CO_2 trapping mineral phases in sandstone aquifers - experimental results

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Saline aquifers of Tertiary and of Carboniferous productive formation of the Upper Silesian Coal Basin (USCB), on the borderland of Poland and Czech Republic are possible localities for CO_2 sequestration. For the purpose of CO_2 sequestration capacity assessment of the aquifers - a hydrochemical modeling was performed, basing on the petrophysical characteristics of the formations, pore water composition, PT values, and kinetic reaction rates of minerals. The first stage of modeling was focused on immediate changes to occur in the aquifer in beginning of CO_2 injection, the second simulated long-term effects of sequestration. SEM examinations of reacted rock samples confirmed, in general, the modeled scenarios of mineral CO2 sequestration in the analyzed part of the USCB.

Stage 2. In the second stage a decrease of CO_2 fugacity to the value of 0.005 bar is observed. The repeated porosity increase, that reaches about 5.3% in almost 14 ka is significant considering the insulating properties of the rock.
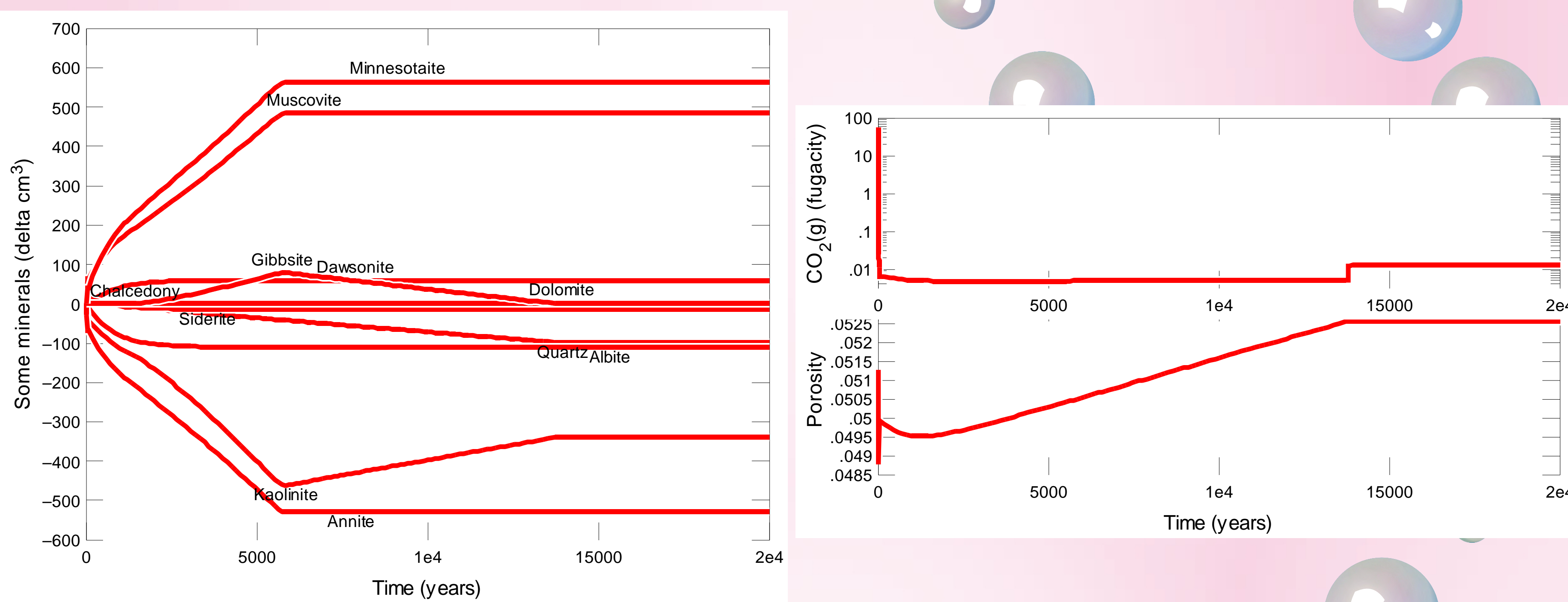

Mineral trapping capacities of the analyzed formations were calculated for the storage period of 20 000 years. Calculations based on the balance of CO_2 contained in the carbonate minerals that precipitate or dissolve in the model. Mineral trapping capacity, for the sandstone aquifers varies between 1,2 and over 6,6 $kgCO_2/m^3$, and for confining cap rocks between 0,89 and 1,42 $kgCO_2/m^3$. The quantity of gas trapped in the form of solution, basing on modeled chemical constitution of pore water reaches 4,07 $kgCO_2/m^3$.

In order to track the effects of gas-rock-water interactions the rock samples were placed in the reaction chamber of the RK1 autoclave, built for the purpose of the work. The chamber was filled with brine, and CO_2 injected to the desired PT values. The experiment was carried on for 75 days. Continuous pH logging, and analyses of fluids sampled from device's chambers enabled monitoring of the reactions.

SEM analyses of reacted samples verified the process of dissolution of skeletal grains, observed in all of the samples; corroded feldspars were frequently covered with secondary clay minerals (a). Dissolution of K-feldspar was apparent in the samples where the potassic lamellae within the crystals were etched relative to the sodic ones (b). Interstices are space for common formation of secondary minerals. Regular (e) or hollow (d)crystals of dawsonite were found to be formed in the pore space between framework grains and within the clay mineral blades.
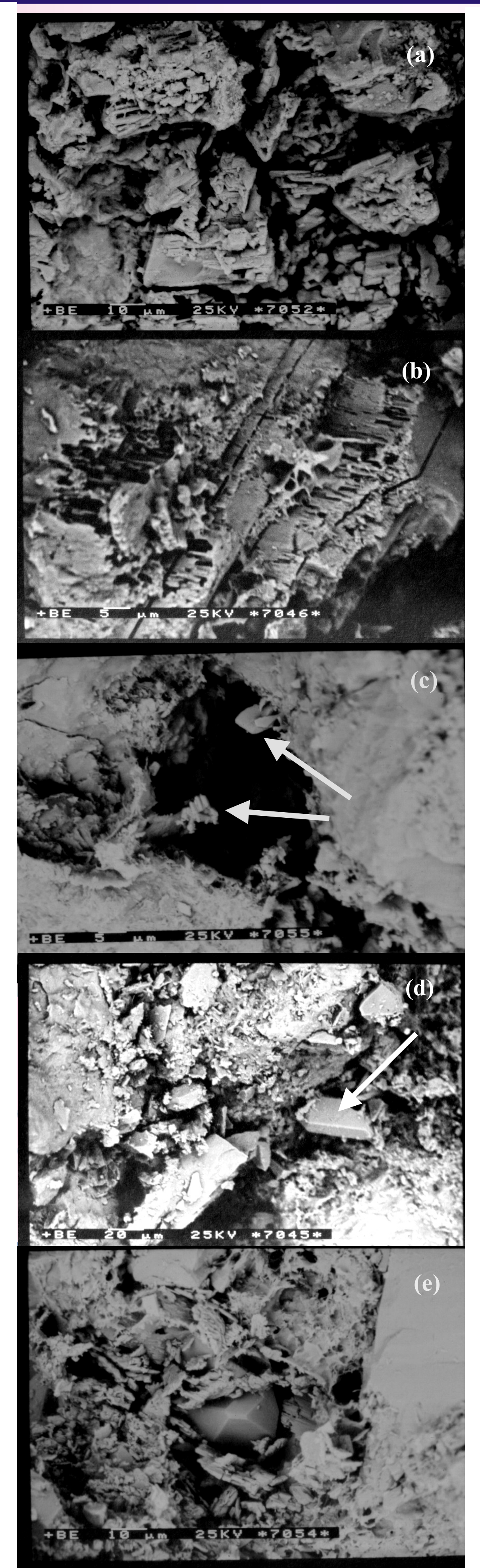
Conclusions

Coupled modeling and experimental works revealed that for the analyzed rocks the mineral trapping mechanism is controlled by dissolution of calcite and kaolinite (or muscovite), and dawsonite and chalcedony precipitation. With increasing time and reaction progress, the K-feldspar was also dissoluted. For the samples containing illite, close to the termination of modeling period (20 000 years), the dissolution of illite enables precipitation of dolomite and muscovite recrystallization. Additional portion of SiO_2 is then released and quartz is able to precipitate. Consumption of hydrogen ions in this reaction supports the rise of pH. In the case of samples in which carbonate minerals are absent, during the CO_2 injection into the pore space the hydrolysis of kaolinite was responsible for the production of chalcedony.