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Characterizing the Effect of Capillary Heterogeneity on Multiphase Flow Pulsation in an Intermediate-Scale Beadpack Experiment using Time Series Clustering and Frequency Analysis

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Abstract

An intermediate-scale beadpack drainage experiment was conducted to investigate how simple layered lamination heterogeneity affects CO_2 flow. Two simple layers of capillary barriers are manually packed in the tank and slow drainage was carried out using analog fluids to mimic the capillary- and gravity-dominated CO_2 upward migration process in deep saline aquifers. Nonwetting phase saturation time series clustering analysis and frequency analysis have been conducted on the experimental data. Additionally, modified invasion percolation numerical simulations were done on a digital model of the beadpack to compare to experimental results. Results show that capillary barriers can lead to strong pulsation behavior, which in turn can cause unexpected early breaching through other barriers. The inlet pressure is found to be able to respond to saturation changes in far regions of the domain, indicating that the wetting phase can transmit pressure changes from the other phase. Although static simulations were not able to capture all the dynamic behavior observed in the experiment, Monte Carlo composite simulation results combining many different realizations can better illustrate how the nonwetting phase will behave in the heterogeneous domain. Our results suggest the need for CO_2 storage site selection with preference given to aquifers with more capillary barriers with finer grain sizes to avoid flow pulsation and to retard plume upward migration.