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Permeability models of porous media: Characteristic length scales, scaling constants and time-dependent electrokinetic coupling

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Four important models that describe the fluid permeability of geological porous media and that are derived from different physical approaches have been rewritten in a generic form that implies a characteristic scale length and scaling constant for each model. The four models have been compared theoretically and using experimental data from 22 bead packs and 188 rock cores from a sand-shale sequence in the UK sector of the North Sea. The Kozeny-Carman model did not perform well because it takes no account of the connectedness of the pore network, and should no longer be used. The other three models (Schwartz, Sen and Johnson (SSJ), Katz and Thompson (KT) and the so-called RGPZ) all performed well when used with their respective length scales and scaling constants. Surprisingly, we have found that the SSJ and KT models are extremely similar, such that their characteristic scale lengths and scaling constants are almost identical even though they are derived using extremely different approaches; the SSJ model by weighting the Kozeny-Carman model using the local electric field, the KT model using entry radii from fluid imbibition measurements. The experimentally determined scaling constants for each model were found to be $c_{SSJ} \approx c_{KT} \approx$ 8/3 $\approx c_{RGPZ}$/3. Use of these models with AC electrokinetic theory has also allowed us to show that these scaling constants are also related to the a value in the RGPZ model and the m* value in time-dependent electrokinetic theory, and then derive a relationship between the electrokinetic transition frequency and the RGPZ scale length, which we have validated using experimental data. The practical implication of this work for permeability prediction is that the Katz and Thompson model should be used when fluid imbibition data is available, while the RGPZ model should be used when electrical data is available.