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Seeing the Fluids inside Rocks (Christiaan Huygens Medal Lecture)

Martin D. Hürlimann
Schlumberger – Doll Research, Cambridge

Measuring the spatial distribution and the chemical composition of the fluids filling the pore space of geological formations lies at the heart of a number of important applications in the Geosciences. Hydrology deals with the distribution and transport of water in the subsoil. It is also concerned with tracking pollutants that might jeopardize the safety of drinking water. The exploration and production of hydrocarbon reservoirs relies on our ability to identify and quantify the hydrocarbons, determine their composition, and assess the flow properties of the reservoir. For carbon storage application, it is essential to understand the connectivity of the pore space and then monitor the injected fluid inside the formation.
A newly developed technique based on magnetic resonance greatly improves our experimental ability to quantify and characterize fluids inside porous media. It relies on the measurement of two-dimensional diffusion – relaxation distribution functions. These measurements probe the effect of individual molecules undergoing Brownian motion inside the pore space.
This talk reviews the principles,required instrumentation, and applications of the new technique. It will be demonstrated that these diffusion – relaxation distribution functions can be used to quantitatively identify different fluid phases, estimate the chemical composition of the fluids, and infer information on the geometry of the pore space. This can be accomplished in situ without the need to extract the fluids from the sample. Compared to conventional NMR techniques, the new modality poses much weaker demands on the strength and homogeneity of the applied magnetic field. This has enabled the implementation of the new measurements on mobile inside-out systems that can investigate samples located outside the apparatus. Such measurements are now routinely performed in well-logging of boreholes at depths of many kilometers with associated high pressures and temperatures.
Finally, opportunities for further applications in other fields are discussed.