Multi-Data Inversion Approach for Retrieving Rock Properties from Measurements on Drill Cuttings

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SUMMARY

Electromagnetic methods can be of great value in monitoring applications (e.g. for geothermal energy, carbon dioxide sequestration, enhanced oil recovery, natural gas discharge zones) due to their sensitivity to reservoir fluids and their properties. Quantitative evaluation of monitoring data requires knowledge of reservoir-specific petrophysical relationships. As sample material for establishing these petrophysical relationships, drill cuttings are often the only rock material available from deep formations due to related high costs and time-consumption of coring. Therefore, estimating various formation properties from cuttings is a common task. However, for physical rock properties like complex electrical conductivity this formation property retrieval is challenging.

We therefore systematically investigated the electrical and structural properties of four different carbonate rocks and one sandstone in both crushed (8 different particle sizes, between 0.03 mm and 10 mm particle size) and plug form with a vast set of methods at normal conditions: complex-valued electrical conductivity, NMR, mercury intrusion porosimetry, nitrogen adsorption, XRD, μCT, scanning electron microscopy. By means of the huge data set we are able to quantify the pore-space, surface and electrical properties as functions of particle size, understand their relations, differentiate between intra- and inter-particle responses. The samples show significant variation in their electrical conductivity depending on salinity, porosity, pore-space heterogeneity and – due to the peculiarities of the crushed samples – the organization of particles in the packing.

We present a three-level model for the crushed rock material, which accounts for particle size and inner structure. Based on this model, it is possible to computationally recover the corresponding properties of the original, undisturbed formation. We realize this by means of a multi-data inversion of complex electrical conductivity, specific surface and porosity data for each rock. The presented inversion approach allows for utilizing the available drill cuttings, while maintaining the direct connection to the original rock.

Keywords: Electrical rock conductivity; Petrophysical joint inversion; Microstructures