



# Innovative Rock Typing with NMR: A Pathway to Optimized CO<sub>2</sub> Storage

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## Summary

Nuclear Magnetic Resonance (NMR) logging is an exceptionally powerful tool for in-situ, direct characterization of the pore system. The relaxation time (T<sub>1</sub>, T<sub>2</sub>) curves obtained at each depth provide direct measurements of pore size distribution and fluid saturation. These curves can also be leveraged to model permeability, assess wettability, and estimate capillary pressure. As the most versatile logging technology available, NMR delivers unparalleled detail about rock properties in a single run. We propose that NMR data can serve as a distinctive 'fingerprint' for differentiating rock types at various depths, offering a direct and reliable method for reservoir evaluation.

In this study, we utilize a classical unsupervised machine learning clustering technique to classify downhole NMR log data from the Aquistore CO<sub>2</sub> injection well into seven distinct rock types. Core samples from a nearby well were analyzed at H<sub>2</sub> laboratory using a low-field NMR spectrometer (2 MHz Oxford GeoSpec) to determine pore size distributions and evaluate T<sub>2</sub> cutoffs. The laboratory results were compared with clustering outcomes from the downhole logs, enabling selective assignment of T<sub>2</sub> values to the corresponding rock types. This approach provided a more accurate estimation of the effective pore volume available for CO<sub>2</sub> storage, identified likely flow pathways, and offered insights into wellbore behavior during injection.

## Theory / Method / Workflow

The first step in the process involves scanning the data for missing points and outliers to ensure the accuracy and integrity of the dataset, removing any errors that might have occurred during data collection. Next, the data is normalized by converting the T<sub>2</sub> distribution at each depth into a standard normal distribution, which helps eliminate bias and ensures that all features contribute equally to the machine learning models, maintaining their parsimony. The third step is estimating the initial number of clusters, which corresponds to the number of rock types. By determining the appropriate number of clusters, you ensure that the model can effectively capture the underlying rock type distributions without introducing unnecessary complexity or overfitting. This balance allows for meaningful classification while maintaining interpretability and efficiency in the clustering process. The fourth step is running the clustering algorithm, calculating the centroids and standard deviations of each cluster to capture the distribution of T<sub>2</sub> values for each rock type. Finally, these centroids and standard deviations are used to establish upper and lower bounds for each cluster's T<sub>2</sub> distribution, creating a look-up table to classify each depth into one of the clusters, thereby categorizing each depth as a specific rock type.

Since very few core samples were available for the Aquistore injection well, we obtained samples from the nearest cored well (101/12-10-001-11W2). The two wells were carefully correlated, and after applying a core depth shift, we selected samples to ensure representation of all seven rock types. These samples were analyzed to determine total porosity, T<sub>2</sub> distribution, and T<sub>2</sub> cut-off under conditions that closely matched those used for the downhole log. The results were then compared with the clustering analysis of the downhole log data, allowing for the appropriate T<sub>2</sub>

cut-off to be applied to each rock type. Finally, we estimated the effective pore volume available for CO<sub>2</sub> storage and compared these estimates with previously published values.

## Results, Observations, Conclusions

Seven distinct lithological types were identified through the clustering analysis (Figure 1), each characterized by a unique petrophysical signature derived from the T2 distributions. These clusters reflect variations in pore geometry, permeability, and irreducible water saturation across the analyzed geological units. Shorter T2 times (left side of the plot) indicate smaller pore sizes, while longer T2 times (right side of the plot) correspond to larger pore systems. Clusters dominated by smaller pores are typically associated with higher clay content, greater bound water fractions, lower permeability, and elevated irreducible water saturation.

Notably, perforated intervals with clean gamma-ray (GR) signatures (Figure 1) consistently correlate with Cluster 1 (red), which is dominated by smaller pores and exhibits petrophysical characteristics indicative of lower reservoir quality. Conversely, non-perforated intervals with somewhat higher GR values are frequently associated with clusters characterized by larger pore systems, such as Clusters 4 and 6. This suggests that these zones may exhibit superior reservoir potential despite their higher GR readings.

Integrating this analysis with laboratory-derived T2 cutoff values will enhance the identification of optimal reservoir horizons for perforation in future wells. Additionally, it will enable more accurate calculations of total and effective pore volume, facilitating improved planning and development of the project.

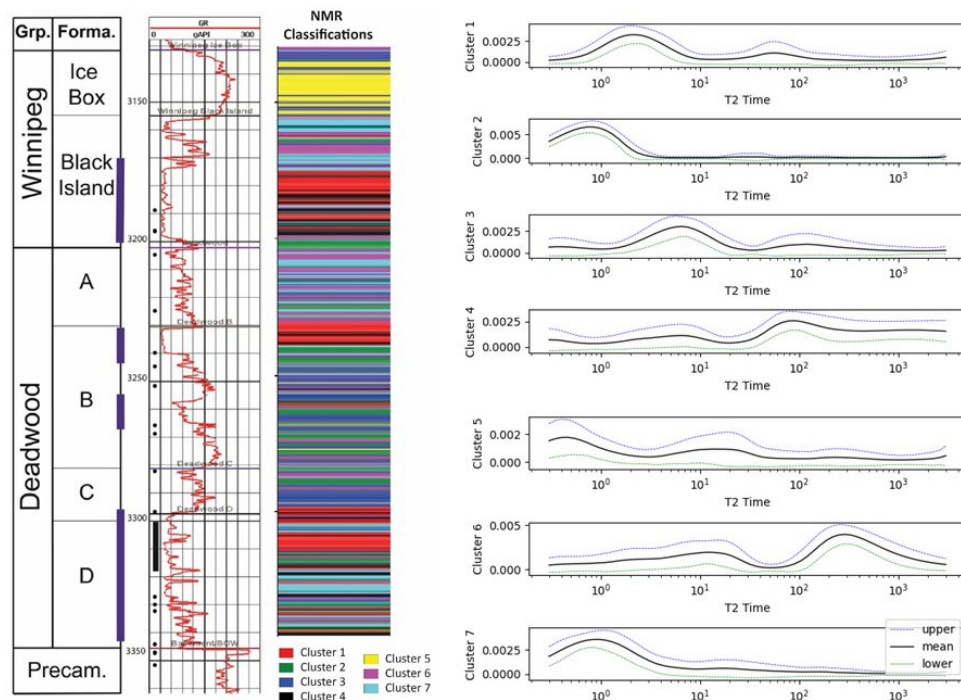


Figure 1: The deadwood and Winnipeg of Cambro-Ordovician age are the target formations of the Aquistore CO<sub>2</sub> injection well. Three tracks are presented here: to the left is the chronostratigraphic column. Purple sections identify the perforations in the injection well. The middle track shows the GR log of the well together with the location of an 18 m core (black line, bottom) and the location of sidewall plugs taken from the well. The right track shows the classification of the downhole NMR log. On the right the mean NMR T2 distribution curve of each cluster, together with its standard deviation are presented.