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Electromagnetic monitoring of CO_2 storage in deep saline aquifers - numerical simulations and laboratory experiments

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The safety of population, environment and equipment is a central task when storing CO_2 in the underground. Therefore, efficient and reliable monitoring techniques applying geophysical methods are necessary. Electromagnetic methods may contribute in a complementary way to other methods because the electric conductivity probably turns out to be a sensitive indicator for CO_2 migration in saline aquifers. Consequently, the knowledge of petrophysical parameters linked with electric conductivity is crucial for a reliable monitoring. The pressure and temperature regime in deep saline aquifers causes the stored CO_2 to occur in a supercritical state ($scCO_2$). The impact of the presence of $scCO_2$ on the local electrical conductivity of the formation is still insufficiently known. Therefore, we have carried out laboratory experiments and numerical simulations to investigate the changes in electrical conductivity induced by migrating $scCO_2$. An experimental set-up was developed and constructed which allows the experimental simulation of the sequestration process on a laboratory scale. Central element is a measuring cell inserted into an autoclave allowing to monitor the average electrical conductivity of a sand sample. As a first step, it could be proved that neither pure CO_2 nor the CO_2 rich binary mixture of CO_2 and water show any relevant electrical conductivity when a pressure of up to 130 bar was employed. In a second step, a water-saturated sand sample was inserted into the measuring cell and observed while its pore water was replaced by CO_2 at pressures up to 130 bar and temperatures up to 40°C. An increase of electrical resistivity by a factor of up to 33 occurred at a residual water content of 14 to 18%. The increase in electrical conductivity induced by the sequestration has also been demonstrated under supercritical conditions. All experimental data could be interpreted with sufficient reliability using Archie's law. The laboratory experiments have been accompanied by numerical simulations. Two-phase flow governing the physical storage of CO_2 was simulated using the software packages COMSOL Multiphysics and Mod2PhaseThermo (Häfner and Boy, 2009). The resulting non-stationary spatial distributions of saturation were transformed into distributions of electrical conductivity using Archie's law (1942) and the law of Waxman Smits (1968). An increase of electrical conductivity by a factor of up to 10 has been predicted.