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Abstract

During an internal investigation of uncertainties connected with the orientations of mapped geological features in cored and percussion drilled boreholes, a particular problem concerning the orientation of the borehole TV-image (BIPS) was discovered. The problem was related to the rotational orientation of the probe, which in some of the logged borehole sections turned out to be inadequately accurate. This resulted in errors and unacceptable uncertainties in the orientation of mapped geological features in those parts of the boreholes. On the basis of a preliminary investigation of the extent of the problems, a revision of the orientations from the BIPS-loggings was carried out for 48 prioritized boreholes in Oskarshamn and 22 prioritized boreholes in Forsmark. The BIPS-images were divided into the following groups according to the method of rotational orientation of the probe: bubble level (63 boreholes), steel ball (5 boreholes) and compass (2 boreholes) oriented BIPS-images.

In a majority of the boreholes the BIPS-images were oriented with a built-in bubble level clinometer or a compass, depending upon the inclination of the borehole. The raw data tapes from these borehole loggings were investigated, resulting in revised values for the orientation of the probe. The resulting data were used to correct the orientations of mapped geological features. The uncertainties of the corrected orientations were also estimated.

The raw data tapes could not be used for revision of BIPS-images oriented with steel ball clinometer because of the unreliable behaviour of this clinometer. Instead, the BIPS-images were revised by comparison with Acoustic Televiewer-images, the orientation of which – after sound examination – was regarded to be of high accuracy. The results from these comparisons were used to correct the orientations of mapped geological features and to estimate the uncertainties of the corrected orientations.

The BIPS-images oriented with steel ball clinometers were unequivocally marred by greater errors in the rotational orientation, compared to the bubble level oriented images which were relatively well oriented. The rotational corrections of BIPS-images oriented with steel ball clinometer are mostly within ± 20° (uncertainty ~ ± 10°) whereas the rotational corrections for BIPS-images oriented with bubble level clinometer are generally within ± 5° (uncertainty ~ ± 3°). Compass oriented BIPS-images from near-vertical boreholes also show larger errors in rotational orientation with correction values of about ± 15° (uncertainty ~ ± 10°).

In some boreholes no correction of the orientation of mapped geological features was performed. The reasons for this were that the boreholes were of lower priority, the raw data tapes were missing or defect or that the revision of bubble level oriented BIPS-images in similar boreholes showed that the original orientation was generally good. For these 64 boreholes (8 core drilled, and 56 percussion drilled boreholes) a general uncertainty value of the BIPS orientation was calculated, based on the results from the revision of BIPS-images from similar boreholes.

The final calculated uncertainties of the orientations of geological features are not affected by the BIPS-image orientation alone, but also by the mapping procedure and the deviation measurement of the borehole. These factors have also been evaluated, and are reported separately.

Sammanfattning

Vid en intern utredning avseende osäkerheterna i orienteringen av karterade geologiska objekt i kärn- och hammarborrhål upptäcktes ett problem som hade att göra med orienteringen av borrhåls TV-bilden (BIPS). Problemet var relaterat till sondens rotationsorientering, som i vissa borrhålssektioner visade sig vara mer eller mindre felaktig. Detta resulterade i fel och oacceptabla osäkerheter även i orienteringen av karterade geologiska objekt i de aktuella borrhålssektionerna. På basen av en preliminär undersökning av problemets omfattning reviderades orienteringarna i BIPS-loggningarna för 48 prioriterade borrhål i Oskarhamn och 22 prioriterade borrhål i Forsmark. BIPS-bilderna delades in i grupperna 1) libell- (63 bilder.), 2) lod- (5 bilder) och 3) kompassorienterade (2 bilder) BIPS-bilder, beroende på vilken orienteringsmetod som använts.

I merparten av de reviderade borrhålen var BIPS-bilden orienterad med en inbyggd libell eller kompass, där valet av metod avgjordes av borrhålets inklination (lutning). Rådatabanden från dessa borrhålsloggningar undersöktes, vilket resulterade i reviderade värden på sondens orientering. Resultatet användes för att korrigera orienteringarna av de karterade geologiska objekten. Dessutom uppskattades värden på osäkerheterna i de korrigerade orienteringarna.

Rådatabanden kunde däremot inte användas vid revidering av lodorienterade BIPS-bilder, där lodet utgörs av en stålkula, eftersom kulan på grund av sin inneboende tröghet är opålitlig som lod. Istället reviderades BIPS-bilderna genom jämförelse med akustisk televiewer-bilder, vilkas orientering bedömdes ha en god noggrannhet. Resultatet från dessa jämförelser användes för att korrigera orienteringarna av de karterade geologiska objekten och för att uppskatta osäkerheten i de korrigerade orienteringarna.

De lodorienterade BIPS-bilderna var entydigt behäftade med större fel i rotationsorientering jämfört med de libellorienterade BIPS-bilderna, vilka generellt var välorienterade. Korrektionen i rotation för lodorienterade BIPS-bilder låg mestadels inom intervallet ± 20° (osäkerhet ~ ± 10°), medan den för libell-orienterade BIPS-bilder generellt uppgick till ± 5°(osäkerhet ~ ± 3°). Kompassorienterade BIPS-bilder från näst intill vertikala borrhål uppvisar också större fel i rotationsorienteringen med korrektionsvärden på omkring ± 15° (osäkerhet ~ ± 10°).

För en del borrhål utfördes ingen korrektion av orienteringen av de karterade geologiska objekten. Orsaken till detta var att borrhålen var av lägre prioritet, att rådatabanden saknades eller var defekta, eller att revisionen av libellorienterade BIPS-bilder i likartade borrhål visat att den ursprungliga orienteringen generellt var god. För dessa 64 borrhål (8 kärnborrhål och 56 hammarborrhål) uträknades ett generellt onoggrannhetsvärde för BIPS-orienteringen baserat på resultatet av revisionen av BIPS-bilder från likartade borrhål.

De slutligen uträknade onoggrannhetsvärdena för orienteringar av geologiska objekt påverkas inte enbart av BIPS-orienteringen utan även av själva karteringsproceduren och avvikelsemätningen av borrhålet. Dessa faktorer har också utvärderats, och rapporteras separat.

Contents

1 Introduction

Swedish Nuclear Fuel and Waste Management Co (SKB) performs site investigations for a repository of nuclear waste in two candidate areas: Forsmark and Laxemar. Boreholes play a key role in the investigation of the bedrock. The boreholes are investigated with reference to geology, hydrology, chemistry, geophysics and other scientific areas.

The documentation of the geology in boreholes is performed in the software Boremap, in accordance with SKB MD 143.006 "Method Description for Boremap Mapping (In Swedish)"[1]. Geological objects mapped in Boremap are mainly rock types, alterations, fractures, crush zones and other structural features. Borehole images, borehole deviation measurements and reference marks along the borehole are used for orienting and positioning the objects (Figure 1-1).

The positions and orientations of mapped geological objects in boreholes are of great importance when modelling the bedrock. Therefore it was crucial to address the reliability of these data, and when necessary, to correct them. A task force was appointed by SKB[2] to revise the orientation data and to quantify the uncertainties in the data. The work was divided into three projects with the following tasks (Figure 1-1):

1) to revise the borehole deviation data and implement uncertainty-values for borehole geometries /1, 2/,
2) to revise geological object orientations in BIPS-images and implement uncertainty-values for geological object orientation data (this report), and
3) to analyse the differences between previous and revised geological object orientation data and their implications to the geological modelling /3/.

This report concerns the revision of geological object orientations in BIPS-images and the implementation of uncertainty-values in Boremap and Sicada. The revision was carried out by analysing the orientation of the borehole images from BIPS-loggings. For some boreholes the revision was based on comparison between BIPS-images and images from Acoustic Televiewer. The work was started in November 2006 and finished in November 2007.

1.1 The BIPS-logging system

A BIPS-image is a borehole image which is recorded with a colour-TV camera (Figure 1-5 and 1-6). The BIPS borehole probe consists of a light source, batteries, a fixed conical mirror and a video camera. The borehole wall is illuminated and mirrored in the conical mirror which in turn is recorded by the video camera (Figure 1-2). The resulting raw data image (Figure 1-3) is simultaneously processed in the ground unit of the BIPS-system. One circle of pixels (maximum 360 pixels) in the raw data image is used to compose one pixel line in the processed image. With custom settings, one pixel line represents 1 mm borehole length. As the logging proceeds down the borehole pixel line after pixel line are stacked upon each other, one for each logged millimetre, resulting in an unfolded 2D BIPS-image.

The BIPS-image is oriented in the borehole, which means that upwards or north of a pixel circle is registered. The pixel circle in the raw data image can thereby be cut in a consistent way. It is the white tip of the pointer (Figure 1-3) that determines where the pixel circle shall be cut to form the edges of the processed BIPS-image. The green half of the pointer shall point upwards or north, while the white part shall point downwards or south. This means that the raw data image is cut along either the low side or the south side of the borehole.

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[1] SKB internal controlling document.

[2] Internal SKB document. Documentum ID 1062926.

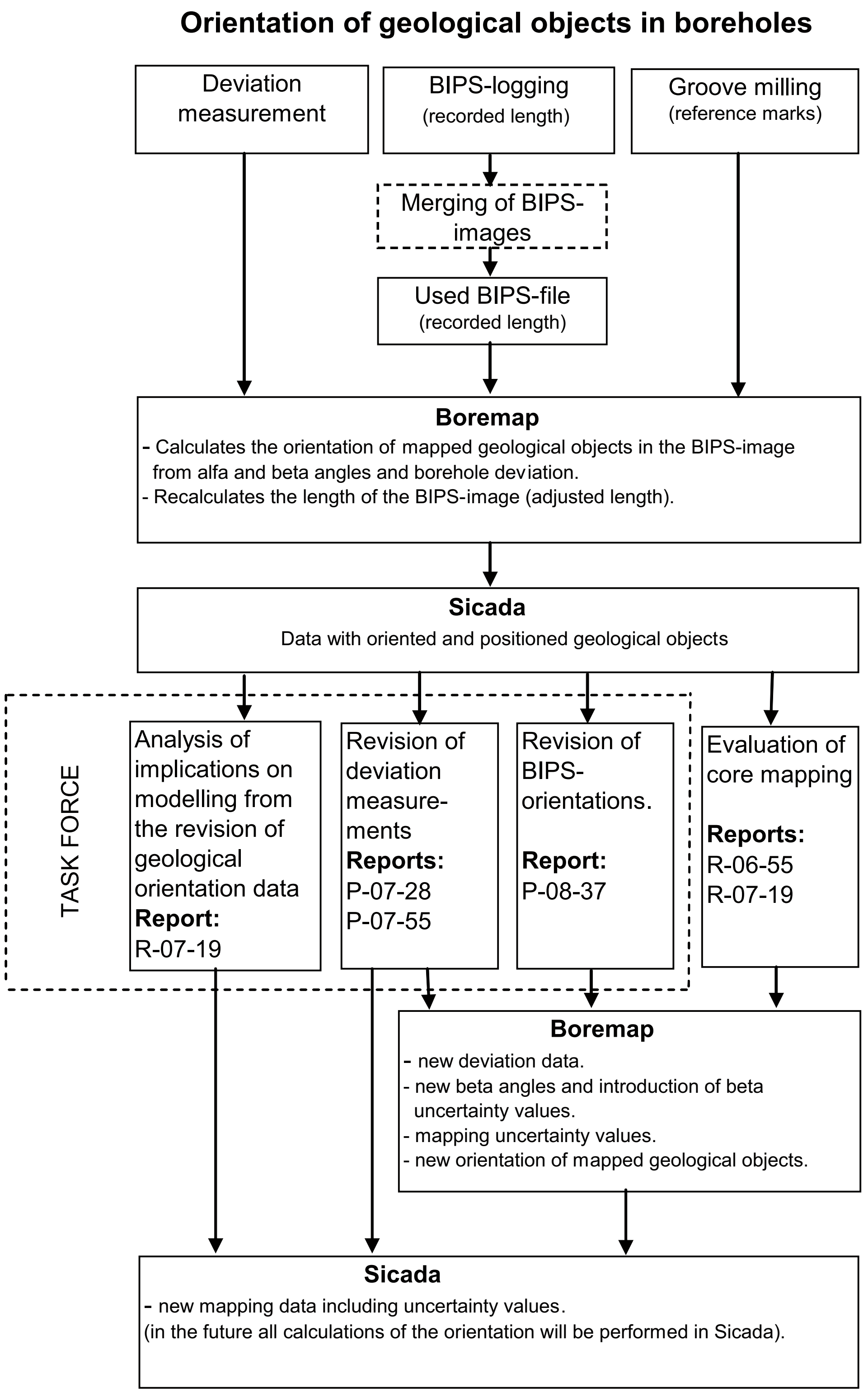


Figure 1-1. *Flow sheet showing factors affecting the orientation of geological objects, from in-data to geological mapping and data handling, as well as the revision of data within Task Force Fracture Orientation and the result of the revision.*

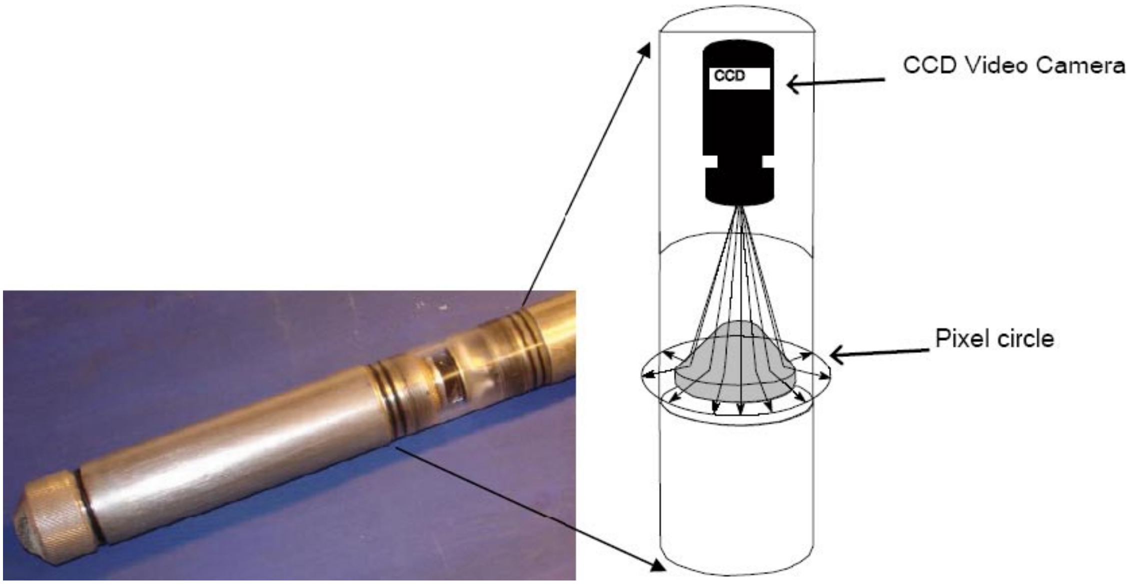


Figure 1-2. *The BIPS-image probe to the left with glass covered conical mirror and light settings. To the right is a schematic presentation of the BIPS-probe.*

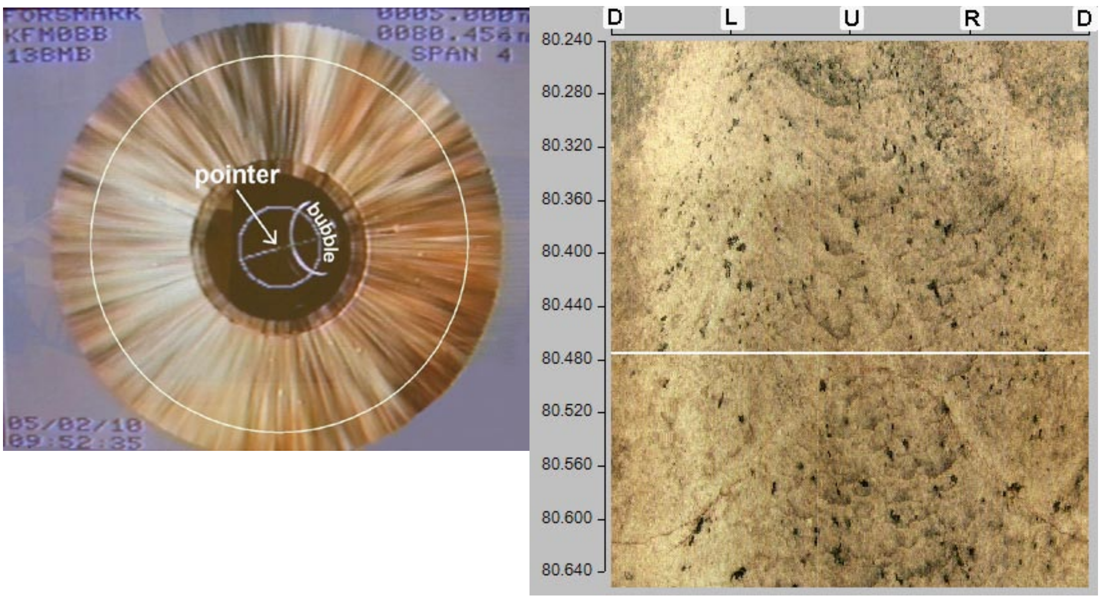


Figure 1-3. *Principles of the BIPS-system. One circle of pixels of the raw data image (left) produces one pixel line in the processed image (right).*

The BIPS-image is either oriented with compass or with clinometer (Figure 1-4). When the inclination of the borehole is between –85° and –90°, i.e. almost vertical, the BIPS-image must be oriented with compass. When orienting the image with compass an automatic orientation can be used.

For non-vertical boreholes clinometer is used for the orientation. During logging the pointer is then tuned manually by the logging operator with a hand wheel. In the beginning of the site investigations a steel ball clinometer was used, but since it was noticed that the orientation of the BIPS-image was not always reliable, the steel ball clinometer was replaced by a bubble level clinometer in November 2003.

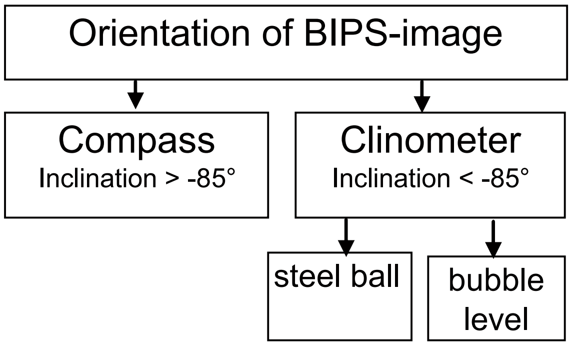


Figure 1-4. Orientation methods of BIPS-images in the borehole.

During gravimetric orientation a semiautomatic orientation can also be used. This is performed in the following way: the operator adjusts manually the pointer gravimetrically and then puts on the automatic setting which keeps the angle to the reference (north) constant during logging. This is sufficient in the case when the borehole is completely straight. When the borehole deviates from the ideal straight line, a deviation in β-angle which corresponds to the borehole deviation will arise if the pointer is not manually adjusted by the operator.

1.2 Geological object orientation in Boremap

The documentation of the geology in boreholes is performed in the software Boremap, which uses BIPS-images for positioning and orienting the geological objects. Planar features appear as sinusoidal traces in the BIPS-image. When mapping a geological object in Boremap, the geologist fits a sinusoidal line to the object trace in the BIPS-image (Figure 1-6). Boremap then calculates the orientation of the object from the sinusoidal line and the borehole orientation (deviation) data. The sinusoidal line consists of two components:

- α-angle and
- β-angle.

The α-angle is the angle towards the borehole axis (Figure 1-5) and it is represented by the amplitude of the sinusoidal line in the BIPS-image. The β-angle is the angle between the maximum of the sinusoidal line and the low side of the borehole and it can be calculated from the distance between the two (Figure 1-6) relative to the image width (which represents 360°). In cases where the BIPS-image is oriented by compass, Boremap still calculates the orientations from the lower side of the borehole using deviation data from the borehole. In the special case when the borehole is vertical Boremap uses the borehole direction values from Sicada.

The β-angle is affected by the orientation of the BIPS-image. If the BIPS-image is wrongly oriented in the borehole, the β-angle will be incorrect and consequently, the orientation of the geological objects will be incorrect. In this work, the orientations of the BIPS-images have been evaluated and the β-angles have been corrected, if needed. Uncertainty values originating from the analysis of the orientation of the BIPS-image have also been set for the β-angles. The results have been implemented in both Boremap and Sicada.

Furthermore, mapping uncertainty values[3] have been set for both α- and β-angles, and they have also been implemented in Boremap and Sicada (see chapter 4.5.5). The total uncertainty in β-angle is the sum of the uncertainties from the BIPS-image and the performed mapping, while the uncertainty in α-angle only arises from the performed mapping.

[3] Internal SKB document. Documentum ID 1063373.

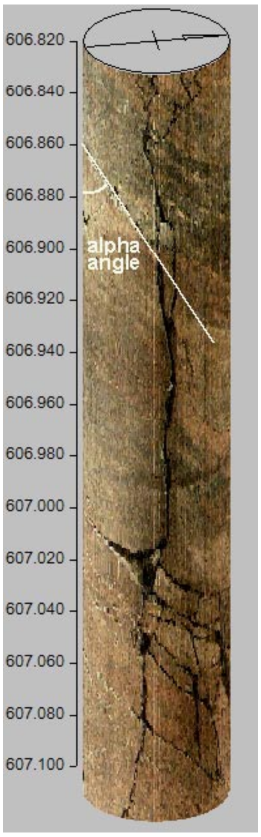


Figure 1-5. *Example of BIPS-image as a virtual drill core, borehole KLX21B, 606.84-607.24 m.*

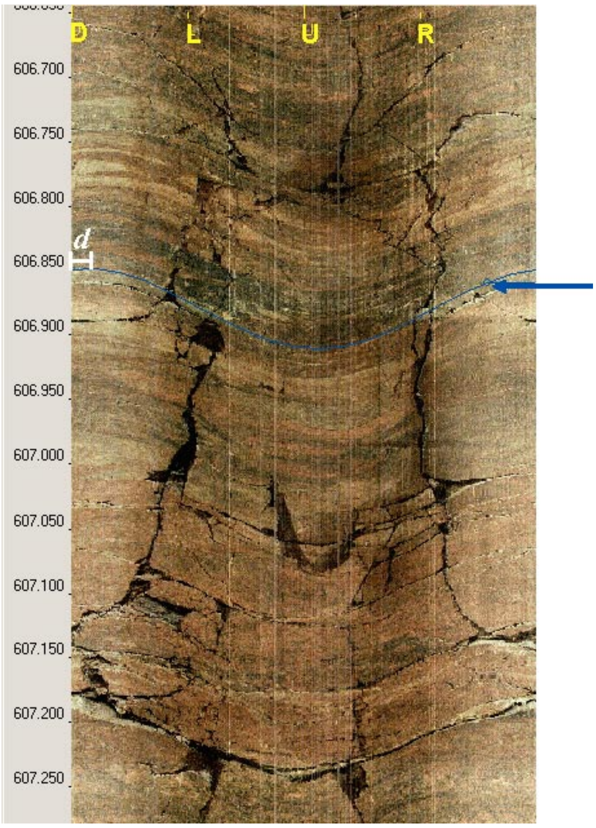


Figure 1-6. *Example of BIPS-image oriented with clinometer, borehole KLX21B, 606.65-607.28 m. It is cut along the low side of the borehole (D = down). The blue line represents a sinusoidal line from which the geological object orientation is calculated in Boremap. d = distance from reference line (low side of borehole), representing the β-angle.*

Normally there are several BIPS-loggings carried out in a borehole, and the images of best quality from these loggings are merged to a so called Used BIPS-file, covering the whole borehole length. This Used BIPS-file is the one used in the Boremap mapping and consequently only these images had to be revised. The revision had to be done from the raw data images as only these include the orientation tools (Figure 1-3). All lengths in this report refer to borehole lengths.

1.3 Nomenclature

The nomenclature used in this report is as follows:

BIPS-image:	Processed optical borehole image (Borehole Image Processing System, manufactured by RaaX Co).
BIPS raw data image:	Unprocessed optical borehole image (camera view).
Used BIPS-file:	The merged BIPS-images which have been used in the geological mapping in Boremap.
BIPS Image Viewer:	Software for viewing the BIPS-images (RaaX Co).
Boremap:	Software created by SKB for mapping the geology in boreholes using BIPS-images.
Sicada:	The database of SKB.
α-angle:	Angle of a plane towards the borehole axis (0–90°).
β-angle:	Traditionally expressed as the angle between a reference line along the borehole and the lower extreme of a plane, measured clockwise (0–360°) when observed in the drilling direction. In Boremap it is the angle between a reference line along the borehole (lower side) and the upper extreme of a plane.
Acoustic Televiewer-image:	Acoustic borehole image (manufactured by Robertson Geologging Ltd.)
Mapping Δα:	Uncertainty value for α-angle originating from the geological mapping (in degrees).
Mapping Δβ:	Uncertainty value for β-angle originating from the geological mapping (in degrees).
BIPS Δβ:	Uncertainty value for β-angle originating from the orientation of the BIPS-image (in degrees).
General BIPS Δβ:	As BIPS Δβ, but the general BIPS Δβ value is a calculated 90th percentile from BIPS Δβ values and β-offsets of similar boreholes (i.e. core or percussion drilled and approx. same inclination) (in degrees).
Total Δβ:	The sum of mapping Δβ and BIPS Δβ (in degrees).
β-offset:	The deviation of the BIPS-orientation (i.e. the angle between pointer and steel ball/bubble/compass), which is equal to the BIPS β-correction (in degrees).

2 Objective and scope

During an internal investigation of uncertainties connected with the orientations of mapped geological features in cored and percussion drilled boreholes, a particular problem concerning the orientation of the BIPS-images was discovered. The problem was related to the rotational orientation of the BIPS probe, which in some of the logged borehole sections turned out to be inadequately accurate. This resulted in errors and unacceptable uncertainties in the orientation of mapped geological features in those parts of the boreholes.

On the basis of a preliminary investigation of the extent of the problems, a revision of the orientations from the BIPS-loggings was carried out. The object with the revision of BIPS-images was to obtain correct orientation data for geological objects and to assess the uncertainty of the orientations.

The orientations of geological objects are calculated from:

1) borehole orientation data (from deviation measurements),

2) α-angle in BIPS-image,

3) β-angle in BIPS-image.

The orientation of the BIPS-image only affects the β-angle and therefore only corrections for β and uncertainties for β (BIPS Δβ) are in the scope of this work.

This report describes the procedure of evaluating the BIPS-image orientations and the implementation of the β-corrections and BIPS Δβ-values in Boremap and Sicada.

The revision comprises 48 prioritized boreholes in Laxemar and 22 prioritized boreholes in Forsmark. The BIPS-images were divided into the following groups according to the method of rotational orientation of the probe: bubble level (63 boreholes), steel ball (5 boreholes) and compass (2 boreholes) oriented BIPS-images

3 Description of equipment

The software BIPS Image Viewer was used to identify the BIPS-images from different loggings composing the Used BIPS-file.

A Sony tape recorder was used to play the BIPS raw data tapes (backup), which were of Video 8 type in NTSC format. An AV-cable was connected between the Sony tape recorder and a DVD-recorder, which also was connected to a monitor (ordinary TV). The BIPS-tapes were copied to the hard disc of the DVD-recorder and were burnt to DVD in the recording quality format Long Play (LP).

The analysis of the orientation of the BIPS-images from the raw data files were performed on ordinary personal computers with DVD-players. The angle between the pointer and bubble level (gravimetric orientation) or compass (magnetic orientation) was measured on the screen with a transparent protractor. The angle (β-offset) and the uncertainty (IC and PI, described in chapter 4.5.1) was documented in an Excel-worksheet together with length (recorded length) of the observation.

The comparison between BIPS- and Televiewer-image was carried out in the software Boremap v.3.9.2.0 and v.3.9.3.0. Before this the Televiewer-image had been converted into .WAI-format which can be read by Boremap. The β-correction was performed with Boremap v.3.9.6.0. Statistical calculations and the curve fit were performed in the software R 2.50.

4 Execution

4.1 Identification of error sources

Before correcting possible errors in geological object orientations in BIPS and assessing the uncertainty of determined orientations, possible sources of errors had to be identified. Primary suspicions about error sources existed, but in order to investigate these suspicions a preliminary investigation was carried out at the turn of the months October–November in 2006.

The logging procedure was looked over in cooperation with the BIPS operator, in order to find out in which stages of the logging procedure errors affecting the orientation may occur. The following possible error sources were identified:

- The bubble size is not optimal, making it difficult to adjust the pointer accurately.
- The probe is rotating faster than the manual rotation adjustment of the hand wheel.
- The probe is rotating faster than the compass movement.
- The probe is not centralized in the borehole resulting in a distorted image.
- The pointer is not centralized in the evaluation circle in the ground unit of the BIPS-system.
- Human error in adjusting the pointer.
- Using the semi automatic orientation a constant angle to compass north is kept, but it does not consider the deviation of the borehole.

The problems with fast rotation of the probe only occur in almost vertical boreholes, and therefore these errors can be disregarded in non-vertical boreholes.

Percussion drilled boreholes with a diameter of approximately 140 mm are more likely to have distorted BIPS-images than core drilled boreholes with a diameter of 76 mm. The distortion is not considered to be an important element, since if it would have been considerable it would have been noticed in the Boremap mapping.

In the preliminary investigation selected raw data tapes were also checked in order to identify sections where the BIPS-images were not correctly oriented and to estimate the deviation from the true orientation.

4.2 Choice of method

There were discussions about how the work should be performed to give the most reliable result. During the preliminary investigation we tested on re-orienting BIPS-images from the raw data tapes. The re-oriented BIPS-images were generated when playing the raw data tape from the tape recorder to the ground unit of the BIPS-equipment. Generating new, correctly oriented BIPS-images was on the other hand not a good alternative for solving the problems. The reason for this was that the after-treatment with correcting the orientation of each observed geological object in the boreholes would have been too extensive. Also, the quality of the regenerated BIPS-image was not as good as the original one.

It was decided that the BIPS-raw data tapes with the logging in real time should be evaluated instead. On the raw data tapes the steel ball/compass/bubble could be seen as well as the pointer which determines the orientation of the image. The angle between the steel ball/compass/bubble and the pointer, which should be 0° when the image is correctly oriented, was measured and used to correct the orientations of the geological objects. The imprecision for all reoriented objects were also quantified as BIPS $\Delta\beta$.

4.2.1 Used BIPS-files

Normally several BIPS-loggings have been conducted in the same borehole, but before this revision work there was no documentation of which BIPS-images were merged to compose the Used BIPS-file. This had to be solved first by ocular comparison of the Used BIPS-file with the different original BIPS-images in each window in the BIPS Image Viewer. In the Used BIPS-file the splice between the two original BIPS-images was possible to see as a grey pixel line or as an abrupt change in image quality. In some rare cases the original images were of same image quality and perfectly merged which made it impossible to specify the exact length for the splice. When the length of the splice was not determined for sure, this was noted with a comment (Appendix 1).

The BIPS-images that were used to compose the Used BIPS-file were documented in an Excel worksheet for the Forsmark and Laxemar sites, respectively (Appendix 1). Start and end length of the merged BIPS-images were documented, as well as their new start and end length (recorded length). When the BIPS-images were merged, image 2 and image 3, etc, received new recorded lengths that continued right after the end length of the former image. In fact the recorded lengths in image 2, 3, etc, were adjusted to the recorded lengths in image 1. In the Used BIPS-file there was no possibility to trace the original recorded lengths.

The documentation of all BIPS-images composing the Used BIPS-files is implemented in Sicada.

4.2.2 Classification of BIPS-images after revision method

For a number of reasons (see below), not all BIPS-images were possible to revise with the method described above. Therefore boreholes with their corresponding BIPS-images were classified into categories, depending on which revision method should be applied in each case (Figure 4-1 and 4-2, Appendix 2). When the BIPS-image could be revised by evaluation of the raw data tapes the borehole was classified as category A. Only BIPS-images oriented with bubble level or compass were classified as category A.

In some cases BIPS raw data tapes were missing or defect for a whole borehole or part of borehole. For these boreholes or borehole sections, which were classified as category B, a general BIPS Δβ-value was calculated for the geological objects, based on BIPS Δβ-values in similar

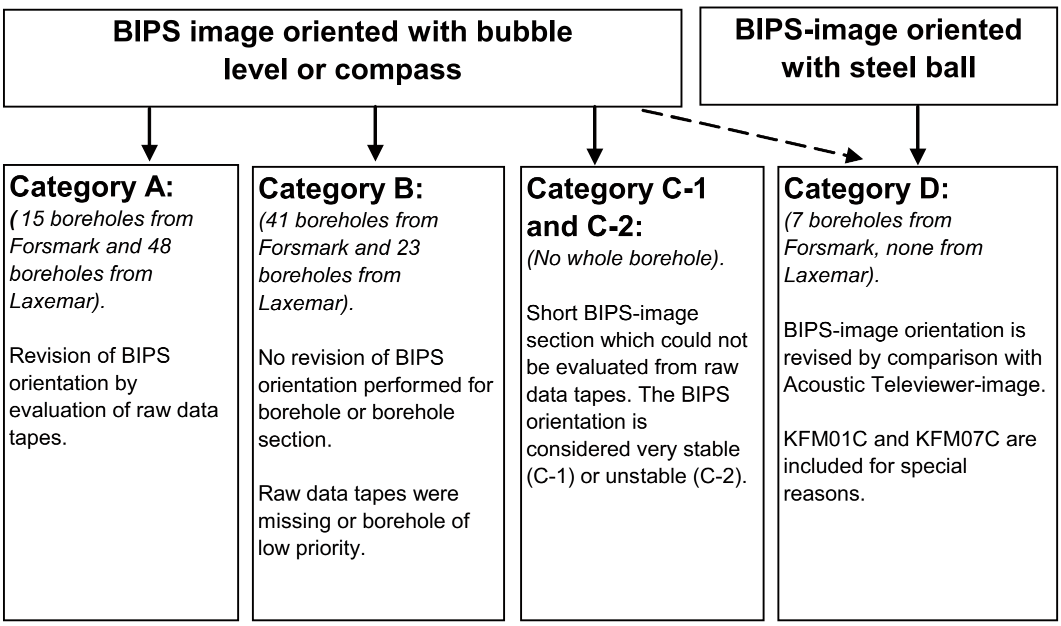


Figure 4-1. Classification of BIPS-image after revision method.

Forsmark				Laxemar			
category A	**category B**	**category D**	**not revised**	**category A**	**category B**	**category D**	**not revised**
L KFM01D	L KFM07B	S KFM01A	C KFM90A	L KLX03	L KLX07B		N KLX01
L KFM02B	L KFM09A	S KFM01B	C KFM90B	L KLX04	L KLX09		T KLX02
L KFM04A	L KFM09B	L KFM01C	C KFM90C	L KLX05	L KLX09F		- HLX01
L KFM05A	S HFM01	S KFM02A	C KFM90D	L KLX06	L KLX10		- HLX02
L KFM06A	C HFM02	S KFM03A	C KFM90E	L KLX07A	L KLX21B		- HLX03
L KFM06B	C HFM03	S KFM03B	C KFM90F	L KLX08	L HLX10		- HLX04
L KFM06C	S HFM04	L KFM07C	- KFM04B	C KLX09B	L HLX17		- HLX05
L KFM07A	S HFM05			L KLX09C	L HLX18		- HLX06
L KFM08A	S HFM06			L KLX09D	L HLX19		- HLX07
L KFM08B	S HFM07			L KLX09E	L HLX20		- HLX08
L KFM08D	S HFM08			L KLX09G	L HLX21		- HLX09
L KFM08C	S HFM09			L KLX10B	L HLX22		- HLX10
L KFM10A	S HFM10			L KLX10C	L HLX23		- HLX11
L KFM11A	S HFM11			L KLX11A	L HLX24		- HLX12
L KFM12A	S HFM12			C KLX11B	L HLX25		- HLX14
	S HFM13			L KLX11C	L HLX30		- HLX16
	S HFM14			L KLX11D	L HLX31		- HLX29
	S HFM15			L KLX11E	L HLX33		
	L HFM16			L KLX11F	L HLX34		
	L HFM17			L KLX12A	L HLX35		
	L HFM18			L KLX13A	L HLX36		
	L HFM19			L KLX14A	L HLX37		
	L HFM20			L KLX15A	L HLX39		
	L HFM21			L KLX16A	L HLX40		
	L HFM22			L KLX17A	L HLX41		
	L HFM23			L KLX18A			
	L HFM24			L KLX19A			
	L HFM25			L KLX20A			
	L HFM26			L KLX22A			
	L HFM27			L KLX22B			
	L HFM28			L KLX23A			
	L HFM29			L KLX23B			
	L HFM30			L KLX24A			
	L HFM31			L KLX25A			
	L HFM32			L KLX26A			
	L HFM33			L KLX26B			
	L HFM34			L KLX27A			
	L HFM35			L KLX28A			
	L HFM36			L KLX29A			
	L HFM37			L HLX13			
	L HFM38			L HLX15			
				L HLX26			
				L HLX27			
				L HLX28			
				L HLX32			
				L HLX38			
				L HLX42			
				L HLX43			
In total c. 9.800 m	**In total c. 7.600 m**	**In total c. 3.800 m**	**In total c. 1.100 m**	**In total c. 13.400 m**	**In total c. 5.900 m**	**In total 0 m**	**In total c. 3.500 m**

Figure 4-2. *BIPS-files listed after candidate area and category. L = bubble level oriented, C = compass oriented, S = steel ball oriented. T = Acoustic Televiewer-image (no BIPS-image), N = not oriented (no BIPS-image), - = not mapped.*

boreholes, i.e. core or percussion drilled respectively and approximately the same inclination (chapter 4.5.2). The Task force decided to leave the orientations of geological objects from these boreholes uncorrected since the investigation showed that bubble level oriented BIPS-images are generally well oriented. The evaluation alternatives would have been too time-consuming in relation to expected results with only minor corrections. Also boreholes of low priority, for example percussion boreholes from Forsmark, were classified as category B.

Shorter sections of BIPS-images which could not be evaluated from the BIPS-raw data tapes for some reason, but where logging conditions were considered stable, were classified as C-1. The β-correction was calculated as the mean value of the values nearest before and after the relevant section, while the uncertainty was set at the greatest value of uncertainty before and after the relevant section + the absolute figure of the difference in β-offset between the section before and after.

Similar sections, where the orientation was not considered reliable, were classified as C-2. If any section would have been classified as C2, the β-correction would have been set at 0 and the BIPS Δβ at ± 180°. However, no BIPS-image section has been classified as C2.

The methods described above were however not satisfactory for BIPS-images oriented with steel ball clinometer and therefore another method had to be worked out for these images. After a number of attempts, correction of the BIPS-images by comparing them with Acoustic Televiewer-images from the same borehole turned out to be a useful method (chapter 4.4). Also, due to the strong rotation of the probe during logging and therefore the need of correcting the BIPS-image orientation, two bubble level oriented BIPS-images (KFM01C and KFM07C) were adjusted with this method. BIPS-images that were revised by comparison with Acoustic Televiewer-images are classified as category D.

Boreholes are listed after BIPS-image category in Figure 4-2, and a schematic presentation of the revision procedure is shown in Figure 4-3. In some category A boreholes occur shorter sections classified as B or C.

4.3 Revision of BIPS-images oriented with bubble level or compass

4.3.1 Copying raw data tapes to DVD

When the BIPS-images and BIPS-intervals which were used in the Boremap mapping were known, the raw data tapes with the logging in real time from the logging occasions in question were converted to DVD (Figure 4-4). This was performed in the following way: a Sony-tape recorder was used to play the BIPS raw data tapes, which were of Video8 type in NTSC-format. An AV-cable was connected between the video tape player and a DVD recorder, which also was connected to a monitor. The BIPS raw data tapes were copied to the hard disc of the DVD-recorder, whereupon they were burnt on DVD in the recording quality Long Play (LP).

Since only one Video8-tape player was available, the copying to DVD made it possible for several persons to evaluate the BIPS-images at the same time. Another advantage was that archive data were modernized.

4.3.2 Revision of the orientation of the BIPS-images

When the raw data tapes from the BIPS-loggings are played, borehole length (recorded length), pointer, compass, and steel ball or bubble can be seen on the screen in real time (Figures 4-5 to 4-7).

In this work the position of the pointer during logging was analysed (Figure 4-8). During the revision of bubble level oriented BIPS-images (Figure 4-6), the angle (β-offset) between the green pointer and the centre of the bubble was measured. Likewise for compass oriented BIPS-images, the angle between the green pointer and the compass was measured. The angle is positive when the green pointer lies clockwise from the bubble or compass, and negative when the green pointer is anticlockwise from the bubble or compass.

Revision working procedure

Category A	Category B	Category C	Category D	
Measurement of β-angle between pointer and compass/centre of bubble. Inaccuracy of image condition (IC) and pointer (PI) is determined (part in the calculation of BIPS Δβ). *Chapter 4.3*	*Whole borehole*: No measure. *Borehole interval*: Comment in the Excel worksheet that interval is not possible to revise. Selection of revised reference boreholes for further calculation. *Chapter 4.5.2*	Comment in the Excel worksheet that interval is not possible to revise. Classified as C1 if orientation is considered stable and C2 if it is not considered stable. *Chapter 4.5.2*	Comparison in Boremap of geological structures visible in both BIPS-image and Televiwer-image. *Chapter 4.4*	**Revision Part 1: Evaluation**
Merging of Excel worksheets into BIPS Beta Offset-file. Calculation of Total inaccuracy (TI) which is equal to BIPS Δβ. Quality control Interpolation of β-offsets between readings/observations. *Chapter 4.5.1*	Calculation of general BIPS Δβ based on the revision of similar BIPS-images. Δβ and β-offset are used for the calculations. Both are weighted on BIPS-image length. *Chapter 4.5.2*	C1:The BIPS Δβ is set to the greatest value of the uncertainties next to the interval in question, plus the difference in β-angle before and after the interval. C2: No β-correction. The BIPS Δβ-value is set to ±180°. *Chapter 4.5.2*	Calculation and correction for different bearing between Sicada data and Televiewer data. Curve fitting of difference in β-angles resulting in β-corrections along BIPS-image. Calculation of BIPS Δβ from Televiewer uncertainty and "residual beta offset". *Chapter 4.5.3*	**Revision Part 2: Data handling and post processing**
The BIPS Δβ-values are summarized with the mapping Δβ-values. Mapping Δα-values are also implemented. Chapter 4.5.5				**Implementation in Boremap and Sicada**
Each geological object receives a β-correction and a total Δβ-value as well as a mapping Δα-value. *Chapter 4.5.4 and 4.5.5*	No β-correction. Total Δβ is summarized from the general BIPS Δβ and the mapping Δβ. All geological objects receive a Δα-value. *Chapter 4.5.4 and 4.5.5*	C1: Each geological object receives a β-correction,a total Δβ-value, and a Δα-value. C2: Total Δβ is set to ±180° and Δα is equal to the mapping Δα. *Chapter 4.5.4 and 4.5.5*	Each geological object receives a β-correction and a Δα-value. Total Δβ is summarized from the general BIPS Δβ and the mapping Δβ. *Chapter 4.5.4 and 4.5.5*	

Figure 4-3. *Schematic description of the working procedure with the revision of BIPS-image orientation.*

Figure 4-4. *BIPS raw data tapes are copied from the Video8-tape player (down to the right) to DVD (down to the left).*

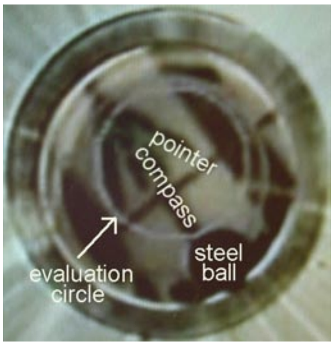


Figure 4-5. *BIPS-image oriented with steel ball clinometer (KFM02A) with clearly visible compass. The pointer is somewhat diffuse and it is not centred in the image. It points almost 45° anti-clockwise from the steel ball.*

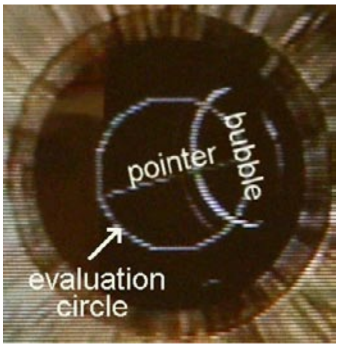


Figure 4-6. *BIPS-image oriented with bubble of average size (KFM08B). The pointer can be clearly observed.*

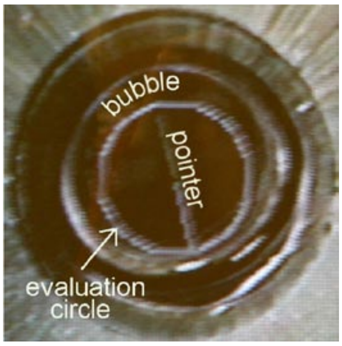


Figure 4-7. *BIPS-image oriented with an enormous bubble (KFM01B).*

Figure 4-8. *The β-angle between pointer and bubble is measured on the right screen. The angle, together with an uncertainty value, is documented in an Excel worksheet on the left screen.*

The analysis was documented in an Excel worksheet (Figure 4-9). Borehole-id, date and time for BIPS-logging, borehole length of observation and measured β-angle between pointer and bubble/compass was documented (the angle is called BetaOffSet in the merged basic document BetaOffSet, chapter 4.5.1). When the BIPS probe was stable during logging a point reading each fifth metre was considered enough. On the other hand, if the pointer oscillated much, or if the BIPS-probe swayed or rotated during logging, the angle was measured at closer intervals. The raw data files were analysed and the point readings were made, to detect possible discrepancies. Usually the raw data files were played faster (8x) between the point readings.

The variation in the measurements was also documented in the Excel worksheet (Figure 4-9) in the column "variation in angle between bubble/pointer (called PI in the merged basic document, chapter 4.5.1). Oscillating pointer and fast rotation of the BIPS-probe are the main factors for PI. The reason for the oscillation is that the digital pointer only registers integer degrees, but it is also affected by the pixel size of the image. A greater variation in the measurements is also caused by strong rotation of the BIPS probe where slowness of the pointer resulted in deviating orientation. This cannot always be exactly corrected for.

Kvalitetskontroll BIPS-orientering utgående från BIPS-kassetter										
Utförare: Gunnar Rauséus										
Vinkel mellan grön pekare och libellens mitt uppmäts (vit pekar mot botten, grön pekar upp).										
+ grader anges då pekaren ligger medurs från libellen (0-180°)										
- grader anges då pekaren ligger moturs från libellen (0-180°)										
Borrhål	BIPS-bild Datum för loggning	Djup Från	Djup Till	Libellens vinkel mot pekaren (?	Variation i vinkel libell/pekare	Sonden roterat	Kvalitets-godkänd utan åtgärd	Kvalitets-godkänd med åtgärd	EJ kvalitets-godkänd	Kommentar
KLX06A	2004-12-28	547.700		10	6			x		pekaren syns dåligt sen föregående mätning
KLX06A	2004-12-28	550.000		10	4			x		
KLX06A	2004-12-28	555.000		10	4			x		
KLX06A	2004-12-28	558.000		10	4			x		
KLX06A	2004-12-28	560.000		10	6			x		
KLX06A	2004-12-28	560.800		10	4			x		
KLX06A	2004-12-28	560.850		0	6		x			
KLX06A	2004-12-28	565.000		0	6		x			
KLX06A	2004-12-28	570.000		0	4		x			
KLX06A	2004-12-28	575.000		0	6		x			
KLX06A	2004-12-28	580.000		0	6		x			
KLX06A	2004-12-28	582.000		0	6		x			
KLX06A	2004-12-28	582.050		3	6			x		
KLX06A	2004-12-28	584.500		3	4			x		
KLX06A	2004-12-28	584.600		0	6		x			
KLX06A	2004-12-28	585.000		0	6		x			
KLX06A	2004-12-28	588.000		0	6		x			
KLX06A	2004-12-28	590.000		0	6		x			
KLX06A	2004-12-28	593.000		2	6			x		
KLX06A	2004-12-28	596.000		2	6			x		
KLX06A	2004-12-28	597.000		5	6			x		
KLX06A	2004-12-28	597.000		0	6		x			
KLX06A	2004-12-28	598.000		5	6			x		
KLX06A	2004-12-28	599.000		0	6		x			
KLX06A	2004-12-28	600.000		-3	4			x		
KLX06A	2004-12-28	602.000		-3	6			x		Ny film
KLX06A	2004-12-28	603.000		-3	6			x		

Figure 4-9. *An example of the Excel worksheet documenting observed β-angle deviations between pointer and bubble (column "Libellens vinkel mot pekaren") with estimated variations (column "Variation i vinkel libel/pekare").*

In addition it was recorded whether the probe had rotated or not (yes/no), and if the quality of the interval can be accepted without measures, with measures or not at all. Each observation had also a comment field which was filled in if necessary.

Each Excel file with data had also a front flyleaf (Figure 4-10) where used BIPS-images and intervals are listed, as well as the used method for orienting the image (bubble level/compass). An estimation of the general uncertainty in the angle measurements due to the human element which is called IC (image condition) in the basic document, (chapter 4.5.1) is also noted. IC is mainly influenced by, for example, big bubble, which makes it difficult to exactly measure the centre of it. The variation in the measurements is stated in integers.

Utvärdering av orientering av BIPS-bilder

Borrhål KLX06

Använda BIPS-filer:

Loggnings datum	Loggnings tid	rec.depth från	rec.depth till	Ny rec. depth från	Ny rec. depth till
2004-12-18	07:51	101.00	407.48	101.00	407.48
2004-12-18	13:44	407.54	600.01	407.48	599.95
2004-12-18	15:49	600.00	960.82	599.95	960.77

Orientering: libel, liten

Korrektionsmetod: Vinkeln mellan libellens mitt och grön pekare (+ om pekaren ligger medurs, - om pekaren ligger moturs om libellens mitt).

Felmarginal i mätningarna:

Sektion, m	Uppskattat fel
101-960.77 m	6

Ej kvalitetsgodkänd sektion

m	%
2.419	0.00

Figure 4-10. *An example of the front flyleaf of the Excel-file with the documentation of the original BIPS-images composing the Used BIPS-file, orientation method, correction method, estimated IC (Image condition or "Uppskattat fel") and not quality proved sections.*

Finally, total borehole length of BIPS-images and not quality-approved sections expressed in percentages were noted, i.e. sections where the orientation of the BIPS-image is unknown and therefore cannot be corrected for.

In the bubble level and compass oriented BIPS-images the β-offsets and BIPS Δβ-values are measured/observed and can be used as they are for the correction of β-angles. The final processing of data is described in chapter 4.5.1. The procedure in the evaluation of bubble level and compass oriented BIPS-images are described schematically in Appendix 3.

In compass oriented BIPS-images, it is also necessary to check whether earth field magnetic disturbances occurred during the logging (Appendix 6) or if there are magnetic sections in the borehole that disturb the compass. Of the evaluated BIPS-images only two were oriented by using compass: KLX09B and KLX11B.

Internal quality check of the revision of BIPS-orientation

Internal quality checks were performed for all revised BIPS-images to ensure that the β-angle corrections were correctly measured and to estimate the variation in the measurements between different persons. This internal quality check was carried out by another person who performed an independent revision in randomly selected sections of the BIPS raw data file. In short (100 m) boreholes one 10–20 m long section was selected, whereas in long (700–900 m) boreholes three 10–20 m long sections were considered enough for quality control.

The result from the independent revision was marked in red and copied to another worksheet together with the evaluation of the corresponding sections in the actual evaluation, which was marked in black, whereupon they were sorted after increasing length. The readings were compared, serving as support in estimating the human (subjective) element (called IC in chapter 4.5.1) in the uncertainty of the measurements. Only observations from exactly the same length should be compared when the probe has oscillated or rotated in the borehole.

The orientations of BIPS-images that were logged after spring 2007 were also revised, but the revisions were not quality checked as described above.

4.4 Revision of BIPS-images oriented with steel ball clinometer

In the beginning of the site investigations a steel ball was used as a reference when orienting the BIPS-image in inclined boreholes, in order to identify the low side of the borehole. Since the steel ball is influenced by inertia causing it to move in steps rather than smoothly during rotation of the BIPS-probe, the ball is not reliable for determining the low side of a sub-vertical borehole. Several attempts were made to find a method for revising and correcting steel ball oriented BIPS-images (chapter 6.4 and 6.5).

Finally, it was decided to correct the BIPS-image with the Acoustic Televiewer-image, since the Televiewer has two independent methods for orientation: a gravimetric one and a magnetic one. The methods are compatible and can therefore be considered reliable. This procedure was used for correcting β-angles and estimating BIPS Δβ-values in the following boreholes which have BIPS images oriented with steel ball clinometer: KFM01A, KFM01B, KFM02A, KFM03A and KFM03B. Also KFM01C and KFM07C with bubble level oriented BIPS-images have been treated in the same way. These BIPS-images needed to be corrected because they were influenced by considerable rotation of the probe during logging. As no raw data tapes were available this was considered the best solution.

The method for evaluating steel ball oriented BIPS-images is described schematically in Appendix 4.

4.4.1 Description of the Acoustic Televiewer

The probe uses a fixed acoustic transducer and a rotating acoustic mirror to scan the borehole walls with a focussed ultrasound beam. The amplitude and travel time of the reflected acoustic signal are recorded simultaneously as separate image logs. On the Acoustic Televiewer image both open and sealed fractures as well as rock contacts can be observed as contrasts in colour (Figure 4-11). When using Acoustic Televiewer images instead of BIPS-images in the software Boremap, the image has to be oriented either with reference to compass or with reference to the low side of the borehole. For orientation of the image the tool uses a 3-axis magnetometer-accelerometer. The magnetometer is used to orient the image with reference to magnetic north, while the accelerometer is used to orient the image with reference to the low side of the borehole. Together the magnetometer and accelerometer give the orientation of the tool, e.g. bearing and inclination, and the Acoustic Televiewer can therefore also be used as a borehole deviation tool.

For simplicity, the Acoustic Televiewer is referred to below as "Televiewer".

4.4.2 Comparison of fractures in both BIPS- and Televiewer-image

A simultaneous comparative mapping of BIPS- and Televiewer-images served as a foundation for the corrections of orientations in boreholes with steel ball oriented BIPS-images in Forsmark (category D). The Used BIPS-file and the magnetically oriented Televiewer-image were opened in Boremap (v.3.9.2 or v.3.9.3) in each mapping and in separate windows on two screens (Figure 4-11). Both images were then length adjusted by using reference marks in the borehole wall (lengths were imported from Sicada). Borehole deviation data were also imported from Sicada in order to get the correct β-reference for the magnetic oriented Televiewer-image.

The comparative mapping in Boremap was performed in the following way: fractures and other structures, which were visible in both images, were mapped in the usual way by fitting a sinus curve to the structure trace in the image according to SKB's Method Description (SKB MD 143.006), but by omitting information that was irrelevant for this work (for example mineral, fracture roughness etc). Only borehole length, α-angle and β-angle were registered. Observations were made at approximately 10 m intervals.

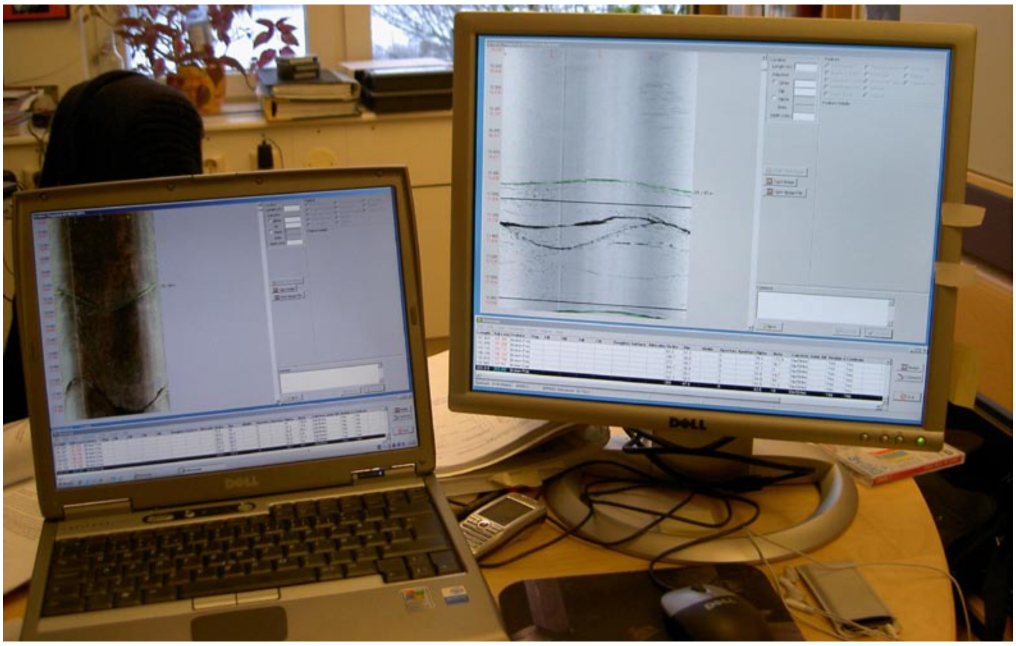


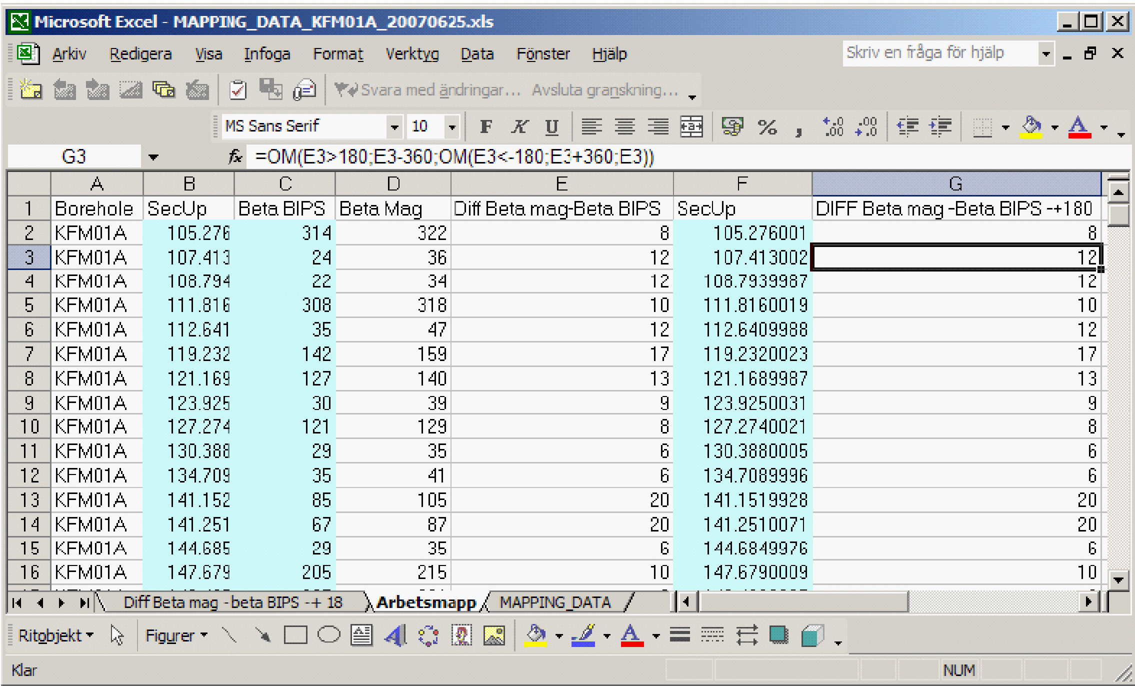
***Figure 4-11.** Comparison of fracture orientation in BIPS-image (left) and Televiewer-image (right) using the Boremap software.*

The resolutions of the BIPS- and Televiewer-images were different. The resolution of the BIPS-image was 1 pixel/mm along the borehole and 360 pixels/360°. The corresponding values for the Televiewer-images were:

KFM01A:	1/2 pixel/mm	180 pixels/360°
KFM01B:	1/2 pixel/mm	180 pixels/360°
KFM01C:	1/8 pixel/mm	90 pixels/360°
KFM02A:	1/2 pixel/mm	360 pixels/360°
KFM03A:	1/2 pixel/mm	120 pixels/360°
KFM03B:	1/2 pixel/mm	180 pixels/360°
KFM07C:	1/2 pixel/mm	180 pixels/360°

4.4.3 First step in calculating the difference in β-angle

Both mapping databases (BIPS and Televiewer, mapping 1 and 2 respectively) were then exported from Boremap to Excel for further processing. Length, β-angles from the BIPS-mapping and β-angles from the Televiewer-mapping were pasted into a new worksheet, after which the differences between the β-angles from Televiewer and BIPS were calculated (given as ± degrees, Figure 4-12). These observed differences in β-angles must also be compensated for magnetic orientation, different borehole deviation data, and uncertainty in the mapping procedure, all which are described further in chapter 4.5.3.



	Borehole	SecUp	Beta BIPS	Beta Mag	Diff Beta mag-Beta BIPS	SecUp	DIFF Beta mag -Beta BIPS -+180
2	KFM01A	105.276	314	322	8	105.276001	8
3	KFM01A	107.413	24	36	12	107.413002	12
4	KFM01A	108.794	22	34	12	108.7939987	12
5	KFM01A	111.816	308	318	10	111.8160019	10
6	KFM01A	112.641	35	47	12	112.6409988	12
7	KFM01A	119.232	142	159	17	119.2320023	17
8	KFM01A	121.169	127	140	13	121.1689987	13
9	KFM01A	123.925	30	39	9	123.9250031	9
10	KFM01A	127.274	121	129	8	127.2740021	8
11	KFM01A	130.388	29	35	6	130.3880005	6
12	KFM01A	134.709	35	41	6	134.7089996	6
13	KFM01A	141.152	85	105	20	141.1519928	20
14	KFM01A	141.251	67	87	20	141.2510071	20
15	KFM01A	144.685	29	35	6	144.6849976	6
16	KFM01A	147.679	205	215	10	147.6790009	10

Figure 4-12. The first step in the correction of the orientations in the mappings of BIPS-images, based on observations in the Televiewer-image, KFM01A.

4.4.4 Checking the borehole deviation measurements of the Televiewer

A corresponding mapping to the one between BIPS- and Televiewer-images was also performed between the two different orientation methods of the Televiewer, but to a lesser extent compared to the former. This was done in order to check the stability and reliability of the orientation methods. The outcoming result was that the two independent orientation methods corresponded well.

As the magnetic orientation method is sensitive to magnetic minerals and earth magnetic field disturbances, data showing total earth magnetic field at the time of the logging of the borehole have been retrieved from Intermagnet´s homepage (station UPS, Uppsala, Appendix 5). Also magnetic sections in the borehole disturb the compass, although only in restricted intervals. Since the comparison of the orientations of Televiewer-images oriented with gravimetric and magnetic methods showed no significant differences in orientation, it can be concluded that no such magnetic sections occurred in the boreholes in question.

4.5 Data handling and post processing

The data handling and post processing is depending on the method that has been used in the revision of the BIPS-image, i.e. into which category the BIPS-image is classified (Figure 4-1 and 4-2). Category A BIPS-images are almost ready for implementation of β-corrections and BIPS Δβ-values, while category B BIPS-images have not been treated at all. The further working procedures are described for each category in the following chapters.

4.5.1 Data handling and post processing of β-offsets and BIPS Δβ-values (category A)

The deviation in β-angles (β-offset) and corresponding BIPS Δβ-values for the bubble level or compass oriented BIPS-images are measured/observed, and can be used directly to correct mapped β-angles. On the other hand, some refining of the documents was performed before the orientations in the Boremap-mappings were corrected.

This refining was made in the following way: the Excel worksheet with β-corrections and Δβ-values from the revision was quality checked. The file was cleared of irrelevant data and supplemented when needed. After that the file was quality signed.

The Excel worksheets, one for each borehole, were merged in a basic Excel document called BetaOffSet-file, where all β-corrections and BIPS Δβ-values of the boreholes were gathered. The merged Excel worksheet then comprised the foundation for correcting the β-angles in each mapping. The merging is performed in a table in MS Access to facilitate copying to the work-databases containing the ordinary mappings. The β-corrections are performed for all mapped features with a supplementary program in Boremap, where all observed β-offsets and BIPS Δβ-values have been imported from the table described above (with source in the BetaOffSet – basic document). Since the β-correction values from the revision were only point readings, interpolation between the readings had to be executed before the actual β-corrections were set on geological objects (Figure 4-13).

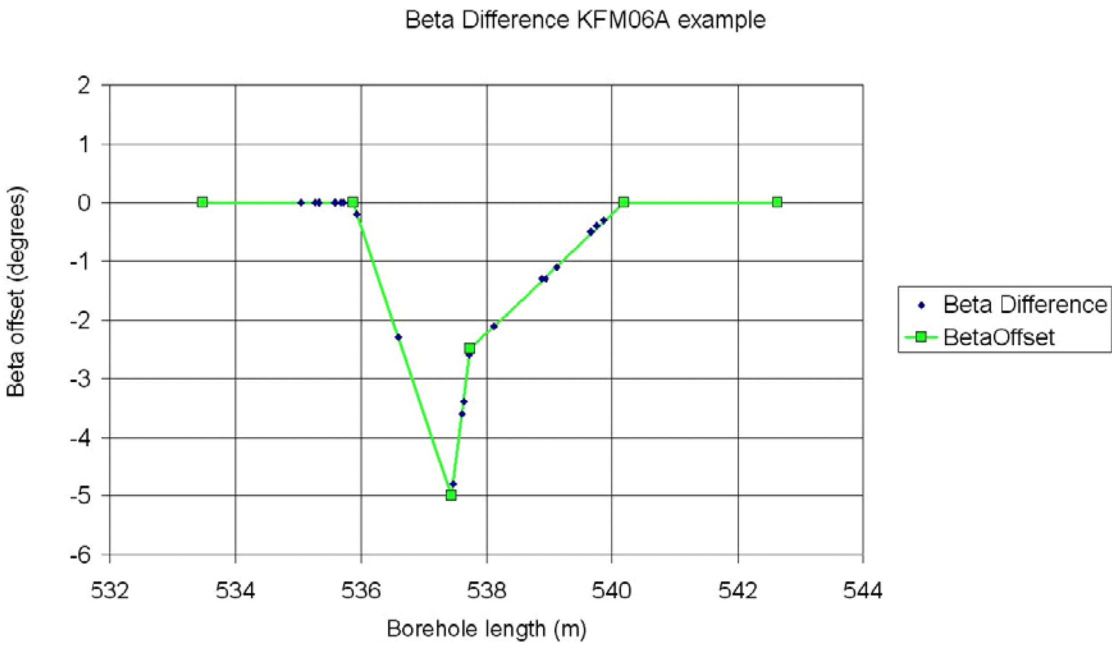


Figure 4-13. *Example showing the interpolation (green line) between the point readings in the revision (green squares) of category A BIPS-images. The blue points show the β-corrections of mapped geological objects.*

The BetaOffSet basic document has the following structure (Figure 4-14):

ImageDate

BetaOffset

IC (image condition)

In this column the general quality that can be achieved is registered, with respect to image quality and human accuracy in measurements. This is registered as a value of the variation, for example 3° (± 3°). The value is constant over long sections, mostly due to image quality.

PI (pointer inaccuracy)

In this column the variation in the stability of the pointer is registered along the borehole. This is registered as a value of variation, for example 2° (± 2°). The value varies with the movements of the pointer. Since the pointer is electronic, it is affected by limit values and is sometimes oscillating between two levels (two degrees), which means that this value is in practice at least ± 1°.

PI (excess)

The PI (excess)-column is a step in the calculation of the total inaccuracy (TI) and is expressed as that part of PI that should be encountered in TI. PI (excess) is the difference between PI and IC if PI is greater than IC; otherwise it is zero.

PM (probe movement)

In this column the change in the β-correction factor from the former reading is registered. If the absolute value of the change in β-offset is greater than IC, the PM-value will be half of the difference between the absolute value of the change and IC. Otherwise the PM-value will be set to zero.

TI (total inaccuracy)

In this column the sum of the columns above is calculated in the following way:
TI = IC + PI (excess) + PM

SondRotate

This is registered if the probe has rotated at the reading in question.

QC_prel

Section is quality proved without β-correction.

QC final

Section is classified and quality proved as:
x = category A
m = category C-1
G = category B
GT = category D
Further processing is required for m, G and GT flagged sections.

Comment

Quality check of the BetaOffSet-file

During the evaluation process, some quality flaws were discovered, after which the merged basic document (BetaOffSet) was examined once again to:

- Correct obvious typing errors in length information in the basic document.

Borehole	MappingNr	SecUp	Used SecUp	SecLow	Used SecLow	ImageDate	Beta Offset	IC (image condition)	PI (pointer inaccuracy)	PI (excess)	PM (probe movement)	TI (total inaccuracy)	SondRotate	QC_prel	QC final	Comment
KFM08A	1	645.000	645.000			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	650.000	650.000			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	655.000	655.000			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	660.000	660.000			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	665.000	665.000			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	670.000	670.000			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	675.000	675.000			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	680.000	680.000			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	685.000	685.000			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	690.000	690.000			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	695.000	695.000			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	699.999	699.999			2005-05-09	5	6	5	0.0	0.0	6.0			x	
KFM08A	1	700.013	700.013			2005-05-10	-3	6	5	0.0	5.0	11.0			x	
KFM08A	1	700.311	700.311			2005-05-10	-2	6	3	0.0	0.0	6.0			x	
KFM08A	1	705.000	704.800			2005-05-10	-2	6	2	0.0	0.0	6.0			x	stabil pekare
KFM08A	1	710.000	709.800			2005-05-10	-2	6	2	0.0	0.0	6.0			x	stabil pekare
KFM08A	1	713.000	712.800			2005-05-10	0	6	2	0.0	0.0	6.0		x	x	stabil pekare
KFM08A	1	720.000	719.800			2005-05-10	0	6	2	0.0	0.0	6.0		x	x	stabil pekare
KFM08A	1	730.000	729.800			2005-05-10	0	6	2	0.0	0.0	6.0		x	x	stabil pekare
KFM08A	1	740.000	739.800			2005-05-10	0	6	2	0.0	0.0	6.0		x	x	stabil pekare
KFM08A	1	750.000	749.800			2005-05-10	0	6	2	0.0	0.0	6.0		x	x	stabil pekare
KFM08A	1	760.000	759.800			2005-05-10	0	6	2	0.0	0.0	6.0		x	x	stabil pekare
KFM08A	1	770.000	769.800			2005-05-10	0	6	2	0.0	0.0	6.0		x	x	stabil pekare
KFM08A	1	780.000	779.800			2005-05-10	0	6	2	0.0	0.0	6.0		x	x	stabil pekare
KFM08A	1	790.000	789.800			2005-05-10	0	6	2	0.0	0.0	6.0		x	x	stabil pekare
KFM08A	1	795.000	794.800			2005-05-10	-2	6	2	0.0	0.0	6.0			x	stabil pekare
KFM08A	1	800.000	799.800			2005-05-10	0	6	2	0.0	0.0	6.0		x	x	stabil pekare
KFM08A	1	805.000	804.800			2005-05-10	0	6	3	0.0	0.0	6.0		x	x	stabil pekare
KFM08A	1	810.000	809.800			2005-05-10	0	6	2	0.0	0.0	6.0		x	x	stabil pekare

Figure 4-14. *Example from the BetaOffSet-file showing borehole length (recorded) of the point reading, the observed β-offset and factors affecting the Δβ, which is called TI in this document (IC, PI, PI excess and PM).*

- Check and, if needed, correct recorded length for the merged BIPS-images, since during the merging of BIPS-images into the Used BIPS-file, which is used in the geological mapping, image 2, 3 etc may receive new recorded lengths (Figure 4-14, length > 705 m marked in yellow, Appendix 1).
- Check that readings from the correct original BIPS-file have been used in the BetaOffSet-document at the lengths where two BIPS-images have been merged.
- Denote the uncertainty values in the same way as other uncertainty values within the Task Force project, i.e. that ± 3° is set to 3° and not to 6° as earlier in this work. This was done in 2008-02-25.

After this, considerations were also taken to the new recorded lengths in the Used BIPS-file (chapter 4.2.1).

4.5.2 Setting β-corrections and BIPS Δβ-values (category B and C)

For some BIPS-images that have been oriented with bubble level, the raw data tapes were missing or defect. Since the evaluation of the other BIPS-images showed that inclined bubble level-oriented BIPS-images are generally well oriented, it was decided to leave these uncorrected, as with BIPS-images from boreholes of lower priority (category B). Instead a general BIPS Δβ was calculated for the whole borehole or borehole interval.

Other similar sections which were not possible to evaluate were treated in other ways, because the BIPS-image orientation in the sections were considered very reliable (category C1) or unreliable (C2)

Calculation of general BIPS uncertainty for category B images

For BIPS-images (whole boreholes) and BIPS-image intervals that were classified as category B, a general uncertainty value was calculated. Also BIPS-images from boreholes of lower priority, for example percussion boreholes in Forsmark, where treated in this way.

Step 1 – Choice of reference values for the calculations

A general uncertainty value was calculated for boreholes which were of lower priority or where raw data tapes where missing. The general uncertainty values originate from the β-corrections and their uncertainties in the revised bubble level oriented BIPS-images (category A). Data from similar boreholes, ie, same borehole type (core drilled or percussion drilled) and of approximately same inclination, were selected. Information on which boreholes were used for the calculation of general uncertainty in a mapping is documented in the Sicada-table: bm_bips_beta_uncert.

Step 2 – Principles of the calculation of general BIPS Δβ

A good statistical measure of the general BIPS Δβ is the 90th percentile of calculated BIPS Δβ-values of the selected reference boreholes. The general BIPS Δβ should also be increased with increased β-corrections, since a correction rejects the point of departure of the uncertainty. A reasonable measure of this is the absolute value of median of the β-corrections. The estimated general BIPS Δβ of a borehole or a borehole interval is the sum of the 90th percentile of the reference BIPS Δβ-values and the median of the reference β-corrections.

Step 3: β-correction and BIPS Δβ are weighted to borehole length

Considerations must also be taken to the uneven distribution of the observations of β-corrections and BIPS Δβ-values. Where logging conditions are stable, only a reading every 5th metre has been performed. In unstable sections with large β-corrections and high BIPS Δβ-values, readings as frequent as each 10th centimetre have been performed. This means that data from the unstable sections are overrepresented compared to the data from stable sections. To correct this, the calculation is weighted on borehole length (Figure 4-15-16). The length weighting calculation is a re-sampling of the data, using a constant step length (of about 0.1m).

The final general uncertainty for a borehole is hence the sum of the weighted median value of the absolute values of β-angle deviations, and the weighted 90th percentile for the uncertainties, calculated on selected boreholes of same type and with same inclination. For easier comparison the figures show density estimates /5, 6, 7/ for the frequency distributions. This is due to the large difference in sample count for the numerical versus weighted data sets. The example data show the 90th-percentile (vertical line) decreasing from 4° to 3.5°. The points on the axis are a rug representation (one-dimensional plot) of the data. This shows the integer values spread in the resampled data.

Processing of borehole sections classified as category C

Some sections of the BIPS raw data tapes were not possible to evaluate (category C). The reasons for this were, for instance, that the pointer or bubble was not visible or that the BIPS raw data tapes were defect in a shorter interval.

In intervals where the difference in β-angle could not be determined, but where the readings have been stable (category C1), the difference in β-angle has been set to the mean value of the values next to the interval in question. The uncertainty has been set to the greatest value of the uncertainties next to the interval in question, plus the difference in β-angle before and after the interval.

The uncertainty value has been set to ± 180° in borehole intervals that were not quality proven (category C2). Such intervals are for example sections where the probe has rotated considerably during logging and the pointer does not follow the movement. No interval has been classified as category C2.

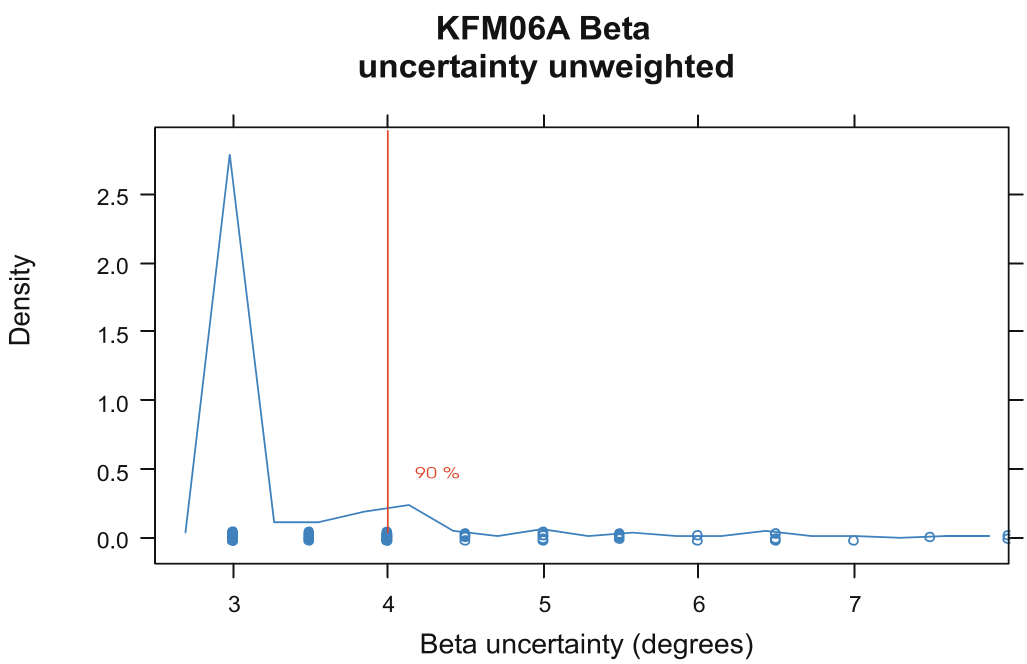


Figure 4-15. *Example showing the density function plotted against the unweighted BIPS Δβ-values in borehole KFM06A.*

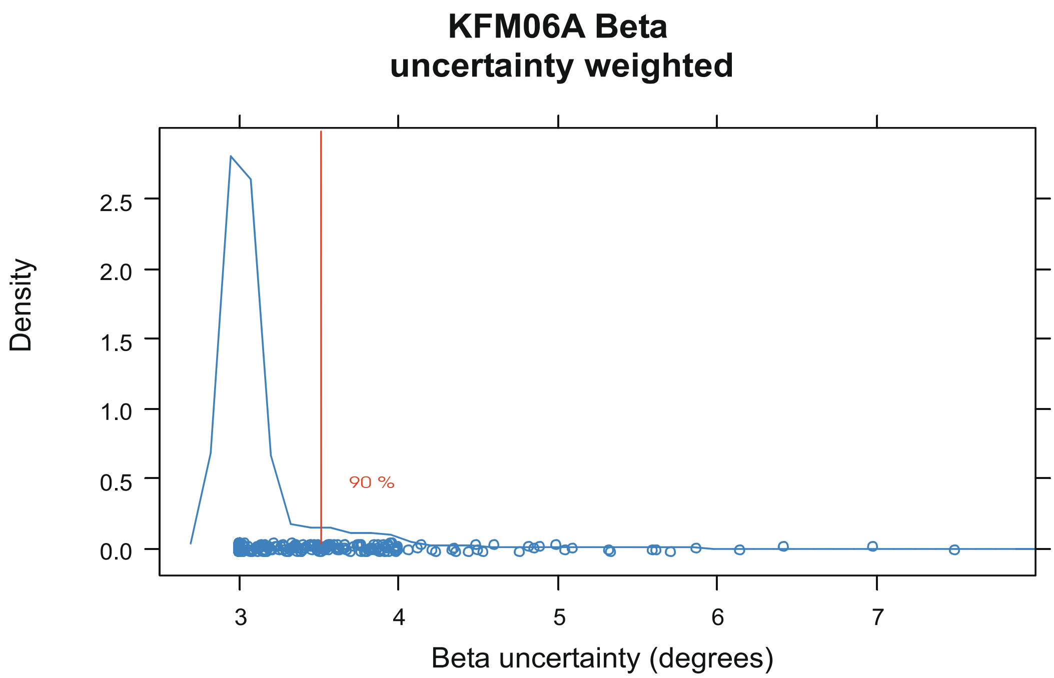


Figure 4-16. *Example showing the density function plotted against the weighted BIPS Δβ-values in borehole KFM06A.*

4.5.3 Calculation of β-offset and BIPS Δβ-values from the comparison of BIPS-image and Televiewer-image (category D)

The registered deviations in β-angle from the comparison of BIPS-images and Televiewer-images (category D), had to be recalculated before they could be used to correct the β-angles in the mappings.

Technical background for β-angle in Boremap

In Boremap, the angle β is always referred to the upper side of the borehole, i.e. in both gravimetric and magnetic oriented images (chapter 1.1–1.2). It would not be possible to specify β with another reference for a magnetic oriented image, since this would cause a mix of references in Sicada. In the hypothetical case with one magnetic and one gravimetric oriented BIPS-image in the same mapping, there would be no information of which reference is used and the orientation data would be mixed. What Boremap therefore does when mapping with a magnetic oriented image, is to calculate where the upper side of the image is from the borehole deviation data in Sicada. The accuracy in the calculation is good, even if inclination of the borehole is nearly –90°. The reason for this is that only azimuth is used. This calculation is thus only affected by the bearing uncertainty from the borehole deviation.

Correcting orientations in boreholes with BIPS-images oriented with steel ball clinometer

The basis for the correction was two Boremap-mappings per borehole, one mapped in Televiewer-image and the other in the BIPS-image that is to be corrected. Fractures that were clearly identifiable in both images were mapped. The difference in β-angle for each fracture gives the error in the orientation, since the Televiewer-image is considered the best available reference.

Step 1 – Calculation of the difference in bearing between the borehole deviation data from Televiewer and Sicada

Differences in β-angles between steel ball oriented and Televiewer-oriented structures can be analysed only after processing of the Televiewer-data in Boremap. This is due to the fact that the Televiewer-images are oriented with a magnetic method referring to the lower side of the borehole (cf. chapter 4.4.2), whereas the BIPS-images are oriented with a gravimetric method referring to the upper side. The Televiewer-data therefore have to be recalculated to be comparable with BIPS-data.

Boremap used the borehole deviation data from Sicada to recalculate the reference direction of the β-angles in the Televiewer-mapping. It was judged, that the Televiewer borehole deviation data is better than the one in Sicada and therefore deviation data had to be exchanged, or a corresponding recalculation of the reference direction of the β-angles had to be performed.

The first main step in the calculations was to bring forth the difference in bearing between the deviation data in the Televiewer and Sicada. The Televiewer data showed a clear oscillation in bearing with a period of 30–50 m. This is introduced by the probe and had to be filtered out with average calculation applied to segments of similar lengths as the period.

The deviation data from the Televiewer has a decimetre resolution which gives rather large quantities and too detailed data. A mean value calculation giving a metre resolution resulted therefore in manageable data (Figure 4-17). The deviation data in Sicada are given each third metre. These values were processed by taking the mean value between two consecutive points and by using this mean value in the interval between the points.

The deviation data in Sicada has the reference direction RT90, but the deviation data of the Televiewer has a magnetic reference direction. This resulted in a constant difference in direction along the borehole. The difference could be calculated from the meridian convergence and the magnetic declination for the site and time in question. These data can be found in Sicada table magnetic_declination, and are for Forsmark 2003: 2.1 and 4.0 respectively, which resulted in a difference in direction of 1.9°. After this correction, the difference between the deviations in Sicada and the Televiewer were ready to be applied on the differences in β from the comparative mapping.

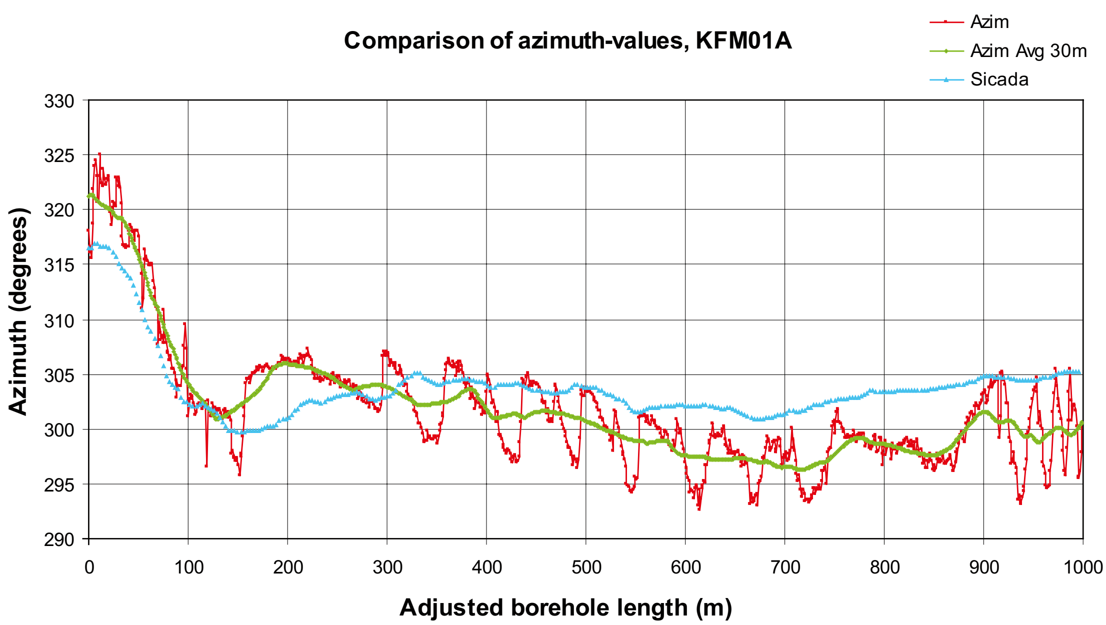


Figure 4-17. *Example of the difference between the azimuth of the Televiewer (original, as well as recalculated after mean value calculation) compared to azimuth-values from Sicada. The azimuth-values from Sicada are adjusted for meridian convergence and magnetic declination.*

A minor complication was that the length scale of the BIPS-image had to be adjusted for to be in accordance with the length scale of Sicada. In the ordinary Boremap-mapping this was already adjusted for. The points for length adjustments were accessible in these mappings and calculations for length adjustments could be performed in Boremap. In the comparative mapping recorded lengths were used, because there was no need for adjusted lengths in this part of the job, since the β-corrections were made on the basis of recorded lengths.

Step 2 – Correction of the difference in bearing between borehole deviation data from Televiewer versus Sicada

From the adjusted lengths it was now possible to obtain the difference in the bearing of the borehole deviation data in Sicada versus Televiewer, and to compensate the difference in β for this. This was the second main step in the calculations.

Step 3 – Curve fitting of the β-correction

After the second step the differences in β were expressed by the borehole deviation data of the Televiewer. It would be possible to use the differences in β straight away as β-correction, but since there was some uncertainty in the angle measurements in the documentation in Boremap (chapter 4.4.2), it was more appropriate to make a curve fit. The curve fit is calculated by Loess (Logical Polynomial Regression Fitting) /4/. The fitted curve was smoother and more probable as a β-correction. Usually there was only a divergence of a few degrees between the differences in β from the curve fit and the documentation in Boremap after corrections described in Step 1 and 2 above (Figure 4-18).

Determination of uncertainty in the β-correction

The uncertainty in the β-correction should be the sum of the uncertainties of the following:

- Televiewer-compass.
- Correction of the Televiewer-image to its compass.
- The comparative mapping.

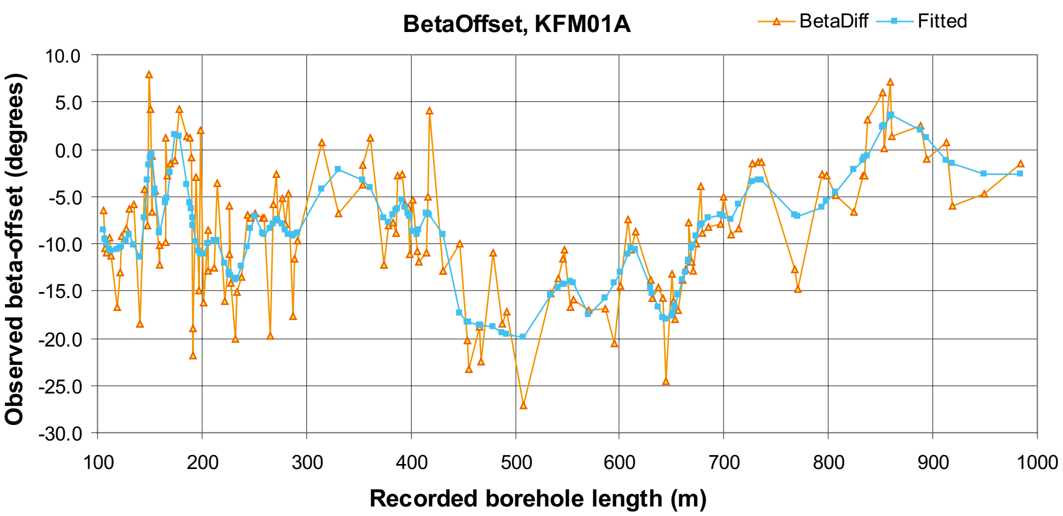


Figure 4-18. *Example of curve fit of the β-correction in KFM01A.*

The first two components were joined together as total uncertainty of the Televiewer, and it was set to ± 5° /2/. This value was set for KFM03A and this was also assumed to be valid for the other boreholes. The value had been discussed within the task force and its validity was also decided for KLX02, a borehole mapped with a Televiewer-image.

The third component was possible to estimate by statistical calculations of the deviations from the fitted curve (Figure 4-19). As usual, the 90th percentile for the deviations was used, weighted on length. The curve fit and the 90th percentile was the third main step in the calculation.

The result (β-corrections and BIPS Δβ-values) was transferred to the ordinary working procedure for application of β-correction/uncertainties on current mappings (chapter 4.5.4 and 4.5.5).

Comparison of β-correction based on bubble level- and Televiewer-evaluation

For one borehole, KFM01C (section 207.43 –439.67 m), the β-corrections were calculated both from revision of raw data files and from comparison with Televiewer-image. The BIPS-image is bubble level-oriented, but raw data tapes were missing for the upper part of the borehole. There is an observable deviation between the β-corrections calculated from the revision of the raw data tapes and the ones calculated after comparison with Televiewer-image (Figure 4-20). This deviation lies mostly within 4°, which is satisfactory for the intended purpose.

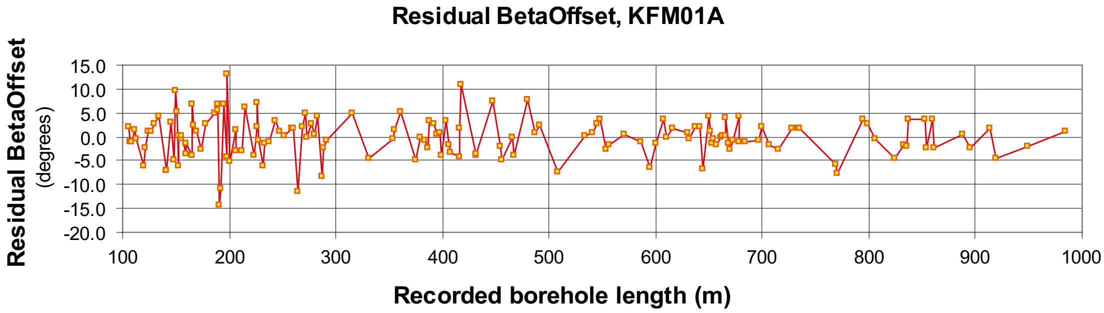


Figure 4-19. *Example of deviations in β-correction in KFM01A from the fitted curve.*

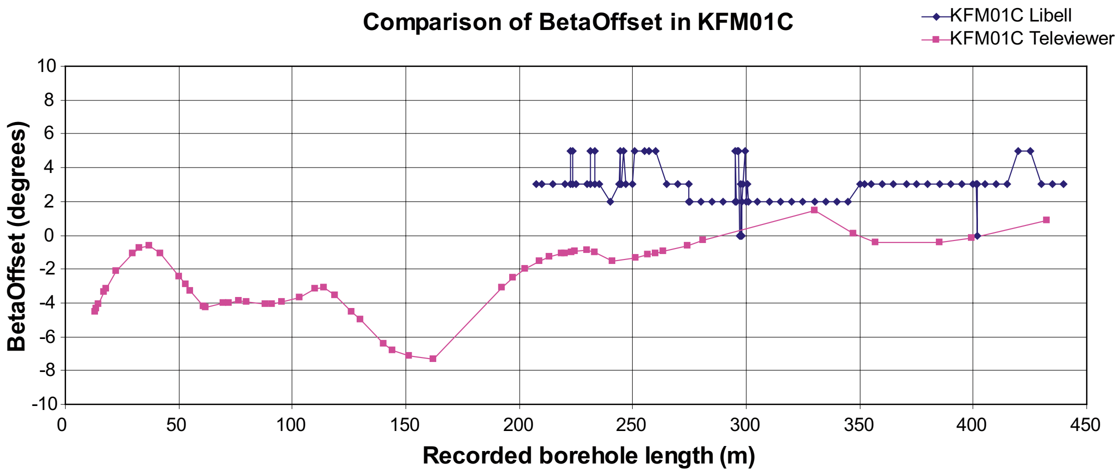


Figure 4-20. *Comparison of calculated β-corrections in KFM01C with the two methods: revision of raw data tapes from bubble level oriented BIPS image ("Libell") and comparison of Used BIPS-file with Televiewer-image ("Televiewer").*

4.5.4 Implementation of β-correction and BIPS Δβ-values

The β-corrections are in the same form, regardless of whether they constitute observed values from the bubble level-evaluation or stem from the comparative mapping with Televiewer (category A, C and D). The β-correction values (β-offset) that are observed as point readings in the revision do not coincide with each object in the geological mapping, and therefore linear interpolation has been performed between the readings. The β-corrections for each mapped feature (fracture, rock type etc) were changed with these interpolated values. No β-correction values are determined for category B boreholes.

There are two kinds of uncertainty values: from the revision of bubble level-oriented BIPS-images (category A and C) there are running values along the borehole, while from the comparison of BIPS- and Televiewer-images (category D) and from calculation of general BIPS Δβ (category B boreholes) there is only one statistically calculated value per borehole. No linear interpolation is performed for BIPS Δβ-values (category A and C); the observed value is instead used from one reading all the way to the next reading.

4.5.5 Boremap mapping uncertainty

The uncertainties in orientations of geological objects caused by mapping inaccuracy was estimated by letting two independent teams map the same parts of two boreholes /8/. An algorithm that automatically couples fractures mapped by one team to the same fracture mapped by the other team was then applied[4]. Out of these data, the mapping uncertainty could be estimated. Figure 4-21 shows the mapping uncertainty values which are implemented in Boremap and Sicada.

Only the implementation was carried out within this work, whereas the comparative mapping itself was carried out within the scope of a previous activity. The Δα-value in Sicada only results from the mapping Δα, while the Δβ-value in Sicada is the sum of the mapping Δβ and the BIPS Δβ.

4.6 Aggravating circumstances for performance of the revision

4.6.1 Missing BIPS raw data tapes

Raw data tapes from the BIPS-loggings were missing or defect for the following prioritized boreholes: KFM09A, KFM09B, KFM01C (11-208.24 m), KFM07B, KFM06B (4-55.52 m), KLX09, KLX09F, KLX10, KLX21B, HLX31, HLX36 and HLX37. For these boreholes a revision was not considered necessary. Instead general uncertainties for the orientations in the mappings were set in accordance with chapter 4.5.2. An exception is KFM01C for which the BIPS-image in its entirety was compared with Televiewer, because greater deviations in orientation were expected in this BIPS-image.

The calculated uncertainties originating from mapping				
Visibility in BIPS	**Visible**			**Not visible**
alpha angle	0°-30°	30°-60°	60°-90°	0°-90°
alpha uncertainty	± 1.4°	± 3.0°	± 3.6°	± 7.4°
beta uncertainty	± 4.0°	± 5.6°	± 25°	± 70°

Figure 4-21. *Calculated uncertainties originating from mapping. Modified after Munier and Stigsson /3/.*

[4] Internal SKB document. Documentum ID 1063373.

4.6.2 Large bubble

When rebuilding the BIPS-probe from the steel ball construction into a bubble level oriented BIPS, the bubble became too large at first. This was corrected fairly soon and therefore only BIPS-images that were logged during this intervening time were oriented with a very large bubble. When the bubble is very large it is difficult to settle the pointer to the upper side of the borehole. The uncertainty of the measurements (IC) is then closer to ± 5° instead of the usual ca ± 2°.

4.6.3 Oblique pointer or partly visible pointer

The angle measurements between pointer and bubble/compass were obstructed by the fact that the pointer rarely was a straight line and that often only one part of the pointer was visible (the green or the white part). This leads to a somewhat greater uncertainty in the measurements. The reason for the oblique or oscillating pointer is that it is digital and can only measure integer degrees. The pixel size also affects the appearance of the pointer.

4.6.4 Non-centred pointer

During some BIPS-loggings, the pointer has not been centred in the raw data image. This has somewhat obstructed the measurements of the angle between pointer and bubble/compass. Attempts have been made to extrapolate the pointer to the centre of the image, in order to obtain a correct angle measurement. However, it must be taken into account that somewhat greater uncertainties in the measurements may occur.

4.6.5 Disturbance of the compass in BIPS-images oriented with steel ball clinometer

During quality control of BIPS-images oriented with steel ball clinometers (the method was later abandoned), leaps were noticed in the angle measurements between pointer and compass. In KFM03A there was a clear connection with the abrupt difference in angle and an exchange of batteries in the light fittings for the built-in compass in the BIPS-probe.

5 Results

The results from the evaluation of the orientations of the BIPS-images are graphically presented in this chapter, while numeric values are found in Sicada in the data from respective borehole. Generally the BIPS-images have been oriented well from the beginning (Figure 5-1) and the correction has been minor, but exceptions occur. BIPS-images from sub-vertical boreholes clearly display large β-offsets, which is clearly shown in Figure 5-3 where most of the β-correction values are from sub-vertical boreholes. In Figure 5-2 histograms show the evaluated uncertainties in the bubble level oriented BIPS-images.

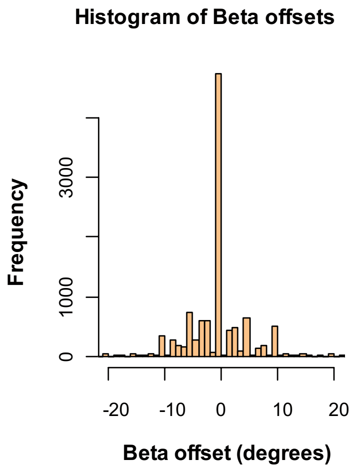


Figure 5-1. *Histogram showing observed β- corrections in bubble level and compass oriented BIPS-images.*

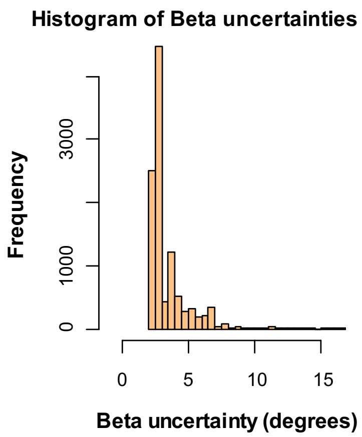


Figure 5-2. *Histogram showing evaluated uncertainties in bubble level and compass oriented BIPS-images.*

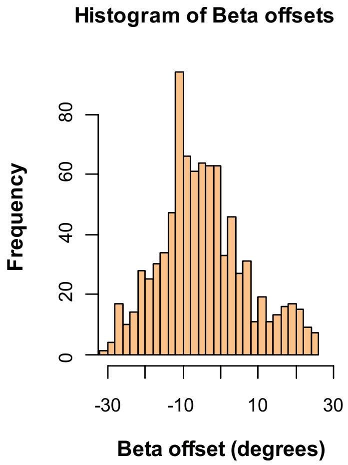


Figure 5-3. *Histogram showing β- corrections in BIPS-images resulting from the comparison with Televiewer-image.*

5.1 Brief presentation of BIPS-images from Forsmark

KFM01A

The BIPS-image of KFM01A is oriented with steel ball clinometer and is merged from three different files, which all were logged 2002-12-11. During the logging, between the second and third image (about 700 m), a battery change in the light fittings of the built-in compass has been performed, which can clearly be observed in the raw data tapes in the position of the compass and the steel ball before and after changing the battery. Magnetized batteries have probably been used, although demagnetized batteries are prescribed. The borehole is on the other hand oriented with steel ball clinometer and has an inclination of ca 80°.

Correction of the BIPS-image has been performed by comparison with Televiewer-image from the same borehole, since a comparison with compass direction is not reliable for these BIPS-images. The β-angles in the mapping of the BIPS-image have been corrected with up to 20° (see graph below). The calculated BIPS Δβ-value for the BIPS-image is ± 9.6°.

The total earth magnetic field during logging of the Televiewer-image is shown in Appendix 5.

KFM01B

The BIPS-image of KFM01B is merged from two different loggings, where 15.00–187.75 m is logged 2003-08-31 and 187.75–496.62 m is logged 2004-03-11. The earlier logging is oriented with steel ball clinometer, while the latter is oriented with a big bubble. Since the same correction method for the whole Used BIPS-file is preferable, it was chosen to compare the BIPS-image with Televiewer-image. The β-angles in the mapping of the BIPS-image have been corrected with up to 10° (see graph below). The calculated BIPS Δβ-value for the image is ± 9.0°.

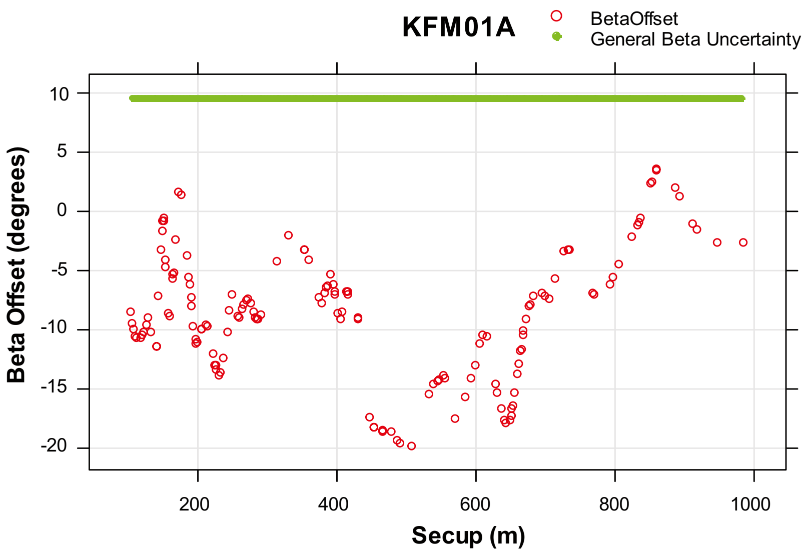
The total earth magnetic field during logging of the Televiewer-image is shown in Appendix 5.

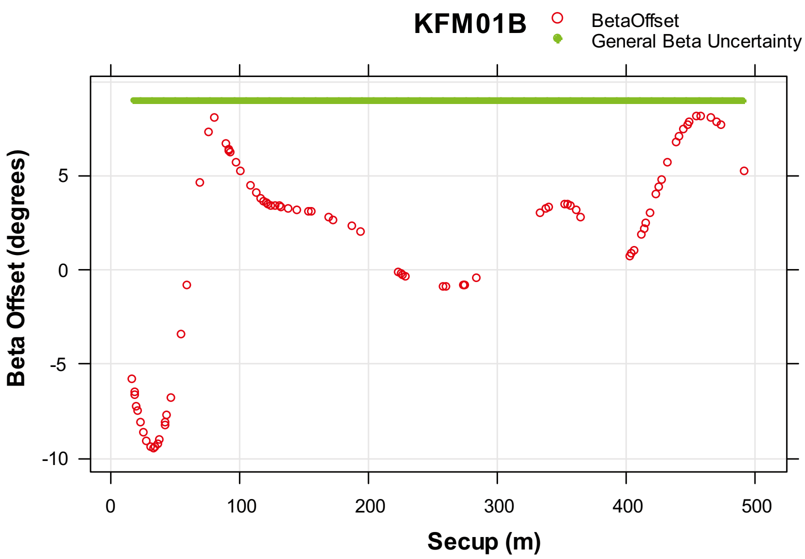
KFM01C

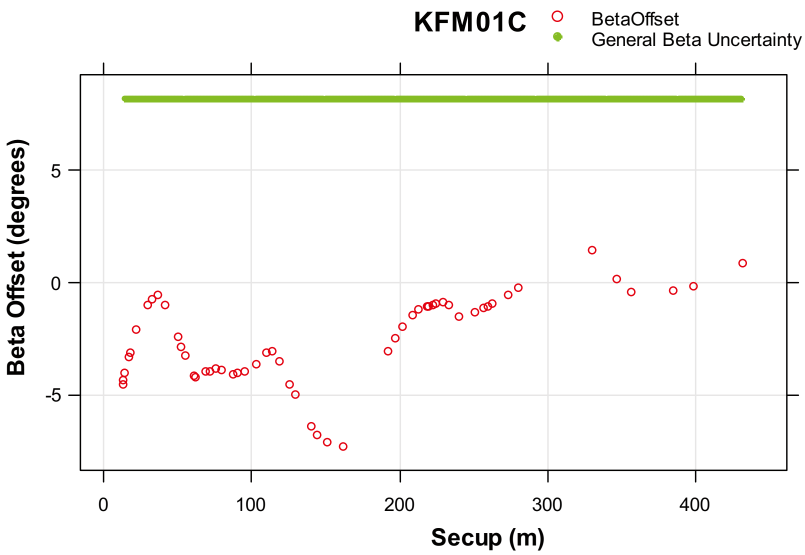
The BIPS-image of KFM01C is merged from three different files: 11.00–208.24 m is logged 2006-01-02, 208.24–275.46 m is logged 2006-03-08 and 275.46–440.33 m is logged the next day. All BIPS-files are oriented with bubble level. The raw data tape from the first file is missing, since the tape recorder was broken at the time for logging. The evaluation of this section was therefore not possible to make from the raw data tapes and in order to use the same method for the whole BIPS-image a correction with Televiewer-image was performed.

The β-angles have been corrected for with 0–8°. The calculated uncertainty value for the β-angles is ± 8.2°.

The total earth magnetic field during logging of the Televiewer-image is shown in Appendix 5.


KFM01A
BetaOffset
General Beta Uncertainty
Beta Offset (degrees)
10
5
0
-5
-10
-15
-20
200
400
600
800
1000
Secup (m)


KFM01B
BetaOffset
General Beta Uncertainty
Beta Offset (degrees)
5
0
-5
-10
0
100
200
300
400
500
Secup (m)


KFM01C
BetaOffset
General Beta Uncertainty
Beta Offset (degrees)
5
0
-5
0
100
200
300
400
Secup (m)

KFM01D

The BIPS-image of KFM01D is merged from three different files, which are logged 2006-03-13 – 2006-03-14. The first file comprises the interval 91.00–455.98 m, the second file 455.98–660.01 m and the third file 660.01–795.99 m. The BIPS-images are oriented with a small bubble and no significant rotation of the probe occurs. The orientation is generally excellent, with exceptions in the interval 135.60–140.80 m where the deviation is up to 50°, the interval 460–480 m with deviations of up to 8º, as well as the interval 690-745 m which has a constant deviation of 5º.

KFM02A

The BIPS-image of KFM02A is logged 2003-04-14 – 2003-04-15 and comprises three BIPS-files which cover the following intervals: 101.00–390.56 m, 390.82–589.00 m and 589.00–998.00 m. Hence, BIPS-image is missing for a shorter interval between 390.56–390.82 m. The BIPS-images are oriented with steel ball clinometer. The correction of the BIPS-file has been performed by comparing the BIPS-image with a Televiewer-image from the same borehole.

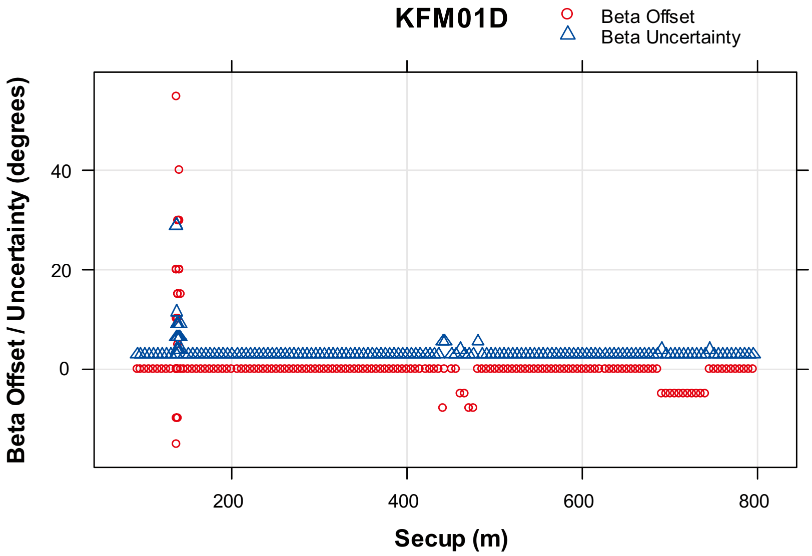
The borehole is almost vertical and rotation of the probe occurs especially in the upper part of the borehole, while the probe has moved more steadily in the other half of the borehole, even if some rotation occurs. The rotation affects the quality of the BIPS-orientation which is visualized in the graph below. The β-corrections of the BIPS-image are large in the upper part of the image and relatively small in lower part of the image. The calculated BIPS Δβ-value is ± 12.4°.

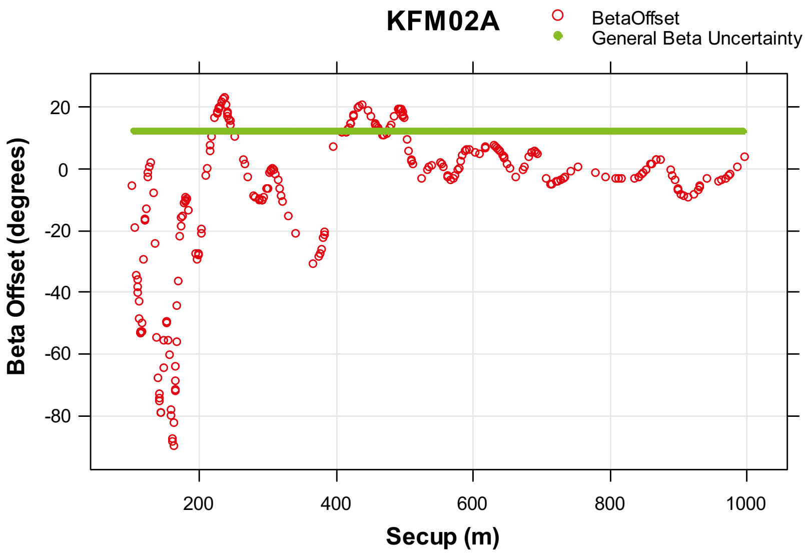
The total earth magnetic field during logging of the Televiewer-image is shown in Appendix 5.

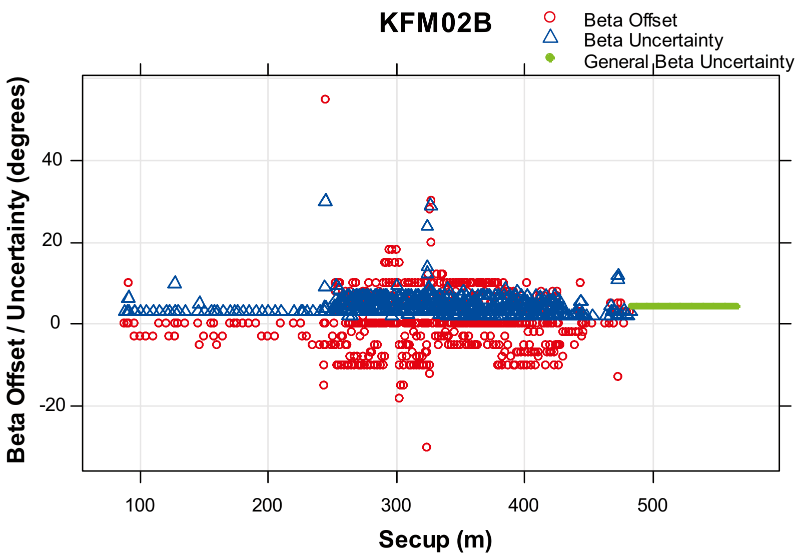
KFM02B

The Used BIPS-file for KFM02B was logged at three different occasions: 2006-11-14, 2007-01-08 and 2007-02-20. They comprise the intervals 88.00–174.67, 174.67–251.52 m, 251.52–449.48 and 449.48–569.16 m. The first two files are logged at the same occasion. The BIPS-file is oriented with a medium size bubble. A discrepancy between the pointer and the bubble occurs throughout the borehole.

In the section 482.42–565.77 m (recorded length), the bubble cannot be seen on the raw data files, and therefore this section has not been corrected for. Only a general uncertainty of ± 4.5° has been set for the interval.


KFM01D
Beta Offset
Beta Uncertainty
Beta Offset / Uncertainty (degrees)
40
20
0
200
400
600
800
Secup (m)


KFM02A
BetaOffset
General Beta Uncertainty
Beta Offset (degrees)
20
0
-20
-40
-60
-80
200
400
600
800
1000
Secup (m)


KFM02B
Beta Offset
Beta Uncertainty
General Beta Uncertainty
Beta Offset / Uncertainty (degrees)
40
20
0
-20
100
200
300
400
500
Secup (m)

KFM03A

The BIPS-image of KFM03A is oriented with steel ball clinometer and is logged 2003-08-31. The Used BIPS-file is merged from two files; the first covers the interval 101.00–450.96 m, while the second covers the interval 450.96–995.00 m. The second file had an original recorded length that differs by 2 m compared to the new length scale in the merged Used BIPS-file (rec. length 453.00–997.04 m).

In the raw data tapes the compass cannot be observed for long sections in the borehole image. The steel ball and the pointer on the other hand generally lie at a constant angle throughout the borehole, accordingly it is easy to assume that the orientation of the BIPS-image is good. This is unfortunately not the case when viewing the graph below presenting the β-corrections for the BIPS-image based on the Televiewer-file. Also, when comparing the end of the first image with the beginning of the second image, it can be stated that there is a huge difference in orientation between the two images. The reason for this is a presumed change of batteries. The β-corrections for KFM03 are great, ranging from 0° to almost 30°. The general uncertainty for the β-angle is ± 10.2°.

The total earth magnetic field during logging of the Televiewer-image is shown in Appendix 5.

KFM03B

The BIPS-image of KFM03B is oriented with steel ball clinometer and it is logged 2003-08-05. The BIPS raw data tapes have been checked, and it was observed that the compass cannot be seen in about half of the raw data file. The steel ball and the pointer lie generally at a constant angle to each other throughout the borehole and the oscillation of the pointer is ca ± 2°.

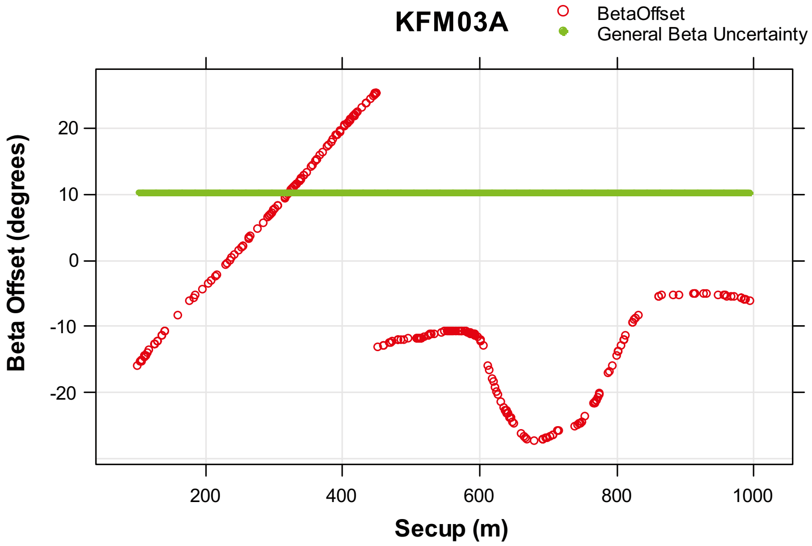
The correction of the BIPS-image has been performed by comparing the BIPS-image with a Televiewer-image from the same borehole. This comparison shows that the BIPS-image is not as well oriented as the raw data image implies. The β-corrections range from 10° to 23° and the uncertainty of the β-values is ± 8.2°.

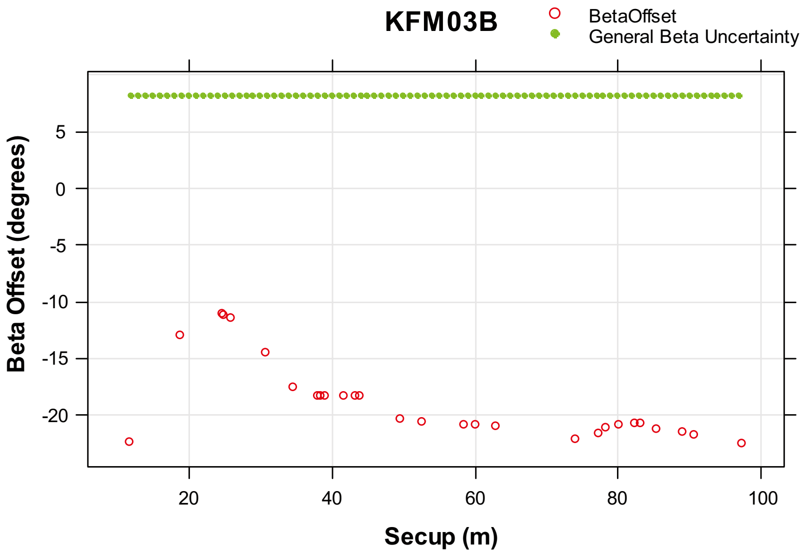
The total earth magnetic field during logging of the Televiewer-image is shown in Appendix 5.

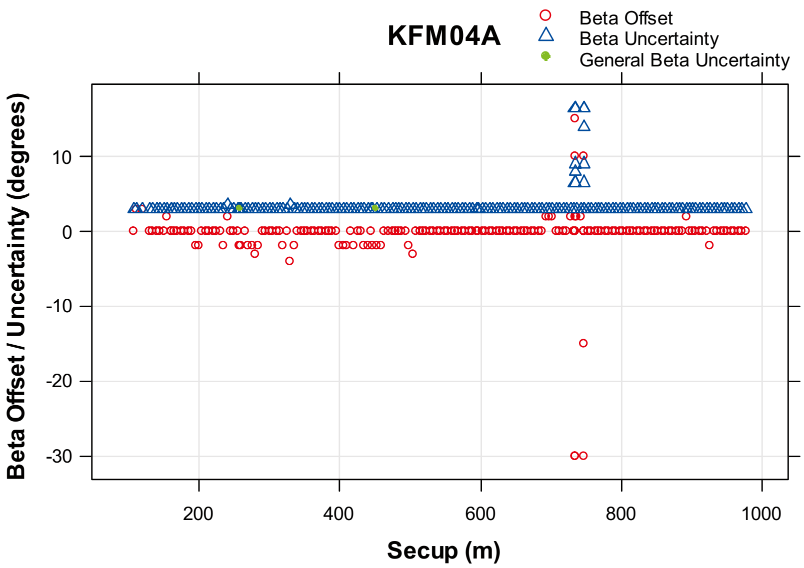
KFM04A

KFM04A is merged from five different files. The first two are logged at the same event on 2003-12-05, while the third is logged 2004-03-08, the fourth 2004-03-09 and the fifth 2004-05-12. The files cover the intervals 108.00–187.54 m, 187.54–448.09 m, 448.09–597.56 m, 597.56–895.82 m and 895.82–981.30 m.

The BIPS-files are oriented with a big bubble. The probe rotates < 30º in two short (< 3 m) sections. The orientation is good except for the interval 736.30–749.60 m, where the pointer diverges from the bubble by < 30º. For the remaining part only small deviations occur (< 4º).


KFM03A
BetaOffset
General Beta Uncertainty
Beta Offset (degrees)
20
10
0
-10
-20
200
400
600
800
1000
Secup (m)


KFM03B
BetaOffset
General Beta Uncertainty
Beta Offset (degrees)
5
0
-5
-10
-15
-20
20
40
60
80
100
Secup (m)


KFM04A
Beta Offset
Beta Uncertainty
General Beta Uncertainty
Beta Offset / Uncertainty (degrees)
10
0
-10
-20
-30
200
400
600
800
1000
Secup (m)

KFM05A

The BIPS-image from KFM05A is merged from four different BIPS-files. The first is logged 2004-05-10, while the others are logged at the same occasion on 2004-06.04. The different files comprise the intervals 109.00–270.48 m, 270.48–530.00 m, 531.00–819.12 m and 819.12–995.00 m.

The BIPS-images are oriented with bubble level. The logging from 2004-05-10 is oriented with a big bubble, while the logging from 2005-06-04 is logged with a smaller bubble. The pointer is under the conditions stable throughout the whole logging, but the contrast is sometimes poor, resulting in an unclear pointer. The logging from the interval 531.25–592.91 m (recorded length) is missing on the raw data tapes for some reason, and therefore this section could not be revised. The general uncertainty for this interval is ± 3.0°.

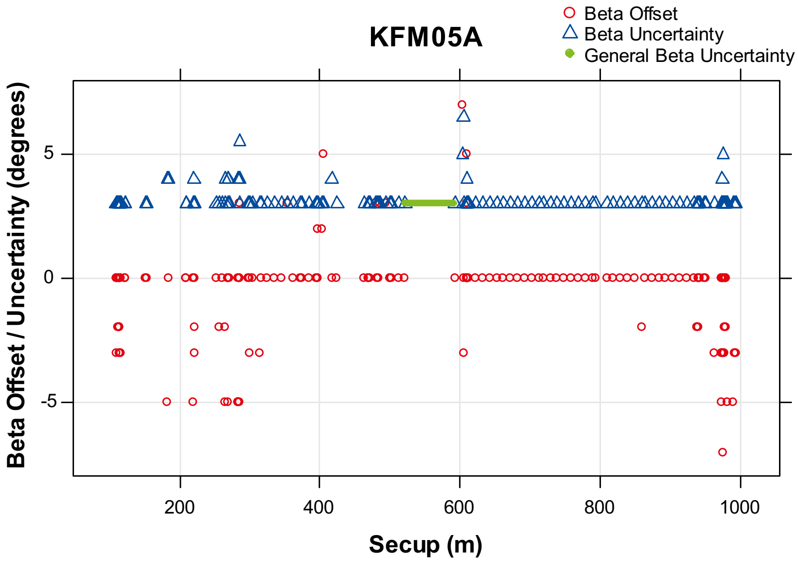
KFM06A

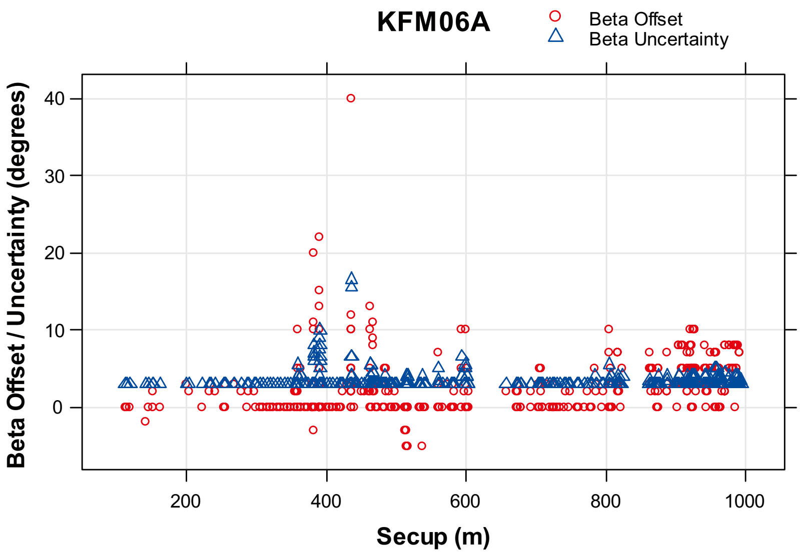
KFM06A is logged 2004-11-01 – 2004-11-02 and the BIPS-image is merged from two files that cover the interval 102.00–500.08 m and 500.08–994.26 m. The BIPS-image is oriented by a rather small bubble and the probe has moved relatively steadily down the borehole.

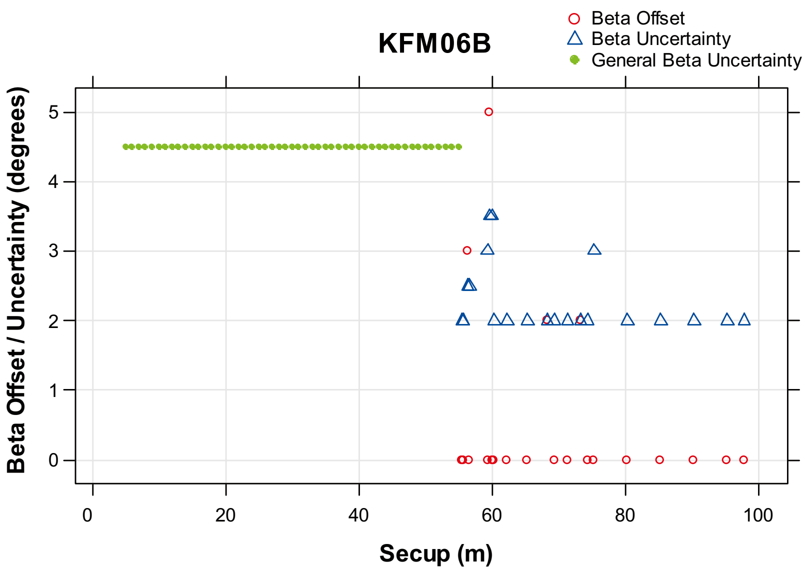
The quality of the orientation in the BIPS-image varies. Usually a difference in orientation of 5° occurs between the logging and the evaluation. Also occasional differences of 10–40° occur, where the pointer has been rotating while the bubble has been still.

KFM06B

The BIPS-image for KFM06B is merged from two different loggings. The raw data tape is missing for the first, and hence this section could not be evaluated (4.00–55.52 m, or 55.7% of the BIPS-image). Instead a general BIPS Δβ-value of ± 4.5° has been set for the interval. The second part (55.52–97.98 m measured in new recorded length) is oriented with a small to medium size bubble, which covers a c 100° segment. This part is generally well oriented and the probe has moved steadily down the borehole.


KFM05A
Beta Offset
Beta Uncertainty
General Beta Uncertainty
Beta Offset / Uncertainty (degrees)
5
0
-5
200
400
600
800
1000
Secup (m)


KFM06A
Beta Offset
Beta Uncertainty
Beta Offset / Uncertainty (degrees)
40
30
20
10
0
200
400
600
800
1000
Secup (m)


KFM06B
Beta Offset
Beta Uncertainty
General Beta Uncertainty
Beta Offset / Uncertainty (degrees)
5
4
3
2
1
0
0
20
40
60
80
100
Secup (m)

KFM06C

The BIPS-image of KFM06C is merged from three different files. The first is logged 2005-08-23 and the other two are logged 2005-08-29. The files comprise the intervals 101.00–398.70 m, 398.70–798.27 m and 798.27–992.20 m. The BIPS-images are oriented with bubble level. The quality of the orientation is generally good and in the evaluation only shorter sections have been noted with diverging orientation.

KFM07A

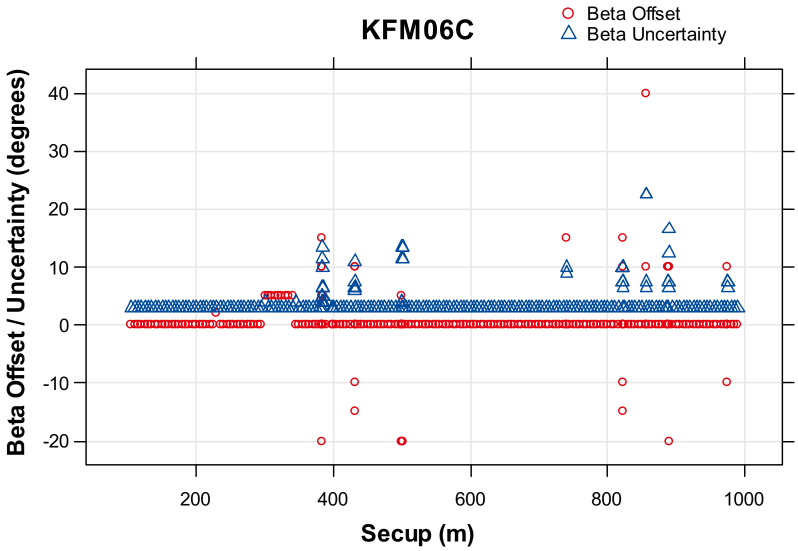
The BIPS-image of KFM07A is merged from two files from two different logging occasions. The first was logged 2005-01-10 and covers the interval 101.00–548.40 m, while the other was logged 2005-02-10 and covers the interval 548.40–990.26 m.

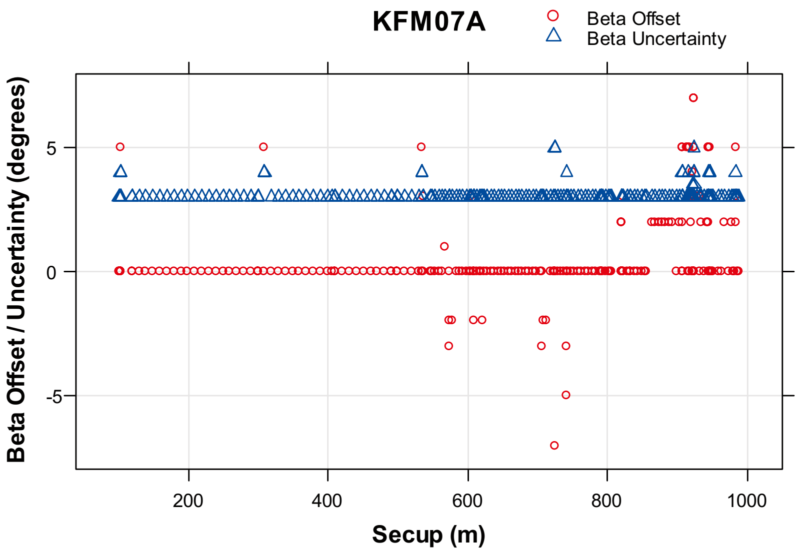
The logging is stable with a medium-size bubble. The original logging generally shows a good quality in orientation.

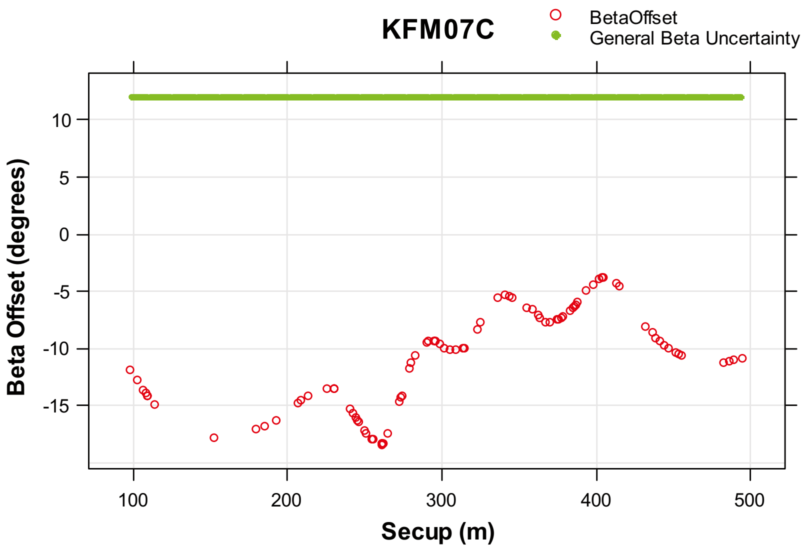
KFM07C

The interval 98.00–420.10 m of the BIPS-image of KFM07C is logged on 2006-07-21 and the interval 420.10–497.57 m on 2006-09-22. The BIPS-probe has rotated in the borehole during logging with approximately one turn for each logged 2 m. Since the orientation of the pointer in relation to the bubble has varied a lot during logging, the BIPS-image was corrected with a Televiewer-image instead. The β-corrections are in the order of 5° to 20°. The calculated BIPS Δβ-value is ± 12.0°.

The total earth magnetic field during logging of the Televiewer-image is shown in Appendix 5.


KFM06C
Beta Offset
Beta Uncertainty
Beta Offset / Uncertainty (degrees)
Secup (m)


KFM07A
Beta Offset
Beta Uncertainty
Beta Offset / Uncertainty (degrees)
Secup (m)


KFM07C
BetaOffset
General Beta Uncertainty
Beta Offset (degrees)
Secup (m)

KFM08A

The BIPS-image of KFM08A is logged 2005-05-09 – 2005-05-10. File one comprises the interval 102.00–500.00 m, file two 500.00–701.00 m and file three 701.00–979.83 m. The BIPS-image is oriented with bubble level. The measured orientation during the evaluation deviates usually by 3–5° from the orientation of the logging event. The BIPS-file is thus relatively well oriented from the beginning. In the internal quality control a difference in the measurements of the β-angles of up to 6° has been registered between the values from the evaluation and the quality control.

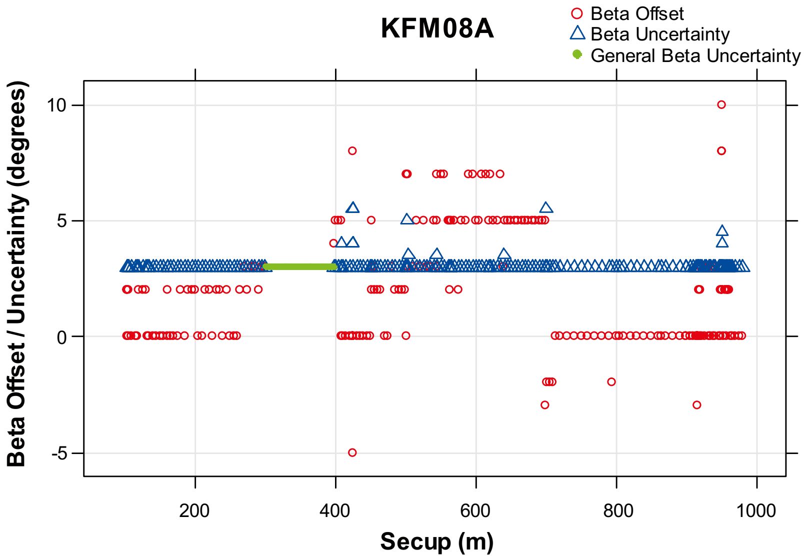
Section 300.00–397.00 m of the BIPS raw data tapes is missing, and hence the orientations have not been evaluated in this section. This section has instead received a general BIPS Δβ-value of ± 3°.

KFM08B

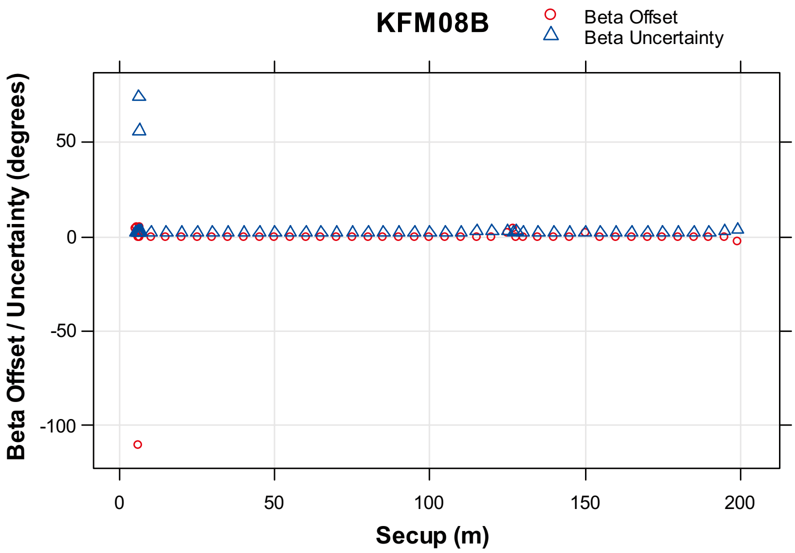
The BIPS-image of KFM08B is oriented with bubble level. The borehole was logged 2005-02-10 and covers the interval 5.00–199.15 m. The pointer has been lying steadily through the borehole and oscillates only ± 2°, with an exception of a discrepancy of 110° in a short interval.

KFM08C

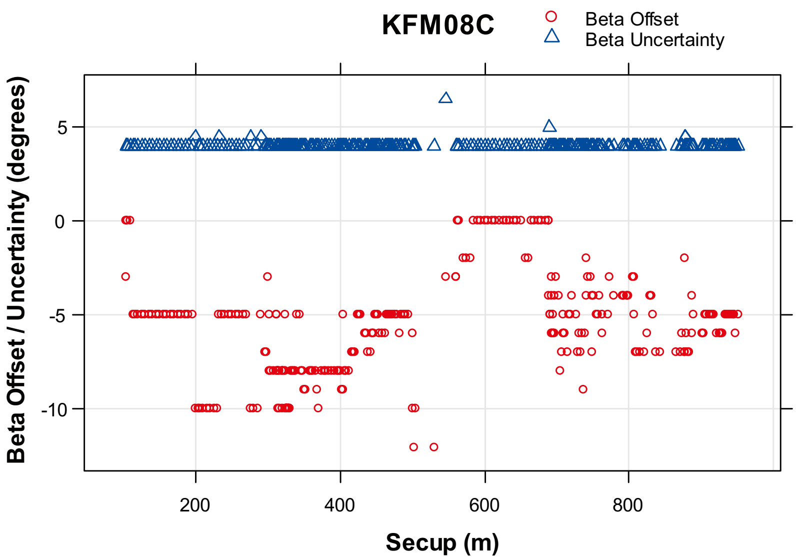
The BIPS-image of KFM08C is logged 2006-06-19 – 2006-06-20 and is merged from two images that comprise the intervals 102.00–643.01 m and 643.01–948.21 m. The BIPS-files are oriented with bubble level. The orientation of the original BIPS-logging differs generally by 5 to 10° compared to the measured orientation in the evaluation. On the other hand, the original orientation does not differ remarkably from the measurements in the internal quality control (described in chapter 4.3.2). Thus, in this borehole the estimations of the orientations are more dependent on the person making them, probably influenced by the fact that the pointer is poorly visible in the image. In addition, measuring from the white part of the pointer or from the green part of the pointer is of significance, since the pointer in the image is rarely a straight line. The probe has been moving steadily down the borehole and rotation can rarely be found.



KFM08A
Beta Offset
Beta Uncertainty
General Beta Uncertainty
Beta Offset / Uncertainty (degrees)
10
5
0
-5
200
400
600
800
1000
Secup (m)



KFM08B
Beta Offset
Beta Uncertainty
Beta Offset / Uncertainty (degrees)
50
0
-50
-100
0
50
100
150
200
Secup (m)



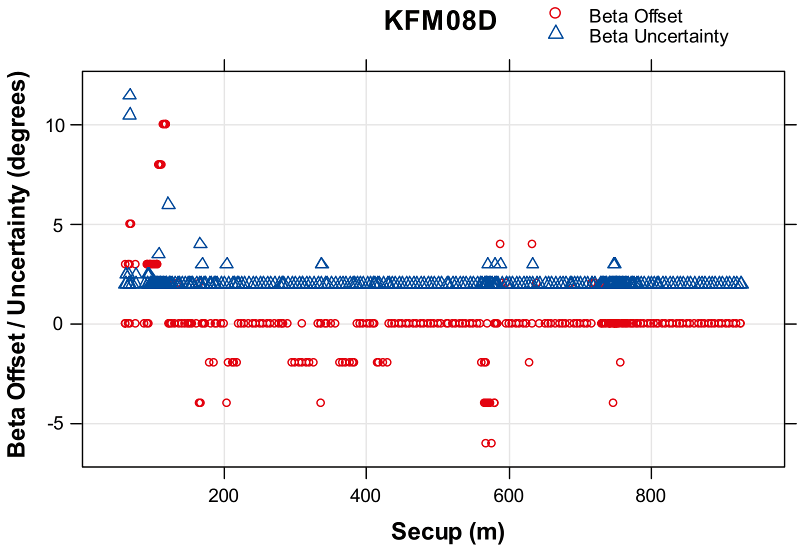
KFM08C
Beta Offset
Beta Uncertainty
Beta Offset / Uncertainty (degrees)
5
0
-5
-10
200
400
600
800
Secup (m)

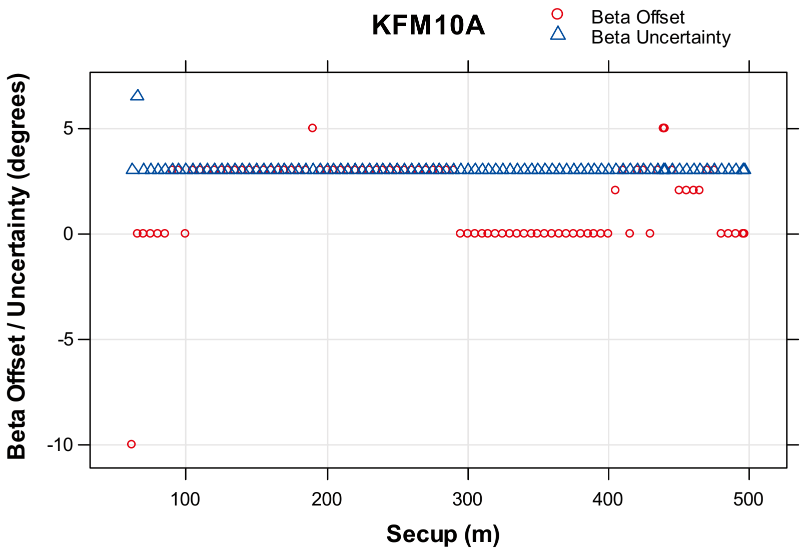
KFM08D

Section 59.00–166.34 m in KFM08D was logged with a small bubble 2007-01-08. The remaining section, 166.34–926.49 m was logged 2007-02-23. The pointer has been lying steadily throughout the borehole and oscillates ± 2°, except the interval 66.57–66.62 m where the variation is ± 20°. The bubble oscillates in a 15° segment from 730 m to 926 m.

KFM10A

The BIPS-image is oriented with bubble level and logged 2006-06-13. The BIPS-image comprises only one file that covers the interval 62.00–496.02 m. The difference between measured orientation during the evaluation and the logging is about 3°. The orientation of the image is hence mostly good. The pointer is not clearly visible in the raw data tapes, which has somewhat obstructed the evaluation.



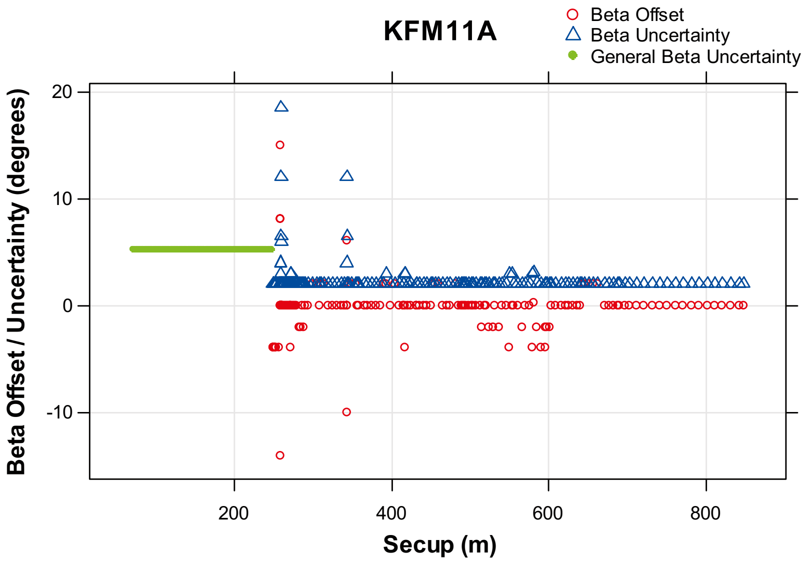


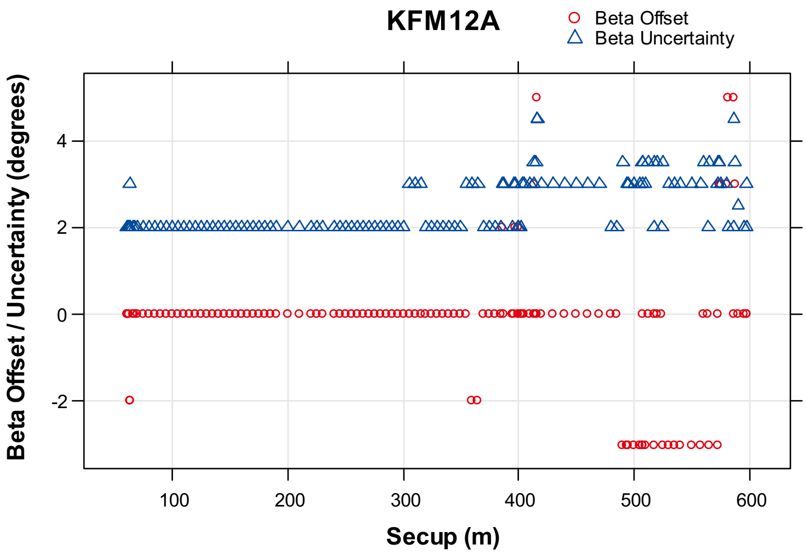
KFM11A

The Used BIPS-file of KFM11A is merged from two different logging events, where bubble level is used for the orientation. The section 71.00–249.98 m was logged 2006-10-01 and the sections 249.98–560.06 m and 560.06–848.12 m were logged 2006-11-24. In the first section, the bubble is not visible in the raw data tapes and therefore an evaluation could not be performed. The section has only received a general BIPS Δβ-value of ± 5.2°. The logging from 2006-11-24 is very well oriented with a few exceptions.

KFM12A

The BIPS-image of KFM12A comprises 61.00–597.63 m and was oriented with bubble level. The logging was performed 2007-03-21. The BIPS-image is generally well oriented, but the uncertainty in the measurements increases in the second half of the borehole due to oscillating BIPS-probe.





5.2 Brief presentation of BIPS-images from Laxemar

KLX03

KLX03 is logged 2004-09-26 and is oriented with bubble level with a small bubble. The BIPS-image is merged from three different files that comprise the intervals 100.00–600.00 m, 600.00–961.14 m and 961.14–994.23 m. The BIPS-images are generally well oriented and only shorter sections can be found where the angle measurements from the evaluation diverge from the logging with as much as 10°. In some sections the probe rotates during logging.

BIPS-raw data tapes are missing for the section 961.17–994.23 m, and therefore the orientation in this interval has not been evaluated. The general BIPS $\Delta\beta$ for the interval is ± 5°.

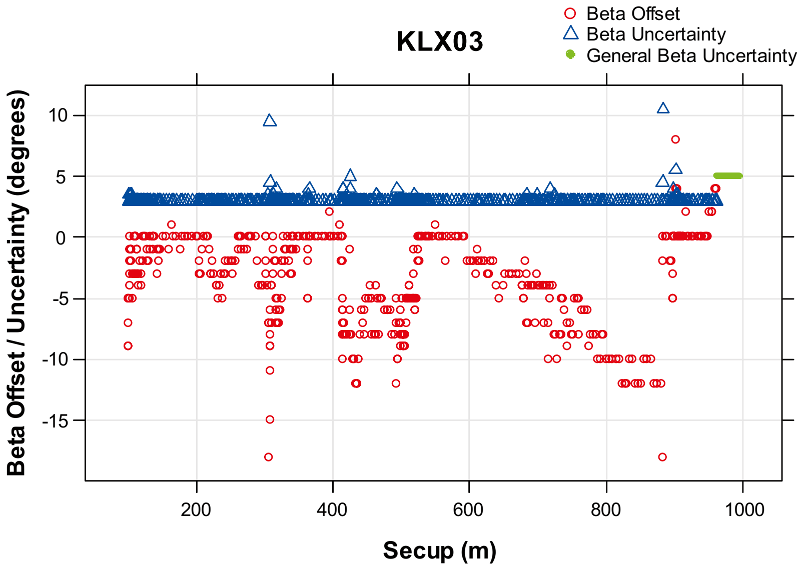
KLX04

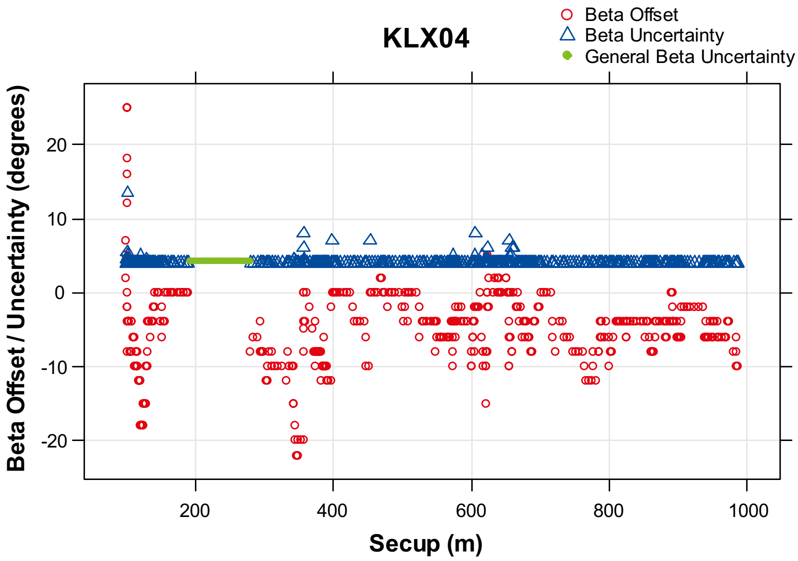
The BIPS-image of KLX04 is logged 2004-07-12 – 2004-07-13 and is merged from two files that cover the intervals 100.00–573.02 m and 573.02–985.75 m. The BIPS-image is oriented with bubble level with a medium size bubble and the orientation in the evaluation is diverging from the original logging all through the BIPS-image with –2 to –10°. In two sections the orientation diverges with about 20°. The results in the measurements in the internal quality control differs relatively much from the measurements in the evaluation. Two degrees can be explained by a systematic error in the internal quality control (the bubble level mould was not correctly drawn). The rest is probably caused by the oscillating pointer. Due to this, the BIPS-image has received a relatively high uncertainty value (IC).

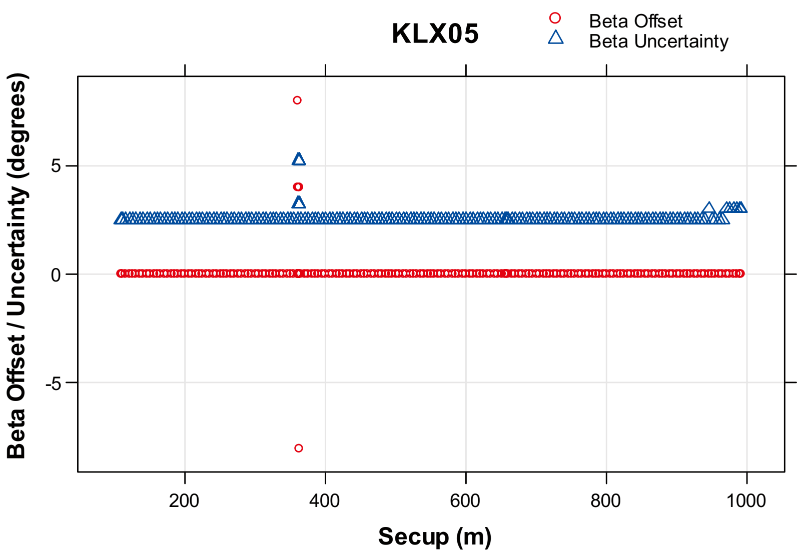
BIPS-raw data tapes are missing in the interval 190.00–280.00 m and therefore this section has only received a general BIPS $\Delta\beta$-value which has been set to ± 4.2°.

KLX05

KLX05 is logged 2005-03-23 and consists of two merged files that cover the intervals 108.00–500.02 m and 500.02–991.32 m. The BIPS-image is oriented with a small bubble and is very well oriented.


KLX03
Beta Offset
Beta Uncertainty
General Beta Uncertainty
Beta Offset / Uncertainty (degrees)
10
5
0
-5
-10
-15
200
400
600
800
1000
Secup (m)


KLX04
Beta Offset
Beta Uncertainty
General Beta Uncertainty
Beta Offset / Uncertainty (degrees)
20
10
0
-10
-20
200
400
600
800
1000
Secup (m)


KLX05
Beta Offset
Beta Uncertainty
Beta Offset / Uncertainty (degrees)
5
0
-5
200
400
600
800
1000
Secup (m)

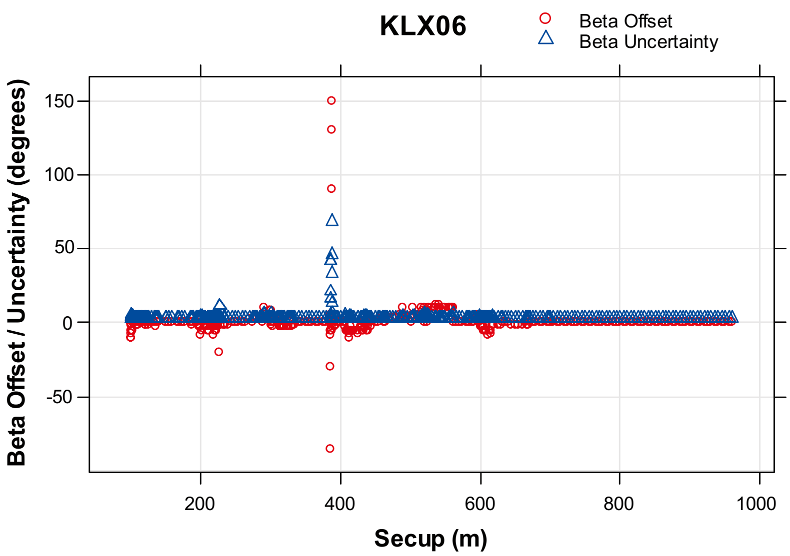
KLX06

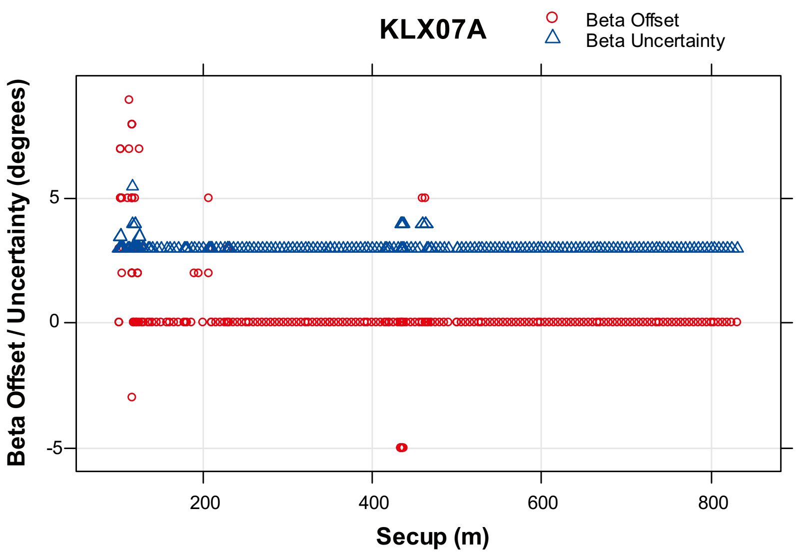
KLX06 is logged 2004-12-28 and consists of three original files that are merged. The files comprise the intervals 101.00–407.48 m, 407.48–599.95 m and 599.95–960.77 m. The BIPS-files are oriented with a small bubble. Generally the orientation has been good and stable all through the borehole, but a few greater discrepancies occur where differences of up to 90° between pointer and bubble have been observed. Smaller oscillation of the BIPS-probe occurs in the last 300 m of the borehole, but the pointer follows the oscillation well.

KLX06 is not a prioritized borehole.

KLX07A

KLX07A consists of two BIPS-files which both are logged 2005-07-06 and cover the intervals 100.02–500.02 m and 500.02–831.72 m. The BIPS-files are oriented with a bubble of medium size. The orientation of the BIPS-image is mostly good and the probe has been moving steadily down the borehole. Some discrepancies in the orientation of the original logging and the evaluation occur in the interval 100–130 m. After that the borehole is very well oriented and there is almost no measurable discrepancy.





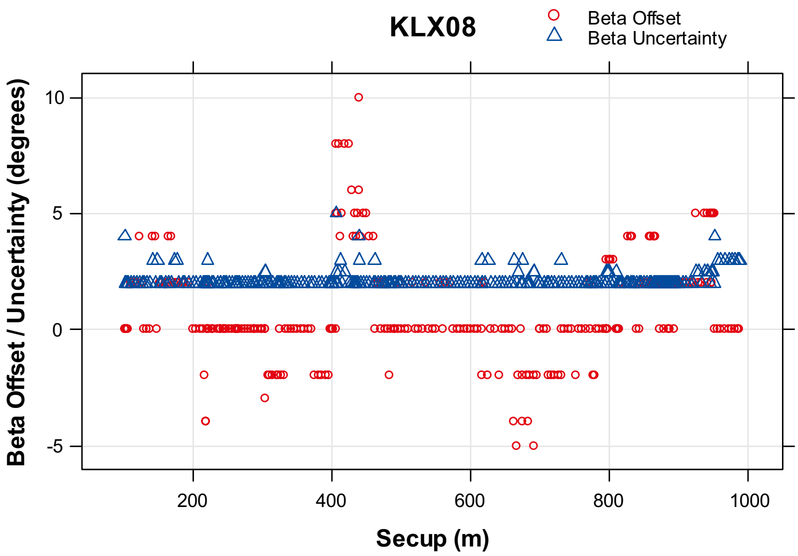
KLX08

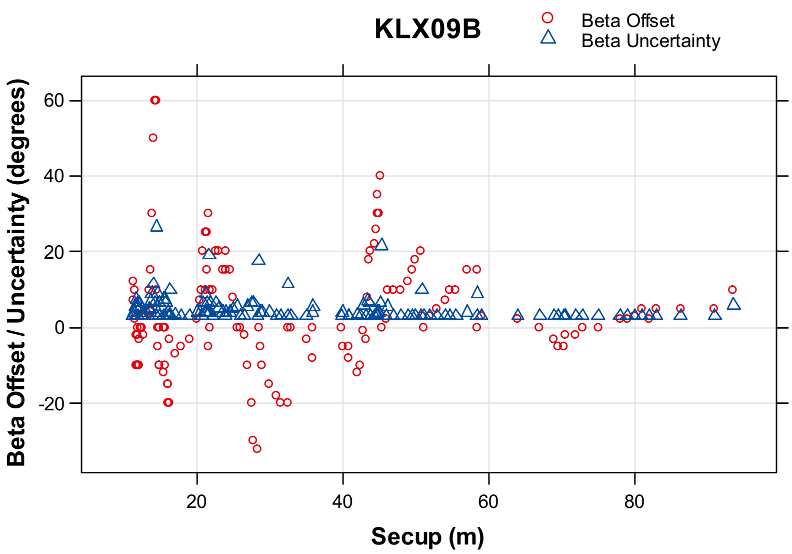
KLX08 is logged 2005-09-26 – 2005-09-27 and consists of two files that cover the intervals 100.13–460.23 m and 460.23–620.02 m. The BIPS-image is oriented with a swelling bubble, which is of medium size in the beginning of the logging and big in the end of the logging. On the other hand, orientation is generally good, with the exception of 950 m and further down, where the bubble is so big that the centre is difficult to measure.

KLX09B

The BIPS-image of KLX09B covers the interval 10.00–99.84 m and is logged 2006-02-06. The BIPS-image is oriented with compass since the borehole is vertical. The probe rotates throughout the borehole and in the beginning of the borehole considerable deviations occur between compass and pointer.

The total earth magnetic field during logging of the BIPS-image is shown in Appendix 6.



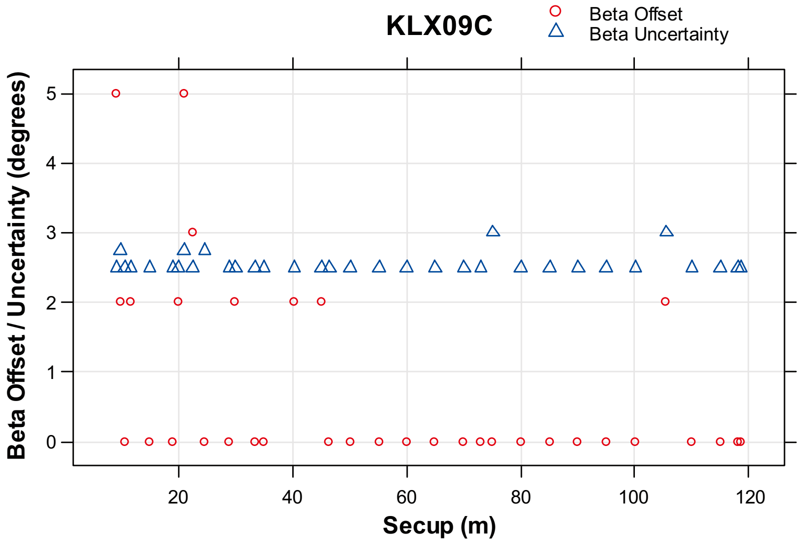


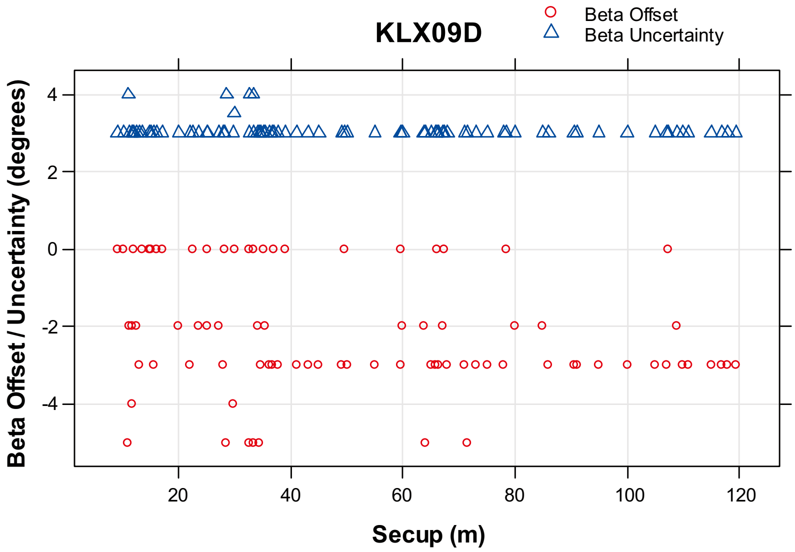
KLX09C

The BIPS-image of KLX09C (9.00–118.62 m) is logged 2006-02-09 with bubble level with a small bubble which covers a segment of about 45°. The probe has not rotated in the borehole; but the pointer has oscillated somewhat. The BIPS-image is well oriented and the evaluated deviation is generally 0–2°.

KLX09D

KLX09D was logged 2006-02-07 and comprises 9.00–119.50 m. The BIPS-image is well oriented with a small bubble. The observed deviation between the angle measurements in the evaluation and the original logging is 0–5°.



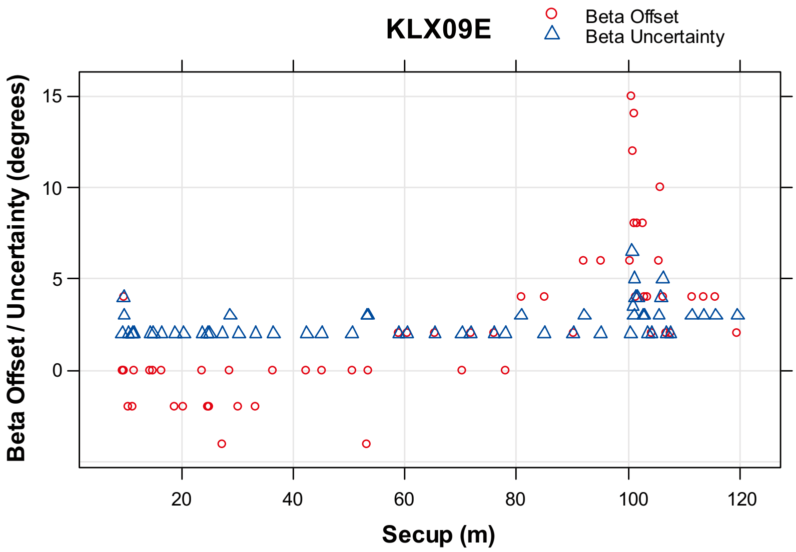


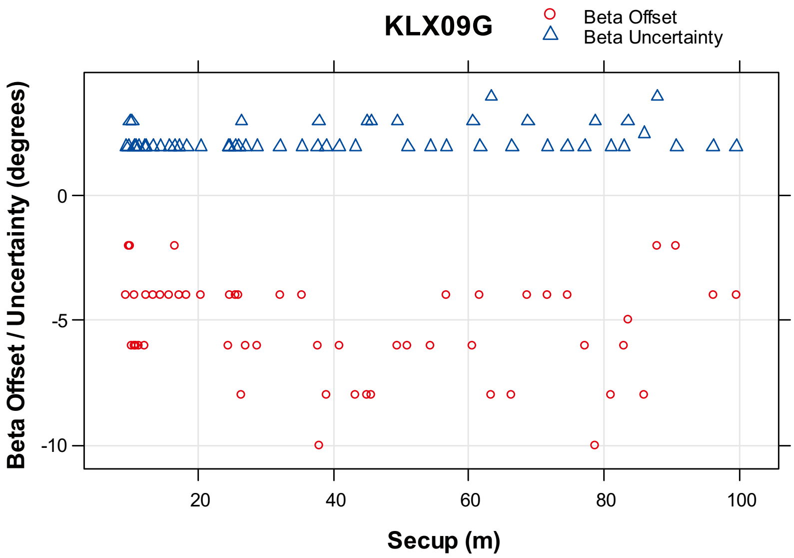
KLX09E

KLX09E was logged 2006-02-08 and covers the interval 8.00–119.72 m. The BIPS-image is oriented with a small bubble. It is well oriented down to 100 m after which the probe was rotating and the deviation became greater (up to 15°).

KLX09G

The BIPS-image of KLX09G comprises 9.00–99.54 m and was logged 2006-02-07. It is oriented with a small bubble. The probe has been moving steadily down the borehole and the bubble oscillates only a little. Observed deviation from the original logging is generally small (–4° to –8°).



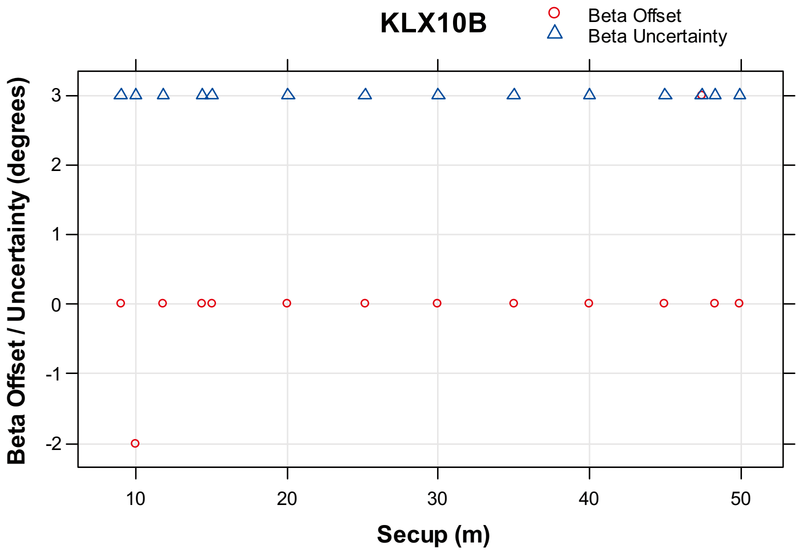


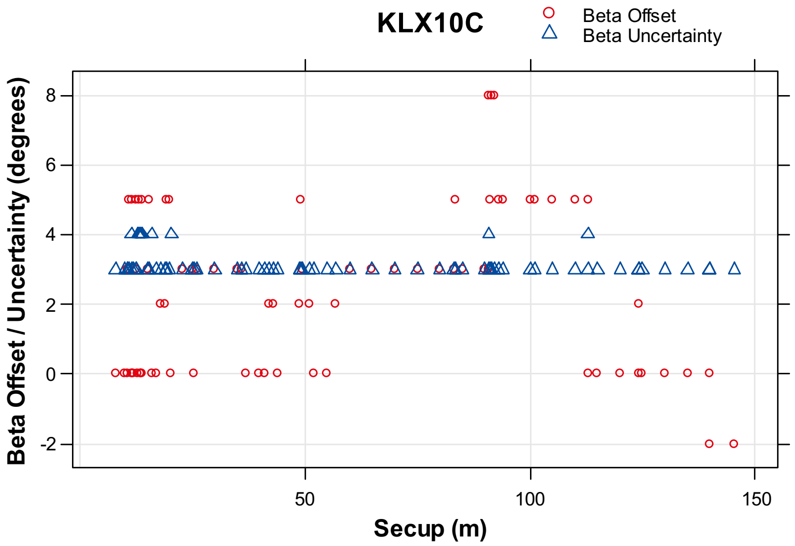
KLX10B

The BIPS-image of KLX10B covers 8.00–49.99 m and was logged 2006-03-22 with a small bubble. The probe has been moving quite steadily down the borehole, but the pointer has oscillated. The BIPS-image is very well oriented.

KLX10C

The BIPS-image of KLX10C is oriented with a small bubble and covers 8.00–145.43 m. The logging was carried out 2006-03-23. The pointer has been stable during logging and it is clearly visible. Only minor deviations in orientation of the original logging have been observed.





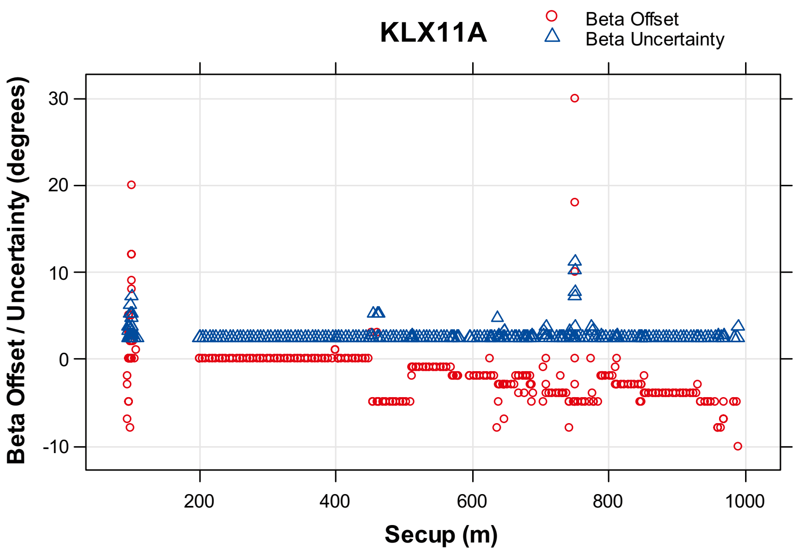
KLX11A

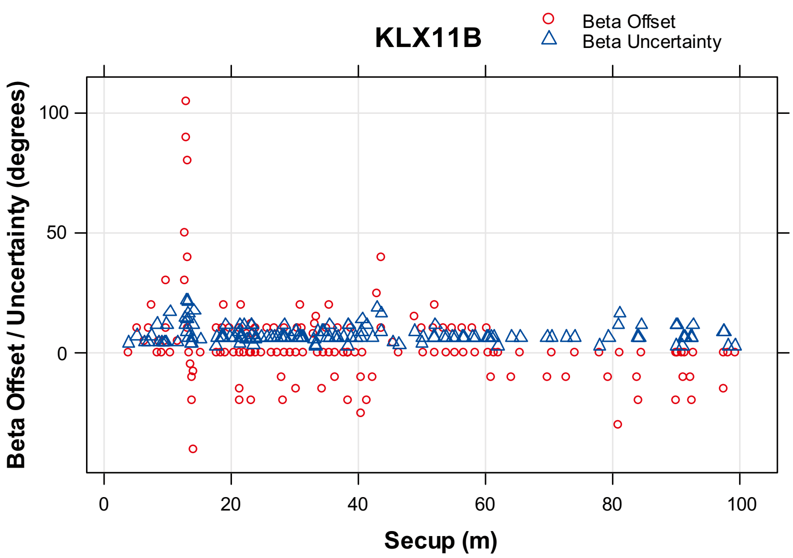
The Used BIPS-file of KLX11A was logged 2006-04-05 and is merged from two files that comprise the intervals 96.00–579.76 m and 579.76–988.41 m. BIPS-image is missing in the interval 579.76–580.01 m. The BIPS-image is oriented with a small bubble, which is visible in 60% of the raw data tapes. The deviation of measured orientation in the evaluation and the original logging varies between 0° and 30° but is generally 5°. The green part of the pointer is indistinct, and therefore only the white part has been used during evaluation.

KLX11B

KLX11B is a vertical borehole and therefore the BIPS-image is oriented with compass. The BIPS-image is merged from two files from two different loggings (2006-05-10 and 2006-08-15) which cover the intervals 4.00–17.74 m and 17.74–99.30 m. The probe is generally rotating in the borehole. The compass is vague in the first file because of the very dark raw data image. For the rest of the borehole, the angle between green pointer and compass can be measured with greater accuracy.

The total earth magnetic field during logging of the BIPS-image is shown in Appendix 6.



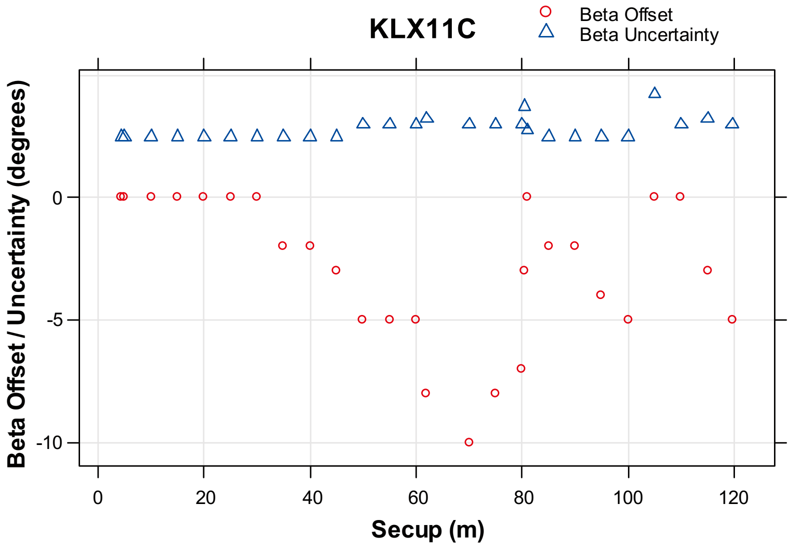


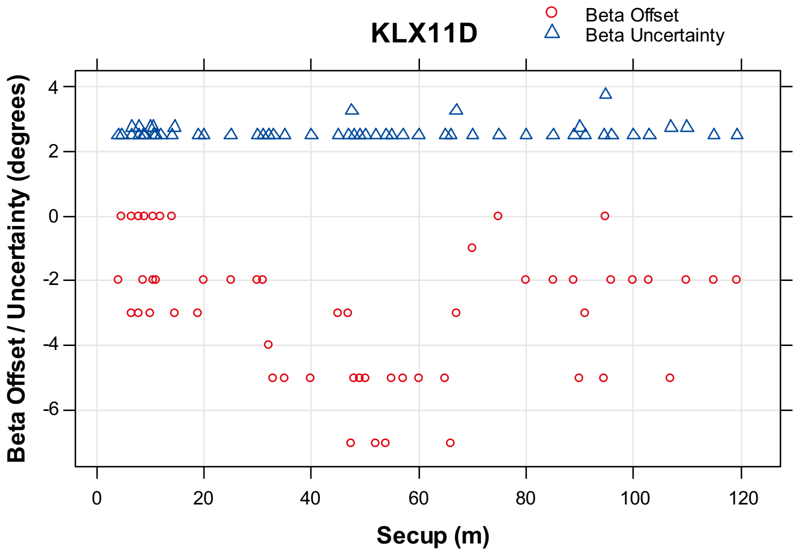
KLX11C

The BIPS-image of KLX11C comprises 4.00–119.62 m and is logged 2006-07-04. It is oriented with a rather small bubble and the pointer is mostly indistinct in the raw data image. Some deviation in orientation of the original logging has been observed.

KLX11D

KLX11D was logged 2006-07-04. The BIPS-image covers 4.00–119.32 m and is oriented with a rather small bubble. The pointer is quite indistinct in the beginning of the raw data image. The observed deviation in orientation of the original logging is quite small.



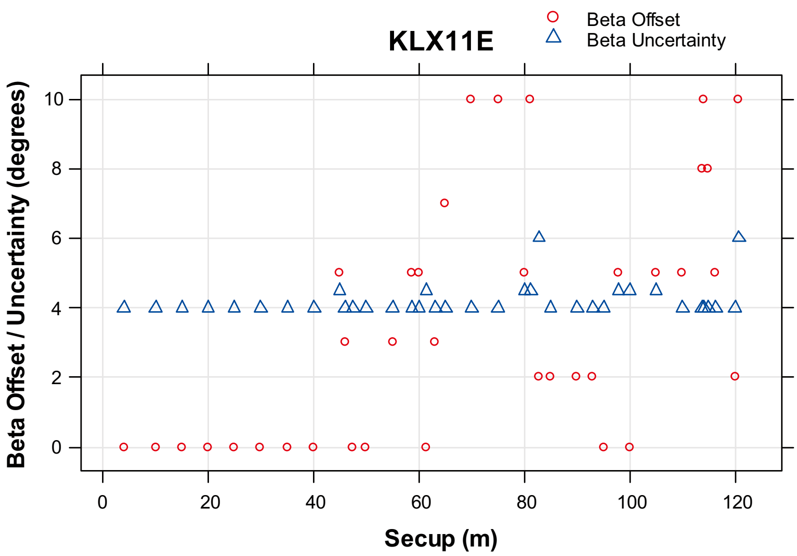


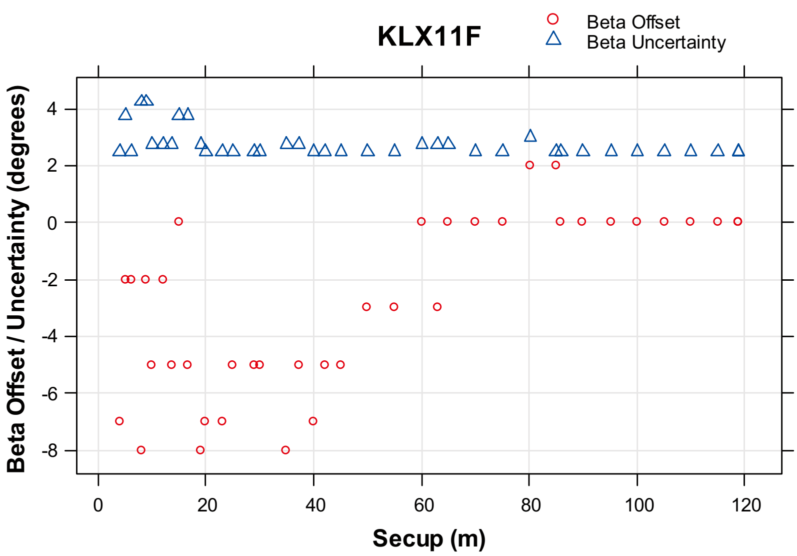
KLX11E

KLX11E was logged with BIPS 2006-05-10 and the BIPS-image covers 4.00–120.72 m. The BIPS-image is oriented with a bubble of small/medium size. The probe has not been rotating during logging, but the pointer oscillates somewhat, which aggravates the evaluation of the orientation.

KLX11F

The BIPS-image of KLX11F covers 4.00–118.9 m and was logged 2006-07-04. It is oriented with bubble level and the probe has only rotated in short intervals. Despite the fact that the probe has mostly moved steadily down the borehole, a discrepancy of 2–8° in the orientation of the original logging has been observed in the interval 12–85 m. After that no discrepancy in orientation is observed.





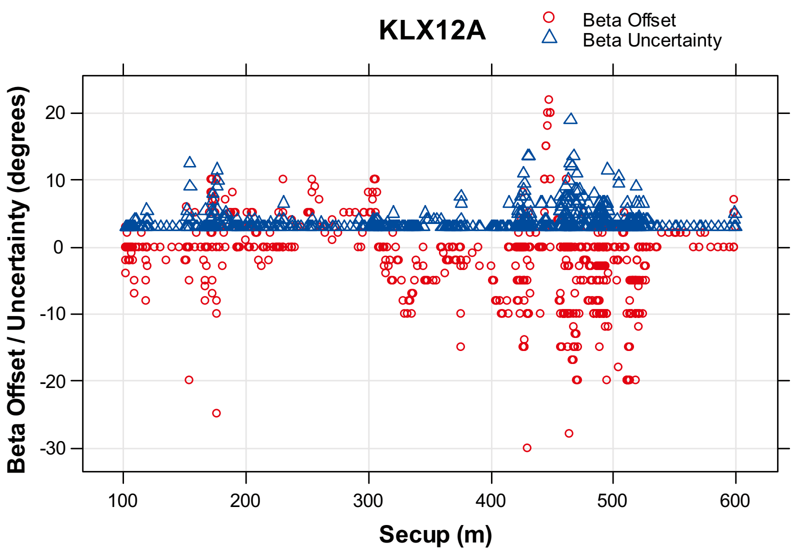
KLX12A

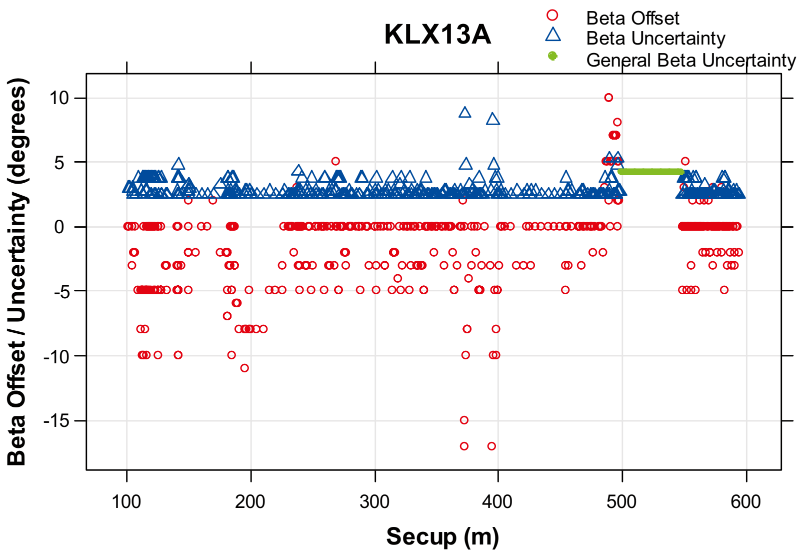
The BIPS-image of KLX12A is merged from three different files. The first covers the interval 101.41–320.52 m, the second 320.52–420.88 m and the third 420.88–599.21 m. The first two are logged 2006-03-24, while the third is logged 2006-03-26. The BIPS-images are oriented with a relatively small bubble. Some rotation of the probe occurs in the beginning of the borehole, otherwise the probe has moved steadily down the borehole, but the pointer has oscillated appreciably. Sections with great discrepancy in orientations between original logging and the evaluation occur throughout the borehole.

KLX13A

KLX13A was logged with BIPS-camera 2006-09-12. The Used BIPS-file is merged from two files comprising 101.00–360.00 m and 360.00–593.92 m. The BIPS-image is oriented with a small bubble. On the raw data tapes the pointer is indistinct throughout the borehole due to poor contrast. The BIPS-probe has rotated during logging from 225 m and down to the end of the borehole.

BIPS raw data tapes are missing for the section 498.00–548.68 m (recorded length). The calculated general uncertainty is ± 4.2°.



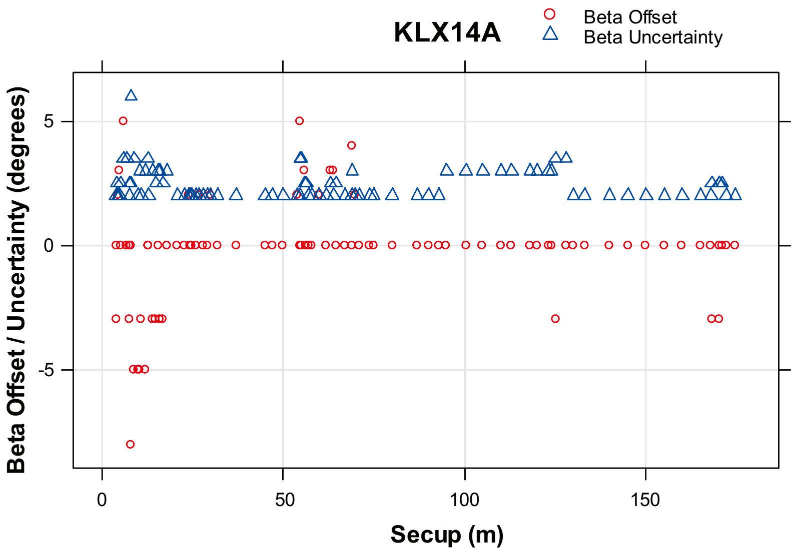


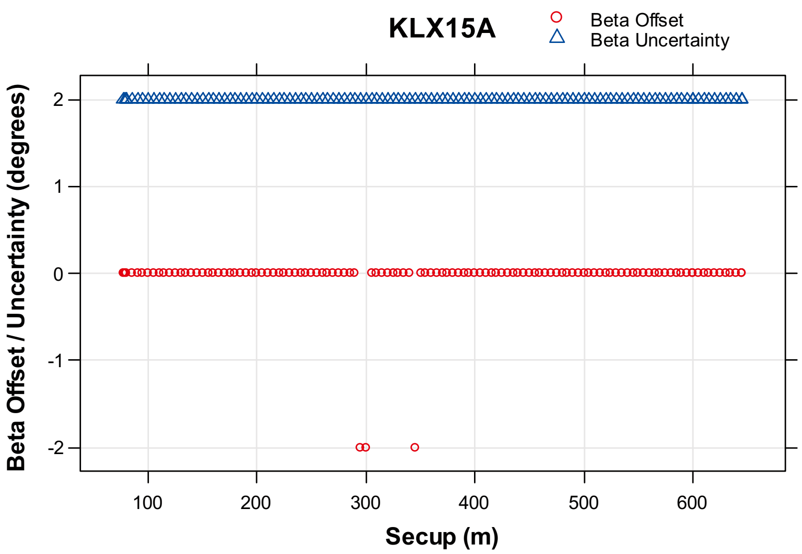
KLX14A

The BIPS-image of KLX14A covers the interval 4.00–174.63 m and is logged 2006-11-08. It is oriented with a bubble of medium size. The probe has been moving steadily down the borehole and generally only small discrepancies in orientation have been observed. In the interval 100–128 m the raw data image is extremely poor and the angle measurements could only be performed in gaps where the image is good. The pointer, on the other hand, is steady throughout the section, and therefore the image is interpreted as being well oriented.

KLX15A

KLX15A was logged with BIPS-camera 2007-03-28 and comprises 77.00–645.22 m. The BIPS-image is very well oriented with bubble level.





KLX16A

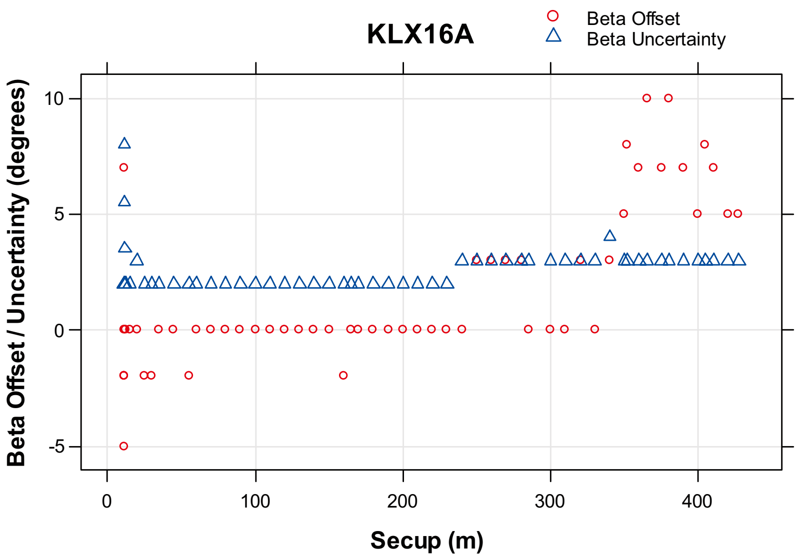
KLX16A was logged with BIPS-camera during one logging in 2007-01-30 and the image covers the recorded length 11.00–427.38 m. The image is oriented with a small bubble. The interval between the readings has been sparser than usual (each 5 or 10 m).

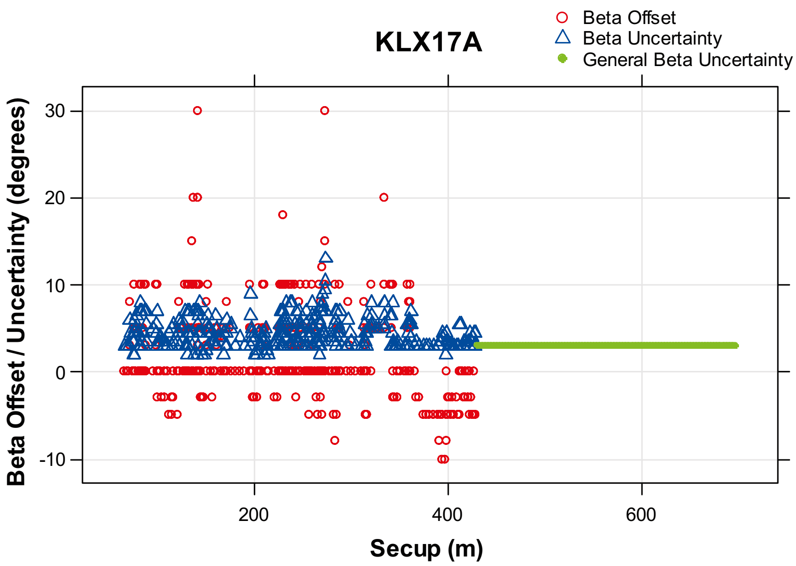
KLX17A

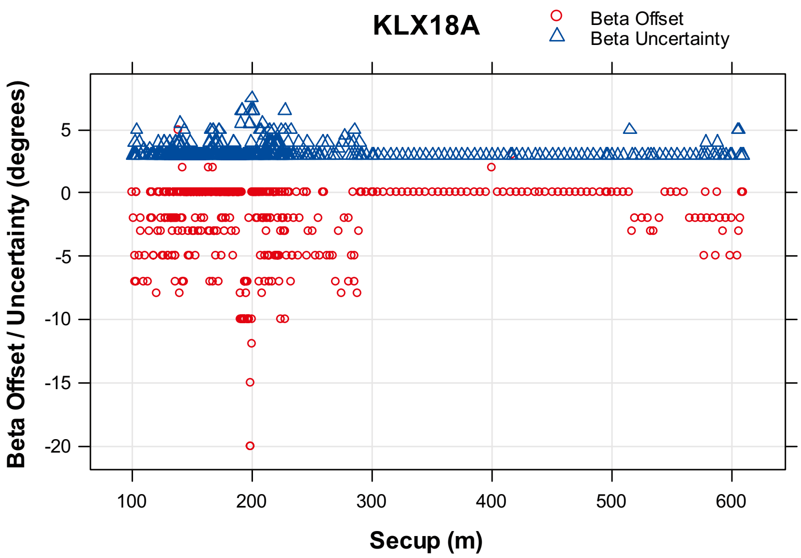
KLX17A was logged with BIPS-camera 2006-11-28. The BIPS-image was oriented with a bubble of medium size and covers the interval 66.00–696.78 m (recorded length). The BIPS-image is quite well oriented, but has a relatively higher uncertainty in intervals where the pointer or probe has oscillated. From 428.60 m (recorded length) to the end of the BIPS-image the bubble cannot be observed in the raw data tapes. Only a stripe of settled drill cuttings on the lower side of the borehole can be observed. On the basis of this stripe, it can be established that the BIPS-image is well oriented all the way to the end of the borehole. It was decided though to classify the interval as category B, and to give it a general uncertainty value instead of reorienting the image on the basis of the sedimentary stripe. The calculated general uncertainty is ± 3.0°.

KLX18A

KLX18A was logged with BIPS 2006-05-15 and this resulted in two BIPS-files, which cover the intervals 100.00–500.01 m and 500.01–609.40 m. Both files have been merged afterwards to one single file. The BIPS-images are oriented after a rather small bubble, which has been favourable in the evaluation. Despite that the borehole is not vertical (inclination ~ –82°) the probe has rotated down to 228 m borehole length. After that the probe has moved more steadily down the borehole, but the pointer has oscillated somewhat. The BIPS-image is relatively well oriented in the interval where the probe has been rotating and well oriented where the logging conditions have been more stable.


KLX16A
Beta Offset
Beta Uncertainty
Beta Offset / Uncertainty (degrees)
10
5
0
-5
0
100
200
300
400
Secup (m)


KLX17A
Beta Offset
Beta Uncertainty
General Beta Uncertainty
Beta Offset / Uncertainty (degrees)
30
20
10
0
-10
200
400
600
Secup (m)


KLX18A
Beta Offset
Beta Uncertainty
Beta Offset / Uncertainty (degrees)
5
0
-5
-10
-15
-20
100
200
300
400
500
600
Secup (m)

KLX19A

KLX19A was logged with BIPS 2006-10-09 and this resulted in two BIPS-files which cover the intervals 100.00–660.01 m and 660.01–794.99 m. The BIPS-image is oriented with a relatively small bubble.

From 263.89 m and downwards the bubble cannot be observed in the raw data tapes, since the whole evaluation circle is completely black – only the pointer itself can be observed. The BIPS-image has probably been oriented on the basis of the sedimentary stripe on the lower side of the borehole during logging. The evaluation of the orientation was also based on the thin sedimentary stripe down to 794.99 m (end of BIPS-image). In the beginning of this interval a thin, quite distinct stripe of sediment can be observed in the centre of an almost 180° segment with very thin cover of sediment. From 485 m and downwards only the 180° segments with sediment can be observed. When possible, the evaluation was based on the thin sedimentary stripe, but in the lower part it was based on the 180° wide segment.

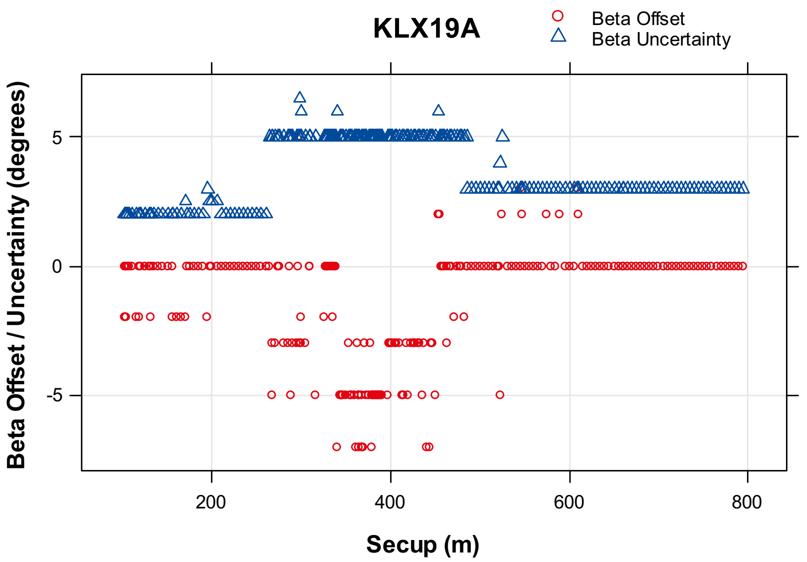
In the interval 310–472 m the raw data image runs on the screen like a rolling hoop. The reason for this is probably that the tape recorder was faulty during logging. Measurements in this interval have only been performed in gaps where enough of the raw data image is visible on the screen. Due to this, a greater uncertainty value (IC) was set for this interval.

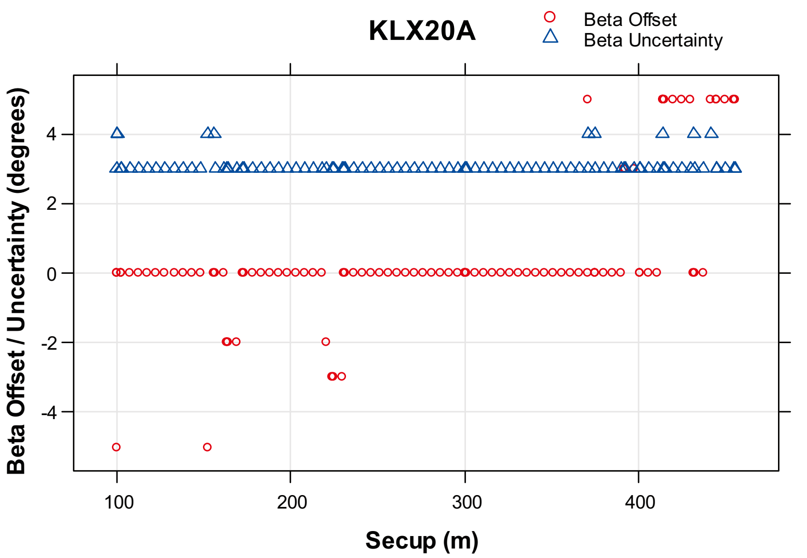
KLX20A

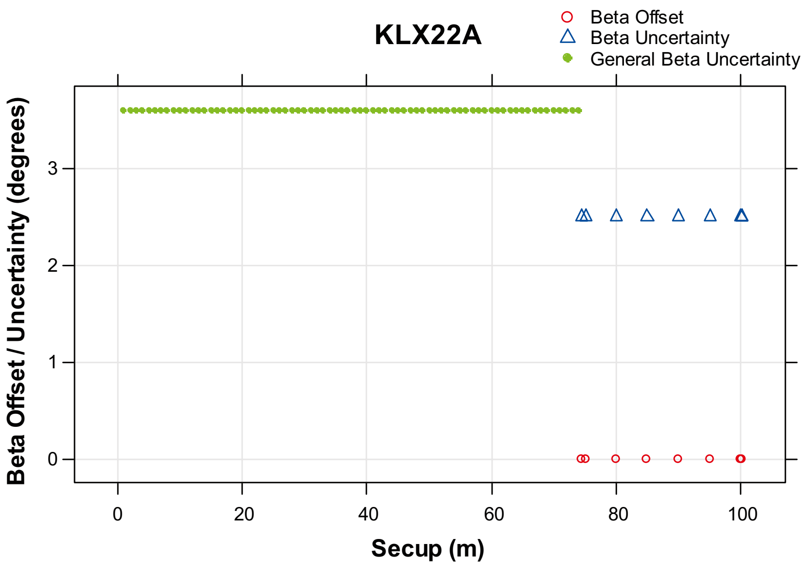
The BIPS-image of KLX20A was logged 2006-05-09 and covers the interval 100.37–455.54 m. The BIPS-image is oriented with a relatively small bubble. The difference between measured orientation in the evaluation and the logging varies between –5° and 5°, but generally the difference is only 2°. The green part of the pointer is indistinct in the raw data image and therefore the white part has been used.

KLX22A

The BIPS-image of KLX22A was logged 2006-07-04 and comprises the section 4.00–100.20 m (recorded length). It is oriented with a relatively small bubble. Only the end of the BIPS-logging can be found on raw data tapes, while the section 4.00–74.91 m is missing. Therefore only the interval 74.91–100.20 has been evaluated. This does not show any greater deviations in BIPS-orientation. A general BIPS $\Delta\beta$-value of ± 3.6°has been set for the first section.


KLX19A
Beta Offset
Beta Uncertainty
Beta Offset / Uncertainty (degrees)
5
0
-5
200
400
600
800
Secup (m)


KLX20A
Beta Offset
Beta Uncertainty
Beta Offset / Uncertainty (degrees)
4
2
0
-2
-4
100
200
300
400
Secup (m)

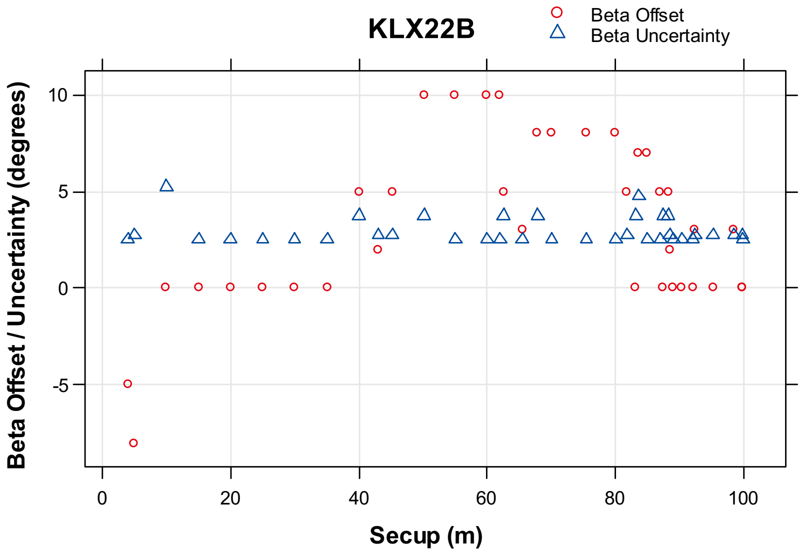

KLX22A
Beta Offset
Beta Uncertainty
General Beta Uncertainty
Beta Offset / Uncertainty (degrees)
3
2
1
0
0
20
40
60
80
100
Secup (m)

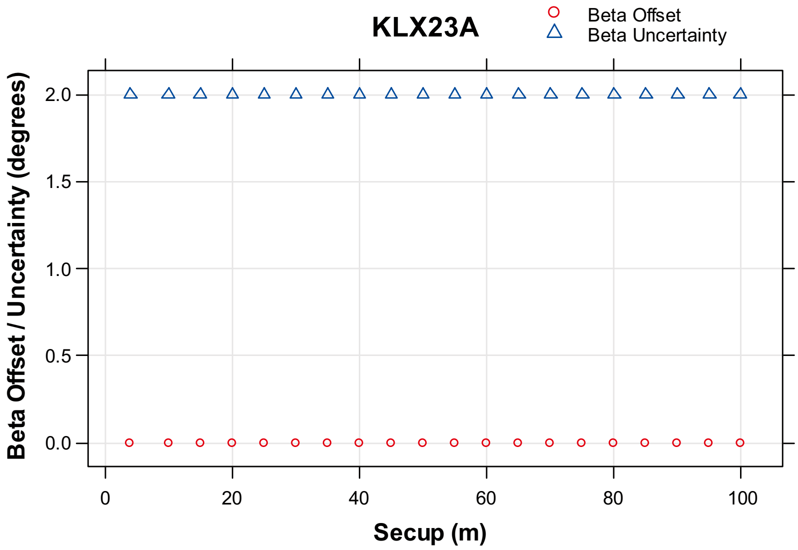
KLX22B

The BIPS-image of KLX22B covers the interval 4.00–99.82 m and was logged 2006-07-04. Orientation conditions have been good: the image is oriented with a small to medium size bubble and the probe has moved steadily down the borehole. On the other hand the pointer has oscillated. In the interval 45–82 m there is a greater deviation in orientation of 5–10°, which can also be confirmed by the thin, visible string of sediments on the lower side of the borehole.

KLX23A

The BIPS-image of KLX23 was logged 2006-07-05 (4.00–99.97 m) and it was oriented with bubble level. The pointer oscillates somewhat, but without greater variations. The BIPS-image is very well oriented.



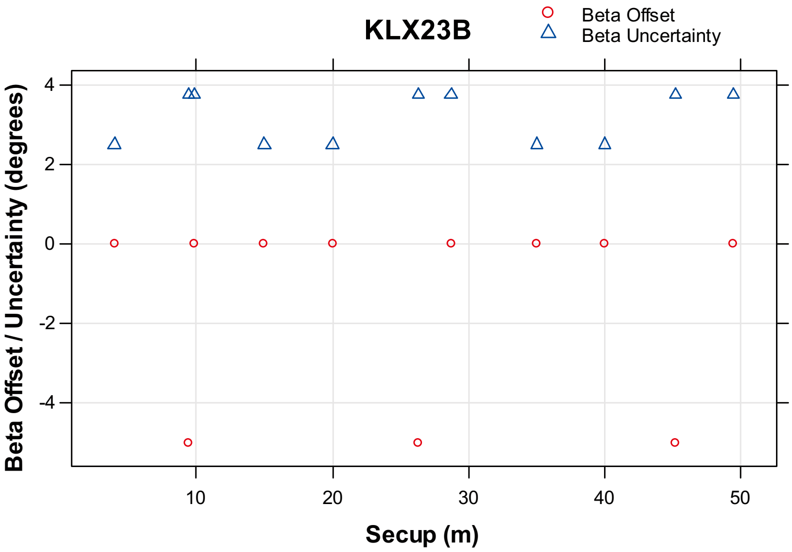


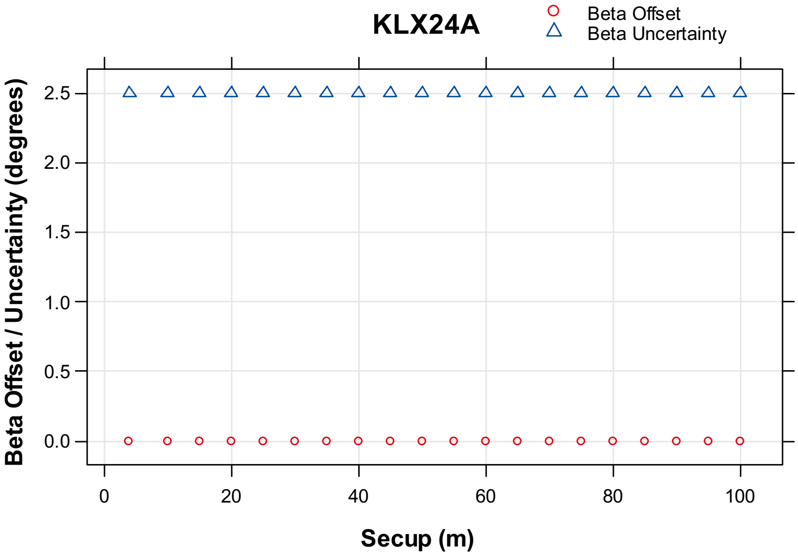
KLX23B

Section 4.00–50.00 m in KLX23 is logged with BIPS 2006-07-05. The BIPS-image is oriented with bubble level and the orientation is good. A discrepancy of 5° occurs in only a few shorter intervals.

KLX24A

The BIPS-image of KLX24A covers the interval 4.00–100.06 m and is logged 2006-08-11. It is oriented with a bubble of medium size. The probe has turned somewhat during logging – however not whole revolutions. The BIPS-image is very well oriented already during logging in the field. No deviation from this has been observed in the evaluation, only in the internal quality control (within human error margin).



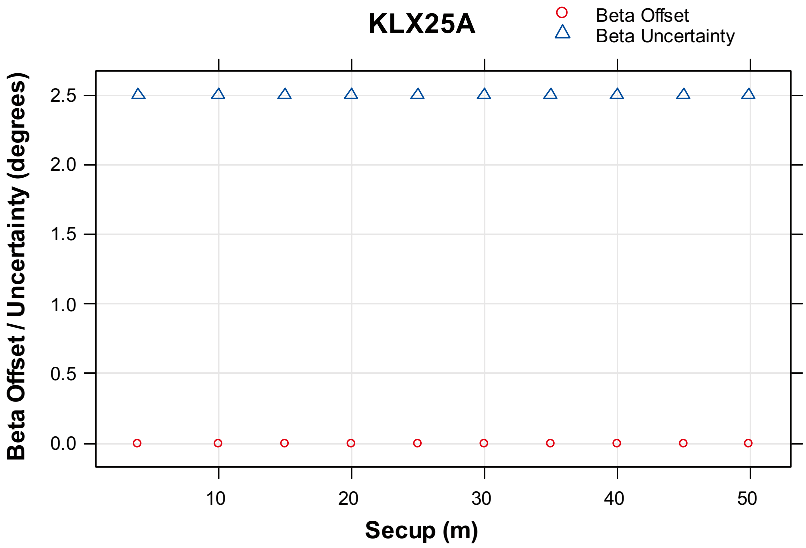


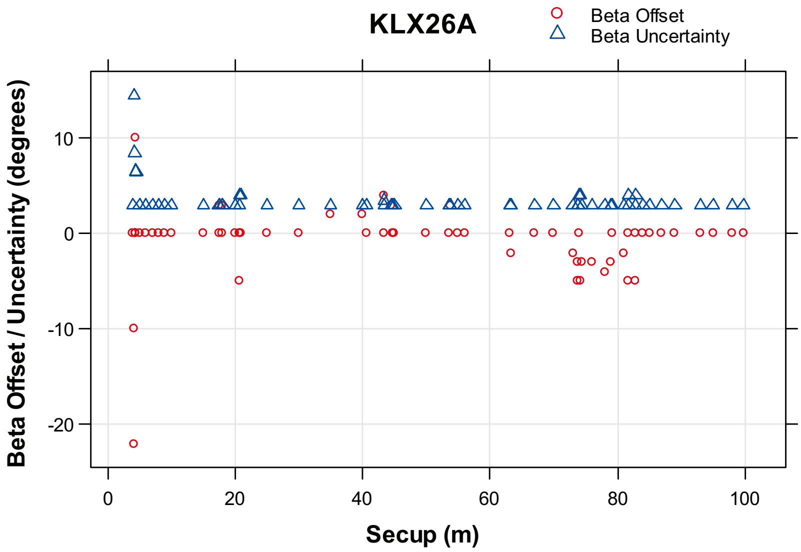
KLX25A

KLX25A was logged 2006-08-12 with BIPS. The BIPS-image is oriented with medium size bubble and covers the interval 4.00–49.87 m. No observable rotation of the probe has occurred during logging. The BIPS-image is very well oriented and no deviations have been observed.

KLX26A

The BIPS-image covers 4.00–99.71 m and is logged 2006-09-11. It is oriented with a bubble of medium size. The probe has moved steadily down the borehole and the uncertainty in the measurements is mostly ± 3°.



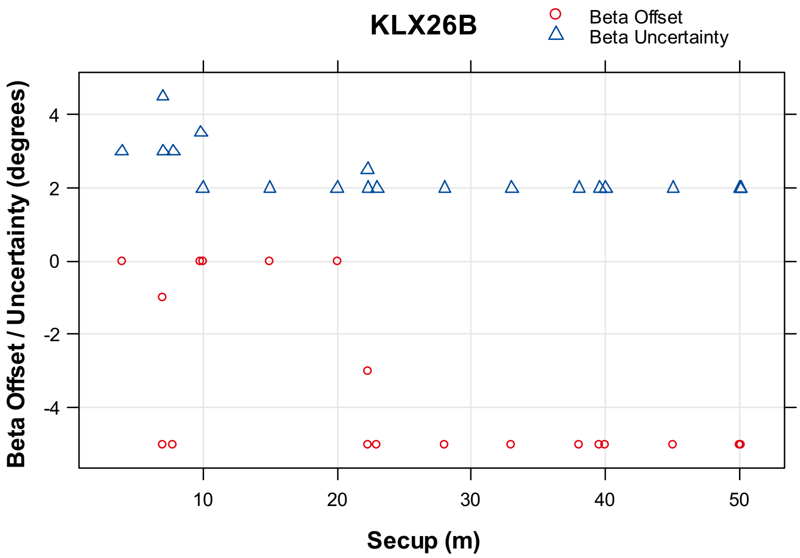


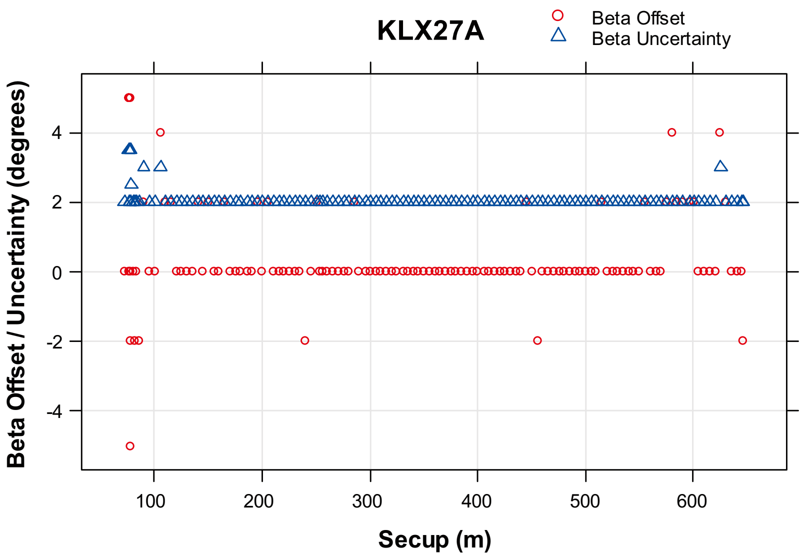
KLX26B

The BIPS-image of KLX26B comprises 4.00–50.07 m and is logged 2006-09-11. It is oriented with a bubble of medium size. The deviation in orientation between the evaluation and the original logging varies between –5° and 0°, but is mostly –5°.

KLX27A

The BIPS-image of KLX27A is oriented with a bubble level and it is merged from two images comprising the intervals 76.00–520.00 m and 520.00–646.53 m. Both images are logged 2007-12-06 after the revision of BIPS-images was considered completed and with the knowledge of possible errors in BIPS-orientation in mind. Despite this, the BIPS-image was evaluated and revised. This evaluation shows that the image is well oriented and possible corrections are within the general uncertainty of the method.





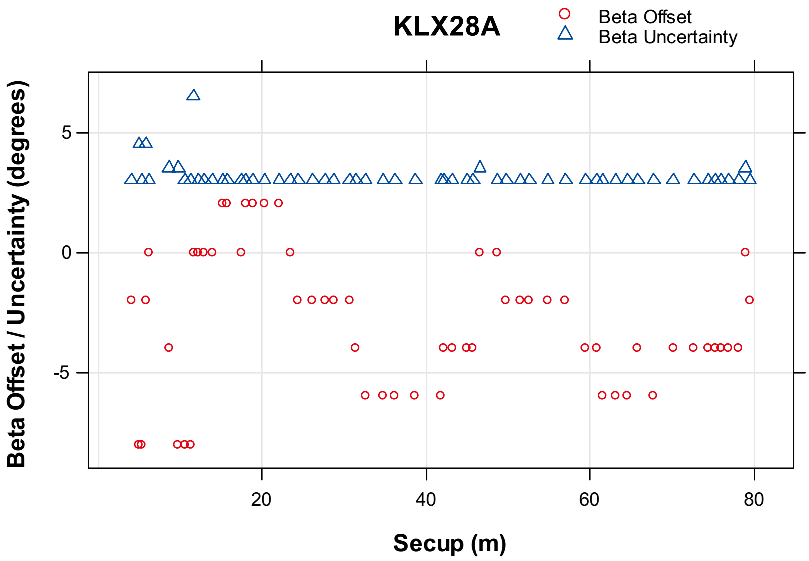
KLX28A

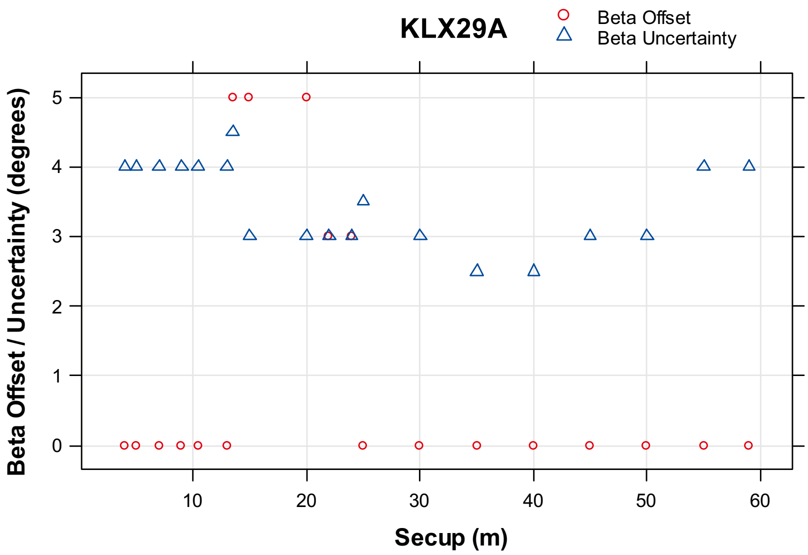
The BIPS-image of KLX28A is oriented with a medium size bubble and covers the section 4.00–79.73 m. The logging was carried out 2006-11-08. The BIPS-image is obscure, and the pointer is poorly visible throughout the borehole. However, orientation of the pointer can be measured with some certainty and it lies relatively steady during logging, varying +2° to –8° from the centre of the bubble. The obscure image contributes to a slightly higher uncertainty value for the measurements.

KLX29A

The BIPS-image of KLX29A was logged 2006-11-27 and covers the interval 4.00–58.96 m. It is oriented with a bubble of medium size. The probe has moved steadily down the borehole, but it is very difficult to observe the pointer due to low contrast in the image. Estimated uncertainty in the measurements is approximately ± 3°.

BIPS-image is missing in a 0.91 m long section.





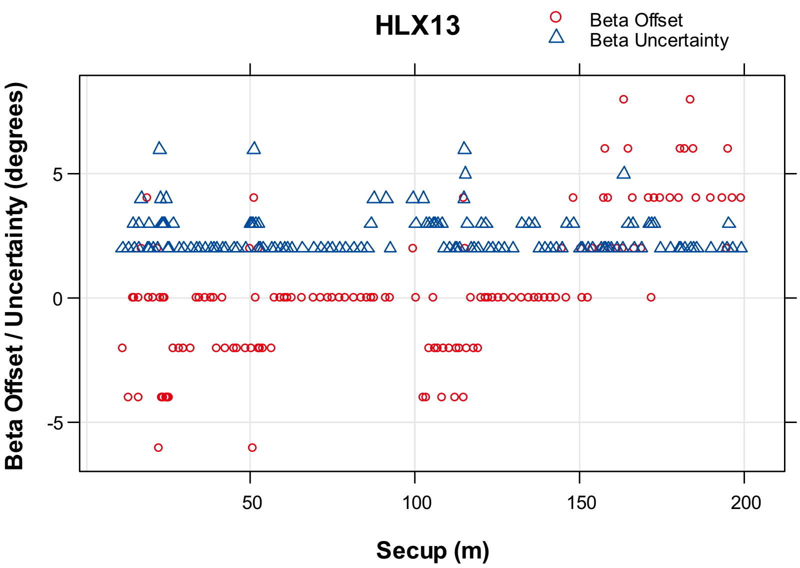
HLX13

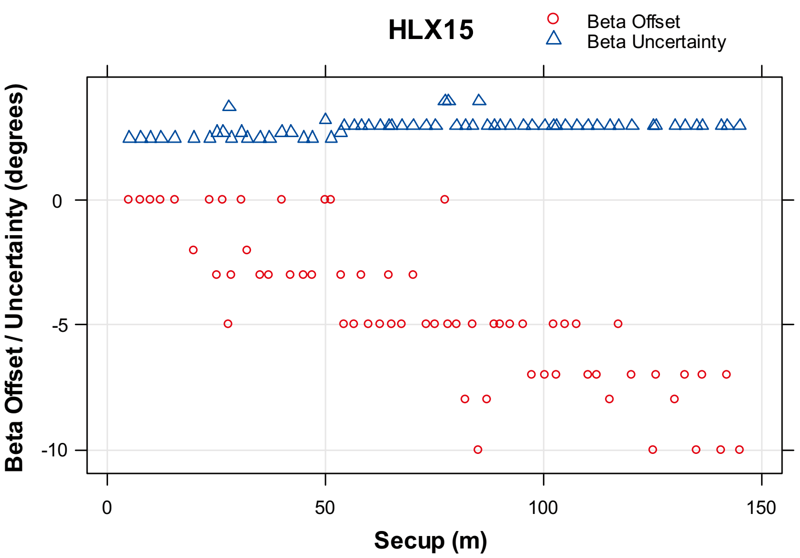
The BIPS-image of HLX13 is oriented with a relatively small bubble. It is merged from two different files which cover the intervals 11.00–85.20 m and 85.20–198.95 m. Both files are logged 2004-05-28. The BIPS-image is mostly well oriented – it deviates generally with –2° to +6°. The BIPS probe has oscillated somewhat throughout the borehole during logging.

HLX15

The BIPS-image of HLX15 is logged 2004-05-27 and comprises the section 11.80–151.38 m. The BIPS-image is oriented with a small bubble, which covers a segment about 60° wide. The probe and the pointer oscillate somewhat throughout the logging; the first is typical for percussion drilled boreholes. From about 54 m and to the end of the borehole the pointer is quite diffuse, and therefore the measurements have been made mostly on the green part of the pointer, since the white part cannot be seen.

The last 5 m of the BIPS-image are missing on the raw data tapes, and therefore no evaluation could be carried out for this section.



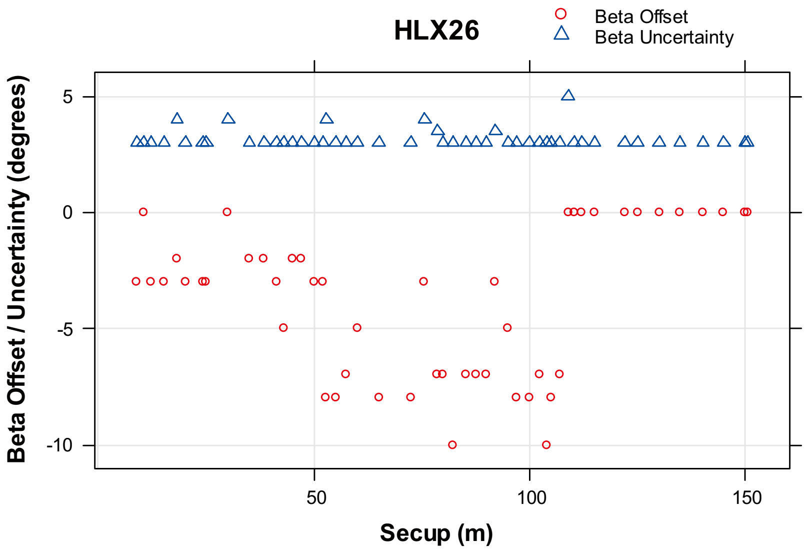


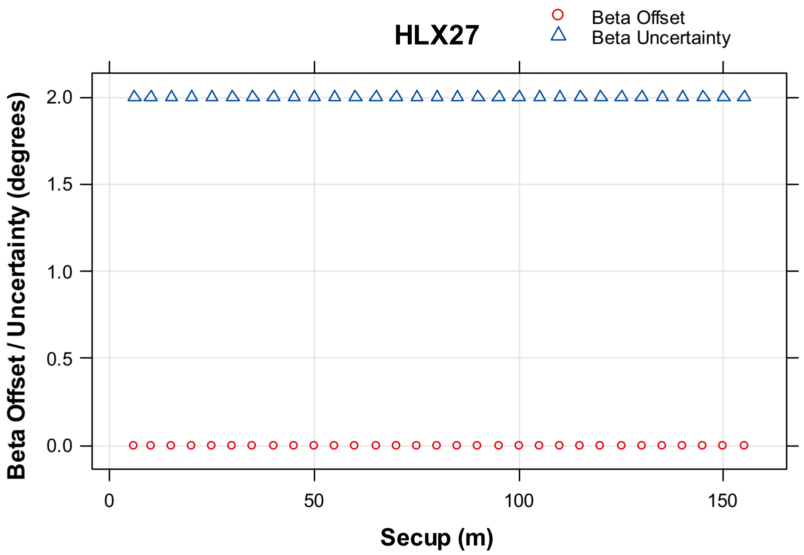
HLX26

The BIPS-image of HLX26 was logged 2004-10-18 and covers 8.00–150.52 m. The BIPS-image is oriented with a relatively small bubble. The probe has swayed somewhat during logging and the pointer has oscillated slightly. No difference in the orientation has been observed from 109 m to the end of the image but a greater difference was noted in the interval 53–107 m (3–10° difference).

HLX27

HLX27 was logged 2004-10-19 and covers 6.00–159.31 m. The BIPS-image is oriented with bubble level and it is very well oriented. No discrepancy between the original orientation and the evaluation has been observed.



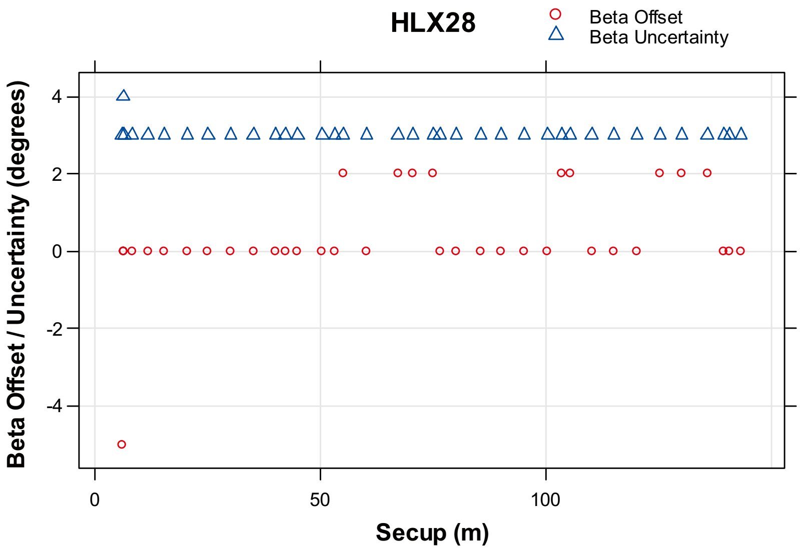


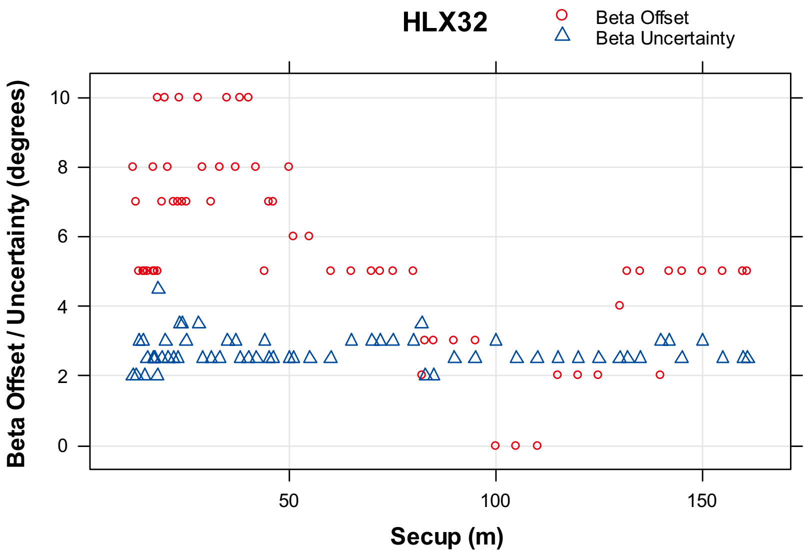
HLX28

The BIPS-image of HLX28 is merged from two files, which both are logged 2004-10-20. The files cover the intervals 6.00–76.42 m and 76.42–143.13 m and they are oriented with a small bubble. The probe has swayed somewhat during logging and the pointer has oscillated. The BIPS-image is well oriented and only small discrepancies occur – at most a discrepancy of 2° has been observed. The pointer was on the other hand difficult to observe and therefore a slightly higher uncertainty value was set.

HLX32

HLX32 was logged 2005-03-21 and comprises the interval 12.00–161.01 m. The BIPS-image is oriented with a medium size bubble. The probe rotates or oscillates throughout the logging. The pointer diverges generally 5° from the centre of the bubble and corrections have therefore been carried out.



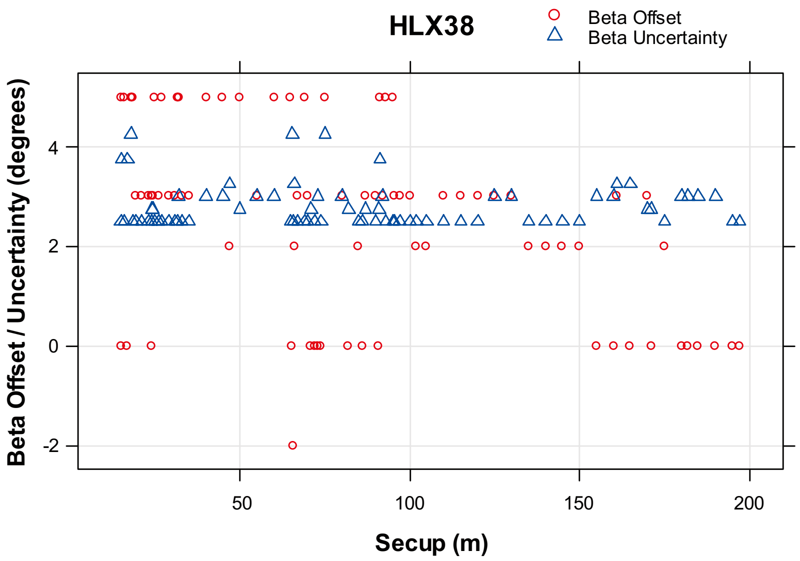


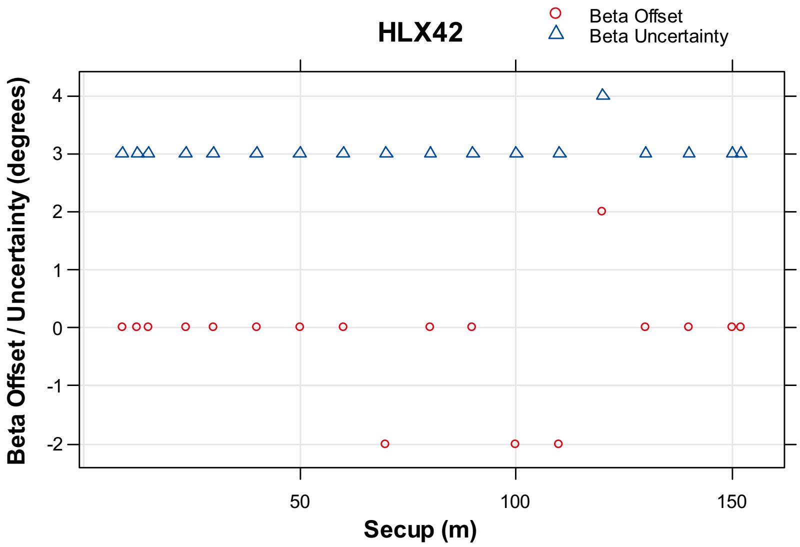
HLX38

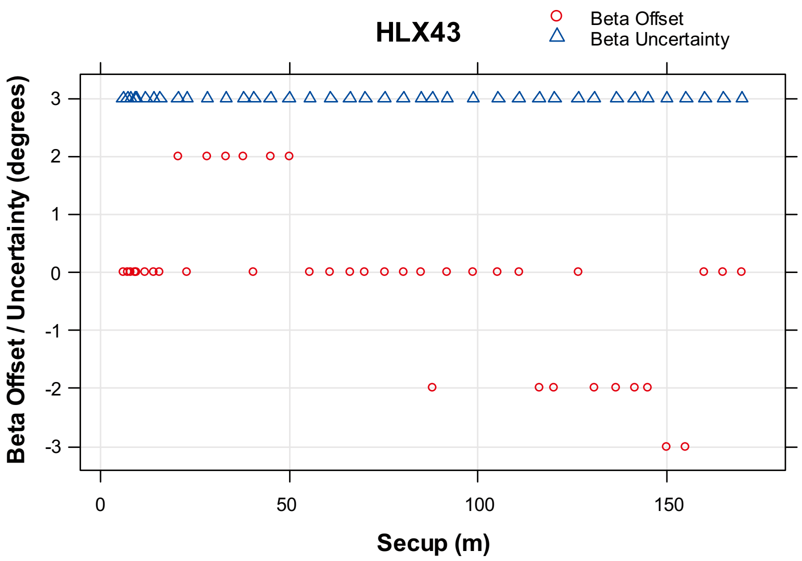
HLX38 was logged 2006-05-14 and the BIPS-image covers the interval 15.00–198.73 m. It is oriented with a small bubble. The probe rotates/oscillates throughout the logging. Minor deviations up to 5° occur from the original orientation.

HLX42

The BIPS-image of HLX42 was logged 2007-01-30 (9.00–152.02 m). It is generally well oriented and β-corrections have been performed in only a few shorter intervals. The pointer has on the other hand oscillated considerably which is reflected in a higher BIPS Δβ-value.







HLX43

HLX43 was logged with BIPS 2006-11-30 and the image comprises 5.00–169.85 m. The BIPS-camera was wrongly set during logging. The green pointer pointed at the centre of the bubble, but the image was set on magnetic orientation (M). Since the borehole is inclined, correction has been performed with respect to the medium size bubble, after which the file has been reworked to become a gravimetric oriented image (G) instead. After changing the BIPS-setting to "G" the β-angles in the mappings were recalculated to cancel out the rotation that Boremap applies to turn the BIPS-image to a vertical position (the image is cut on the lower side). This had to be done because the BIPS-image was flagged as magnetically oriented (the image is cut in South) during the Boremap mapping. This correction is performed on the same principles that are described in chapter 4.5.3, "Technical background for β-angle in Boremap".

The angle between pointer and the centre of the bubble is mostly 0°, which means that the original BIPS-image was very well oriented; disregarding the wrong instrument setting which is hereby corrected.

5.3 General BIPS Δβ in boreholes classified as category B

When the orientation of the BIPS-image was not evaluated (category B, Appendix 2) a general BIPS Δβ-value was calculated for the borehole. The results from the calculations are shown in Figure 5-4 and the procedure is described in chapter 4.5.2. Category B boreholes had either faulty or missing BIPS raw data tapes, or were of lower priority, for example percussion boreholes in Forsmark. β-corrections and BIPS Δβ-values from boreholes were used in the calculations. These reference boreholes are also listed in Figure 5-4.

One single borehole has been mapped with a Televiewer-image instead of a BIPS-image (KLX02). This has received a general Δβ-value of ± 5°/2/.

Borehole	General BIPS Δβ (degrees)	Comment	Site
KFM07B	3	Based on KFM01D KFM07A KFM08B KFM10A	Forsmark
KFM09A	3	Based on KFM04A KFM06A KFM06C	
KFM09B	3	Based on KFM01D KFM10A	
HFM01	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM02	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM03	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM04	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM05	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM06	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM07	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM08	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM09	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM10	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM11	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM12	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM13	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM14	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM15	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM16	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM17	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM18	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM19	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM20	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM21	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM22	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM23	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM24	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM25	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM26	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM27	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM28	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM29	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM30	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM31	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM32	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM33	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM34	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM35	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM36	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM37	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HFM38	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
KLX07B	7.5	Based on KLX04 KLX09B KLX11B KLX13A	Laxemar
KLX09	4.2	Based on KLX18A KLX11A	
KLX09F	5.3	Based on KLX09C KLX09D KLX09E KLX09G	
KLX10	4.2	Based on KLX18A KLX11A	
KLX21B	3	Based on KLX12A KLX11A KLX05 KLX06	
HLX10	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX17	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX18	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX19	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX20	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX21	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX22	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX23	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX24	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX25	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX30	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX31	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX33	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX34	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX35	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX36	4.7	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32	
HLX37	4.7	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32	
HLX39	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX40	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	
HLX41	4.6	Based on HLX13 HLX15 HLX26 HLX27 HLX28 HLX32 HLX38 HLX42	

Figure 5-4. *List of general BIPS Δβ-values of boreholes as well as the reference boreholes for the calculations.*

6 Experiences from the evaluation work

6.1 Revision with BIPS-tape recorder and TV-screen

In the beginning of this project, test revisions were performed in order to work out a method for how the revision should be performed in the best way. At that time the BIPS tape recorder was connected to a TV-screen, in order to get a larger screen. Measured angles between pointer and bubble were noted in an Excel-work sheet in the same way as in this work. The method worked relatively well, but there was only one tape recorder available. The reason for copying the tapes to DVD was to make the work more efficient and make it possible for several persons to work with the evaluation at the same time, and also to modernize and secure the storage of data.

The rewinding of the tapes, which were not rewound to the start, was time consuming. Another disadvantage was that the image was poorly visible when the tape was paused, causing flicker across the evaluation circle. Therefore the tape recorder had to be in play-mode when performing the measurements, which resulted in rewinding the tape back and forth, especially for BIPS-images oriented with steel ball clinometer. For the DVDs there was no deteriorated image quality when paused to make accurate angle measurements and when fast forwarding the files the image quality was maintained.

A TV-screen radiates electromagnetism more than a LCD computer screen, which in the long run would have caused eye fatigue.

6.2 Logging vertical boreholes and percussion drilled boreholes

In the evaluation work, problems were observed with the BIPS-orientation in vertical boreholes, since the semiautomatic pointer could not follow the relatively fast rotation of the probe well enough. This was usually the case for boreholes with inclination steeper than –85°, but also for some boreholes with the inclination –80°. In more inclined boreholes there was generally no rotation of the BIPS-probe.

This problem has been observed earlier in the site investigation. The advantages and disadvantages of the usage of bow-springs (stabilizers) have been up to discussion, but it was only after the preliminary investigation of this work (November 2006) that the BIPS probe received bow-springs to reduce the rotation in vertical boreholes.

A similar phenomenon also occurs in inclined percussion drilled boreholes, but here the probe oscillates during logging instead of rotating whole turns. This is probably due to the larger borehole diameter and that the probe has not been fully centralized in the borehole.

6.3 Bubble level as reference for the orientation of BIPS-image

The bubble is following the rotation of the probe very well, and can be considered a reliable upward indicator in inclined boreholes (inclination not steeper than –80°). The pointer does not always follow the bubble when the probe is rotating fast. This rotation, on the other hand, occurs in most cases only in almost vertical boreholes. Another problem is that the size of the bubble has not been optimized in all loggings. In some of the first BIPS-images oriented with bubble level, the bubble covers the entire evaluation circle which makes it difficult to observe where the upper side of the borehole is (Figure 4-7).

6.4 Steel ball clinometer as reference for the orientation of BIPS-image

In the beginning of the site investigations, a steel ball clinometer was used to indicate the low side of the borehole during BIPS-logging. When evaluating the raw data tapes from BIPS-images oriented with steel ball clinometer, it could easily be observed that the steel ball cannot be considered a reliable indicator of the orientation because of its slowness during rotation of the probe. It was observed repeatedly that the steel ball was stationary for long periods during logging and then, suddenly, it dropped tens of degrees. Meanwhile the compass rotated evenly, showing no abrupt rotation. The intermittent movements of the steel ball were not systematic; sometimes it dropped 10° at a time, other times it dropped 110°. Hence, it was the right decision to exchange the steel ball clinometer in the BIPS-probe with a bubble level clinometer.

6.5 Compass as reference for the orientation of BIPS-image

Compass works theoretically as a reference for the orientation of BIPS-images in vertical bore-holes (inclination steeper than –80°). On the other hand, the automatic compass is influenced by inertia when the rotation is fast. The compass is also sensitive to magnetic disturbances such as magnetic storms, magnetic minerals in the bedrock or other magnetic disturbances nearby, such as a nuclear power plant. Before logging a BIPS-image oriented with compass, possible magnetic disturbances that may affect the orientation must be known and demagnetized batteries must be used.

In the beginning of the revision of steel ball oriented BIPS-images, compass was used as a reference for the β-corrections. For example KFM01A and KFM02A were evaluated in this way, by measuring the angle clockwise from compass north to the green pointer (360°). This method was abandoned because of the shortages described above.

7 Recommendations

7.1 Automatic orientation of the BIPS-image

We suggest that an automatic orientation of the BIPS-image should be developed. This would eliminate the human element when orienting the BIPS-image. At the moment the BIPS-image is oriented manually by the operator who tunes the pointer with a small hand wheel. When logging in real time, pointing exactly at the centre of the libel is not always an easy task, especially when the probe is rotating. Also when the probe moves smoothly down the borehole, the operator must keep full attention on the clinometer looking for minor rotations. This causes eye fatigue since the work is very monotonous and lasts up to 10 h.

A requirement of an automatic orientation is that it has to be fast enough to follow the bubble even when the probe is rotating fast. It also has to be accurate when detecting the centre of the bubble level, which can vary in size and shape due to different pressures and different inclinations.

If no automatic orientation of the BIPS-image can be developed we suggest that not only one, but two operators should perform the BIPS-logging, to ensure good quality in BIPS-orientation.

Another idea is to create software for processing the BIPS-image after logging. At first an automatic evaluation of the BIPS-image orientation could be performed, i.e. the angle between the green pointer and the centre of the bubble is measured automatically. After that the orientation of the BIPS-image could be corrected before the geological mapping is performed.

7.2 Complement to the BIPS-logging routines

Demagnetized batteries must always be used in the BIPS-probe, regardless of orientation method. The evaluation of BIPS-images oriented with steel ball clinometer is a good example of why only demagnetised batteries must be used. When using the semi-automatic orientation of the BIPS-probe this is also crucial, since it uses compass as reference as it is designed today. The BIPS logging protocol should be complemented with a note that the magnetism of the batteries is checked.

7.3 Borehole orientation

When planning the drilling, consideration should be taken to the problems with rotating instruments in vertical and almost vertical boreholes. In order to receive good orientation data we recommend that no borehole with an inclination steeper than –80° should be drilled.

We also recommend the usage of bow springs when logging almost vertical boreholes with BIPS.

7.4 Documentation of Used BIPS-file

We recommend that a procedure is worked out for the merging of BIPS-images. Only after commencement of this project merging of BIPS-images has been documented. However, there exists neither any description of the procedure as such, nor an instruction of how to document merging of BIPS-files from individual boreholes. Work has been started to correct these quality shortages.

7.5 Alternative methods for evaluating the orientation of BIPS-images

When raw data tapes are accessible for the BIPS-images, these should be used in the first place when evaluating or revising the orientation of BIPS-images, if the borehole is inclined and oriented with bubble level. The errors in this kind of measurements are about ± 3°, which can be considered acceptable. When BIPS-images are oriented with compass, the raw data tapes can be used after checking that no magnetic disturbances occur that may affect the orientation.

When BIPS raw data tapes are missing, or when they are faulty, other methods can be used. As a suggestion, the BIPS-image can be compared with a BIPS-image from another logging from the same borehole. The raw data tapes from this logging can be checked first to ensure that the image is correctly oriented, or to document necessary correction of the measurements. After that, both BIPS-images can be compared with each other in Boremap by orienting the same fractures or rock contacts in both images and comparing their β-angles. If the raw data tape from the reference BIPS-image is evaluated, the orientations from the mapping of the first BIPS-file can be corrected accordingly.

References

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Documentation of merged BIPS-files

Documentation of merged BIPS-images. Site Forsmark

Borehole	Image 1					Image 2							Image 3							Image 4							Image 5							Comment
	Logging date	Logging time	Orienta-tion	From	To	Logging date	Logging time	Orienta-tion	From	To	New from	New to	Logging date	Logging time	Orienta-tion	From	To	New from	New to	Logging date	Logging time	Orien-tation	From	To	New from	New to	Logging date	Logging time	Orien-tation	From	To	New from	New to	
KFM01A	2002-12-11	08:43	steel ball	101.00	650.00	2002-12-11	11:15	steel ball	650.00	696.66	650.00	696.66	2002-12-11	17:18	steel ball	696.68	995.98	696.66	995.96	NO														
KFM01B	2003-08-31	09:30	libell	15.00	187.75	2004-03-11	09:30	big libell	187.85	496.74	187.75	496.62	NO																					
KFM01C	2006-01-02	17:38	libell	11.00	208.24	2006-03-08	14:05	libell	207.43	274.65	208.24	275.46	2006-03-09	13:22	libell	274.58	439.45	275.46	440.33	NO														
KFM01D	2006-03-13	15:56	libell	91.00	455.98	2006-03-14	07:51	libell	455.96	659.99	455.98	660.01	2006-03-14	10:12	libell	660.01	795.99	660.01	795.99	NO														
KFM02A	2003-04-14	20:46	steel ball	101.00	390.56	2003-04-15	09:25	steel ball	391.84	590.02	390.82	589.00	2003-04-15	11:49	steel ball	590.00	999.00	589.00	998.00	NO														Difference in orientation between image 1 and image 2.
KFM02B	2006-11-14	11:36	libell	88.00	174.67	2006-11-14	12:39	libell	174.67	251.52	174.67	251.52	2007-01-08		libell	251.52	449.48	251.52	449.48	2007-02-20		libell	449.48	569.16	449.48	569.16	NO							
KFM03A	2003-08-31	17:15	steel ball	101.00	450.96	2003-09-01	10:12	steel ball	453.00	997.04	450.96	995.00	NO																					
KFM03B	2003-08-05	18:36	steel ball	5.00	99.27	NO																												
KFM04A	2003-12-05	11:10	libell	108.00	187.54	2003-12-05	12:07	libell	187.54	448.09	187.54	448.09	2004-03-08	19:43	libell	449.49	598.96	448.09	597.56	2004-03-09	08:53	libell	600.19	898.45	597.56	895.82	2004-05-12	00:32	libell	899.83	985.29	895.82	981.30	Ca 6 cm is missing between image 1 and image 2 in "Used" file.
KFM05A	2004-05-10	07:21	libell	109.00	113.89	2005-06-03	11:30	libell	113.89	531.00	113.89	531.00	2005-06-03	19:30	libell	531.00	819.35	531.00	819.35	2005-06-04	01:18	libell	819.39	995.04	819.35	995.00	NO							Image is missing between 530 and 531 m.
KFM06A	2004-11-01	13:34	libell	102.00	500.08	2004-11-02	06:29	libell	500.08	994.26	500.08	994.26	NO																					Clear discontinuity in the BIPS-image at 102.28 m.
KFM06B	2004-07-17	08:51	libell	4.00	55.52	2005-02-10	16:05	libell	55.22	97.48	55.52	97.78	NO																					
KFM06C	2005-08-23	15:00	libell	101.00	398.70	2005-08-29	14:54	libell	398.71	798.28	398.70	798.27	2005-08-29	21:43	libell	798.30	992.23	798.27	992.20	NO														Clear discontinuity in the BIPS-image at 102.12 m.
KFM07A	2005-01-10	13:11	libell	101.00	548.40	2005-02-10	16:20	libell	550.12	991.98	548.40	990.26	NO																					
KFM07B	2005-06-21	09:44	libell	1.87	65.06	2005-11-07	10:16	libell	65.00	297.88	NO	NO	NO																					Image 1 and image 2 are not merged. The borehole diameter is different for both sections.
KFM07C	2006-07-21	22:42	libell	98.00	420.01	2006-09-22	13:37	libell	420.66	498.21	420.01	497.57	NO																					
KFM08A	2005-05-09	14:33	libell	102.00	500.00	2005-05-09	18:44	libell	500.00	701.00	500.00	701.00	2005-05-10	08:50	libell	701.20	980.03	701.00	979.83	NO														
KFM08B	2005-02-10	09:06	libell	5.00	199.15	NO																												
KFM08C	2006-06-19	17:14	libell	102.00	643.01	2006-06-20	08:53	libell	643.41	948.61	643.01	948.21	NO																					
KFM08D	2007-01-08	11:53	libell	59.00	166.34	2007-02-23	10:54	libell	166.34	580.01	166.34	580.01	2007-02-23	16:52	libell	579.97	926.45	580.01	926.49	NO														
KFM09A	2005-11-06	06:51	libell	7.00	561.00	2006-11-06	14:52	libell	560.96	791.87	561.00	791.91	NO																					
KFM09B	2006-01-25	07:35	libell	9.00	310.20	2006-01-25	12:07	libell	310.17	445.89	310.20	445.92	2006-01-24	20:39	libell	445.92	610.00	445.92	610.00	NO														
KFM10A	2006-06-13	09:24	libell	62.00	496.02	NO																												
KFM11A	2006-10-01	17:36	libell	71.00	249.98	2006-11-24	13:03	libell	249.92	560.00	249.98	560.06	2006-11-24	18:35	libell	560.02	848.08	560.06	848.12	NO														
KFM12A	2007-03-21	12:20	libell	61.00	597.63	NO																												

Documentation of merged BIPS-images. Site Oskarshamn

Borehole	Image 1							Image 2							Image 3							Image 4							Comment
	Logging date	Logging time	Orientation	From	To	New From	New To	Logging date	Logging time	Orienttion	From	To	New From	New To	Logging date	Logging time	Orienttion	From	To	New From	New To	Logging date	Logging time	Orienttion	From	To	New From	New To	
HLX13	2004-05-28	7:06	libell	11.00	85.20	11.00	85.20	2004-05-28	7:55	libell	85.16	198.91	85.20	198.95	NO														
HLX15	2004-05-27	17:26	libell	11.80	151.38	11.80	151.38	NO																					
HLX19	2004-09-30	16:22	libell	12.00	148.94	12.00	148.94	NO																					
HLX21	2004-09-28	16:03	libell	9.00	147.02	9.00	147.02	NO																					
HLX22	2004-09-29	9:53	libell	9.00	162.36	9.00	162.36	NO																					
HLX23	2004-09-29	15:56	libell	6.00	65.09	6.00	65.09	2004-09-29	16:37	libell	65.07	159.29	65.09	159.31	NO														Exact length for the splice is uncertain. Within an interval of +- 0.5 m.
HLX24	2004-09-30	9:55	libell	9.00	174.55	9.00	174.55	NO																					
HLX25	2004-09-28	9:25	libell	6.00	51.10	6.00	51.10	2004-09-28	9:55	libell	51.10	201.53	51.10	201.53	NO														Almost 4 cm has got lost when merging the images.
HLX26	2004-10-18	14:26	libell	9.00	150.52	9.00	150.52	NO																					
HLX27	2004-10-19	9:18	libell	6.00	159.31	6.00	159.31	NO																					
HLX28	2004-10-20	6:47	libell	6.00	76.42	6.00	76.42	2004-10-20	8:09	libell	76.38	143.09	76.42	143.13	NO														
HLX30	2005-08-31	10:03	libell	9.00	162.03	9.00	162.03	NO																					
HLX31	2005-10-20	9:58	libell	9.00	128.14	9.00	128.14	NO																					
HLX32	2005-03-21	14:22	libell	12.00	161.01	12.00	161.01	NO																					
HLX34	2005-07-20	16:42	libell	8.00	131.65	8.00	131.65	2005-07-21	7:35	libell	131.60	150.47	131.65	150.52	NO														
HLX35	2005-07-20	8:44	libell	5.00	150.46	5.00	150.46	NO																					
HLX36	2005-12-06	15:57	libell	5.00	192.85	5.00	192.85	NO																					
HLX37	2005-12-07	11:35	libell	11.00	198.64	11.00	198.64	NO																					
HLX38	2006-05-14	16:04	libell	15.00	198.73	15.00	198.73	NO																					Diffuse and practically useless from appr. 130 m and downwards.
HLX43	2006-11-30	16:54	libell	5.00	169.85	5.00	169.85	NO																					During logging set on compass, although image is oriented by libel. Corrected for.
KLX01			Televiewer																										
KLX02			Televiewer																										
KLX03	2004-09-26	8:32	libell	100.00	600.00	100.00	600.00	2004-09-26	13:55	libell	600.00	961.14	600.00	961.14	2004-09-26	20:02	libell	961.03	994.12	961.14	994.23	NO							
KLX04	2004-07-12	16:53	libell	100.00	573.02	100.00	573.02	2004-07-13	8:32	libell	573.00	985.73	573.02	985.75	NO														
KLX05	2005-03-23	9:02	libell	108.00	500.02	108.00	500.02	2005-03-23	16:13	libell	500.00	991.31	500.02	991.32	No														
KLX06	2004-12-28	7:51	libell	101.00	407.48	101.00	407.48	2004-12-28	13:44	libell	407.54	600.01	407.48	599.95	2004-12-28	15:49	libell	600.00	960.82	599.95	960.77	NO							
KLX07A	2005-07-06	15:45	libell	100.00	500.00	101.00	501.00	2005-07-06	19:54	libell	500.02	831.70	501.00	832.68	No														
KLX07B	2005-07-07	8:01	libell	9.00	199.32	9.00	199.32	NO																					
KLX08	2005-09-26	18:15	libell	100.13	460.23	100.13	460.23	2005-09-27	7:53	libell	460.23	620.01	460.23	620.02	2005-09-27	9:37	libell	620.01	950.34	620.02	950.34	2005-09-27	15:06	libell	950.36	987.25	950.34	987.23	There are two loggings.
KLX09	2005-12-01	18:32	libell	101.00	481.56	101.00	481.56	2005-12-05	12:56	libell	481.64	870.41	481.56	870.33	No														
KLX09B	2006-02-06	16:48	compass	10.00	99.84	10.00	99.84	NO																					
KLX09C	2006-02-09	15:44	libell	9.00	118.62	9.00	118.62	NO																					
KLX09D	2006-02-07	14:58	libell	9.00	119.50	9.00	119.50	NO																					
KLX09E	2006-02-08	15:17	libell	8.00	119.72	8.00	119.72	NO																					
KLX09F	2006-02-09	8:26	libell	8.00	151.20	8.00	151.20	NO																					
KLX09G	2006-02-07	16:32	libell	9.00	99.54	9.00	99.54	NO																					
KLX10	2005-11-22	10:44	libell	101.09	460.45	101.09	460.45	2005-11-23	7:22	libell	460.24	951.54	460.45	951.74	2005-11-23	14:43	libell	951.60	992.00	951.74	992.15	No							Seems to be a discontinuity at 101.04 m.
KLX10B	2006-03-22	12:28	libell	8.00	49.99	8.00	49.99	NO																					
KLX10C	2006-03-23	15:01	libell	8.00	145.43	8.00	145.43	NO																					
KLX11A	2006-04-05	8:34	libell	96.00	579.76	96.00	579.76	2006-04-05	13:47	libell	580.00	988.65	580.01	988.66	No														Missing BIPS-image between 579.756 and 580.0105 m.There is a part in the original fil. Problems when merging the images?
KLX11B	2006-05-10	18:12	compass	4.00	17.74	4.00	17.74	2006-08-15	9:19	compass	17.77	99.33	17.74	99.30	NO														
KLX11C	2006-07-04	9:17	libell	4.00	119.62	4.00	119.62	NO																					
KLX11D	2006-07-04	12:37	libell	4.00	119.32	4.00	119.32	NO																					
KLX11E	2006-05-10	13:02	libell	4.00	120.72	4.00	120.72	NO																					
KLX11F	2006-07-04	10:56	libell	4.00	118.90	4.00	118.90	NO																					
KLX12A	2006-03-24	9:26	libell	101.41	320.52	101.41	320.52	2006-03-24	13:53	libell	320.54	420.90	320.52	420.88	2006-03-26	18:29	libell	420.85	599.17	420.88	599.21	No							
KLX13A	2006-09-12	8:33	libell	101.00	360.00	101.00	360.00	2006-09-12	11:22	libell	360.00	593.92	360.00	593.93	No														
KLX14A	2006-11-08	16:03	libell	4.00	174.63	4.00	174.63	NO																					There are two loggings.
KLX16A	2007-01-30	17:14	libell	11.00	427.38	11.00	427.38	NO																					
KLX17A	2006-11-28	12:46	libell	66.00	500.00	66.00	500.00	2006-11-28	17:33	libell	500.00	696.78	500.00	696.78	NO														
KLX18A	2006-05-15	10:41	libell	100.00	500.01	100.00	500.01	2006-05-15	15:06	libell	500.01	609.40	500.01	609.40	NO														
KLX19A	2006-10-09	16:05	libell	100.00	660.01	100.00	660.01	2006-10-09	22:12	libell	660.01	794.99	660.01	794.99	NO														
KLX20A	2006-05-09	11:14	libell	100.37	455.54	100.37	455.54	NO																					
KLX21B	2007-01-02	15:35	libell	100.00	500.01	100.00	500.01	2007-01-02	20:05	libell	500.00	856.216	500.011	856.23	NO														Merged 2007-02-12 by "geocdo".
KLX22A	2006-07-04	17:00	libell	4.00	100.20	4.00	100.20	NO																					
KLX22B	2006-07-04	18:15	libell	4.00	99.82	4.00	99.82	NO																					
KLX23A	2006-07-05	16:42	libell	4.00	99.79	4.00	99.79	NO																					
KLX23B	2006-07-05	15:59	libell	4.00	50.00	4.00	50.00	NO																					
KLX24A	2006-08-11	10:38	libell	4.00	100.06	4.00	100.06	NO																					
KLX25A	2006-08-12	8:48	libell	4.00	49.87	4.00	49.87	NO																					
KLX26A	2006-09-11	13:15	libell	4.00	99.71	4.00	99.71	NO																					
KLX26B	2006-09-11	14:43	libell	4.00	50.07	4.00	50.07	NO																					
KLX28A	2006-11-08	8:15	libell	4.00	79.73	4.00	79.73	NO																					
KLX29A	2006-11-07	9:29	libell	4.00	58.96	4.00	58.96	NO																					

Appendix 2

Boremap: Guidelines for β-adjustment and calculation of uncertainties in quality revision within Task Force for Fracture Orientation

Updated 2008-02-15 (supersedes 2007-10-22)

Category	Guidelines: How value is determined	Application in the table bm_bips_beta_offset	Comments on traceability in Sicada
A. Borehole with bubble-level oriented or compass oriented BIPS image. (Special cases are in category B, C-1 and C-2)	The values for beta-adjustment (angle differences) and uncertainties are obtained in the quality check	The values are found in the columns • Beta offset • TI • **x** in column QC_final	Satisfactory traceability in used table bm_bips_beta_offset.
B. Borehole sections where generalised uncertainty is to be used (usually borehole or parts of borehole without raw data tapes, where it has not been possible to determine angle difference and uncertainty).	• No adjustment of beta can or should be done, ie, set at 0. • The uncertainty is calculated as the sum of the weighted median value for the absolute value of the beta correction and the weighted 90% percentile of uncertainties, calculated for selected boreholes with similar inclination.	Noting in the columns: • Beta offset: no value • TI: no value • **G** in column QC_final	The selection of boreholes used as basis, and the calculated uncertainty are noted in table bm_bips_beta_uncert.
C-1. Borehole section where for some reason it has not been possible to determine angle difference and uncertainty, despite access to tapes, but the assessment is that nothing radical has happened to the probe in the interval and accordingly the uncertainty is deemed relatively small, also in the cases where there are no tapes. An expert opinion is that the conditions are so stable that the generalised uncertainty is not warranted. (Approved QC)	• The angle difference (beta-adjustment) is calculated as the mean value of the values nearest before and after the relevant section. • The uncertainty is set at the greatest value of uncertainty before and after the relevant section + absolute figure of the difference in beta offset between the section before and after. The TI value is extrapolated in the case where this occurs highest up or furthest down in the borehole.	Noting in the columns: • Beta offset: no value • TI: no value • **m** in column QC_final	Calculated beta-adjustment and uncertainty are noted in Sicada as algorithm, in description in table bm_bips_beta_offset.

Category	Guidelines: How value is determined	Application in the table bm_bips_beta_offset	Comments on traceability in Sicada
C-2. Borehole section where it has not been possible to determine angle difference and uncertainty, despite access to tapes, and the assessment is that strong rotation of the probe is not excluded. (Basic coded as Not approved QC)	• The angle difference (beta-adjustment) set at 0. • The uncertainty set at ± 180°.	Noting in the columns: • Beta offset: no value • TI: no value • **U** in column QC_final	Beta-adjustment and uncertainty are noted in Sicada as algorithm, in description in table bm_bips_beta_offset.
D. Borehole with steel-ball oriented BIPS image where comparison mapping of BIPS image in relation to Televiewer image is made. Also applied to whole boreholes with bubble-level oriented BIPS image where the probe has rotated strongly (sub-vertical boreholes) and raw data tapes are missing to some extent.	• The angle difference (beta-adjustment) is measured in BIPS and Televiewer (on same fracture); the values are evened out by curve fitting which reduces random uncertainties in the mapping and to some degree oscillation of the Televiewer probe. Correction is made for difference in borehole deviation data between SICADA's object_location and the Televiewer (GP830). • The uncertainty values are calculated as 90% -percentile for the differences between the observed and the curve fitted values + uncertainty in the Televiewer's orientation (± 5°).	Noting in the columns: • Beta offset: curve fitted value • TI: no value • **GT** in column QC_final	Beta-adjustment is noted in Sicada as algorithm, in description in table bm_bips_beta_offset. The calculated uncertainty is noted in table bm_bips_beta_uncert. The comparison mapping and the calculation result are saved in SICADA's file directory.

Appendix 3

Flow chart for BIPS-line in the evaluation work

Appendix 4

Flow chart for Televiewer-line in the evaluation work

BIPS/Televiewer line

Appendix 5

Total earth magnetic field during logging with Televiewer

The earth magnetic field may negatively affect loggings that uses compass. Therefore it is crucial to know whether there are any disturbances in the magnetic field during logging. It is the variation in declination that may affect the orientation of the Televiewer negatively.

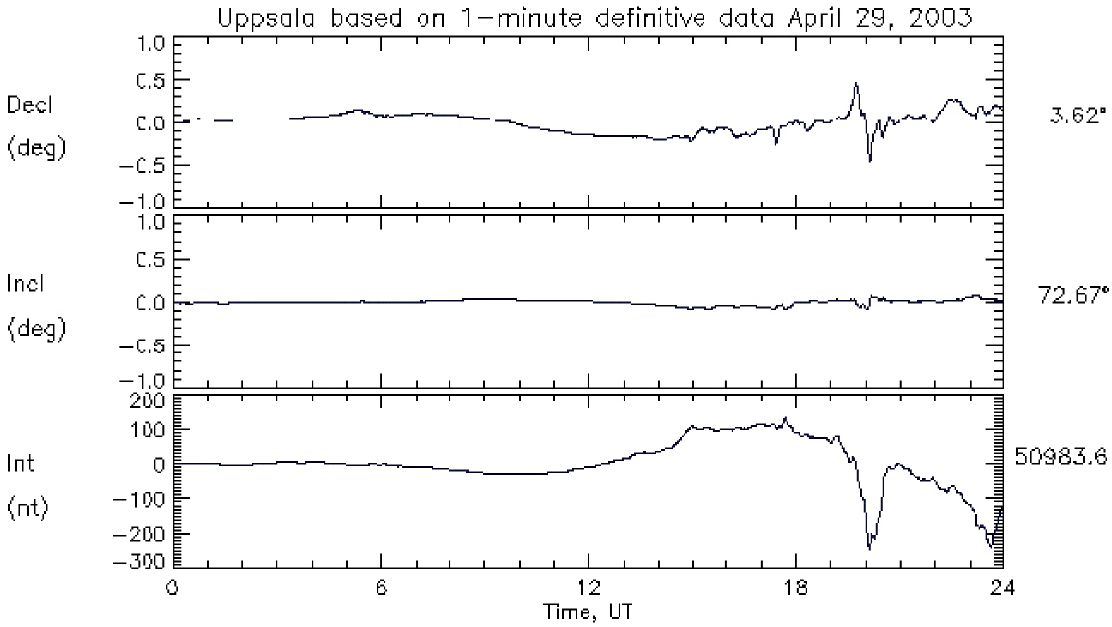

__Figure A5-1.__ Total earth magnetic field during logging KFM01A with Acoustic Televiewer. The upper curve shows the declination.

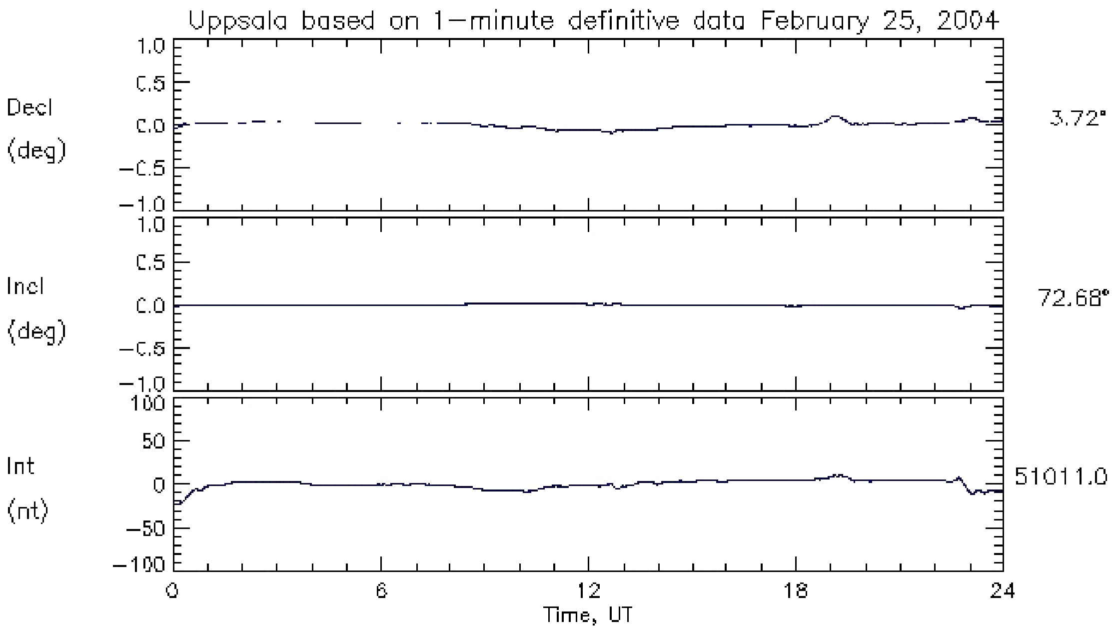

__Figure A5-2.__ Total earth magnetic field during logging KFM01B with Acoustic Televiewer. The upper curve shows the declination.

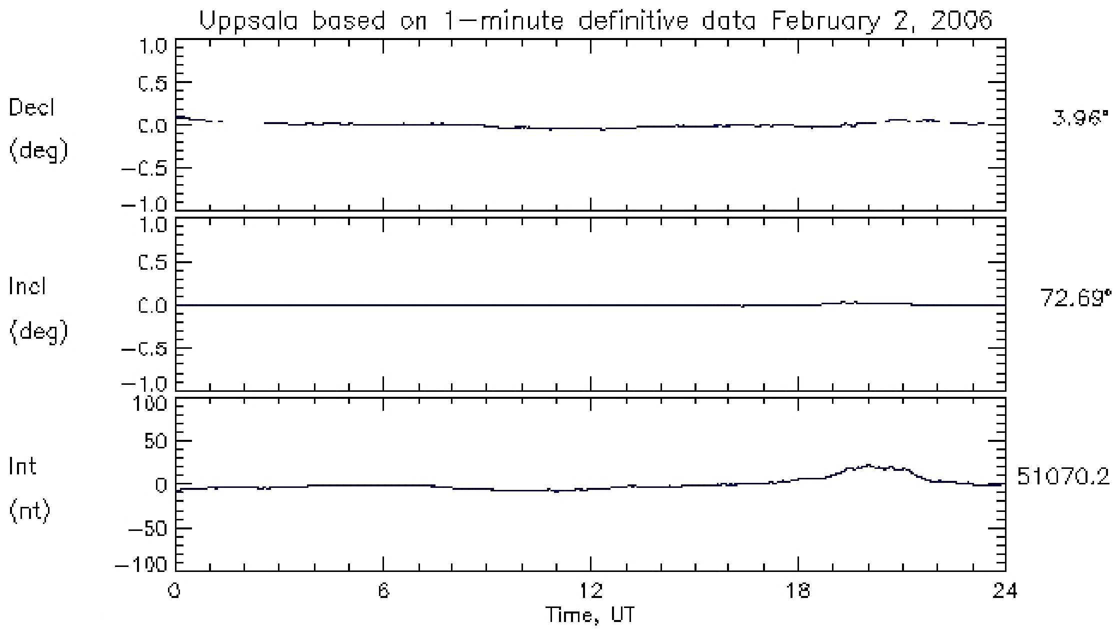

Figure A5-3. *Total earth magnetic field during logging KFM01C with Acoustic Televiewer. The upper curve shows the declination.*

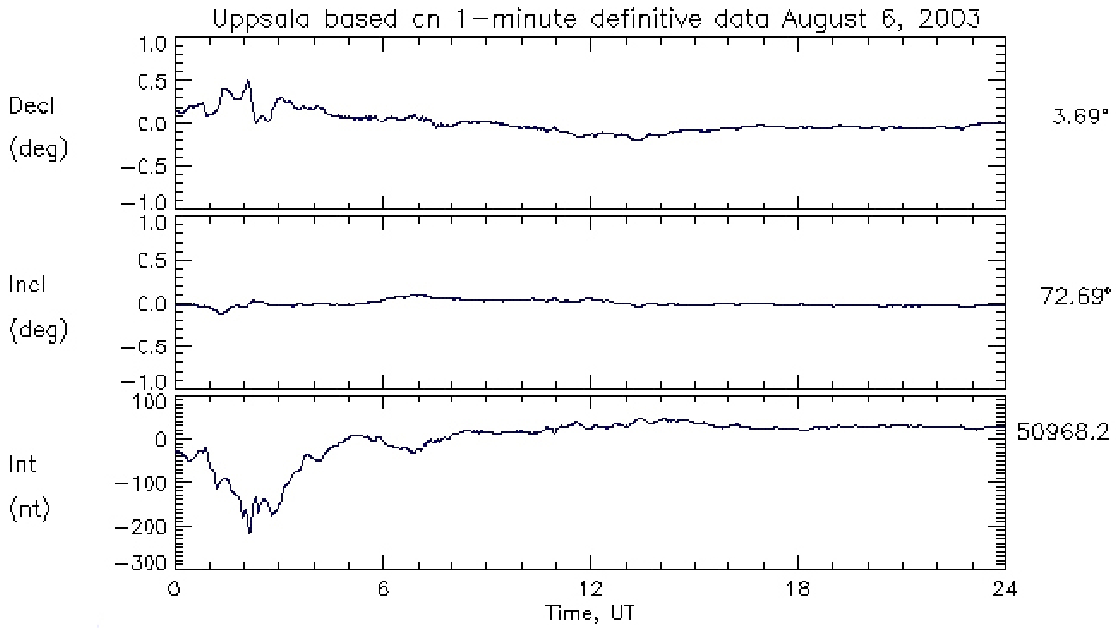

Figure A5-4. *Total earth magnetic field during logging KFM02A with Acoustic Televiewer. The upper curve shows the declination.*

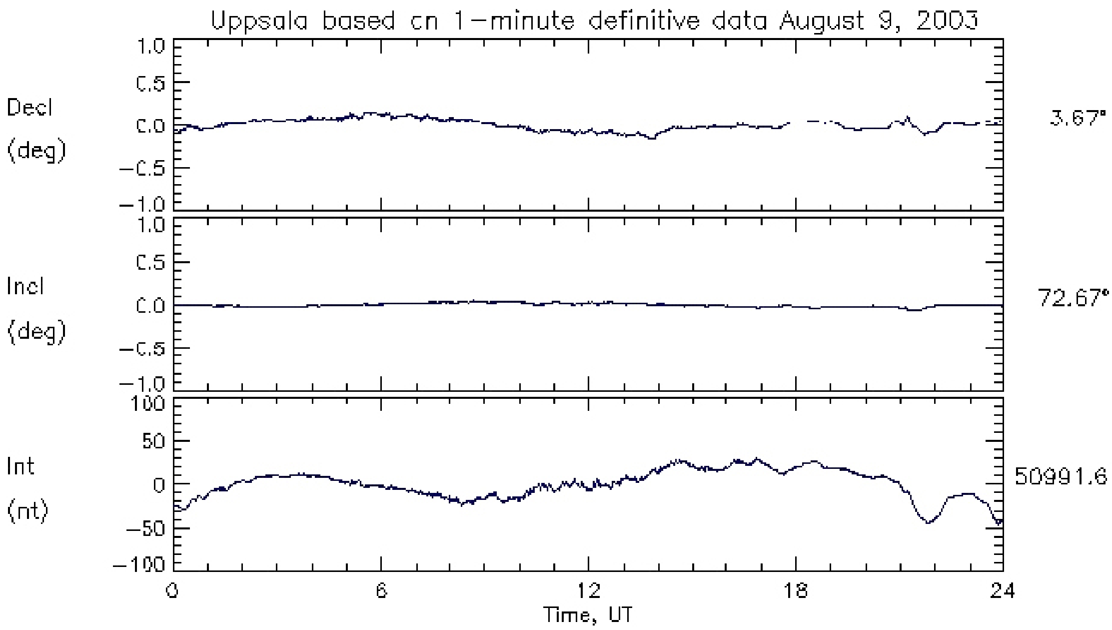

Figure A5-5. *Total earth magnetic field during logging KFM03A with Acoustic Televiewer. The upper curve shows the declination.*

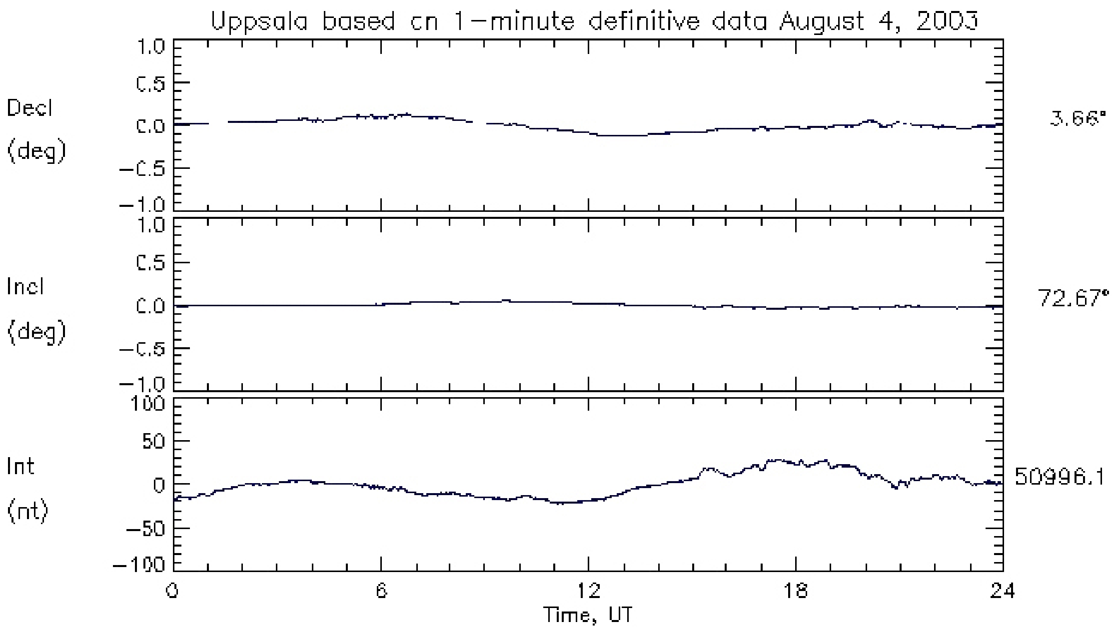

Figure A5-6. *Total earth magnetic field during logging KFM03B with Acoustic Televiewer. The upper curve shows the declination.*

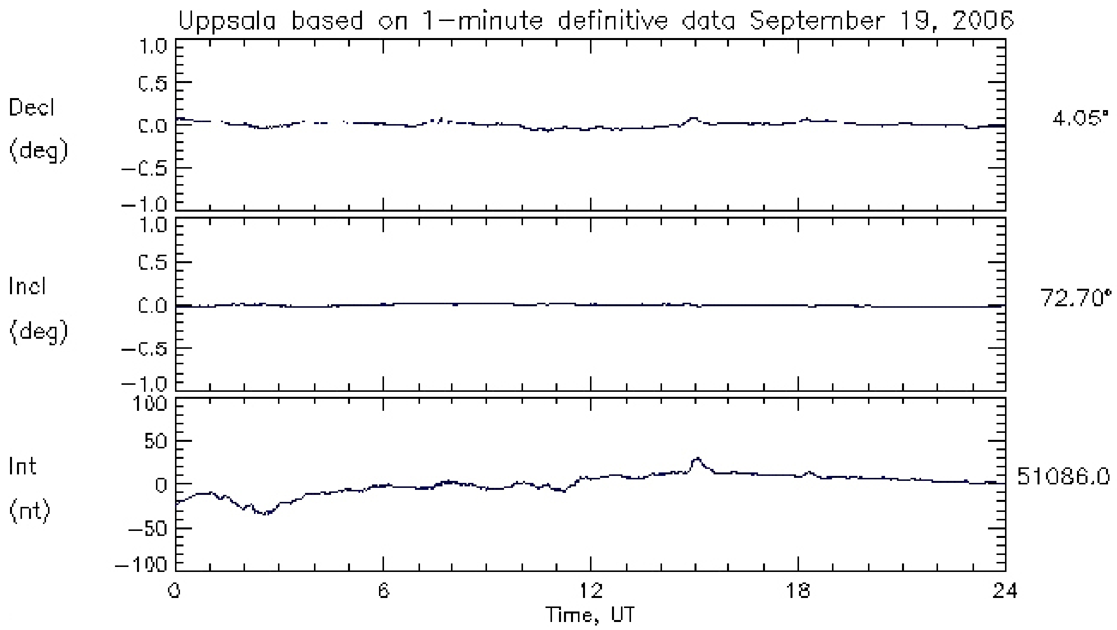

Figure A5-7. *Total earth magnetic field during logging KFM07C with Acoustic Televiewer. The upper curve shows the declination.*

Total earth magnetic field during logging with compass oriented BIPS-images

The earth magnetic field may disturb the reliability of the compass negatively. Of the components of the magnetic field, it is the variation in declination that affects the compass.

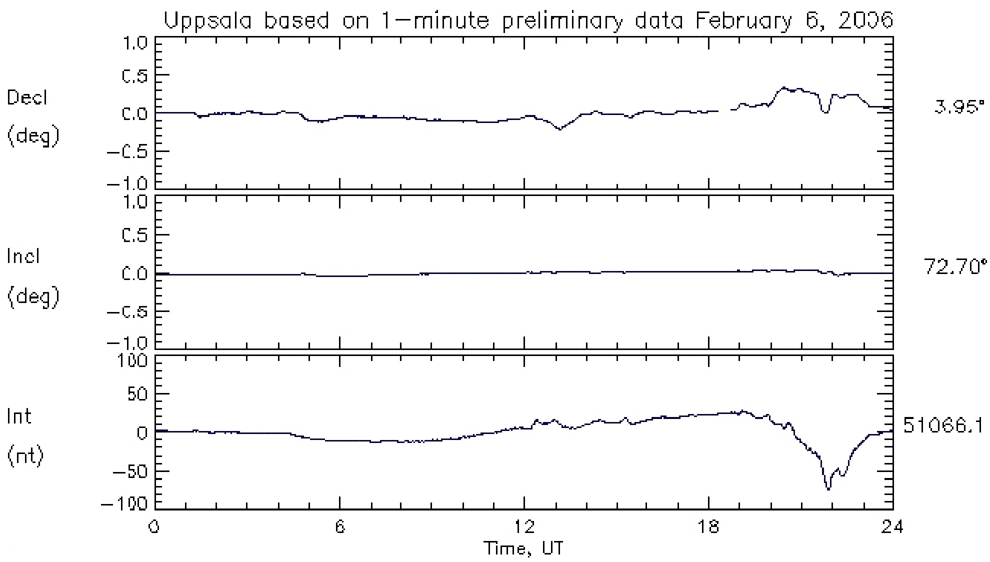

Figure A6-1. *Total earth magnetic field during logging with compass oriented BIPS-image in borehole KLX09B, 2006-02-06. The upper curve shows the declination.*

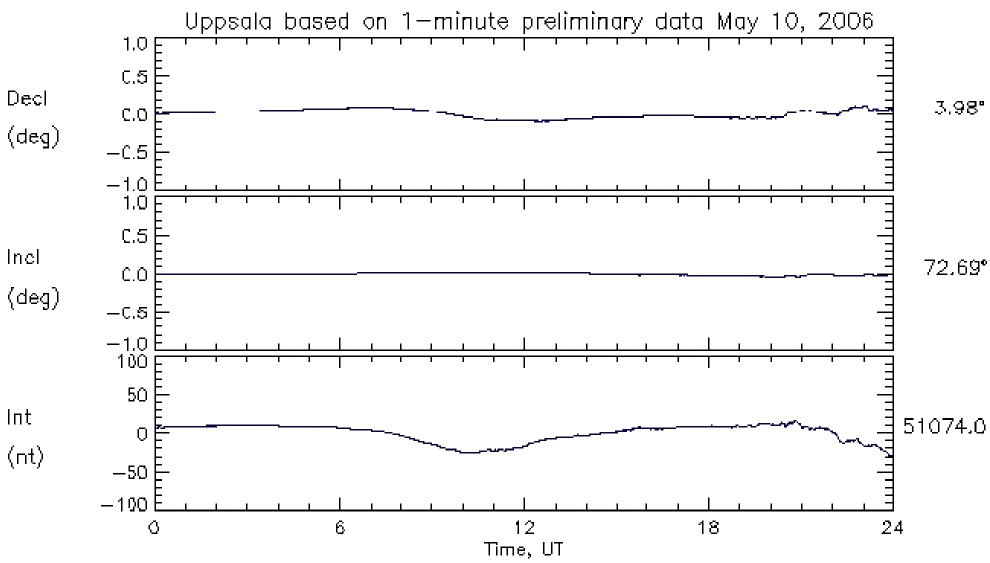

Figure A6-2. *Total earth magnetic field during logging with compass oriented BIPS-image in borehole KLX11B, 4–17.74 m, 2006-05-10. The upper curve shows the declination.*

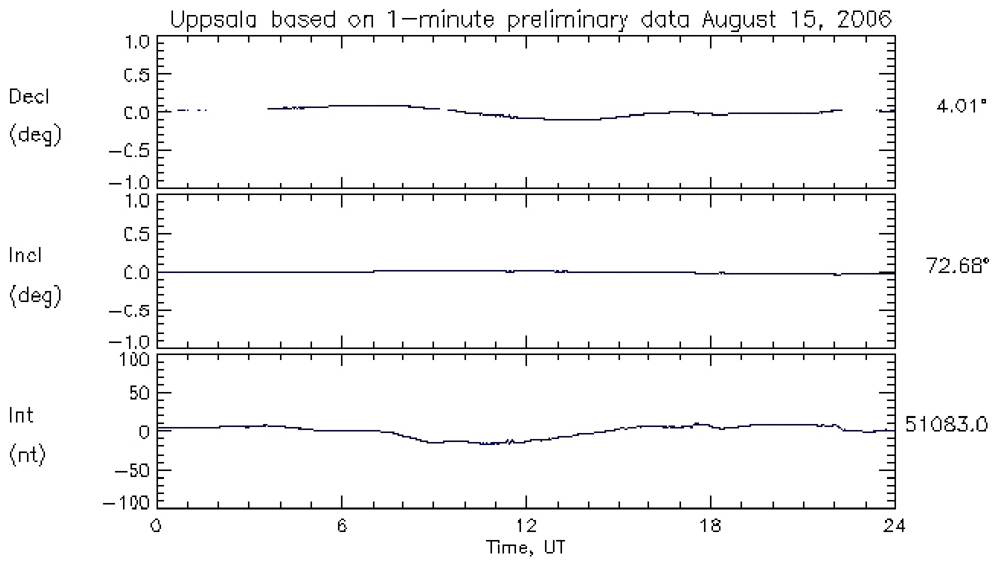

Figure A6-3. *Total earth magnetic field during logging with compass oriented BIPS-image in borehole KLX11B, 17.74–99.30 m, 2006-08-15. The upper curve shows the declination.*