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Characterizing Ice Melting Dynamics in Porous Media with NMR-MRI

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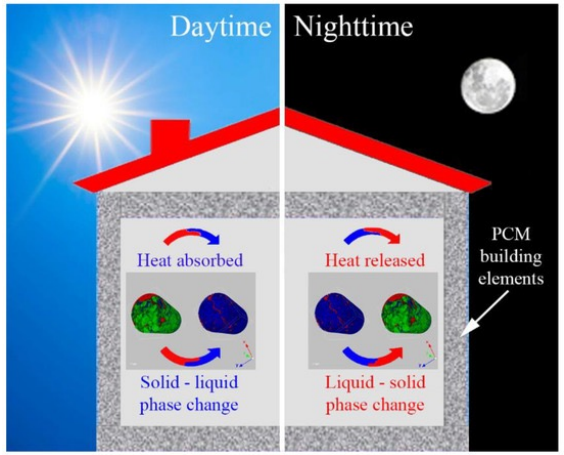
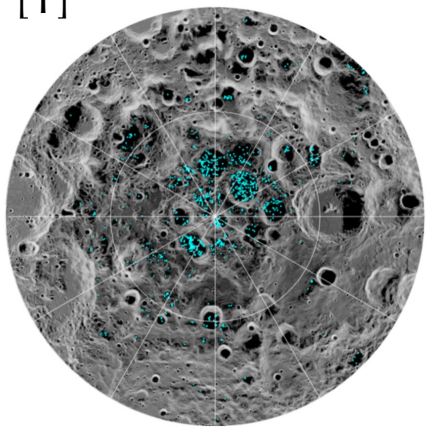
Background

➢ Applications of melting dynamics in porous media



Improving solid-liquid PCM effective thermal conductivity [1]

Thawing of permafrost [2]



Water harvesting for in-situ resource utilization [3]

➢ To study melting dynamics

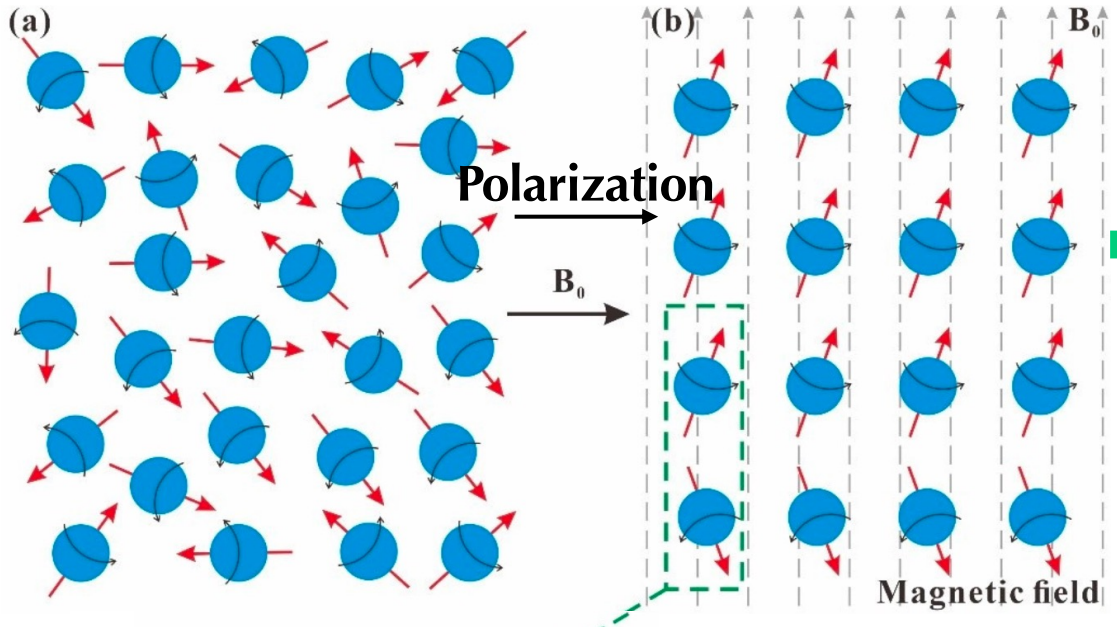
- **X-ray scan machine**

- **PET scan machine**

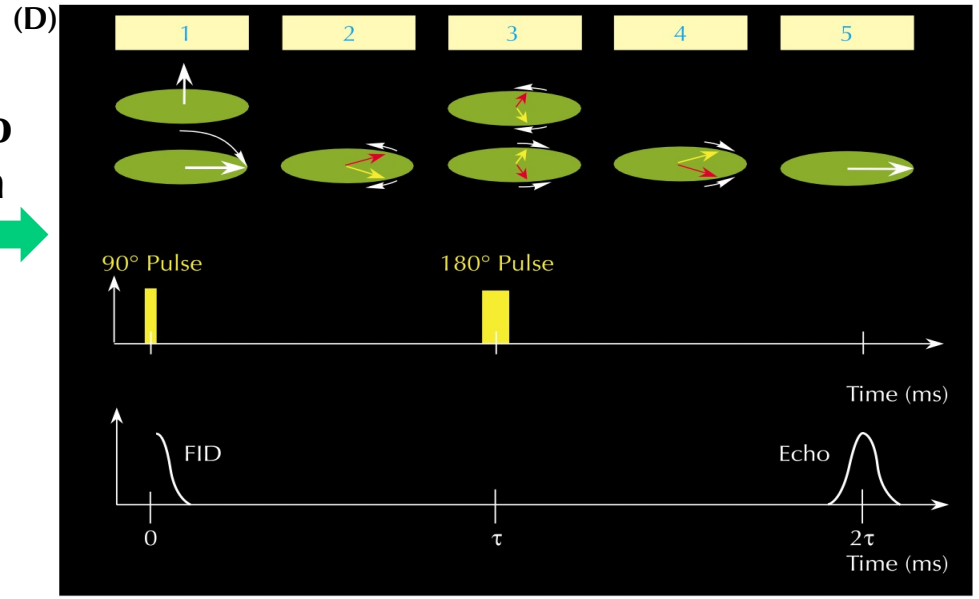
- **NMR/MRI analyzer**

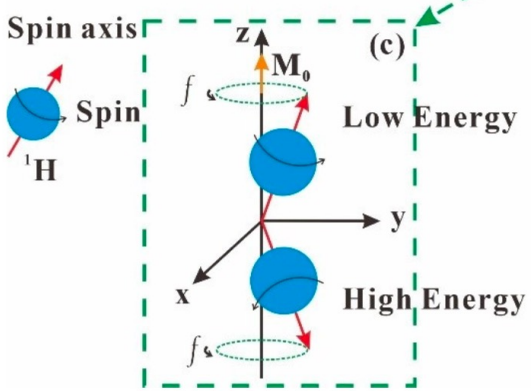
1. Noninvasiveness (nondestructive)
2. Lack of Ionizing Radiation
3. Flexibility

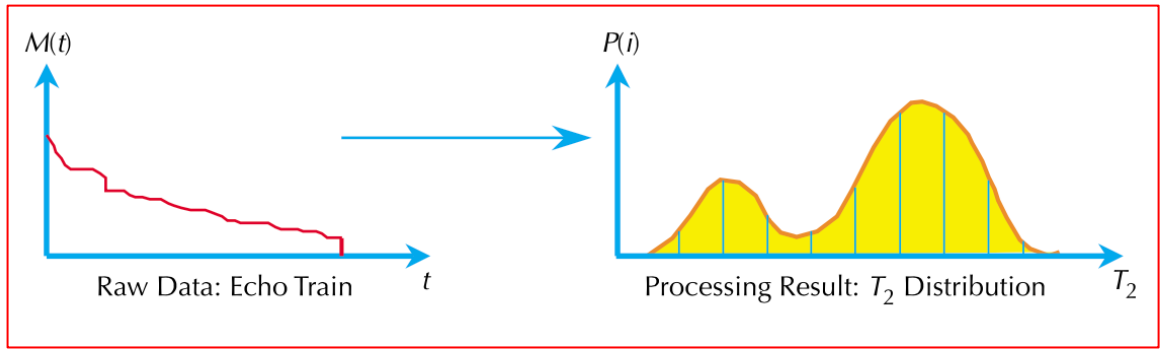
Working Principles of NMR/MRI



Spin echo detection



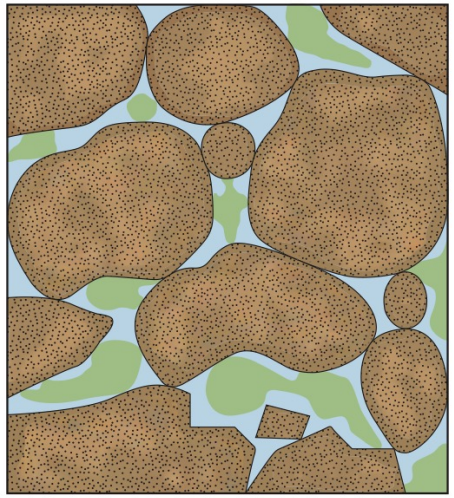




(E)

Echo-Fit for T_2 Distribution

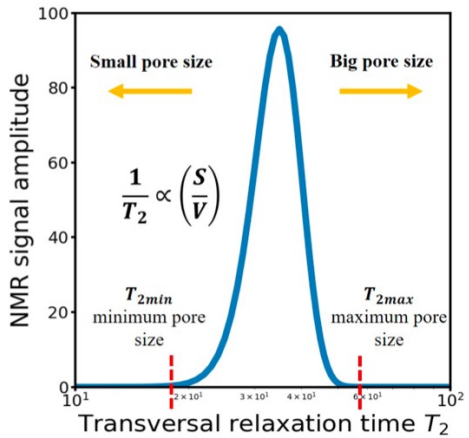
NMR T_2 Curve → Pore size/Water status



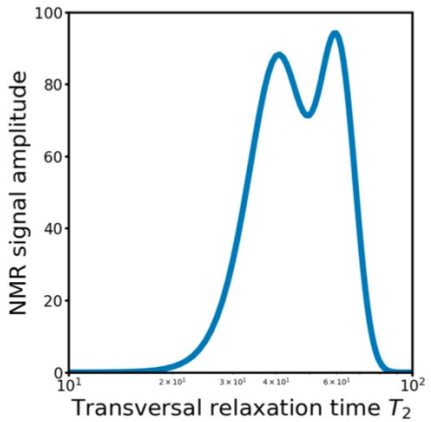
Water wet pores [4]

$$\frac{1}{T_2} = \frac{1}{T_{2bulk}} + \frac{1}{T_{2surface}} + \frac{1}{T_{2diffusion}}$$

For water: $T_{2bulk} >>> T_{2surface}$



Homogenous porous sample

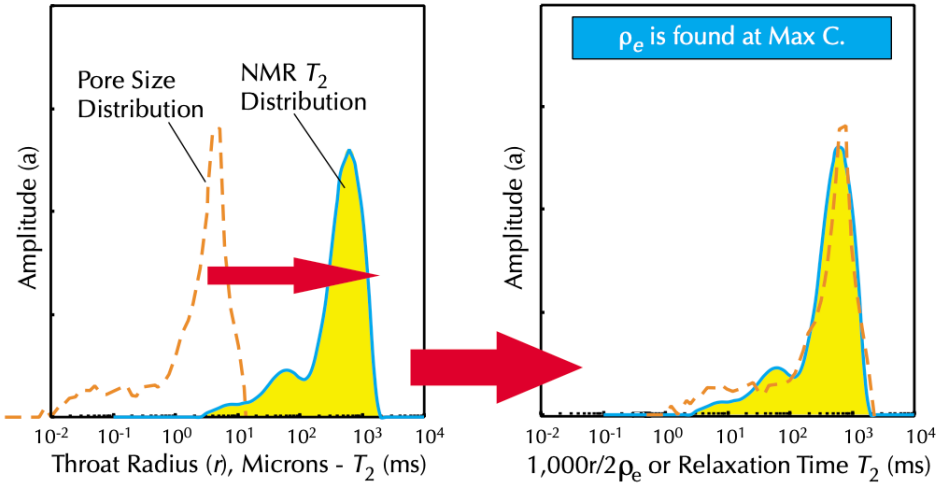


Heterogeneous porous sample

At very short TE (≅0.2 ms) diffusion relaxation is negligible

Therefore:

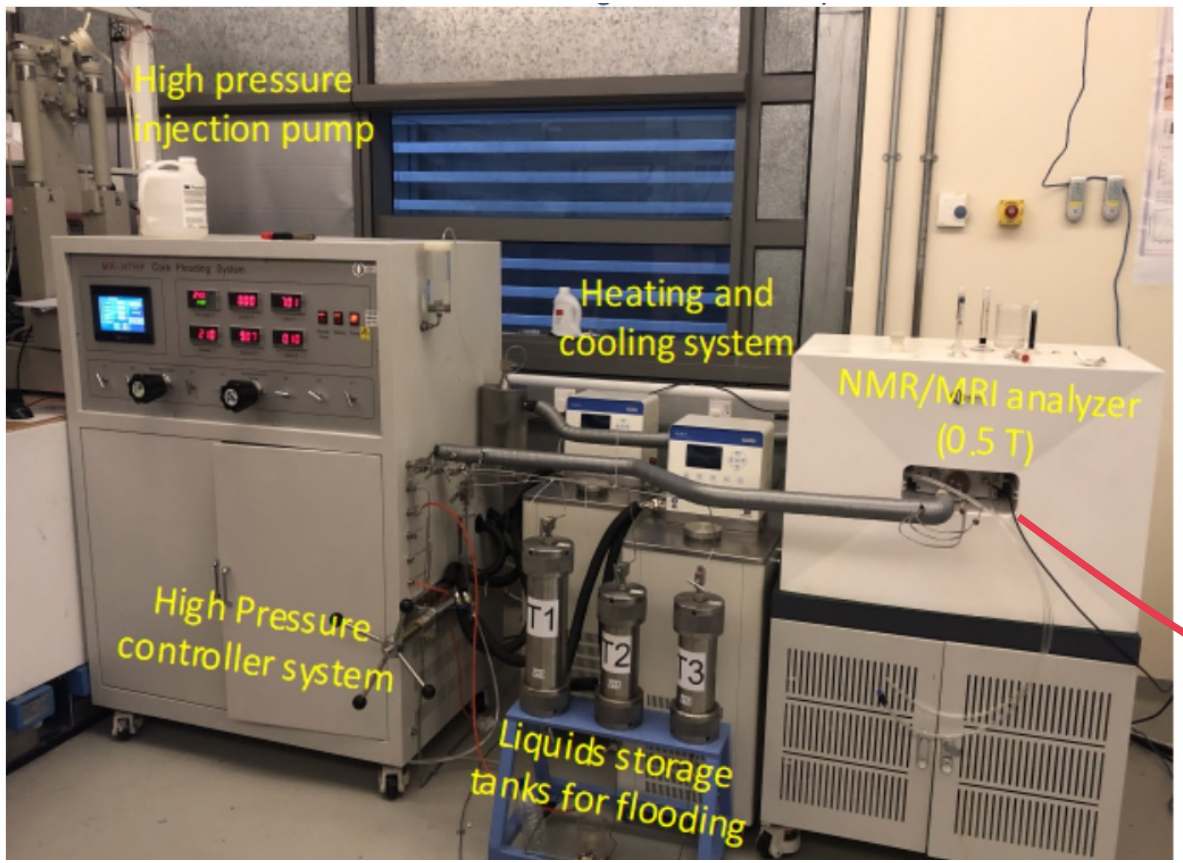
$$\frac{1}{T_2} \approx \frac{1}{T_{2surface}} = \rho\left(\frac{S}{V}\right)$$



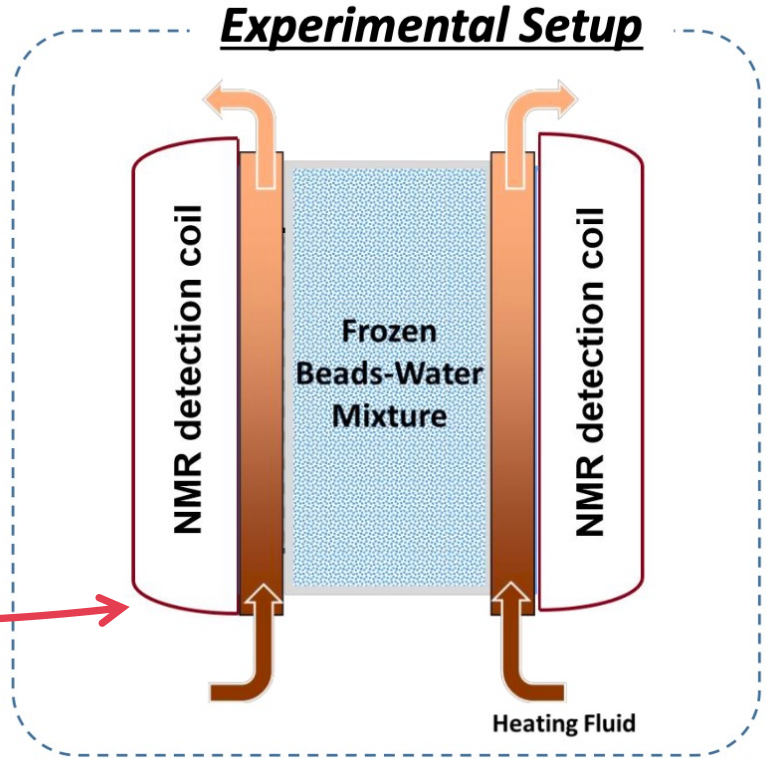
[5].

Experimental Setup

Low-field Proton NMR analyzer (0.5 T)

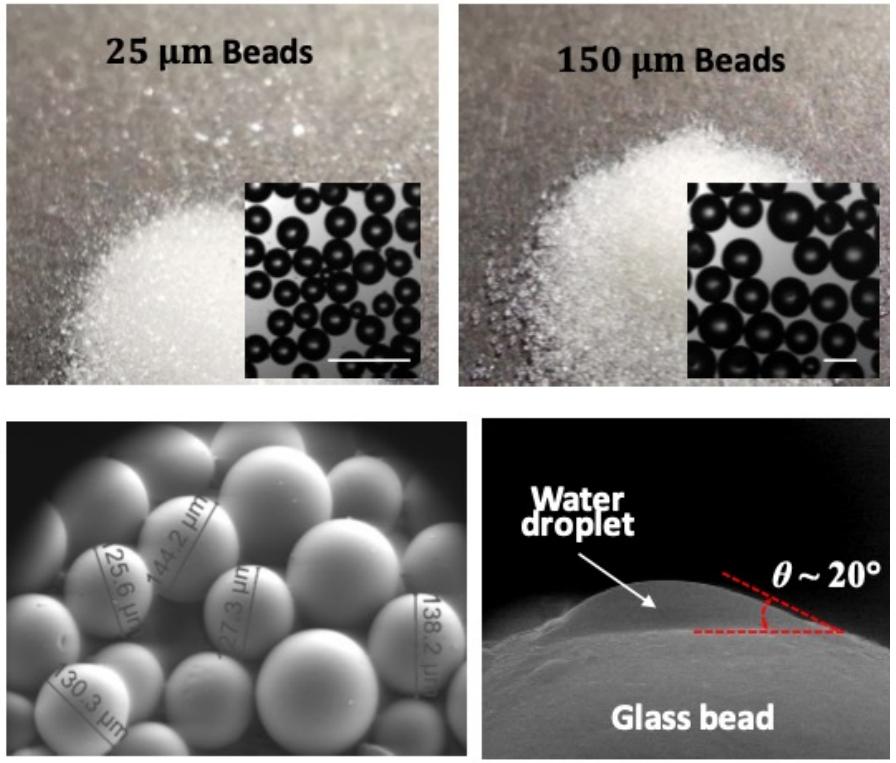


NMR detection coil



Sample Preparation

Morphologies of soda lime glass bead

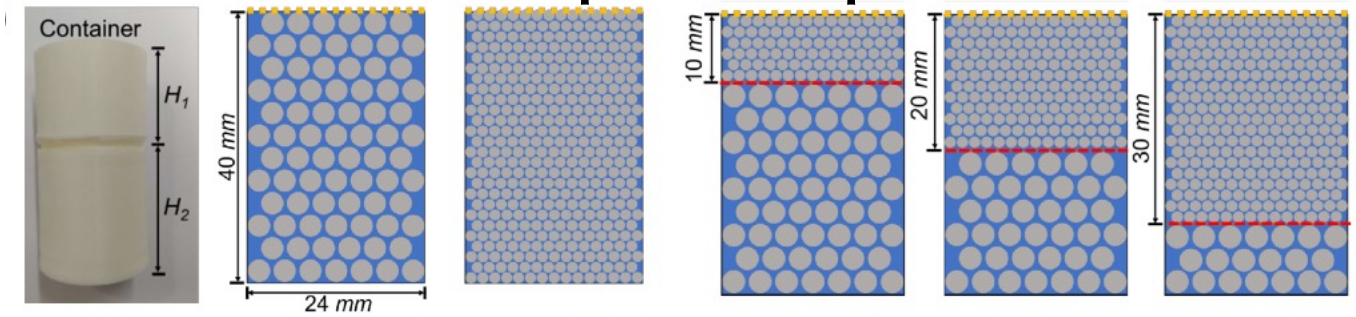


ESEM image (contact angle ≅ 20°)

Thermophysical properties of soda lime glass bead

Physical Properties	Value
Density (g/cm^3)	2.5
Thermal conductivity (W/m.℃)	1.06
Specific heat (J/g.℃)	0.87
Melting temperature (℃)	1000

Different porous samples

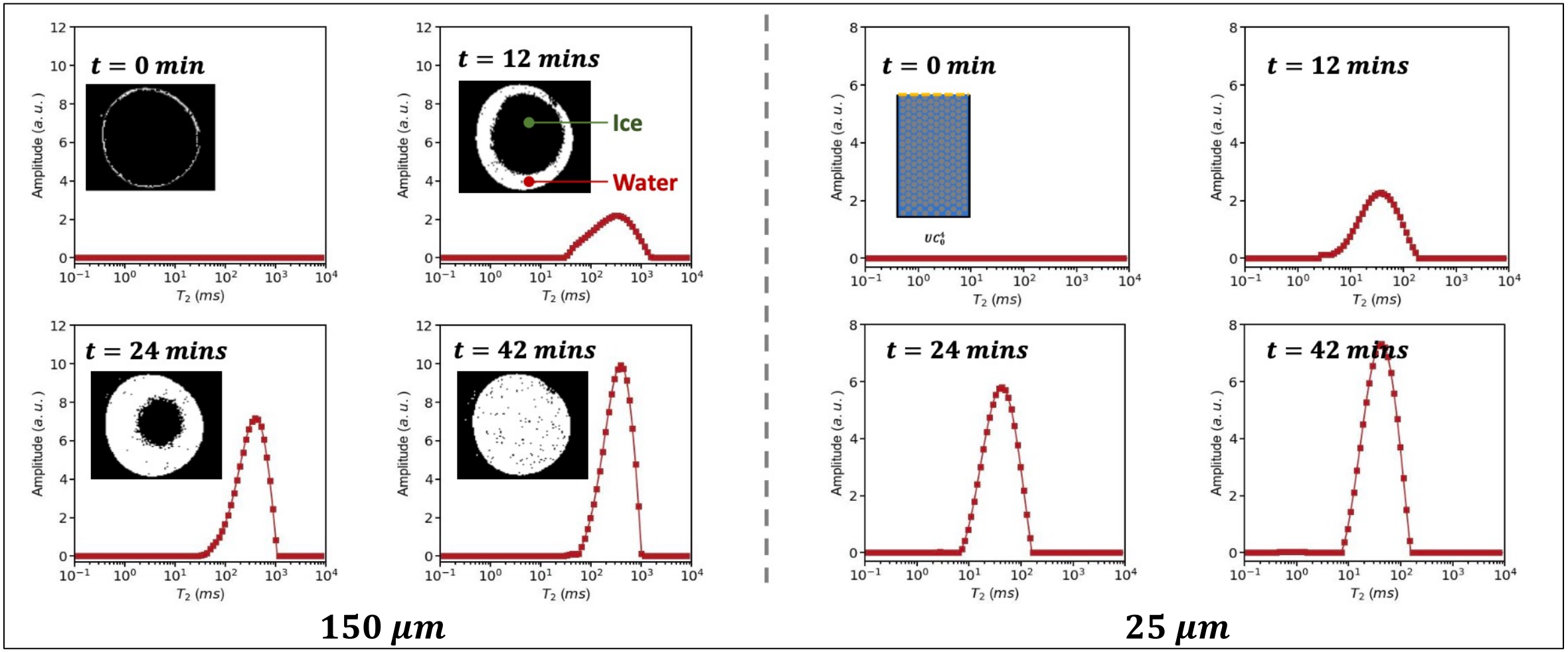


Homogenous porous media

Heterogenous porous media

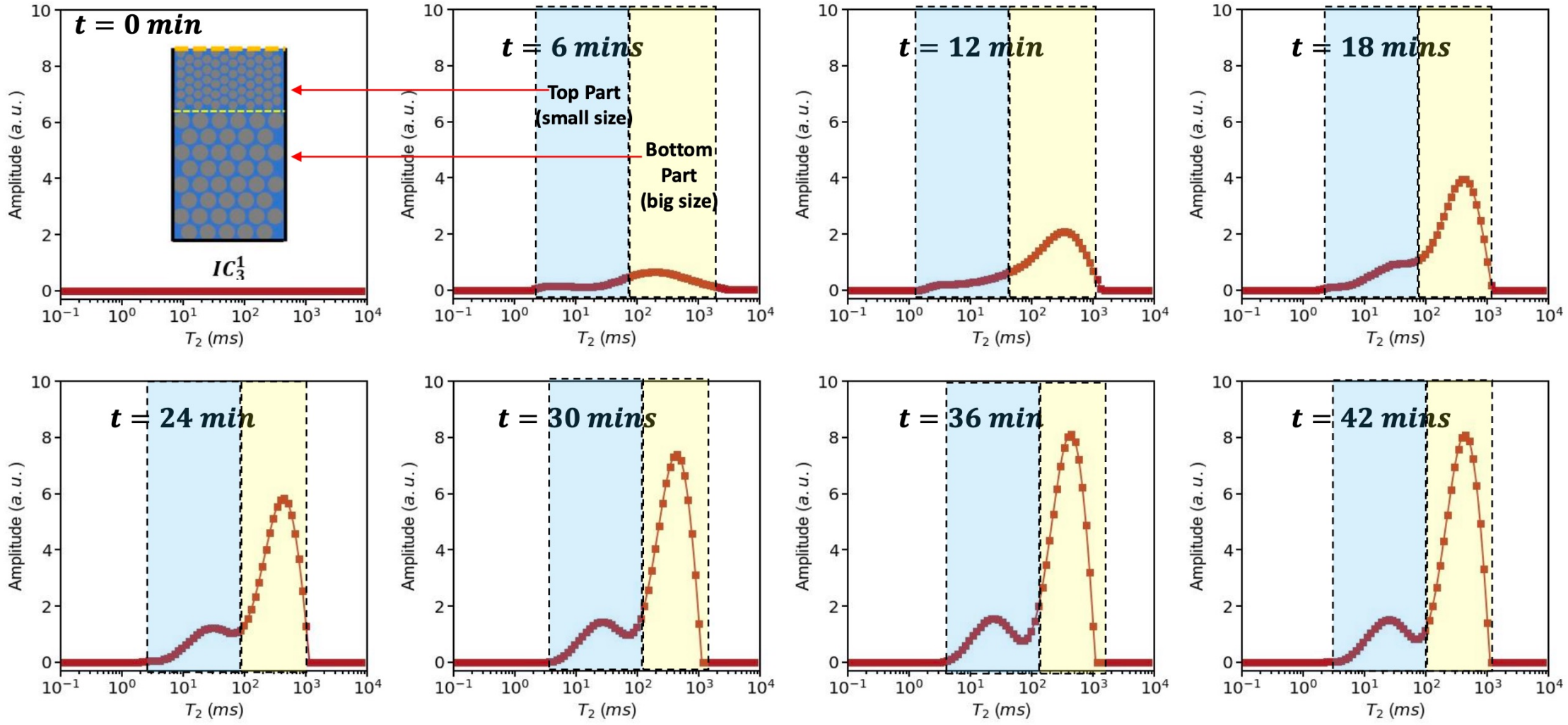
T2 curve evolution during Melting of ice

In uniform sample

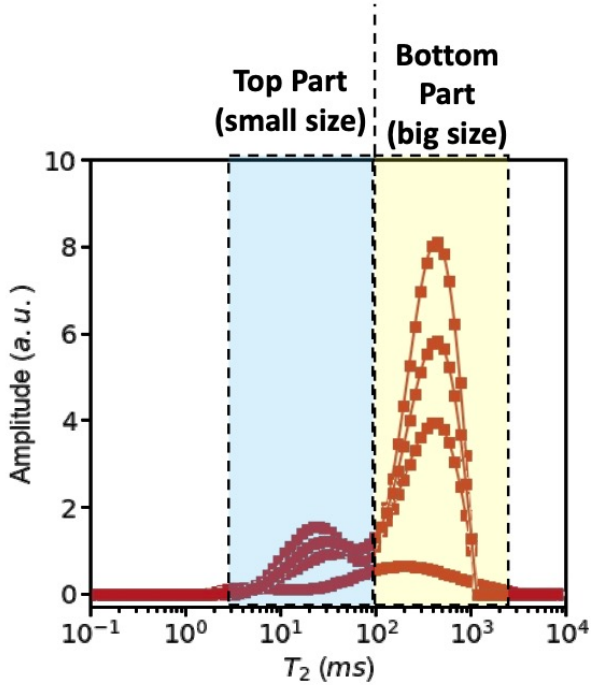


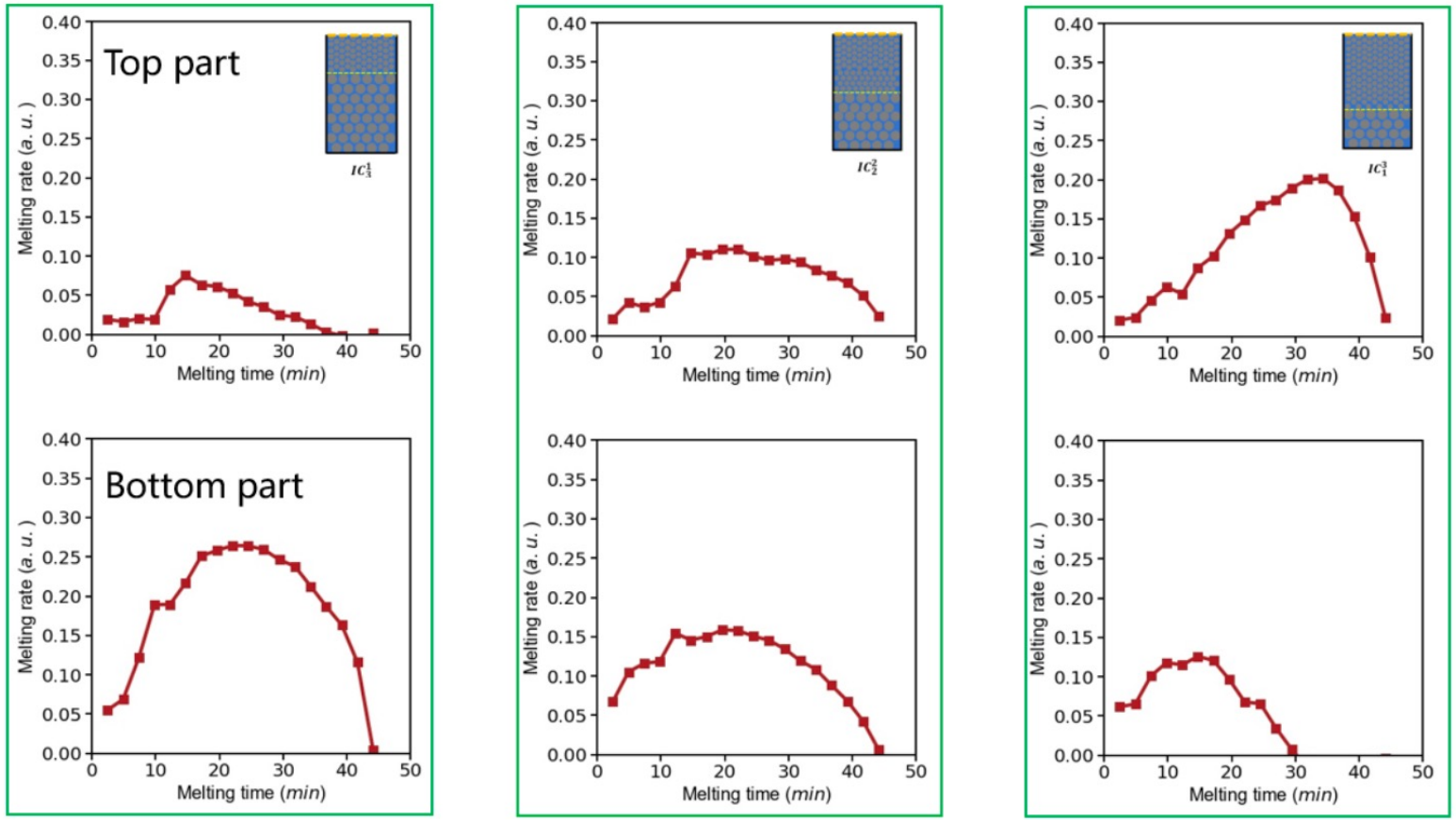
T2 curve evolution during Melting of ice

In heterogeneous sample

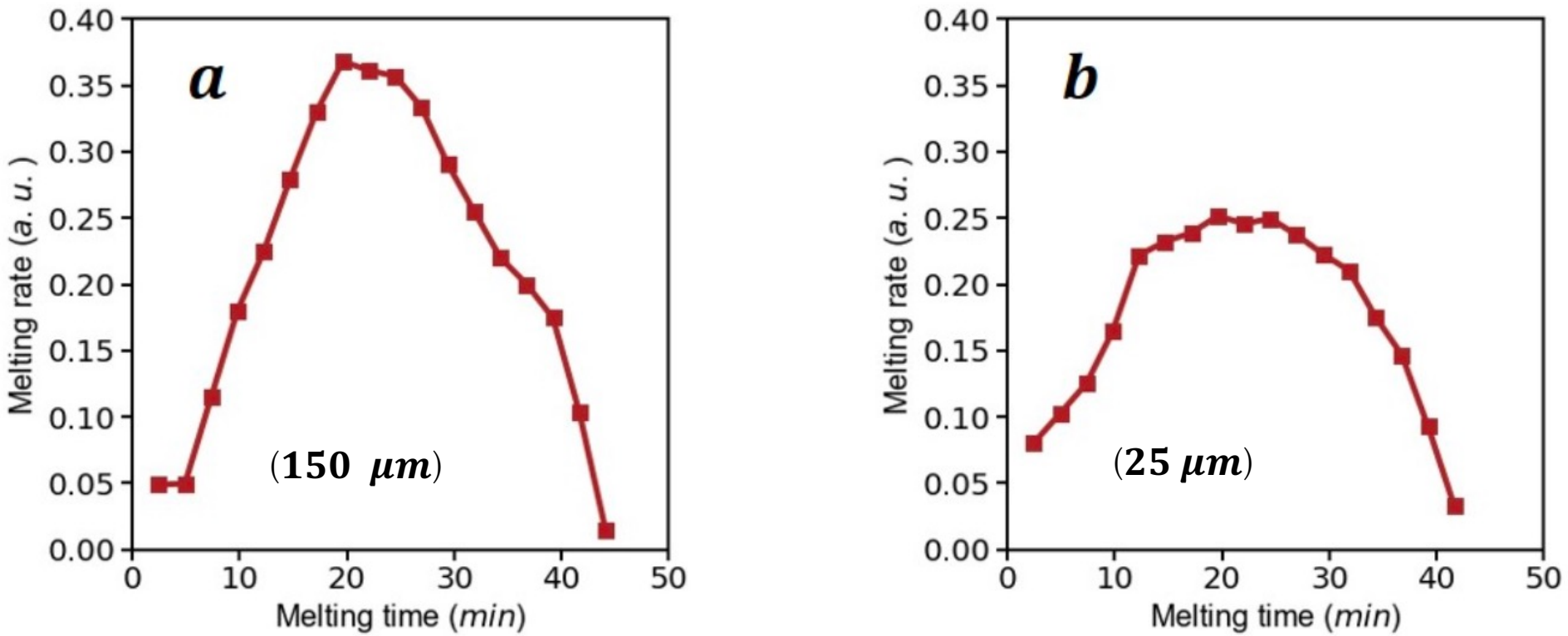


Melting rate in heterogenous porous media



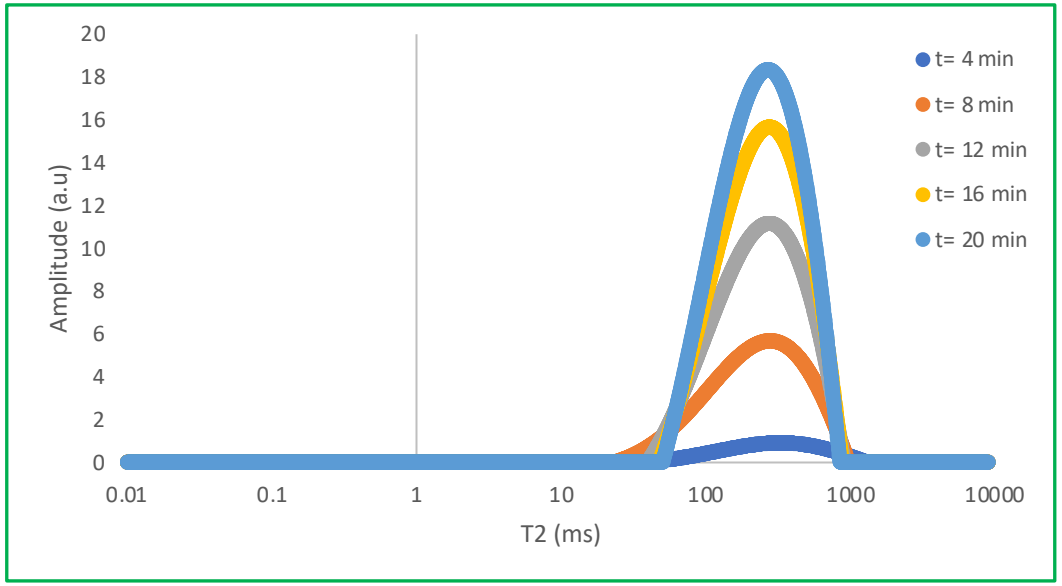


Melting rate of homogenous porous media

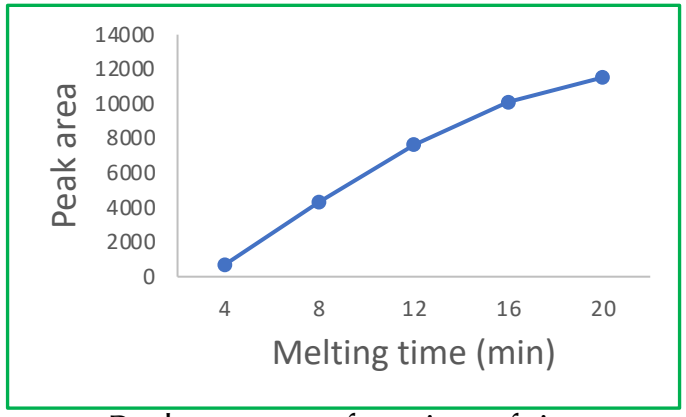


Ice melting in porous media

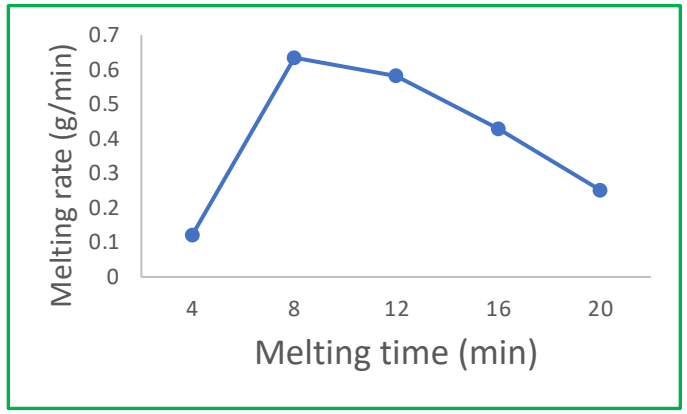
Representative size: 0.07-0.11 mm



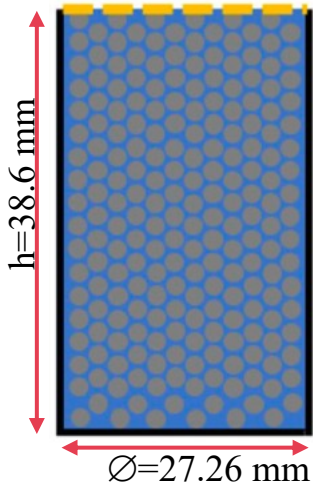
T_2 curve distribution



Peak area as a function of time

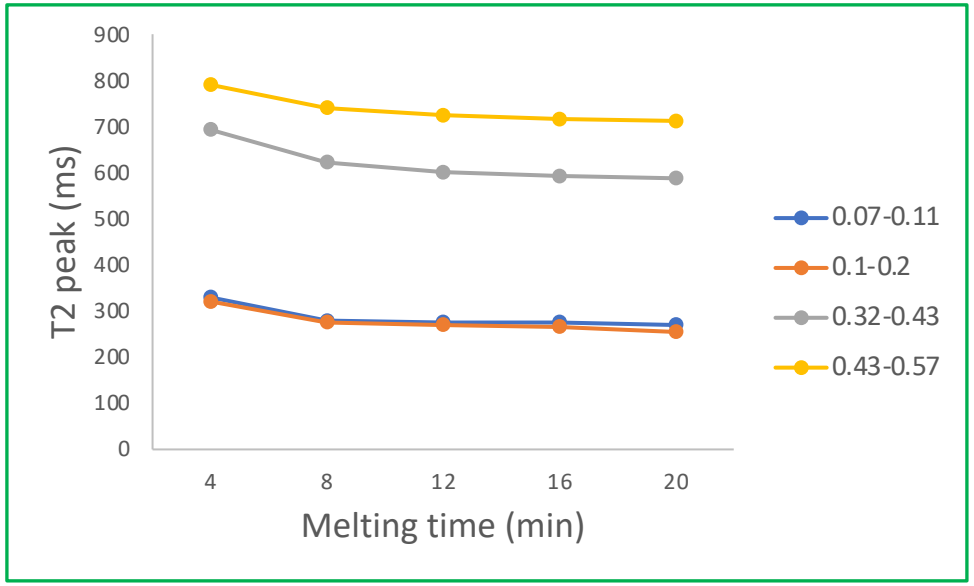


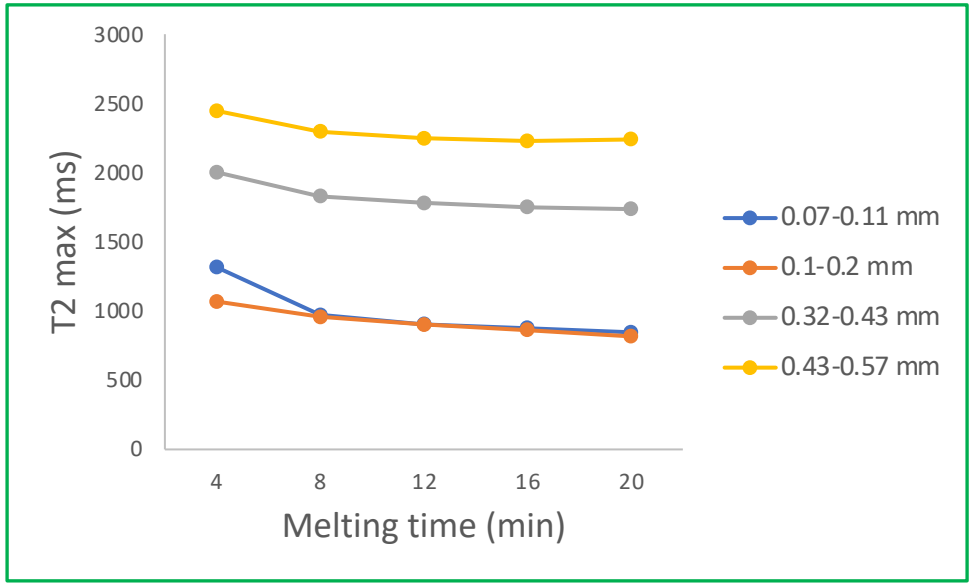
Melting rate in g/min

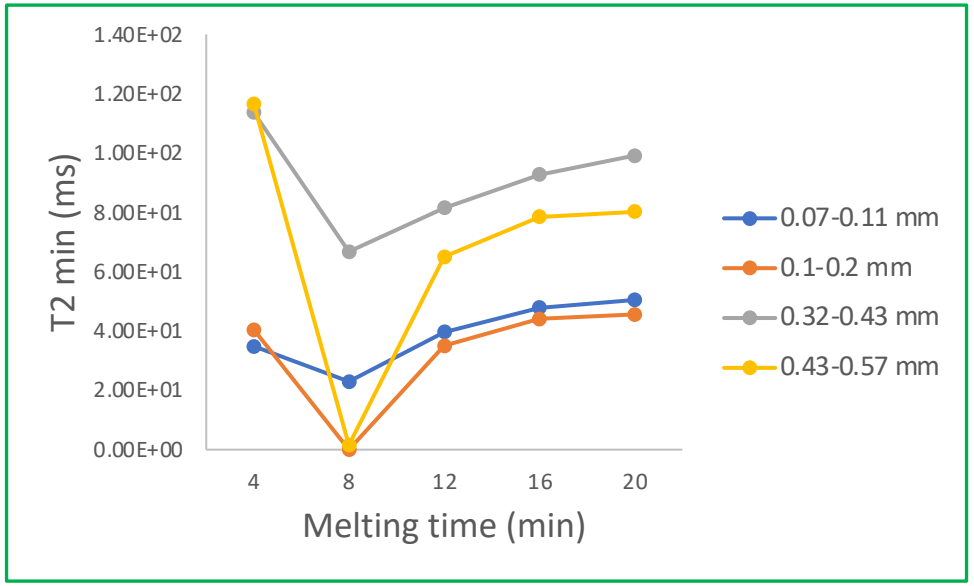


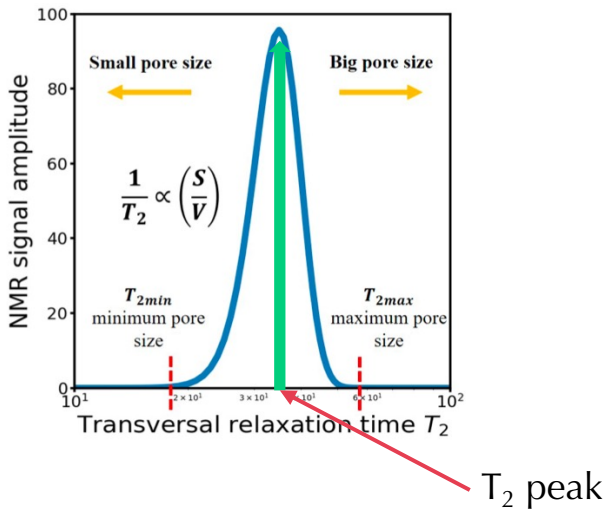
Dimensions of cylinder

Shift in T_2 peak, T_2 max & T_2 min values:



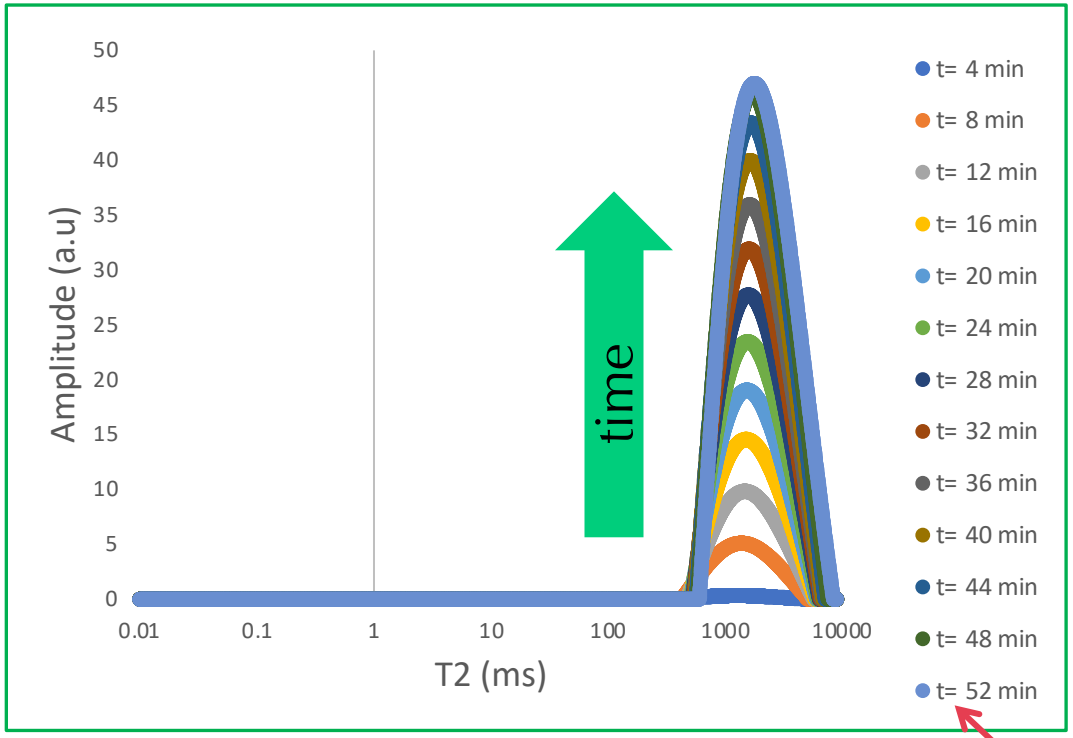






Ice melting without glass beads

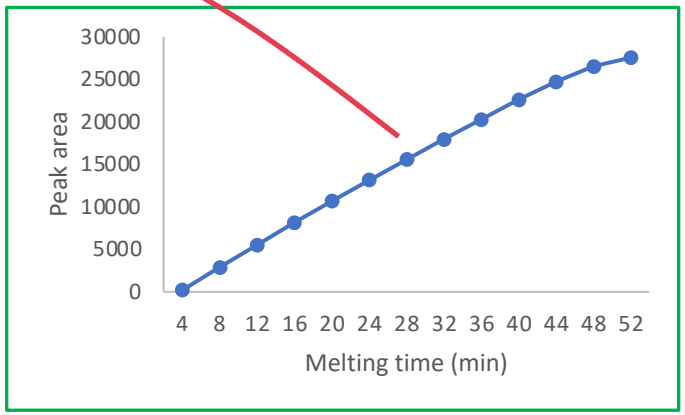
The same cylinder is filled with DI water only



T_2 curve distribution without glass beads

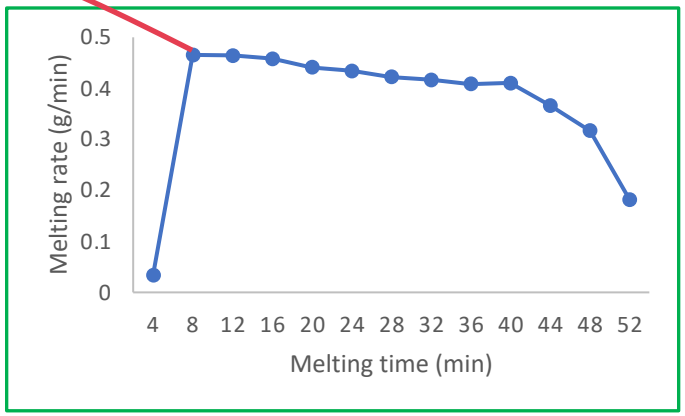
Takes T=52 min to melt the pure water

unifrom increase in the amount of ice melted



Peak area as a function of time

Max: 0.465 g/min



Melting rate (g/min)

Conclusion:

- Insertion of soda lime glass beads into the sample expedite the melting process.
- Melting rate increases with reduction in porosity.
- Ice in small pores are melting first relative to the big pores (shifting of T_2 peak towards smaller value)

References:

[1] C.V. Podara, I.A. Kartsonakis, and C.A. Chartidis, "Towards Phase Change Materials for Thermal Energy Storage: Classification, Improvements and Applications in the Building Sector", *Applied sciences*, vol. 11, no. 4, Dec. 2021.

[2] "Arctic Permafrost Thaw Will Start Toppling Buildings Across Northern Hemisphere by 2050 ", newsweek.com. https://www.newsweek.com/climate-change-permafrost-thawing-arctic-methane-infrastructure-1253152 (accessed May 10, 2022)

[3] "Is There Ice on Other Planets?", nasa.gov. https://spaceplace.nasa.gov/ice-on-other-planets/en/ (accessed May 10, 2022)

[4] W. Abdallah, J.S. Buckley, A. Carnegie, J. Edwards, E. Fordham, A. Graue, C. Signer, H. Hussain, B. Montaron, M. Ziauddin, "Fundamentals of Wettability", vol 19, no. 2, *Oilfield Review, 2007*.

[5] G.R. Coates, L. Xiao, and M.G. Prammer, *NMR logging principles and applications*, Hou: Halliburton energy services, Sep 1999, pp. 1-253.

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