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Monitaring subsurface CO2 condition by applying rock physics

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Geophysical monitoring is important for evaluating stability of CO2 at CO2 sequestration sites. Since physical properties of rocks are controlled by fluid states in pores or cracks, changes of physical properties of rocks will help us to understand CO2 behavior at CO2 reservoir or cap rocks which seal the isolated CO2.

The most notable change will appear when gaseous CO2 appear in pores or cracks. The seismic anisotropy and the complex resistivity will be very much affected by gaseous CO2 in rocks. Considerable changes of seismic anisotropy in mudstone will be expected when gaseous CO2 appears in pores. Gaseous CO2 also affects complex resistivity in sandstone, where phase delay between current and voltage appear in the low frequency range between 100 Hz and 0.01 Hz. Those characteristics will be applicable to understand well log data at CCS sites in connection with CO2 behavior.

Mudstones often show anisotropy in which seismic velocity distribution is characterized by an angle from the unique axis. This is called transverse isotropy (TI). In anisotropic media, wave vibrations are generally not parallel (P wave) or orthogonal (S wave) to the propagation directions. Those are called quasi-P (qP) wave and quasi-S (qS) wave. In TI, qS wave is often referred to as qSv wave because vibration direction is perpendicular to Sh wave which vibrates parallel to the isotropic plane. The velocity difference between Sh wave and qSv wave indicates shear wave splitting. When fluids in pores and cracks change from liquid to gas, anisotropy will change. The change of anisotropy is characterized by using shear-wave splitting. The change in shear-wave splitting can be studied by a model which contains oriented cracks within a TI medium. By using the model, we can estimate the change of shear-wave splitting when fluid in cracks changes from liquid to gas. The estimated change in shear-wave splitting for one of natural mudstones is more than 4 %. This amount of change in shear-wave splitting can be measurable in field observations.

Another important change in the reservoir rock is the electrical impedance of rock. Rock electrical impedance is characterized by frequency response of real and imaginary parts of the impedance, associated with the phase difference between current and voltage in the frequency range between 100 Hz and 0.01 Hz. This is explained as a relaxation process of ion movement near the electric double layer. Since gaseous CO2 in pores controls the distribution of the electric double layer in rock, the change of complex resistivity is associated with the states of CO2 in the reservoir of CCS site.

Keywords: CCS, rock physics, seismic velocity, anisotropy, rock resistivity