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Ph.D. DISSERTATION DEFENSE

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Title:	**Multiscale study of flow in porous media and the applications to subsurface water and energy systems**
Chairperson:	**Dr. Cheng Chen, Department of Civil, Environmental & Ocean Engineering, Charles V. Schaefer, Jr. School of Engineering & Science**
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ABSTRACT

The complex nature of flow and transport in porous media has led to substantial research across various disciplines in recent decades. One of the key porous media properties that controls fluid flow is permeability. In subsurface environments, the spatial variability of permeability, along with the existence of natural fractures and anisotropic properties of the media, result in highly unpredictable flow patterns. A comprehensive investigation of permeability across scales— from pore to field scale —is essential for enhancing fluid behavior models in applications such as carbon sequestration, groundwater management, and energy storage. This dissertation initially investigates pore-scale processes by applying renormalization group theory (RGT) to determine the effective pore-throat radius and develop two theoretical models for estimating permeability in pore networks of varying sizes. These models illustrate the capability of RGT to precisely capture the scale-dependent nature of permeability. In the second part, we investigate the scale dependence of permeability in heterogeneous geologic formations utilizing RGT and finite-size scaling analysis. We study the influence of varying occupation probabilities on the effective permeability of formations by simulating formations with various levels of heterogeneity over multiple domain sizes and employing finite-size scaling theory to further examine the scale dependency of permeability. In the concluding section, we study the impact of natural fractures and heterogeneous permeability fields on the density-driven convective flow of CO_2 in saline aquifers. Using a 2D finite element model, we examine the effects of varying permeability correlation lengths, natural fractures, fracture orientation, and stratification within the domain.