Simulation of Fluid Flow in a Shallow Reservoir with Faults and Fractures on the base of Sulcis Fault Lab Data

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Abstract

Sulcis Fault Lab is an experimental injection site in Sardinia, Italy operated by Sotacarbo. A test CO_2 injection is planned to be performed at the site near a fault in a shallow fractured reservoir at the depth of 200 m. An observation well has been drilled near the planned injection well location. The injection well should be drilled in near future crossing the fault and will inject about 5000 stm^3 of CO_2 below the fault in the CBU geological unit. Both the injection and observation wells will be used to monitor CO_2 invasion and potential leakage out of the CBU unit (e.g. through the fault). Although no data of fluid saturations are available from the drilling of the observation well, a shallow observation well has found water saturated formation at its maximin depth of 80 m. Therefore, an uncertainty with saturation of the CBU unit at the location of the injection well is present. At the same time, mud losses were observed during the drilling indicating high conductivity of some formations, that was assumed to be related with presence of natural fracture networks.

The main objectives of the study were evaluation of the injection envelope (pressure and rate ranges) for planned injection volumes and maximum pressure restrictions and studying possibilities for CO_2 plume and leakage monitoring using pressure gauges installed in the injection and observation wells. A mechanistic reservoir model approximating actual reservoir geometry has been assembled based on the SFL data on geology and well completions including the CBU unit and three geological units above. All these units are fractured formations with negligible primary porosity and permeability, where fluids are assumed to flow through the natural fracture networks and potentially faults and nearby damaged zones. Two potential scenarios of CO_2 injection into water and air saturated CBU unit and potential leakage to the upper units have been studied. Due to the time constrains of the thesis, the following approximations were chosen: single porosity approach for fracture flow with explicit description of faults; single-phase (Nitrogen) flow for CO_2 injection into air saturated formation (due to moderate PVT data difference for N_2 and CO_2 at the injection conditions) and two-phase (water-CO_2) flow for water saturated formation. Rubis from Kappa Engineering was chosen as reservoir simulator for this study.

The results of the simulations provided evaluation of the injection envelope for two initial saturation cases and potential pressure profiles for the injection scenarios. In particular, this thesis showed that fault conductivity within the CBU unit is not likely to impact on the pressure build-up behavior as a result of CO_2 injection. Boundary conditions (isolated fault block or open formation) have strong impact on pressure build-up in the target formation. Test cases with vertical communication between the units were simulated and showed large impact of the communication on pressure build-up and CO_2 migration. The importance of environmental concerns argued that the connection of the layers should be considered in further studies. Finally, the thesis showed comparison of simulations for water and air saturated formations. The latter showed much lower pressure build-up for the same volume injected due to large air compressibility compared to water.