CO_2 storage in the Salamanca Formation: Numerical Study

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1 Introduction

CO_2 geological storage has become a popular alternative to mitigate global warming. When considering formation's feasibility for CO_2 storage, the reservoir's integrity must be studied. For instance, the behaviour of discontinuities when subjected to CO_2 is studied to determine the magnitude of the seismic (Mazzoldi, et al., 2012) and leakage events (Hawkes, et al., 2014) that their slip could produce. To do this, reservoir scale analysis should be conducted.

For this study, the Salamanca Formation was proposed as a possible CO_2 underground storage. This Formation is composed of interbedded layers of depleted oil and gas reservoir rocks and caprocks. The depleted oil and gas reservoir rock presents high permeability and porosity (Rodríguez, et al., 2014), associated to great store volumes. In contrast, the caprock has low permeability and porosity values (Foix, 2009), acting as a natural barrier against possible CO_2 leaks. To analyse the long-term integrity of the Salamanca Formation as CO_2 storage, a coupled numerical study was conducted.

2 Materials and Methods

For the case study, the underground was designed as interbedded reservoirs and cap rocks, crossed by a subvertical discontinuity, into which a flow of CO_2 was injected. The poroelastic and hydraulic phenomena were coupled using COMSOL Multiphysics as calculation software. To study the long-term integrity of Salamanca Formation when injecting CO_2, the fault's reactivation time was determined. The magnitude of the seismic event (Wells, 1994), was also studied.

For the analysis, rock layers were considered linear elastic materials. Since the objective was to study the fault's reactivation, the Mohr-Coulomb failure criterion was proposed. From the coupled study, the shear and effective normal stresses developed over time at the fault were obtained. The point of analysis was chosen considering that the fault zone is usually located along the fault in the surroundings of the interface between the lower cap rock and the reservoir into which CO_2 is being injected (Urpi, et al., 2015).

The properties of each of the strata are presented in Tab. 1. Characteristic values for the Banco Verde and Banco Negro layers, as well as the natural discontinuity, were obtained from previous laboratory studies (Laskowski, et al., 2025) (Laskowski, et al., 2025). As for the properties of the Upper Formations, Fragmentosa, and Glauconítico strata, estimates were made based on the available literature (Foix, 2009) (Rodríguez, et al., 2014).

Tab. 1: Properties of the strata. UF: Upper Formations, BN: Banco Negro, BV: Banco Verde, F: Fragmentosa, G: Glauconítico, D: Discontinuity.

Properties	**Strata**					
	UF	**BN**	**BV**	**F**	**G**	**D**
Thickness [m]	1000	10	20	134	10	1
Length [m]	1000	1000	1000	1000	1000	100
Porosity [%]	10	5	13	5	13	20
Permeability [m^2]	10^{-17}	10^{-18}	10^{-16}	10^{-18}	10^{-16}	10^{-17}
Young's Modulus [GPa]	10	10	10	10	10	0.64
Poisson's Ratio	0.3	0.2	0.25	0.2	0.25	0.27
Density [kg/m^3]	2394	2530	2340	2530	2340	2340
Biot-Willis Coefficient	1	1	1	1	1	1
Cohesion [kPa]	-	-	-	-	-	0
Friction Angle [º]	-	-	-	-	-	23.9

3 Results

According to the literature (Urpi, et al., 2015), fault reactivation occurs at the interface between the CO_2 reservoir rock and the underlying cap rock. In this context, to determine the reactivation of the fault, the shear and effective normal stress, as well as the evolution of the shear stress in terms of time in the study point were studied. In Fig. 1, it is possible to note how the fault's reactivation time was determined. Complementing this information with the average displacement suffered by the discontinuity, the magnitude of the earthquake produced was calculated to be 0.3 (Wells, 1994), which represents an event that cannot even be classified as minor.

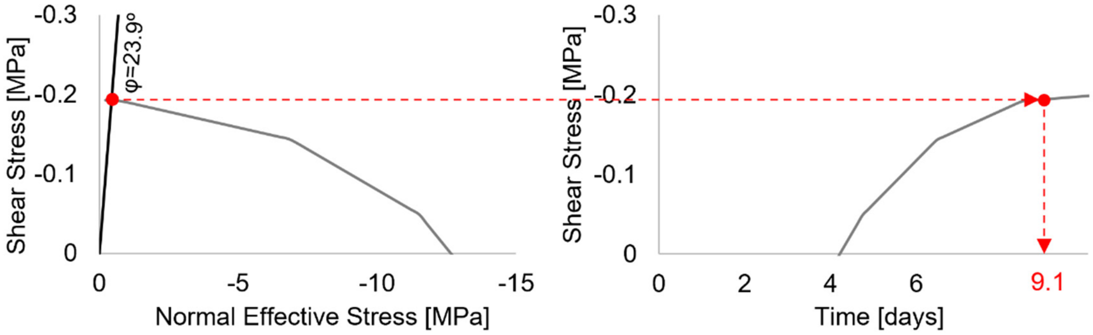

Fig. 1: Fault's reactivation time determination.

As shown in Fig. 2, the point at which fault reactivation begins is located between the Fragmentosa and Banco Verde layers. This graph corroborates the findings of (Urpi, et al., 2015) and validates our selection of the point of analysis. It should be noted that the maximum shear stress produced at the reactivation point is 0.2 MPa, which corresponds to the value previously determined using the Mohr-Coulomb failure criterion as the fault shear stress.

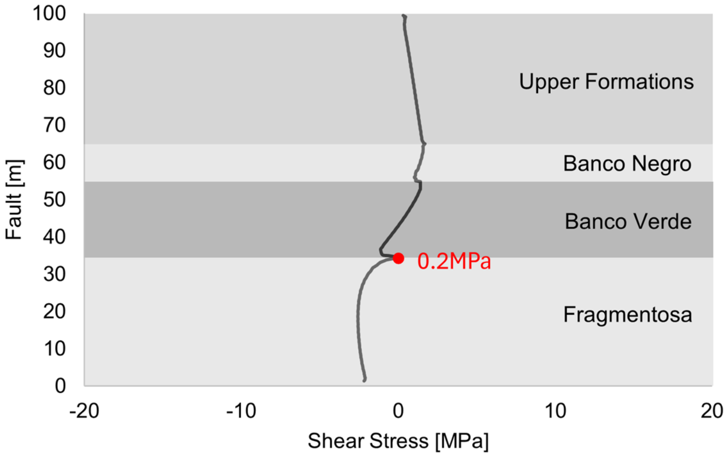

Fig. 2: Shear stress distribution along the fault.

4 Conclusion

The aim of this article was to analyse the effects of the reactivation of a fault in Salamanca Formation when injecting CO_2. A numerical simulation was conducted coupling the poroelastic and hydraulic phenomena. It was noted that the reactivation point was along the fault in the interface between the reservoir rock and the underlying caprock. Additionally, the induced earthquake was weaker than a minor event and unlikely to generate significant seismicity. Further studies should consider other types of discontinuities, to ensure a thorough study of the integrity of the reservoir when considered as a long-term CO_2 storage.

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