P-05-83

Oskarshamn site investigation

Simplified Boremap mapping of percussion boreholes HLX15, HLX26, HLX27, HLX28 and HLX32 on lineament NW042

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December 2005

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ISSN 1651-4416
SKB P-05-83

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Keywords: Simplified boremap mapping.

Abstract

Simplified Boremap mapping has been performed for percussion boreholes HLX15, HLX26, HLX27, HLX28 and HLX32 situated at the linked lineament NW042, in the southern part of the Laxemar sub area at the site investigation 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.

The dominating rock type of all the mapped boreholes is quartz monzodiorite (at least 90% or more), carrying minor amounts of fine-grained diorite-gabbro, all cut by mainly thin dykes of fine-grained granite and occasional pegmatite. No major increase of open fractures is observed, although in borehole HLX28 large water yielding open fracture occurs, while a smaller one occurs in HLX32. Borehole HLX27 contains both smaller water yielding open fracture zone and two bigger ones at greater length along the borehole. Alteration occurs mainly in the form of red staining (oxidation) and is relatively minor in boreholes HLX15, HLX27 and HLX28, while in HLX26 and HLX32 most of the rock is more or less altered (oxidized).

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 HLX15, HLX26, HLX27, HLX28 och HLX32 på lineament NW042 i södra 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 borrningen i förbindelse med digitala BIPS-bilder (Borehole Image Processing System) av borrhålsväggarna.

Den dominerande bergarten i alla de karterade borrhålen är kvarts monzodiorit (90 % eller mer), den innehåller mindre mängder av finkornig diorit-gabbro, allt klipps av i huvudsak tunna gångar bestående till största delen av finkornig granit och enstaka pegmatit. Inga större förhöjningar i antalet öppna spricker observerades, dock förekommer i borrhål HLX28 stora vattenförande öppna spricker, medan en mindre förekommer i HLX32. Borrhål HLX27 innehåller både en mindre vattenförande öppen spricka och två större på mera djup. Omvandling förekommer i huvudsak som rödfärgning (oxidering) och förekommer i mindre mängder i borrhål HLX15, HLX27 och HLX28, medan i borrhål HLX26 och HLX32 största delen av berget är mer eller mindre omvandlad (oxiderat).

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

Contents

1 Introduction

To investigate the linked, east-west trending lineament with the designation NW042 in the southernmost part of the Laxemar sub area of the Oskarshamn site investigation, see Figure 1-1, six percussion boreholes were drilled in 2004 and beginning of 2005 /1/.

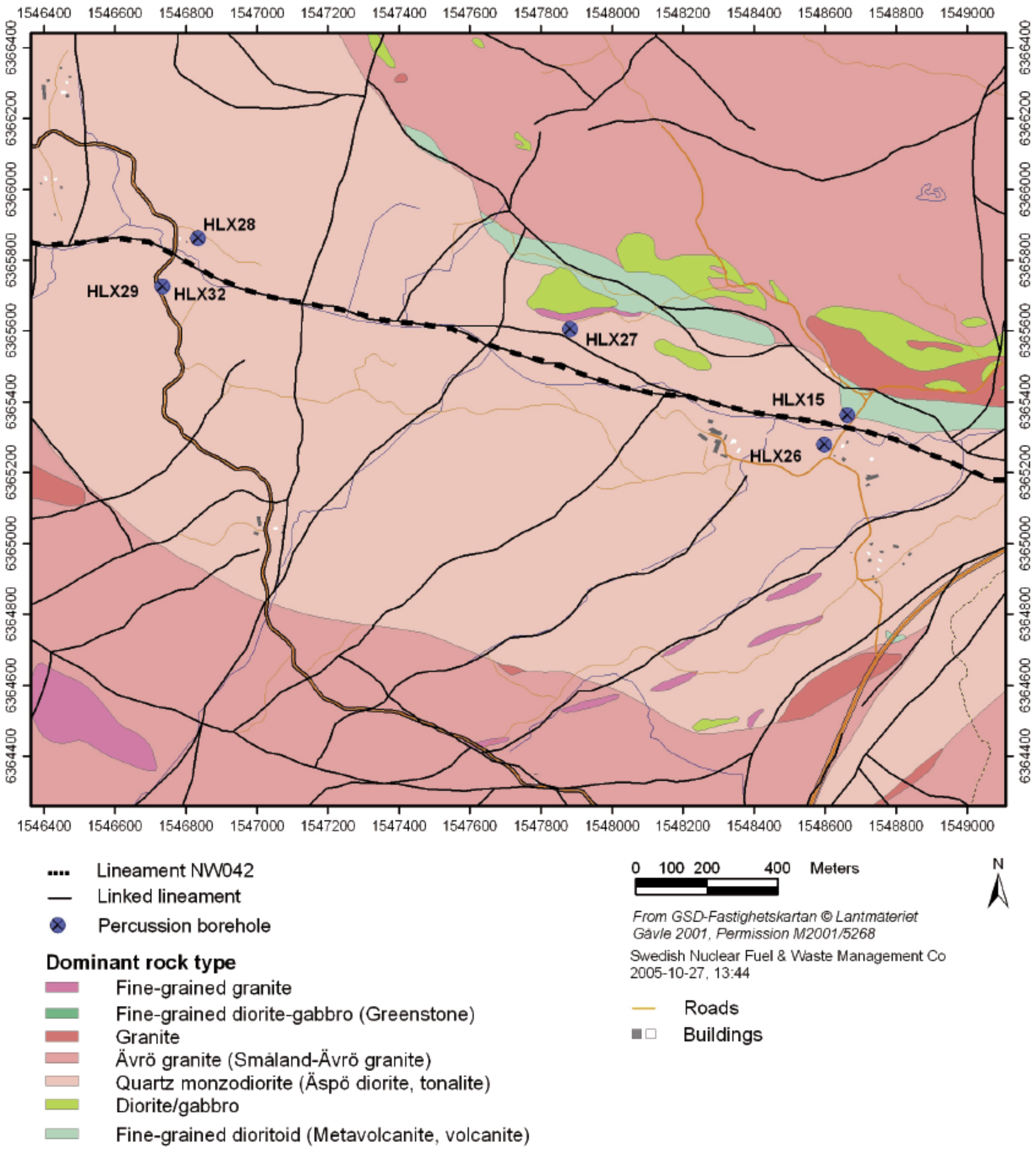


Figure 1-1. *Location of boreholes HLX15, HLX26, HLX27, HLX28, HLX29 and HLX32 in the Laxemar sub area. The map shows the bedrock geology, linked lineaments, roads and houses. The boreholes are located on both sides of the east-west trending lineament NW042.*

This document reports data gained by Simplified Boremap mapping of five of these percussion boreholes; HLX15, HLX26, HLX27, HLX28 and HLX32 during the later part of 2004 and the beginning of 2005. HLX32 was drilled as a replacement for HLX29 which is only 12.9 m because of sandy material that was encountered after the 6 m long casing, between 7.1 and 8 m /1/. The work was carried out in accordance with activity plan AP PS 400-04-124. Table 1-1 lists the controlling documents for performing this activity. Both activity plan and method description are SKB internal controlling documents.

After completing a percussion borehole it is logged with a colour TV-camera to produce images of the borehole wall called a BIPS-image (Borehole Image Processing System) /2/, /3/ and /4/. 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). Using the preliminary mapping of drill cuttings /1/ for comparison (see Chapter 4.1), the Simplified Boremap mapping is based on the BIPS-image where both petrography (rock types, rock occurrences and alteration) and structures (open fractures, crush zones and ductile deformation) of the bedrock that the borehole cuts through can be determined. In addition the mapping software (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 plans	Number	Version
Förenklad Boremapkartering av HLX21 till HLX27	AP PS 400-04-124[1]	1.0
Method description	**Number**	**Version**
Metodbeskrivning för Boremap - kartering	SKB MD 143.006	1.0

[1] An amendment including the mapping of HLX15, HLX28 and HLX32 is included in activity plan AP PS 400-04-124.

2 Objective and scope

The purpose of this survey is to map the lithology and structural parameters of percussion boreholes HLX15, HLX26, HLX27, HLX28 and HLX32 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 (> 1 m wide).
- Rock occurrences (> 0.2 to < 1 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 standard.

The accuracy 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).

The BIPS-image quality varies; borehole HLX15 is of good quality /2/, at least below 53.9 m (adjusted length). Between 12.2–53.9 m the borehole walls glitter in the light from the BIPS-camera so the possibility of recognizing alteration and rock type is very limited, even open fractures are difficult to discern, see Figure 3-2.

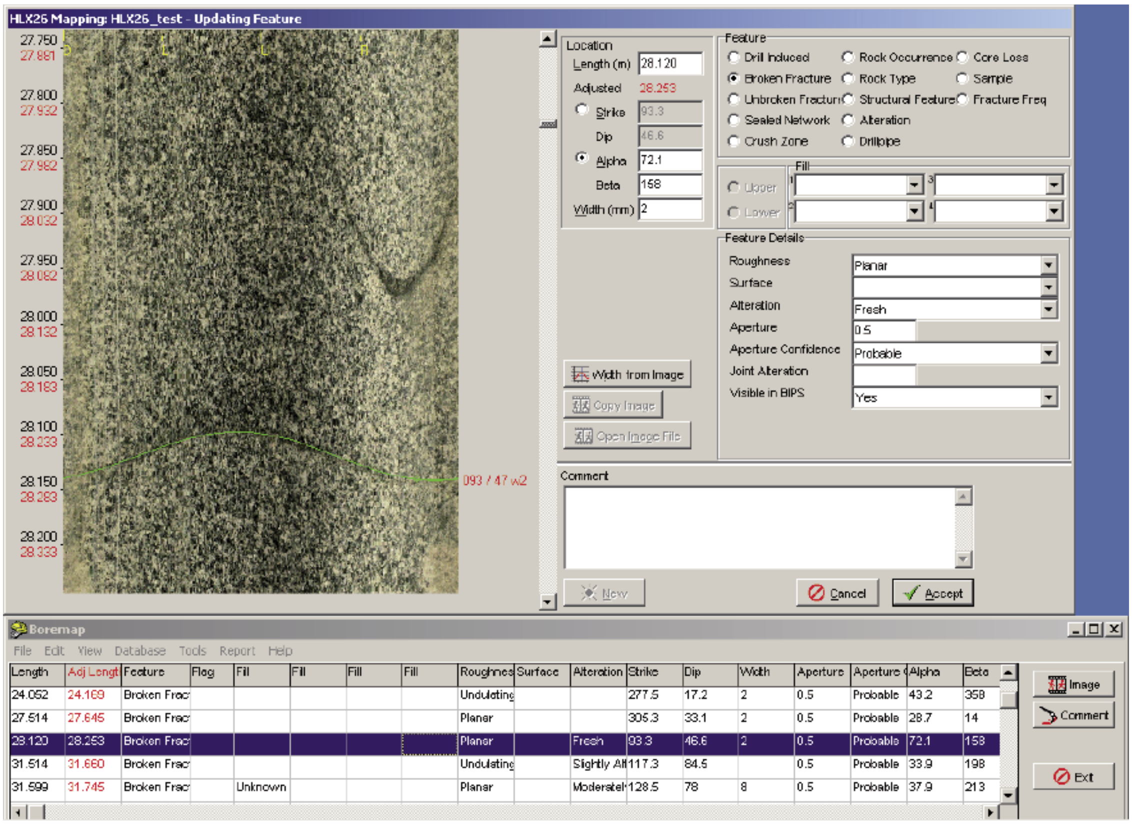


Figure 3-1. Good quality BIPS-image as it is seen in Boremap. Borehole HLX26, showing unaltered (fresh), medium to coarse grained, massive Quartz monzodiorite with one open fracture marked (green line).

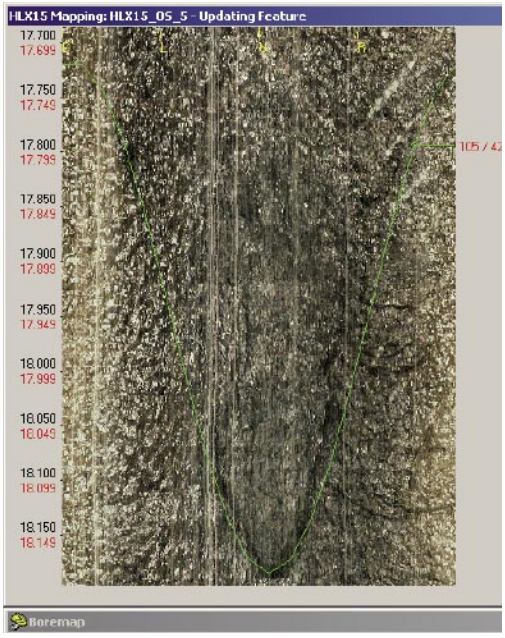


Figure 3-2. *BIPS-image as seen in Boremap, borehole HLX15 at 17.6–18.1 m (adjusted length), showing the lack of visibility above the groundwater level, wet and glittering borehole walls. Vertical lines are impurities from protective glass on BIPS-camera and lighter colour on the sides is mud on the lower side of borehole wall. One probable open fracture is marked (green line).*

The same applies for borehole HLX26 down to the ground water surface at 22 m (adjusted length) as seen in Figure 3-3, below that the BIPS-image is of good quality, see Figure 3-1.

The BIPS-image of borehole HLX28 is of good quality, while HLX27 has relatively bad visibility because of poor water quality and at the bottom of borehole the width of a big open fracture zone can not be seen because of muddy water /3/, see Figure 5-3.

Borehole HLX32 is of good quality down to approximately 29 m where the visibility starts to get poorer and it steadily gets worse /4/. At ca 89 m the mud on the lower side of the borehole wall covers up to ca 50%. At ca 124 m the mud is both suspended in the water and on the lower side of the borehole wall. This increases so that between ca 137–144 m visibility goes from poor to very poor and finally at ca 156 to 161 m there is almost no visibility at all because of muddy water, see Figure 3-4.

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.

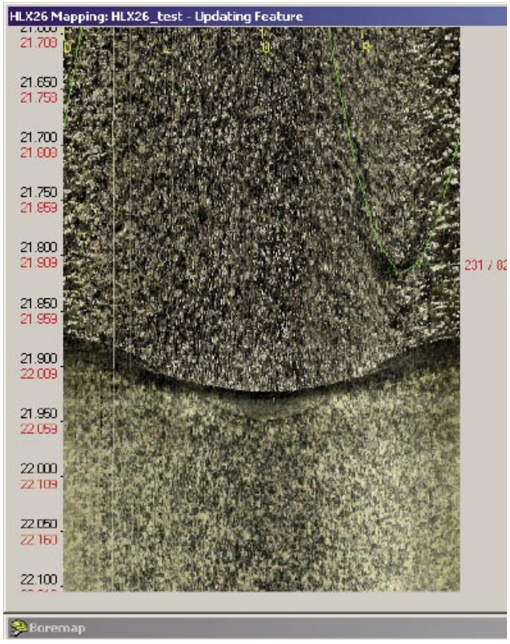


Figure 3-3. BIPS-image as seen in Boremap, borehole HLX26 at 21.7–22.2 m (adjusted length) showing the groundwater surface and the sharp difference of visibility of the borehole walls.

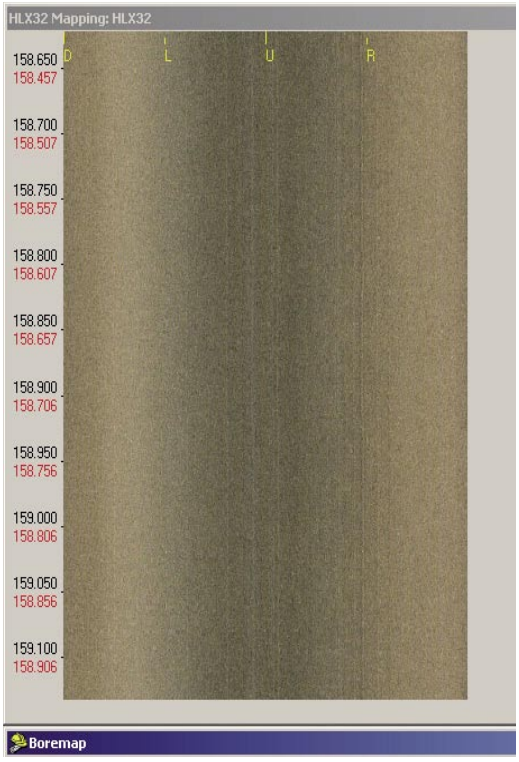


Figure 3-4. *BIPS-image as seen in Boremap, showing borehole HLX32 between 158.5–158.9 m with almost no visibility because of muddy water.*

4 Execution

4.1 General

Simplified Boremap mapping is comprised of data from:

- BIPS-image.
- Preliminary mapping of drill cuttings /1/.
- Results from percussion drilling /1/.
- Available geophysical measurements and interpretations.

The BIPS-image is opened in Boremap where the observed appropriate parameters are marked and described. To increase the accuracy of the mapping 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 length of the BIPS-image is adjusted from bottom of casing (Figure 4-1) 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 Acoustic televiewer deviation measurements is used with a Moving average filter (31 points) to correct for changes in direction of boreholes with length, except for borehole HLX32 where no measurements with the Acoustic televiewer deviation have taken place.

Table 4-1. Borehole data for HLX15, HLX26, HLX27, HLX28 and HLX32 (values from top of casing). Data taken from SKB database SICADA and Boremap (adjusted length).

ID-code	Northing	Easting	Bearing (°)	Inclination (°)	Diameter (mm)	Borehole length (m)	End of casing (m)	BIPS-image interval, adj. length (m)
HLX15	6365361.975	1548664.018	184.648	–58.366	137	151.9	12.04	12.0–151.3
HLX26	6365278.707	1548600.525	12.372	–60.420	137	151.2	9.10	9.1–151.2
HLX27	6365605.073	1547882.686	190.999	–59.412	137	164.7	6.10	6.1–159.1
HLX28	6365861.704	1546834.473	201.375	–59.485	136	154.2	6.10	6.1–143.8
HLX32	6365725.793	1546734.363	28.590	–58.669	140	162.6	12.30	12.3–157.5

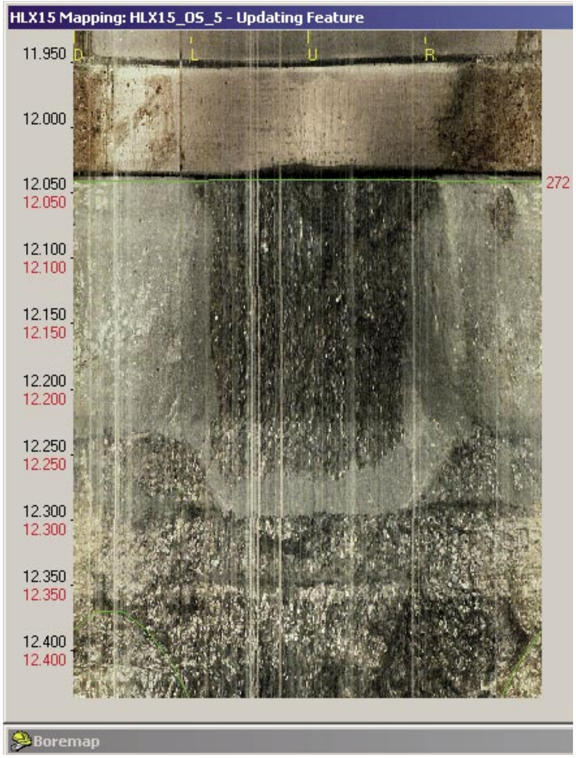


Figure 4-1. *BIPS-image as seen in Boremap, borehole HLX15 showing the lowest part of the casing pipe, some rests of concrete from the bottom plug and the borehole wall which is here above ground water level and therefore the visibility of the borehole wall is very limited. Vertical streaks are impurities on protective glass of BIPS-camera and light grey material is lowest part of the concrete seal /1/. Bottom of casing pipe is at 12.04 m.*

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 1–5:

- Lithology. Rock contacts, rock types (> 1 m wide) and rock occurrences (> 0.2 to < 1 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 and are visible for the whole width of the 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°) and a short line pointing to the direction (0–360°).
  - 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

No formal nonconformities have been registered during the activity. The upper part of borehole HLX15 from end of casing at 12 m to 53.9 m adjusted length (see Figure 3-2 and Figure 4-1) and borehole HLX26 from end of casing at 9.1 m to 22 m adjusted length (see Figure 3-3) are above ground water level and therefore the BIPS-image is of low quality there, which results in greater uncertainties of the Boremap mapping. The bottom of HLX27 (below approximately 158.7 m adjusted length) can not be seen because of muddy water and is not mapped. The lower parts of HLX32 are very muddy and with impaired visibility, the Boremap mapping stopped completely five meters above the bottom of the image and is of very limited quality for at least the lowest 20 m of the BIPS-image.

5 Results

Below the results from mapping of lithology, alteration and open fractures are given for boreholes HLX15, HLX26, HLX27, HLX28 and HLX32. The percentages of different lithologies are given in Tables 5-1 through 5-5. The amount of alteration (oxidation and water yielding fractures) as well as their intensity is listed in Table 5-6 and finally the number of open fractures and the fracture frequency per meter can be seen in Table 5-7.

HLX15

See Appendix 1 for WellCAD presentation of mapping results.

Lithology: The dominant rock type is quartz monzodiorite, cut by dykes and veins of pegmatite, see Figure 5-1 and fine-grained granite, see Table 5-1.

Table 5-1. Lithology of HLX15. Percents calculated from adjusted length of BIPS-image.

Rock name	SKB rock code	%
Quartz monzodiorite	501036	93.4
Pegmatite	501061	5.7
Fine-grained granite	511058	0.9

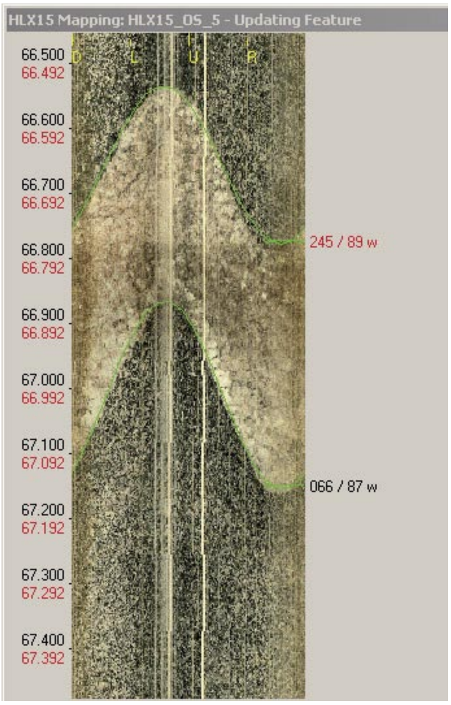


Figure 5-1. *BIPS-image as seen in Boremap. Borehole HLX15 showing Quartz monzodiorite cut by white pegmatite. Vertical stripes in the middle of BIPS-image are air-bubbles on the outside of the protective glass of the camera. Horizontal shadow is a result of the automatic blender of the BIPS-camera.*

Alteration: The rock is mainly fresh with very little alteration. Most of the weak oxidation that occurs is below approximately 125 m, see Table 5-6.

Open fractures: Mapped open fractures are 131, resulting in an average of 0.94 per meter, see Table 5-7, a slight increase in fracture frequency can be noted below approximately 88 m.

HLX26

See Appendix 2 for WellCAD presentation of mapping results.

Lithology: The dominant rock type is quartz monzodiorite, containing several xenoliths/enclaves of fine-grained diorite-gabbro, all cut by minor dykes and veins of fine-grained granite, see Figure 5-2 and pegmatite, see Table 5-2.

Table 5-2. Lithology of HLX26. Percents calculated from adjusted length of BIPS-image.

Rock name	SKB rock code	%
Quartz monzodiorite	501036	92.1
Fine-grained diorite-gabbro	505102	3.8
Fine-grained granite	511058	3.4
Pegmatite	501061	0.7

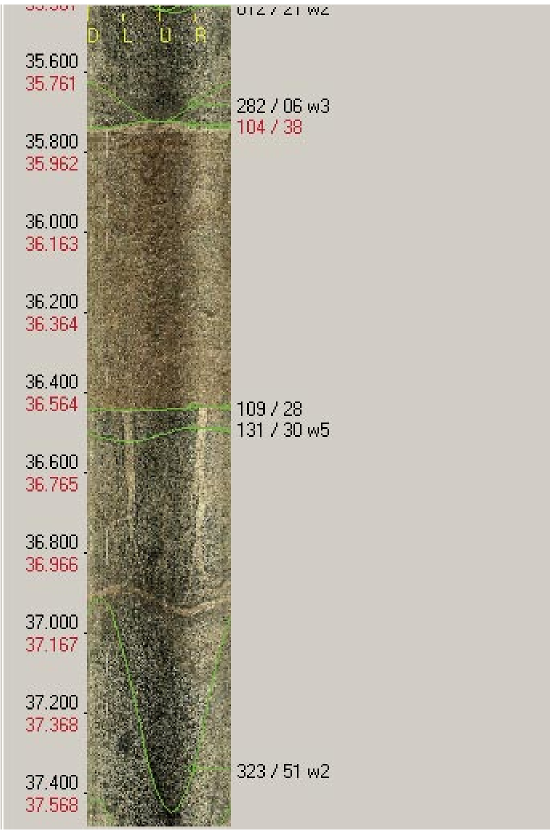


Figure 5-2. *BIPS-image as seen in Boremap, showing borehole HLX26. Quartz monzodiorite cut by fine-grained granite dyke, three open fractures marked. Notice thin veins (too thin to be mapped) consisting of fine-grained granite one showing altered contacts (weak oxidation).*

Alteration: Alteration in the form of oxidation occurs often, the intensity is mainly weak, see Figure 5-2 and some medium, as well as minor with faint intensity, in total 47% see Table 5-6. The oxidation is mainly between approximately 39 to 123 m and strongest between approximately 48 to 70 m. Within the area of stronger oxidation the BIPS-image shows alteration in two of the fine-grained diorite-gabbro which where identified as saussuritization in the rock cuttings, in total 2% of the rock alteration, see Table 5-6.

Open fractures: Mapped open fractures are 162, resulting in an average of 1.14 per meter, see Table 5-7, a slight increase in fracture frequency can be noted between approximately 54 to 78 m.

Ductile structures: Two foliations of medium intensity are measured at approximately 46.1–46.5 m depth striking ca 281° and dipping ca 32° to the north. One measurement at ca 92.2 m strikes ca 244° and dips ca 42° to the north while the last measurement at 137.7 m strikes 38° and dips 32° to the south east, see Table 5-8 and Figure 5-7.

HLX27

See Appendix 3 for WellCAD presentation of mapping results.

Lithology: The dominant rock type is quartz monzodiorite, containing several xenoliths/enclaves consisting of fine-grained diorite-gabbro, all cut by minor dykes and veins of fine-grained granite and pegmatite, see Table 5-3.

Table 5-3. Lithology of HLX27. Percents calculated from adjusted length of BIPS-image.

Rock name	SKB rock code	%
Quartz monzodiorite	501036	95.9
Fine-grained diorite-gabbro	505102	1.3
Fine-grained granite	511058	1.9
Pegmatite	501061	0.9

Alteration: No alteration (oxidation) is noted in the borehole walls, the rock is mostly fresh.

Open fractures: Mapped open fractures are 160, resulting in an average of 1.045 per meter, see Table 5-7. Two increases in fracture density are noted, which coincide with water carrying zones of total ca 1.8 m width. The uppermost shows increased number of fractures at 105.9 m, a 0.2 m wide zone yielding approximately 16 l/min of groundwater. At 158 m there is a big open fracture zone at the bottom of borehole, possibly 1.6 m wide, the bottom can not be seen because of muddy water, yielding approximately 78 l/min of groundwater, see Figure 5-3.

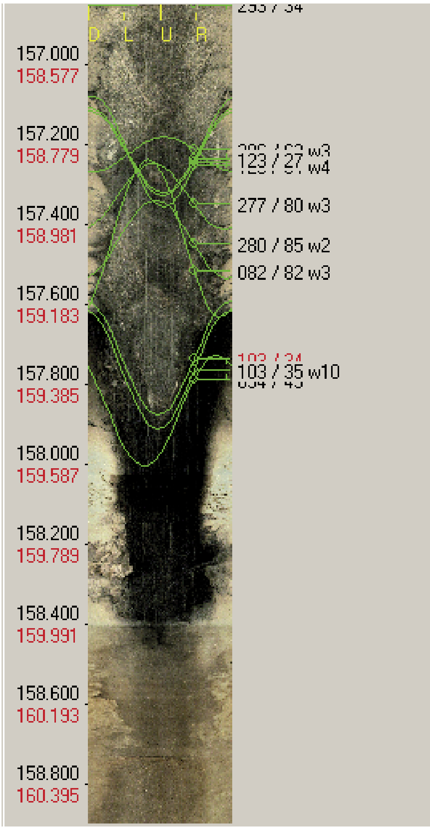


Figure 5-3. *BIPS-image as seen in Boremap, borehole HLX27 showing the upper part of the open fracture that yields approximately 78 l/min of groundwater. Lower part can not be seen because of muddy water.*

HLX28

See Appendix 4 for WellCAD presentation of mapping results.

Lithology: The dominant rock type is quartz monzodiorite, containing several xenoliths/enclaves of fine-grained diorite-gabbro, all cut by minor dykes and veins of fine-grained granite, and pegmatite, see Figure 5-4 and Table 5-4.

Table 5-4. Lithology of HLX28. Percents calculated from adjusted length of BIPS-image.

Rock name	SKB rock code	%
Quartz monzodiorite	501036	90.7
Fine-grained diorite-gabbro	505102	2.1
Fine-grained granite	511058	6.4
Pegmatite	501061	0.8

Alteration: Alteration in the form of oxidation occurs, mostly weak but occasionally medium, in total 22% see Table 5-6. The alteration is found where the fracture density is higher.

Figure 5-4. *BIPS-image as seen in Boremap, borehole HLX28 showing weakly oxidised quartz monzodiorite cut by fine-grained granite dyke and containing veined and fine-grained diorite-gabbro enclave (fragment).*

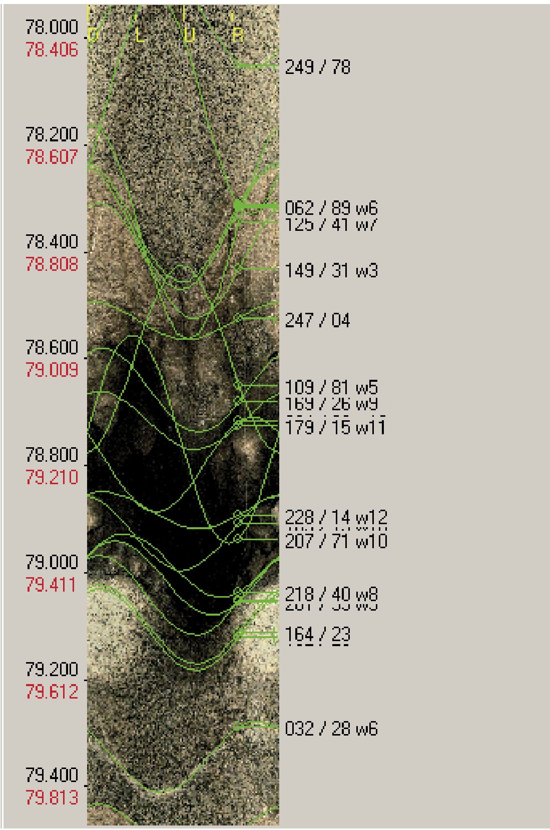


Figure 5-5. *BIPS-image as seen in Boremap, borehole HLX28 showing big open fracture (0.6 m wide) at approximately 79 m yielding > 60 l/min of groundwater. Rock type is quartz monzodiorite, cut by fine-grained granite dyke, where the open fractures are concentrated.*

Open fractures: Mapped open fractures are 157, resulting in an average of 1.14 per meter, see Table 5-7. One strong increase in fracture density is noted at 78.9 m (adjusted length) a water yielding, big open fracture zone approximately 0.6 m wide, see Figure 5-5, yielding large amounts of groundwater (more than 60 l/min) /1/. Weaker increases in fracture density are noted at approximately 62 to 64 m and 105 to 108 m in connection with the xenoliths/enclaves of fine-grained diorite-gabbro.

Ductile structures: Two foliations of medium intensity are measured here, at approximately 13.6 m length striking ca 136° and dipping ca 3° to the south west, and approximately 86.3 m length striking ca 219° and dipping ca 17° to the north west, see Table 5-8 and Figure 5-7.

HLX32

See Appendix 5 for WellCAD presentation of mapping results.

Lithology: The dominant rock type is quartz monzodiorite, with occasional xenoliths/enclaves of fine-grained diorite-gabbro, all cut by small intrusives, dykes and veins of fine-grained granite and pegmatite, see Table 5-5.

Table 5-5. Lithology of HLX32. Percents calculated from adjusted length of BIPS-image.

Rock name	SKB rock code	%
Quartz monzodiorite	501036	91.0
Fine-grained granite	511058	6.5
Fine-grained diorite-gabbro	505102	2.4
Pegmatite	501061	0.1

Alteration: Alteration in the form of red oxidation dominates the borehole walls, it is mostly weak, but also medium occurs, in total 79% see Table 5-6. The alteration stops at approximately 127 m.

Open fractures: Mapped open fractures are 409, average of 2.82 per meter, see Table 5-7. Two increases in fracture density are noted, one medium strong at 23.1 m consisting of a big open fracture 0.3 m wide, partly filled with secondary minerals and yielding some groundwater (approximately 16 l/min), see Figure 5-6. The other zone is a weak increase in open fractures and occurs at 33.4 to 36.8 m (adjusted length), approximately 3.4 m wide. Generally open fracture frequency is higher in HLX32 than the other four boreholes down to approximately 120 m.

Table 5-6. Total alteration of percussion boreholes HLX15, HLX26, HLX27, HLX28 and HLX32.

Alteration	Intensity	HLX15 (%)	HLX26 (%)	HLX27 (%)	HLX28 (%)	HLX32 (%)
Oxidation	Faint		1			
	Weak	12	32		20	71
	Medium		14		2	8
Saussuritization	Medium		2			
	Strong		0.1			

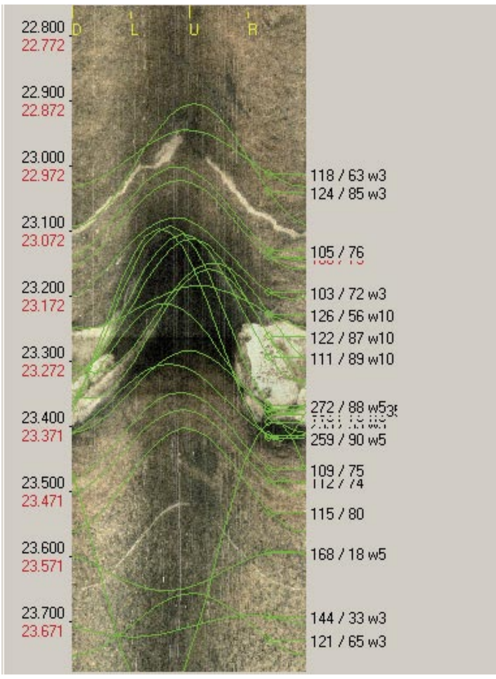


Figure 5-6. *BIPS-image as seen in Boremap, borehole HLX32 showing big open fracture (0.3 m wide) at approximately 23.1 m, it is partly filled with secondary mineral (fracture filling). The yield of water into borehole here is approximately 16 l/min. Rock type consists of weakly oxidized quartz monzodiorite.*

Table 5-7. Total number of open fractures in percussion boreholes HLX15, HLX26, HLX27, HLX28 and HLX32.

	Total number of open fractures	Fractures/meter
HLX15	131	0.94
HLX26	162	1.14
HLX27	160	1.05
HLX28	157	1.14
HLX32	409	2.82

Table 5-8. Structural measurements in percussion boreholes HLX26 and HLX28.

Borehole	Length	Structure	Intensity	Strike	Dip
HLX26	46.143	Foliated	Medium	273.2	28.3
HLX26	46.541	Foliated	Medium	289.7	35.9
HLX26	92.183	Foliated	Medium	244.2	41.8
HLX26	137.679	Foliated	Medium	37.8	31.8
HLX28	13.556	Foliated	Medium	135.6	2.8
HLX28	86.309	Foliated	Medium	218.5	17.2

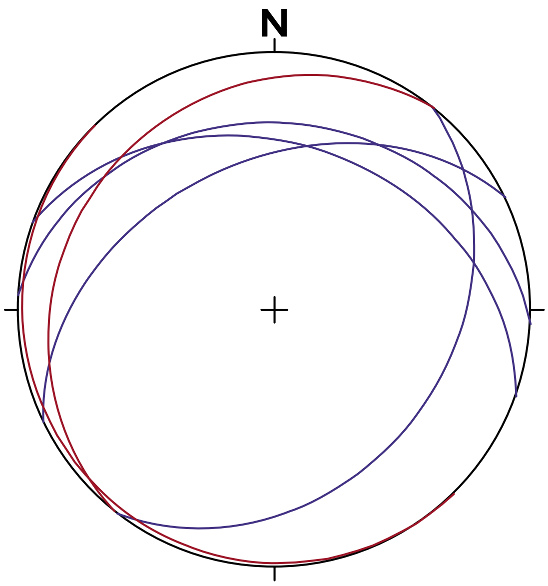


Figure 5-7. *Stereogram showing structural measurements (foliations) from borehole HLX26 and HLX28. Foliation planes from HLX26 shown with blue lines and from HLX28 with red lines.*

6 Summary and discussions

The lithology dominating these five boreholes is quartz monzodiorite, with the main variation being the amount of fine-grained diorite-gabbro xenoliths, as well as dykes and veins of fine-grained granite and pegmatite. Alterations, mainly in the form of red staining (oxidation), see Figure 6-1 and Figure 6-2, vary between boreholes.

Borehole HLX15 shows some increase in fracture frequency below approximately 88 m and in borehole HLX26 a slight increase in fracture frequency can be seen between approximately 54 to 72 m associated with some red oxidation (alteration). This gives an indication of weakness in the rock, but whether this constitutes the linked lineament at the surface /7/ is difficult to say.

Borehole HLX27 cuts through two water yielding open fracture zones, a weaker zone around 100–110 m and a stronger zone at approximately 155 m to the end of the borehole. No other indications of deformational zones can be found in this borehole, fractures are relatively evenly distributed along the borehole walls. Borehole HLX28 cuts through groundwater yielding open fractures at approximately 79 m. Borehole HLX32 also cuts through a groundwater yielding fracture zone. The existence of water yielding open fracture zones does not proof the existence of a deformational zone, but it suggests one possible explanation of the linked lineament at the point of intersection with the boreholes.

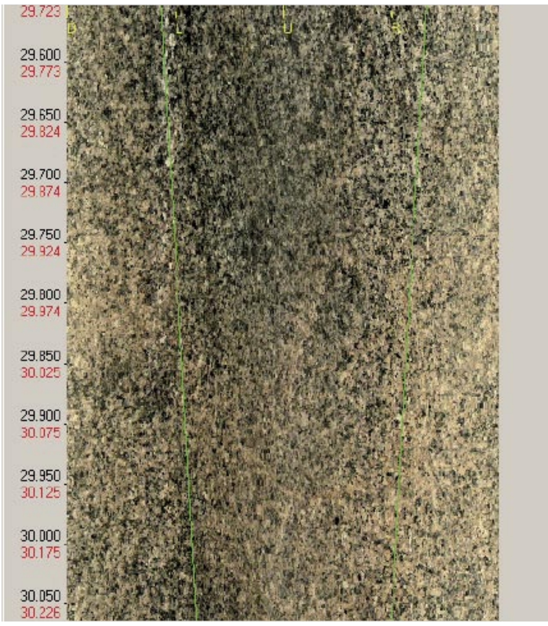


Figure 6-1. *BIPS-image as seen in Boremap, borehole HLX28 showing typical altered, here weakly red stained (oxidized), massive, medium to coarse grained quartz monzodiorite.*

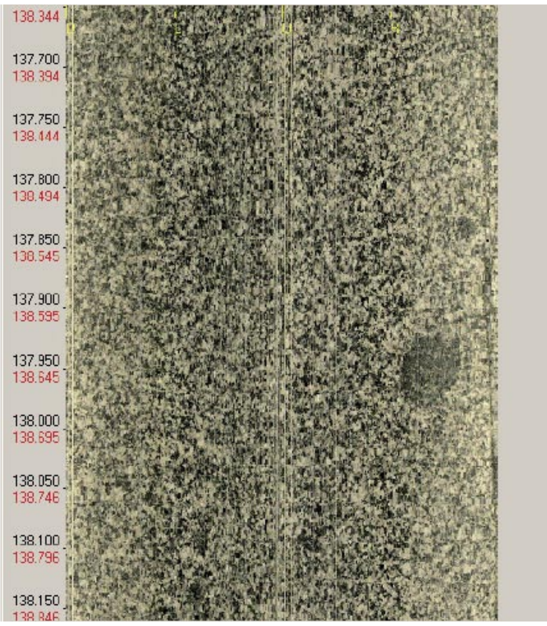


Figure 6-2. *BIPS-image as seen in Boremap, borehole HLX28 showing the fresh, massive, medium-coarse grained quartz monzodiorite with occasional small fragment/enclave of fine-grained diorite gabbro.*

One observation worth noting here is the distribution of alteration (red staining) in the borehole rock walls. It is noticeably more extensive and stronger in the two boreholes drilled to the north (HLX26 and HLX32), while the boreholes with southerly directions showed very little alteration (HLX15, HLX27 and HLX28). Either the two holes HLX26 and HLX32 just happen to be in a more altered part of the bedrock or possibly the alteration dips to the north.

The Acoustic televiewer deviation measurements that have been done for boreholes HLX15 /5/ and HLX26–28 /6/ have been calculated with a Moving average filter (31 points) and used in the Boremap mapping to correct for changes in the direction of each borehole with length. No Acoustic televiewer deviation measurements were conducted for HLX32 so the measurements of top of casing are used for the entire length of the 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 (foliations) were measured in two boreholes HLX26 and HLX28. In HLX26 the foliation indicates ductile zones striking approximately east-west and dipping to the north, except for the one at greatest length which strikes northeast-southwest and dips to the south-east. In HLX28 the foliation is northeast-southwest striking structures dipping slightly to the northwest and flat lying northwest-southeast striking foliation dipping very slightly to the southwest, see Figure 5-7.

7 References

/1/ **Ask H, Samuelsson L-E, Zetterlund M, 2005.** Oskarshamn site investigation. Percussion drilling of boreholes HLX15, HLX26, HLX27, HLX28, HLX29 and HLX32 for investigation of lineament NW042. SKB P-04-235. Svensk Kärnbränslehantering AB.

/2/ **Gustafsson J and Gustafsson C, 2004.** Oskarshamn site investigation. RAMAC and BIPS logging in boreholes KAV04A, KAV04B, HLX13 and HLX15. SKB P-04-195. Svensk Kärnbränslehantering AB.

/3/ **Gustafsson J and Gustafsson C, 2004.** Oskarshamn site investigation. RAMAC and BIPS logging in boreholes HLX10, HLX26, HLX27 and HLX28. SKB P-04-297. Svensk Kärnbränslehantering AB.

/4/ **Gustafsson J and Gustafsson C, 2005.** Oskarshamn site investigation. RAMAC and BIPS logging in boreholes KLX05 and HLX32. Svensk Kärnbränslehantering AB.

/5/ **Nielsen U T, Ringgaard J, 2004.** Oskarshamn site investigation. Geophysical borehole logging in borehole KAV04A, KAV04B, HLX13 and HLX15. SKB P-04-202. Svensk Kärnbränslehantering AB.

/6/ **Nielsen U T, Ringgaard J, Horn F, 2004.** Oskarshamn site investigation. Geophysical borehole logging in borehole KLX04, HLX26, HLX27 and HLX28. SKB P-04-306. Svensk Kärnbränslehantering AB.

/7/ **Triumf C-A, 2004.** Oskarshamn site investigation. Joint interpretation of lineaments. SKB P-04-049. Svensk Kärnbränslehantering AB.

Simplified geology HLX15

Title	SIMPLIFIED GEOLOGY HLX15		Appendix 1
Site	LAXEMAR	Coordinate System	RT90-RHB70
Borehole	HLX15	Northing [m]	6365361.98
Diameter [mm]	137	Easting [m]	1548664.02
Length [m]	151.900	Elevation [m.a.s.l.]	4.81
Bearing [°]	184.65	Drilling Start Date	2004-04-27 07:00:00
Inclination [°]	-58.36	Drilling Stop Date	2004-04-29 09:30:00
Date of mapping	2004-07-29 12:12:00	Plot Date	2005-11-10 00:23:56

ROCKTYPE LAXEMAR
- Pegmatite
- Quartz monzodiorite

ROCK OCCURRENCE
- Fine-grained granite
- Pegmatite

ROCK STRUCTURE
- Massive

FRACTURE ALTERATION
- Slightly Altered
- Moderately Altered
- Fresh

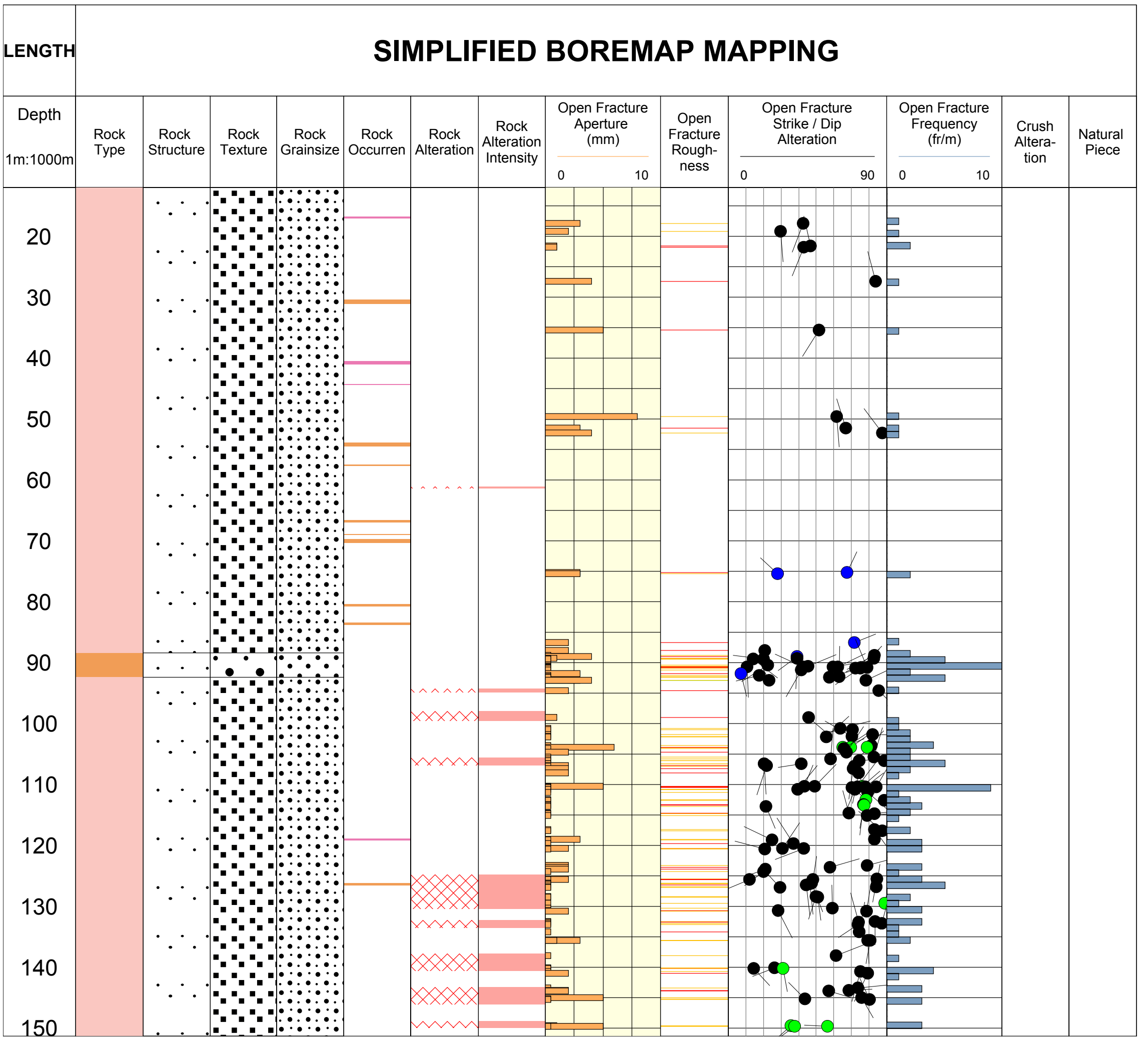
ROCK ALTERATION
- Oxidized

ROCK TEXTURE
- Equigranular
- Unequigranular

ROCK GRAINSIZE
- Medium to coarse grained
- Coarse-grained

INTENSITY
- Weak

ROUGHNESS
- Planar
- Undulating
- Stepped



Simplified geology HLX26

Title SIMPLIFIED GEOLOGY HLX26 **Appendix 2**

SKB

Site	LAXEMAR	**Coordinate System**	RT90-RHB70
Borehole	HLX26	**Northing [m]**	6365278.71
Diameter [mm]	137	**Easting [m]**	1548600.53
Length [m]	151.200	**Elevation [m.a.s.l.]**	6.48
Bearing [°]	12.37	**Drilling Start Date**	2004-09-23 16:40:00
Inclination [°]	-60.41	**Drilling Stop Date**	2004-09-28 18:00:00
Date of mapping	2004-12-07 18:10:00	**Plot Date**	2005-11-10 00:23:56

ROCKTYPE LAXEMAR
- Fine-grained granite
- Quartz monzodiorite
- Fine-grained diorite-gabbro

ROCK OCCURRENCE
- Fine-grained granite
- Pegmatite
- Fine-grained diorite-gabbro

ROCK STRUCTURE
- Veined
- Massive

FRACTURE ALTERATION
- Slightly Altered
- Moderately Altered
- Fresh

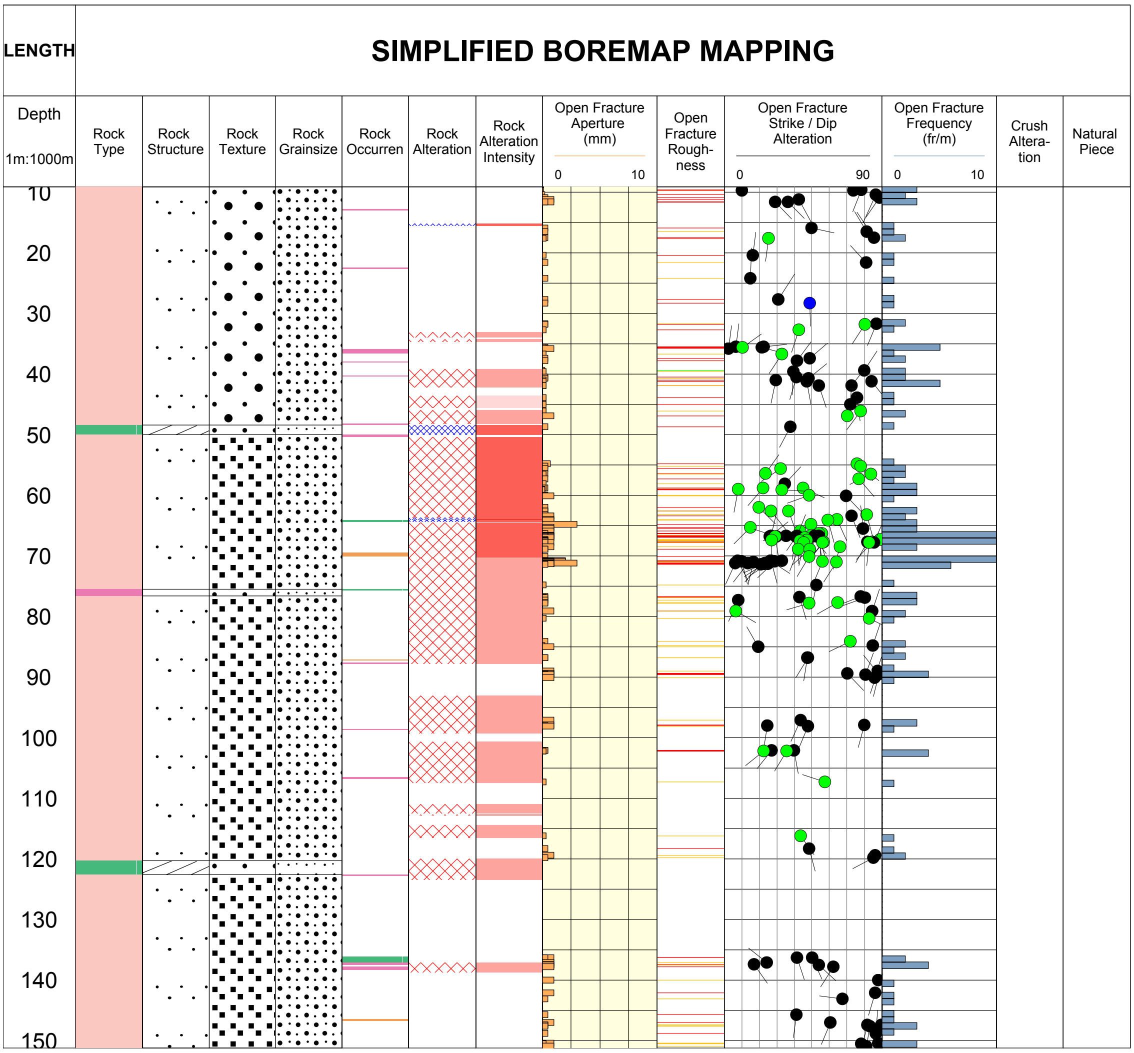
ROCK ALTERATION
- Oxidized
- Saussuritization

ROCK TEXTURE
- Equigranular
- Unequigranular

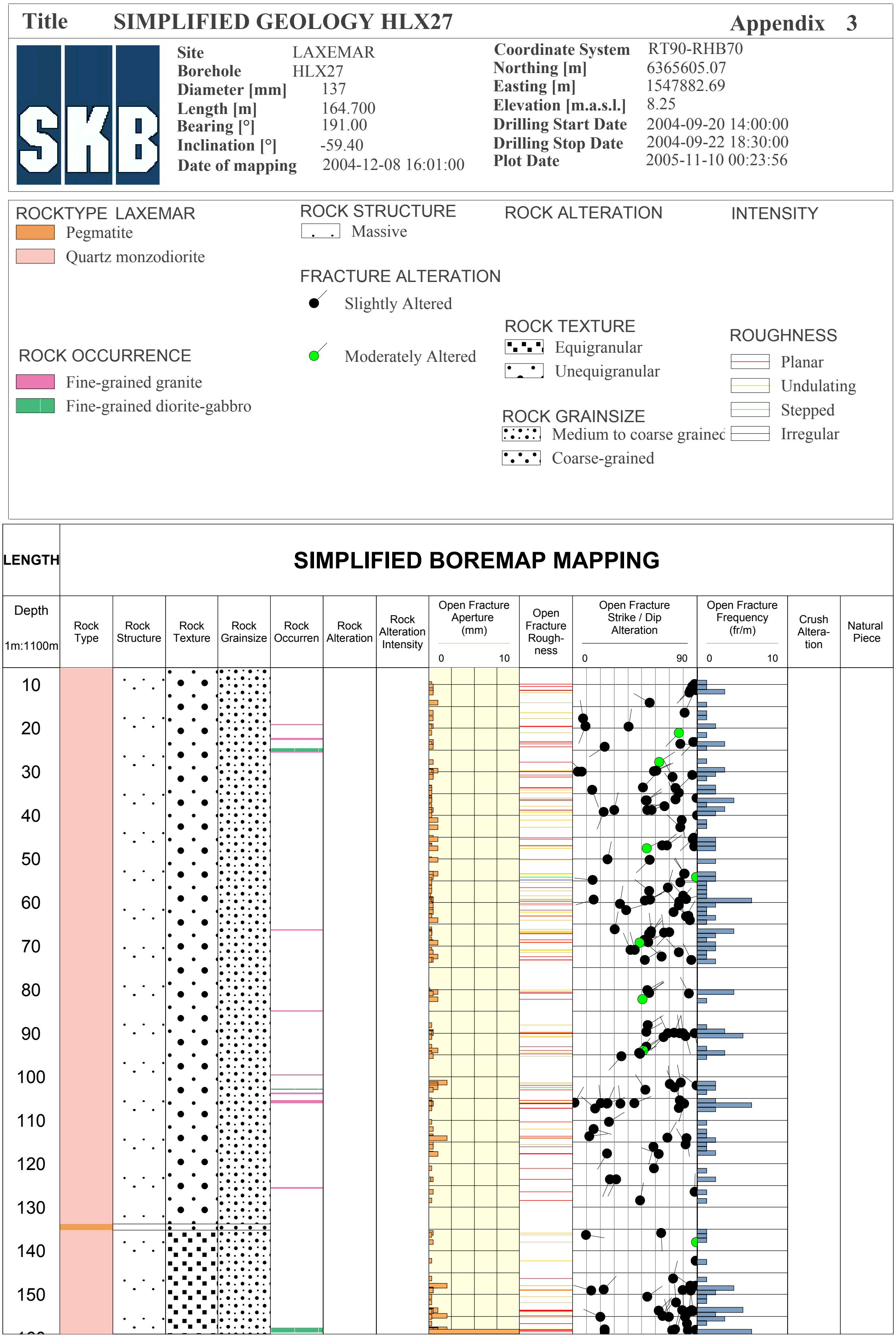
ROCK GRAINSIZE
- Fine to medium grained
- Medium to coarse grained

INTENSITY
- Faint
- Weak
- Medium
- Strong

ROUGHNESS
- Planar
- Undulating
- Stepped

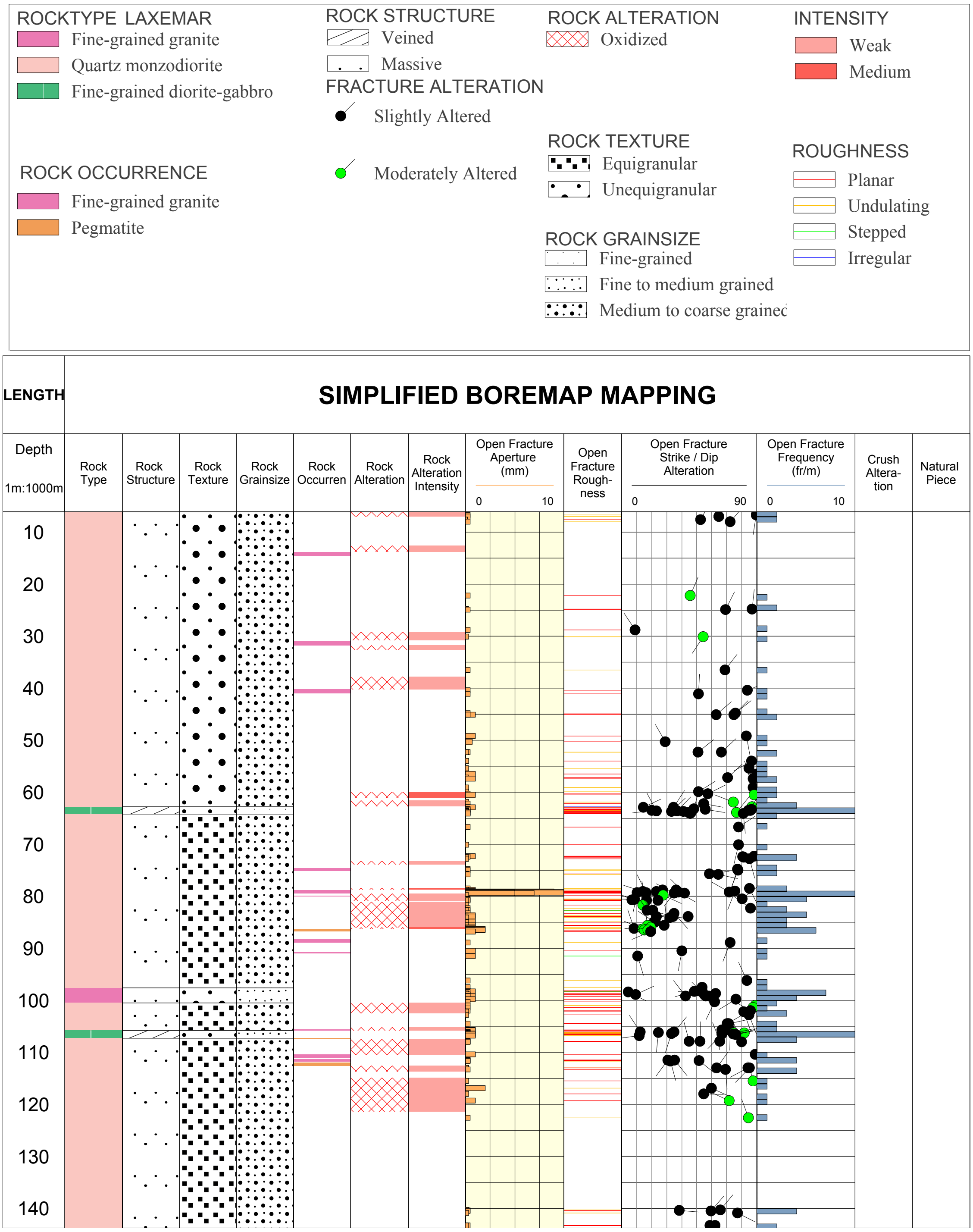


Simplified geology HLX27



Simplified geology HLX28

Title	SIMPLIFIED GEOLOGY HLX28		Appendix 4
Site	LAXEMAR	Coordinate System	RT90-RHB70
Borehole	HLX28	Northing [m]	6365861.70
Diameter [mm]	136	Easting [m]	1546834.47
Length [m]	154.200	Elevation [m.a.s.l.]	13.42
Bearing [°]	201.38	Drilling Start Date	2004-09-29 13:40:00
Inclination [°]	-59.48	Drilling Stop Date	2004-10-02 07:30:00
Date of mapping	2004-12-09 15:39:00	Plot Date	2005-11-10 00:23:56



Simplified geology HLX32