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Sensitivity study of pulsed neutron gamma monitoring to evaluate saturation changes for depleted gas field conditions in the context of CO_2 storage

Gunther Baumann, Jan Henninges, and Marco De Lucia
GFZ German Research Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany (baumann@gfz-potsdam.de)

Saline aquifers and depleted gas fields have a high potential for CO_2 storage operations in order to reduce emissions into the atmosphere. One important question in the context of CO_2 storage is the monitoring of saturation changes caused by displacement of the in-situ fluids in the pore space. Pulsed neutron gamma (PNG) logs are widely used for formation evaluation through casing in oil and gas fields. Based on these experiences the task is to study the potential of PNG monitoring to evaluate saturation changes due to CO_2 injection under the low contrast conditions in depleted gas fields at the borehole scale.

A neutron generator emits bursts of high energy neutrons periodically, which interact with the surrounding borehole and formation. Due to the collision with these neutrons, atoms from the surrounding environment emit gamma rays with characteristic energies depending on their atomic number. After elastic and inelastic scattering with the atoms, going along with short time gamma ray emission, the neutrons reach the low energy thermal level. At this thermal energy level the neutrons are finally captured mainly by hydrogen and chlorine also with a corresponding emission of gamma rays. This long period gamma ray emission is the basis for pulsed neutron gamma logging from capture processes. The value of the probability to capture thermal neutrons is the capture cross section (Σ) which is derived from the decline of gamma rays with time. Monitoring of saturation changes is performed in time lapse mode comparing baseline measurements before injection with repeat measurements during injection.

The high Σ contrast between brine and CO_2 results in a high sensitivity to evaluate saturation changes. Therefore the PNG method is successfully applied in saline aquifers to evaluate the saturation changes from CO_2 injection. Moreover, dry-out effects together with resulting salt precipitation can affect the Σ reading, and has therefore to be carefully taken into account. Ignoring the salt precipitations e.g. the chlorine would result in an underestimation of the CO_2 saturation.

This contribution shows a sensitivity analysis for PNG monitoring to evaluate saturation changes for depleted gas fields under conditions similar to the Altmark site, Germany. The Σ contrast between the formation gases, mostly N_2, CH_4, and the injected CO_2 is in the range of typical pulsed-neutron gamma tools accuracy and therefore difficult to detect. Taking into account possible drying effects especially in injection wells the Σ contrast is quite higher and is the subject of the sensitivity study.