Constructing Saturation Height Function Based on NMR and Rock Typing in Tight Carbonate Gas Reservoir

Introduction

A recent well in the study has been logged with an advanced suite of logs with multiple core points, where conventional saturation using multimineral model disagrees with the core saturation data. Reservoir is characterized by its low porosity (2-12 p.u.) and low permeability (less than 60 mD) in most intervals. Aside from NMR, advanced log like dielectric was also obtained to get information about the formation water salinity in this formation, which agrees with the Pickett's plot at the water zone reference at the lower interval at around 30,000 ppm range of NaCl equivalent.

A conventional water saturation based on resistivity (Archie's equation), however, in some intervals, discrepancies between core and log were observed. Both extremes of rock type exist within the well, an interval with poor-quality rock, and interval with good quality rock. At the poor-quality rock shows computed water saturation higher than core water saturation (pessimistic) whereas the good-quality rock shows computed water saturation lower than core water saturation (optimistic).

While the resistivity-based method works in the good-quality rock, authors believed that the resistivity-based saturation computes too pessimistic result in the poor-quality rocks. To address this challenge, a saturation height function based on NMR combined with rock-typing is developed for this well.

Rock-Typing Methods

In the studied area, a PGS (Pore-Geometry-Sytem) was used to generate rock types that represent the core data as shown in Figure 1 below.

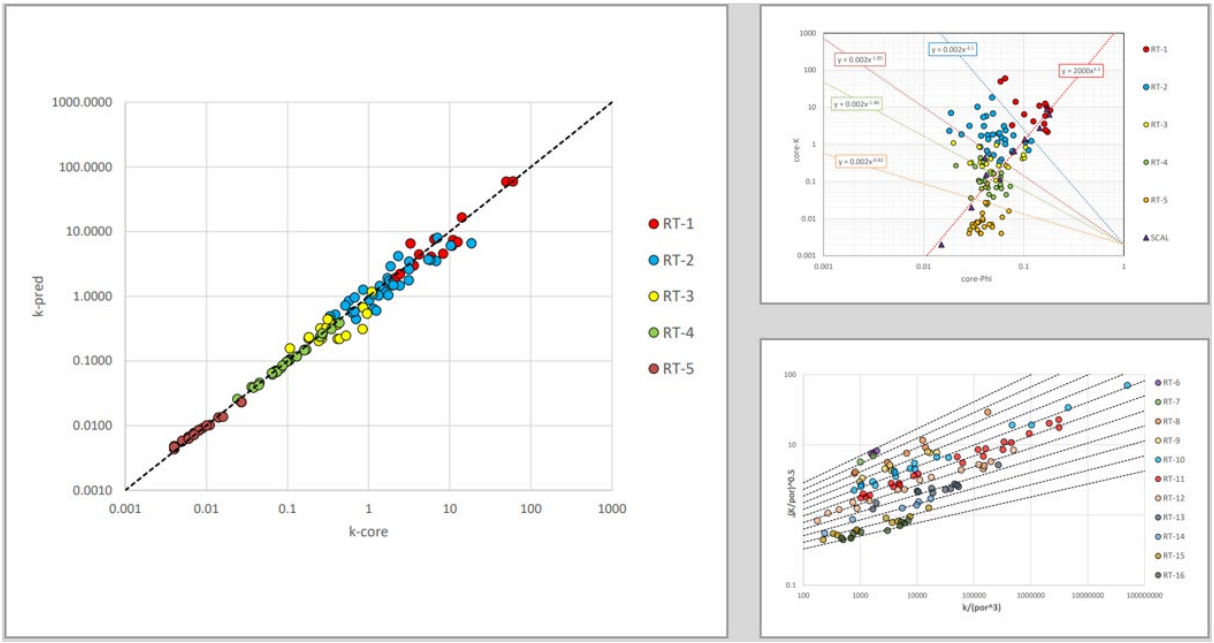

Figure 1 *Core porosity-permeability relationship and its rock-types*

The initial rock types comprise of eleven rock-types then be grouped into five rock-types based on its proximity to each other to simplify the analysis and calibration with NMR data later.

Saturation Height Function (SHF) based on Nuclear Magnetic Resonance (NMR)

Saturation height function has been used extensively to determine water saturation based on a function of the height above free water level (HAFWL), and the pore throat size characterization (pore radius

size). The latter used to be inferred from rock-types, which may induce some uncertainty associated with the relationship between rock-types and actual pore radius.

Using NMR data, one can generate a synthetic Pc from NMR data which then can be calibrated with actual Pc data from core, grouped based on the rock-types, to generate a better representation of Pc curve of the reservoir. The method is essentially based on that the size of the pore throat has a relation with the size of the pore itself (Glorioso et al, 2002). The process is shown at Figure 2, the calibration between synthetic-T2 and PC generates different offsets across different rock-types. As shown in Figure 2, the offsets get bigger as the rock-types gets poorer.

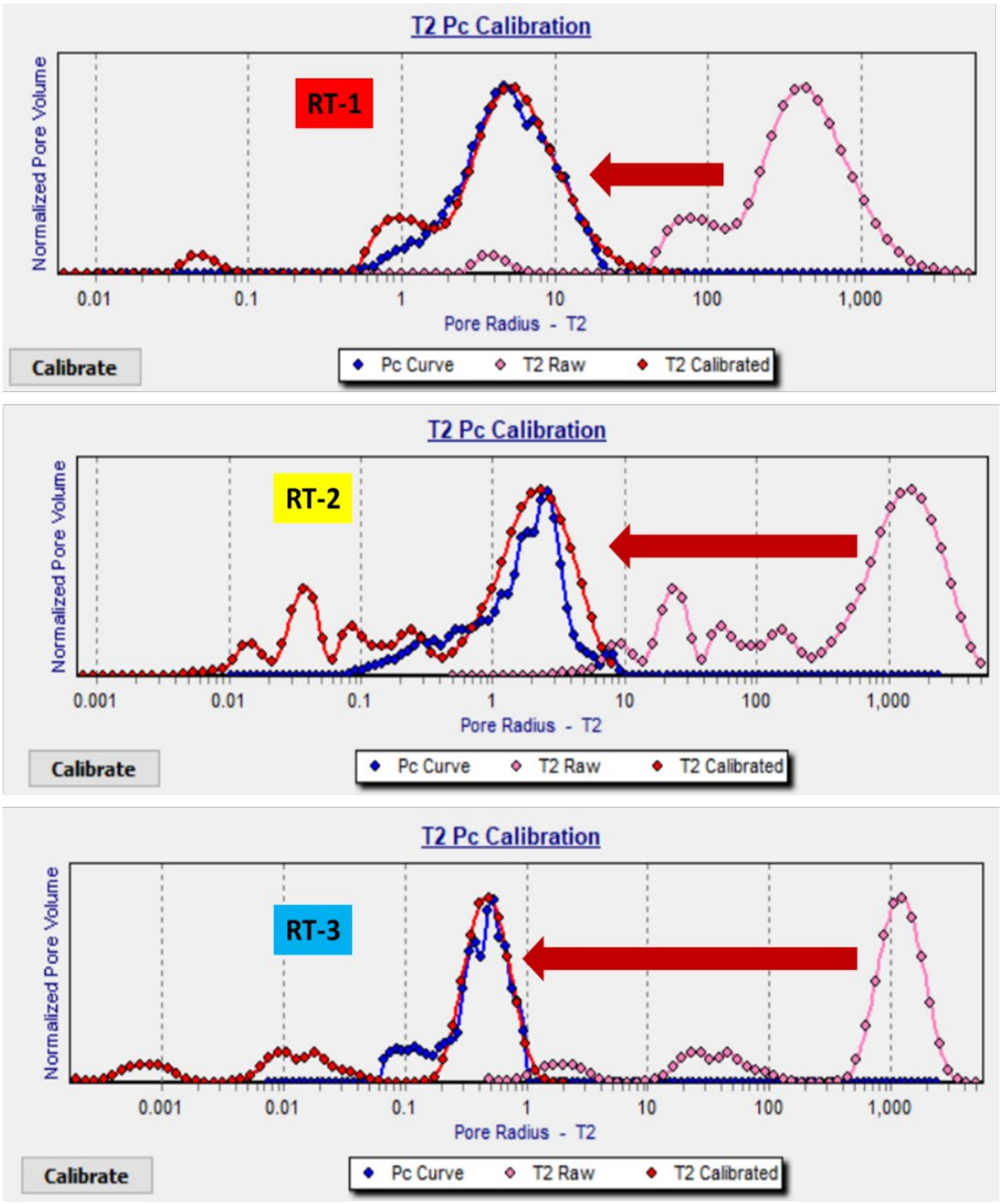

Figure 2 *Synthetic PC from NMR T2 to Pc Calibration on RT-1 to RT-3 with varying offsets.*

This was captured by the water saturation from SHF-NMR-calibrated as shown in Figure 3 (last track) in comparison to core water saturation and resistivity-based saturation. Across rock with poor-quality, the SHF would be better aligned with core water saturation because the offsets are larger than the one at good-quality rock.

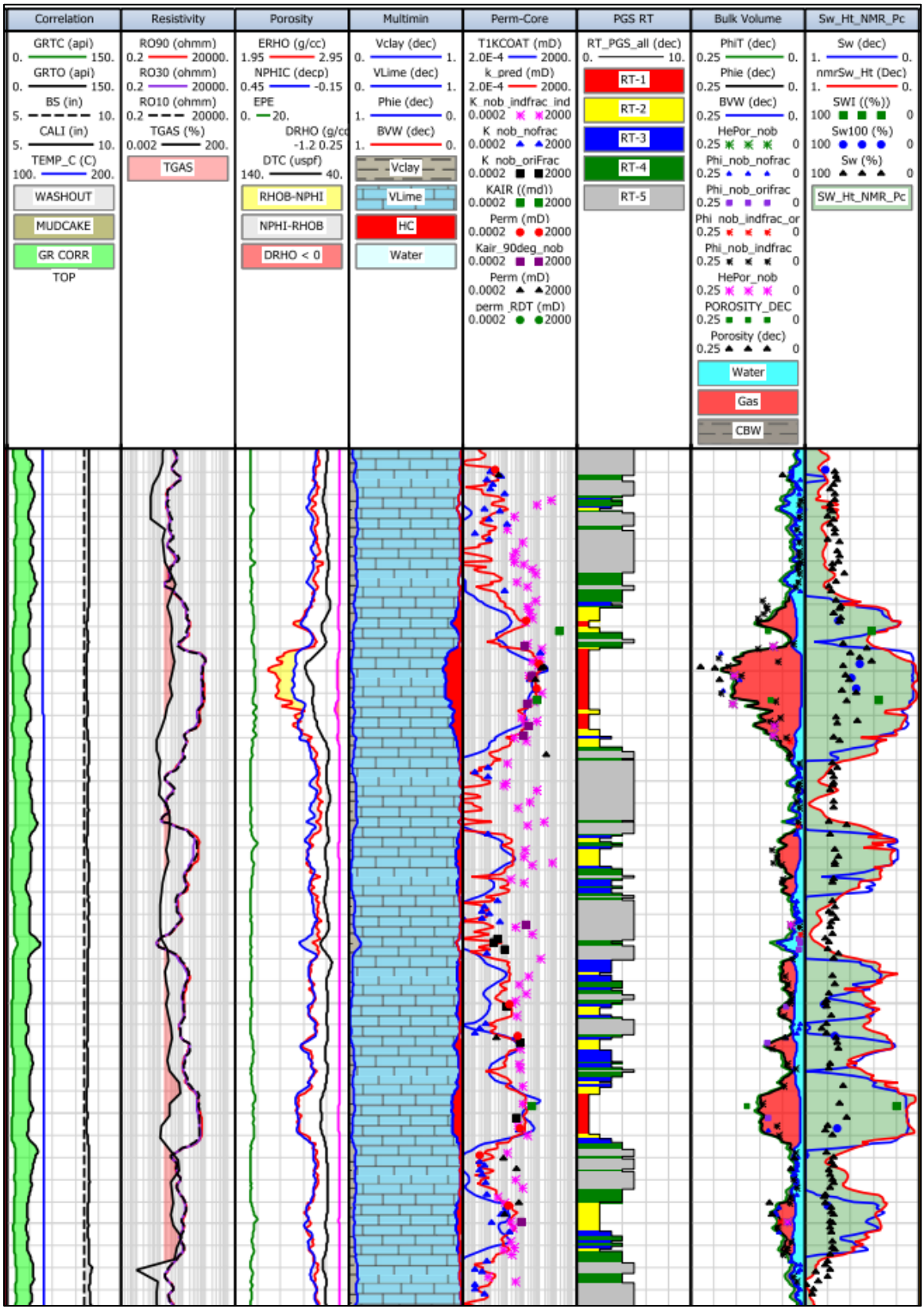

Figure 3 *SHF Sw based on NMR against conventional saturation and core saturation (last track).*

Future Improvement

Although the SHF from NMR improves the water saturation profile in this well, some of the calibration process is not necessarily good. Taking an example from the RT-5 at Figure 4 below, the poorest rock-type in the well, shows a multimodal distribution from synthetic-Pc versus relatively unimodal-flat distribution of pore-sizes/ Pc curve (blue lines-dots).

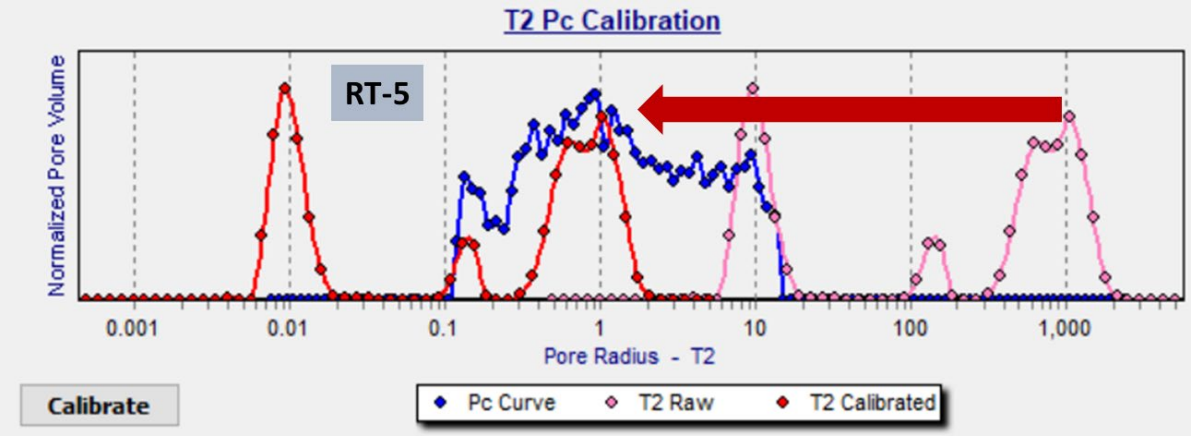

Figure 4 *SHF Sw based on NMR against conventional saturation and core saturation (last track).*

In general, the calibration works fine, but for very poor rock-type, the offset would depend on the how good is the resemblance between core Pc data and synthetic-Pc data.

Conclusions

The construction of saturation height function based on NMR T2 relaxation provides water saturation with a better alignment to core water saturation data, especially at poorer-quality rock. This was also captured when calibrating the synthetic-Pc vs Core Pc where the poorer rock-type would have a larger offset compared to the good-quality rock types.

Therefore, the use of rock-typing is recommended to provide a better basis in determining the amount of shift/offset when calibrating, as the synthetic-Pc may not be an exact resemblance of the pore-size distribution data from core, especially across poor-quality rock.

Acknowledgement

The author would like to thank Medco Energi team and Halliburton for supporting this publication.

References

Glorioso, J.C., Aguirre, O., Piotti, G., and Mengual, J. [2003] Deriving Capillary Pressure and Water Saturation from NMR Transversal Relaxation Times. Society of Petroleum Engineering, SPE 81057.