P-07-137

Forsmark site investigation

Complementary resistivity measurements on samples from KFM01A, KFM02A, KFM06A, KFM08A, KFM08C and KFM09A

Hans Thunehed, GeoVista AB

June 2007

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

ISSN 1651-4416
SKB P-07-137

Forsmark site investigation

Complementary resistivity measurements on samples from KFM01A, KFM02A, KFM06A, KFM08A, KFM08C and KFM09A

Hans Thunehed, GeoVista AB

June 2007

Keywords: Resistivity, Formation factor, AP PF400-06-007.

Abstract

This report presents the execution and the results from measurements of electrical resistivity on core samples from the boreholes KFM01A, KFM02A, KFM06A, KFM08A, KFM08C and KFM09A at Forsmark. The formation factor was calculated based on the results of the measurements. A total of 8 core samples were tested. The resistivity was measured after soaking the samples in a 1 M NaCl-solution for eight weeks. The median resistivity value was 849 Ωm, corresponding to a median value of the formation factor of $0.170 \cdot 10^{-3}$. Most measurements resulted in small phase angles between the applied current and the measured potential. However, one sample from KFM08A (686.92–686.95 m) did show elevated phase angles, corresponding to polarisation with a rather large time constant. This is interpreted to be due presence of conducting minerals or clay minerals that also might have affected the resistivity measurement of this sample.

Sammanfattning

Denna rapport presenterar genomförandet av och resultaten från mätningar av elektrisk resistivitet på borrkärneprover från KFM01A, KFM02A, KFM06A, KFM08A, KFM08C och KFM09A i Forsmark. Formationsfaktorn har beräknats med mätningarna som underlag. Totalt 8 provbitar har undersökts. Resistiviteten mättes efter det att proven legat i 1 M NaCl-lösning i åtta veckor. Medianvärdet var 849 Ωm, svarande mot ett medianvärde på formationsfaktorn på $0{,}170 \cdot 10^{-3}$. De flesta mätningar resulterade i små fasvinklar mellan strömmen genom provet och den uppmätta potentialskillnaden. Ett prov från KFM08A (686,92–686,95 m) uppvisade emellertid förhöjda fasvinklar motsvarande en polarisation med relativt lång tidskonstant. Detta tolkas vara orsakat av konduktiva mineral eller lermineral som också kan ha påverkat mätningen av resistivitet av detta prov.

Contents

1 Introduction

This document reports the data gained by the resistivity measurements on samples from KFM01A, KFM02A, KFM06A, KFM08A, KFM08C and KFM09A, 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 400-06-007. In Table 1-1 controlling documents for performing this activity are listed. Both activity plan and method descriptions are SKB's internal controlling documents.

The sample preparations were performed by GeoVista AB and the measurements were made by GeoVista AB at the laboratory of the Division of Applied Geophysics at the University of Luleå. Sample preparations were done in January 2007 and the measurements were performed in March 2007 after the samples had been soaked in saline water for eight weeks.

The data from the measurements have been delivered to SKB for storage in Sicada traceable by the activity plan number.

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

Activity plan	Number	Version
Provtagning och analyser av borrkärnor under 2006 för bestämning av bergets transportegenskaper	AP PF 400-06-007	1.0
Method descriptions	**Number**	**Version**
Mätning av bergarters petrofysiska egenskaper (Bilaga 4)	SKB MD 230.001	2.0

2 Objective and scope

The purpose of resistivity measurements and the calculation of the formation factor are to gain knowledge about the transport properties of the rock mass. The resistivity is a measure of the disability to conduct electric current in the form of ions in the pore space of a rock sample. Low resistivity will thus correspond to a high ability of conduction and vice versa. The resistivity of the water that the sample has been soaked in is often normalised with the resistivity of the sample. The resulting ratio is then referred to as the formation factor.

3 Equipment

3.1 Description of equipment/interpretation tools

The samples were prepared and soaked in saline water in accordance with SKB MD 230.001, see Table 1-1. Resistivity measurements were then performed with an in-house two-electrode equipment of Luleå University /1/. The equipment has been calibrated against precision resistors and RC-circuits. The electric conductivity of the soaking water was measured with a Conductivity Meter 840039 from Sper Scientific. Plotting of the data and statistical calculations were made with Grapher v. 6.0 (Golden Software) and Microsoft Office Excel (Microsoft Corporation).

4 Execution

4.1 Sample preparation and measurements

The measurements were carried out in accordance with the method description SKB MD 230.001. A summary of the method is given below.

The testing was performed on core pieces (30 mm long) with plane-parallel end surfaces. The samples were dried at a temperature of 110°C for 24 hours. The end surfaces were then covered by protecting tape and the remaining sample surface was covered by silicon after which the tape was removed. The samples were then placed in vacuum for three hours and afterwards dropped into a 1.0 M NaCl-solution. The samples were kept in the solution for eight weeks after which the resistivity along the sample axis was measured with an in-house equipment /1/ of Luleå University, Division of Applied Geophysics. The measurements were made with a two-electrode system at the frequencies 0.1, 0.6 and 4.0 Hz. The phase angle between applied current and measured potential difference was retrieved as a by-product during the measurements. Some samples were re-measured to check the repeatability of the results. Samples with suspicious or unstable phase angle values were also re-measured.

4.2 Data processing

The raw data of the measurements were entered into an MS Excel-file. The formation factor was calculated as the ratio between the resistivity of the soaking water and the resistivity of the samples at 0.1 Hz:

$$Formation\_factor = \frac{\rho_{water}}{\rho_{sample}}$$

Measurements were made at three base frequencies (see above) and their harmonics. For the majority of the samples, the resistivity varied very little between the frequencies and the 0.1 Hz values can thus safely be used as an approximation of the true D.C. resistivity (see also section 5).

4.3 Nonconformities

The samples should be soaked for ten weeks before measurements according to the method description. In order to have the results entered into Sicada before March 31st 2007 (data freeze 2.3), the soaking time was reduced by two weeks. This is however not considered to affect the results in any major way.

5 Results

Original data from the reported activity are stored in the primary database Sicada. Data are traceable in Sicada by the Activity Plan number (AP PF 400-06-007). Only data in 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. However, such revision of the database will not necessarily result in a revision of this 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 resistivity values of the samples showed relatively moderate spread. The median value was 849 Ωm, corresponding to a median value of the formation factor of $1.70 \cdot 10^{-4}$. A histogram of the formation factor results can be seen in Figure 4-1.

A majority of the samples have formation factor values below $3.0 \cdot 10^{-4}$. No outliers with significantly different formation factors have been found.

The phase angle measurements can be used to get an indication of possible presence of minerals with electronic conduction and also as a quality indicator. The phase angle is due to induced polarisation in the samples. Two main mechanisms exist for such polarisation. The polarisation can arise at an interface between electrolytic and electric conduction, i.e. at the surface of conductive mineral grains like e.g. pyrite or magnetite. The other mechanism is due to a difference in diffusion speed between an-ions and cat-ions through thin membrane pores. Most samples show small phase angles (Figure 4-2). Values above 3 mrad can be seen for two high-resistivity samples from KFM09A. The reason is probably that the current is forced through thin membrane pores in these samples. One sample (KFM08A, 686.92 – 686.95 m), shows higher than normal phase angles corresponding to a polarisation with a long time constant. The anomalous property is interpreted to be due presence of minerals with electronic conduction or clay minerals. It cannot be ruled out that such minerals have biased the measurement of resistivity to a lower value for this sample.

A random selection of samples were re-mounted in the sample holder and re-measured to check the repeatability of the results. The maximum recorded difference between the two measurements was less than 2%.

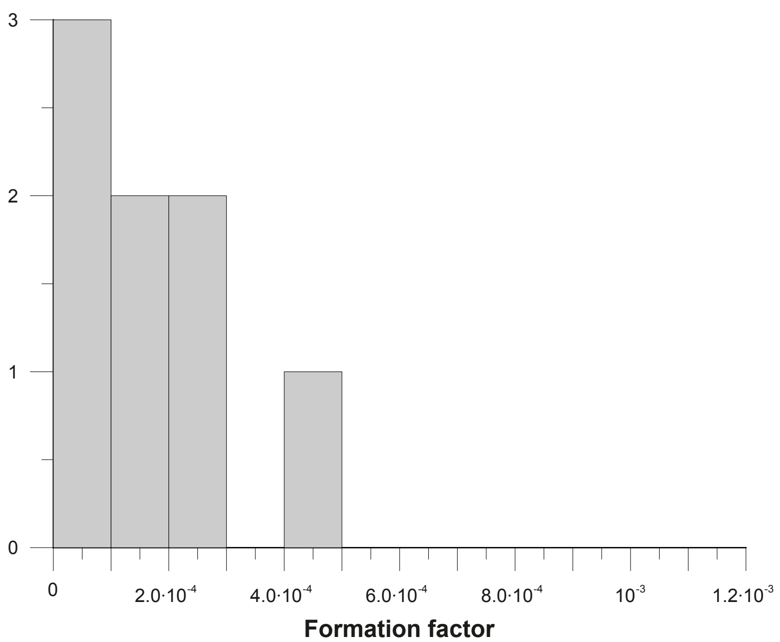

Figure 4-1. *Histogram of calculated formation factor for all samples in the study.*

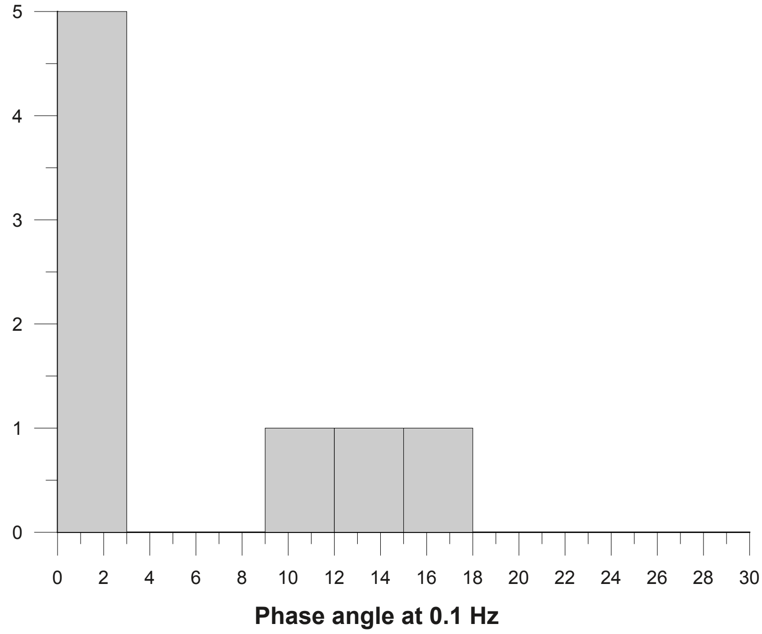

Figure 4-2. *Histogram of measured phase angles (at 0.1 Hz) for all samples from this study.*

References

/1/ **Triumf C-A, Thunehed H, Antal I, 2000.** Bestämning av elektriska egenskaper hos vulkaniter från Skellefte- och Arvidsjaurgrupperna. SGU-2000:8.

Appendix 1

Resistivity and formation factor values

All samples where soaked in water with a resistivity of 0.14 Ωm.

Borehole	Secup (m)	Seclow (m)	Resistivity at 0.1 Hz (Ωm)	Phase angle at 0.1 Hz (mrad)	Formation factor
KFM01A	778.83	778.86	282	0.8	4.96E–04
KFM02A	552.33	552.36	604	0.8	2.32E–04
KFM06A	145.31	145.34	1,827	2.9	7.66E–05
KFM06A	440.09	440.12	995	2.0	1.41E–04
KFM08A	686.92	686.95	703	17.1	1.99E–04
KFM08C	830.64	830.67	671	1.9	2.09E–04
KFM09A	423.43	423.46	12,829	14.9	1.09E–05
KFM09A	798.08	798.11	7,729	9.3	1.81E–05