PS NMR T_2 Cut-Off Determination for Shales*

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Abstract

Unconventional resources are expected to become increasingly important to meet the world's growing energy demand. Shale reservoirs are of particular interest, but they are also hard to characterize. Nuclear magnetic resonance is a valuable tool that has been used successfully to evaluate petrophysical properties of rocks in conventional reservoirs. The tool's measurements can be interpreted to understand the pore size distribution of the rock and the fluids present, which can ultimately lead to the development of theoretical models to estimate permeability. This study presents the results of low field NMR measurements in fully and partially saturated shale samples. T_2 distributions were acquired on samples from the Perth Basin initially fully saturated with 30,000 ppm KCl brine, later centrifuged and finally heated. Analysis of the data shows that while a conventional centrifuge does not provide enough capillary pressure to remove the non-capillary bound fluids from shale samples, oven heating can be a feasible method to determine a cut-off between movable and immovable fluids. The average optimum temperature at which the samples have to be heated to evaporate all free water was found to be 62°C and an average T_2 cut-off of 0.27 msec was also established. This procedure allows a more accurate understanding of fluid distribution in shales, crucial for a good petrophysical characterization.

Reference Cited

DMP WA, 2014, Western Australia's Petroleum and Geothermal Explorer's Guide - 2014 Edition: Petroleum Division and Geological Survey of Western Australia, Western Australia Department of Mines and Petroleum, 148 p.

NMR T_2 CUT-OFF DETERMINATION FOR SHALES

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ABSTRACT

Shale reservoirs are very heterogeneous and have a complex pore network with very small pore sizes, making petrophysical characterization particularly challenging. Low-field nuclear magnetic resonance is a valuable tool that can be used successfully to evaluate fluids and petrophysical properties of conventional reservoirs. The tool's measurements can be interpreted to understand the pore size distribution of the rock, which can ultimately lead to the development of models to estimate permeability.

Low-field NMR was used to investigate the pore structure of samples from the Carynginia formation, a Permian shale in the north of the Perth basin. T_2 experiments were performed after the samples were saturated with KCl brine, then centrifuged and finally oven-dried. The T_2 distributions were analysed and a cut-off was established to indicate the producible porosity.

SHALE RESERVOIRS

- Very small pore sizes
- Very low permeability (K << 0.1 md)
- Highly heterogeneous
- High content of clay

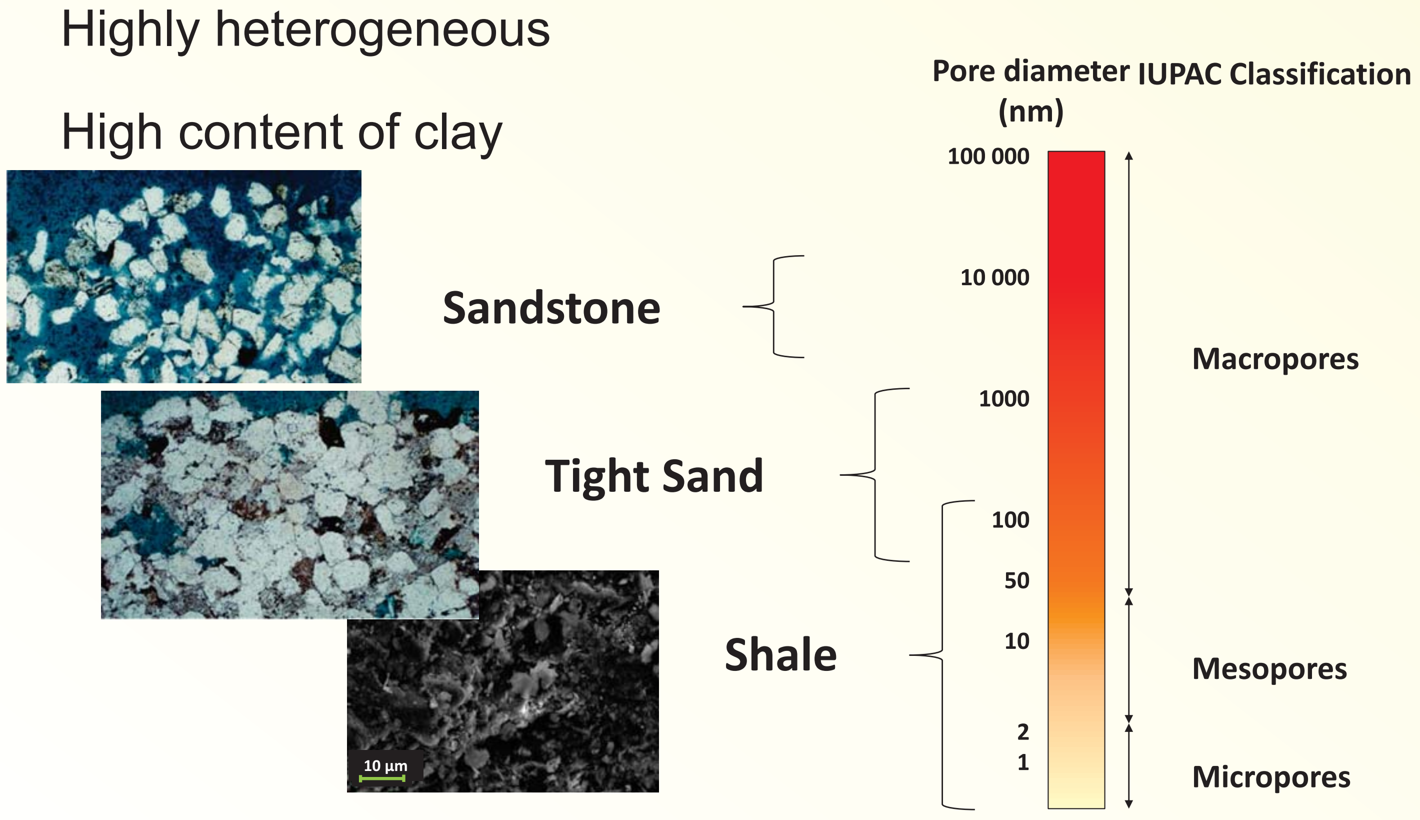

Figure 1. Comparison of pore sizes in conventional and unconventional reservoirs

GEOLOGICAL SETTING

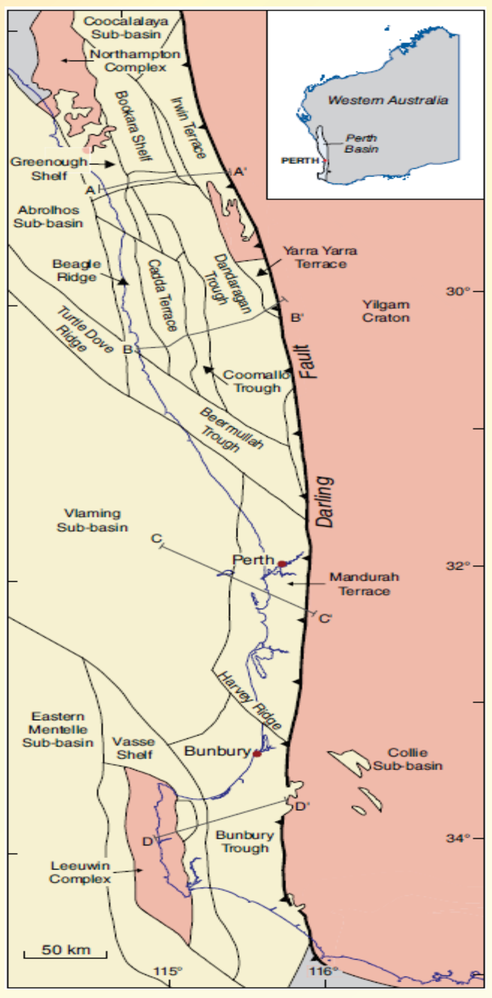

Figure 2. Location of the Perth basin (DMP WA, 2014)

- The Perth basin extends onshore and offshore in the southwest of Western Australia.
- It contains two main organic-rich shale formations: Triassic Kockatea and Permian Carynginia.
- The Permian Carynginia shale is a shallow marine deposit. The kerogen is type III and is gas prone. Its estimated to hold almost 25 Tcf of technically recoverable shale gas (2015).

T_2 EXPERIMENTS

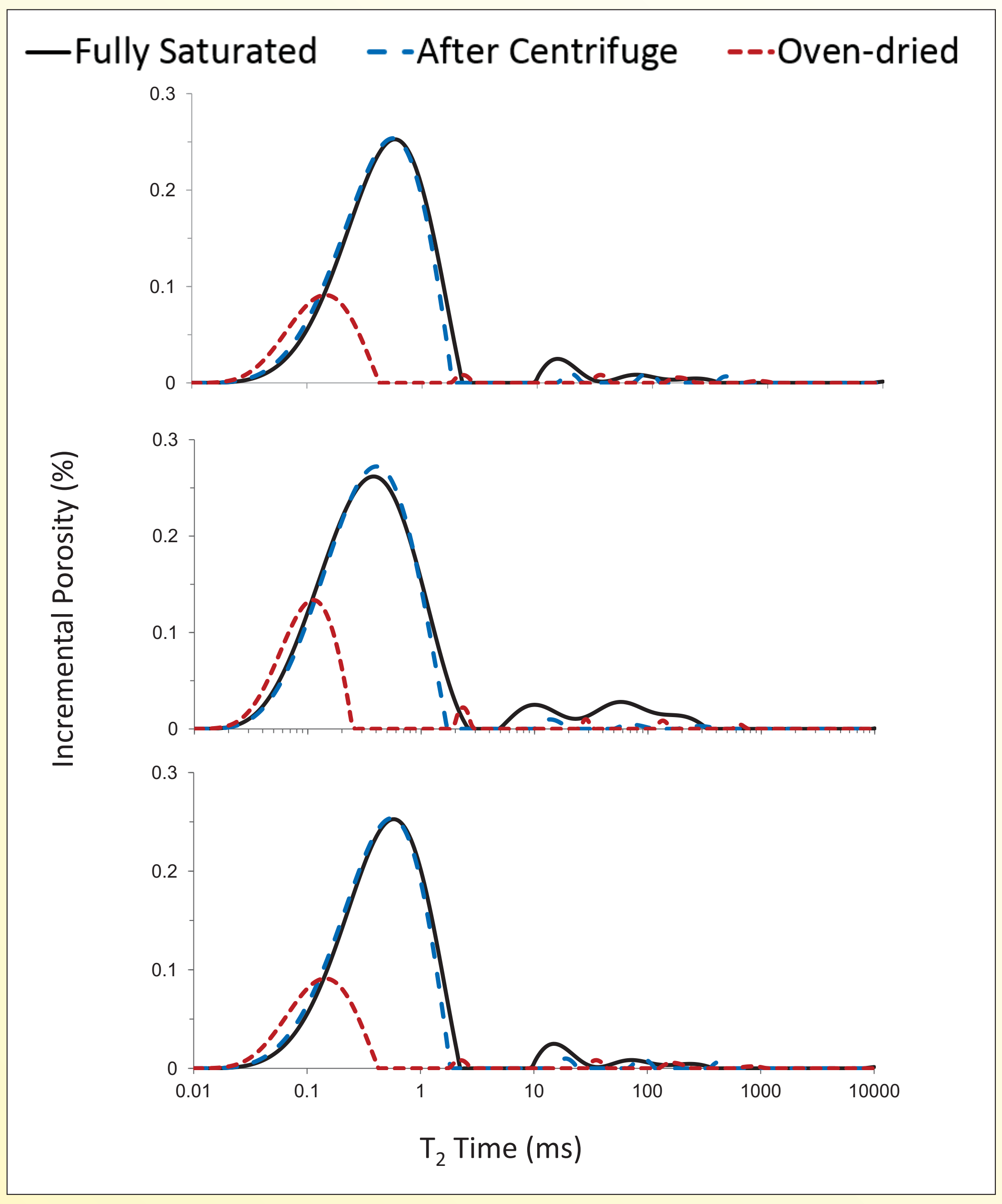

Figure 3. NMR T_2 distributions for shale samples fully saturated, after being centrifuged and after being oven-dried, using a 0.1ms echo spacing.

T_2 CUT-OFF DETERMINATION

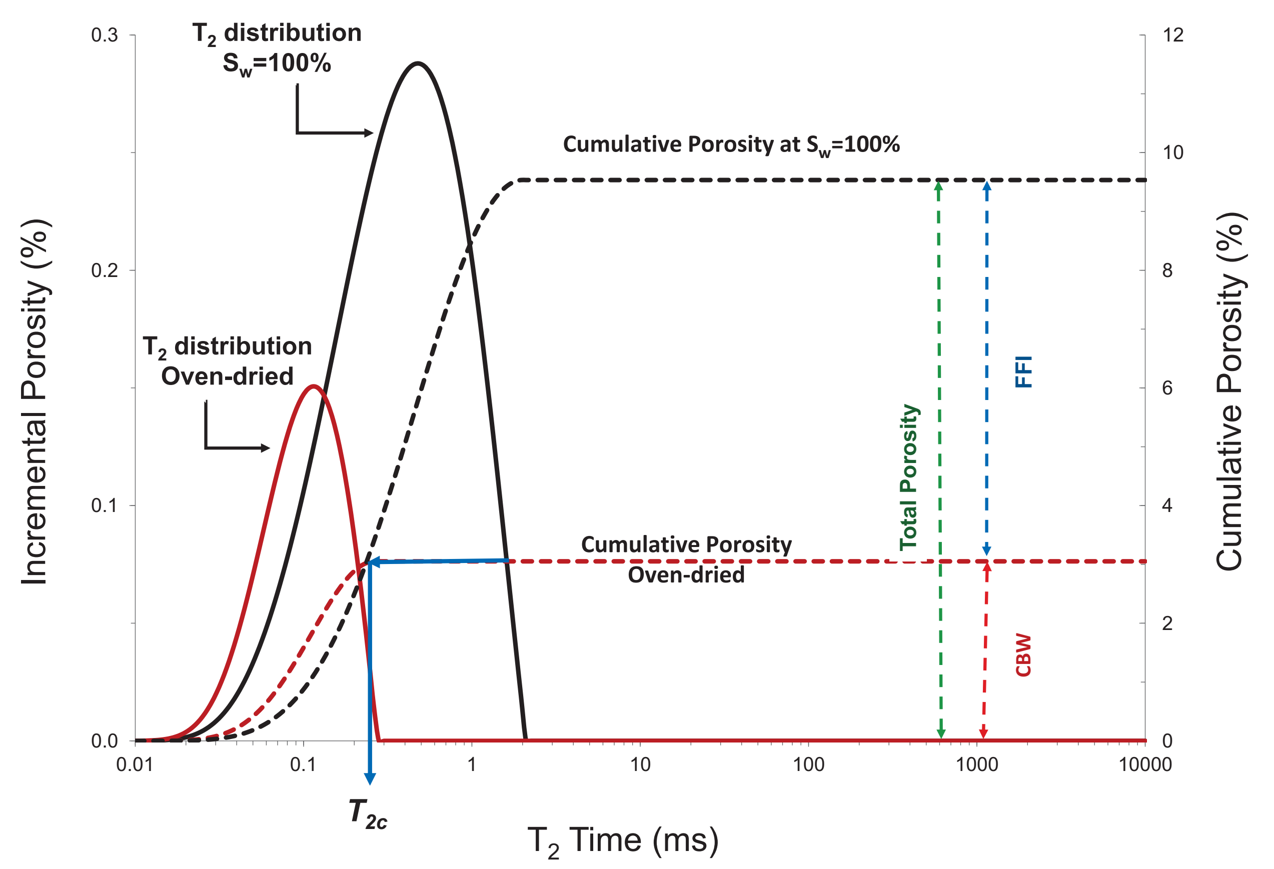

Figure 4. Procedure to determine a T_2 cut-off value (T_{2c})

Sample	BVI (%)	$T_{2\ cut\text{-}off}$ (ms)	FFI (%)
1	3.3	0.26	6.7
2	3.3	0.24	6.7
3	2.1	0.24	11.0

CONCLUSIONS

- Micro-fractures can be induced across the core samples while the re-saturation process takes place, so the type of brine should be cautiously selected to minimize clay swelling.
- Most of the transverse relaxation occurs below 3 ms in saturated samples. The unimodal distribution observed is consistent with a single dominant pore size.
- A conventional centrifuge can't remove the capillary bound fluid from shale samples
- The commonly accepted clay bound water cut-off of 3 ms is unsuitable for shales.
- Our calculated T_2 cut-off for clay bound water was between 0.24 and 0.26ms.