T_1 and T_2 correlation for fluid typing and quantification

Application Note 4

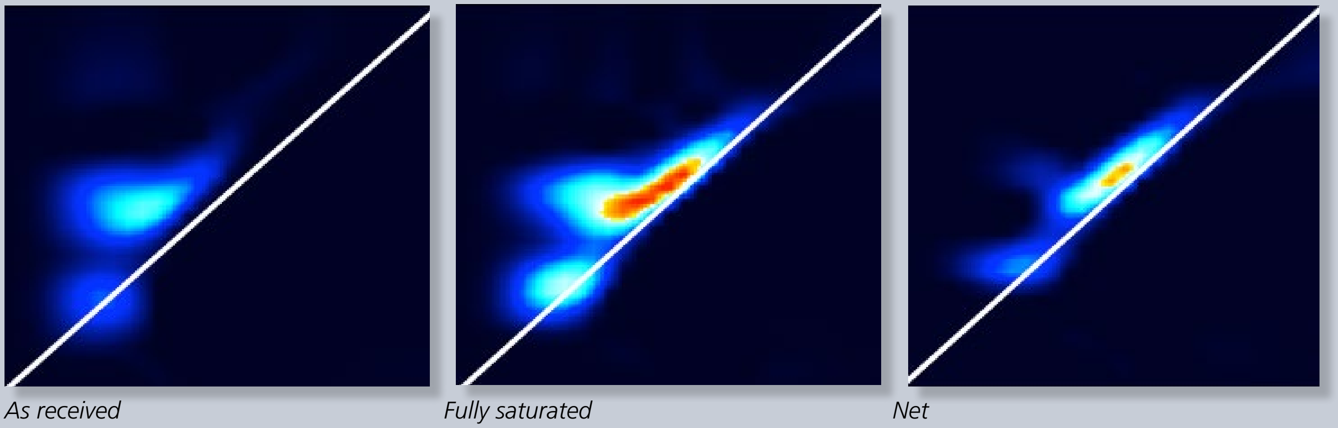
In recent years, lab based NMR core analysis researchers have begun to take advantage of enhanced signal-to-noise ratios (SNR) and shorter tau values to implement more data rich measurement techniques. In the past, extremely long acquisition times for T_1-T_2 maps, or correlation plots, made them next to impossible to obtain. Current SNR levels have eliminated this limitation and have allowed researchers to begin exploring what can be learned from these maps.

Here, we show how T_1-T_2 maps can be used to differentiate fluids with different viscosities. We demonstrate how water and bitumen can be discriminated with T_1-T_2 maps in representative shale formations. Further, we show how measuring T_1 and T_2 at different temperatures allows us to differentiate between components of varying viscosity.

Method

Initial inversion recovery CPMG T_1-T_2 measurements were obtained on six shale samples in the as received state. (Figure 1, left panel). The samples were then placed in brine under 2,000 psi of pressure for 48 hours to fully saturate the samples and the inversion recovery CPMG T_1-T_2 measurements were repeated. (Figure 1, center panel). All measurements were performed on an Oxford Instruments **GeoSpec**2 2/75 2 MHz spectrometer with a 40 mm probe. The as received T_1-T_2 measurement was then subtracted from the fully saturated T_1-T_2 measurement to give the net T_1-T_2 measurement (Figure 1, right panel).

Figure 1: *T_1-T_2 maps of shale core in various conditions*



As received *Fully saturated* *Net*

GREEN IMAGING TECHNOLOGIES, INC.

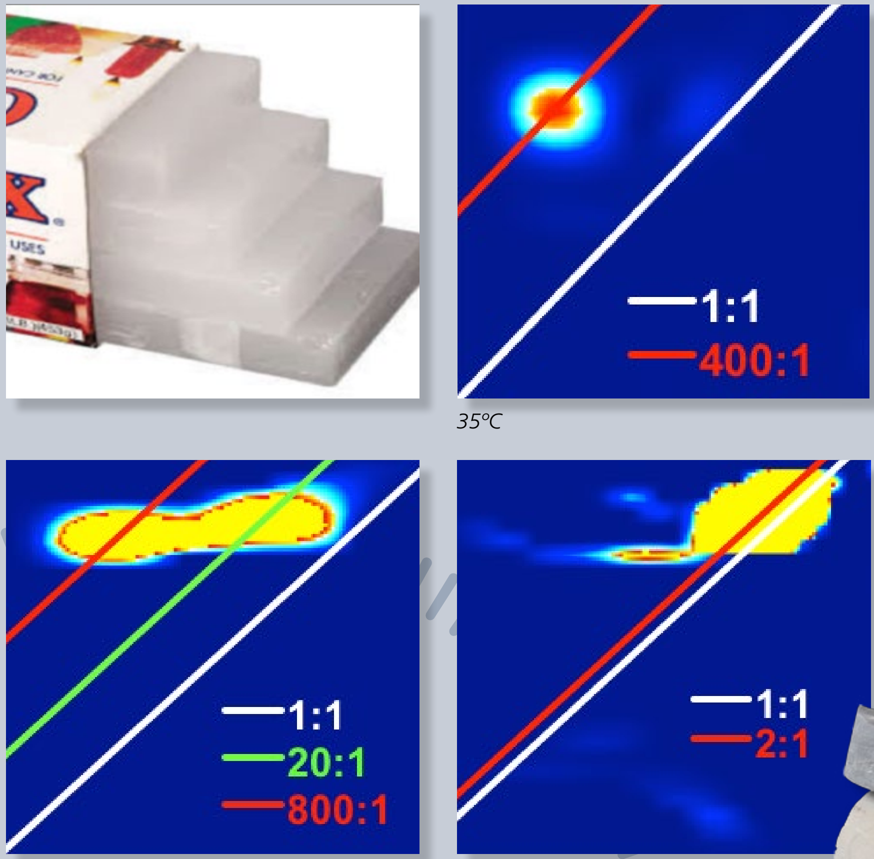
OXFORD INSTRUMENTS

The Business of Science®

T_1 and T_2 correlation for fluid typing and quantification

Results

The T_1/T_2 ratio can be used to determine the origins of the signal in net T_1-T_2 maps [1]. In fluids with low viscosities, T_1 and T_2 are similar, but as viscosity increases T_1 and T_2 will deviate [2]. Higher ratios indicate more viscous materials such as bitumen while lower ratio contributions are likely due to water. In the T_1-T_2 maps of Figure 1, high signal intensity is red while low intensity is shown in blue. The white diagonal line represents a T_1/T_2 ratio of 1:1.



35°C

45°C.

70°C

Temperature studies

Solid Wax

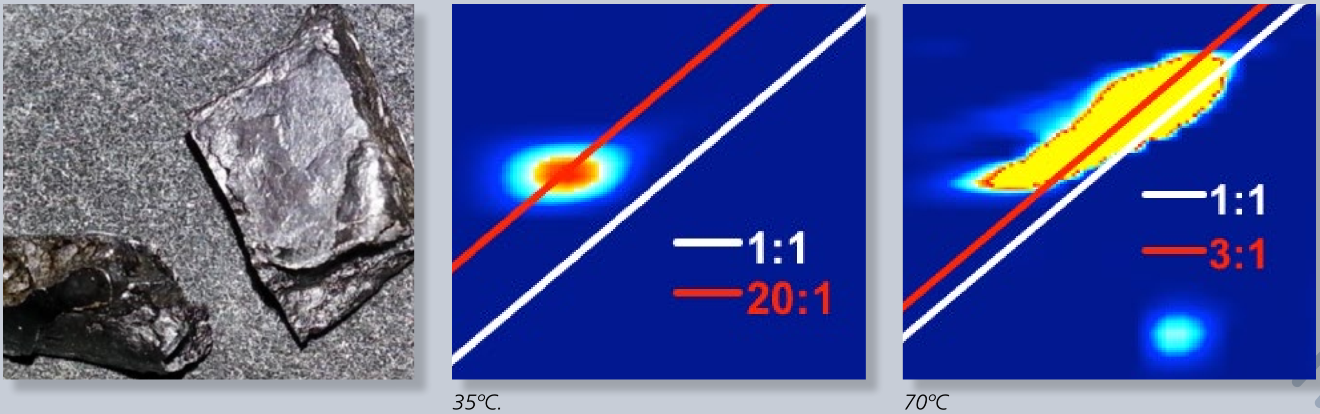
An initial measurement was taken on a solid wax sample at 35°C. Figure 2 shows T_1-T_2 maps of wax at different temperatures. The T_1-T_2 map shows signal at a high T_1/T_2 ratio indicating a highly viscous material. When the sample was heated to 45°C the signal spread to lower T_1/T_2 ratios. At a temperature of 70°C the sample was liquefied and the signal was present around the 2:1 line.

Figure 2: *T_1-T_2 maps of wax at various temperatures.*

Ozocerite

Figure 3 shows similar studies performed on ozocerite, a naturally occurring bitumen. At 35°C, signal appeared along the 20:1 line and at 70°C an extended signal area appeared near the 1:1 line. When the material becomes less viscous the T_1/T_2 ratio shifts to lower values.

Figure 3: *T_1-T_2 maps of ozocerite at various temperatures.*

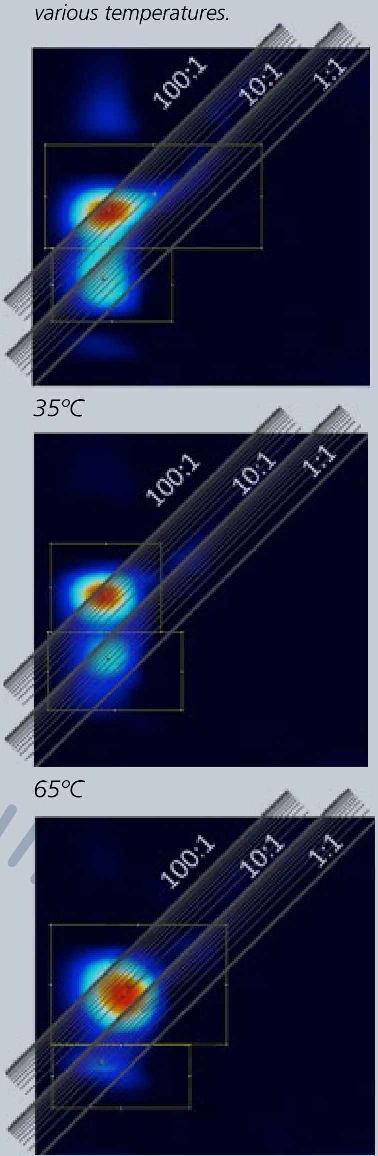


35°C.

70°C

T_1 and T_2 correlation for fluid typing and quantification

***Figure 4:** T_1-T_2 maps of shale at various temperatures.*



35°C

65°C

110°C

Further temperature studies were performed on a group of eight shale samples. As with the previous studies, T_1-T_2 maps were acquired but in this study the temperatures were 35°C, 65°C, and 110°C. Figure 4 shows a representative shale sample at these three temperatures. In the top panel, we see the results at 35°C with the bitumen populations appearing in the 10:1 to 100:1 ratio range and the water peak nearer the 1:1 ratio line. In the middle panel, the results at 65°C are shown. The two peaks begin to separate but show very little change. At 110°C, (bottom panel) the water has begun to dissipate indicating drying. The bitumen peak also decreases, moving towards the 1:1 ratio line, indicating a change in viscosity.

References

[1] E. Rylander, P. M. Singer, T. Jiang, R. Lewis, R. McLin, S. Sinclair, SPE-164554 (2013).

[2] N. Bloembergen, E. M. Purcell and R. V. Pound, Nature, 160, 475-476 (1947).

[3] Ali Tinni, 2013, personal communication. Work was supported by the Unconventional Shale Gas Consortium at the Mewbourne School of Petroleum and Geological Engineering, the University of Oklahoma.

Oxford Instruments Industrial Analysis

For more information: **magres@oxinst.com**
www.oxford-instruments.com

UK

Tubney Woods, Abingdon, Oxfordshire, OX13 5QX, UK
Tel: +44 (0) 1865 393 200 **Fax:** +44 (0) 1865 393 333

USA

300 Baker Avenue, Suite 150, Concord, MA, 01742, USA
Tel: +1 978 369 9933 **Fax:** +1 978 369 8287

China

Floor 1, Building 60, No.461, Hongcao Road,
Shanghai, 200233, China
Tel: +86 21 6073 2925 **Fax:** +86 21 6360 8535

Green Imaging Technologies

For more information: **info@greenimaging.com**
www.greenimaging.com

Canada

520 Brookside Drive, Suite B, Fredericton, NB, E3A 8V2,
Canada
Toll Free: +1 888 944 8462
Tel: +1 506 458 9992 **Fax:** +1 506 458 9615

The Business of Science®