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Consequences of Simplified Geologic Models for CO_2 Sequestration: Example from the Powder River Basin, NE Wyoming and SE Montana

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Geologic uncertainty related to the subsurface storage of carbon dioxide centers on establishing storage capacity, evaluating injectivity and predicting migration paths and rates. Unfortunately, existing simplified geologic models for geologic sequestration fail to retain the multiple scales of heterogeneity that affect these attributes and therefore they cannot be used to assess the geologic uncertainty associated with carbon storage in sedimentary basins. Simplification involves reducing the number of geologic parameters in the model, using large grid cells, and treating geologic storage sites as homogeneous reservoirs. Homogeneous models make it easier to assess important fluid and/or fluid-rock interactions, but they poorly represent the actual reservoir architecture governing subsurface flow. Storage reservoirs contain heterogeneities at multiple scales; this affects fluid migration pathways and rates, which need to be understood at the time scale required for subsurface sequestration (1000 yrs). In this study uncertainty and risk associated with geologic sequestration are being assessed through the generation and application of 3D geologic models that capture multiple scales of reservoir heterogeneity at the basin scale. This research focuses on the static three-dimensional architecture of a portfolio of storage sites considered representative of cratonic sedimentary basins in North America.

This geologic model incorporates 30,000 wells correlated across the two kilometers-thick and 70,000 Km^2 area of the Powder River Basin (up to 60 picks per well from the Precambrian to top Cretaceous). The workflow involves seven steps: 1) perform basin analysis, petroleum system analysis and identification of high pore volume storage sites (reservoirs), 2) correlate reservoir class to sedimentary system, 3) perform 1D rock-to-subsurface data calibration, 4) generate stratigraphic framework emphasizing the hierarchy of stratigraphic cycles, 5) define sedimentation regions that characterize changes in sedimentary architecture within and between cycles, 6) use stratigraphic changes in sedimentary architecture to modulate 3D property and heterogeneity distributions and 7) geostatistically distribute rock properties and generate of petrophysical models. This basin-scale model contains five reservoir classes (RCs) that correlate to different Paleozoic and Mesozoic sedimentary systems (step 1) (Fig. 1A). The five RCs represent common sedimentary systems in cratonic sedimentary basins (step 2) and include in decreasing depth: RC1, greenhouse carbonate platform (12 m.y.); RC2, icehouse mixed carbonate/eolian sandstone system (4 m.y.); RC3, sandstone valley-fill encased in marine shale; RC4, deltaic and ramp turbidite sandstone system (8 m.y.) and; RC5, wave-dominated shoreface to shelf sandstone system (4 m.y.) (Fig. 1B).