The influence of the preparation method on the SIP spectra of unconsolidated sediments

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Materials and Methods

A fine sand sample with a narrow grain size distribution ranging from 0.1 to 0.3 mm and three soil samples with a wider grain size distribution (Figure 1) are subject of this study. Each material is put into the SIP sample holder pictured in Figure 2.

Three different ways to prepare the SIP samples are considered in this study (Figure 3). All samples are saturated with a sodium chloride solution with a fluid conductivity of 30 mS/m. The SIP spectra are measured with a VMP 3 equipment (Princeton Applied Research) at a room temperature of approximately 20 °C.

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Introduction

The preparation method applied to samples of unconsolidated sediments strongly influences the pore space of the sample and thus can yield different SIP spectra for one material. The literature covering the influence of the applied preparation procedure on measured SIP spectra is sparse (e.g. Halisch and Weller, 2006; Koch et al., 2009). Within the scope of a master’s thesis (Bairlein, 2011) the SIP spectra of fine sand and soil samples are studied in terms of different preparation methods. The interpretation of the measured SIP spectra and a quantitative analysis involving the parameters resulting from a Debye decomposition (Nordsiek and Weller, 2008) are presented.

Porosity estimation

Determination of the bulk density enables a rough estimation of the porosity of the samples under the assumption that a constant grain density of 2.65 g/cm³ (for quartz minerals) can be applied. The resulting porosities for all four materials are plotted in Figure 4.

SIP on soil samples

To compare the resulting SIP spectra and their reproducibility we plotted the mean value of the phase angle and the standard deviation for the soil samples from Schunter and Groß Gleidingen, respectively. The mean phase angle spectra (Figure 5) for the Schunter samples are constant for the major part of the investigated frequency range and remain lower than 5 mrad. The standard deviation (Figure 6) is less than 0.5 mrad for frequencies greater than 0.1 Hz for all three preparation methods.

For the soil samples from Groß Gleidingen the mean phase angle spectra (Figure 7) increase with frequency. The standard deviation (Figure 8) for method 3 is significantly lower than for methods 1 and 2, indicating that the reproducibility of the SIP spectra increases with the compaction of the sample. This effect can be observed for the soil sample from Groß Gleidingen with a wide grain size distribution, but not for the more well-sorted material from Schunter.
Debye decomposition

Application of the Debye decomposition approach to the measured SIP data yields the integrating parameters direct current (DC) resistivity, total chargeability, and mean relaxation time. Weller et al. (2010) describe the normalized chargeability as the ratio of total chargeability to DC resistivity and find a linear relationship between this parameter and the specific surface normalized to total pore volume. The relaxation time or time constant, respectively, derived from SIP spectra is usually regarded as a measure of the hydraulic length scale of the pore space. In this study, we take a closer look at the influence of the preparation method on the DC resistivity, the normalized chargeability, and the mean relaxation time.

DC resistivity

According to Archie (1942) the relation between DC resistivity and porosity can be described by a power law with two empirical parameters \( a \) and \( m \), where the latter is called the cementation exponent. In Archie’s original approach the parameter \( a \) is fixed to 1. In Figure 9 we plotted the DC resistivity resulting from the Debye decomposition versus the estimated porosity of the samples. Fitting a general approach of Archie’s equation with variable parameters \( a \) and \( m \) to the data of all preparation methods yields a cementation exponent that corresponds to the value found by Archie for unconsolidated sands.

Normalized chargeability

The normalized chargeability is a parameter related with the surface to pore volume ratio and is thus also depending on the clay content of the investigated soil samples. An increase of the normalized chargeability with clay content is noticeable in Figure 10. The IP effect of the fine sand sample was very weak, so we performed only measurements with the first and the second preparation method and neglected the sample for further interpretation. The variation of the normalized chargeability according to the three preparation methods is low. The relative error of the normalized chargeability is between 9 % (Schunter) and 21 % (Wolfenbüttel). For the relative error concerning the different samples we find values of 70 % (method 7) and 101 % (method 3). This indicates that the normalized chargeability is not influenced significantly by the preparation method.

Mean relaxation time

Excluding the fine sand sample, an increase of the mean relaxation time with the mean grain size of the samples is visible in Figure 11. The variation of this parameter in relation to the preparation method appears to be slightly higher compared to the normalized chargeability.

Conclusions

- Effect of tapping on the side of the sample holder is low, preparation methods no. 1 and 2 show similar porosities and SIP spectra
- For samples with a wide grain size distribution, method 3 yields a distinct compaction and lower standard deviation of the phase angle spectra
- Normalized chargeability appears to be less sensitive than the mean relaxation time to variations of the preparation method
- Providing information about the applied preparation method is essential for SIP investigations on unconsolidated sediments

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References


