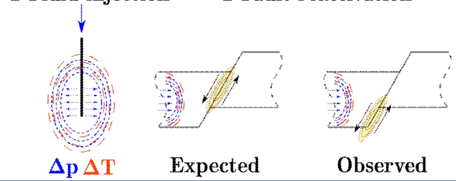
Lateral growth of the fault damage zone as a result of induced seismicity

Víctor Vilarrasa[1,2]*, Roman Y. Makhnenko[3] and Francesco Parisio[1,4] *(victor.vilarrasa@idaea.csic.es)

[1] Institute of Environmental Assessment and Water Research, Spanish National Research Council (IDAEA-CSIC), Barcelona, Spain; [2] Associated Unit: Hydrogeology Group UPC-CSIC, Barcelona, Spain; [3] Dept. of Civil & Environmental Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, USA; [4] Dept. of Environmental Informatics, Helmholtz Centre for Environmental Research – GmbH – UFZ, Leipzig, Germany

Summary

Geo-energy applications such as geologic carbon storage, geothermal energy extraction, and subsurface energy storage, **imply fluid injection and production resulting in pressure and temperature diffusion**. **Consequent changes** in the initial hydraulic and thermal state **may induce seismicity**, usually nucleated at faults that cross the injection formation. Through fully coupled hydro-mechanical simulations, we investigate the fault stability affected by fluid injection into a porous aquifer that is overlaid and underlain by low permeable clay-rich formations. **We find that aquifer pressurization as a result of fluid injection causes significant stress changes around the fault**. Simulation results show that the least stable situation occurs at the contact between the aquifer and the fault damage zone – unexpectedly not within the fault. **Induced earthquakes are likely to nucleate on the edge of the fault damage zone**, leading to a lateral growth of the damage zone and a possible spreading of the fault zone.

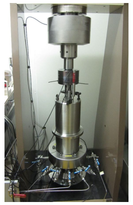


Material properties

Material	Permeability (m^2)	Porosity (-)	Entry pressure (MPa)	Young's modulus (GPa)	Poisson ratio (-)
Storage formation	$4 \cdot 10^{-14}$	0.23	0.02	14.0	0.31
Damage zone reservoir	$2 \cdot 10^{-13}$	0.25	0.02	7.0	0.35
Shale	$8 \cdot 10^{-20}$	0.05	10.0	3.0	0.40
Damage zone shale	$1.5 \cdot 10^{-19}$	0.09	5.0	1.4	0.42
Fault core	$1 \cdot 10^{-19}$	0.10	4.0	1.0	0.30

(Vilarrasa *et al.*, 2016; Makhnenko *et al.*, 2017)

Triaxial cell



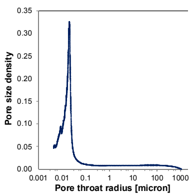
Specimen size 100 mm

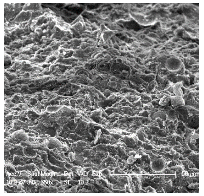
Oedometric cell

Specimen size 12.5 mm

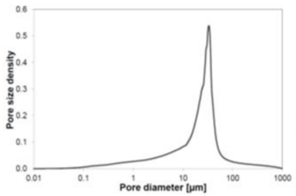
Experiments performed at supercritical conditions for CO_2

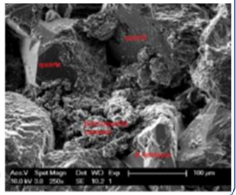
Shale (Opalinus clay)



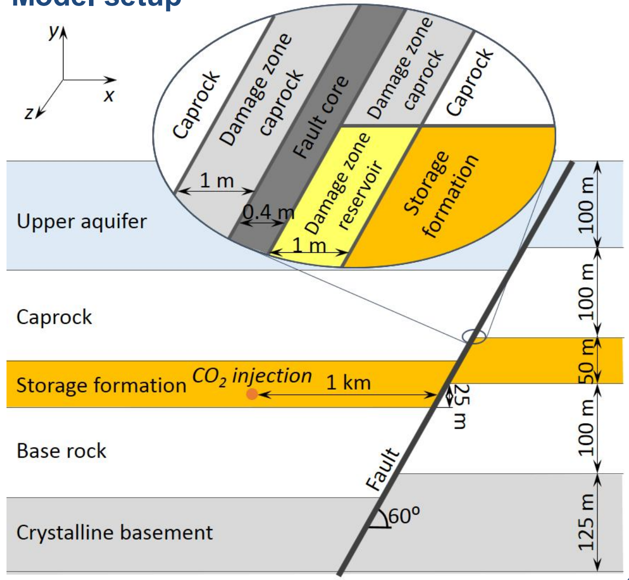


Reservoir (Berea sandstone)

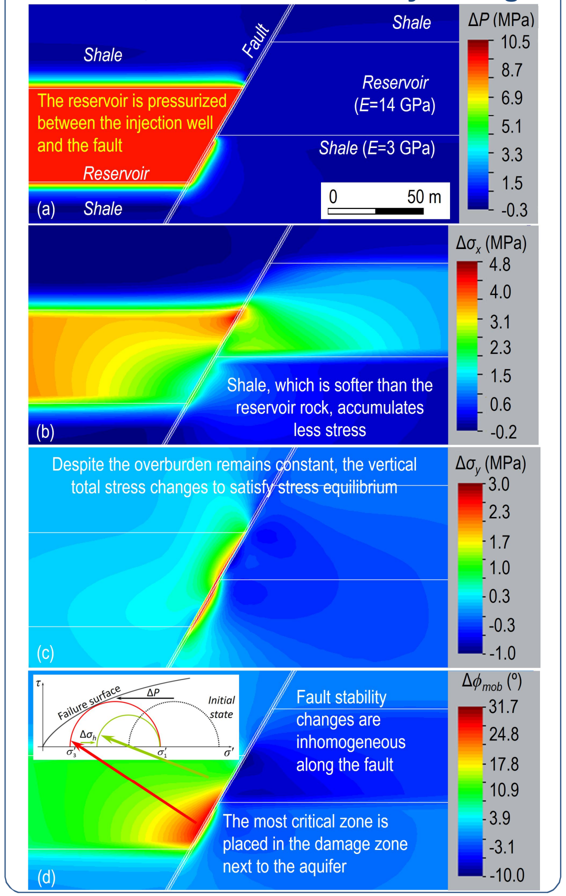




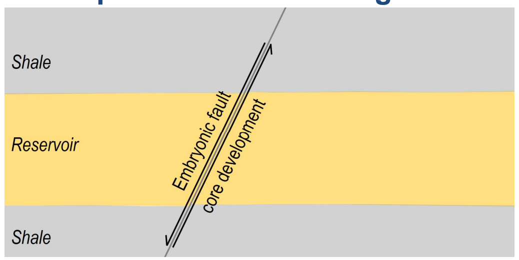
Model setup



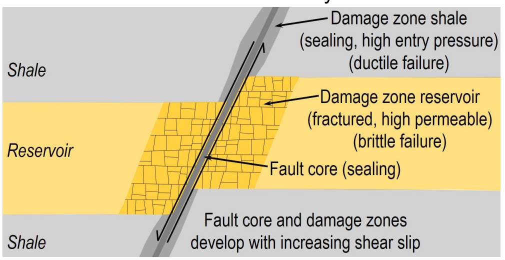
Pressure, stress and stability changes



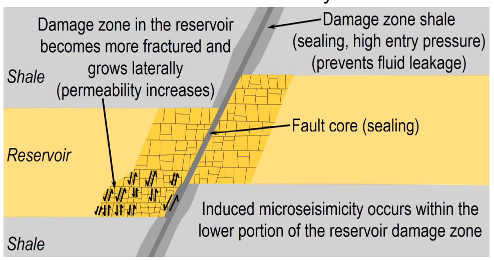
Conceptual model of fault growth evolution



Natural seismicity



Induced seismicity



Conclusions

We model fluid injection into a semi-closed reservoir bounded by a low-permeable fault, which causes reservoir pressurization between the well and the fault. Despite this pressurization, **shale stability is maintained**. However, **fault stability undergoes inhomogeneous changes, with the least stable situation occurring at the contact between the aquifer and the fault damage zone where the aquifer is juxtaposed with the caprock**.

References

Makhnenko, R.Y., Vilarrasa, V., Mylnikov, D. et al. (2017). *Energy Procedia*, 114:3219-28

Vilarrasa, V., Makhnenko, R., Gheibi, S. (2016). *J. Rock Mech. & Geotech. Eng.*, 8(6):805-818

Acknowledgments

V.V. would like to acknowledge funding from the European Research Council (ERC) under European Union's Horizon 2020 research and innovation programme (grant agreement No 801809)

European Geosciences Union General Assembly 2019, Vienna, Austria, 7-12 April 2019