944 m adjusted length, the rocktype is porphyritic Ävrö granite with open fractures (marked as green lines).

The BIPS-image quality varies /1/; borehole HLX17 is of relatively good quality, mud covers the lowermost part of the borehole wall, it can be seen in the BIPS-image from the upper part (Figure 5-1) and is covering approximately 40% of the borehole wall at the bottom.

HLX18 has relatively poor visibility down to approximately 34 m, below that down to approximately 140 m the visibility is good. Below 140 m, mud on the lowermost part of the borehole wall reduces visibility, but it is not until below approximately 174 m that it seriously affects the visibility of the borehole wall.

The BIPS-image of borehole HLX19 is of relatively good quality, mud covers the lowermost part of the borehole wall but it does not affect the visibility more than marginally.

For closer examination of drill cuttings normal field geologist equipment was used; a hand held lens, streak plate (a piece of white, unglazed porcelain), small magnet, hydrochloric acid (HCl 10% solution) and a knife. A stereomicroscope Zeiss Stemi DV 4 (magnification 8x–32x) was used when necessary. Susceptibility meter JH-8, from Geoinstruments Finland, was used for measurements of the magnetic susceptibility in the drill cuttings.

4 Execution

4.1 General

Simplified Boremap mapping is comprised of data from:

- BIPS-image,
- preliminary mapping of drill cuttings,
- results from percussion drilling,
- available geophysical measurements and interpretations.

The BIPS-image is opened in Boremap where the observed parameters are marked and described. Comparisons are made with preliminary mapping of drill cuttings, drilling penetration rate and, when available, results from geophysical measurements.

4.2 Preparations

Data from the SKB database SICADA used for Simplified Boremap mapping is listed in Table 4-1. The BIPS-image is opened in Boremap and the length is adjusted from bottom of casing to bottom of image according to a constant (the measured length registered in the BIPS-image deviates from the true length by a factor of approximately 0.5 m per 100 m).

The orientation of the borehole i.e. the azimuth and dip are the basis for calculating the strike and dip of the mapped planar structures. In this report data from Optical Televiewer tool for deviation measurements (OPTV) /4/ is used with a Moving average filter (31 points) to correct for any change in the direction of the borehole with length.

Table 4-1 Borehole data for HLX17, 18 and 19 (values from top of casing). Data taken from SKB database SICADA and Boremap (adjusted length).

ID-code	Northing	Easting	Bearing (degrees)	Inclination (degrees)	Diameter (mm)	Bore-hole length (m)	End of casing (m)	BIPS-image interval, adj length (m)
HLX17	6365951.514	1550040.753	310.940	-59.492	139	202.2	9.10	9.1–202.1
HLX18	6365919.121	1550067.642	135.914	-57.600	139	181.2	15.12	15.1–181.2
HLX19	6365757.879	1550090.867	130.043	-57.895	137	202.2	12.12	12.1–149.5

4.3 Execution of measurements

BIPS-images make it possible to map features in percussion boreholes that are not discernible using rock cuttings and/or geophysical measurements. Planar structures such as open fractures, rock contacts, and deformational structures can be mapped accurately.

Below is a list of the parameters that are mapped with a short description and explanations for the WellCAD representation in Appendix 1–3:

- Lithology. Rock contacts, rock types (> 2 m wide) and rock occurrences (> 0.2 to < 2 m wide).
 - The lithological classification is sometimes difficult in the drill cuttings because of small fragment size of drill cuttings and the sometimes strong red oxidation of the rock, but usually not a problem when drill cuttings and BIPS-image can be compared.
 - Rock structure, texture and grain size is easily discerned in good quality BIPS-images, especially in medium to coarse grained rocks, while finer grained rocks often need to be seen in the drill cuttings. The WellCAD presentation shows these parameters for the rock types only, although they are also mapped for the rock occurrences.
 - Sharp rock contacts are easily mapped, but diffuse and undulating contacts of e.g. veins are often approximations. Rock contacts are shown as horizontal lines in the Well CAD presentations, regardless of their true orientation.
- Alteration and alteration intensity.
 - The only rock alteration that is mapped with some certainty in good quality BIPS-images are the red colouring of the rock (oxidation) and its intensity. Other alterations are normally difficult to identify in the BIPS-image, but can sometimes be recognized in the drill cuttings.
- Open fractures and crush zones.
 - Only fractures that show apertures in the BIPS-image are mapped. Their apparent aperture is measured in the image, if a fracture is less than 1 mm wide it is assigned an aperture of 0.5 mm (Open Fracture Aperture).
 - Roughness of open fractures is determined as planar, undulating or stepped and represented as coloured lines (Open Fracture Roughness).
 - The alteration intensity of open fractures are determined and represented as coloured dots (Open Fracture Alteration) in the WellCAD presentation. The strike and dip of each fracture is represented with the coloured dot marking the dip (0–90 degrees) and a short line pointing to the direction (0–360 degrees).
 - The number of open fractures is calculated by the software for each meter and represented in the column Open Fracture Frequency (fr/m).
 - Crush zones are also mapped from the BIPS-image, the average size of fragments is measured in mm (Natural Piece Size) and the alteration intensity is decided. The colouring is the same as the Open Fracture Alteration in the WellCAD representation. Two interpreted main fracture directions are also marked within each crush zone.

4.4 Data handling

The Simplified Boremap mapping of the percussion boreholes is performed on a local computer disk at the core storage facility and saved on back-up in SKB internal network. When a borehole has been mapped the file is quality checked by the author and by a computer routine in Boremap. The data is then submitted to SKB for exportation to SICADA.

4.5 Nonconformities

HLX16 is not included in this report since no BIPS-image was made of the borehole. The BIPS-image of HLX19 stopped at 149 m and therefore no mapping is done below that length /1/.

5 Results

Below the results from mapping of lithology, alteration and open fractures are given for boreholes HLX17–19. The percentages of different lithologies are given in Tables 5-1 through Table 5-3. The amount of alteration (oxidation and fracture zone alteration) as well as their intensity is listed in Table 5-4 and finally the number of open fractures and the fracture frequency per meter can be seen in Table 5-5. Furthermore the results are given in Appendix 1 to 3 as WellCAD presentations.

HLX17

See Appendix 1 for WellCAD presentation of mapping results.

Lithology: The dominant rock type is Ävrö granite, containing xenoliths of fine-grained diorite-gabbro, see Figure 5-1. One subordinate diorite/gabbro occurs. Minor dykes and/or veins of fine-grained granite and pegmatite have been noted, see Table 5-1.

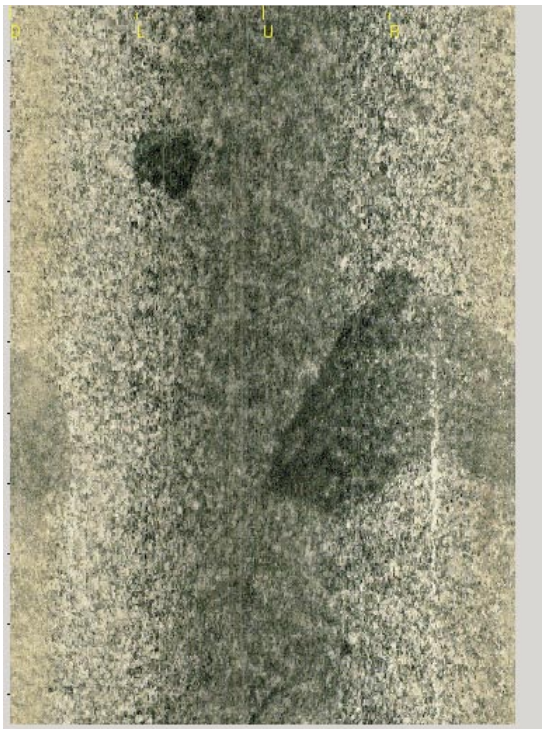


Figure 5-1. BIPS-image as seen in Boremap, borehole HLX17 showing fresh (no red oxidation) Ävrö granite with xenoliths of fine-grained diorite-gabbro. Thin layer of mud can be seen on bottom of borehole wall (right and left edges of image).

Table 5-1. Lithology of HLX17. Percents calculated from adjusted length of BIPS-image.

Rock name	SKB rock code	%
Ävrö granite	501044	93.4
Fine-grained diorite-gabbro	505102	0.6
Diorite/gabbro	501033	1.8
Fine-grained granite	511058	2.7
Pegmatite	501061	1.5

Alteration: Alteration in the form of oxidation occurs, the intensity is mostly weak but even medium occurs, in total 32%, see Table 5-4.

Open fractures: A total of 172 open fractures were mapped, resulting in an average of 0.89 fractures per meter, this corresponds with good quality rock, see Table 5-5.

HLX18

See Appendix 2 for WellCAD presentation of mapping results.

Lithology: The dominant rock types are Ävrö granite and fine-grained dioritoid (Figure 5-2). Subordinate dykes and veins of both fine-grained granite and pegmatite have been noted. Xenoliths of fine-grained diorite-gabbro occur in the Ävrö granite and one enclave of diorite/gabbro in the fine-grained dioritoid, see Table 5-2.

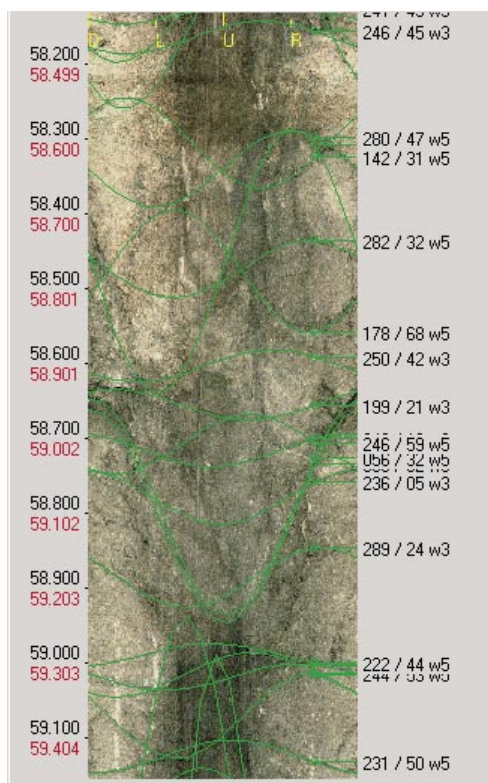


Figure 5-2. BIPS-image as seen in Boremap, borehole HLX18, between 58.5–59.4 m (adjusted length) showing contact between fine-grained granite and fine-grained dioritoid and many open fractures (marked with green lines).

Table 5-2. Lithology of HLX18. Percents calculated from adjusted length of BIPS-image.

Rock name	SKB rock code	%
Ävrö granite	501044	77.5
Fine-grained dioritoid	501030	15.5
Fine-grained granite	511058	3.5
Pegmatite	501061	2.4
Fine-grained diorite-gabbro	505102	0.5
Diorite/gabbro	501033	0.6

Alteration: The whole length of the borehole walls shows some kind of alteration. Alteration in the form of oxidation dominates the rock walls with both weak and medium intensity, in total 99%, see Table 5-4.

Open fractures: A total of 865 open fractures were mapped, resulting in an average of 5.2 fractures per meter, see Table 5-5. This reflects a strongly fractured rock with the highest frequency of open fractures between 15m (below the casing) to approximately 105 m, see Figure 5-2 and Appendix 2. One crush zone is marked at 99.9–100.6 m with strike/dip 244/49 and the average length of rock pieces in the crush zone approximately 80 mm, see Appendix 2, “Natural Piece”. The strike of this zone is roughly parallel to the linked lineament on the surface.

HLX19

See Appendix 3 for WellCAD presentation of mapping results.

Lithology: The dominant rock type in the upper part of the borehole is Ävrö granite. Below 119.6 m the borehole consists of fine-grained dioritoid, see Figure 5-3. Minor diorite/gabbro and fine-grained diorite-gabbro occur also, mainly as xenoliths. The Ävrö granite and the fine-grained diorite-gabbro are cut by dykes of pegmatite and finally the Ävrö granite is cut by dykes and veins of fine-grained granite, see Table 5-3.

Alteration: Alteration in the form of oxidation is common down to approximately 120 m, the intensity is mainly weak, but medium occurs also, in total 69%, see Table 5-4. Below approximately 120 m the rock is mostly free from oxidation.

One possible structural feature was mapped in HLX19 at 75.035 m adjusted length. A weak ductile shear, less than 5 cm wide, with strike/dip: 211/24.

Table 5-3. Lithology of HLX19. Percents calculated from adjusted length of BIPS-image.

Rock name	SKB rock code	%
Ävrö granite	501044	62.3
Fine-grained dioritoid	501030	21.4
Diorite/gabbro	501033	5.7
Fine-grained diorite-gabbro	505102	3.7
Pegmatite	501061	6.2
Fine-grained granite	511058	0.8

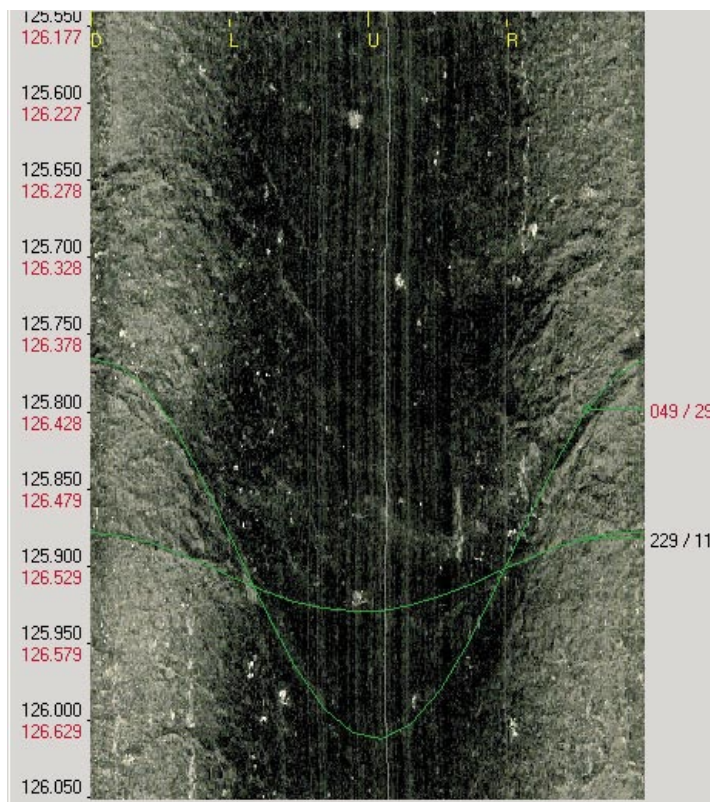


Figure 5-3. BIPS-image as seen in Boremap, borehole HLX19 showing fine-grained dioritoid, with two open fractures and feldspar megacrysts.

Open fractures: A total of 390 open fractures were mapped, resulting in an average of 2.83 fractures per meter, see Table 5-5. This reflects a medium quality rock with a slight increase in fracture frequency below approximately 81 m, except for one crush zone marked at 36.85–36.94 m with strike/dip 94/31 and the average length of rock pieces in the crush zone approximately 35 mm, see Appendix 3, “Natural Piece” and Figure 5-4.

Table 5-4. Total alteration of percussion boreholes HLX17, HLX18 and HLX19.

Alteration	Intensity	HLX17 (%)	HLX18 (%)	HLX19 (%)
Oxidation	Weak	29	66	55
	Medium	3	33	14

Table 5-5. Total number of open fractures in percussion boreholes HLX17, HLX18 and HLX19.

	Total number of open fractures	Fractures/meter
HLX17	172	0.89
HLX18	865	5.20
HLX19	390	2.83

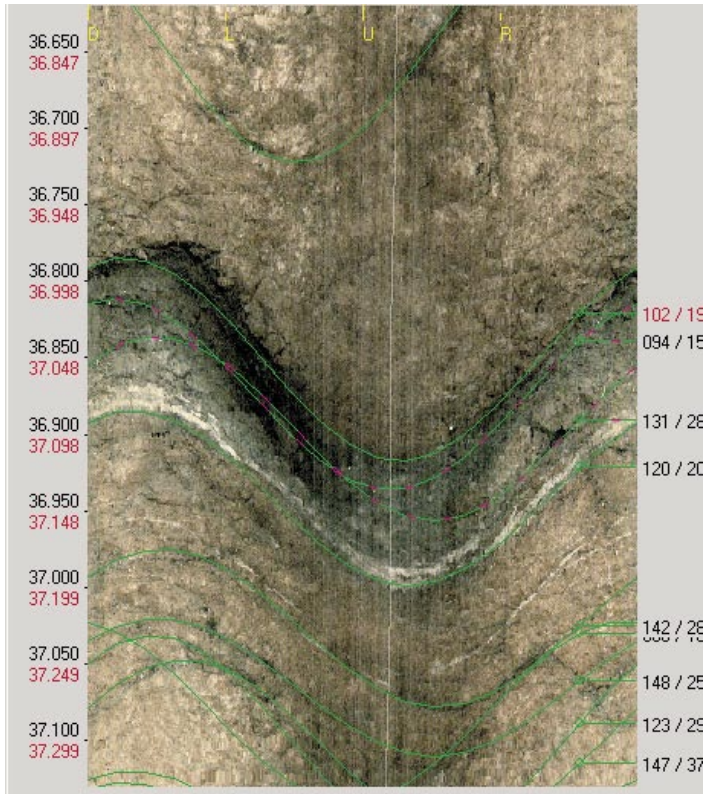


Figure 5-4. BIPS-image as seen in Boremap, borehole HLX19 showing crush zone at 36.85–36.94 m in Pegmatite.

6 Summary and discussions

Borehole HLX17 is dominated by Ävrö granite with very low quantity of open fractures and relatively low alteration of the borehole walls, except for the slight increase below approximately 160 m. Boreholes HLX18 and HLX19 are different, they are still dominated by Ävrö granite but with more mafic rocks (especially HLX19) and with much higher number of open fractures (especially HLX18). Both HLX18 and HLX19 show more extensive alteration (red oxidation) of the borehole walls than HLX17. This indicates that boreholes HLX18 and HLX19 cut through deformation zones, while HLX17 does not. This is especially evident in HLX18 from 15.1 m (below casing) to approximately 110 m. To a lesser extent the same applies to HLX19 from approximately 80 m to 149.5 m.

The interpretations of geophysical borehole data for HLX18 estimates the fracture frequency as generally moderate or low /5/, while the fracture frequency from the BIPS-image shows high fracture frequency, underlines the necessity of using more than one method for investigating the percussion boreholes.

The classification of the mafic rocks in boreholes HLX18 and HLX19 differs between the preliminary geology which is based on drilling results alone and the Simplified Boremap mapping.

In HLX18 the mafic rock is fine-grained and low in susceptibility, so it was considered a fine-grained diorite-gabbro in the preliminary mapping. When the rock cuttings could be compared to the BIPS-image where feldspar megacrysts could be seen as well as the alteration, see Figure 5-2, which explains the often low susceptibility, the result became that the mafic rock is presently considered to be a fine-grained dioritoid (Appendix 2).

In HLX19 at the length of 119.6 m, the rock considered a Diorite/gabbro based on the rock cuttings, became a fine-grained dioritoid, because of the feldspar megacrysts that can be clearly seen in the BIPS-image (Figure 5-3) as well as the fine grain-size of the rock (Appendix 3).

In this report data from Optical Televiewer tool for deviation measurements (OPTV) /4/ is used with a Moving average filter (31 points) by the Boremap software to correct the strike and dip of mapped planar structures in each borehole.

The parameters not represented in the WellCAD representations are either uncommon or difficult to map from the BIPS-image. As an example fracture minerals which sometimes occur in open fractures are all labelled as unknown mineral, because of the difficulties in identifying them accurately from the BIPS-image. In the rock cuttings secondary minerals are identified when possible, but can normally not be assigned to a specific fracture. Only one alteration type of open fractures is identified in the BIPS-image i.e. red colouring of rims, but they can rarely be verified in the rock cuttings.

Ductile structures e.g. foliations, ductile shear zones etc are mapped if they occur in the borehole walls. One weak ductile shear, less than 5 cm wide, with strike/dip: 211/24 was mapped in HLX19 at approximately 75 m adjusted length, indicating that ductile deformation has taken place in the rock.

References

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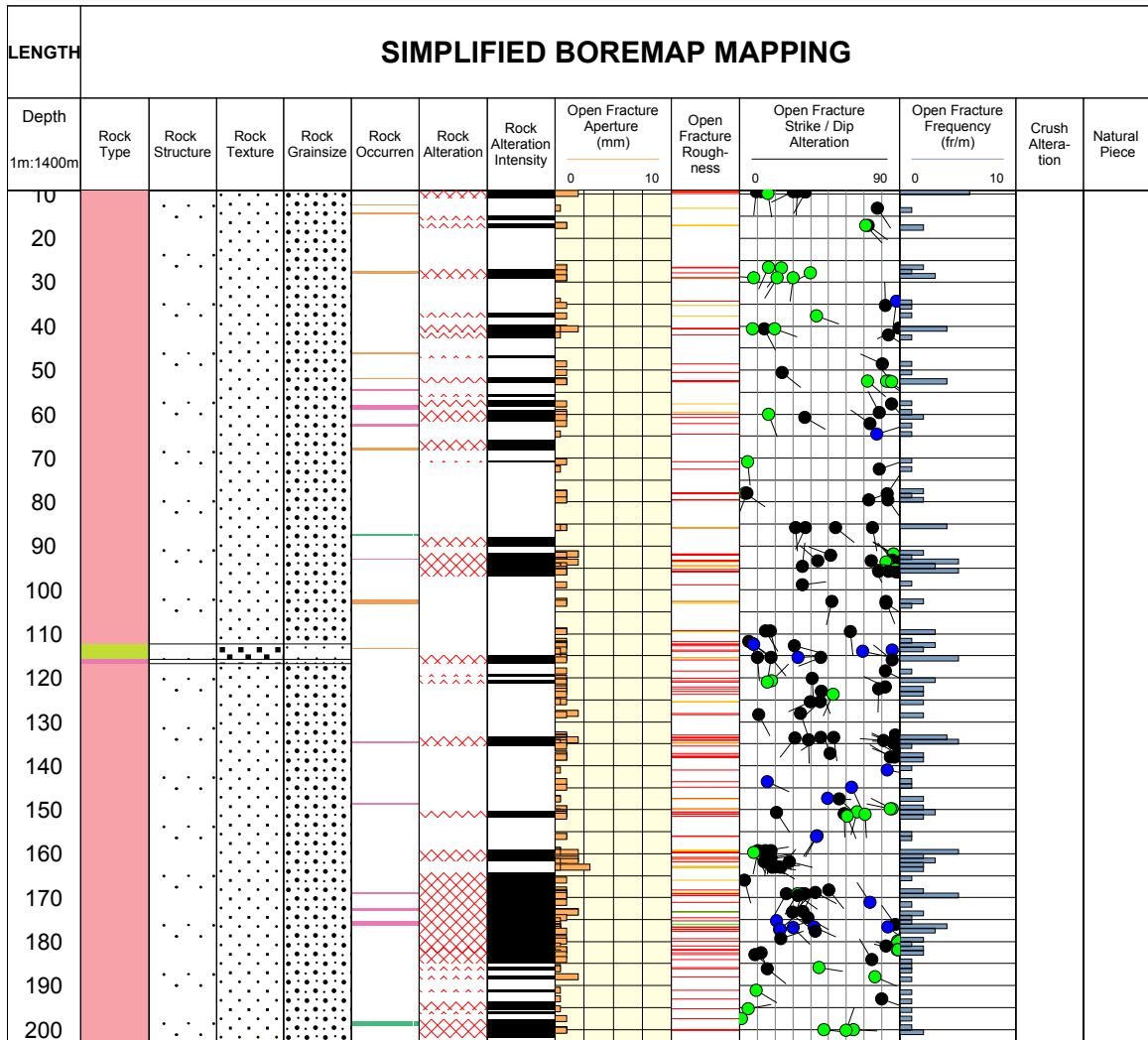
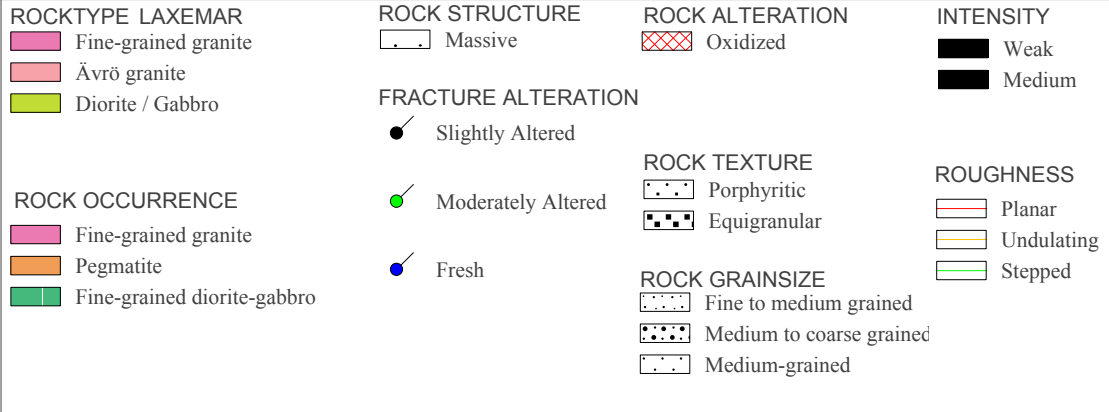
Title SIMPLIFIED GEOLOGY HLX17

Appendix 1



Site LAXEMAR
 Borehole HLX17
 Diameter [mm] 139
 Length [m] 202.200
 Bearing [°] 310.94
 Inclination [°] -59.48
 Date of mapping 2004-10-12 10:45:00

Coordinate System RT90-RHB70
 Northing [m] 6365951.51
 Easting [m] 1550040.75
 Elevation [m.a.s.l.] 3.35
 Drilling Start Date 2004-06-28 14:30:00
 Drilling Stop Date 2004-07-01 09:00:00
 Plot Date 2005-08-31 23:34:32



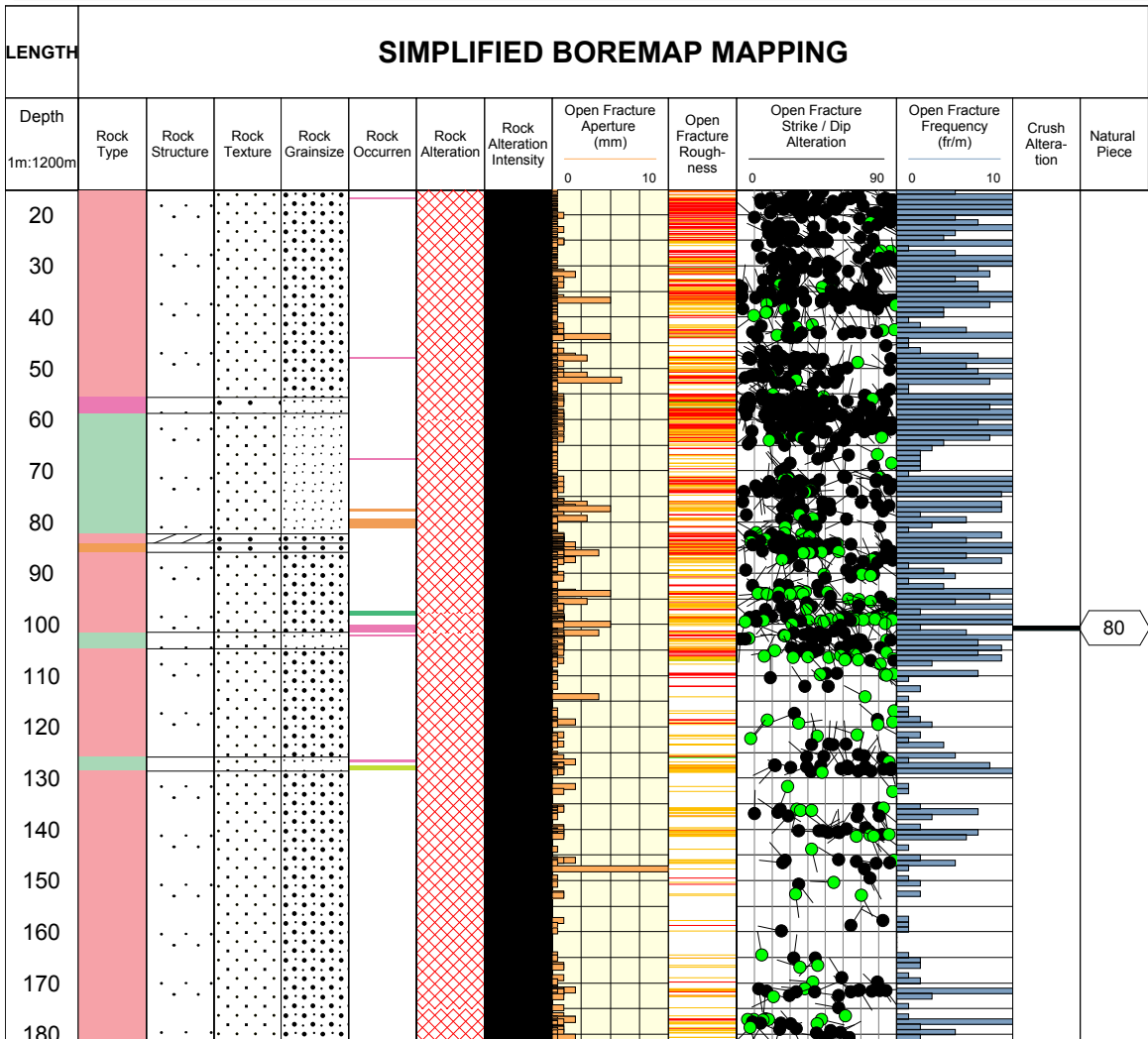
Title **SIMPLIFIED GEOLOGY HLX18** Appendix 2



Site LAXEMAR
 Borehole HLX18
 Diameter [mm] 139
 Length [m] 181.200
 Bearing [°] 135.91
 Inclination [°] -57.59
 Date of mapping 2005-03-15 17:14:00

Coordinate System RT90-RHB70
 Northing [m] 6365919.12
 Easting [m] 1550067.64
 Elevation [m.a.s.l.] 4.04
 Drilling Start Date 2004-07-01 12:00:00
 Drilling Stop Date 2004-07-06 17:30:00
 Plot Date 2005-08-31 23:34:32

ROCKTYPE LAXEMAR Fine-grained granite Pegmatite Ävrö granite Fine-grained dioritoid	ROCK STRUCTURE Veined Massive FRACTURE ALTERATION Slightly Altered Moderately Altered	ROCK ALTERATION Oxidized ROCK TEXTURE Porphyritic Unequigranular ROCK GRAINSIZE Fine to medium grained Medium to coarse grained Coarse-grained	INTENSITY Weak Medium ROUGHNESS Planar Undulating Stepped
ROCK OCCURRENCE Fine-grained granite Pegmatite Diorite / Gabbro Fine-grained diorite-gabbro			





Site LAXEMAR
 Borehole HLX19
 Diameter [mm] 137
 Length [m] 202.200
 Bearing [°] 130.04
 Inclination [°] -57.89
 Date of mapping 2005-04-05 17:14:00

Coordinate System RT90-RHB70
 Northing [m] 6365757.88
 Easting [m] 1550090.87
 Elevation [m.a.s.l.] 5.95
 Drilling Start Date 2004-08-10 13:30:00
 Drilling Stop Date 2004-08-12 20:15:00
 Plot Date 2005-08-31 23:34:32

