Optimizing the search for hydrocarbons in Unconventional and Conventional Reservoirs through New-Generation Logging and Data Analytics

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What's Next?
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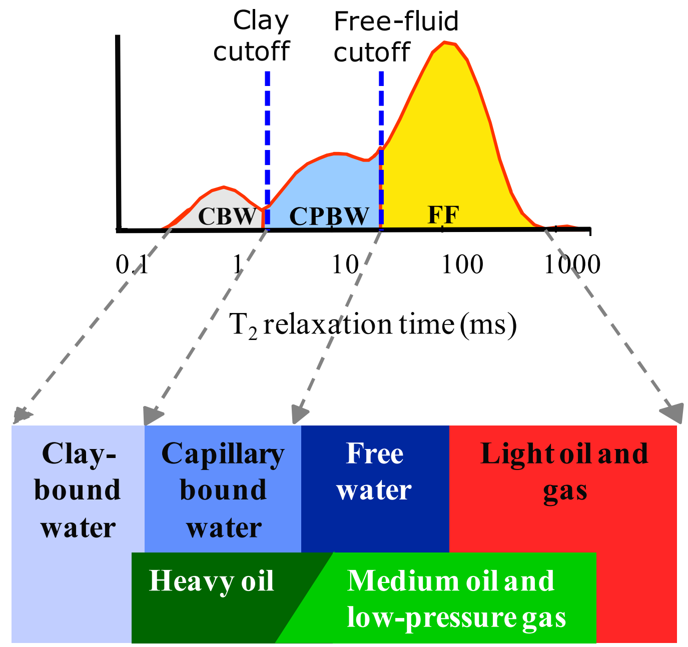
Outline

- Introduction to NMR logging
- Increase data information content through T_1T_2 logging
- Significance of T_1/T_2 ratio in rocks
- Using data-driven method to extract petrophysical information from T_1T_2 log
- Field examples in unconventional and conventional reservoirs

Applications of NMR logging in formation evaluation

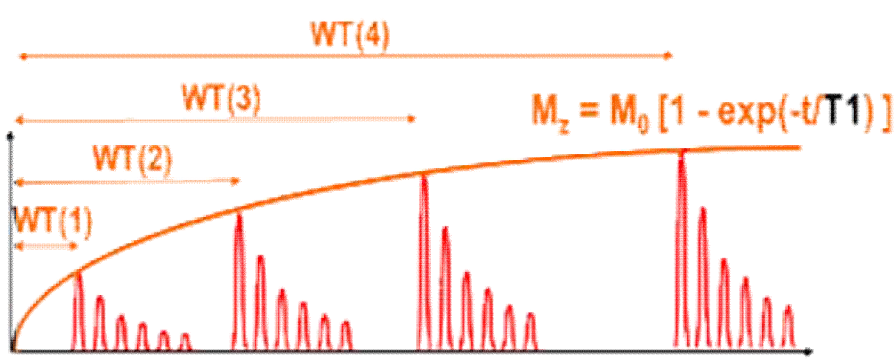
- NMR logging measures response of hydrogen nuclei in reservoir fluids, presented as T_2 distribution logs
- Applications:
  - Lithology independent porosity
  - Pore size distribution
  - Permeability
  - Fluid saturations
  - Hydrocarbon types and oil viscosity

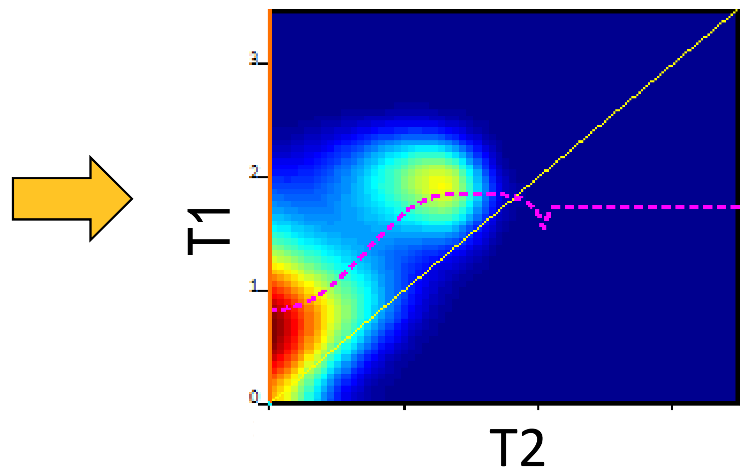


T_1T_2 logging enhances the ability to resolve fluid types

- New-generation NMR logging tool provides simultaneous measurement of T_1 and T_2 relaxation times using advanced data acquisition schemes
- T_1 and T_2 relaxation time contain complimentary information about fluid motions

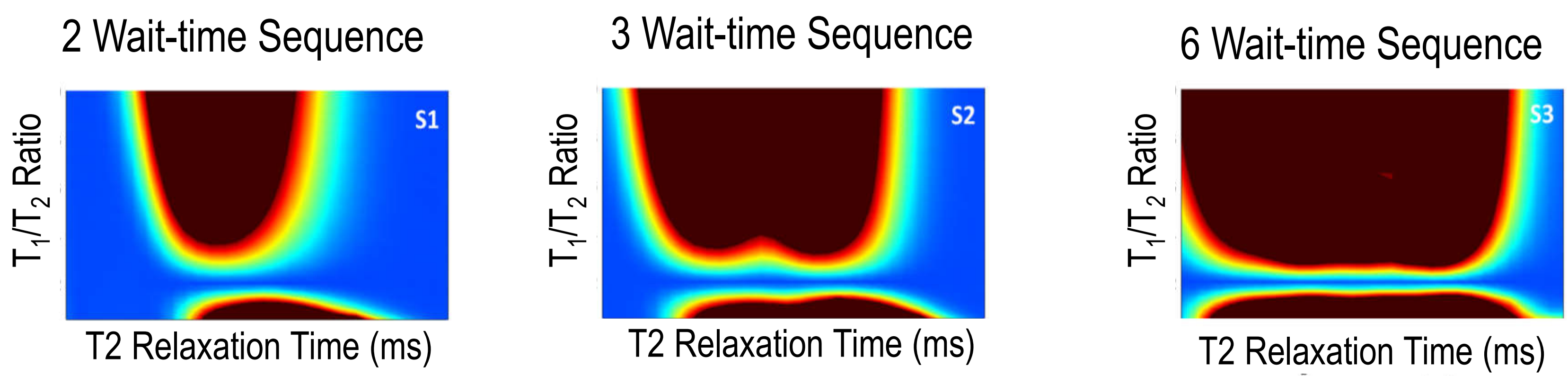
Multi-wait time data acquisition scheme





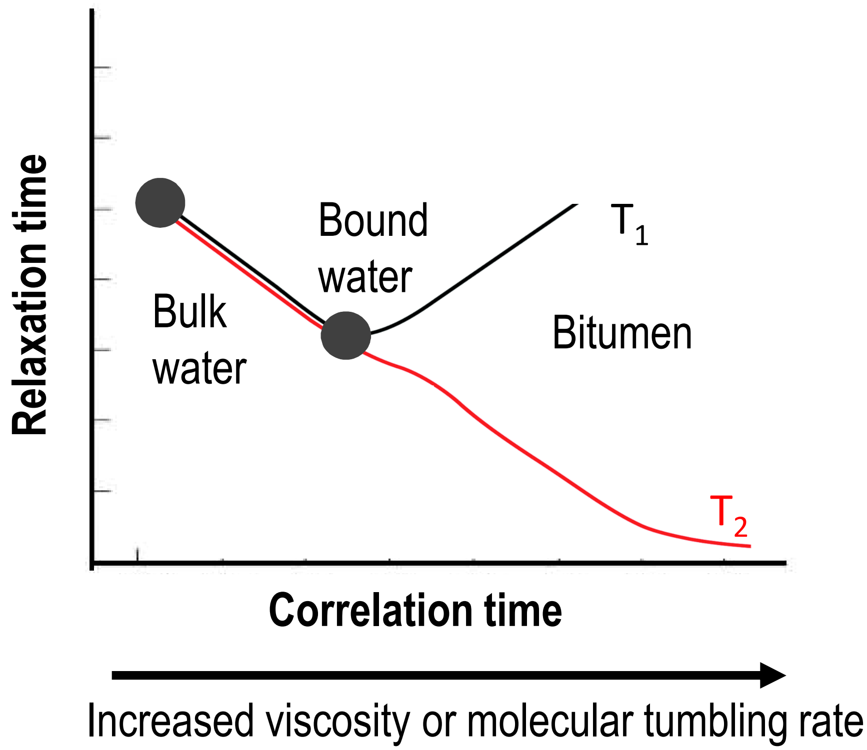
T_1T_2 log also reduce porosity uncertainty

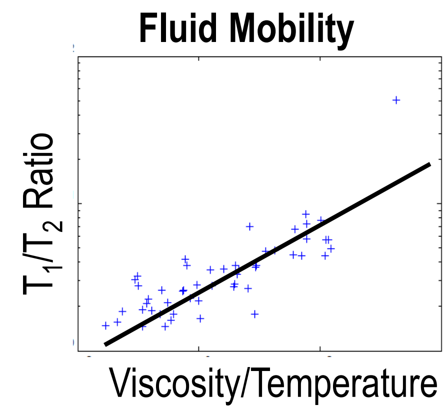
- T_1/T_2 ratio is an important parameter for accurate estimation of porosity and T_2 distribution
- Sensitivity to T_1/T_2 ratio increases with number of measurements with different wait times

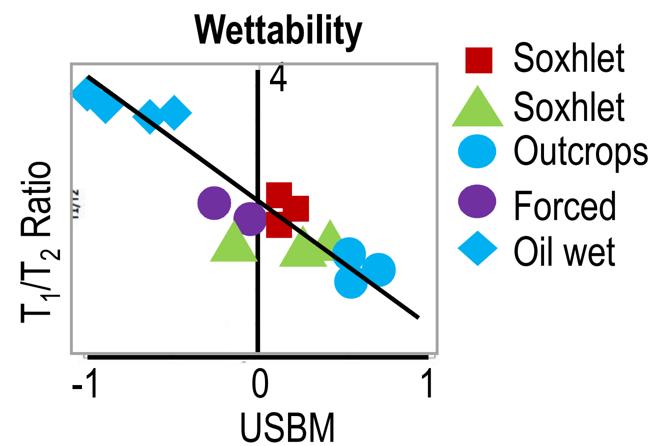


Porosity uncertainty is proportional to blue area

Extraction of fluid mobility and wettability from T_1T_2 measurements in reservoirs

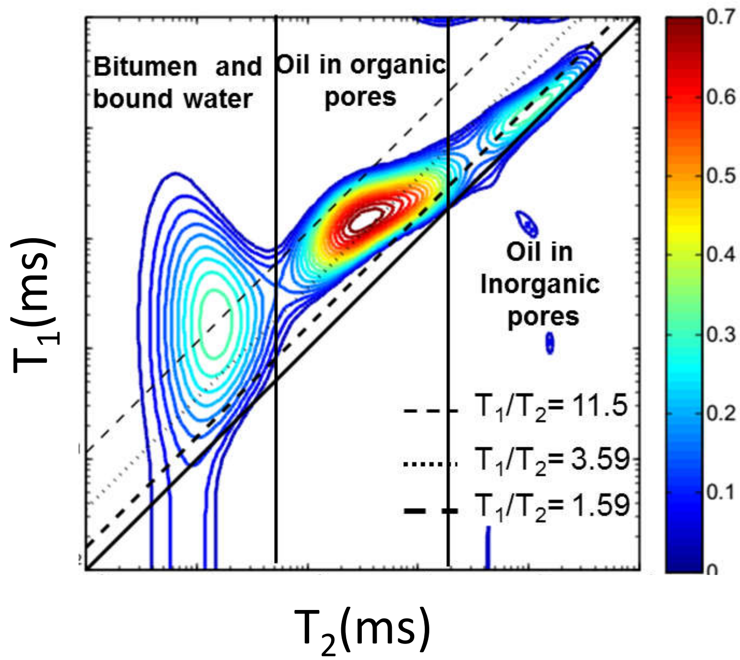






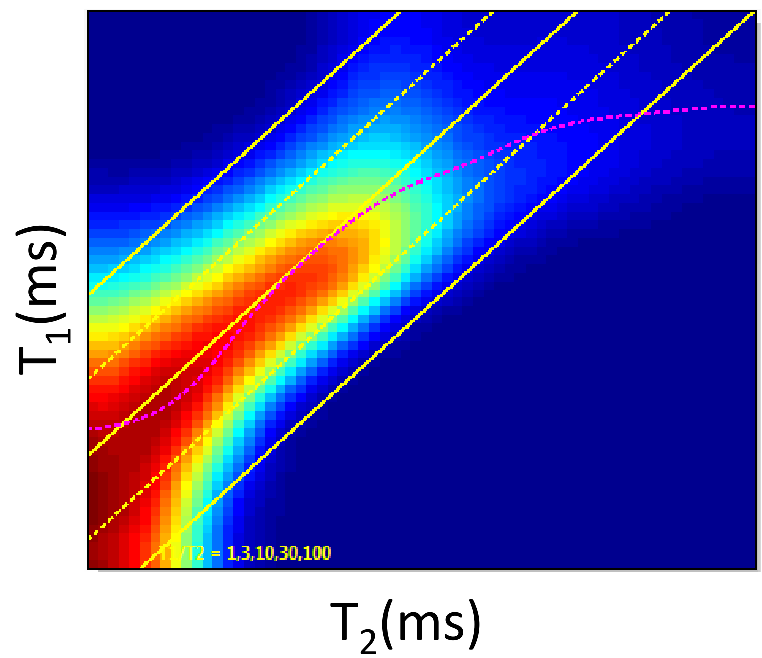
Challenges of T_1T_2 fluid characterization

Laboratory measurement on a shale sample



Fluid responses are well separated

Downhole measurement in Eagle Ford



Fluid responses overlap due to low SNR

What is this Image?

Is it possible to accurately resolve the underlying features from this image?

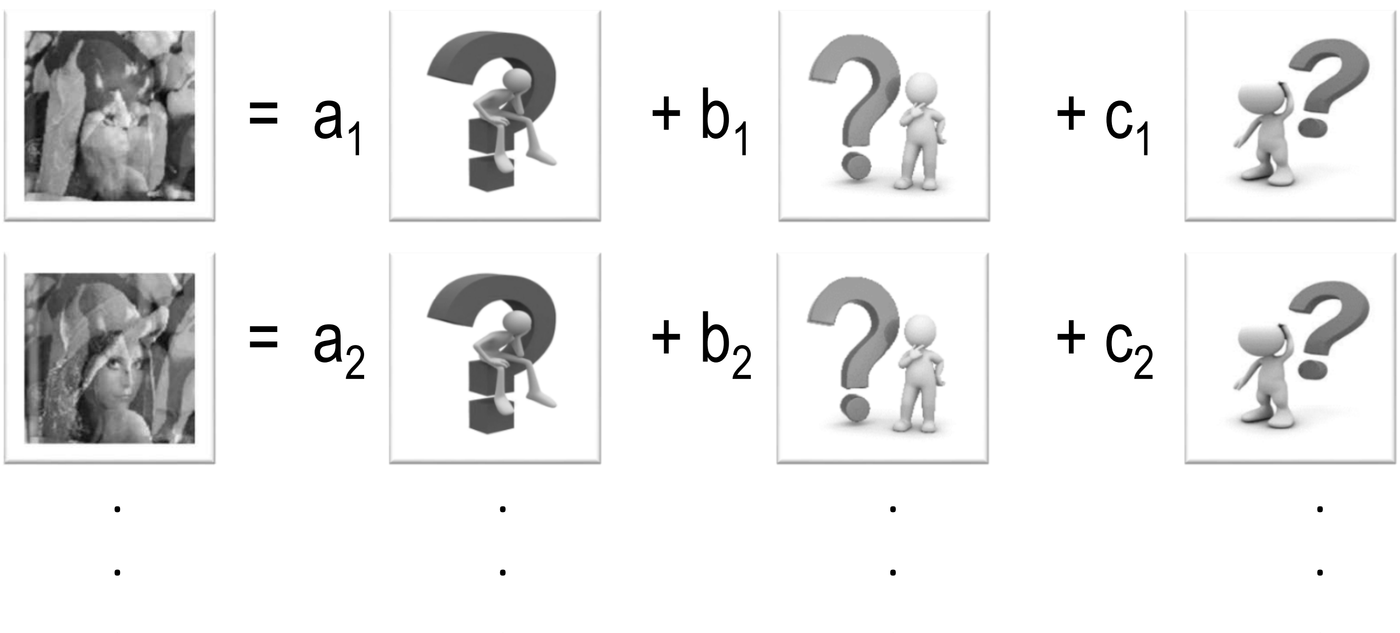
No

Problem of resolving underlying features

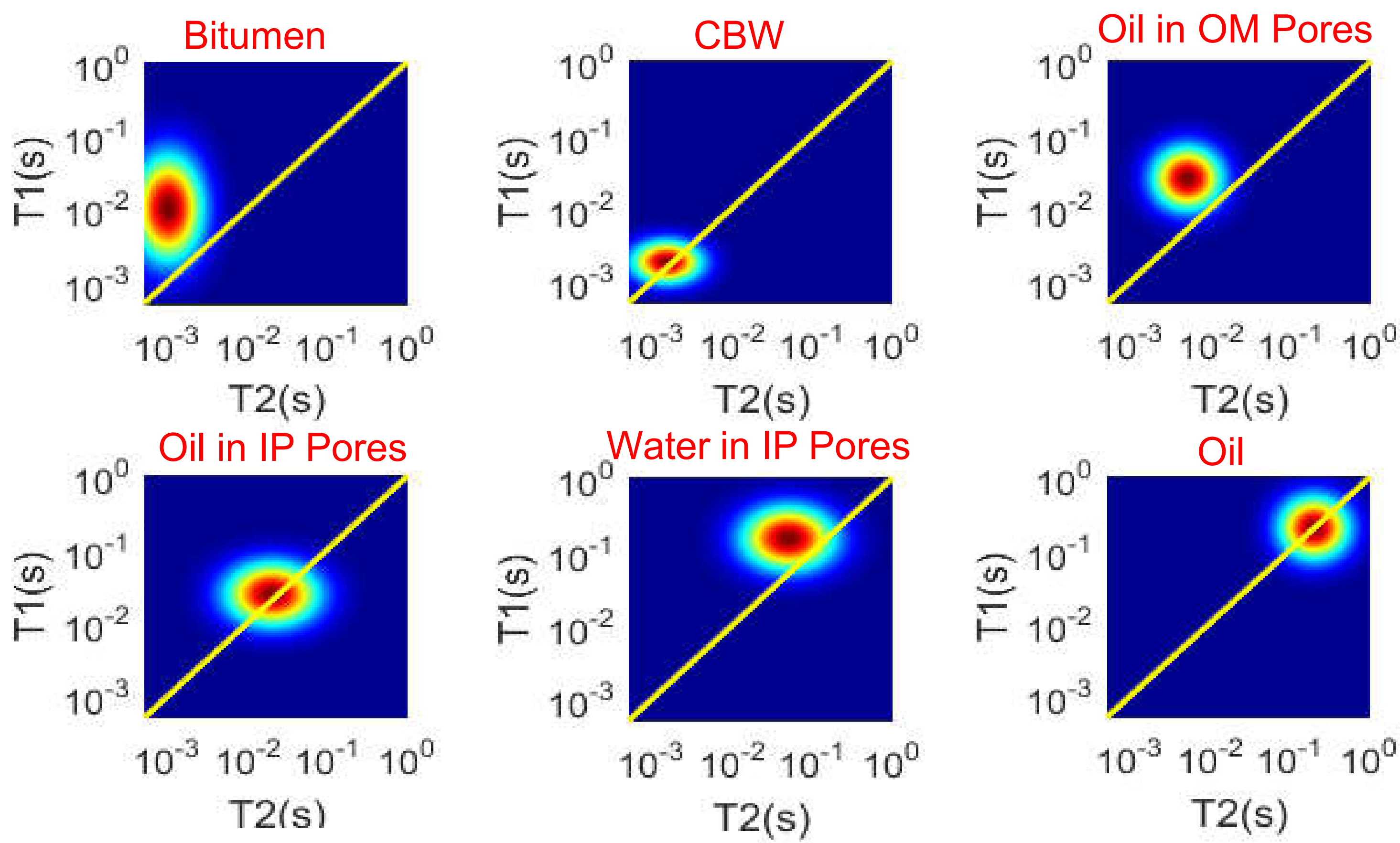
- Can we uncover underlying patterns from a collection of **varied** high-dimensional data without any *a-priori* information?

Data analytics approach

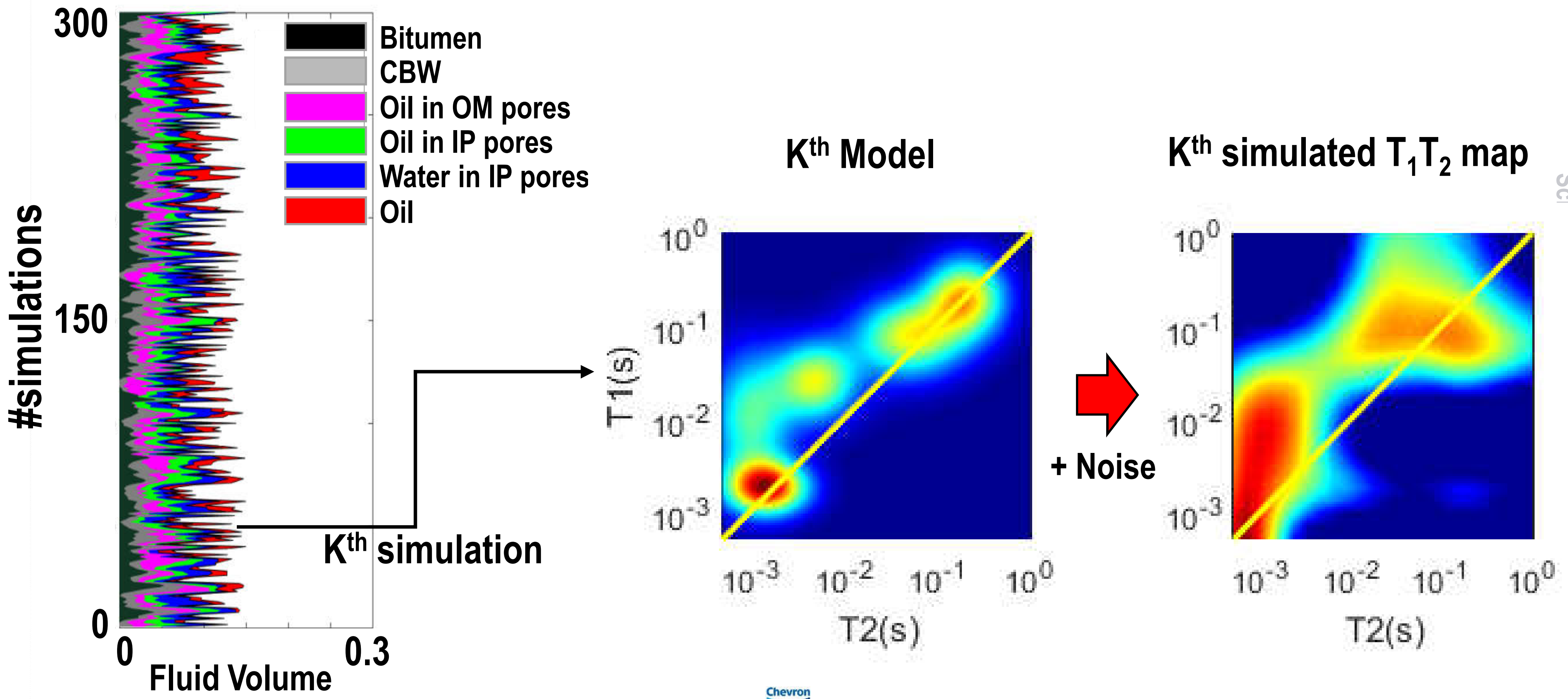
- Represent each sample as a linear combination of **underlying constituents**
- No assumption about underlying constituents is made



Six fluid types used for simulating T_1T_2 NMR logs

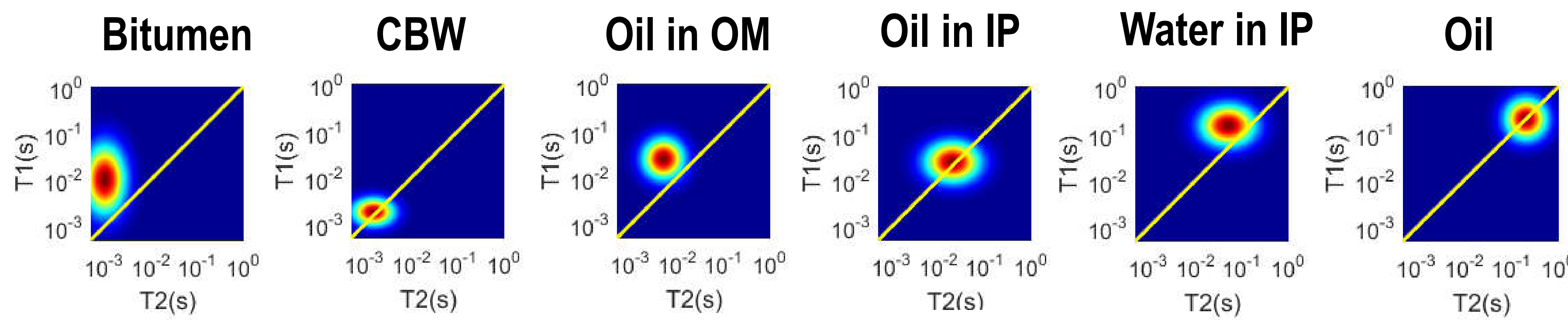


Simulated T_1T_2 logs cannot resolve fluid types

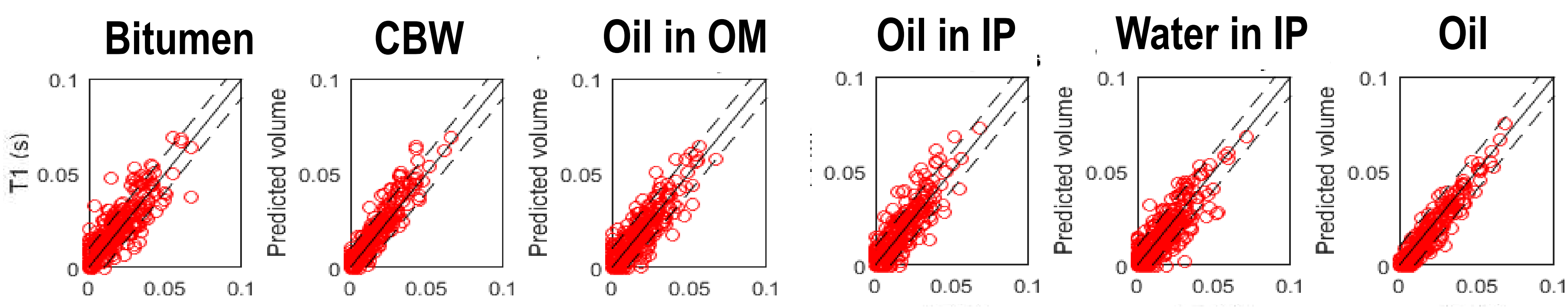


Data-driven technique identifies six fluid signatures

Fluid models



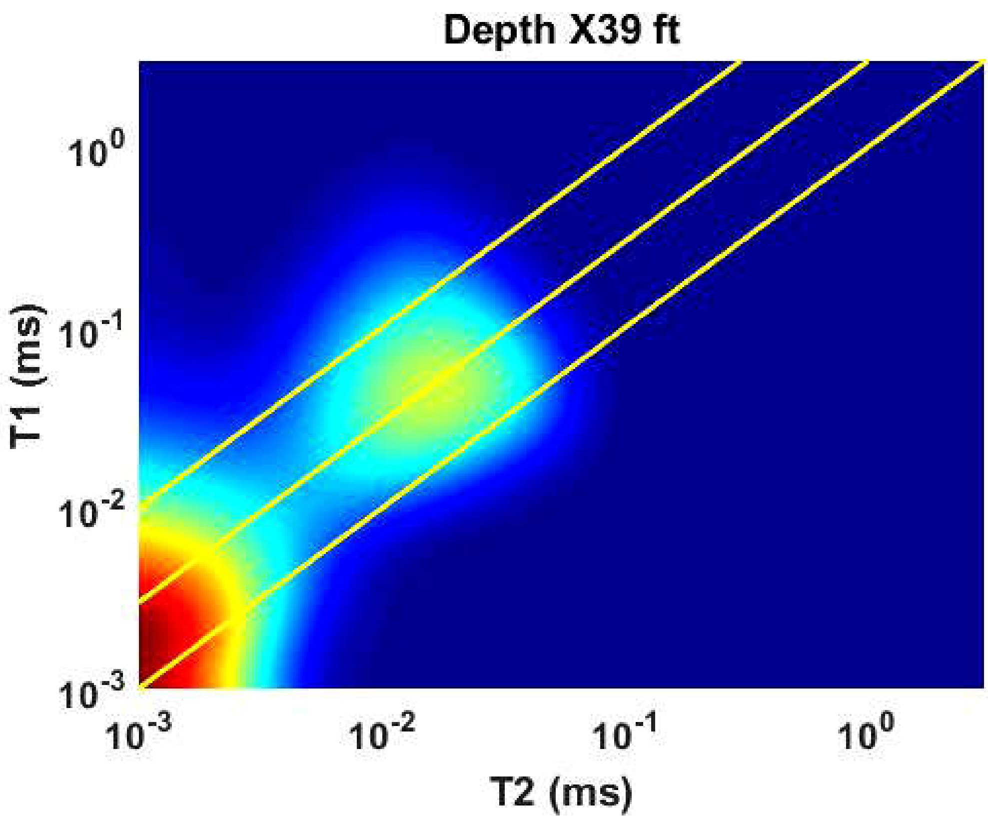
Derived fluid signatures and volumes



Field example 1: T_1T_2 NMR logging in shale play

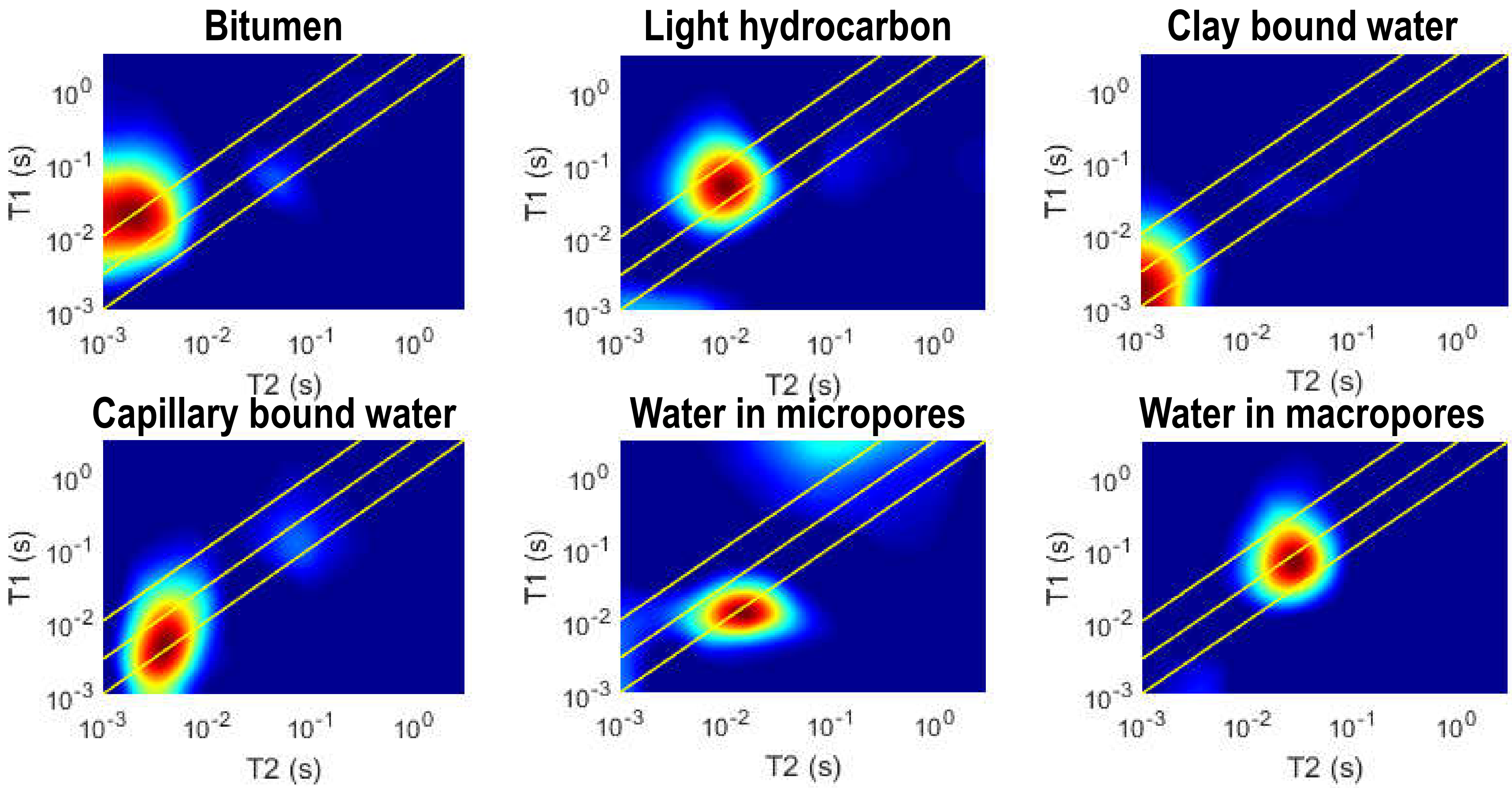
- Midland basin shale play with organic-rich shales and silts.
- Nano- and micro-pores with natural fractures.
- Porosity < 10 PU, Permeability ~ 10^{-6} Darcy.
- Key challenge is how to quantify movable hydrocarbon from logs.

T_1T_2 maps respond to variation in fluid types



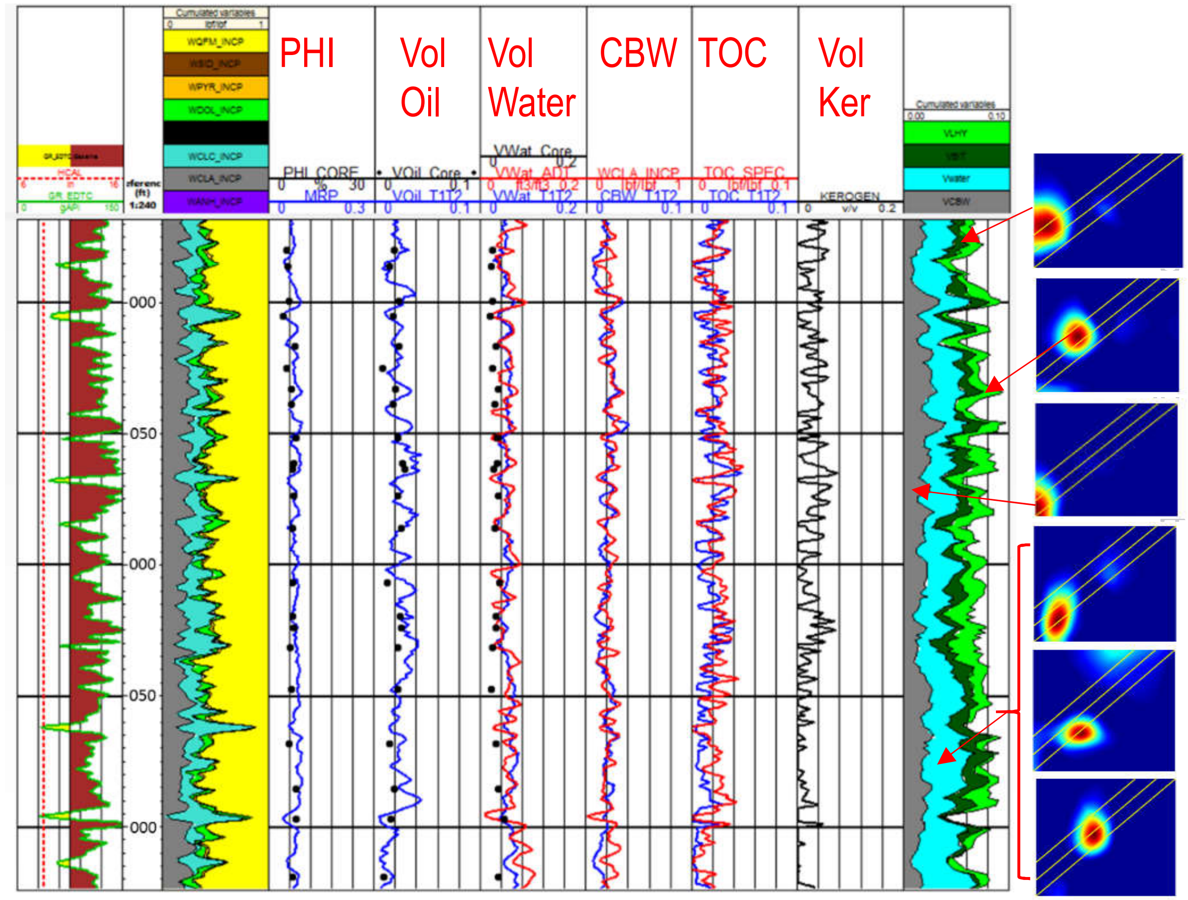
Broad peaks, but peak patterns vary with depth due to changes of volume of each fluid type in formation

Fluid signatures in Midland basin shale play



Fluid characterization in Midland basin

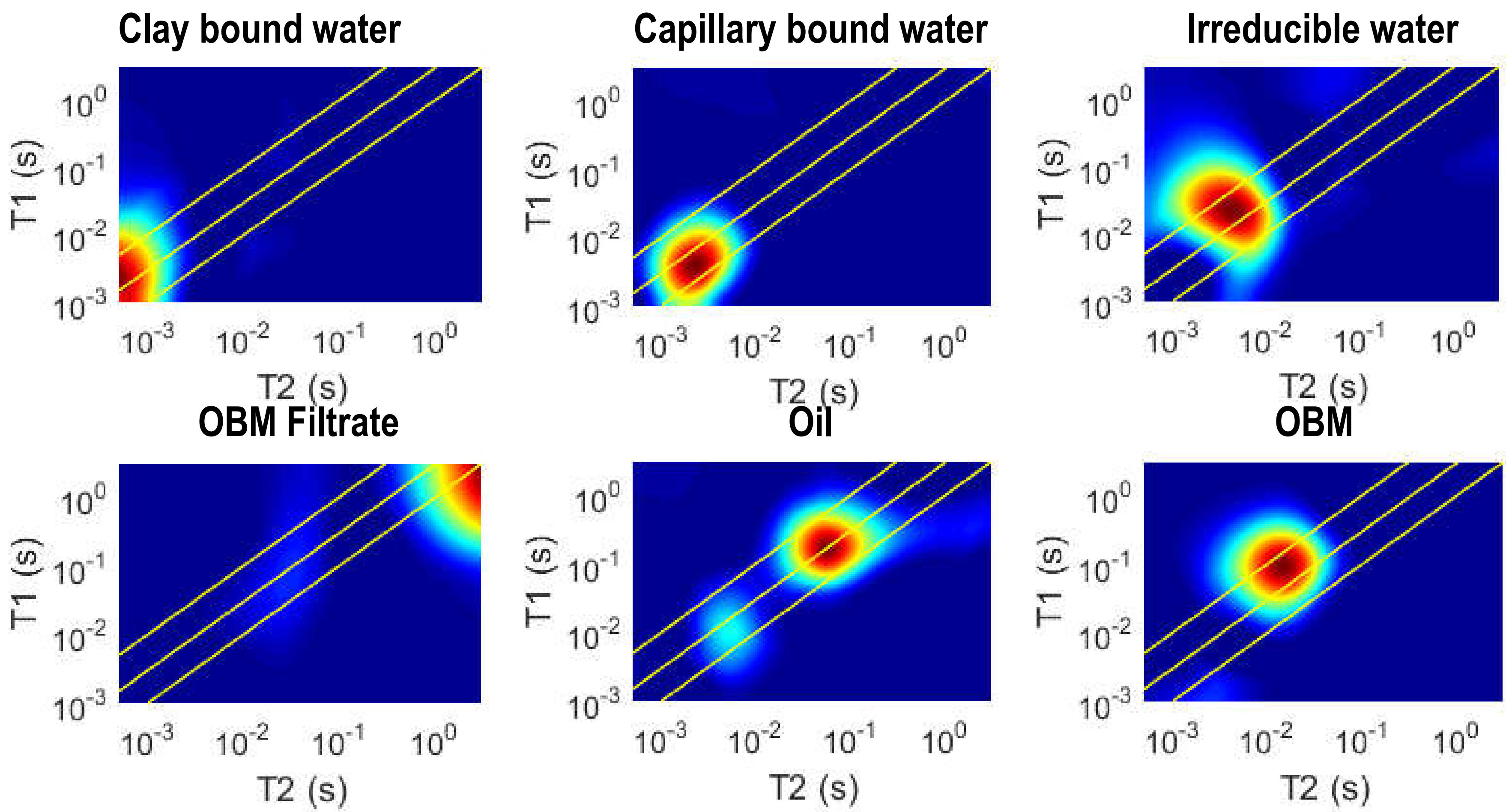
- Total oil and water volumes show good comparison with core data
- Clay-bound water and TOC agrees with spectroscopy measurements
- No adjustable parameters needed for computation of fluid volumes



Field example 2: T_1T_2 NMR logging in deepwater Gulf of Mexico

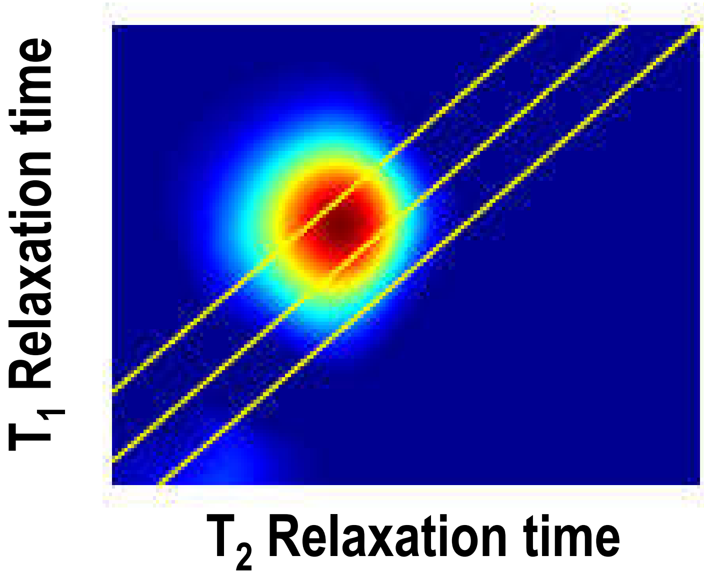
- Wilcox tight sand formation with thin sand shale laminations.
- Clay-bound water is a key petrophysical parameter that only NMR can provide.
- Oil viscosity changes with depth due to asphaltene content variation.

Fluid signatures in conventional reservoir

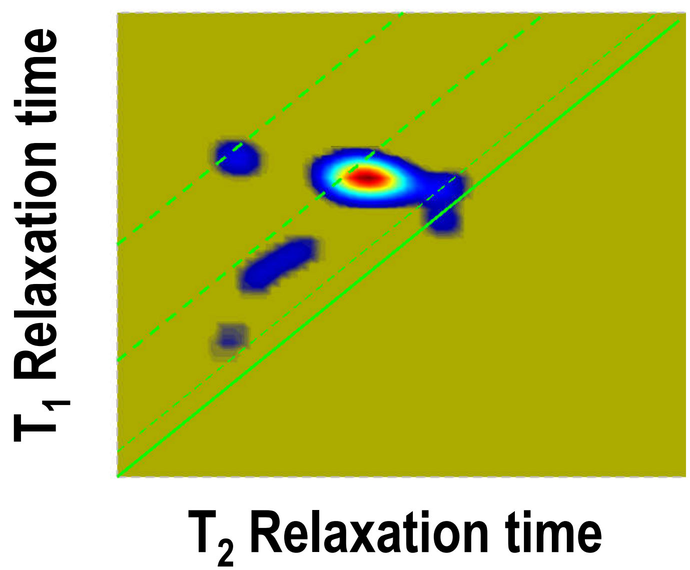


Comparison between the OBM signature extracted from the log, with that measured in the lab

DA-extracted



Lab-measured



Conclusions

- Data-driven techniques hold tremendous potential for extracting insights from logging data
- No a-priori knowledge about the reservoir or empirical models required
- Information content in data from entire well or multiple wells utilized simultaneously
- Comprehensive fluid characterization in conventional and unconventional reservoirs enabled using data-driven technique from NMR T_1T_2 logging