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Image-based pore-scale simulations of nuclear magnetic resonance response for enhanced reservoir characterization

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Nuclear Magnetic Resonance (NMR) is a powerful tool to assess physical quantities that characterize porous media, offering detailed information about the fluid molecules confined in the pore space. This work presents a computational implementation of image-based simulations of NMR experiments in porous media using the Random Walk method with a particular focus on reservoir rocks. We explore and discuss the computational challenges of running such simulations on personal hardware instead of using multicore clusters, which is the conventional approach. In that sense, the proposed solution includes a scheme for data compression and a strategy for massive parallelization in the graphics processing unit. Moreover, we present applications simulating NMR diffusometry and relaxometry experiments. In the first study, the time-dependent apparent diffusion coefficient is measured by simulating the Pulsed-Field Gradient NMR technique. This quantity's asymptotic behavior in both short and long-time ranges is then used to recover the surface-to-volume ratio and the tortuosity of the underlying porous medium. We explore the correlation between the recovered parameters and the absolute permeability in a set of synthetic granular media and segmented microtomographic images of sandstones and carbonates. In the second study, we explore the influence of the diffusive relaxation mechanism in the transverse relaxation time, T_2. The relevance of this mechanism arises in the presence of strong internal magnetic field gradients induced by a pronounced contrast between the magnetic susceptibility of fluid molecules and mineral components of the solid phase. These simulations require a two-step workflow: in the first step, we compute a spatial description of the magnetic field inside the pore space by solving Maxwell equations under zero-current condition using an image-based finite elements implementation; second, we feed our random walk simulations with the computed field map, incorporating its dynamic effect in the magnetized spins. We perform such simulations in sintered models of glass beads containing localized concentrations of iron oxides and sandstones of varying mineral compositions. Not only will this enhanced relaxation alter the otherwise straightforward interpretation of T_2 relaxation times into pore sizes, but it may also indicate the presence of clay components in the mineral phase. In both studies, experimental data is provided for comparison purposes.

Participation

In-Person

References

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