Characterization and Modeling of a CO_2 Huff 'n' Puff to Predict and Verify EOR Production and CO_2 Storage

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A CO_2 Enhanced Oil Recovery (EOR) Huff 'n' Puff project was commenced in the E. Goetz 1. well in the Northwest McGregor Field of Williams County, North Dakota. The Northwest McGregor huff 'n' puff is a Plains CO_2 Reduction Partnership (PCOR) Phase II project in which CO_2 was injected into a fractured carbonate reservoir for the dual purpose of EOR and associated storage. The perforated interval and injection target is the fractured upper Mission Canyon Formation. Oil produced from this zone is generally trapped in small lenses of partially dolomitized grainstones and packstones interbedded in lime mudstones. Northwest McGregor shows are generally found in peloidal, ooidal, and pisolitic grainstones and packstones bearing skeletal remains of calcareous algae, coral, or crinoid fragments. Above the Mission Canyon are typical sub- to supratidal mixed-layer carbonate anhydrite sequences capped by a thick salt zone.

In order to understand short- and long-range temporal dynamics of the CO_2 injection, a static geologic model was produced. Characterization and modeling in support of dynamic simulations included normalizing all logs and performing an error-minimizing stochastic multimineral petrophysical and fluid analysis. Neural networks were used to produce matrix permeability, fracture density, and missing zones or logs in the study area. Petrophysical results were verified with Qemscan, x-ray diffraction, petrographic analysis, and cutting and core descriptions. This produced the main components for a macro/micro-facies and fluid model, with the major lithofacies being limestones, dolomites, and anhydrites. Within the dolomites and limestones, the diagenetic depo-facies consisted of grainstones, packstones, and mudstones. Large-scale trend modeling used traditional sequential indicator and Gaussian simulations, while small downscaled injection models used discrete and continuous multiple point statistics to model the gradational mudstone to grainstone sequence common with platform carbonates. Vertical seismic profiles (VSP), temporally resolute reservoir saturation tool (RST) logs, and produced fluid analysis were used to history-match fluid and gas saturations as well as rock matrix mineralogy, produced water, and petroleum compositions. The short-term outcome of the CO_2 huff 'n' puff was a definite increase in produced oil and a decline of produced water in comparison to historic data.