Monitoring of CO2 behavior after injection into geological formation (II)–modeling seismic velocity and attenuation

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We carried out dense seismic measurements in the ultrasonic band during CO2-injection experiments in porous sandstone samples under laboratory conditions. The obtained high-quality seismic data enabled detailed determination of the relative velocity and attenuation coefficient of compressional waves using the difference seismic tomography method. We confirmed that the difference tomography method, when employed using differential arrival times and relative amplitudes determined from the cross-correlation of waveforms, is efficient in imaging the changes in velocity and attenuation associated with the partial replacement of water by CO2.

On average, as a result of gaseous, liquid, and supercritical CO2 partially replacing pore water, P-velocity fell by 7.5, 12, and 14.5%, respectively, while 1/Q increased by factors of 3.3, 2.7, and 3.7.

Our results are in good agreement with the White and Dutta-Ode theory for partial saturation, indicating that fluid diffusion plays a major role in velocity dispersion and energy loss at ultrasonic frequencies. Numerical results obtained for patch sizes of b=1.3-1.5 mm are consistent with the observed velocity and attenuation data. These results demonstrate that following an increase in CO2 saturation, compressional wave attenuation is characterized by a rapid increase, a peak at 30-40% CO2 saturation, and a gradual decrease until full CO2 saturation is achieved (if it is possible); however, the final obtained CO2 saturation is only about 30-40%. It is difficult to achieve a higher degree of CO2 saturation.

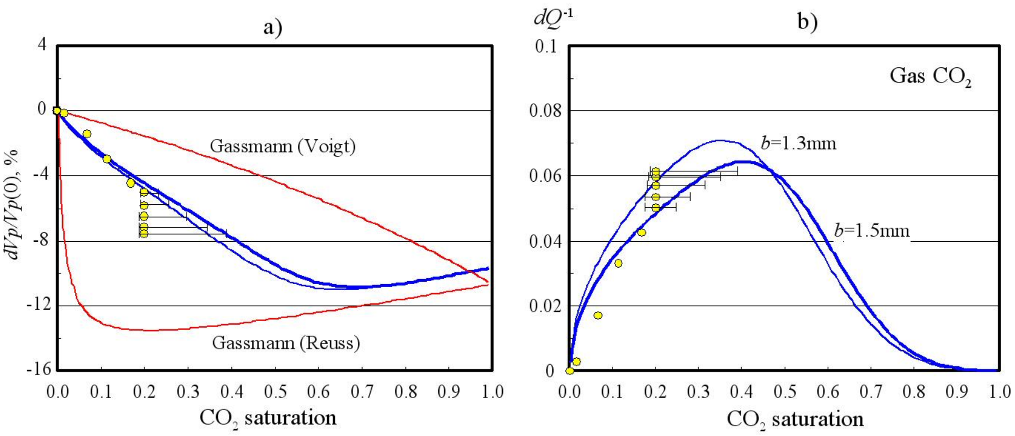

Figure 1. Comparison of observed velocity reductions and increase of Q^{-1} with numerical results obtained using the White and DuttaOdé model.