GSCO2 Geosciences: Basic Science for Understanding Candidate CO_2 Reservoirs

GSCO2 Center for Geologic Storage of CO_2

Introduction

Understanding subsurface flow dynamics, including carbon dioxide (CO_2) plume migration and trapping, requires understanding a diverse set of geologic properties of the reservoir, from the pore scale to the basin scale. The uncertainty about site-specific geology stems from the inherent variation in rock types, depositional environments, and reservoir properties. Methodologies and tools are needed to represent reservoir properties from the pore to field scale and to take into consideration small-scale features that could significantly affect the storage integrity.

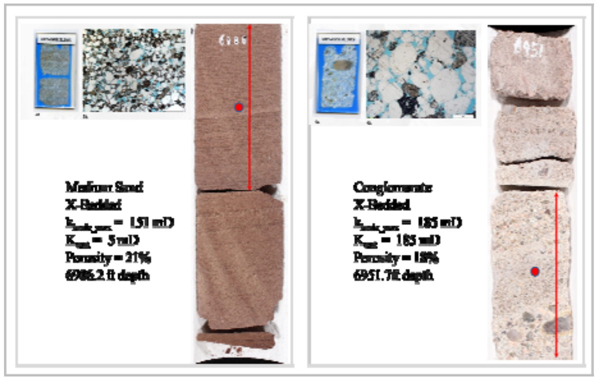


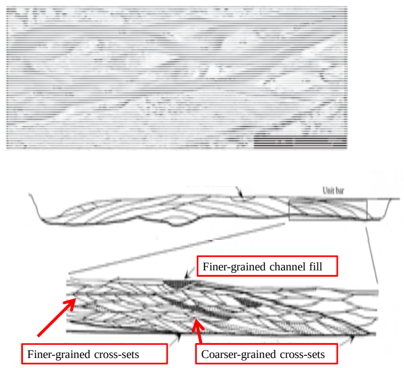
Figure 1 Core samples, thin sections, and photomicrographs from the Lower Mt. Simon Sandstone reservoir.

Current practice in modeling tends to aggregate parameters across scales and to include only a limited amount of the available data. A viable geological model must include all components of a storage site at a level of detail where all key features are taken into account. For example, the amount of CO_2 trapped in the reservoir by capillary trapping processes is a complicated nonlinear function of the spatial distribution of permeability, permeability anisotropy, capillary pressure, relative permeability of brine and CO_2, permeability hysteresis, and residual gas saturation. Importantly, the spatial variability (heterogeneity) of these petrophysical attributes, which control capillary trapping, is defined by a multiscaled and hierarchical sedimentary architecture within sandstone formations.

Sedimentary Architecture and Petrophysical, Mineralogical, and Geomechanical Attributes

What aspects of sedimentary architecture are relevant to CO_2 plume dynamics and CO_2 storage in candidate clastic reservoirs? Data and observations on petrologic, sedimentologic, and stratigraphic aspects are usually abundant along vertical directions as sampled by boreholes but are sparse in lateral directions. Vertically defined relationships must be studied in the context of a three-dimensional, quantitative, basic-science understanding of sedimentary geology, in order to infer lateral variation in the proportions, geometries, juxtapositioning, mineralogy, and petrophysical properties of geobodies at all relevant scales. GSCO2 research includes studies characterizing pore networks (micro-CT scanning), petrologic and petrophysical studies of core as related to depositional and diagenetic identification and interpretations, and studies of sedimentary architecture in outcrop and modern depositional systems.

Figure 2 The S. Saskatchewan River (top; Sambrook et al., 2006) serves as a modern analogue of the Mt. Simon Sandstone. A detailed image (bottom; Lunt et al. 2004) of a unit bar.



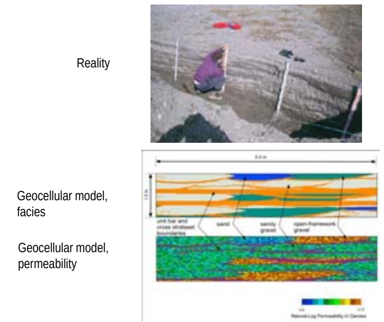
Basin-Scale System: Stratigraphy and Structure of the Sedimentary Basin

What aspects of basin-scale structure and stratigraphy are relevant to CO_2 storage in candidate reservoirs? Identifying and understanding these aspects will lead to more predictable consequences of subsurface storage and containment, improved model defensibility, and better resource allocation in model development. For example, basement topography controls sedimentology and thickness of overlying basal sandstones. Basal units appear to affect the distribution of microseismic events during CO_2 injection and therefore must be understood. Faults and buried impact structures can escape detection and compromise reservoir storage. How can we predict size, frequency, and spatial distribution of structures in this context, and what is the optimal level of detail to represent them?

Synthesizing Geologic Understanding within Viable Geocellular Models

New insights and understanding of sedimentary architecture and related petrophysical attributes within candidate reservoirs at different scales need to be synthesized in viable, multiscaled digital geologic models (geocellular models), which ultimately represent the spatial distribution of parameters required in multiphysics flow and transport simulations of CO_2 injection and storage. GSCO2 research expands on approaches for stochastic and geometric-based geocellular modeling linked to depositional processes. Three-dimensional facies connectivity is quantified with relevant statistics that characterize spanning clusters of higher permeability pathways. Connectivity deviates from percolation theory as a result of hierarchical geologic structure and varies as a function of proportions, geometry, and the juxtaposition of facies.

Figure 3 Comparison of what is observed in reality to representations in geocellular models.



GSCO2 Facilitated Collaborative Research

The GSCO2 provides an infrastructure for scientific collaboration between researchers from many different institutions and many different fields of expertise. In addition to collaboration within the Geology theme, there is active collaboration between scientists across different themes. These include collaborative research with investigators in the Multiphysics Flow and Transport theme in studies of how sedimentary architecture affects capillary trapping of CO_2 within reservoirs, in the Geomechanics theme in studies of geologic controls on microseismicity associated with CO_2 injection, and in the Geophysics theme in research that enables remote sensing imagery of injected CO_2 within the reservoir.

References

Sambrook Smith, G. H., P. J. Ashworth, J. L. Best, J. Woodward, and C. J. Simpson. 2006. "The Sedimentology and Alluvial Architecture of the Sandy Braided South Saskatchewan River, Canada." *Sedimentology* 53 (2): 413–434.

Lunt, I. A, J. S. Bridge, and R. S. Tye. 2004. "A Quantitative, Three-dimensional Depositional Model of Gravelly Braided Rivers." *Sedimentology* 51 (3): 377–414.

Acknowledgment

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