An approach to the geochemical modelling of water-rock interaction in CO_2 storage geological reservoirs: the Weyburn Project (Canada) case study

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Geological storage is one of the most promising technologies for reducing anthropogenic atmospheric emissions of CO_2. Among the several CO_2 storage techniques, sequestration in deep-seated saline aquifers implies four processes: a) supercritical fluid into geologic structure (physical trapping), b) dissolved $CO_{2(aq)}$ due to very long flow path (hydrodynamic trapping), c) dissolved $CO_{2(aq)}$ (solubility trapping), and d) secondary carbonates (mineral trapping). The appealing concept that CO_2 can permanently be retained underground has prompted several experimental studies in Europe and North America sponsored by IEA GHG R&D, EU and numerous international industrials and governments, the most important project being the *International Energy Agency Weyburn CO_2 Monitoring & Storage*, an EnCana's CO_2 injection EOR project at Weyburn (Saskatchewan, Canada).

Owing to the possible risks associated to this technique, numerical modelling procedures of geochemical processes are necessary to investigate the short- to long-term consequences of CO_2 storage. Assumptions and gap-acceptance are made to reconstruct the reservoir conditions (pressure, pH, chemistry, and mineral assemblage), although most strategic geochemical parameters of deep fluids are computed by *a posteriori* procedure due to the sampling collection at the wellhead, i.e. using depressurised aliquots.

In this work a new approach to geochemical model capable of to reconstruct the reservoir chemical composition (T, P, boundary conditions and pH) is proposed using surface analytical data to simulate the short-medium term reservoir evolution during and after the CO_2 injection. The PRHEEQC (V2.11) Software Package via thermodynamic corrections to the code default database has been used to obtain a more realistic modelling. The main modifications brought about the Software Package are: i) addition of new solid phases, ii) use of P>0.1 Mpa, iii) variation of the CO_2 supercritical fugacity and solubility under reservoir conditions, iv) addition of kinetic rate equations of several minerals and v) calculation of reaction surface area.

The Weyburn Project was selected as case study to test our model. The Weyburn oil-pull is recovered from the Midale Beds (1300-1500 m deep) that consist of two units of Mississippian shallow marine carbonate-evaporites: i) the dolomitic "Marly" and ii) the underlying calcitic "Vuggy", sealed by an anhydrite cap-rock. About 3 billions mc of supercritical CO_2 have been injected into the "Phase A1" injection area. The INGV and the University of Calgary (Canada), have carried out a geochemical monitoring program (ca. thrice yearly- from pre-injection trip: "Baseline" trip, August 2000, to September 2004). The merged experimental data are the base of the present geochemical modeling.

On the basis of the available data, i.e. *a)* bulk mineralogy of the Marly and Vuggy reservoirs; *b)* mean gas-cap composition at the wellheads and *c)* selected pre- and post-CO_2 injection water samples, the in-situ (62 °C and 0.1 MPa) reservoir chemical composition (including pH and the boundary conditions as P_{CO2}, P_{H2S}) has been re-built by the chemical equilibrium among the various phases, minimizing the effects of the past 30-years of water flooding in the oil field.

The kinetic evolution of the CO_2-rich Weyburn brines interacting with the host-rock minerals performed over 100 years after injection have also been computed. The reaction path modeling suggests that CO_2 can mainly be neutralized by solubility and mineral trapping via Dawsonite precipitation. To validate our model the geochemical impact of three years of CO_2 injection (September 2000-2003) has been simulated by kinetically controlled reactions. The calculated

chemical composition after the CO_2 injection is consistent with the analytical data of samples collected in 2003 with a <5 % error for most analytical species, with the exception of Ca and Mg (error >90%), likely due to the complexation effect of carboxilic acid.