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Project Title: Determination of Wettability of Rock via Sodium NMR
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The wettability properties of rock pore surfaces are of vital importance for the determination of oil recovery procedures. Rock pores can hold large amounts of difficult-to-recover oil, if the wettability conditions are chosen incorrectly. The main goal of this project is to determine how sodium NMR can allow the determination of water wettability properties. The rationale for the hypothesis is that sodium ions interact with charged surfaces, which normally are also the sites that favor water wetting.

Over this reporting period, we have performed experiments on several different rock samples, including the sandstones Berea, Fontainebleau, Bentheimer, and Austin chalk using ^{23}Na NMR. The NMR signals indicated different fractions of sodium environment within rocks, including free sodium, slowly tumbling sodium, and bound sodium. The data analysis of the initial results indicated that additional control experiments were necessary. For example, we determined that certain sandstones have immobilized sodium ions, or ordered sodium, but it was not clear how to distinguish between the two pools. Additional factors that needed further examination were the large magnetic field inhomogeneities present especially in Berea sandstone.

We have optimized the methodology for ^{23}Na NMR in the inhomogeneous media at high magnetic fields, and have studied different diffusion regimes within these environments. Notably, in the case of Austin chalk, we were able to identify fractions of sodium that resides in anisotropic environments via multiple-quantum filtered (MQF) experiments (see Fig. 1 below). These signals could be attributed to sodium interacting with the surface, or sodium in the slow motion regime (immobilized). This ambiguity was the subject of detailed investigation. Additional core samples were requested from Schlumberger, Inc in order to test different hypotheses as to the origin of the signals. A manuscript is in preparation, but requires further control experiments and data analysis, which we are hoping to perform during the no-cost extension.

In addition, we have identified intriguing new effects of ion relaxation in liquids, especially at high salt concentrations. These effects are being studied using Li and Na spectroscopy. The comparison between the two nuclei allows us to test the influence of quadrupolar relaxation, and to provide baseline data for rock measurements. The identification of the different sodium fractions in the pores of different sandstones will provide new tools for the identification of pore surface wettability properties.

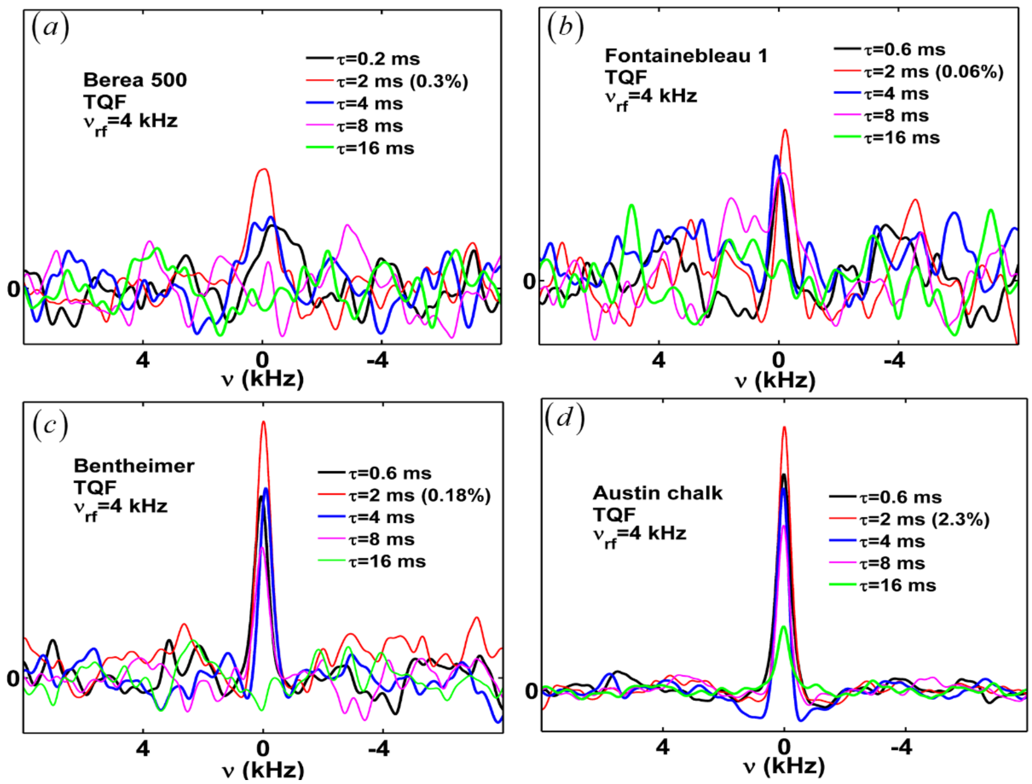

Fig. 1: ^{23}Na triple-quantum filtered (TQF) spectra for different delay times τ for Berea 500 (a), Fontainebleau 1 (b), Bentheimer (c) and Austin chalk (d). τ: 0. 6 ms – black line (in the case of (a) it is 0.2 ms); 2 ms – red line; 4 ms – blue line; 8 ms – pink line and 16 ms – green line. The relative intensity of the red peak was calibrated with respect to 90^0-pulse excitation.