Lab Data as Ground Truth?
A Digital Rock Physics Approach to Resistivity Data Representativeness

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SUMMARY

Geophysical simulation studies and the interpretation of inversion results depend on laboratory measurements and petrophysical correlations derived from these datasets. However, the scarcity of sample material and the time-intensive nature of lab processes often result in sparse datasets, raising concerns about their representativeness and reliability. Measured data are typically statistically representative of individual samples, making extrapolation challenging due to the inherent heterogeneity and variable internal structure of geomaterials.

To address this challenge, we propose a workflow that includes random microstructure modeling, finite element simulation of rock properties, and subsequent statistical and petrophysical evaluation. Our geometric modeling approach generates ensembles of randomized microstructure geometries, specifically pore space geometries. Each ensemble is parameterized using a set of hyperparameters (e.g., mean particle size, mean pore size) to guide the underlying modeling algorithms. These algorithms mimic realistic pore space generation processes, are conceptually simple, applicable in 2D and 3D, allow easy external parameterization, and do not require large amounts of real rock data. Each ensemble consists of unique model realizations sharing common characteristics, allowing statistical evaluation of geometric parameters such as porosity or fractal dimension.

We then calculate the electrical resistivity of each random microstructure using the finite element method and the FEMALY code. The results are statistically evaluated and compared with laboratory data. We present datasets for three different rock types and their associated pore space types, assessing the microvariability in electrical resistivity and the ability of our approach to accurately reflect the porosity dependence of electrical resistivity. Finally, we discuss the implications and potential of our approach for integrating and upscaling petrophysical data in field-scale geophysics.

Keywords: Electrical properties; Microstructure; Finite element method; Statistical methods