Preface

CO₂ geological storage: Integrating geochemical, hydrodynamical, mechanical and biological processes from the pore to the reservoir scale

The trend in global warming observed since the beginning of the industrial revolution is attributed to a great extent to the accumulation of anthropogenic carbon dioxide (CO₂) in the Earth’s atmosphere (IPCC, 2007). The capture and storage of CO₂ in geological formations is considered to be one of the most promising approaches to reduce further emissions and to minimize the existing climatic risk until alternatives to fossil fuels become available (e.g. Gunter et al., 1997; Holloway, 1997; Bachu, 2000; Gunter et al., 2000; IPCC, 2007, and thereafter).

During the last decade, fundamental research has focused increasingly on the short and long term effects of the massive injection of anthropogenic carbon dioxide in various geological environments, such as depleted oil and gas reservoirs, saline aquifers, coal beds and (ultra) basic rocks, in order to assess the feasibility of storing large amounts of CO₂ in the subsurface. Sequestration processes involve different trapping mechanisms according to the physico-chemical and biological conditions encountered in the host reservoir. Hydrodynamics involves the storage of CO₂ as a free-phase (i.e. gas, liquid or supercritical CO₂) in structural or stratigraphic traps. Solubility trapping consists of dissolution of CO₂ as aqueous carbonated species in formation water. Mineral trapping involves the incorporation of CO₂ in a stable mineral phase, for example via the precipitation of secondary carbonate minerals. This last mechanism appears the most desirable approach as it ensures a permanent and secure sequestration of CO₂.

There are still significant fundamental research needs that must be addressed before geologic formations can be widely used for carbon sequestration. Experimental and numerical modelling of the fate of injected CO₂ and the assessment of the sealing capacity of the wellbores and caprocks must be conducted. Appropriate monitoring methodologies relying both on geophysics and geochemistry need also to be validated on pilot sites. Additionally, because bacteria can be involved in mineral dissolution and formation, the potential effects of subsurface microbial ecosystems on the fate of injected CO₂ must be evaluated.

Since the first Chemical Geology special issue on CO₂ sequestration (Oelkers and Schott, 2005), a growing scientific community has contributed to the better understanding of the coupled biological, geochemical, mechanical and hydrodynamical processes that result from the strong disequilibrium induced by injection of large amounts of CO₂ into wellbores and reservoirs and the accompanying modification of the pH of the formation waters. New concepts are now emerging to study the consequences and kinetics of these effects, using well-controlled laboratory experiments and field observations that are aimed at improving and validating numerical codes for CO₂ trapping. In particular, experimental studies are now focusing on the thermodynamic stabilities and the kinetics of dissolution and precipitation of important rock-forming minerals in order to determine the extent and rate of formation of stable carbonate minerals in injection environments. In addition, the modification of deep biosphere metabolisms potentially induced by the injected CO₂ and the complex kinetics associated with biologically-induced precipitation of carbonates are now thought to represent key aspects of the mineralization processes. In parallel, dissolution and precipitation can modify the hydrodynamical and mechanical properties of a reservoir, inducing permanent deformation and eventually failure, and significant modification of the storage volume and transport properties of the reservoir. However, experiments sometimes fail to reproduce natural processes due to the imposed time and scale constraints, and investigations on natural analogues or on pilot sites are also needed in order to unravel coupled complex processes.

This special volume includes studies of the bio–mechanico–hydro–geochemical processes that arise from the interactions between CO₂ and minerals, wellbore cement or reservoir rocks. This collection of papers provides an overview of the current experimental work aimed at characterizing some of these research needs: the solubility and dissolution/precipitation rates of carbonate minerals in the laboratory at temperatures and CO₂ partial pressures representative of storage sites (Bénezeth et al., 2009-this issue; Golubev et al., 2009-this issue; Pokrovsky et al., 2009a-this issue); the effects of organic and inorganic ligands (Pokrovsky et al., 2009b-this issue); the role of microbial activity (Dupraz et al., 2009a-this issue, b-this issue); and the nature and extent of mineral trapping of CO₂ associated with carbonation of silicates (Daval et al., 2009-this issue; Dufaud et al., 2009-this issue; Hangx and Spiers, 2009-this issue). Complementary to investigations at the mineral scale, batch experiments at the core scale allow assessment of the reactivity of reservoir rocks (Sterpenich et al., 2009-this issue) or cement (Regnault et al., 2009-this issue; Wigand et al., 2009-this issue) upon CO₂ injection and the induced geomechanical effects (Liteanu and Spiers, 2009-this issue). Hydrodynamic effects are investigated using reactive transport experiments and modelling (Luquot and Gouze, 2009-this issue; Noiriel et al., 2009-this issue). Numerical modelling also enables the assessment of the interactions of CO₂ with rocks both at the pore-scale (Flukiger and Bernard, 2009-this issue) and at the reservoir-scale (Cantucci et al., 2009-this issue). For this purpose, new estimates of accessible surface areas of reactive minerals, based on image analysis are proposed (Peters, 2009-this issue). Field studies, including geological analogue (Boschi et al., 2009-this issue) and monitoring (Assayag et al., 2009-this issue) investigations, provide new constrains on the extent and timing of fluid–rock interactions in the presence of CO₂.

The starting point for this special volume stems from a session of the EGU General Assembly 2007 in Vienna, Austria, co-organized by Pascale Bénézet, Bénédicte Ménez and Catherine Noiriel, entitled:
"CO₂ Geological Sequestration: bio-mechano-geochemical processes from the pore-scale to the reservoir-scale". The compilation of papers in this special issue highlights the efforts that are made toward our better understanding of CO₂-fluid–mineral interactions. The guest editors wish to thank all the reviewers for their contributions, their time and their insightful comments. Lastly, we would like to thank the Editor-in-Chief Jeremy Fein for his support of this special issue, and the Editorial Managers for Chemical Geology, Peggy Tan and Tim Horscroft for their assistance in all editing aspects of this project.

References


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