Standard geophysical methods for monitoring CO₂ injection have severe limitations in many cases. In particular, while the presence of CO₂ can be more sensitive to changes in CO₂ saturation than traditional 4-D seismic, saturation in most reservoirs. We hypothesize that time-lapse AVO may be We present an example using Berea sandstone that combines laboratory and numerical experiments to show that AVO can successfully track changes in CO₂ saturation.

Defining the Problem
- At Sleipner, CO₂ is injected in the Utøya Formation, a massive, high porosity sandstone aquifer with shaly interbeds.
- 4-D seismic was selected for monitoring and verification, with the hope of being able to track CO₂ dispersion.
- While 4-D seismic successfully located CO₂ as it moved through the aquifer, the volume or saturation of CO₂ at any given location was undetectable (Tory and Gal, 2004).

Proposing a Solution
- At McElroy, a low-porosity carbonate is overlain by a higher-porosity carbonate. Velocity changes following CO₂ are predicted to be ±1%, and undetectable using 4-D seismic.
- However, the predicted changes in AVO parameters A and B are ±10%, and easily detectable (Wang et al., 1998).

Geophysical Observations
- We have developed a multiprobe physical properties scanner, which allows for millimeter-scale imaging of physical properties on a stabbed sample of rock or soil.
- The scanner probe allows for the following physical properties to be measured: gas permeability, P and S-wave velocities, and complex electrical impedance.
- We believe we have characterized the heterogeneity and anisotropy of a factory-made block of Berea sandstone. Berea sandstone has long been regarded as a laboratory standard of homogeneity, isotropic behavior.
- However, we find that permeability, resistivity, and velocity exhibit complex anisotropy at a variety of scales, which we believe is due to the stress field near the sample. Heterogeneity varies by a factor of 3, velocity varies by ±10%, and resistivity varies by ±20%.

Assign Local Physical Properties
- We performed a pressure model from the porosity and permeability measurements on the Berea block. We also used cluster analysis of the physical properties measurements to identify petrophysical facies within the Berea block. The identified facies are then treated as distinct regions within the sample which have similar physical properties. For this example we simplified the Berea sample from a continuous distribution of properties to an assemblage of 5 petrophysical units.

Upscaling
- We compare effective elastic properties of the Berea block at the scale of seismic resolution through a finite-element simulation. The advantage of this method is that the underlying spatial correlation of the heterogeneity is preserved as a general form of anisotropy in the upscaled elastic stiffness.
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