Investigating liquid displacement in porous media using spatially resolved NMR spectroscopy

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Introduction: Paramagnetic impurities in rock materials are causing line broadening ($\Delta\nu$) that obscures the quality of data obtained in high field MRI and NMR [1]. We have created a core model system for spatially localized high field MRI/NMR measurements with high image quality and where liquid signals can be separated due to chemical shift differences. Recently, we showed that correlations between internal gradients (G_0) and differences in magnetic susceptibility ($\Delta\chi$) enable determination of pore size distributions [2, 3]. Furthermore, G_0-$\Delta\nu$ correlations can be used to determine grain size heterogeneities [3, 4]. Here we present results from spatially resolved G_0-$\Delta\chi$ and G_0-$\Delta\nu$ correlations obtained during liquid displacement in samples with varying properties.

Methods: The core model system consists of closely packed NC4X high purity quartz sand (The Quartz Corp). All experiments were conducted on a Bruker Ascend 500MHz vertical wide bore spectrometer equipped with a MicWB40 micro-imaging probe using methods presented in [2, 3].

Results and Discussion: Examples of spatially resolved NMR data obtained from liquids in areas of different grain sizes and wettability are shown in the figures below. The data reveals how these properties of the porous system influence the confinement and dynamic behavior of the liquids.

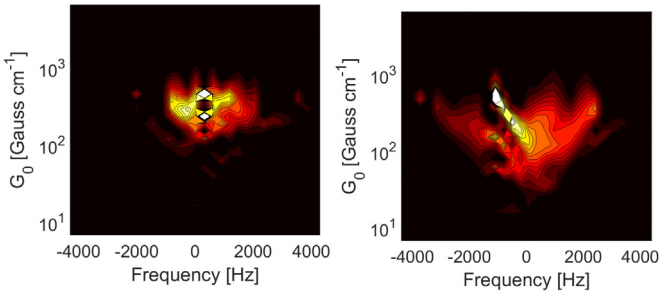

Fig. 1: Spatially resolved G_0–$\Delta\nu$ correlations from areas of different degrees of grain size heterogeneities.

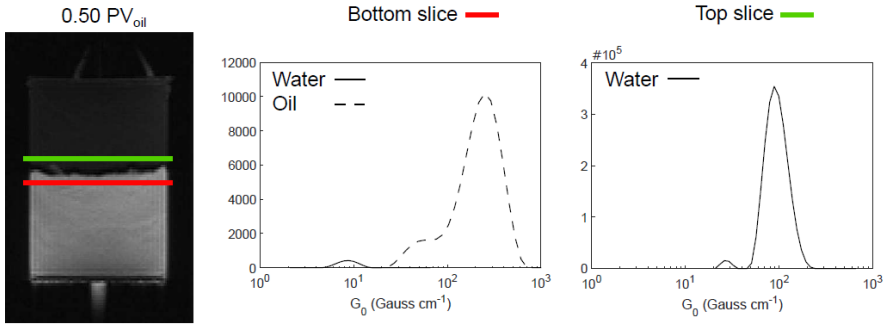

Fig. 2: Examples of spatially resolved G_0 distributions acquired from water and oil signals during oil imbibition in an oil-wet sample. Signals from water and oil are separated due to their differences in chemical shift.

Conclusions: The presented core model system and spatially resolved NMR methods presented reveals detailed information about local confinement during liquid displacement in porous systems.

References: [1] J. Mitchell et al., Phys. Rep, 526, (2013). [2] H. N. Sørgård, J.G. Seland, J. Magn. Reson, 301, (2019). [3] R.T. Lewis, J.G. Seland, Mic. Mes. Mater. 269, (2018). [4] L.M. Burcaw, P.T. Callaghan, J. Magn. Reson. 216 (2012).