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Integrating multi-scale geophysical and drill-core data to improve hydraulic characterization of continental sedimentary basins

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Physical properties of rocks in the uppermost continental crust e.g. sedimentary basins are very heterogeneously distributed and anisotropic making it necessary to perform advanced post processing techniques on geophysical data. Whereas e.g. electrical resistivity or seismic tomography allow only for identifying physical properties' variability on a scale from roughly several tens of metres to several hundred metres, drill cores reveal physical heterogeneity on the cm-scale. To study the impact of small scale acoustic and hydraulic heterogeneity on fluid flow in a sedimentary basin we use combined data sets from the Thuringian Basin in Germany, a small southern extension of the North German Basin characterised by Permian to Triassic sediments. Our data sets consist of three reflection seismic lines acquired within the framework of the multidisciplinary project INFLUINS (INtegrated FLUid dynamics IN Sedimentary basins) and as site survey for deep drilling, geophysical logging data from a 1,179 m deep drill hole in the centre of the Thuringian Basin, and Multi Sensor Core Logger (MSCL) data of the cores recovered from this drill hole.

Geophysical borehole logging was performed immediate after drilling on the highest vertical resolution (about 10 cm) possible using state of the art commercial logging tools. MSCL-data were acquired at an even higher resolution of about 1 to 2 cm , which enables both, calibrating logging data and zooming in the spatial heterogeneity of physical properties. These measurements are complemented with laboratory measurements of rock physical properties (e.g. thermal conductivity, permeability) using selected core samples. Here, we mainly focus on seismic (sonic velocity, density) and hydraulic (porosity, permeability) parameters. This multi-methodological approach allows us on the one hand to estimate improved local to regional average values for physical parameters but most importantly also to highlight the role of thin layers, the physical properties of which differ specifically from other, thicker layers, on e.g. large scale fluid flow. Further, we tested several cluster analysis algorithms to derive lithology from physical properties, a strategy potentially feasible to estimate lithological stratigraphy from non-cored drill holes, which then would provide a low-cost approach to better characterized drill sites, which were not cored due to the high costs of coring.

The combination of high-resolution information with depth from borehole logging (1D) on the cm- to metre-scale with 2D seismic reflection data and therefore up to 2.5D velocity models on the tens to hundreds metre-scale provides a basis suitable for interpreting basin architecture on the seismic to sub-seismic scale.