Characterizing CO₂ Residual Trapping through Experiments
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ABSTRACT
CO₂ storage in deep geologic formations is a necessary method to address the climate change problem. To ensure long-term security of the injected CO₂, a better understanding of the post-injection CO₂ residual trapping phenomena is needed. Using multiphase coreflooding experimental methods, we seek to characterize and predict the amount of CO₂ residual trapping after injection.

OBJECTIVES
Spatial heterogeneity is ubiquitous and exists from the pore scale to field scale. While large-scale heterogeneities have been much studied, small-scale heterogeneities received much less attention. However, it has recently been shown that millimeter-scale or subcore-scale heterogeneities have significant effects on large-scale CO₂ injection (drainage) processes, but how subcore-scale heterogeneities affect the CO₂ post-injection (imbibition) and trapping processes is still unknown. Furthermore, many uncertainties still remain about residual trapping. Historically, the dominant mechanism for residual trapping has been identified as snap-off trapping at the pore scale. However, recent studies have shown that capillary heterogeneity trapping at the subcore scale can also be significant. The relative importance of these two residual trapping mechanisms has not yet been established. In addition, the traditional method of quantifying residual trapping using an initial-residual saturation (IR) plot based on slice-average values has yielded all too many confusingly fitted trapping relationships. Consequently, utilizing advanced CT imaging techniques, we are able to construct voxel-level IR plot and directly visualize what factors affect CO₂ residual trapping.

METHODS
By conducting coreflooding experiments on sandstone samples with different degrees and nature of heterogeneity, we can investigate voxel-level trapping relationships, and gain insights into how subcore-scale heterogeneities contribute to CO₂ residual trapping.

EXPERIMENTAL RESULTS
Immiscible CO₂/water coreflooding experiments on different types of sandstone rocks were conducted.
- Sandstone types include Fontainebleau, Berea (Liver, Split), Bentheimer, Dundee, etc.
- CO₂ saturation field is more heterogeneous during drainage than imbibition.

- The resulting voxel-level trapping relationships indicate that the linear trapping relationship is a better fit than Land’s trapping relationship.
- Within a sandstone core, nonwetting phase trapping does not appear to correlate with subcore-scale porosity.

CONCLUSIONS
The following conclusions can be drawn from the experimental results.
- Subcore-scale heterogeneities have less significant effects on imbibition than on drainage, as the CO₂ saturation field is more uniform after imbibition.

FUTURE WORK
- Conduct coreflooding experiments on sandstone samples with similar porosity but different degree of subcore-scale heterogeneity, or on homogeneous sandstone samples with low porosity.
- Conduct coreflooding experiments on sandstone samples with different lamination directions to explore whether spatial arrangement of subcore-scale heterogeneity matters or not.

REFERENCES
- CO₂ trapping review paper: IPCC, 2005; Krevor et al., 2015
- Land’s trapping relationship: Land, 1968