

# **Experimental Study of P and S Wave Velocities on Jurassic Carbonate Rock Saturated by Brine and Supercritical CO<sub>2</sub>**

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## **Abstract**

Supercritical CO<sub>2</sub> injection into geological formations is an alternative solution to reduce CO<sub>2</sub> emission and at the same time, it can be utilized for enhanced oil recovery. However, monitoring CO<sub>2</sub> flooding into carbonate reservoirs in the laboratory requires intensive studies and advanced analysis to anticipate incorrect interpretation of field data. This paper presents an experimental study of brine and supercritical CO<sub>2</sub> injection into a carbonate plug. The datasets for this study were derived from the core drilled in Wadi Daqlah which is an outcrop analog for late Jurassic Arab-D reservoirs and is located almost 100 km north of Riyadh, central KSA. We prepare the plug in a cylindrical shape and take the trim end for thin section analysis. The thin section analysis indicates facies similar to those reported from subsurface reservoirs. We scan the plug using X-ray tomography to observe internal pore connectivity and grain shapes. Porosity and permeability measurements are conducted using helium and nitrogen gases. We modified a triaxial frame enabling P and S wave ultrasonic velocity measurements under high pressure and temperature and also compatible with CO<sub>2</sub> fluid. The velocities are measured on the specimen in dry, brine, and CO<sub>2</sub>-saturated conditions. First, we inject CO<sub>2</sub> into the plug at 10 MPa pore pressure in the liquid phase. Second, we increase the temperature to 45°C that transforms the CO<sub>2</sub> into a supercritical state. After the complete removal of CO<sub>2</sub>, we inject brine into the plug and monitor the velocity evolution. Lastly, we perform supercritical CO<sub>2</sub> flooding to flush the brine out of the plug. The thin section analysis of the sample indicates foraminiferal intraclastic grainstone to rudstone facies with visible interparticle porosity. The measured porosity of this plug is 13.7% and the permeability is 0.974 mD. The P wave velocity incrementally increases from dry (4329 m/s) to supercritical CO<sub>2</sub> (4337 m/s), liquid CO<sub>2</sub> (4361 m/s), and brine (4422 m/s) saturated conditions due to bulk modulus effects. P wave amplitude in the brine-saturated condition is three times higher than in the supercritical CO<sub>2</sub>-saturated condition implying lower attenuation. S wave velocities decrease in fluid-saturated conditions than in dry conditions due to mass density effects. S wave velocities at liquid CO<sub>2</sub>-saturated are higher than in dry and supercritical CO<sub>2</sub> conditions suggesting that temperature also affects the velocities. The implication of this experimental study provides insight into supercritical CO<sub>2</sub> monitoring in the reservoir. Reservoir monitoring using the 4D seismic method should aware that seismic amplitude in the field is not only affected by velocity change but also by attenuation.