Abstract

The Midwest Regional Carbon Sequestration Partnership (MRCSP) is responsible for the assessment of large-scale carbon dioxide (CO2) storage associated with enhanced oil recovery (EOR) operations in oilfields that have undergone primary production. As part of this overall program, Battelle has collaborated with The Ohio State University (OSU) and Lawrence Livermore National Laboratory (LLNL) to perform studies investigating potential geochemical reactions caused by the injection of CO2 and resulting changes to the hydrologic conditions (i.e., porosity and permeability) of the reservoir.

Initially, geochemical equilibrium modeling was performed using analytical data from brine samples collected from the EOR reservoirs. The models indicated that the brines were supersaturated with respect to several carbonate and sulfate minerals prior to the injection of CO2. The model results also indicate that the saturation levels of these minerals increased with the injection of CO2. Following the modeling efforts, rock (core) samples collected from the reservoirs were analyzed using scanning electron microscopy-energy dispersive x-ray spectroscopy (SEM-EDX) and powder x-ray diffraction (XRD) to investigate the elemental chemistry and mineralogy of the mineral precipitates present in the large pores and vugs of the core samples. Additionally, stable carbon isotope analyses were performed on the mineral precipitates to assess the origin of the carbon present in the carbonate minerals.

High-resolution micro x-ray computed tomography (XRCT) analysis of core samples collected following the injection of CO2 was performed to investigate changes in the rock fabric, pore geometry, and fracture conditions resulting from the CO2 injection. The XRCT scans did not find evidence of mineral dissolution along the fracture surfaces, nor were significant through-going connected fluid pathways observed in any of the core sub-samples. The most compelling evidence for CO2-induced dissolution was subtle, comprised of localized areas of elevated porosity.
within regions displaying similar textures, or slight fracture widening in some cases. In contrast, the evidence of mineral precipitation, lining large pores and even fractures of one sample, was apparent throughout the sub-samples.
Investigation of Potential Geochemical Reactions in Large-Scale Carbon Dioxide-Enhanced Oil Recovery (CO2-EOR) Carbonate Reservoirs

Laura Keister1, Matthew Place1, Amber Conner1, David Cole2, Julia Sheets3, Susan Welch2, Kelly Lang2, Megan Smith3, and Susan Carroll3
1Battelle Memorial Institute, 2Ohio State University, 3Lawrence Livermore National Lab

INTRODUCTION
Carbon Dioxide has been injected into the Dover 33 Reef over the past 20+ years as part of EOR operations. During this period, a cumulative 1,555,417 metric tons of CO2 have been injected. In 2012, MRCSP collected brine and gas samples for geochemical analysis to determine the influence of CO2 injection on the overall geochemistry of the reef, and whether such changes alter the porosity/permeability. In addition, core samples of the formation were collected in 2016 after injection was complete. Post-injection, the core samples were analyzed for δ13C of carbonates, minerals, elemental composition, and microtextural (dissolution/precipitation) features.

GEOLeGIC BACKGROUND
• Reef formed in paleo shallow shelf carbonate depositional system forms circular belt along the margin of the Michigan Basin (Sears, 1979)
• Dover 33 reef is approximately 1 km² aerial extent and 100 m in vertical relief
• Reef trend is generally divided in an up-dip direction into gas-, oil-, and water-saturated zones
• Reef height, pay thickness, and channel porosity.

TECHNICAL APPROACH
Equilibrium models in PHREEQG suggest brines are supersaturated with respect to carbonate, sulfates, and halide minerals – potentially resulting in precipitation.

MINERALOGICAL AND LIGHT MICROSCOPY RESULTS
XCT scans of the core (5588'), a 3D image of the core and its inclusion was constructed for two different orientations. Aviso software was used to render a 3D image from XCT scans of sample 5588', including a partially infilled vug.

PHREEQC modeling predicts of chemical reactions between the reservoir rock and the injected CO2 composition. Post-injection indices suggest precipitation of that mineral is favorable.

CONCLUSIONS/FUTURE WORK
CT images from the CO2-EOR interval show little textural evidence of dolomite dissolution. These samples for CO2-EOR interval are expected to have significant smoothing or widening of fractures and vugs, possibly due to dissolution channels, rounding of pores, increases in high porosity regions, or through-going connected fluid pathways. LLNL found evidence of mineral precipitation, but was unable to attribute it to diagenesis or CO2-EOR.

Acknowledgements
The study is part of the Midwestern Regional Carbon Sequestration Partnership (MRCSP) Michigan Basin Collaborative Agreement # DE-FC26-0NT42589 with co-funding by Core Energy, LLC, and other partners.