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Hydrology and
Earth System
Sciences
Discussions

Interactive comment on "Impact of controlled changes in grain size and pore space characteristics on the hydraulic conductivity and spectral induced polarization response of "proxies" of saturated alluvial sediments" *by* K. Koch et al.

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We found the comments of the referees very insightful, constructive, and useful and hence we shall make a concerted effort to accommodate them in their entirety in the course of the revised version of this manuscript. In the following, we outline in detail our proposed reactions to these reviews.

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Interactive Discussion

Discussion Paper

Replies to the Comments by Referee Lee Slater:

General comment: This discussion paper presents some high quality spectral induced polarization and grain size hydraulic conductivity datasets that have been collected following a systematic variation of physical properties of artificial alluvial soils. This nicely collected dataset deserves to be published as it yields further phenomenological insights into the relationship between SIP measurements/parameters and soil grain size characteristics and hydraulic properties.

However, I have identified some specific technical issues that I feel must be addressed prior to publication:

1. Cole-Cole type interpretations of SIP spectra go a lot further back than Vanhala (1997) – suggest referring to classic Pelton et al (1978) paper on the subject.

We propose to address this comment, by modifying the pertinent part of the text as follows: "Pelton (1978) was arguably first to illustrate that the phenomenological adequacy of Cole-Cole-type models (Cole and Cole, 19941) for phenomenological description of the observed SIP responses (e.g., Vanhala, 1997; Dias, 2000). Recently, Revil and Florsch (2010) supplied a corresponding theoretical justification, which is based on the polarization of the Stern layer and supported by the results of several recent studies (Leroy et al., 2007; Jougnot et al., 2010; Schmutz et al., 2010). A number of workers also found consistently good correlations between hydraulic conductivity and the Cole-Cole time constant for a range of geological materials (e.g. Binley et al. 2005; Kemna et al. 2005; Zisser et al. 2010)."

2. Reference to Wennertype spacing is misleading and should be changed. Wenner configuration is based on point electrodes and the Wenner geometric factor used to convert resistances to resistivity is based on point electrodes. This geometric factor is not correct for your samples and I hope it was not used.

We now realize this ambiguity in the wording. The actual geometric factor used with our data is A/l= r^2*Pi/l (Zimmermann, personal communication, 2008), with r= 0.03 m; l= 0.1 m. To address this point, we therefore propose to modify the revised manuscript as follows:

Original text: “The potential electrodes are rings of silver wire fixed into grooves at 1/3 and 2/3 of the sample holder’s length thus resulting in a constant, Wenner-type spacing of 10 cm between the individual electrodes.“ Modified text: “The potential electrodes correspond to rings made of silver wire placed into grooves along the inner wall of the 30-cm-long measurement cylinder (Figure 2). These groves are located at a distance of 10 cm from either end of cylinder. This results in an equi-distant spacing of 10 cm between individual electrodes and a geometric factor given as k=r^2*Pi/l with r and l denoting the radius of the measurement cylinder and the distance between the potential electrodes, respectively.”

3. How was surface area calculated from the laser particle size analyzer? Your work is a bit confusing in that you repeatedly talk about surface area whereas it is surface area to pore volume that is the parameter sensitive to hydraulic conductivity. Your figure 4 suggests that you have normalized your surface area to a volume – but what volume, and how do you get to this from the laser particle size analyzer measurements?

To address this question, we propose to add the corresponding text to the revised version of the manuscripts: “Specific surface measurements based on laser diffraction methods aim at estimating the grain diameters through the assumption of a specific geometrical form factor of the grain, which in our case is spherical. The signal of the diffracted light from a measured grain is thus fitted to that of an equivalent sphere. Hence, specific surface area measurements of this type provide us with the so-called geometric surface area of a grain, which is equal to the surface of the equivalent sphere. The corresponding specific surface area, given by the surface of this equivalent sphere divided by its volume, does therefore neither account for the small-scale grain surface roughness nor to the porosity. For a granulometrically heterogeneous sample, this parameter thus represents a combined measure of sorting and grain size of the overall distribution."

4. Compaction will increase surface area per unit volume but not total surface area. Throughout the paper be careful in that you should be considering surface area to pore volume or total volume rather than just surface area measured with your laser particle size analyzer. This needs to be clarified on page 6066. Also, make it clear that the discussion of changes in surface area that you are referring to here were not measured changes in surface area using your laser diffraction approach. Similarly, it is surface area to pore volume that is assumed to represent the inverse of hydraulic radius in Kozeny-Carmen type models for hydraulic conductivity characterization and not simply surface area as measured with the particle size analyzer. Perhaps you realize this, but this is not clear from the text of the paper.

Thank you for pointing this out. For the revised manuscript, we propose to clarify the use of the term "specific surface area" on page 6066 by changing in the text "specific surface area" to "surface area per unit pore volume" in lines 20, 22, and 25, as well as page 6067 line 17. With regards to the Kozeny-Carman comparison it needs to be stated that it is misleading the way it was written. The authors think that the reference does not help the overall comprehension of the discussion of the results, and hence propose to remove it from the revised version of the manuscript.

5. Why do you consider it "interesting" and (apparently) "surprising" that the measured K values (using a constant head test) provide a stronger correlation with sample time constant than if K is estimated from grain size parameters? Of course, grain size parameters often provide poor estimates of K as they are so simple in terms of formulation, so would this result not be expected? Binley et al. (2005) already pointed out that time constant appears to be better correlated with K than with other measures of the interfacial surface (e.g. surface area) and discussed this interesting observation. Some reference to this is probably warranted.

To address this issue, we propose to replace the existing text: "Finally, Fig. 7 compares the observed K values with inferred ones based on common granulometric models (Hazen, 1892; Beyer, 1964) with the t [Greek letter Tau will be used in the revised manuscript] values of the corresponding samples. Interestingly, we find a systematically stronger correlation for the measured K-values compared to the K-values inferred from empirical relations based on granulometric criteria."

With the following in the revised version the manuscript: "Finally, Fig. 7 compares the observed K-values and the ones inferred based on common granulometric models (Hazen, 1892; Beyer, 1964) with the t [Greek letter Tau will be used in the manuscript]-values of the corresponding samples. Interestingly, we find a systematically stronger correlation for the measured K-values compared to the K-values inferred from empirical relations. In this context, it is interesting and important to note that these relationships are based on well sorted sand samples comparable to the ones considered here. Hence, given that the time constant data fits the actual measurements of hydraulic conductivity better than granulometrically-based estimates, points to the fact that the phenomenology of the SIP response cannot be reduced to a single textural factor, such as, for example, the grain size. As a consequence, this is once again an indication that consideration of multiple structural parameters will be necessary, when trying to identify parameters governing the source processes of induced polarization. In this context, Binley et al. (2005) pointed out that the Cole-Cole model time constant appears to be better correlated with K than with other measures of the interfacial surface, such as, for example, the surface area per unit pore volume. In their work, values of the time constant are compared to median grain size d50 (rˆ2=0.62; as compared to rˆ2=0.64 in our study (graph not shown)), pore throat diameter (rˆ2=0.61), surface area per unit volume (rˆ2=0.75), and hydraulic conductivity (rˆ2=0.78; compared to rˆ2=0.77 for uncompacted samples and rˆ2=0.94 for compacted samples (Fig. 6, 7)). Although these findings are for consolidated sandstone samples, the results agree well with the quality of our findings. However, results shown in Figures 4 and 5 indicate that changes in the sorting have a direct impact on these relationships. This is further indication of the actual complexity of petrophysical parameter relationships and their impact on processes dominating hydraulic conductivity as well as induced polarization measures."

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 6057, 2010.

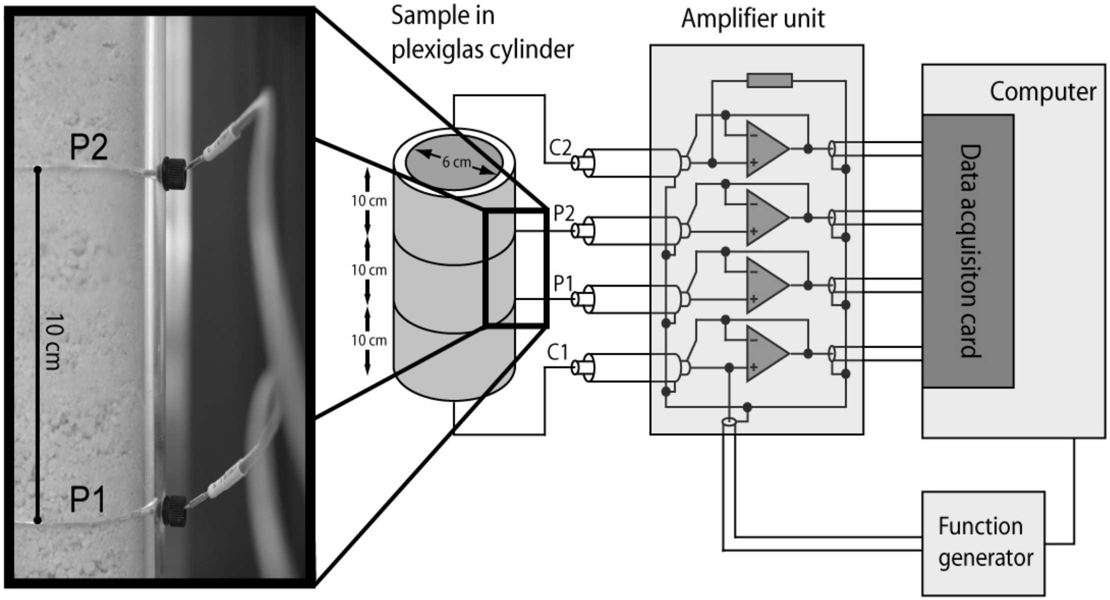

Fig. 1. Experimental setup and schematic illustration of the high-sensitivity impedance spectrometer used for the SIP measurements presented in this study.