A mechanism of fluid exchange associated to CO_2 leakage along activated fault during geologic storage

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Abstract

This study employed a sophisticated 3-D numerical model, TOUGH2/ECO2N, to examine the intricacies of fluid exchange resulting from CO_2 leakage along activated faults. The primary focus was on understanding the interactions among CO_2, brine, and freshwater. Notably, the study revealed a significant fluid exchange process, primarily involving the transfer of CO_2 and freshwater from fault A to fault B. This research underscores the benefits of strategically positioned pump wells, particularly in the presence of two major faults. Furthermore, it conducted a parametric analysis to gauge the impact of fault permeability, saline aquifer permeability, and fault width on fluid exchange, with a specific focus on leakage rates and the volumes of CO_2 and freshwater via fault A and fault B. The results show that increasing the permeability of both the fault and the saline aquifer leads to higher leakage rates and larger amounts of CO_2 and freshwater. Additionally, the width of the fault, particularly when located farther from the injection well, exerts a more substantial influence on the leakage rates and quantities of CO_2 and freshwater compared to the width of the fault near the injection well. In essence, this investigation offers valuable insights for enhancing the safety and efficiency of CO_2 geological storage.

Keywords: CO_2 leakage, fault, fluid exchange, brine leakage, freshwater loss.

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A B S T R A C T

Currently, the fluid exchange among CO_2, brine and freshwater is rarely reported, associated to CO_2 leakage along activated fault during geologic storage. To investigate the fluid exchange, a 3-D numerical model was proposed considering CO_2 leakage along two faults. Through analyzing the leakage rates of CO_2, brine and freshwater, the fluid exchange associated to CO_2 leakage was observed among CO_2, brine and freshwater. Then, the exchange mechanism was concluded, including the major fluid exchange between two faults, as well as the minor fluid exchange along the same one fault. In the major fluid exchange, CO_2 leaks from saline aquifer to freshwater aquifer along fault near the injection well, while freshwater leaks from freshwater aquifer to saline aquifer along fault far from the injection well. The major fluid exchange is harmful for CO_2 geological storage, because more CO_2 leaks upward into freshwater aquifer in the fluid exchange. In the fault near injection well, the minor fluid exchange is observed, i.e., CO_2 leaks upward and freshwater leaks downward. In the fault far from injection well, the minor fluid exchange is also found, i.e., brine leaks upward and freshwater leaks downward. An implication from the fluid exchange was obtained through setting pump wells. The results show that setting pump wells reduces the leakage amount of CO_2 and brine obviously. Additionally, based on the numerical model, the parametric analysis was performed on the fluid exchange, including the permeability of fault, the permeability of saline aquifer and the fault width. Especially, the fluid exchange was herein reflected by leakage rates and amounts of CO_2 and freshwater. The results show that: (1) CO_2 and freshwater have larger leakage rates and amounts when increasing the permeability of the fault and the saline aquifer; (2) the width of the fault far from injection well has a more significant effect on the leakage rates and amounts of CO_2 and freshwater, compared to the width of the fault near injection well.

1. Introduction

In United Nations Framework Convention on Climate Change of 2015, almost 200 parties made the commitment of reducing carbon emissions into atmosphere to control the global average temperature increasing. Currently, the most effective way to reduce carbon emissions into atmosphere is CO_2 geological storage [1–9]. CO_2 geological storage is related to inject supercritical CO_2 into underground formation, especially into saline aquifer. Saline aquifers are widely distributed in underground space and have huge pore volumes. As a result, they are regarded as an ideal site of CO_2 geological storage [10–22]. In saline aquifers, the caprock is a natural barrier to prevent the injected CO_2 escaping from reservoirs. However, some unexpected faults exist in the caprocks most possibly [23–30]. These faults are closed before CO_2 injecting, but they are most probably to be reactivated as CO_2 injecting. This is because CO_2 injection increases the fluid pressure around the fault, and decreases the effective stress around the fault [31–34]. In such case, CO_2 leakage occurs along reactivated faults. Associated to CO_2 leakage, brine and freshwater would escape or lose along the fault from their respective formation. In detail, brine would leak from saline aquifers, while freshwater would flow into saline aquifers from the formation above CO_2 storage reservoir. This means that

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