Estimation of CO$_2$ retention using NMR-derived pseudo capillary pressure curves: A case study from the Otway Basin of South Australia

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Abstract
Mercury Injection Capillary Pressure (MICP) analysis is a common technique for determining seal capacity (the maximum column height of carbon dioxide that can be retained by a cap rock); such analyses are vital for evaluating potential sites for safe geological storage of CO$_2$. One disadvantage of MICP analysis is that it requires testing of actual rock samples generally derived from cores from drilled wells. As coring is a costly addition to most operational well drilling programs, a more cost effective method for determining seal capacity, such as the use of wireline well data is desirable. This study investigates the use of the Nuclear Magnetic Resonance (NMR) well log, calibrated to rock samples, as a means of generating pseudo MICP curves to predict threshold pressures and subsequently predict maximum column height retentions for the storage of CO$_2$ (in gaseous, liquid or supercritical state). This technique hinges on a relationship existing between rock pore throat size (measured by MICP analysis) and rock pore body size (measured by NMR). In order to evaluate this technique, petroleum wells were identified which had both conventional core and an NMR well log over the same interval.

The Redman-1 petroleum well in the Otway Basin of South Australia was one of the wells used to test this methodology. The well has conventionally cored heterogeneous Pretty Hill Formation over which MICP analyses was conducted. The well also has an NMR log spanning the same interval, which comprises both fine grained (seal rock) and coarse grained (reservoir) rock. This provided the test conditions necessary to assess the accuracy of the pseudo capillary pressure curves of both reservoir and seal lithologies. The study interval was first sampled and analysed with the MICP porosimeter. Pseudo mercury injection curves were then produced over the intervals where the MICP samples were taken. The alignment of both the shape and position of the MICP curves was
assessed, the threshold pressures were picked and the maximum CO₂ column height retentions
determined.

The Redman-1 pseudo capillary pressure curves show the best agreement with the conventional
MICP curves of any of the wells where the technique was tested. However, even minor differences
in curve shape resulted in significant differences in the interpreted threshold pressures, which in
turn led to considerable differences in the maximum CO₂ column height retentions calculated. This
observed variation is in part due to a greater sample interval calculated by the NMR well log. The
results show that the maximum CO₂ column heights from the pseudo MICP curves have a similar
trend as the maximum CO₂ column heights determined by the MICP analyses performed on
conventional core samples. Ongoing studies aim to refine the methodology, determine sites pre-well
for nominal calibration of samples and define empirical correction factors, specific to formation
lithology where core is not available.

The ability to produce pseudo capillary pressure curves along the entire wellbore allows the analysis
of a far greater rock volume than through the analysis of individual core samples, thus more
effectively accounting for formation heterogeneity. In addition, the technique is quick, non-
destructive and results in a substantial reduction in coring requirements, making it significantly
lower cost than traditional methods.