CEST 2019

16th International Conference on Environmental Science and Technology

Rhodes, Greece, 4 to 7 September 2019

Numerical simulation of CO_2-brine-rock interactions on CO_2 sequestration in Shihezi Formation of Ordos Basin in China

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Abstract

Geochemical reactions play an important role in CO_2 geological storage environments. CO_2-brine-rock interactions will be enhanced in low pH environment, because of acidity in reservoir being strengthened due to CO_2 dissolution. TOUGHREACT is used conduct kinetic batch modeling and reactive transport modeling in Shihezi formation in Ordos basin, where the first CCS project is carried out in China. Simulations are based on the core data, which are focused on effects of CO_2 for pH, gas saturation, geochemical interactions, porosity and permeability in formation. Results show thath K-feldspar and albite, main components of alkaline feldspar, are dissolved, while ankerite and siderite are precipitated. Quartz, calcite and dawsonite are dissolved first and then precipitated, whose reaction mechanisms are associated with environment pH value, temperature and electrolyte existing. These results are consistent with observations in laboratory experiments. For CO_2 squestration, whether minerals are dissolved and precipitated, amount of CO_2 will be consumed, which will promote CO_2 dissolution in formation resulting in CO_2 sequestrated underground. These processes may be very slow, but dissolved and mineralized deposits are ideal CO_2 storage.

Keywords: CO_2 geological storage; CO_2-brine-rock interaction; reactive transport model

1. Introduction

CO_2 geological storage is one of the most important technologies in Carbon Capture and Storage (CCS) (Bachu S., et al, 2003, 2007). Characteristics of reservoir and caprock are key factors for long term storage, whereas effects of injected CO_2 in geological site can not be ignored, which play momentous roles for safe sequestration. CO_2 commercial utilization and storage projects have accumulated abundant experiences and real testing data(Bateman K., et al, 2013; Mitiku A. B., et al, 2013), which can provide reference significance.

CO_2-brine-rock geochemical interactions are focused on as well as geomechanics in CCS. There are two techniques concerned on geochemical reactions: experiments and numerical simulation. In the former, products can be observed directly and analyzed by instruments. However, limitations on core samples amount, core samples differences, and time scales, will restrict the reliability and generalization of experiments. Furthermore, properties of pore structure, fluid contents variety changed by CO_2 injection will not be verified simply in laboratory. Numerical simulation can reproduce multi-component solute transport process for thousands of years, where integrates several processes including fluid flow, solute transport and geochemical reaction.

2. CO_2 Storage Area and Main Interactions

2.1. Background

Shenhua group is the largest coal enterprise of China, which is carrying out the first demonstration project of exhaust gas capture and storage in saline aquifer from the process of coal liquefaction(Wu Y., 2013). Simulations are based on the core data from Shihezi formation of Ordos basin including minerals content and brine composition (Wang T., et al, 2013).

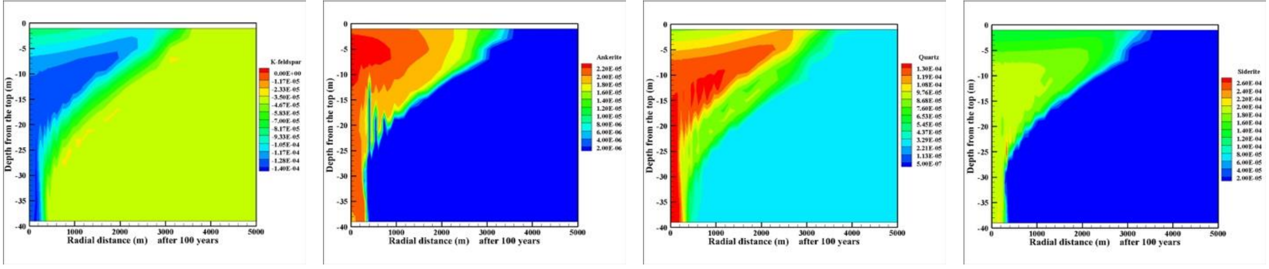
2.2. main geochemical interactions and their effects

At the initial phase of CO_2 injection, CO_2 will be stored in free state in the reservoir. Hydrogen ion, induced by carbonic acid due to CO_2 dissolution, will reduce the pH value of brine, which will increase the reactivity of rock, and provide initial conditions for the CO_2-brine-rock reaction. Minerals dissolution and precipitation occur simultaneously. If the former predominates, reservoir porosity will increase as well as its permeability. Otherwise, if minerals precipitation plays a dominant role in reactions, reservoir porosity will reduce as well as its permeability.

Sawtooth structure is formed on the cleavage surface of the clastic albite, indicating albite dissolution during CO_2 sequestration. However, dawsonite, as the main product of the albite dissolution, can not be found. This means it dissolves after precipitation.

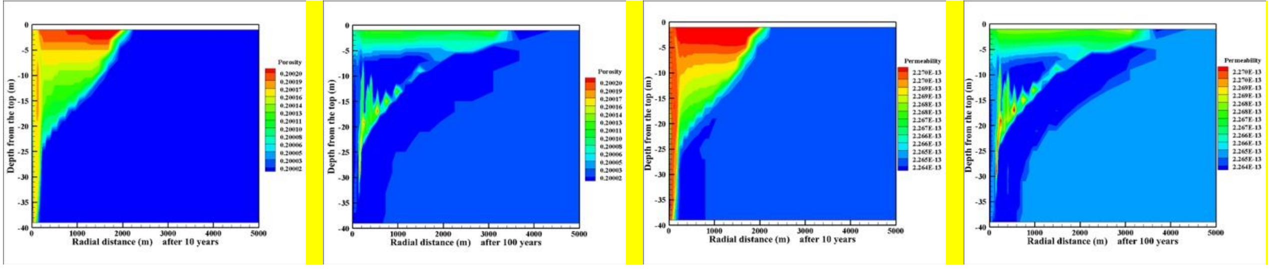
K-feldspar is the key component of alkaline feldspar, which disolves as well as albite, depicted in Fig. 1(A). Kaolinite, product of K-feldspar dissolution, precipitates first and then dissolves in acidic condition. After 100 years, there is almost no kaolinite observed. There is no ankerite observed after CO_2 injection 10 years, either.

However, amount of ankerite is precipitated after 100 years, depicted in Fig. 1(B). At first, Quartz dissolves predominantly in acidic environment because of salt effect due to electrolyte existing. During CO_2 sequestration, quartz precipitation is related to dissolution of K-feldspar and albite. Additionally, quartz precipitation strength is also associated with environment pH value, depicted in Fig. 1(C). Siderite, as an insoluble carbonate, is precipitated in great amount after CO_2 injection, depicted in Fig. 1(D), where Fe^{2+} comes from composition $FeSO_4$ in brine.



(A) K-feldspar (B) ankerite (C) quartz (D) siderite

Figure 1. four typical minerals after CO_2 injection 100 years



(A) porosity after 10 years (B) porosity after 100 years (C) permeability after 10 years (D) permeability after 100 years

Figure 2. Variations of porosity and permeability

2.3. evolution of pore structure in reservoir

Variations of both porosity and permeability are similar, depicted in Fig. 2, because the relationship between porosity and permeability is chosen as positive correlated. On one hand, large amount of CO_2 will enter into rock pore under the pressure during CO_2 injection, where the predominant CO_2-brine-rock interactions are minerals dissolution. Reservoir porosity increase is beneficial to expanding storage capacity for reservoir, and the corresponding permeability will improve mobility of multi-phase fluid. On the other hand, CO_2 migration will raise the efficiency of residual CO_2 storage and dissolved CO_2 storage, which has a positive effect on the feasibility of CO_2 storage.

3. Conclusion

CO_2-brine-rock interaction will lead to amount of CO_2 mineralization referred to as mineral trapping after CO_2 injection. Furthermore, variations of porosity and permeability, caused by CO_2-brine-rock interaction, will promote mineral composition dramatically in reservoir. It has significant influence on CO_2 storage capacity.

Acknowledgment

This work is supported by National Natural Science Foundation of China under Grant No. 41602134, U1562214, China Postdoctoral Science Foundation under Grant No. 2017T100223, Outstanding Youth Program of Heilongjiang Natural Science Foundation under Grant No. YQ2019D001.

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