Hydrol. Earth Syst. Sci. Discuss., 12, C2489–C2492, 2015
www.hydrol-earth-syst-sci-discuss.net/12/C2489/2015/

Hydrology and Earth System Sciences
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Discussions

Interactive comment on "Effective damage zone volume of fault zones and initial salinity distribution determine intensity of shallow aquifer salinization in geological underground utilization" *by* M. Langer et al.

Anonymous Referee #2

Received and published: 10 July 2015

This is a well written paper on a timely topic of how geologic carbon storage may salinize freshwater aquifers due to brine flow through faults. Several configurations, including open and closed boundaries, presence of secondary aquifer or not and length of the permeable faults. The study is interesting, but since faults have a very complex architecture, a more detailed discussion on the permeability of faults should be done.

Major comments:

1) It is assumed that faults hydraulically connect reservoir layers separated by confining

layers. However, the fault zone architecture is very complex and can act either as a barrier to flow or as a conduit (Caine et al., 1996). Actually, the permeability considered for this numerical study is reasonable for the fracture zone of a typical reservoir layer, with a more permeable fracture zone (Cappa and Rutqvist, 2011), but without the low permeable core. This distribution gives rise to a low permeability perpendicular to the fault (horizontal permeability) and a high permeability parallel to the fault (vertical permeability). However, in multilayer systems like the one considered in this study, with alternating layers of reservoir-caprock, the permeability within the caprock layers is usually of lower permeability than that of the surrounding rock due to clay smearing (e.g. Crawford et al., 2008; Egholm et al., 2008). Thus, the vertical permeability of faults is very heterogeneous (Vilarrasa and Carrera, 2015). Apart from including a discussion on this point, explaining the complexity of faults, it should be acknowledged that due to the high complexity of faults, this assumption will only be valid for certain faults.

2) The analytical solution of leakage through a fault proposed by Zeidouni (2012) should be cited either in the Introduction or the Discussion.

3) Page 4, lines 5-8: the radius of influence is in fact proportional to the square root of the hydraulic diffusivity.

4) Grid is very coarse, but it is justified.

5) Instead of injecting CO_2, an equivalent volume of water is injected. CO_2 density is calculated from the initial pressure and temperature conditions. However, the high injected flow rate induces a significant overpressure (see Figure 6). Since CO_2 is very compressible, CO_2 density will increase and thus the displaced volume of brine will be smaller. Thus, CO_2 compressibility effects should not be neglected.

6) Page 21, lines 6-9: accounting for the storage coefficient would induce a delay in pressure buildup evolution. So for a given time, overpressure would be slightly lower, leading to just a "slight" less intense brine displacement. It should be emphasized that

this effect will be small.

7) Some discussion on attenuation or mitigation measures to minimize salinization of freshwater aquifers should be done.

8) Why don't you simulate the three interlayered reservoirs that will probably dampen brine displacement?

9) Page 26, lines 11-16: nothing is said in the manuscript about the hydro-mechanical couplings that may affect fault stability, so it cannot be a conclusion. However, this is a very important aspect, and should be included in the discussion. A recent paper of Rinaldi et al. (2015), in which modeling of fault stability of a 3D fault is done, should be cited as well.

10) Figure 3: The legend should be corrected because the results of this Figure correspond to a model with closed boundary conditions, so instead of B_O, should be B_C.

REFERENCES Caine, J.S., Evans, J.P. and Forster, C.B. (1996). Fault zone architecture and permeability structure. Geology 24(11):1025-1028.

Cappa, F. and Rutqvist, J. (2011). Modeling of coupled deformation and permeability evolution during fault reactivation induced by deep underground injection of CO2. International Journal of Greenhouse Gas Control 5(2):336-346.

Crawford, B.R., Faulkner, D.R, and Rutter, E.H. (2008). Strength, porosity, and permeability development during hydrostatic and shear loading of synthetic quartzâĂŘclay fault gouge. Journal of Geophysical Research: Solid Earth 113, B03207, doi: 10.1029/2006JB004634.

Egholm, D.L., Clausen, O.R., Sandiford, M., Kristensen, M.B. and Korstgård, J.A. (2008). The mechanics of clay smearing along faults. Geology 36(10):787-790.

Rinaldi, A. P., Vilarrasa, V., Rutqvist, J. and Cappa, F. (2015). Fault reactivation during

CO2 sequestration: effects of well orientation on seismicity and leakage. Greenhouse Gases: Science and Technology, doi: 10.1002/ghg.1511.

Vilarrasa, V. and Carrera, J. (2015). Geologic carbon storage is unlikely to trigger large earthquakes and reactivate faults through which CO2 could leak. Proceedings of the National Academy of Sciences, 112(19): 5938-5943.

Zeidouni, M. (2012). Analytical model of leakage through fault to overlying formations. Water Resources Research, 48(12), W00N02, doi:10.1029/2012WR012582.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 5703, 2015.