P-04-305

Forsmark site investigation

Mise-á-la-masse measurements

An experiment to test the possibility for detecting the outcropping of the fracture zone DZ2 in HFM14

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November 2004

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Abstract

Mise-á-la-masse (MAM) measurements were conducted in borehole HFM14 with a current electrode placed at ca 100 m borehole length, where a fracture zone denoted DZ2 is observed. The objective was to test the possibility to detect where the DZ2 zone outcrops to the bedrock surface. The experiment was successful in the sense that a clear maximum was detected between Drill Site 5 and 1. This maximum is believed to correspond to the location of the outcropping fracture zone.

Sammanfattning

Mise-á-la-masse (MAM) mätningar utfördes med en strömelektrod placerad i borrhålet HFM14 vid borrhålslängd ca 100 m, där en sprickzon (DZ2) är identifierad. Syftet med mätningarna var att testa möjligheten att lokalisera var zonen DZ2 skär bergytan. Experimentet var framgångsrikt i den meningen att ett signifikant maximum påvisades mellan borrplatserna 5 och 1. Detta maximum kan med stor sannolikhet antas vara kopplad till sprickzonens ytgående.

Contents

1 Introduction

This document reports the results gained by the mise-á-la-masse measurements, 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 400-04-113. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

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

Activity plan	Number	Version
Mise-á-la-masse measurements	AP PF 400-04-113	1.0
Method descriptions	**Number**	**Version**
No method description exists		

This report includes measurements between Drill Site 5 and 1, where the percussion drilled borehole HFM14 is used for the location of the current electrode. See map in Figure 1-1 and technical data in Figure 1-2.

All measurements were conducted by Malå GeoScience AB during November 2004. The used investigation technique comprised:

- Resisitivity measurements (ABEM SAS1000 system) with the mise-á-la-masse technique.

The delivered raw and processed data have been inserted in the database of SKB (SICADA). The SICADA field note reference to the present activity is presented in Table 1-2.

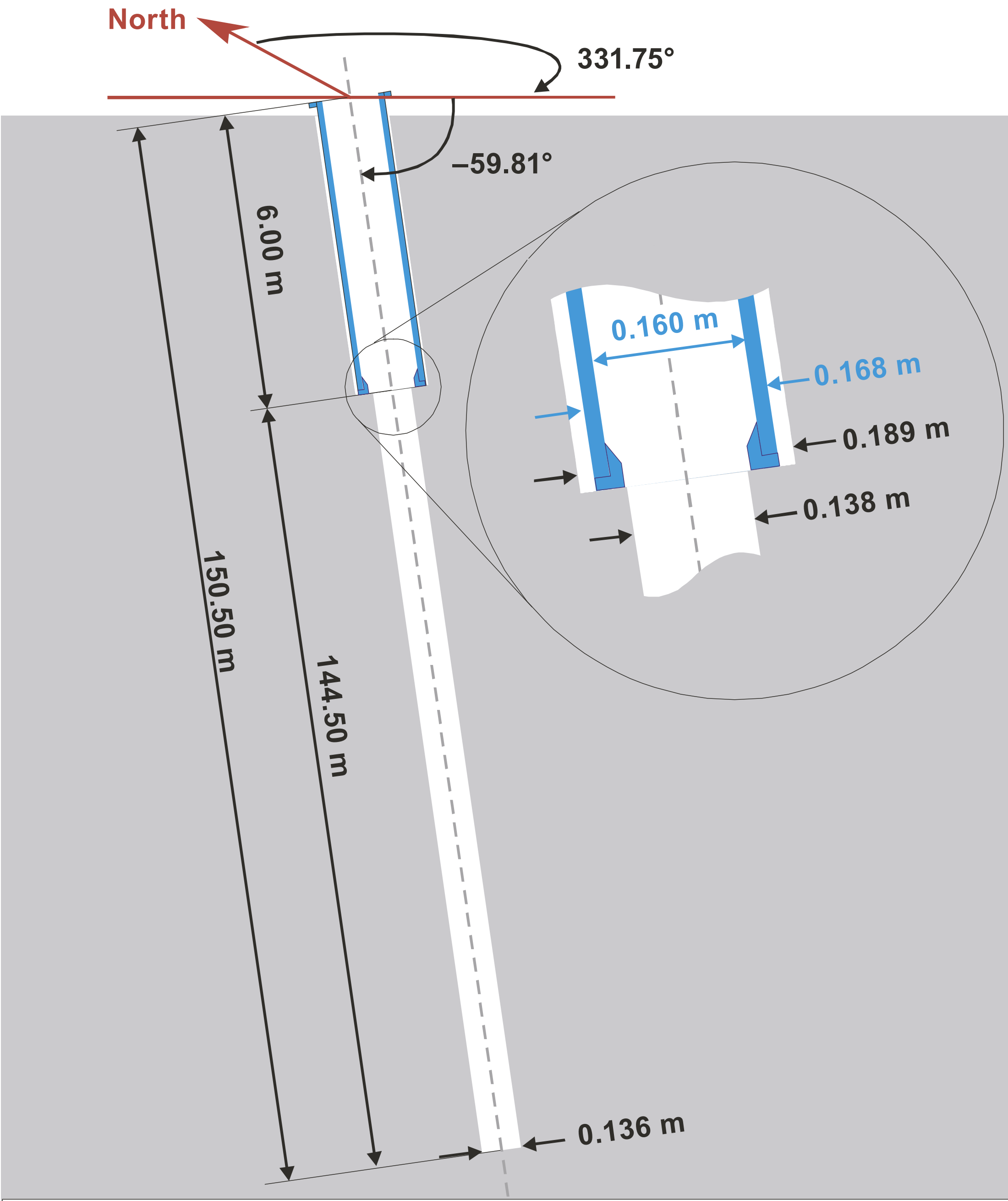
Table 1-2. Data references.

Subactivity	Database	Identity number
Mise-á-la-masse measurements	SICADA	Field note Forsmark 409

Figure 1-1. *The location of the measured profiles. The current reference electrode is denoted IREF and the voltage reference electrode VREF. The projection of the upper 102 m of HFM14 is displayed also (between UP and DOWN).*

Technical data

Borehole HFM14



Drilling reference point	
Northing:	**6699313.14 (m), RT90 2,5 gon V 0:-15**
Easting:	**1631734.59 (m), RT90 2,5 gon V 0:-15**
Elevation:	**3.91 (m a s l), RHB 70**
Drilling period	
Drilling start date:	**2003-10-06**
Drilling stop date:	**2003-10-09**

Figure 1-2. *Technical data of borehole HFM14.*

2 Objective and scope

The purpose of the test measurements was to investigate the possibility of the mise-á-la-masse method for locating the position of fracture zones at the ground surface. For this reason a suitable fracture zone was pointed out. This zone, referred to as DZ2 in the geological single-hole interpretation /1/, is penetrated by borehole HFM14 at a borehole length of 92–104 m.

3 Equipment

3.1 Description of equipment/interpretation tools

The following equipment was used:

- Terrameter SAS1000.
- Cable drum with a lead electrode for injecting current in the borehole.
- Non-polarizable electrodes for measuring the potential difference on ground surface.
- GPS unit (Garmin ETREX) for location of the measuring points.
- Radios for communication between the instrument operator at the borehole and the remote filed operator with the moving potential electrode. The SFR radio system was used during this field operation.
- Software “GPS Utility” ver 4.15.3 for coordinate transformation and creating maps of the measured profiles.
- Software “Surfer” ver 7.0 for mapping the results.

The Terrameter SAS 1000, see Figure 3-1, is originally designed for resistivity measurements, but is also very well suited for MAM measurements. The principle of the equipment is to transmit a current with varying polarity (plus-minus-minus-plus) and simultaneously measures the corresponding voltage. This procedure eliminates drift and other possible disturbances.

Figure 3-1. *The Terrameter SAS 1000 (left) and a non-polarizable electrode (right).*

The non-polarizable electrodes (used as well for the reference electrode as for the measuring electrode) generates very little noise. The purpose of using non-polarizable electrodes is to establish a stable connection between the electronic conductor (the cables) and the ionic conductor (the ground). A lead wire inside gypsum containing lead-chloride accomplishes this.

The equipment is calibrated from factory and no further calibration is necessary. Furthermore, only relative levels are needed for this study.

4 Execution

4.1 General

The principle of the MAM-method is described in Figure 4-1. The borehole used for the location of current electrode was HFM14 at a depth of 102 m. The potential electrode was moved along two profiles in the area between Drill Site 5 and 1, and the reference electrodes, both current and voltage, were located at the south east side of Drill Site 5.

The current electrode in borehole HFM14 is located at:

X = 1631704.5, Y = 6699351.3, Z = –89.5 (RT90) (Z measured from ground surface).

The reference current electrode is located at:

X = 1631830.6, Y = 6699236.9, Z = 0 (RT90).

The reference potential electrode is located at:

X = 1631738.1, Y = 6699180.2, Z = 0 (RT90).

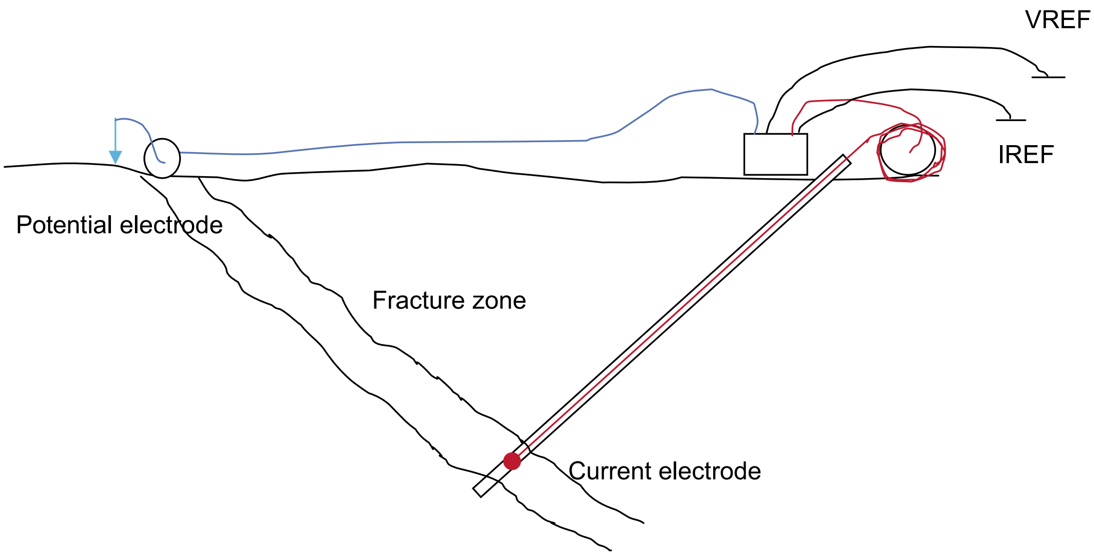


Figure 4-1. *Sketch of the MAM-layout. The current electrode is located in a borehole in contact with the fracture zone. A current is injected, and the corresponding voltage is measured at the ground surface with a moving potential electrode. The current and voltage reference electrodes are located far from the area of investigation. The location of these reference electrodes are seen in Figure 1-1.*

The Table 4-1 below comprises the execution of the fieldwork.

Table 4-1. Execution of fieldwork.

ID #	Description
1	Establishing reference potential electrode VREF.
2	Establishing reference current electrode IREF.
3	Establishing current electrode in the borehole at 102 m borehole length.
4	Establishing all other cable connections.
5	Placing a 50m measuring tape along the decided profile direction.
6	Moving operator establish a measuring point (at location 0, 5, 10, … m) along the measuring string.
7	Moving operator calls the instrument operator on the radio and gives a READY FOR MEASURING signal.
8	The instrument operator performs the measurement and save the reading on paper and in the instrument solid-state memory.
9	The instrument operator calls the moving operator on the radio and gives a READY signal.
10	ID 6–9 is repeated along the measuring tape.
11	When a 50m section is finished, the moving operator measures the coordinates (using a GPS) of the start and stop of the measuring tape.
12	ID 5–11 is repeated until the end of the profile.

The measuring procedure described in Table 4-1 has proved to be efficient for this sort of measurements. By only measuring the coordinates of the endpoints of the measuring tape, the GPS will have time enough to achieve readings with small errors (6–8 m), even in difficult environment with dense forest.

It is essential for the measurement accuracy to transmit as high a current as possible. For this reason the reference current electrode consisted of two steel electrodes connected in parallel to reduce the contact resistance into the ground. In most of the measurements a current of of 100 mA was transmitted.

4.2 Data handling/post processing

The instrument measures and displays the voltage divided by the transmitted current (mV/A). This implies, that all values can be regarded as voltage readings, normalized to an output current of 1 Amp.

The standard deviation of all single measurements was below 0.2%. No further data processing is performed.

The coordinates, measured at the endpoints of the measuring string every 50 m, was interpolated to all intermediate measuring point using EXCEL.

4.3 Analyses and interpretations

The voltage readings, together with the coordinates, are imported to Surfer in order to create an equipotential map.

The interpretation is based on the fact that on a homogenous ground the equipotentials on the ground surface will be concentric circles with the epicentre of the electrode at the centre /2/. A deviation from this behaviour is an indication of e.g. the extent of a fracture zone.

4.4 Nonconformities

No method description exists for this method. The work described here conforms to the Activity Plan.

5 Results

In order to demonstrate the data quality, the data from one of the profiles is displayed in Figure 5-1. The spacing between the measuring stations is 5 m. It is seen that the data quality is very good with only very little scattering.

In Figure 5-2 the final result is shown. The equipotential curves indicate an area with an isolated maximum. This maximum is believed to correspond to the area where the zone DZ2 in HFM14 reaches the surface.

Another possible application of the MAM method is to answer the question whether a fracture zone is penetrated by two boreholes. In such case, a current electrode can be placed in contact with the fracture zone in one borehole. A logging procedure in the other borehole will then reveal if the same fracture zone appears in the other hole. In borehole applications the results will probably be more distinct due to the fact that there are no soil cover to smears out the anomaly.

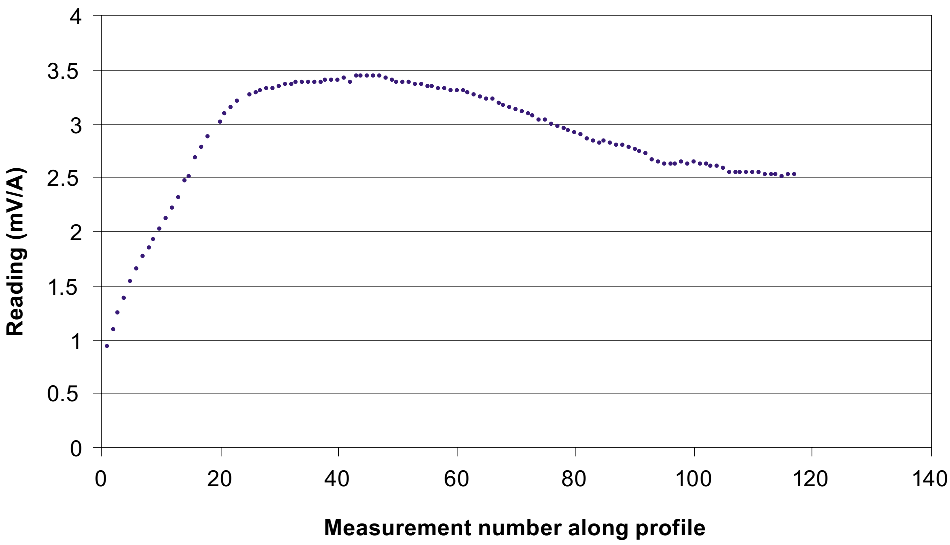


Figure 5-1. *The readings along the profile denoted 100, 101, …, 112 (see Figure 1-1).*

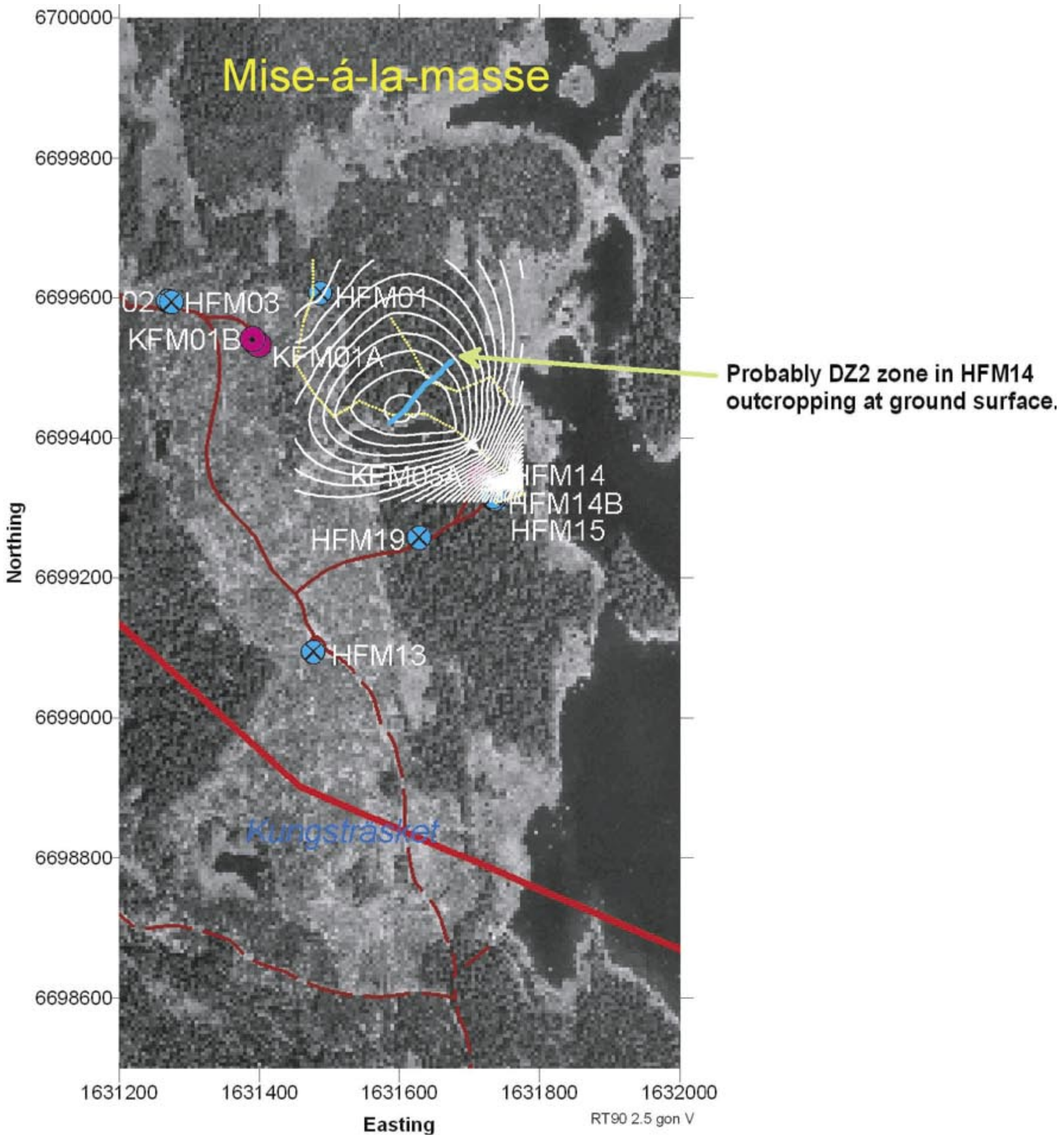


Figure 5-2. *Equipotential curves from the mise-á-la-masse measurements. The area with the maximum values is believed to correspond to the area where the DZ2 zone reaches the surface. A possible interpretation is indicated in blue.*

References

/1/ **Carlsten S, Petersson J, Stephens M, Thunehed H, Gustafsson J, 2004.** Geological single-hole interpretation of KFM05A, HFM14-15 and HFM19 (DS5). SKB P-04-296, Svensk Kärnbränslehantering AB.

/2/ **Parasnis D S, 1997.** Principles of Applied Geophysics, fifth edition. Chapman & Hall, London. ISBN 0 412 80250 3.

Appendix 1

Coordinates of MAM measurements

The coordinates (every ca 50 m) along the profiles are given in RT90 coordinates in the table below. Also the coordinates of the current and voltage reference electrodes are given.

Point #	Easting	Northing
100	1631737.95	6699307.70
101	1631756.20	6699348.36
102	1631716.40	6699379.24
103	1631680.01	6699412.04
104	1631636.31	6699434.94
105	1631590.36	6699432.70
106	1631542.57	6699452.99
107	1631505.89	6699430.66
108	1631476.91	6699463.75
109	1631451.21	6699505.69
110	1631462.40	6699565.69
111	1631475.51	6699603.72
112	1631475.78	6699654.25
113	1631588.50	6699570.13
114	1631615.92	6699528.25
115	1631640.92	6699481.41
116	1631681.51	6699467.00
117	1631730.18	6699487.34
118	1631759.40	6699448.33
119	1631776.01	6699320.07
120	1631769.45	6699367.24
IREF	1631830.55	6699236.87
VREF	1631738.08	6699180.22