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Forsmark site investigation

Resistivity measurements on samples from KFM01A and KFM02A

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This report concerns a study which was conducted for SKB. The conclusions and viewpoints presented in the report are those of the author and do not necessarily coincide with those of the client.

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Abstract

This report presents the execution and the results from measurements of electrical resistivity on core samples from the boreholes KFM01A and KFM02A at Forsmark. The formation factor was calculated based on the results of the measurements. A total of 79 core samples were tested. The resitivity was measured after soaking the samples in a 1 M NaCl-solution for 10 weeks. The resistivity values obtained were fairly uniform with a median value of 452 Ωm (1st quartile: 343 Ωm, 3rd quartile: 767 Ωm), corresponding to a median value of the formation factor of 0.286×10^{-3}. A slight increase of the formation factor with depth can be seen for both boreholes.

Sammanfattning

Denna rapport presenterar genomförandet och resultaten från mätningar av elektrisk resistivitet på borrkärneprover från KFM01A och KFM02A vid Forsmark. Formationsfaktorn har beräknats med mätningarna som underlag. Totalt 79 provbitar har undersökts. Resistiviteten mättes efter det att proven legat i 1 M NaCl-lösning i tio veckor. Resistivitetsvärdena var tämligen enhetliga med ett medianvärde på 452 Ωm (första kvartil: 343 Ωm, tredje kvartil: 767 Ωm), svarande mot ett medianvärde på formationsfaktorn på 0.286×10^{-3}. En viss ökning av formationsfaktorn mot djupet kan observeras för bägge borrhålen.

Contents

1 Introduction

SKB performs site investigations for localization of a deep repository for high level radioactive waste. The site investigations are performed at two sites, Forsmark and Simpevarp. This document reports the execution and results gained from resistivity measurements on core samples from the boreholes KFM01A and KFM02A at Forsmark.

The work presented in this report has been performed by GeoVista AB in accordance with the instructions and guidelines presented by SKB in the method description MD 230.001 and the activity plan AP PF 400-03-58 (SKB internal controlling document).

2 Objective and scope

The purpose of resistivity measurements and the calculation of the formation factor is 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 Execution

3.1 Sample preparation and measurements

The measurements were carried out in accordance with the SKB instruction "Metodik för resistivitetsmätningar" (Appendix to AP PF 400-03-58). A summary of the method is given below.

The testing was performed on 5 cm long core pieces with plane-parallel end surfaces. The samples were dried at a temperature of 110°C for 24 hours. The end surfaces were covered by protective tape and the remaining sample surface was covered by silicon after which the tape was removed. The samples were placed in vacuum for three hours and then placed in a 1.0 M NaCl-solution. The samples were kept in the solution for ten weeks and the resistivity along the sample axis was thereafter measured with an in-house equipment /1/ of Luleå University, department 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.

3.2 Data processing

The raw data of the measurements were entered into a 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:

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

The resistivity varied very little between the frequencies and the values can therefore be safely used as an approximation of the true DC resistivity.

4 Results

The resistivity values of the samples were fairly uniform. The median value was 452 Ωm (1st quartile: 343 Ωm, 3rd quartile: 767 Ωm). The results from the two boreholes were also quite similar with median values of 418 Ωm (KFM01A) and 532 Ωm (KFM02A) respectively. The median value of the calculated formation factor was 0.286×10^{-3}. Histograms of the formation factor results can be seen in Figure 4-1.

The phase angle measurements can be used to indicate possible presence of minerals with electronic conduction and also as a quality indicator. All samples except one show small phase angles (Figure 4-2). The small phase angles of about one to five mrad might be explained by small amounts of magnetite in the samples. The small amounts magnetite will probably not have any significant effect on the resistivity measurements.

The formation factor tends to increase slightly with depth for both boreholes (Figure 4-3). The increase is however hardly statistically significant. One sample with anomalously low formation factor can be seen in Figure 4-3 (199.95–200.00 m, KFM01A) and one with anomalously high formation factor (140.00–140.05 m, KFM01A). The former sample also shows a rather large phase angle of 9 mrad whereas the phase angle measurements were unstable for the latter one. The samples were measured several times with similar results. The results for these samples should be used with some caution. The phase angle results might e.g. indicate some problem with the measurements.

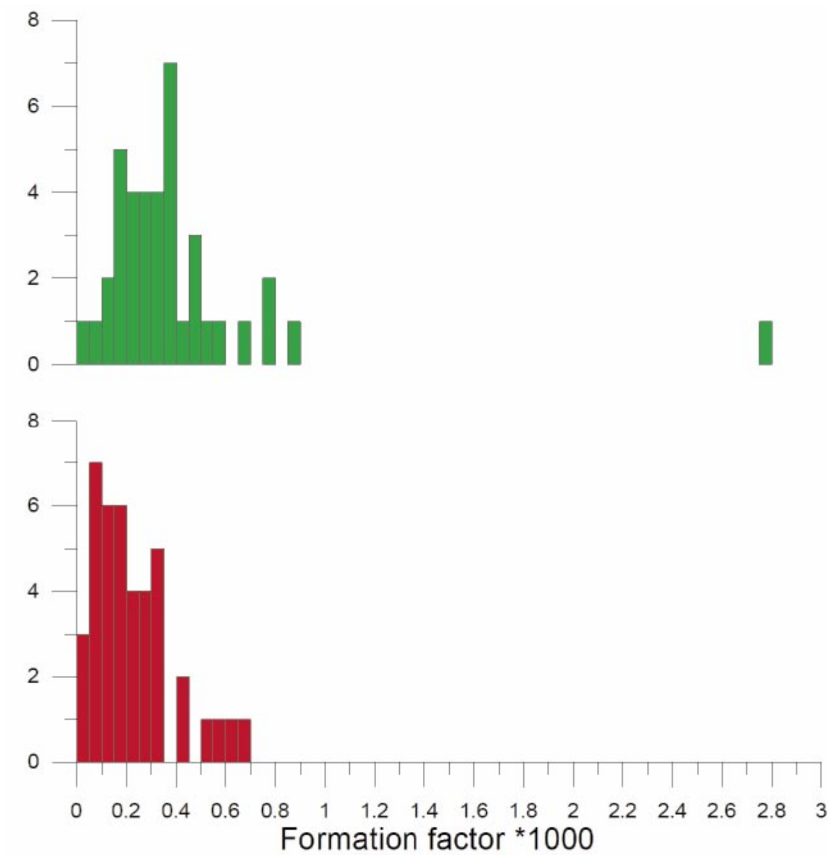

Figure 4-1. *Histograms of calculated formation factor for samples from KFM01A (top) and KFM02A (bottom).*

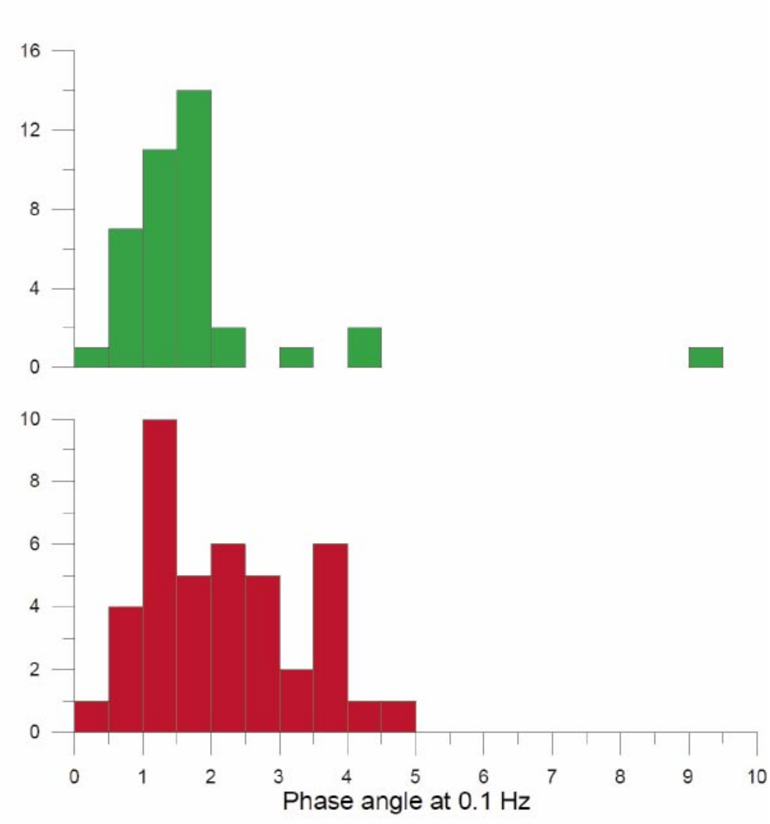

***Figure 4-2.** Histograms of measured phase angles (in mrad) for samples from KFM01A (top) and KFM02A (bottom).*

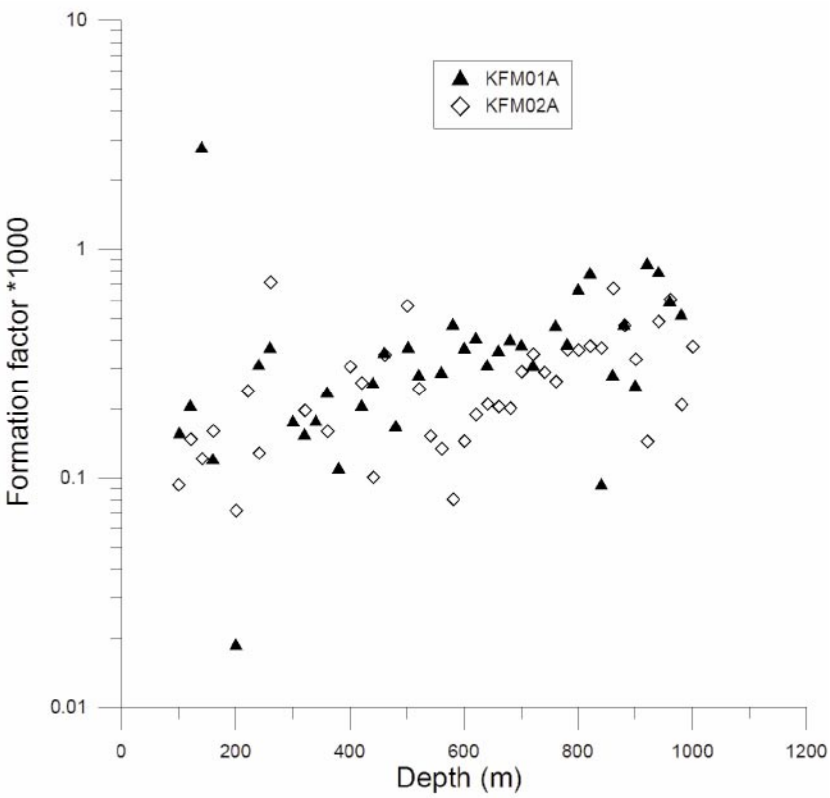

***Figure 4-3.** Formation factor plotted as a function of sampling depth along the cores.*

A subset of samples was remeasured to check for the repeatability of results. The maximum difference between two measurements of the same sample was 11.7% and the median difference was 6.4%. The latter number can be seen as an indicator of the accuracy of the measurements.

The following data have been delivered to SKB: Measured resistivity and phase angle at 0.1 Hz, calculated formation factor and resistivity of soaking water.

The reference to SICADA is field note no 387.

References

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