DEVELOPMENT OF A LOW FIELD MRI-BASED APPROACH FOR OBSERVATION OF WATER PENETRATION INTO CLAY: PRELIMINARY RESULTS

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INTRODUCTION

Magnetic resonance imaging (MRI) are considered one of the most efficient and non-invasive methods of observing water content in permeable substances.[1,3] MRI can visualize and quantify the movement of water in real time.[3] In this study, MRI was used to observe the water penetration through clay. Furthermore, MRI can acquire three-dimensional data due to its radio-frequency signals from any orientation.[2,4] The contrast of the images produced by MRI is a display of the fluid concentration.[4] As such, any change in the contrast intensity is interpreted as a regional change in the concentration of fluid.[1,4] This report summarizes the preliminary results from a series of experiments performed with an MRI. The primary goal of the study is to provide a non-destructive method to quantify the permeation of clay using different amounts of water to determine if the low-field MRI approach can be viable option when evaluating the development of storage containers. This investigation is motivated with the intent to develop better and more environmentally friendly containers used to store radioactive waste.

BULK RELAXATION

Bulk Relaxation Measurements including the T_2*, T_2 and T_1 relaxation time constants for a different Water Content:

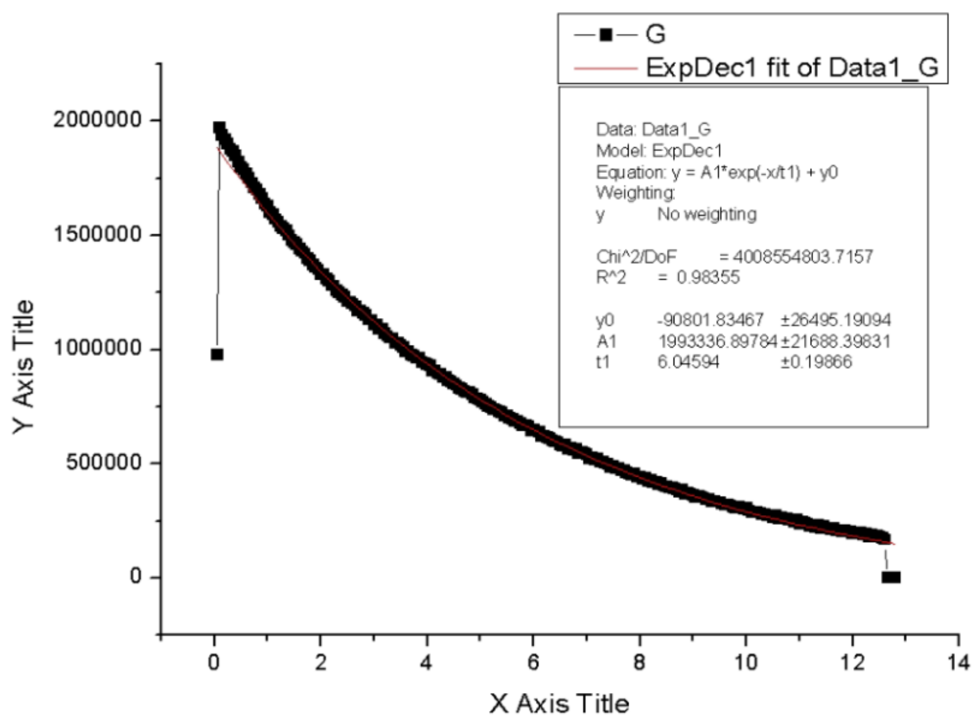

Figure 1. T_2 Decay Curve (dots) and the Best Fit

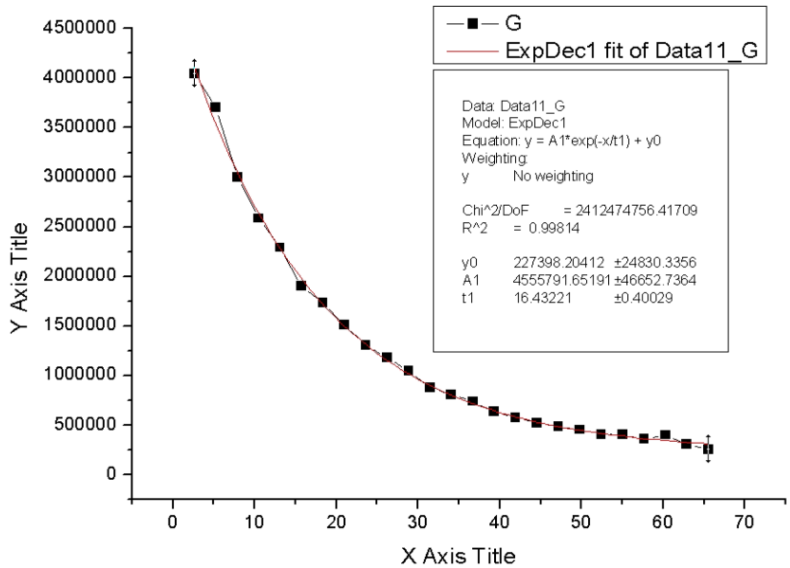

Figure 2. T_2 Decay Curve (dots) and the Best Fit

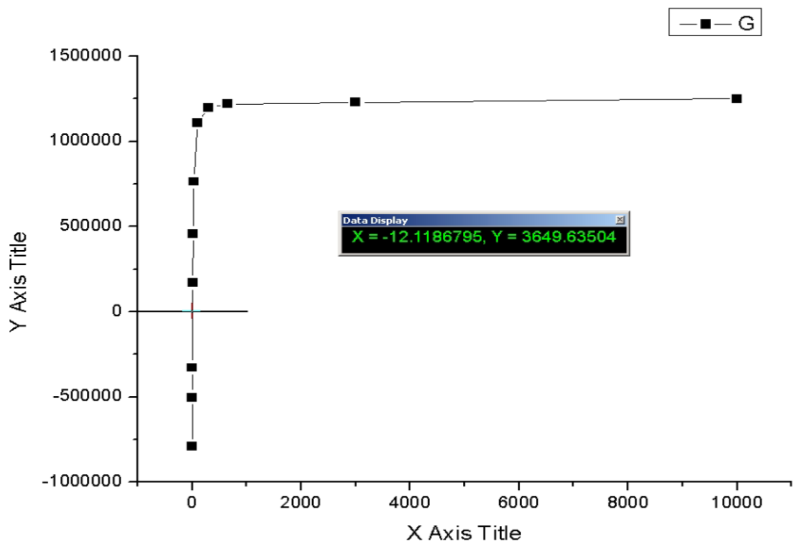

Figure 3. T_1 Recovery Curve (dots) and the Best

Table 1. Relaxation Constants vs Volume of water

Water Content	$\langle T_2^* \rangle \pm$ SD ms	$\langle T_1 \rangle$ ms	$\langle T_2 \rangle \pm$ SD ms
baseline	3.6 ± 0.08	5.5	7.3 ± 1.4
+1ml	4.1 ± 0.10	5.5	14.5 ± 2.4
+1ml	4.7 ± 0.12	5.5	12.7 ± 2.5
+1ml	5.1 ± 0.13	5.5	N/A
+1ml	5.4 ± 0.15	5.5	16.4 ± 0.4

As the volume of water increases, the values of the relaxation time constants T_2^* and T_2 increases whereas the value of T_1 remains constant.

2D X-CENTRIC PULSE

2D of the Water Content Distribution Imaging with the X-Centric Pulse Sequence

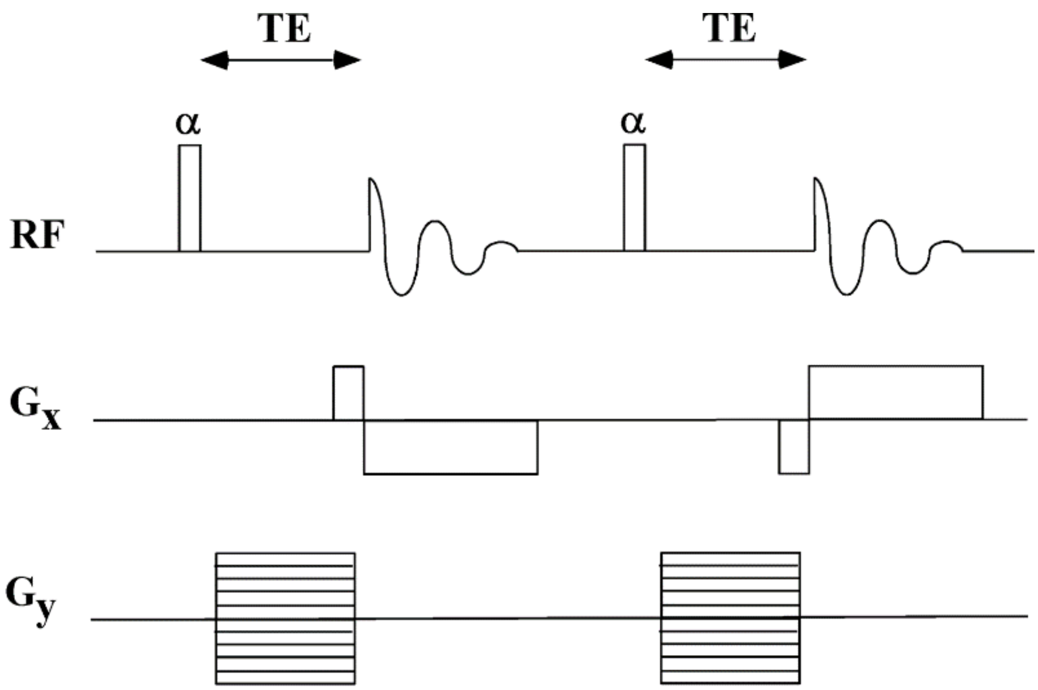

Figure 4. Pulse sequence timing diagram of the X-Centric FGRE acquisition scheme. The X-Centric approach minimizes signal loss due to short T_2* since the number of k-space points acquired before the center of the kx line is significantly reduced.

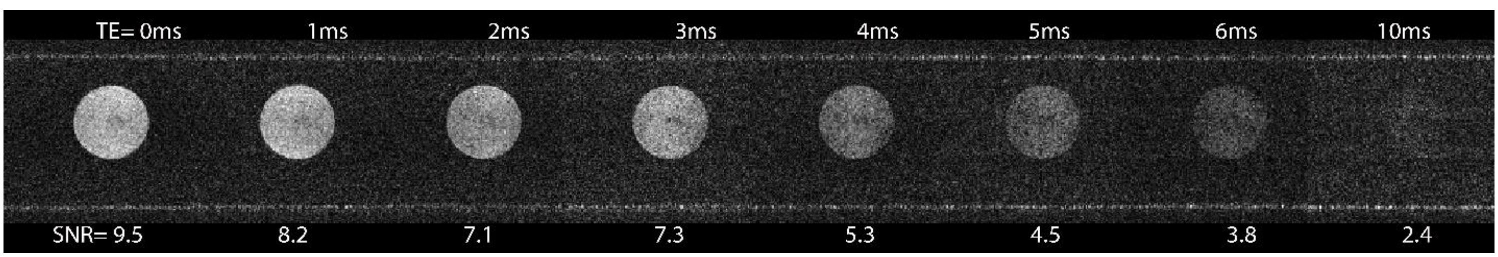

Figure 5. Representative unweighted (TE=0ms) & weighted Images of the Water Content Distribution. The signal degradation of weighted Images reflects the short T_2* value role.

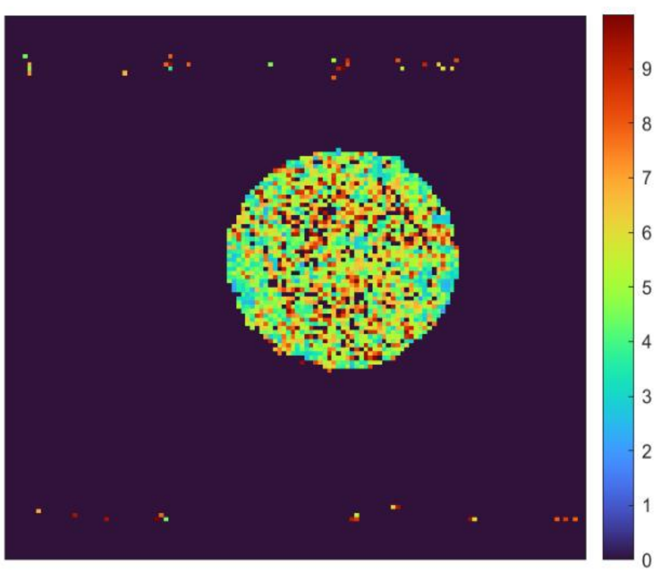

Figure 6. T_2*-map obtained using the x-centric pulse sequence at nine different echo-times. The map was generated from the images shown in Figure 5.

The map showing a non-uniform T_2* distribution reflecting a difference in the water content.

FUTURE WORK

3D Imaging of the Water Content Distribution with the X-Centric Pulse Sequence

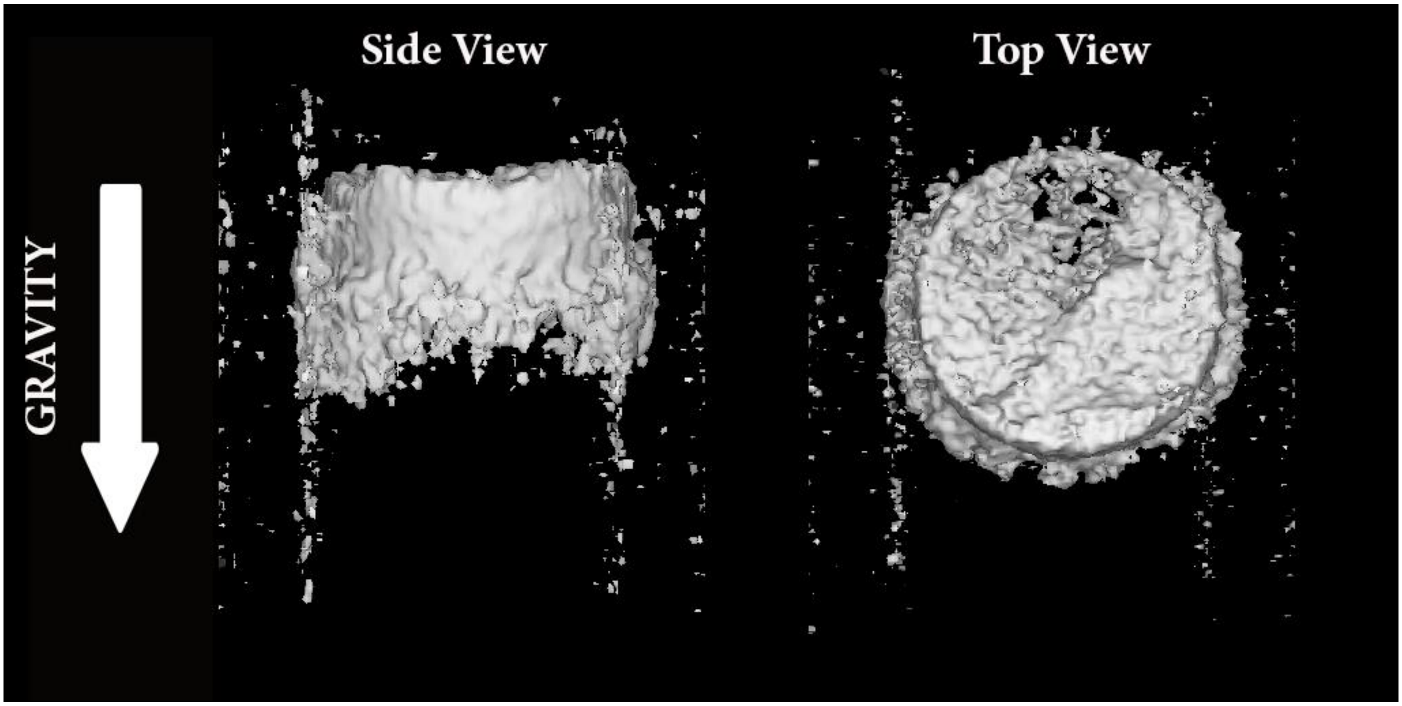

Figure 7. Representative 3D high-resolution image of the water content inside clay obtained at the time-zero. Images was squired with the 3D X-Centric pulse sequence. Image showing the water on top of the clay at the very beginning of the water penetration.

CONCLUSION

Using the low-field MRI we have successfully developed a two-dimensional imaging technique called x-centric for visualizing the water distribution along with T_2*-mapping. We were also able to acquire three-dimensional images of the water content using 3Dx-centric. Based on the successful imaging results, it is determined that the low-field MRI approach was indeed a successful non-invasive method to quantify the permeation of clay using different amounts of water.

REFERENCES

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4. Ouriadov, A. (2020). *The Use of 1H MRI for the Static and Dynamic Visualization and Quantification of the Distribution of Water in Clay: Preliminary Results*. University of Western Ontario/LHRI. https://file:///C:/Users/shiva/Desktop/AOuriadov_Initial_Clay_Report_May11_2020.pdf

APPENDIX

Table 1. T_2 Parameters*

AppendixObs. Freq.	3.129924	**pw**	186u	**Z_2**	100	**Z_x**	100
Acq. Points	256	**rd**	300u	**Z_3**	100	**Z_y**	100
Point 1D	256	**ad**	50u	**Z_4**	120		
SW +/-	10000.0Hz	**Acq. Time**	12.8				
Filter	10000.0	**Last Delay**	200m	**G_x**	589		
Dwell Time	50u	**f1 amp**	100	**G_y**	203		
Acq. Time	12.8m	**f1 attn**	13	**G_z**	-150		
Last Delay	200m	**C13_pw90**	12u				
Obs. Freq.	3.129924	**pw**	186u	**Z_2**	100	**Z_x**	100
Acq. Points	256	**rd**	300u	**Z_3**	100	**Z_y**	100
Point 1D	256	**ad**	50u	**Z_4**	120		
SW +/-	10000.0Hz	**Acq. Time**	12.8				
Filter	10000.0	**Last Delay**	200m	**G_x**	589		
Dwell Time	50u	**f1 amp**	100	**G_y**	203		
Acq. Time	12.8m	**f1 attn**	13	**G_z**	-150		
Last Delay	200m	**C13_pw90**	12u				

Table 2. T_1 Parameters

Obs. Freq.	3.129924	**pw**	186u	**Z_2**	100	**Z_x**	100
Acq. Points	64	**tramp**	500u	**Z_3**	100	**Z_y**	100
Point 1D	64	**rd**	1m	**Z_4**	120		
SW +/-	10000.0Hz	**ad**	1u				
Filter	10000.0	**Acq. Time**	3.2m	**G_x**	589		
Dwell Time	50u	**Last Delay**	5s	**G_y**	203		
Acq. Time	3.2m	**F1 Ampl**	100	**G_z**	-150		
Last Delay	5s	**F1 Attn**	13				

Table 3. T_2 Parameters

Obs. Freq.	3.129924	**pw**	168u	**Z_2**	100	**Z_x**	100
Acq. Points	40	**ad**	50u	**Z_3**	100	**Z_y**	100
Point 1D	1000	**Tacq/2**	1.31072m	**Z_4**	120		
SW +/-	10000.0Hz	**pw2**	350u				
Filter	10000.0	**Acq. Time**	2m	**G_x**	600		
Dwell Time	50u	**Last Delay**	1s	**G_y**	200		
Acq. Time	2m	**f1 amp**	100	**G_z**	-200		
Last Delay	1s	**f1 attn**	13				