Thermal Conductivity of Synthetic Materials Across Varying Saturation States

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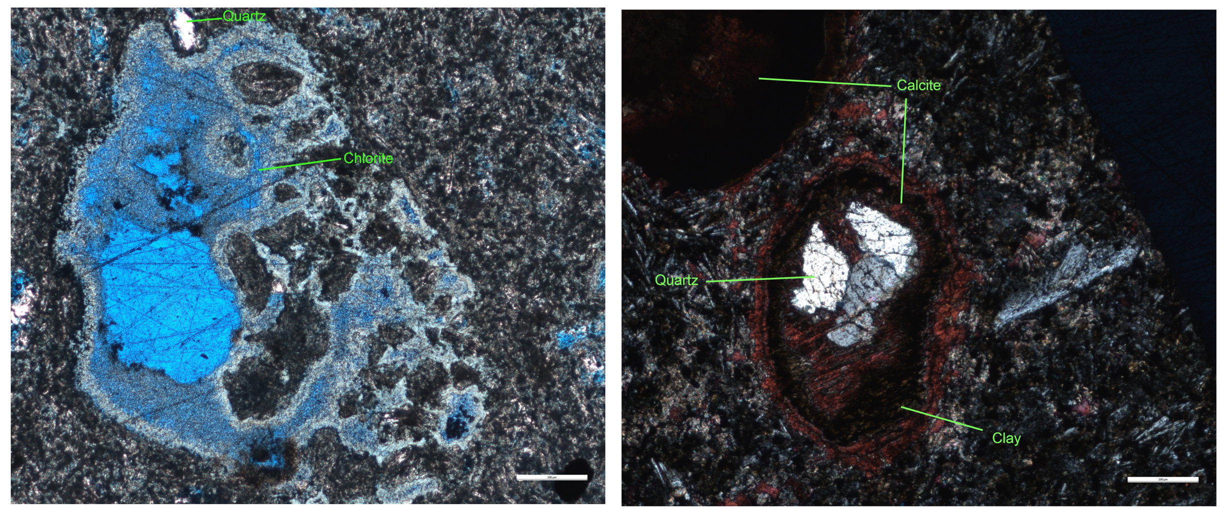
Introduction

In subsurface conditions, **geological formations retain moisture and fluids** due to infiltration through the Earth's crust, **influencing thermal conductivity** crucial for geothermal applications and gas storage capacity.



Geological pore structures affect fluid-rock interactions via wettability, surface chemistry, and mineral diversity; synthetics provide controlled environments for precise experimentation.

To investigate these effects, **synthetic materials** with known compositions and porosities serve as **standardized benchmarks**, offering a systematic approach to understanding the complexities of natural materials.

Research Gaps

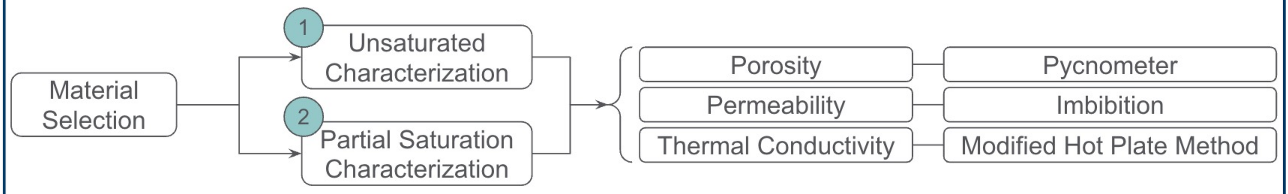
- Sparse characterization of synthetics.
- Limited accessibility and reproducibility of effective thermal conductivity measurements.
- Inadequate consideration of saturation effects on thermal conductivity.
- Limited understanding of material properties across different saturation methods and degrees.

Objective

Characterize micro- and nanoporous synthetics across **varying saturation levels** to assess **porosity**, **permeability**, and **thermal conductivity** for calibrating workflows on complex, heterogeneous natural materials.

Workflow

Methodology:

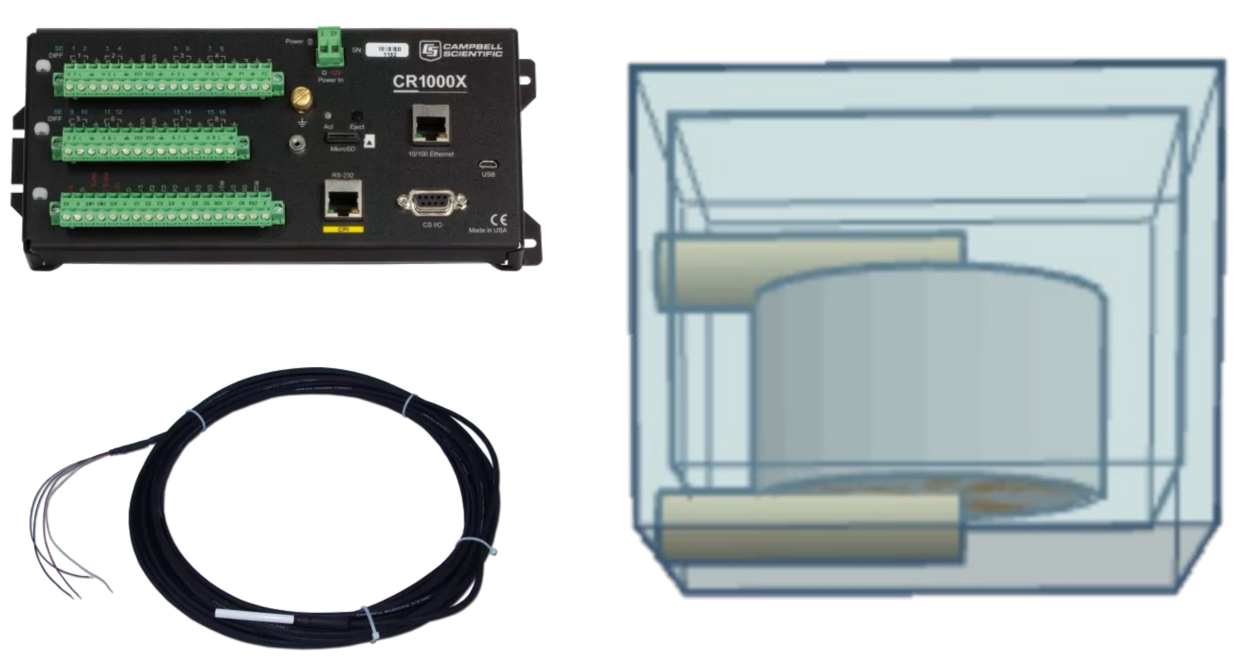


Case Study: Glass Frits

Disks vary in pore sizes from fine (4.0 - 5.5 μm) to extra coarse (170 - 220 μm).

Applications: gas dispersion, washing, absorption, and filtration

Modified Hot Plate Method:

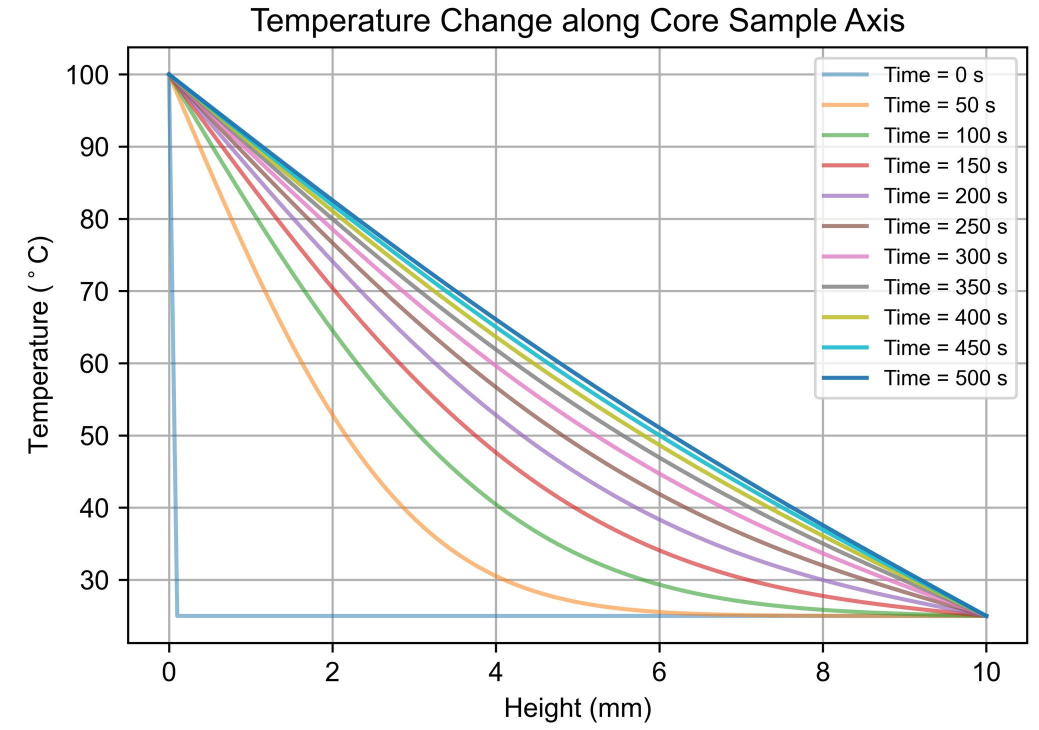


Results

Fourier-Biot Equation: models heat transfer in porous media by combining Fourier's law of heat conduction with Biot's theory of heat transfer between solids and fluids

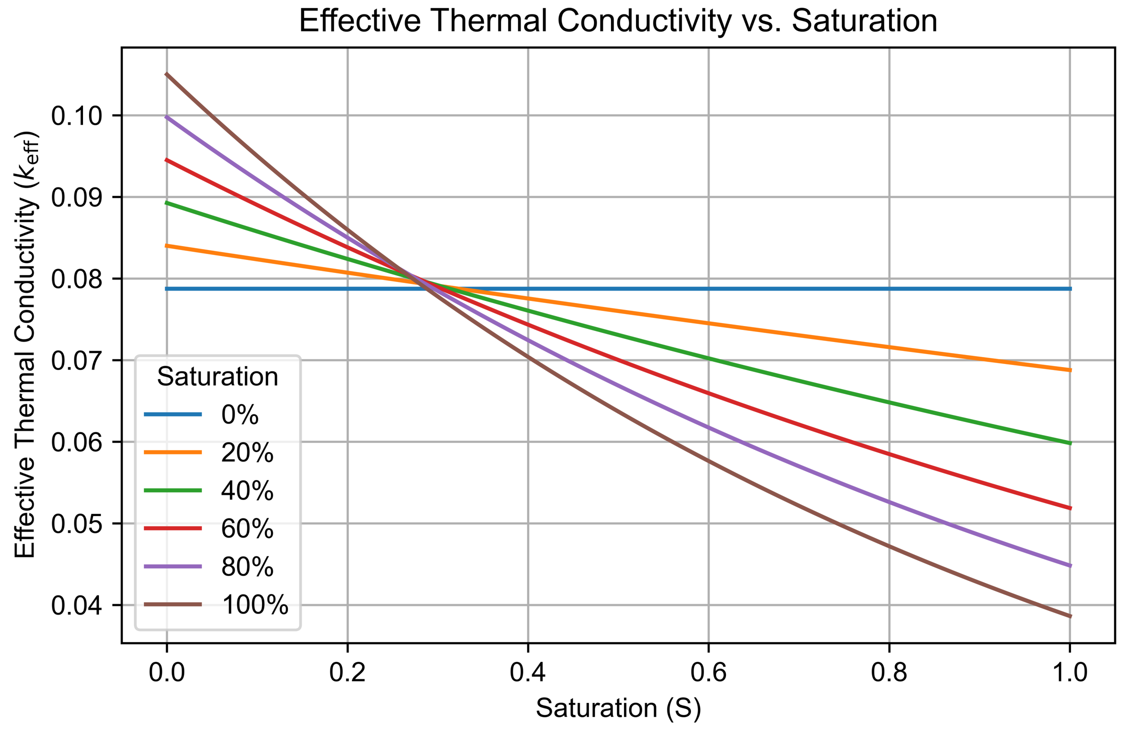
$$\frac{1}{r}\frac{\partial}{\partial r}\left(k.r\frac{\partial T}{\partial r}\right)+\frac{1}{r^2}\frac{\partial}{\partial \phi}\left(k.r\frac{\partial T}{\partial \phi}\right)+\frac{\partial}{\partial z}\left(k\frac{\partial T}{\partial z}\right)+q_V=\rho c_p\frac{\partial T}{\partial t}$$

Theoretical Solution: Unsaturated Glass Frit



Measure effective thermal conductivity along core sample axis at different saturations and compare with theoretical unsaturated benchmark.

Main Objective



Investigate how effective thermal conductivity varies with saturation in a material and analyze the impact of pore size and distribution on this behavior.

Implications

Improved Geothermal Efficiency

Enhanced Gas Storage Reliability

Research Impacts

Standardized Testing Framework

Innovative Material Development

Future Steps

Modified Hot Plate Method:
- Finalize design
- Produce 3-D model

Glass Frit Case Study:
- Unsaturated characterization
- Partially to fully saturated characterizations
  - Ex: 20-25%, 50-55%, 70-75%, 95-100%

Vary Pore Size/Distribution:
- Repeat methodology for glass frits of same composition, but different porosity

Additional Case Studies:
- Apply workflow to other synthetics
  - Ex: ceramics, quartz, plastics, etc.
- Apply workflow to complex natural materials
  - Ex: basalts, sandstones, etc.
- Apply workflow to building materials
  - Ex: cements, concretes, etc.

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