Fluid analysis with low-field NMR

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Nuclear magnetic resonance measurements of relaxation and diffusion are currently used in oil wells to determine the pore sizes in the rocks and the amount of oil, gas and water inside the pores. Of all the downhole tools, NMR is the only one that can give detailed information about the fluid *inside* the rock. In this presentation, we will explain how NMR relaxation and diffusion can be used to measure properties of the oil.

Both diffusion and relaxation are sensitive to the dynamics of the molecules in the oil, which makes them sensitive to the size of the molecules and also to changes in phase. In addition, at low fields, NMR relaxation is sensitive to time scales which are on the order of the rotational correlation times expected for particles with radii of a few nanometers. This makes low-field NMR sensitive to asphaltene aggregation and clustering.

In this presentation, we will show how we can use 2D NMR measurements to determine information about the chemical composition and phase behavior of the oil. In particular, by comparing the diffusion and relaxation distributions of an oil, we can distinguish oils that are high in saturates, oils that are heavily biodegraded and oils that contain asphaltenes. For viscous oils, the correlations between diffusion and relaxation can also be used to distinguish oils with asphaltene, waxing or emulsions, as shown in Fig. 1. In addition, field cycling, where NMR relaxation is measured over a range of frequencies, is very sensitive to the presence of asphaltenes, as shown in Fig. 2. It can be used to obtain dipole-dipole correlation functions of the maltene molecules in the oils, which can be used to shed light on the aggregation state of the asphaltenes. Lastly, we will show how we can use ideas borrowed from polymer physics to determine the size distributions of the molecules in oils that are high in saturates

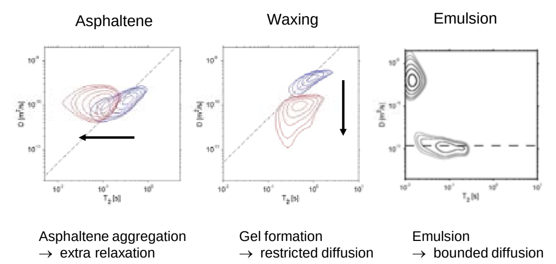

Fig. 1. Diffusion-relaxation maps for oils with asphaltene, waxing and emulsions. The plot on the left shows that the relaxation times decrease when asphaltene is added to the maltene. The plot in the middle shows that the diffusion coefficients decrease when the temperature is reduced and wax is formed. The plot on the right shows that the bound phase and continuous phase can be distinguished in emulsions.

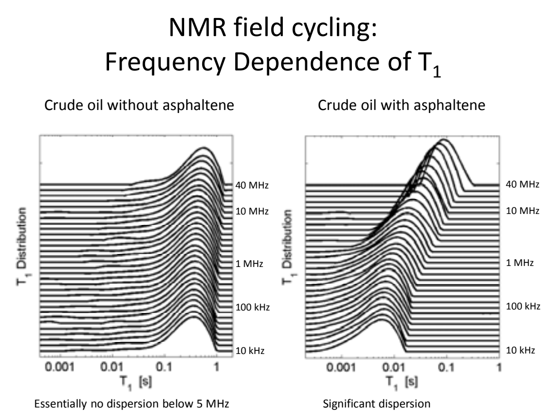

Fig. 2. Field cycling data for two crude oils. The T_1 distributions are shown as a function of frequency. The oil on the left is a crude oil with no asphaltenes, and its T_1 distribution has no dependence on frequency. The oil on the right has asphaltene in it, and its T_1 distribution depends on frequency.