P-07-105

Forsmark site investigation

Boremap mapping of telescopic drilled borehole KFM12A

Eva Samuelsson, Peter Dahlin,
Emil Lundberg, Gunnar Rauséus
Geosigma AB

Jesper Petersson, Ulf B Andersson, Peter Danielsson,
Jan Ehrenborg, Linda Lindström, Anders Wängnerud
Vattenfall Power Consultant AB

December 2007

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 250, SE-101 24 Stockholm
Tel +46 8 459 84 00

ISSN 1651-4416
SKB P-07-105

Forsmark site investigation

Boremap mapping of telescopic drilled borehole KFM12A

Eva Samuelsson, Peter Dahlin,
Emil Lundberg, Gunnar Rauséus
Geosigma AB

Jesper Petersson, Ulf B Andersson, Peter Danielsson,
Jan Ehrenborg, Linda Lindström, Anders Wängnerud
Vattenfall Power Consultant AB

December 2007

Keywords: Geology, Fractures, BIPS, Boremap, Drill core, AP PF 400-06-117.

Abstract

This report presents the results from the Boremap mapping of core drilled borehole KFM12A located at drill site 12 in the Forsmark candidate area. Drill site 12 (DS 12) is situated to the south west of the tectonic lens, the candidate area for deposition of nuclear waste. The borehole has a length of 601.04 m and was drilled with the bearing 36° and the inclination –60.6°. The aims of the drilling were to receive lithological and structural data of the rock volumes in the Forsmark zone.

The dominant rock type in KFM12A is a generally foliated metagranodiorite (~ 52%) followed by a pegmatite or pegmatitic granite (~ 12%), foliated amphibolite (~ 10%), cataclastic rock (~ 10%) and felsic to intermediate volcanic rock (~ 9%). Subordinate rock types are fine- to medium-grained granite (~ 4.6%), diorite, quartz diorite and gabbro (~ 4%), fine- to medium-grained metagranitoid (~ 3%), metatonalite to granodiorite (~ 3%) and calc-silicate rock (1%). Subordinate rock types comprise aplitic metagranite (< 1%), quartz-dominated hydrothermal veins (< 1%), breccia (< 1%) and sedimentary rock (< 1%).

The borehole shows fracture frequencies of 3.9 open and partly open fractures/m (crush excluded) and 9.2 sealed fractures/m (sealed fracture networks excluded). KFM12A has a generally high fracture frequency but shows a dense concentration of fractures in the following intervals: 145–154 m, 204–219 m, 256–260 m, 345–366 m and 375–392 m. Alteration most dominantly occurs between c. 190 m and 400 m, where the rock generally is affected by oxidation, epidotization and silicification. Other alteration types are present but occurs more sporadically.

Sammanfattning

Denna rapport redovisar resultatet från Boremapkartering av kärnborrhålet KFM12A vid borrplats 12 utanför Forsmark kandidatområde. Borrplats 12 är beläget sydväst om den tektoniska linsen, som har utvalts att vara kandidatområde för deponering av kärnavfall. Borrhålet är 601,04 meter långt och är borrat med bäringen 36° och inklinationen –60,6°. Syftet med borrningen är att erhålla litologi- och strukturdata för bergvolymen i Forsmarkzonen.

Den dominerande bergarten i KFM12A är en generellt folierad metagranodiorit (~ 52 %), följt av pegmatit till pegmatitisk granit (~ 12 %) och folierad amfibolit (~ 10 %), kataklastisk bergart (~ 10 %) och felsisk till intermediär metavulkanit (~ 9 %). Underordnade bergarter är fin- till medelkornig granit (~ 4.6 %), metadiorit-gabbro (~ 4 %), fin- till medelkornig metagranitoid (~ 3 %), metatonalit till granodiorit (~ 3 %) och kalksilikatbergart (~ 1 %) såsom mindre förekomster av aplitisk metagranit (< 1 %), kvartsdominerade hydrotermala gångar (< 1 %), breccia (< 1%) och sedimentär bergart (< 1 %).

Borrhålet uppvisar en sprickfrekvens på 3,9 öppna och delvis öppna sprickor/m (krossar exkluderade) och 9,2 läkta sprickor/m (läkta spricknätverk exkluderade). KFM12A har en generellt hög sprickfrekvens men visar även en koncentration av sprickor i följande intervall: 145–154 m, 204–219 m, 256–260 m, 345–366 m and 375–392 m. Omvandlingar är mest förekommande mellan ca 190 och 400 m där bergarten generellt sett är påverkad av oxidation, epidotisering och kiselomvandling. Andra omvandlingstyper förekommer, men sporadiskt.

Contents

1 Introduction

This document reports the data gained by the Boremap mapping of the core drilled borehole KFM12A, which is one of the activities performed within the site investigation at Forsmark. The work was carried out in accordance with activity plan AP PF 400-06-117. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

Original data from the reported activity are stored in the primary database Sicada, where they are traceable by the Activity Plan number (AP PF 400-06-117). Only data in SKB's databases are accepted for further interpretation and modelling. The data presented in this report are regarded as copies of the original data. Data in the databases may be revised, if needed. Such revisions will not necessarily result in a revision of the P-report, although the normal procedure is that major data revisions entail a revision of the P-report. Minor data revisions are normally presented as supplements, available at www.skb.se.

The borehole KFM12A was drilled from drill site 12 (DS 12), approximately 3 km to the south-west of the candidate area which is of interest for future nuclear waste disposal (Figure 2-1) /1/. The borehole was drilled in order to receive lithological and structural data of the rock volumes in the Forsmark zone.

The drilling of KFM12A was finished on Mars 9th, 2007 /4/. The Boremap mapping of the borehole started on March 29th and was finished on May 15th. Some details in the mapping were revised on June 20th.

The geological documentation of core drilled boreholes according to the Boremap method is based on the use of BIPS-images of the borehole wall and the simultaneous study of the drill core. Position, aperture and orientation of features are based on the adjusted BIPS-image, while other data such as rock type, alteration, fracture mineralogy and surface are observed in the drill core. The Boremap mapping will be used for further 3D-modelling in the Forsmark area.

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

Activity plan	**Number**	**Version**
Boremapkartering av kärnborrhål KFM12A	AP PF 400-06-117	1.0
Method descriptions	**Number**	**Version**
Metodbeskrivning för Boremapkartering	SKB MD 143.006	2.0
Mätsystembeskrivning för Boremap	SKB MD 146.001	1.0
Nomenklatur vid Boremapkartering	SKB MD 143.008	1.0
Instruktion: Regler för bergarters benämningar vid platsundersökningen i Forsmark	SKB MD 132.005	1.0

2 Objective and scope

The aim of this activity was to document lithologies, alterations, ductile structures and the occurrence and character of fractures in the bedrock penetrated by the core drilled borehole KFM12A. The detailed documentation will be used in 3D-modelling of the area.

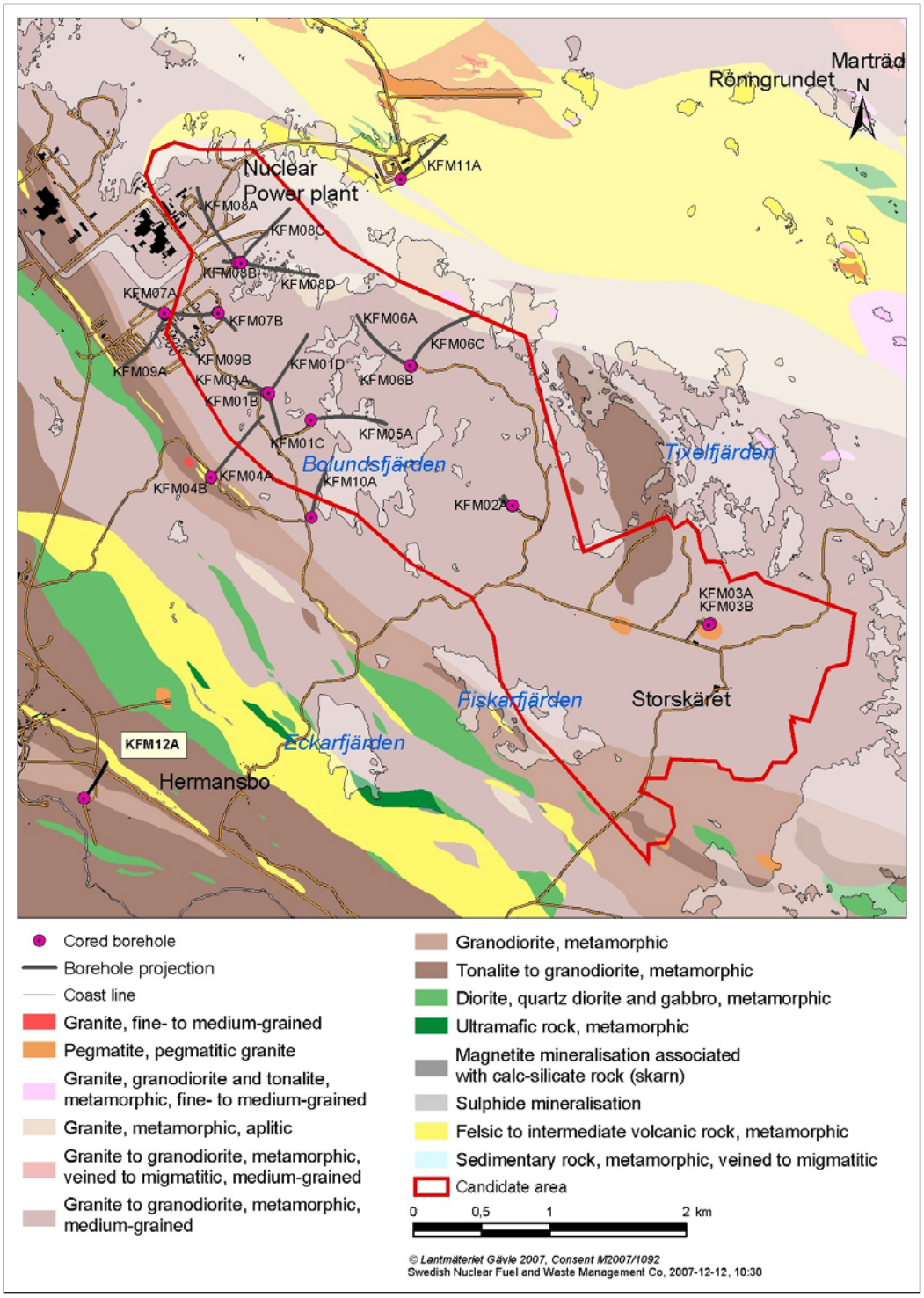


Figure 2-1. *Location of borehole KFM12A.*

3 Equipment

3.1 Description of equipment and interpretation tools

Mapping of BIPS-images and drill core was performed with the software Boremap v. 3.9.2.0. The Boremap software is loaded with the bedrock and mineral standard used for surface mapping at the Forsmark investigation site to enable correlation with the surface geology. The Boremap software calculates actual directions (strike and dip) of planar structures penetrated by the borehole (foliations, fractures, fracture zones, rock contacts etc). Data on inclination, bearing and diameter of the borehole are used as in-data for the calculations (Table 4-2, Appendix 2). The BIPS-image lengths were calibrated (Table 4-1).

Additional software used during mapping are BIPS Image Viewer and MicroSoft Access 2002. The schematic data presentation was made in WellCad v. 4.0.

The following equipment was used to facilitate the core documentation: folding rule, 10% hydrochloric acid, rock hardness tool/scratcher, hand lens, paintbrush and tap water.

3.1.1 BIPS-image quality

The following factors may disturb the mapping:

1) blackish coatings probably related to the drilling equipment,
2) vertical bleached bands from the drill cuttings in suspension,
3) light and dark bands at high angle to the borehole related to the automatic aperture of the video camera,
4) vertical enlargements of pixels due to stick-slip movement of the camera probe.

The BIPS-image of KFM12A suffers from blackish coatings from the drill rod and dark bands of unknown origin, mostly on the right side of the borehole image. The BIPS-image quality is listed in Table 3-1.

Table 3-1. BIPS-image quality.

From	To	% visible	Comment
61.40	71.00	40	Acceptable. The borders of the the image is diffuse due to sediments. Rusty spiral pattern caused by the the drill rod. White strips parallel to the borehole, probably due to water or scratches on the window of the camera probe.
71.00	76.40	60	Good. The borders of the the image is diffuse due to sediments. Semitransparent rusty spiral pattern caused by the the drill rod. Thin parallel lines with a rusty apperance which cuts the image with an angle of ap. 45°. White strips parallel to the borehole, probably due to water or scratches on the window of the camera probe.
76.40	93.80	80	Good. The borders of the the image is diffuse due to sediments. Thin widely spaced parallel lines with a rusty apperance which cuts the image with an angle of ap. 45°. White strips parallel to the borehole, probably due to water or scratches on the window of the camera probe.
93.80	177.70	80	Good. The borders of the the image is diffuse due to sediments. White strips parallel to the borehole, probably due to water or scratches on the window of the camera probe.
177.70	241.30	60	Acceptable. The borders of the the image is very diffuse due to sediments. White strips parallel to the borehole, probably due to water or scratches on the window of the camera probe.
241.30	244.50	60	Acceptable. The borders of the the image is very diffuse due to sediments. Thin parallel lines with a rusty apperance which cuts the image with an angle of ap. 45°. White strips parallel to the borehole, probably due to water or scratches on the window of the camera probe.
244.50	312.50	60	Acceptable. Acceptable. The borders of the the image is very diffuse due to sediments. White strips parallel to the borehole, probably due to water or scratches on the window of the camera probe.
312.50	363.60	70	Good. The borders of the the image is diffuse due to sediments. Semi-transparent rusty spiral pattern caused by the the drill rod. Thin parallel lines with a rusty apperance which cuts the image with an angle of ap. 45°. White strips parallel to the borehole, probably due to water or scratches on the window of the camera probe.
363.60	380.60	90	Good. The whole image is covered by a very thin veil of sediments. The image is somewhat striped due to elongated pixels in the borehole direction. White strips parallel to the borehole, probably due to water or scratches on the window of the camera probe.
380.60	496.05	90	Good. The borders of the the image is diffuse due to sediments. White strips parallel to the borehole, probably due to water or scratches on the window of the camera probe.
496.05	496.20	0	Bad. Horizontall, parallel, closely spaced lines with a rusty apperence.
496.20	498.10	90	Good. The borders of the the image is diffuse due to sediments. White strips parallel to the borehole, probably due to water or scratches on the window of the camera probe.
498.10	499.30	60	Acceptable. The borders of the the image are diffuse due to sediments.Thin parallel lines with a rusty apperance which cuts the image with an angle of ap. 45°.
499.30	500.45	80	Acceptable. Dark right side of image probably because camera has not been centralized.
500.45	571.25	95	Good. The borders of the the image is diffuse due to sediments.
571.25	598.52	65	Good. The borders of the the image is very diffuse due to sediments.

4 Execution

4.1 General

Boremap mapping of the drill core KFM12A was performed and documented in accordance with the activity plan AP PF 400-06-117 (SKB, internal document) and the method description for Boremap mapping (SKB, MD 143.006, Version 2.0, Metodbeskrivning för Boremap-kartering, SKB, internal controlling document). The mapping was preceded by an overview documentation of the geology in the borehole by Kenneth Åkerström. All observations are made on ocular inspection, since no other data were available.

The mapping was performed between Mars 29th and May 15th in 2006 by Eva Samuelsson, Gunnar Rauséus, Emil Lundberg and Peter Dahlin from Geosigma AB together with Anders Wängnerud, Peter Danielsson, Jan Ehrenborg, Ulf B Andersson, Linda Lindström from Vattenfall Power Consulting. The general lithology was mapped in advance on a simple mapping sheet by Jesper Petersson, VPC. This mapping sheet was used as a guideline during the detailed Boremap mapping of the borehole. The intervals 60.205–61.39 m and 598.52–600.95 m were mapped without BIPS-image (Table 4-2).

4.2 Preparations

The length registered during the BIPS-logging deviates from the true length, which usually increases with depth. Therefore length adjustment of the BIPS-image was made using reference slots cut into the borehole wall. The slots are cut at approximately every 50th metre and with reference to the end of casing (see Table 4-1). However, the adjusted length may still deviate from the numbers given in the drill core boxes, as the core recovery may yield erroneous lengths.

Geometrical data for the borehole is given in Table 4-2. Background data (Appendix 2) prior to the Boremap mapping included:

- Borehole diameter.
- Reference slots for length adjustments.
- Borehole deviation.

Table 4-1. Length adjustments.

Rec. length (m)	Adj. length (m)	Difference (m)
100.007	100.000	–0.007
149.921	150.000	+0.079
199.834	200.000	+0.166
250.669	251.000	+0.692
299.608	300.000	+0.392
349.512	350.000	+0.488
399.386	400.000	+0.614
450.213	451.000	+0.787
499.196	500.000	+0.804
549.091	550.000	+0.909

Table 4-2. Borehole data for KFM12A.

Mapping interval	Northing	Easting	Bearing (°)	Inclination (°)	Diameter (mm)	Borehole length (m)	BIPS-image interval (m)	End of casing
60.205–61.39			036	–60.6	86		No image	61.39
61.39–598.52					77		61.00–598.52	
598.52–600.95					77	601.04	No image	

4.3 Execution of measurements

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

4.3.1 Fracture definitions

Definitions of different fracture types and apertures, crush zones and sealed fracture network are found in SKB MD 143.008 (Nomenklatur vid Boremapkartering, internal controlling document).

Two types of fractures are mapped in Boremap; broken and unbroken. Broken fractures are fractures that split the core while unbroken fractures do not split the core. All fractures are described with their fracture minerals and other characteristics, e.g. width, aperture and roughness. Visible apertures are measured down to 1 mm in the BIPS-image. Smaller apertures, which are impossible to detect in the BIPS-image, are denoted a value of 0.5 mm. If the core pieces do not fit well, the aperture is considered “probable”. If the core pieces do fit well, but the fracture surfaces are dull or altered, the aperture is considered “possible”.

All fractures with apertures > 0 mm are treated as open in the SICADA database. Only few broken fractures are given the aperture = 0 mm. Unbroken fractures usually have apertures = 0 mm. Unbroken fractures that have apertures > 0 mm are interpreted as partly open and are included in the open-category in SICADA. Open and sealed fractures are finally frequency calculated and shown in Appendix 1.

4.3.2 Fracture alteration and joint alteration number

Joint alteration number is principally related to the thickness of, and the clay content in a fracture /2/. Over 1 mm thick fractures rich in clay minerals are usually given joint alteration numbers between 2 and 4. The majority of the broken fractures are very thin to extremely thin and seldom contain clay minerals. These fractures receive joint alteration numbers between 1 and 2.

A subdivision of fractures with joint alteration numbers between 1 and 2 was introduced to facilitate both the evaluation process for fracture alterations and the possibility to compare the alterations between different fractures in the boreholes. The subdivision is in accordance with the subdivision introduced by Ehrenborg and Steiskal /3/. This is not valid for the section 300–598 m.

4.3.3 Mapping of fractures not visible in the BIPS-image

Not all fractures are visible in the BIPS-image, and these fractures are oriented using the *guideline method* /3/, with one modification. The orientation performed in this work is based on the following data:

- Amplitude (measured along the drill core) which is the interval between fracture extremes along the drill core.

- The relation between the rotation of the fracture trace and a well defined structure visible in both drill core and BIPS-image. This rotation is measured with measuring tape on the drill core.
- Absolute depth relative to a well defined structure visible in both drill core and BIPS-image.

The fractures mapped with *the guide-line method* are mapped as "non-visible in BIPS" and can therefore be separated from fractures visible in BIPS which probably have a more accurate orientation. The use of *the guide-line method* is not valid for the section 300–598 m.

4.3.4 Definition of veins and dikes

A rock sequence that covers less than 1 m of the drill core is mapped as a "rock occurrence" in Boremap. Rock occurrences that cover more than 1 m of the drill core are mapped as a separate *rock type.*

Chiefly two different types of rock occurrences are mapped: veins and dikes. If the rock occurrence cannot be classified as a vein or a dyke, the occurrence type is mapped as "unspecified". In Forsmark there are boudinated veins, xenoliths, blobs etc and the occurrence type is usually difficult to determine from the drill core.

4.3.5 Mineral codes

In cases where properties or minerals are not represented in the mineral list, the following mineral codes have been used in the mapping of KFM12A. This is not valid for the section 300–598 m.

- X1 = Bleached fracture walls.
- X2 = Interpreted grouting, which is only observed in the borehole wall and hence in the BIPS-image (not used in this borehole).
- X3 = The drill core is broken at a right angle and the broken surfaces have a polished appearance. This is caused by rotation of two core pieces along an intermediate fracture wearing away possible mineral filling. It is impossible to say whether this fracture was open or sealed in situ.
- X4 = Dull fracture surface, no visible fracture mineral.
- X5 = Fresh fracture surface, no detectable fracture mineral.
- X6 = Striated surfaces, probably slickensided.
- X7 = Saussurite.
- X8 = Analcime.

4.4 Data handling

In order to obtain the best possible data security, the mapping was performed on the SKB network, with regular back-ups on the local drive in accordance with the consultants' quality plan. Each day, a summary report was printed in order to find possible misprints. If misprints were observed, they were corrected before the mapping proceeded. When the mapping was completed, data was checked once more for possible misprints. Before exporting data to SICADA, borehole lengths, mapping lengths, deviation data and length adjustments were checked again where after the mapping was checked by a routine in Boremap which detects logical defects.

4.5 Nonconformities

4.5.1 Late in-data

Not all necessary in-data were available in the SICADA database when the mapping was to start. Lacking technical data such as depth adjustments were updated in SICADA during mapping.

4.5.2 Core loss

No core loss was documented in KFM12A.

4.5.3 Overrepresented fracture mineral

The frequency of calcite in fractures is overrepresented relative to other minerals, since it is detected by reaction with diluted hydrochloric acid even though it is macroscopically invisible.

4.5.4 Fracture roughness and surface

The estimation of roughness of fractures in this work diverges rather much from the mappings by Vattenfall Power Consultant. For example: Geosigma considers over half of the fractures as undulating, while the rest are stepped, planar and irregular. The proportion of planar, undulating, stepped and irregular fractures in the mappings of Vattenfall Power Consultant is different. This is because the personal interpretation of the definitions of fractures /5/, since the definitions are made for another scale, i.e. tunnels and excavations, and not for boreholes.

4.5.5 Foliation intensity

The intensity of the foliation was partly controlled by the general mapping done by Jesper Petersson. This resulted in sections with high strain were given higher foliation intensity. In earlier mappings borehole intervals with foliation intensity that would be mapped as medium with medium grain-size by Vattenfall Power Consultant were mapped as weak with fine- to medium grain-size by Geosigma. The reduction in grain size is, according to VPC, a sign of higher strain and should therefore be mapped with larger foliation intensity. This is why, in earlier mappings, the change in strain is clearer in the work done by VPC. These differences are now corrected so that Geosigma follows the same method for interpretation of foliation intensity as VPC.

5 Results

The Boremap mapping of KFM12A is stored in SICADA and it is only these data that shall be used for further interpretation and modelling. The interpreter should be aware of the assumptions mentioned in Chapter 4.

Results from the Boremap mapping are briefly described in this chapter and the graphical presentation of the data is given in Appendix 1 (WellCad-diagram).

5.1 Lithology

5.1.1 General

Borehole KFM12A is located about 3 km southwest of the Forsmark site investigation area in a ductile, high-strain belt of predominantly metagranodiorite. It was drilled more or less perpendicular to the structural trend in the area into the NW–SE striking Forsmark deformation zone (ZFMNW004), which separates rock domain 24 and 30 /cf 1/. In the drill core, the zone is manifested by an interval of strongly cataclastic rock (rock code 108003) between 286 and 338 m length. Virtually all protolith information in this intervals are masked or have been obliterated by extensive alteration and cataclasis. The most common rock type elsewhere in the borehole is a fine- to medium-grained metagranodiotite (rock code 101056), which locally tends to be tonalitic. Additional rock types that form continuous occurrences of volumetric importance are metagabbro/diorite (rock code 101033), amphibolite (rock code 102017), fine- to finely medium-grained granite (rock code 111058) and, in the lowermost 200 m of the borehole, felsic to intermediate rocks of inferred volcanic origin (rock code 103076). An extensive occurrence of pegmatitic granite (rock code 101061) appears at 267–285 m length. Other frequent rock types, none forming occurrences more than a few metres in borehole length, are a few skarn-like rocks (rock code 108019) as well as dykes and veins of pegmatites, pegmatitic granite (rock code 101061) and fine- to finely medium-grained granitoids (rock code 101051), generally of granodioritic to tonalitic composition. Except for a few minor late veins, all rocks have experienced Svecofennian metamorphism under amphibolite facies conditions.

5.1.2 Rock types

Metagranodiorite (101056) are by far the most widespread rock type in the borehole. However, the textural character is changing throughout the borehole. In the uppermost part, down to 145 m length, it is typically K-feldspar porphyritic and medium-grained. Below that level it becomes abruptly equigranular and tends to be more fine- to finely medium-grained. Further down, below the cataclastic rock at 285–338 m length, it appears even more fine-grained, due to deformational grain-size reduction. The colour of the rock ranges from greyish red to grey. Compositionally, it is typically granodioritic locally with a tendency to be tonalitic. An interval at between122.85–124.86 m and a number of intervals between 536 m and 571 m length are clearly tonalitic, and were hence mapped as metamorphic tonalite to granodiorite (101054).

Except for some skarn-like material, mafic rocks within KFM12A are either registered as amphibolite (102017) or as metagabbro/diorite (101033). Generally, the amphibolites are fine-grained, equigranular with a large proportion of biotite, whereas the inferred metagabbro/diorite tends to be more medium medium-grained and texturally more well-preserved. There is, however, a considerable variability in the textural and structural character of the rocks and the distinction between the two varieties is not always clear. Most lacks compositional banding and all contacts are more or less parallel with the tectonic fabric. Various sulphides, primarily pyrite, have been identified in a few occurrences. Individual occurrences ranges typically up to a few

metres in borehole length. The most extensive interval of amphibolite, exceeding 11 m, occurs at 179.99–191.26 m length, whereas the longest intervals of inferred metagabbro/diorite occur at 342.37–348.62 and 363.56–370.70 m length.

Felsic to intermediate metavolcanic rocks (103076) are generally restricted to the lower half of the borehole, below 340 m length. The rock is generally equigranular, dark grey to reddish grey in colour and all contacts are parallel with the tectonic fabric. A few occurrences show a fine-scale compositional banding, but most are structureless, and except for the grain-size, there is no textural or structural macroscopic feature that unambiguously points towards a volcanic origin of the rocks. Moreover, there are two intervals of inferred volcanic breccia at 524.03–524.78 and 527.42–527.88 m length. Some of the more homogeneous varieties are difficult to distinguish from the fine-grained varieties of the metagranodiorite (101056) or even the fine- to finely medium-grained metagranitoids (101051), as described below. The most extensive interval of inferred metavolcanic rock, with a continuous borehole length of about 19 m, occurs at 570.25–589.45 m length.

Occurrences of fine- to medium-grained metagranitoids (101051) of mostly granodioritic to tonalitic composition are found sporadically throughout the borehole. Individual occurrences range up to a few metres in borehole length, though the majority is less than one metre. These rocks are equigranular, locally slightly feldspar porphyritic and ranges from dark grey to reddish grey in colour. The mineral fabric is commonly linear and external contacts are typically discordant to the tectonic foliation in the wall rock.

The occurrence of fine- to medium-grained granite (111058), which locally is highly reminiscent of the fine-to medium-grained metagranitoid, is generally restricted to the upper and lower hundred metres of the borehole. Six occurrences exceed one metre in borehole length. The other are typically a few decimetres in length. Similar to the granodioritic to tonalitic metagranitoids (101051), they are equigranular with linear mineral fabric and discordant external contacts. A distinctive criterion apart from their granitic composition and late-tectonic character is their anomalously high natural gamma radiation relative to the granodioritic to tonalitic metagranitoids /7/.

Dykes, veins and segregations of pegmatite and pegmatitic granite are frequent throughout KFM12A. Most occurrences are some decimetre or less and only four pegmatites/pegmatitic granites exceed one metre in borehole length. The most extensive occurrences of pegmatitic granite is about 18 m in borehole length and occurs at 266.97–285.04 m. The pegmatitic granites are generally texturally heterogeneous, often with a highly variable grain-size, and some occurrences include intervals of finely medium-grained, equigranular granite. Despite the textural variability and temporal span within this unit, most of these rocks were grouped as ‘pegmatite, pegmatitic granite’ (rock code 101061).

Aplitic metagranite (101058) occurs sporadically in the upper 200 m of the borehole and occurrences below that level are rare. Except for two occurrences at 72.96–74.98 and 146.61–148.18 m length, they are all a few decimetres in borehole length. All lithological contacts are parallel with the tectonic fabric.

The occurrence of skarn-like material (rock code 108019) is generally concentrated to the strongly cataclastic rock at 285–338 m length, which correspond to the Forsmark zone. Four decimetre-wide occurrences of skarn-like material have been found outside this interval. The rock is distinguished by the high content of epidote. Other frequent components are quartz, whitish feldspar, hornblende and magnetite.

In addition, there are a few minor occurrences of granite in KFM12A that not appear to fit into the bedrock nomenclature defined by SKB MD 132.005. Instead it was coded as 1058 (unspecified granite). Quartz-dominated segregations or veins were coded as 8021. A 6 mm wide occurrence of what appears to be a breccia or sedimentary rock at 314.12–314.13 m length was coded as 6000.

5.1.3 The cataclastic interval

The cataclastic rock (108003) occupies the length interval between 286.43 and 337.86 m of KFM12A. Generally, the interval can be separated into two units on the basis of mineral alteration and intensity of the cataclastic deformation. The contact between the two units is rather sharp and occurs at 312.49 m length. Both the alteration and cataclasis are extremely intense in the lower unit (312.49−337.86 m), rendering the recognition of primary mineralogy and texture impossible. Macroscopically, the rock appears to have been strongly affected by silicification and epidotization, combined with several generations fine-scaled cataclasis. The upper unit (286.43−312.49 m), on the other hand, is clearly less intensely affected by both the alteration and cataclastic processes. Local preservation of the primary metamorphic texture and mineralogy give hints of the protoliths. However, except for a few intervals characterised by high epidote content and silica density /7/, which were registered as calc-silicate rock (108019), all rocks have been mapped as cataclasite (108003). The predominant alteration types in this unit are inferred epidotization, chloritization and sassuritization.

5.2 Ductile deformation

Most rocks in KFM12A are characterized by a strong foliation combined with varying degrees of deformational grain-size reduction, especially in the lower half of the borehole below the cataclastic interval at 285–338 m length. Some rocks in the intensely deformed lower half show also a more or less pronounced compositional banding, which is parallel with the local foliation. The most intensely deformed intervals have been recorded as ‘ductile shear zones’. Most such occurrences are concentrated to an interval between 340 and 575 m length. The borehole length of individual zones is typically less than one decimetre, though the maximal recorded length is almost 4 m. In addition, there are a number of zones with a clearly brittle component, which are registered as ‘brittle-ductile shear zones’. They occur more sporadically throughout the borehole. The most extensive intervals, however, are found between 226 and 242 m length. The protolith in these, often highly deformed and grain-size reduced zones, seems mainly to be the metagranodiorite (101056), but all rock types recorded have been affected. Furthermore, there are three interval with centimetre-wide zones registered as mylonitic at 337.88–337.90, 374.12–384.42 and 449.05–452.89 m length.

Also a linear fabric component is distinguishable in some of the foliated rocks. This is most pronounced in the uppermost 120 m of the borehole, where it locally becomes more distinct than the foliation component. Some rocks, such as certain pegmatitic granites, the fine- to medium-grained metagranitoids (101051) and the fine to medium-grained granite (111058) are post-tectonic with respect to the main tectonic foliation, and are hence massive or show only a weak mineral lineation. It must, however, be emphasized that the distinctness of a fabric does not necessarily reflect the intensity of the strain. The fact that a rock may appear massive not always implicate that they actually are unaffected by strain. It is, for example, often difficult to distinguish tectonic fabric visually in the pegmatitic granites and some of the fine-grained mafic rocks. Furthermore, most rocks have undergone varying degrees of static recrystallization.

The structural orientation of the foliation and banding in KFM12A are rather consistent throughout the borehole, striking SE to SSE and dipping steeply towards the SW. Virtually all shear zones in the borehole are more or less parallel with the local tectonic foliation (Figure 5-1).

5.3 Alteration

The interval 188.37–337.86 m is dominated by oxidized rock, generally weak to moderately altered. One part of the interval, 286.92–337.86 m is affected by epidotization, silicification, saussuritization and chloritization as well as some minor occurrences of argillitization, carbonatization and sericitization. Vuggy granite is found in the interval 230.56–239.72 m

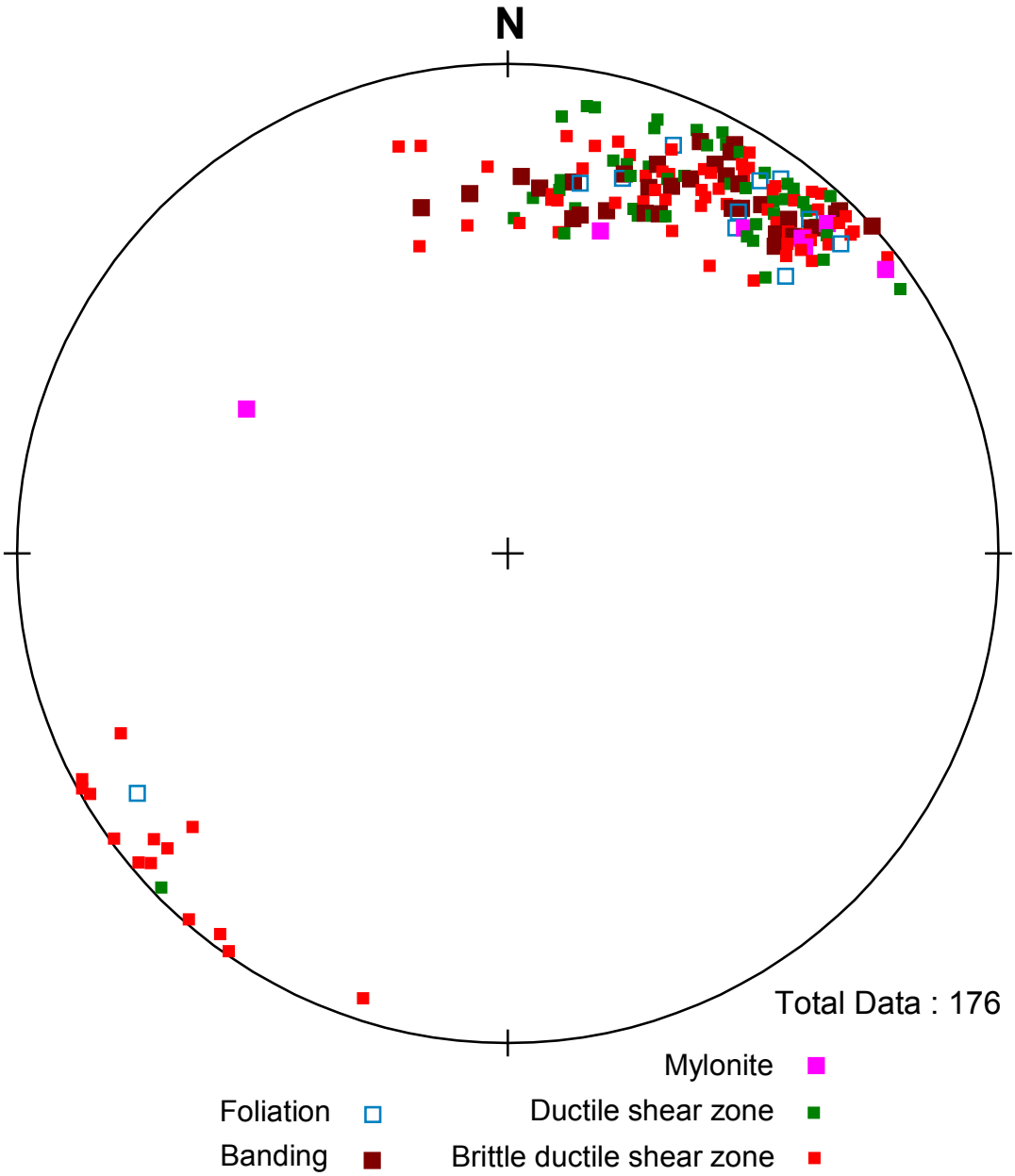


Figure 5-1. *Lower hemisphere, equal area stereographic projection showing poles to ductile and brittle-ductile structures in KFM12A.*

where the rock is affected by medium quartz dissolution, strong oxidation and minor occurrences of chloritization, argillitization and carbonatization. In the intervals 350.61–363.96 m and 372.83–400.52 m, the rock is affected by generally weak oxidation and faint to weak albitization. Two intervals between 419.07– 449.33 m and 499.48–532.60 m show faint to weak oxidation as well as minor occurrences of albitization, epidotization, albitization and saussuritization /6/. At 451.13 m a section with sericite altered rock has been observed. The intensity of the sericitization varies between faint and strong.

5.4 Fractures and crushed sections

A number of 4 415 unbroken and 2 642 broken fractures were documented in KFM12A (61.39–598.52 m). Of the unbroken fractures 32 show an aperture, while 567 of the broken fractures are considered artificial and have an aperture = 0. This result in the following interpreted fracture frequencies: 9.2 sealed fractures/m (sealed network excluded), 3.9 open fractures/m (crushed sections excluded) and 0.06 partly open fractures/m.

The open and sealed fractures are concentrated to the following intervals: 145–154 m, 204–219 m, 256–260 m, 345–366 m and 375–392 m. In these intervals a few fracture apertures range up to 3 mm and the fractures surface alteration are generally fresh. The joint alteration is higher in the last two sections with a value between 1.5 and 2. The peak in number of fractures is mostly an effect of a large number of sealed fractures. The most frequent fracture minerals are calcite, chlorite, laumontite, quartz and clay minerals.

There are 14 crushed sections in KFM12A. They occur at 128.08–128.10 m, 229.89–229.91 m, 273.98–274.05 m, 274.22–274.24 m, 274.59–274.94 m, 300.92–300.98 m, 310.74–310.78 m, 315.73–316.02 m, 326.18–326.19 m, 333.87–333.90 m, 371.14–371.25 m, 447.87–447.90 m, 514.35–514.38 m and 536.71–536.61 m. The crush zones are generally striking E-W with a dip ranging from sub-horizontal to sub-vertical. Dominating minerals in the crushed sections are calcite, chlorite, clay minerals and quartz. The first crushed section, 128.08–128.10 m, is highly altered.

KFM12A has a large number of sealed networks (244) ranging in width from 1 cm up to almost 23 m. Two of the large range sealed networks, 219.88–242.68 m and 286.38–294.11 m, coincide with a concentration of moderately altered open fractures. There are also a large number of sealed networks between 308 and 338 m covering approximately 29 m of the section. The mean piece length of this section is c. 17 mm.

5.5 Core discing and other probably drill induced features

Six sections of drill induced crushed core have been observed in KFM12A. The crushed core has visible markings from the drill rod and no mineral surfaces have been found, only fresh fracture surfaces with an irregular shape. Most of the drill induced crush has been observed between 274.05 and 275.56 m. Fractures in this interval that are visible in the BIPS-image but can not be correlated with any fracture surface in the core, have been mapped using default “feature details” and a separate comment is applied. These fractures have a correct orientation, but information about mineral filling and feature details are missing since it is impossible to find the individual fractures in the core. Also it is not defined if these fractures are considered sealed or open.

References

/1/ **SKB, 2005.** Preliminary site description, Forsmark area – version 1.2. SKB R-05-18, Svensk Kärnbränslehantering AB.

/2/ **Barton N, 2002.** Some new Q-value correlations to assist in site characterization and tunnel design. International Journal of Rock Mechanics & Mining Sciences Vol. 39 (2002), pp 185–216.

/3/ **Ehrenborg J, Steiskal V, 2004.** Oskarshamn site investigation. Boremap mapping of core drilled boreholes KSH01A and KSH01B. SKB P-04-01, Svensk Kärnbränslehantering AB.

/4/ **Claesson, L-Å, Nilsson, G, Ullberg, A 2006.** Forsmark site investigation. Drilling of the telescopic borehole KFM12A at drill site DS12. SKB P-07-46, Svensk Kärnbränslehantering AB.

/5/ **International Society for Rock Mechanics Commission on Standardization of Laboratory and Field Tests, 1978.** Suggested Methods for the Quantitative Description of Discontinuities in Rock Masses. International Journal of Rock Mechanics & Mining Sciences, Vol.15 (1978), pp 319–368.

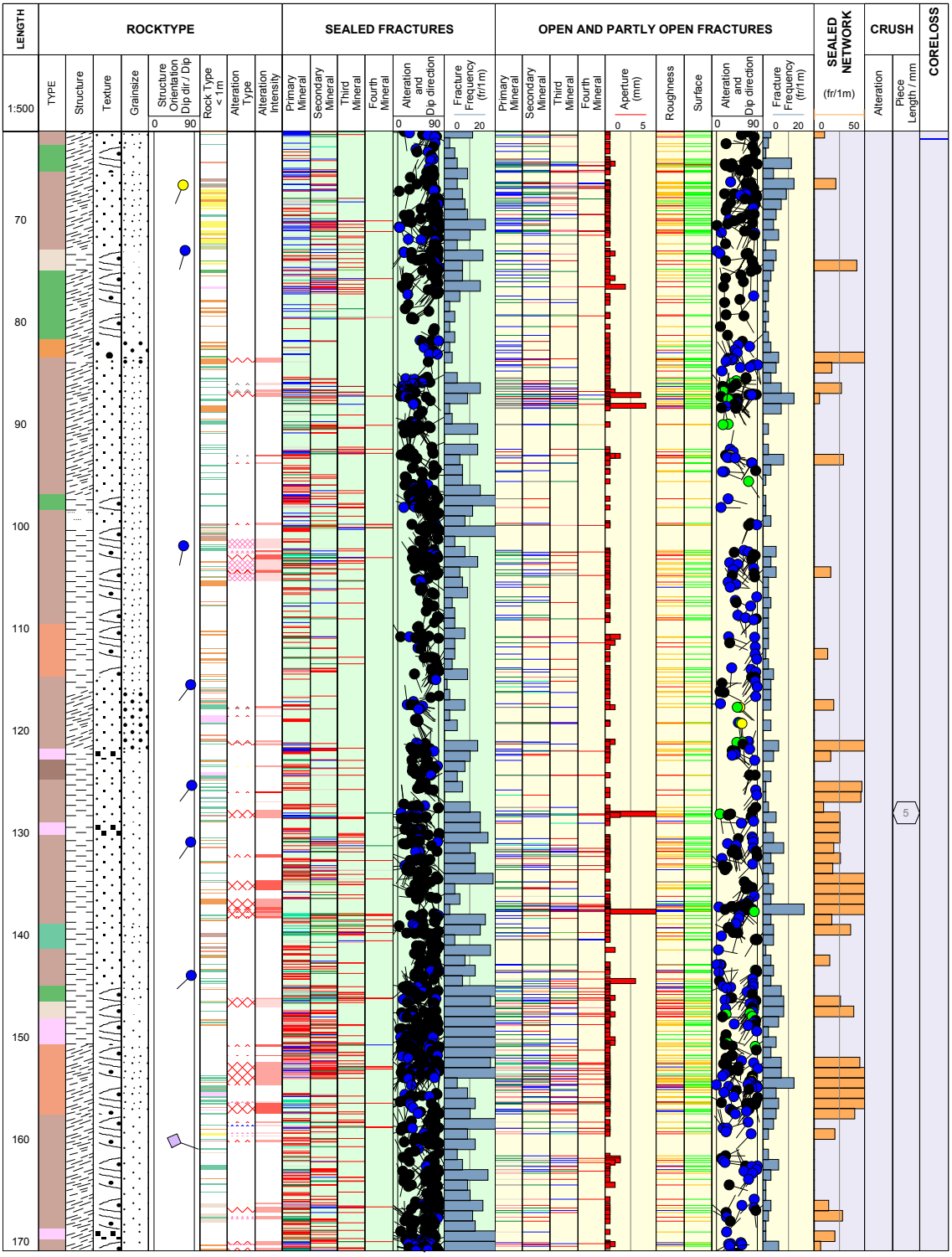
/6/ **Petersson J, Berglund J, Danielsson P, Skogsmo G, 2005.** Forsmark site investigation. Petrographic and geochemical characterisitics of bedrock samples from boreholes KFM04A–06A, and a whitened alteration rock. SKB P-05-156, Svensk Kärnbränslehantering AB.

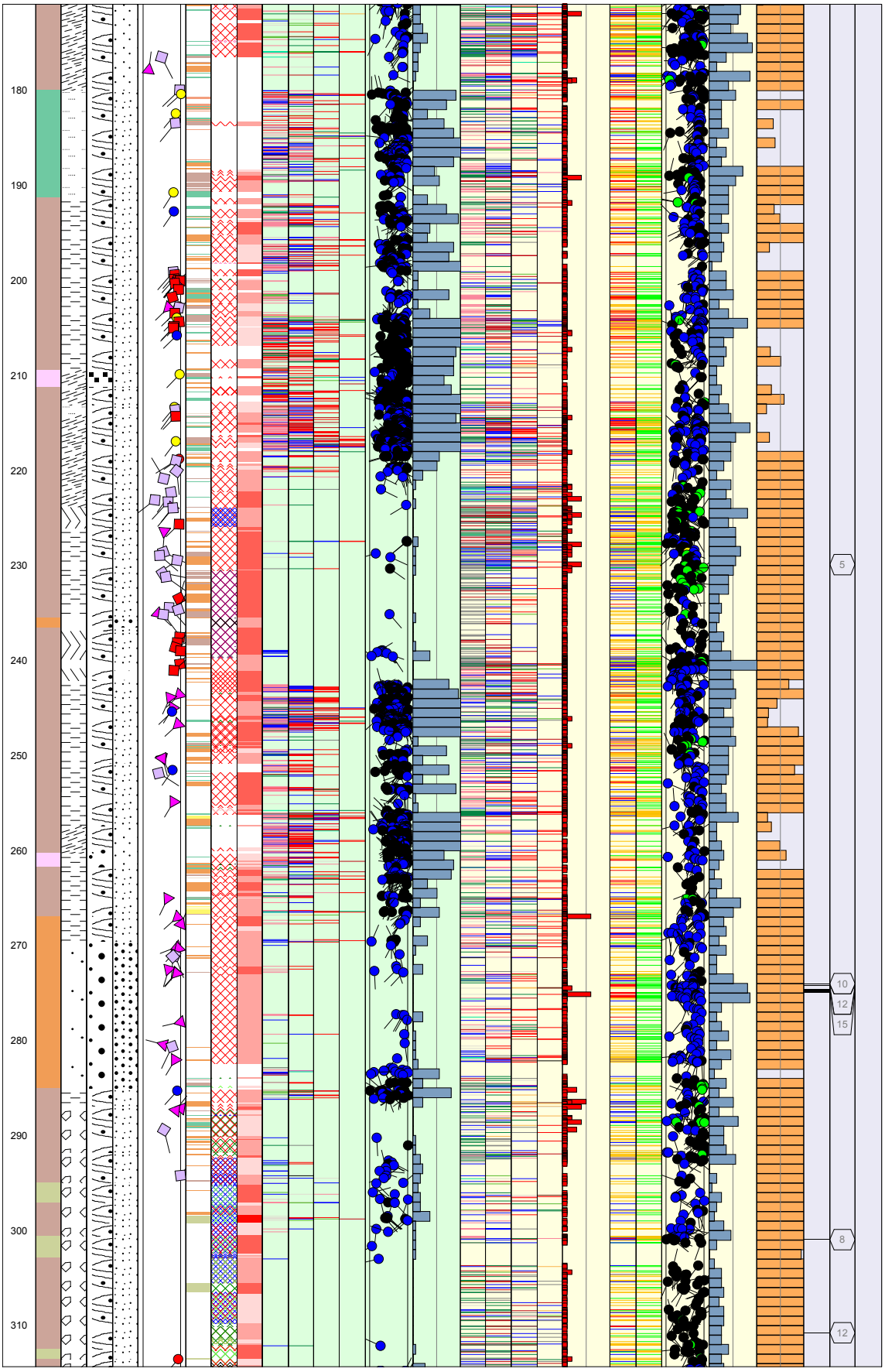
/7/ **Mattsson H, 2007.** Forsmark Site Investigation. Interpretation of geophysical borehole measurements from KFM12A. SKB P-07-129, Svensk Kärnbränslehantering AB.

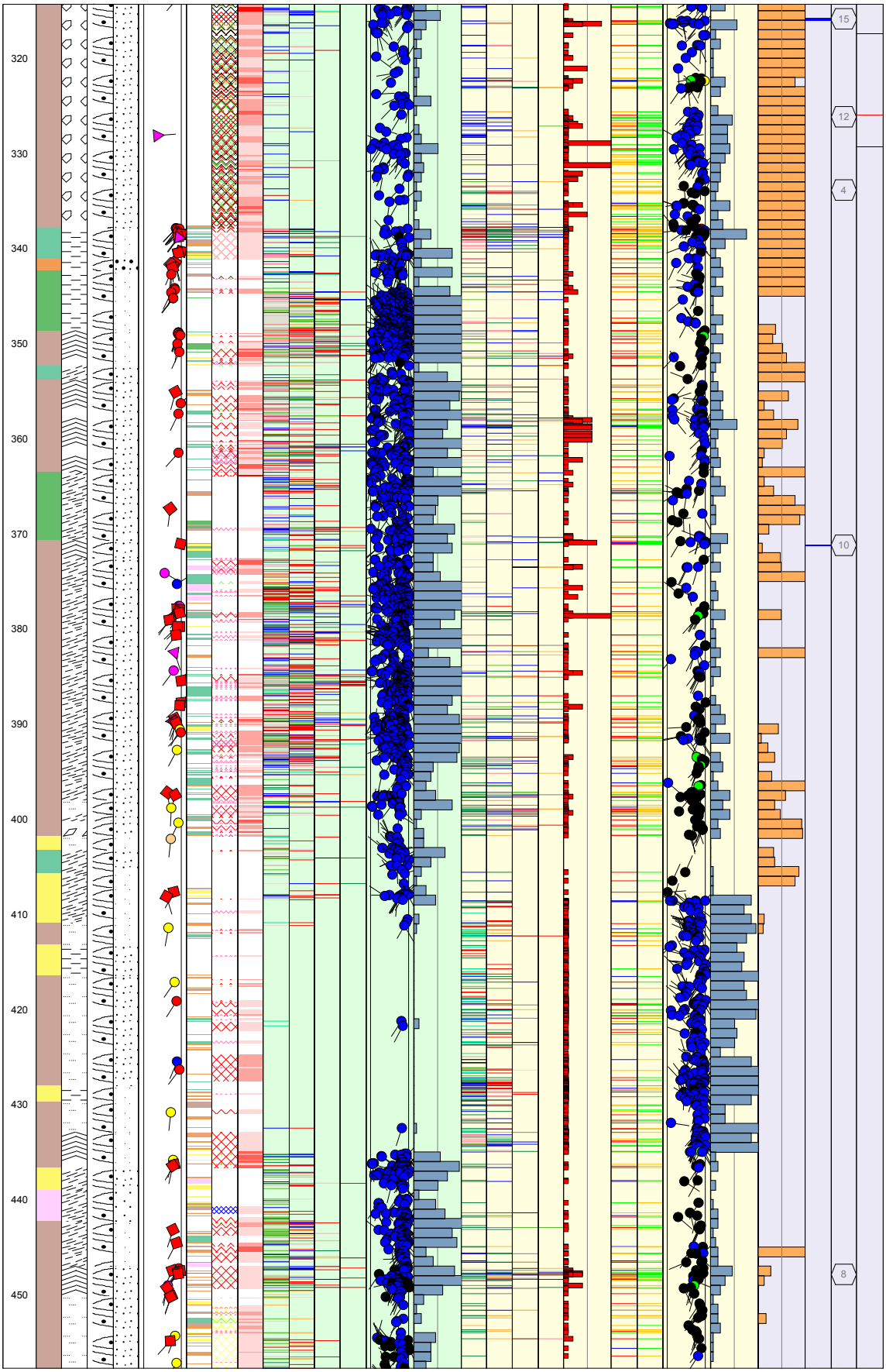
WellCad diagram of KFM12A

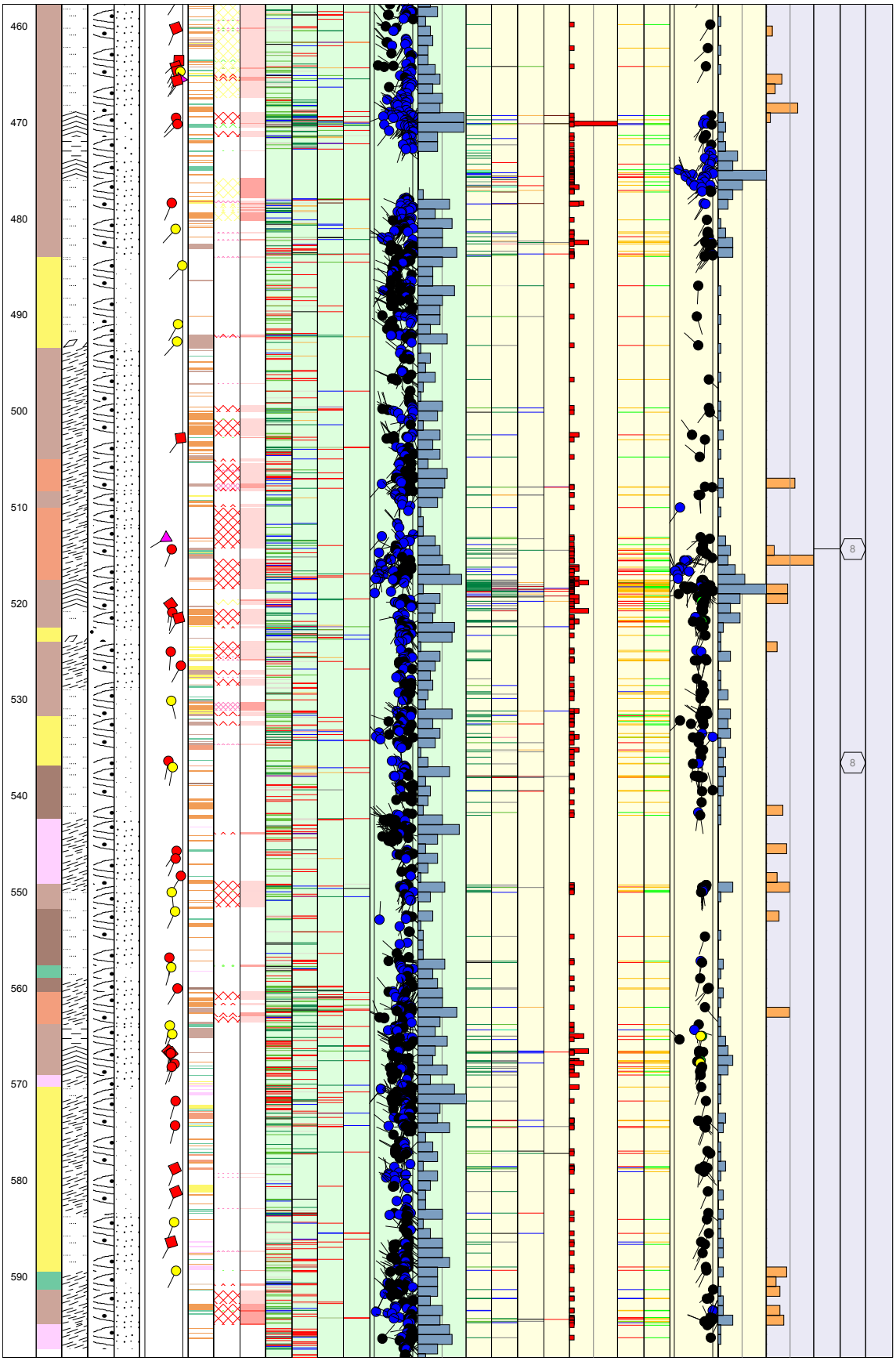
Title GEOLOGY IN KFM12A **Appendix: 1**

Site	FORSMARK	**Coordinate System**	RT90-RHB70
Borehole	KFM12A	**Northing [m]**	6696576.85
Diameter [mm]	77	**Easting [m]**	1630051.64
Length [m]	601.040	**Elevation [m.a.s.l.]**	10.74
Bearing [°]	36.20	**Drilling Start Date**	2007-02-22 00:00:00
Inclination [°]	-60.55	**Drilling Stop Date**	2007-03-12 00:00:00
Date of coremapping	2007-03-29 08:32:00	**Plot Date**	2007-09-26 22:05:32
Rocktype data from	p_rock	**Signed data**	




180
190
200
210
220
230
240
250
260
270
280
290
300
310
5
10
12
15
8
12


320
330
340
350
360
370
380
390
400
410
420
430
440
450
15
12
4
10
8


460
470
480
490
500
510
520
530
540
550
560
570
580
590
8
8

Appendix 2

Indata: length reference marks, borehole diameter and borehole length

Reference Mark T – Reference mark in drillhole

KFM12A, 2007-03-10 09:30:00 – 2007-03-10 15:30:00

Bhlen (m)	Rotation speed (rpm)	Start flow (l/h)	Stop flow (l/h)	Stop pressure (bar)	Cutter time (s)	Trace detectable	Cutter diameter (mm)	Comment	QC
100.00	400.00	500	250	40.0	53	ja		[101.05/101.15]	*
150.00	400.00	500	250	35.0	80	ja		[151.27/151.37]	*
200.00	400.00	500	250	35.0	46	ja		[201.52/201.62]	*
251.00	400.00	500	250	35.0	49	ja		[252.73/252.83]	*
300.00	400.00	500	250	35.0	58	ja		[301.94/302.04]	*
350.00	400.00	500	250	35.0	45	ja		[352.19/352.29]	*
400.00	400.00	500	250	35.0	53	ja		[402.37/402.47]	*
451.00	400.00	500	250	35.0	51	ja		[453.61/453.71]	*
500.00	400.00	500	250	35.0	51	ja		[502.89/502.99]	*
550.00	400.00	500	250	34.0	68	ja		[553.06/553.16]	*

Printout from SICADA 2007-05-30 10:39:58.

Hole Diam T – Drilling: Borehole diameter

KFM12A, 2007-02-22 00:00:00 – 2007-03-12 00:00:00 (0.000 – 601.040 m)

Sub secup (m)	Sub seclow (m)	Hole diam (m)	Comment	QC
59.750	61.500	0.0860	Borrad 59,75–60,21 och upprymd ner till 61.5	*
61.500	601.040	0.0773	Hagby WL	*

Printout from SICADA 2007-05-30 10:56:50.

Magnetic Acc Dev T – Magnetic accelerometer deviation measurement

KFM12A, 2007-03-28 15:40:00 – 2007-03-28 17:35:00 (3.000–597.000 m)

Bhlen (m)	Dip (°)	Magnetic bearing (°)	Easting (m)	Northing (m)	Elevation (m)	Mag-field (nT)	Mag-dip (°)	Grav-field	Toolroll (°)	Magtool-face (°)	Dls (°/m)	Dls 30 (°/30 m)	Status	Magh (nT)	Magv (nT)	Updown (m)	Left-right (m)	Short-fall (m)	QC
3.00	–60.55	33.80				80432	60.55	0.9991	68.69	159.65	0.000		3	39543.0	70041.0	0.00	0.00	0.00	*
6.00	–60.33	33.80				11733	77.35	0.9992	68.96	223.70	8.000		3	2570.0	11448.0	–0.23	0.58	–0.09	*
9.00	–60.14	33.80				48768	63.60	0.9996	76.58	210.16	7.007		3	21682.0	43683.0	–0.45	1.24	–0.19	*
12.00	–60.08	33.80				52515	72.58	0.9994	197.86	345.62	3.981		1	15720.0	50107.0	–0.52	1.71	–0.23	*
15.00	–60.07	33.81				51372	72.99	0.9998	200.81	349.14	0.234		0	15033.0	49123.0	–0.69	2.49	–0.34	*
18.00	–60.09	33.81				50927	73.53	0.9999	201.73	350.26	0.577		0	14436.0	48838.0	–0.89	3.33	–0.47	*
21.00	–60.19	33.81				51319	72.91	1.0000	202.56	349.45	0.119		0	15080.0	49053.0	–1.11	4.20	–0.60	*
24.00	–60.43	33.81				51364	73.06	0.9999	201.06	348.04	0.086		0	14967.0	49135.0	–1.33	5.05	–0.73	*
27.00	–60.38	33.82				51127	73.32	0.9997	204.44	352.25	0.018		0	14671.0	48976.0	–1.55	5.89	–0.86	*
30.00	–60.49	33.82				50917	73.72	0.9998	202.60	353.06	0.697		0	14271.0	48877.0	–1.75	6.69	–0.98	*
33.00	–60.52	33.82				50801	72.89	1.0001	204.55	351.63	0.363		0	14950.0	48552.0	–1.94	7.47	–1.09	*
36.00	–60.56	33.82				50782	73.24	0.9999	202.88	350.60	0.137		0	14643.0	48626.0	–2.15	8.28	–1.21	*
39.00	–60.41	33.82				51167	73.17	0.9994	203.28	352.96	0.724		0	14812.0	48976.0	–2.34	9.05	–1.31	*
42.00	–60.27	33.83				51279	71.83	1.0001	202.53	346.05	0.976		0	15995.0	48721.0	–2.53	9.84	–1.43	*
45.00	–60.28	33.83				50707	73.08	1.0001	209.48	356.06	0.288		0	14761.0	48510.0	–2.76	10.72	–1.57	*
48.00	–60.21	33.83				50551	72.23	0.9999	208.98	354.55	0.631		0	15425.0	48140.0	–2.98	11.57	–1.70	*
51.00	–60.28	33.83				50780	72.56	1.0001	209.33	355.97	0.104		0	15222.0	48445.0	–3.17	12.38	–1.82	*
54.00	–60.16	33.84				50973	72.95	0.9997	209.67	358.04	0.193		0	14950.0	48731.0	–3.35	13.19	–1.93	*
57.00	–60.04	33.84				51144	73.10	1.0000	206.14	354.87	0.060		0	14872.0	48934.0	–3.52	14.01	–2.05	*
60.00	–60.04	33.84				51014	73.32	0.9999	22.02	171.50	0.164		0	14645.0	48866.0	–3.69	14.82	–2.17	*
63.00	–60.09	33.84				50948	73.18	0.9990	146.18	295.24	0.025		0	14746.0	48767.0	–3.86	15.60	–2.28	*
66.00	–60.05	33.65				50907	73.13	0.9992	145.00	294.08	0.035		0	14775.0	48715.0	–4.03	16.39	–2.39	*
69.00	–60.00	33.54				50905	73.13	0.9991	144.00	293.22	0.025		0	14769.0	48716.0	–4.20	17.17	–2.50	*
72.00	–59.92	33.49				50899	73.14	0.9996	150.42	299.79	0.025		0	14766.0	48711.0	–4.36	17.95	–2.61	*
75.00	–59.91	33.40				50918	73.10	0.9995	152.04	301.37	0.016		0	14803.0	48719.0	–4.52	18.74	–2.71	*
78.00	–59.85	33.15				50881	73.05	0.9995	151.72	301.11	0.045		0	14830.0	48671.0	–4.67	19.52	–2.82	*

Bhlen (m)	Dip (°)	Magnetic bearing (°)	Easting (m)	Northing (m)	Elevation (m)	Mag-field (nT)	Mag-dip (°)	Grav-field	Toolroll (°)	Magtool-face (°)	Dls (°/m)	Dls 30 (°/30 m)	Status	Magh (nT)	Magv (nT)	Updown (m)	Left-right (m)	Short-fall (m)	QC
81.00	–59.83	33.15				50925	73.10	0.9994	152.71	302.26	0.007		0	14804.0	48726.0	–4.82	20.29	–2.93	*
84.00	–59.79	33.07				50935	73.09	0.9992	152.84	302.46	0.021		0	14816.0	48733.0	–4.97	21.07	–3.03	*
87.00	–59.78	33.04				50957	73.01	0.9995	152.43	301.87	0.006		0	14886.0	48734.0	–5.12	21.85	–3.14	*
90.00	–59.77	32.92				50870	73.03	0.9994	150.95	300.52	0.021		0	14844.0	48656.0	–5.26	22.62	–3.24	*
93.00	–59.77	33.05				50853	73.07	0.9992	151.81	301.41	0.022		0	14809.0	48648.0	–5.41	23.40	–3.35	*
96.00	–59.74	32.89				50928	73.00	0.9994	153.91	303.45	0.029		0	14889.0	48703.0	–5.55	24.17	–3.46	*
99.00	–59.72	32.73				50685	73.45	0.9992	153.17	303.66	0.121		0	14437.0	48585.0	–5.70	24.95	–3.56	*
102.00	–59.72	32.58				50850	73.03	0.9995	160.01	309.81	0.173		0	14838.0	48637.0	–5.84	25.73	–3.67	*
105.00	–59.71	32.73				50792	73.16	0.9994	163.38	313.47	0.025		0	14716.0	48613.0	–5.98	26.50	–3.77	*
108.00	–59.65	32.55				50823	72.96	0.9998	200.01	349.71	0.037		0	14896.0	48591.0	–6.12	27.27	–3.88	*
111.00	–59.66	32.82				50926	72.92	0.9996	200.17	349.64	0.046		0	14954.0	48681.0	–6.26	28.04	–3.98	*
114.00	–59.65	32.68				50784	73.11	0.9996	200.32	350.38	0.024		0	14755.0	48594.0	–6.39	28.81	–4.08	*
117.00	–59.62	32.37				50762	73.05	1.0000	200.77	350.87	0.054		0	14797.0	48557.0	–6.53	29.58	–4.19	*
120.00	–59.63	32.67				50827	73.07	1.0000	200.22	350.21	0.051		0	14801.0	48624.0	–6.66	30.35	–4.29	*
123.00	–59.60	32.59				50972	72.94	1.0002	200.35	350.08	0.018		0	14953.0	48729.0	–6.79	31.12	–4.39	*
126.00	–59.60	32.68				50980	73.00	1.0000	201.03	350.86	0.015		0	14908.0	48751.0	–6.93	31.89	–4.50	*
129.00	–59.59	32.30				50848	72.98	0.9996	200.66	350.63	0.064		0	14886.0	48620.0	–7.06	32.66	–4.60	*
132.00	–59.59	32.47				50919	73.11	0.9999	201.00	351.25	0.029		0	14794.0	48722.0	–7.19	33.42	–4.70	*
135.00	–59.57	32.08				50850	73.10	0.9999	200.86	351.31	0.066		0	14781.0	48654.0	–7.32	34.19	–4.80	*
138.00	–59.55	32.60				50847	73.11	0.9999	200.85	351.09	0.088		0	14777.0	48652.0	–7.44	34.95	–4.91	*
141.00	–59.46	32.49				50818	73.07	1.0001	202.07	352.40	0.034		0	14798.0	48615.0	–7.57	35.72	–5.01	*
144.00	–59.41	32.30				50959	72.99	1.0000	201.92	352.18	0.037		0	14910.0	48729.0	–7.69	36.49	–5.11	*
147.00	–59.40	32.28				50793	72.95	1.0000	201.84	352.02	0.004		0	14895.0	48560.0	–7.82	37.26	–5.22	*
150.00	–59.37	32.41				50612	73.00	1.0000	201.34	351.65	0.025		0	14798.0	48400.0	–7.94	38.03	–5.32	*
153.00	–59.37	32.12				50873	72.90	1.0000	202.10	352.28	0.049		0	14957.0	48624.0	–8.05	38.80	–5.42	*
156.00	–59.33	32.19				50896	72.99	1.0001	201.34	351.80	0.018		0	14885.0	48671.0	–8.17	39.56	–5.52	*
159.00	–59.32	32.52				50936	73.04	1.0001	201.12	351.57	0.056		0	14855.0	48722.0	–8.29	40.34	–5.63	*
162.00	–59.36	32.51				50838	73.06	0.9999	201.10	351.54	0.014		0	14811.0	48633.0	–8.41	41.11	–5.73	*
165.00	–59.34	32.25				51036	72.89	1.0001	201.09	351.23	0.045		0	15016.0	48777.0	–8.52	41.88	–5.83	*

Bhlen (m)	Dip (°)	Magnetic bearing (°)	Easting (m)	Northing (m)	Elevation (m)	Mag-field (nT)	Mag-dip (°)	Grav-field	Toolroll (°)	Magtool-face (°)	Dls (°/m)	Dls 30 (°/30 m)	Status	Magh (nT)	Magv (nT)	Updown (m)	Left-right (m)	Short-fall (m)	QC
168.00	–59.36	32.43				50708	72.97	1.0000	201.59	351.82	0.032		0	14852.0	48485.0	–8.64	42.65	–5.94	*
171.00	–59.38	32.15				50897	72.89	1.0004	202.39	352.50	0.048		0	14977.0	48643.0	–8.76	43.42	–6.04	*
174.00	–59.37	32.18				50948	72.94	1.0000	201.89	352.15	0.006		0	14948.0	48705.0	–8.88	44.18	–6.14	*
177.00	–59.37	32.27				50962	72.99	0.9998	202.60	352.94	0.015		0	14912.0	48731.0	–9.00	44.95	–6.24	*
180.00	–59.32	32.04				50885	72.94	1.0000	202.14	352.54	0.042		0	14926.0	48647.0	–9.11	45.72	–6.34	*
183.00	–59.31	32.09				50917	72.98	0.9998	202.08	352.59	0.009		0	14900.0	48688.0	–9.23	46.48	–6.45	*
186.00	–59.27	32.11				50933	72.97	1.0001	202.89	353.41	0.013		0	14915.0	48700.0	–9.34	47.25	–6.55	*
189.00	–59.28	32.12				50878	73.04	0.9997	203.06	353.74	0.003		0	14846.0	48664.0	–9.45	48.01	–6.65	*
192.00	–59.27	32.18				50782	73.04	0.9998	203.04	353.71	0.011		0	14815.0	48573.0	–9.56	48.78	–6.75	*
195.00	–59.25	31.92				50901	73.02	1.0000	203.22	353.99	0.045		0	14864.0	48682.0	–9.67	49.55	–6.85	*
198.00	–59.27	31.90				50893	73.01	1.0000	203.05	353.79	0.007		0	14868.0	48673.0	–9.78	50.31	–6.95	*
201.00	–59.25	31.68				50905	72.97	1.0002	203.12	353.86	0.038		0	14913.0	48672.0	–9.89	51.07	–7.05	*
204.00	–59.26	31.73				50881	73.00	0.9998	203.27	354.08	0.009		0	14874.0	48658.0	–10.00	51.83	–7.15	*
207.00	–59.27	31.32				50806	72.98	1.0001	203.50	354.43	0.070		0	14872.0	48580.0	–10.10	52.58	–7.25	*
210.00	–59.26	32.02				50845	73.10	1.0002	203.96	354.87	0.119		0	14784.0	48648.0	–10.21	53.33	–7.35	*
213.00	–59.27	31.69				50906	72.96	1.0001	204.26	354.95	0.056		0	14917.0	48671.0	–10.32	54.10	–7.45	*
216.00	–59.29	31.74				50908	72.98	0.9998	203.78	354.47	0.010		0	14903.0	48677.0	–10.42	54.85	–7.55	*
219.00	–59.28	31.76				50918	73.02	1.0001	202.61	353.40	0.005		0	14874.0	48697.0	–10.53	55.61	–7.65	*
222.00	–59.30	31.63				50909	73.00	1.0001	204.79	355.58	0.023		0	14886.0	48685.0	–10.64	56.37	–7.75	*
225.00	–59.34	31.59				50890	73.02	1.0000	204.46	355.26	0.018		0	14860.0	48672.0	–10.75	57.12	–7.84	*
228.00	–59.40	31.60				50894	73.04	1.0001	204.54	355.32	0.017		0	14843.0	48681.0	–10.86	57.87	–7.94	*
231.00	–59.40	31.48				50865	73.04	1.0001	204.13	354.95	0.020		0	14837.0	48653.0	–10.97	58.62	–8.04	*
234.00	–59.44	31.46				50859	73.05	1.0001	204.22	355.01	0.015		0	14831.0	48649.0	–11.08	59.37	–8.14	*
237.00	–59.46	31.48				50881	73.03	1.0002	203.85	354.56	0.006		0	14850.0	48666.0	–11.19	60.12	–8.23	*
240.00	–59.47	31.37				50902	72.99	1.0002	204.20	354.84	0.019		0	14888.0	48676.0	–11.31	60.87	–8.33	*
243.00	–59.53	31.41				50925	73.01	1.0000	204.74	355.32	0.019		0	14882.0	48702.0	–11.42	61.61	–8.43	*
246.00	–59.53	31.38				50925	73.03	0.9996	204.73	355.39	0.006		0	14860.0	48709.0	–11.54	62.35	–8.52	*
249.00	–59.54	31.25				50925	72.98	0.9998	204.61	355.17	0.022		0	14905.0	48694.0	–11.65	63.10	–8.62	*
252.00	–59.57	30.99				50947	72.96	0.9999	204.23	354.81	0.045		0	14934.0	48709.0	–11.77	63.83	–8.71	*

Bhlen (m)	Dip (°)	Magnetic bearing (°)	Easting (m)	Northing (m)	Elevation (m)	Mag-field (nT)	Mag-dip (°)	Grav-field	Toolroll (°)	Magtool-face (°)	Dls (°/m)	Dls 30 (°/30 m)	Status	Magh (nT)	Magv (nT)	Updown (m)	Left-right (m)	Short-fall (m)	QC
255.00	–59.57	30.90				50782	73.10	0.9999	204.77	355.79	0.015		0	14760.0	48589.0	–11.88	64.57	–8.80	*
258.00	–59.62	31.00				50875	72.76	1.0001	204.64	354.60	0.022		0	15076.0	48591.0	–11.99	65.30	–8.90	*
261.00	–59.56	31.12				50861	73.04	1.0002	204.44	355.18	0.027		0	14839.0	48648.0	–12.11	66.03	–8.99	*
264.00	–59.54	31.03				50925	72.99	1.0000	204.88	355.58	0.016		0	14894.0	48698.0	–12.22	66.77	–9.08	*
267.00	–59.61	30.72				50933	72.98	1.0002	205.11	355.82	0.057		0	14909.0	48702.0	–12.33	67.50	–9.18	*
270.00	–59.60	30.91				50944	72.98	1.0001	204.31	354.96	0.033		0	14911.0	48713.0	–12.44	68.23	–9.27	*
273.00	–59.53	30.83				50942	72.97	1.0002	204.30	355.06	0.027		0	14921.0	48707.0	–12.56	68.96	–9.36	*
276.00	–59.50	30.69				50940	72.98	1.0002	204.77	355.66	0.025		0	14913.0	48708.0	–12.66	69.69	–9.45	*
279.00	–59.48	30.70				50946	72.97	1.0001	203.81	354.72	0.008		0	14917.0	48713.0	–12.77	70.42	–9.55	*
282.00	–59.43	30.70				50942	72.96	1.0006	203.52	354.46	0.016		0	14933.0	48705.0	–12.87	71.15	–9.64	*
285.00	–59.41	30.69				50933	72.98	1.0000	203.87	354.92	0.007		0	14905.0	48703.0	–12.98	71.88	–9.73	*
288.00	–59.28	30.81				50934	72.99	1.0002	203.44	354.63	0.046		0	14901.0	48706.0	–13.08	72.61	–9.82	*
291.00	–59.23	30.74				50934	72.97	1.0004	203.94	355.18	0.022		0	14919.0	48700.0	–13.17	73.35	–9.92	*
294.00	–59.19	30.71				50925	72.99	1.0001	203.45	354.82	0.013		0	14899.0	48697.0	–13.27	74.08	–10.01	*
297.00	–59.22	30.75				50935	72.99	1.0000	203.77	355.08	0.011		0	14904.0	48705.0	–13.36	74.82	–10.10	*
300.00	–59.22	30.74				50933	73.00	1.0003	204.16	355.50	0.003		0	14892.0	48708.0	–13.45	75.56	–10.20	*
303.00	–59.20	30.80				50930	72.99	1.0001	204.09	355.42	0.013		0	14899.0	48703.0	–13.55	76.29	–10.29	*
306.00	–59.14	30.87				50918	73.00	1.0000	202.40	353.79	0.022		0	14891.0	48692.0	–13.64	77.03	–10.38	*
309.00	–59.10	30.80				50919	73.01	1.0002	203.04	354.56	0.017		0	14876.0	48698.0	–13.73	77.77	–10.48	*
312.00	–59.10	30.73				50876	72.97	0.9998	203.09	354.53	0.012		0	14905.0	48644.0	–13.82	78.51	–10.57	*
315.00	–59.07	30.61				50900	72.96	1.0001	203.46	354.99	0.023		0	14916.0	48666.0	–13.90	79.25	–10.66	*
318.00	–59.02	30.53				50890	72.94	1.0001	202.79	354.37	0.020		0	14928.0	48651.0	–13.99	79.98	–10.76	*
321.00	–58.96	30.46				50894	72.94	0.9997	202.83	354.54	0.023		0	14929.0	48655.0	–14.07	80.72	–10.85	*
324.00	–58.91	30.37				50899	72.93	0.9999	203.00	354.79	0.025		0	14945.0	48656.0	–14.14	81.45	–10.94	*
327.00	–58.92	30.21				50904	72.92	0.9998	203.14	354.99	0.028		0	14949.0	48660.0	–14.22	82.18	–11.03	*
330.00	–58.90	30.17				50886	72.93	1.0000	202.58	354.49	0.009		0	14940.0	48644.0	–14.29	82.91	–11.12	*
333.00	–58.84	30.22				50853	72.95	1.0003	202.79	354.83	0.023		0	14907.0	48619.0	–14.36	83.64	–11.21	*
336.00	–58.80	30.16				50886	72.93	1.0000	202.68	354.73	0.016		0	14940.0	48644.0	–14.43	84.37	–11.31	*
339.00	–58.75	30.15				50893	72.92	1.0001	203.04	355.16	0.018		0	14947.0	48648.0	–14.50	85.10	–11.40	*

Bhlen (m)	Dip (°)	Magnetic bearing (°)	Easting (m)	Northing (m)	Elevation (m)	Mag-field (nT)	Mag-dip (°)	Grav-field	Toolroll (°)	Magtool-face (°)	Dls (°/m)	Dls 30 (°/30 m)	Status	Magh (nT)	Magv (nT)	Updown (m)	Left-right (m)	Short-fall (m)	QC
342.00	–58.73	30.13				50873	72.98	1.0000	202.93	355.23	0.008		0	14895.0	48643.0	–14.56	85.84	–11.49	*
345.00	–58.66	30.05				50899	72.94	1.0001	203.03	355.37	0.027		0	14934.0	48659.0	–14.62	86.57	–11.58	*
348.00	–58.61	30.10				50895	72.94	1.0001	203.22	355.60	0.018		0	14931.0	48656.0	–14.68	87.30	–11.67	*
351.00	–58.57	30.62				50760	73.04	0.9998	203.43	355.85	0.091		0	14808.0	48552.0	–14.74	88.04	–11.76	*
354.00	–58.52	29.78				50792	73.00	1.0002	203.41	356.25	0.147		0	14848.0	48573.0	–14.79	88.78	–11.86	*
357.00	–58.48	29.74				50898	72.97	0.9999	202.75	355.59	0.017		0	14907.0	48666.0	–14.84	89.50	–11.95	*
360.00	–58.41	29.55				50848	72.97	1.0003	204.11	357.13	0.039		0	14895.0	48618.0	–14.89	90.23	–12.04	*
363.00	–58.37	29.50				50829	72.99	1.0000	204.18	357.35	0.017		0	14867.0	48606.0	–14.93	90.95	–12.12	*
366.00	–58.31	29.32				50817	72.94	1.0003	204.65	357.86	0.037		0	14907.0	48582.0	–14.96	91.68	–12.21	*
369.00	–58.26	29.19				50845	72.86	1.0000	205.33	358.49	0.028		0	14981.0	48588.0	–15.00	92.40	–12.30	*
372.00	–58.23	29.12				50821	72.89	1.0001	205.21	358.51	0.016		0	14954.0	48571.0	–15.03	93.11	–12.39	*
375.00	–58.19	29.06				50751	72.97	0.9997	205.81	359.40	0.016		0	14862.0	48527.0	–15.05	93.83	–12.48	*
378.00	–58.15	28.98				50843	72.91	1.0000	205.79	359.31	0.020		0	14946.0	48596.0	–15.08	94.55	–12.56	*
381.00	–58.10	28.86				50819	72.86	1.0001	204.95	358.49	0.026		0	14978.0	48562.0	–15.10	95.26	–12.65	*
384.00	–58.07	28.89				50884	72.94	1.0000	206.24	359.70	0.104		0	14924.0	48646.0	–15.12	95.98	–12.74	*
387.00	–58.05	28.89				50807	72.82	1.0002	206.23	359.34	0.025		0	15011.0	48539.0	–15.15	96.71	–12.83	*
390.00	–58.01	28.92				50800	72.77	1.0001	206.36	359.76	0.117		0	15049.0	48520.0	–15.17	97.44	–12.92	*
393.00	–57.94	28.74				50816	72.86	0.9998	206.35	0.17	0.039		0	14979.0	48558.0	–15.18	98.15	–13.00	*
396.00	–57.89	28.74				50887	72.83	1.0000	206.44	0.24	0.015		0	15026.0	48618.0	–15.19	98.87	–13.09	*
399.00	–57.89	28.95				50926	72.85	1.0000	206.67	0.40	0.037		0	15020.0	48661.0	–15.20	99.58	–13.18	*
402.00	–57.83	28.57				50648	72.72	1.0004	206.99	0.71	0.070		0	15041.0	48363.0	–15.20	100.30	–13.26	*
405.00	–57.82	28.47				50631	73.73	1.0000	206.94	1.76	0.454		0	14189.0	48602.0	–15.22	101.04	–13.36	*
408.00	–57.76	28.36				50827	72.82	1.0002	207.09	1.37	0.532		0	15016.0	48558.0	–15.23	101.78	–13.45	*
411.00	–57.75	28.26				50266	73.63	1.0000	207.22	2.51	0.313		0	14167.0	48228.0	–15.24	102.51	–13.54	*
414.00	–57.71	28.16				49358	73.07	1.0001	207.12	0.23	0.315		1	14376.0	47218.0	–15.26	103.28	–13.64	*
417.00	–57.69	28.06				50396	72.85	1.0001	207.17	2.02	0.746		0	14860.0	48155.0	–15.27	104.01	–13.73	*
420.00	–57.67	27.95				50910	73.33	1.0004	207.15	2.20	0.303		0	14606.0	48770.0	–15.27	104.72	–13.82	*
423.00	–57.66	27.85				50521	73.05	1.0000	206.91	1.72	0.132		0	14729.0	48326.0	–15.26	105.44	–13.90	*
426.00	–57.62	27.75				49866	72.48	1.0004	206.87	358.68	0.562		1	15012.0	47552.0	–15.27	106.20	–14.00	*

Bhlen (m)	Dip (°)	Magnetic bearing (°)	Easting (m)	Northing (m)	Elevation (m)	Mag-field (nT)	Mag-dip (°)	Grav-field	Toolroll (°)	Magtool-face (°)	Dls (°/m)	Dls 30 (°/30 m)	Status	Magh (nT)	Magv (nT)	Updown (m)	Left-right (m)	Short-fall (m)	QC
429.00	–57.57	27.65				50661	72.57	1.0003	207.20	0.08	0.279		0	15177.0	48334.0	–15.29	106.97	–14.10	*
432.00	–57.55	27.55				50317	73.12	1.0001	207.25	0.22	0.468		0	14611.0	48149.0	–15.31	107.75	–14.21	*
435.00	–57.49	27.44				50797	72.85	1.0002	207.36	2.05	0.806		0	14981.0	48538.0	–15.32	108.52	–14.30	*
438.00	–57.50	27.34				51465	72.71	1.0000	207.20	1.29	0.081		0	15297.0	49139.0	–15.31	109.23	–14.39	*
441.00	–57.49	27.24				50905	73.37	1.0003	207.25	2.87	0.017		0	14572.0	48775.0	–15.30	109.95	–14.48	*
444.00	–57.45	27.14				50698	72.73	1.0006	207.45	1.96	0.110		0	15050.0	48413.0	–15.28	110.66	–14.56	*
447.00	–57.40	27.03				50963	72.53	1.0002	207.48	1.50	0.023		0	15303.0	48612.0	–15.26	111.37	–14.65	*
450.00	–57.36	26.93				51102	72.53	1.0003	207.23	1.48	0.054		0	15340.0	48745.0	–15.23	112.08	–14.73	*
453.00	–57.26	26.83				50719	72.85	1.0002	207.07	1.86	0.116		0	14953.0	48465.0	–15.21	112.79	–14.82	*
456.00	–57.23	26.73				50761	73.07	1.0002	206.87	2.43	0.077		0	14786.0	48559.0	–15.18	113.51	–14.91	*
459.00	–57.18	26.62				51020	72.76	1.0001	206.82	2.34	0.194		0	15123.0	48727.0	–15.14	114.21	–14.99	*
462.00	–57.13	26.52				51057	72.80	1.0003	206.99	2.60	0.028		0	15100.0	48773.0	–15.10	114.89	–15.07	*
465.00	–57.01	26.42				50800	72.94	1.0001	206.59	2.76	0.049		0	14906.0	48564.0	–15.05	115.58	–15.15	*
468.00	–56.92	26.32				50972	72.89	1.0000	207.06	3.56	0.110		0	15000.0	48715.0	–14.99	116.26	–15.23	*
471.00	–56.89	26.21				50848	72.14	1.0001	207.17	0.95	0.311		0	15598.0	48396.0	–14.93	116.95	–15.31	*
474.00	–56.82	26.11				50967	72.92	1.0001	207.09	3.68	0.280		0	14973.0	48718.0	–14.87	117.65	–15.39	*
477.00	–56.72	26.11				50918	72.88	1.0005	206.78	3.65	0.087		0	14993.0	48660.0	–14.80	118.33	–15.47	*
480.00	–56.63	26.17				50808	73.03	1.0003	206.88	4.16	0.034		0	14828.0	48596.0	–14.72	119.00	–15.55	*
483.00	–56.56	26.11				50650	73.24	1.0001	206.65	4.50	0.026		0	14603.0	48500.0	–14.64	119.67	–15.63	*
486.00	–56.48	26.05				49855	72.75	1.0000	206.56	2.00	0.451		1	14787.0	47612.0	–14.57	120.38	–15.71	*
489.00	–56.42	25.99				50190	72.76	1.0001	206.76	1.94	0.123		0	14875.0	47935.0	–14.51	121.12	–15.81	*
492.00	–56.40	25.93				51016	72.88	1.0005	206.55	3.64	0.527		0	15015.0	48757.0	–14.44	121.84	–15.89	*
495.00	–56.38	25.87				50682	73.23	1.0001	206.29	3.86	0.098		0	14620.0	48528.0	–14.35	122.53	–15.98	*
498.00	–56.33	25.81				50995	72.81	1.0001	206.92	4.39	0.241		0	15073.0	48716.0	–14.25	123.21	–16.05	*
501.00	–56.24	25.75				50606	73.05	1.0001	206.59	4.81	0.050		0	14755.0	48408.0	–14.15	123.87	–16.13	*
504.00	–56.24	25.69				50964	72.94	1.0000	205.98	2.81	0.356		0	14955.0	48720.0	–14.05	124.55	–16.21	*
507.00	–56.17	25.64				50646	73.18	1.0004	206.43	4.14	0.094		0	14659.0	48478.0	–13.96	125.26	–16.30	*
510.00	–56.23	25.58				50835	73.10	1.0004	206.19	4.11	0.140		0	14778.0	48640.0	–13.86	125.95	–16.38	*
513.00	–56.20	25.52				51021	72.85	1.0002	206.01	3.29	0.051		0	15041.0	48753.0	–13.76	126.63	–16.46	*

Bhlen (m)	Dip (°)	Magnetic bearing (°)	Easting (m)	Northing (m)	Elevation (m)	Mag-field (nT)	Mag-dip (°)	Grav-field	Toolroll (°)	Magtool-face (°)	Dls (°/m)	Dls 30 (°/30 m)	Status	Magh (nT)	Magv (nT)	Updown (m)	Left-right (m)	Short-fall (m)	QC
516.00	–56.12	25.46				50689	73.25	1.0000	205.97	4.55	0.122		0	14606.0	48539.0	–13.66	127.30	–16.54	*
519.00	–56.11	25.40				51152	72.87	1.0000	205.94	3.21	0.160		0	15063.0	48884.0	–13.55	127.98	–16.62	*
522.00	–56.10	25.34				51204	72.93	1.0000	206.17	3.37	0.065		0	15029.0	48949.0	–13.45	128.68	–16.70	*
525.00	–56.05	25.28				51069	72.71	1.0001	206.34	3.96	0.259		0	15179.0	48761.0	–13.34	129.36	–16.78	*
528.00	–56.03	25.22				50771	73.11	1.0001	206.04	4.23	0.093		0	14751.0	48581.0	–13.23	130.03	–16.86	*
531.00	–56.02	25.16				49879	72.60	1.0000	205.91	3.96	0.279		1	14915.0	47597.0	–13.11	130.69	–16.94	*
534.00	–55.96	25.10				50626	72.94	1.0002	205.87	4.42	0.079		0	14855.0	48398.0	–12.98	131.34	–17.01	*
537.00	–55.98	25.04				50839	72.84	1.0001	205.76	4.36	0.077		0	14999.0	48576.0	–12.86	131.98	–17.08	*
540.00	–55.95	24.98				50975	72.99	1.0005	205.00	3.20	0.217		0	14916.0	48744.0	–12.73	132.64	–17.16	*
543.00	–55.93	24.92				50723	73.33	1.0001	204.90	3.75	0.022		0	14554.0	48590.0	–12.61	133.31	–17.24	*
546.00	–55.89	24.86				50790	73.10	1.0004	204.35	2.72	0.028		0	14762.0	48597.0	–12.49	133.99	–17.31	*
549.00	–55.82	24.80				50506	73.30	1.0000	204.56	3.68	0.093		0	14512.0	48376.0	–12.37	134.66	–17.39	*
552.00	–55.78	24.74				50339	72.88	1.0001	203.51	1.69	0.043		0	14815.0	48109.0	–12.24	135.33	–17.47	*
555.00	–55.80	24.68				51063	72.91	0.9993	132.25	290.24	0.064		0	15010.0	48807.0	–12.12	136.01	–17.55	*
558.00	–55.73	24.63				51098	73.15	0.9989	132.28	290.87	0.024		0	14814.0	48903.0	–11.99	136.69	–17.63	*
561.00	–55.72	24.57				51415	72.98	0.9991	132.11	290.69	0.100		0	15053.0	49163.0	–11.86	137.37	–17.71	*
564.00	–55.68	24.51				51146	73.05	0.9996	132.46	290.59	0.200		0	14912.0	48924.0	–11.74	138.05	–17.80	*
567.00	–55.65	24.45				50762	72.94	0.9995	132.27	290.02	0.061		0	14894.0	48528.0	–11.61	138.75	–17.88	*
570.00	–55.56	24.39				50714	73.42	0.9992	132.00	290.41	0.145		0	14471.0	48606.0	–11.49	139.47	–17.97	*
573.00	–55.51	24.33				50138	74.24	0.9993	132.52	292.59	0.015		0	13616.0	48254.0	–11.37	140.20	–18.06	*
576.00	–55.44	24.27				50166	73.41	0.9992	132.38	290.50	0.135		0	14326.0	48077.0	–11.26	140.94	–18.16	*
579.00	–55.40	24.21				49970	73.43	0.9996	132.43	291.46	0.288		1	14251.0	47895.0	–11.13	141.67	–18.25	*
582.00	–55.35	24.21				50719	73.25	0.9996	132.33	292.53	0.478		0	14617.0	48567.0	–10.98	142.34	–18.33	*
585.00	–55.30	23.94				50872	73.07	0.9994	132.50	292.56	0.053		0	14814.0	48667.0	–10.82	142.98	–18.41	*
588.00	–55.27	23.79				50855	72.88	0.9994	132.66	291.34	0.327		0	14967.0	48603.0	–10.66	143.64	–18.48	*
591.00	–55.22	23.64				50955	73.14	0.9994	132.30	292.76	0.384		0	14780.0	48765.0	–10.49	144.30	–18.56	*
594.00	–55.15	23.42				50452	73.23	0.9993	132.93	293.76	0.047		0	14555.0	48307.0	–10.31	144.92	–18.63	*
597.00	–55.10	23.42				50680	73.19	1.0005	232.83	32.80	0.260		0	14655.0	48515.0	–10.14	145.56	–18.71	*

Printout from SICADA 2007-05-30 11:57:18.