# Experimental and modeling studies of $CO_2$-water-rock interactions in the Rio Bonito saline aquifer, Paraná Basin, Brazil

R.S. IGLESIAS, J.M. KETZER, S. EINLOFT, J. DULLIUS, R. LIGABUE, V. LIMA AND D.C. SILVA

Carbon Storage Research Center (CEPAC), Pontifícia Universidade Católica do Rio Grande do Sul, Porto Alegre, RS, Brazil (rodrigo.iglesias@pucrs.br)

Geological storage of $CO_2$ is one of the most promising solutions for climate change mitigation. $CO_2$ captured from large stationary sources such as coal-fired power plants, oil refineries and industries, can be safely injected and stored in appropriate geological formations, such as mature oil fields, unmineable coal deposits and saline aquifers.

Here we report an experimental and modeling study of $CO_2$-water-rock interactions of subarkose Permian sandstones from the Rio Bonito Formation aquifer, in the Paraná Basin, Brazil. These sandstones are the most promising reservoirs for geological storage in Brazil, owing to the good reservoir quality (high porosity and permeability), adequate depth (more than 800 m), occurrence of high salinity formation water (> 10.000 mg/L) and the proximity of large stationary $CO_2$ sources in the south and southeast of Brazil. This work aims to study the mineralogical integrity of the Rio Bonito sandstone reservoirs, analysing the dissolution of original minerals and precipitation of carbonate mineral phases resulting from the reaction with supercritical $CO_2$.

Experiments were performed in a stainless steel batch reactor, equipped with pressure meter and temperature control. Three sandstone samples were reacted separately with deionized water and $CO_2$ (added as dry ice), in a 5:80:105 m/m ratio. The system was allowed to react continuously for 100 h. To increase the reaction rates, higher temperature than expected for reservoir conditions was employed (200°C). Pressure reached a maximum of 100 bars,. Sandstone samples were dried in a dissecator and characterized by Scanning Electron Microscopy (SEM) before and after the reactions. Results of the study indicated the dissolution of K-feldspars and carbonates. Calcium and iron carbonate ($CaCO_3$ and $FeCO_3$), calcium sulfate, kaolinite, and silica precipitation was observed, as an evidence of pyrite and K-feldspar alterations.

Geochemical modeling of the reactions was carried out using the PHREEQC code V2.8. Equilibrium and kinetic batch modeling of the reacting system was performed. Results are in agreement with the observed dissolution/precipitation behaviour of the minerals in the experiments.

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# Penetrative convection in Earth's mantle: Reconciling geophysical and geochemical perspectives on mantle structure and evolution

P.D. IHINGER

University of Wisconsin-Eau Claire, 105 Garfield Ave., Eau Claire, WI, 54701 (ihinger@uwec.edu)

The nature of mantle convection continues to be the subject of debate. Geochemical observations of mantle-derived magmas suggest that globally distributed reservoirs with relatively uniform composition exist within the mantle. These data have led to Earth models that call for layered chemical shells with minimal exchange of material occurring between them. Yet, geophysical observations indicate that large circulation cells span the entire depth of the mantle and seem to obviate long-standing, compositionally distinct layers in Earth's mantle. Here, a penetrative convection model is revisited and expanded upon to reconcile these alternative explanations. The model calls for independent layered reservoirs whereby passive material transfer is inhibited by the endothermic phase transition occurring at 660 km depth. The upper mantle consists of rapidly circulating, well-mixed material that is continually depleted in incompatible and volatile elements via formation of oceanic and continental crust. The lower mantle is composed of independently circulating material that is shielded from chemical fractionation processes. Only material originating from thermal boundary layers as part of the large scale convective flow (slabs and plumes) may penetrate the boundary between the two reservoirs. The dense Ca, Al-rich (Mg-poor) basaltic fractions of penetrating slabs descend to D" and remain chemically isolated from the overlying lower mantle. The less dense, Mg-rich (Ca, Al-poor) fractions of penetrating slabs mix into the lower mantle, imparting a depleted character to the otherwise undegassed reservoir. Upwelling plumes originate in D" and rise to the base of the lithosphere to produce hotspot magmas with the character of recycled oceanic crust. Some lower mantle material is entrained into every upwelling plume, imparting an undegassed component (FOZO) to all hotspot magmas. The phase transition serves to regulate both material and heat transfer across the boundary, and the transition should naturally evolve to a depth that will allow only a fraction of slabs to penetrate into the lower mantle (as observed today). The penetrative convection model is consistent with first-order geophysical and geochemical observations of Earth's mantle.