Risk analysis of injection-induced seismicity associated with geological CO2 storage through enhanced oil recovery

Yashvardhan Verma[1], Vikram Vishal[1], and PG Ranjith[2]

[1]Indian Institute of Technology Bombay
[2]Monash University

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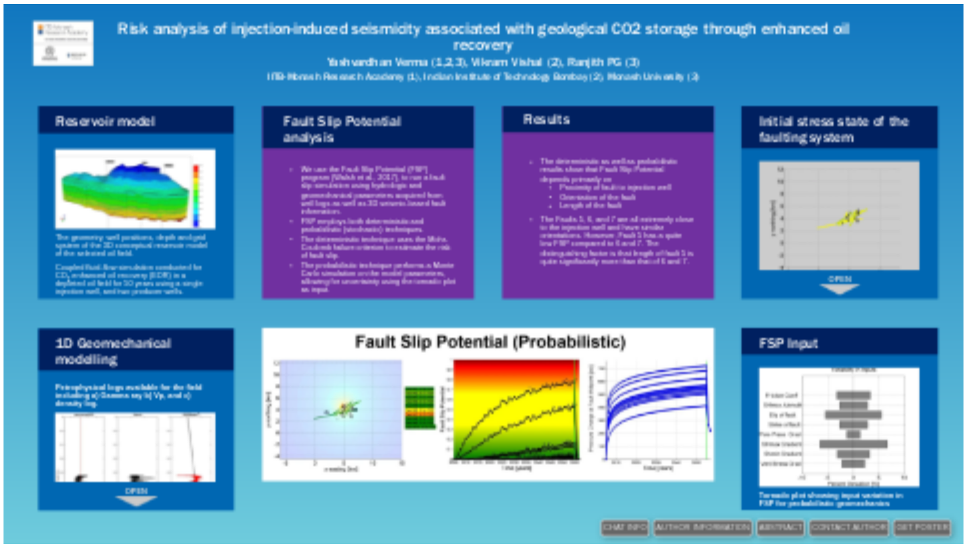
Abstract

CO2 enhanced oil recovery (EOR) is being increasingly deployed for the exploitation of depleted conventional oil and gas fields, due to the twofold benefit of improved recovery efficiency and reduction in carbon dioxide emissions. Geomechanics starts playing an increasingly important role with the injection of CO2 in the subsurface and the subsequent pore pressure buildup. However, the release of pressure through oil production enables a higher amount of CO2 to be introduced into the ground without causing undesirable effects. Understanding the stress perturbation due to fluid injection and withdrawal aids in comprehending the fault activation mechanism and the risks of induced seismicity. The current study evaluates the geomechanical influence of CO2 injection for enhanced oil recovery in a depleted oil field, and assesses the risk of injection and production induced seismicity as a constraint in geologic containment of CO2. The Ankleshwar field in Cambay basin in India is chosen for the study. The field is a potential CO2 EOR site due to its excellent permeability and recovery efficiency. Coupled multiphase fluid flow modeling and geomechanical analysis were carried out to study the hydro-mechanical characteristics of CO2 injection and fluid production. The rise in pore pressure near the injection site induces stress changes even far away from the site of injection due to poroelastic coupling in rocks. The risk of induced seismicity was then analyzed through simulation of fault slip potential in the field. FSP analysis suggests orientation of faults along with proximity to injection site are key parameters influencing fault stability in the Ankleshwar field.

Risk analysis of injection-induced seismicity associated with geological CO2 storage through enhanced oil recovery

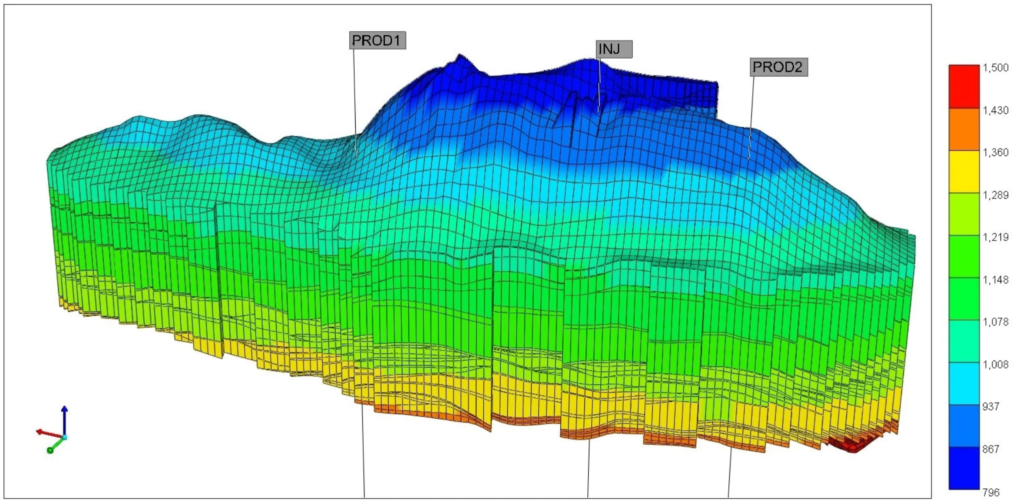


Yashvardhan Verma (1,2,3), Vikram Vishal (2), Ranjith PG (3)

IITB-Monash Research Academy (1), Indian Institute of Technology Bombay (2), Monash University (3)

PRESENTED AT:

RESERVOIR MODEL



The geometry, well positions, depth and grid system of the 3D conceptual reservoir model of the selected oil field.

Coupled fluid-flow simulation conducted for CO_2 enhanced oil recovery (EOR) in a depleted oil field for 50 years using a single injection well, and two producer wells.

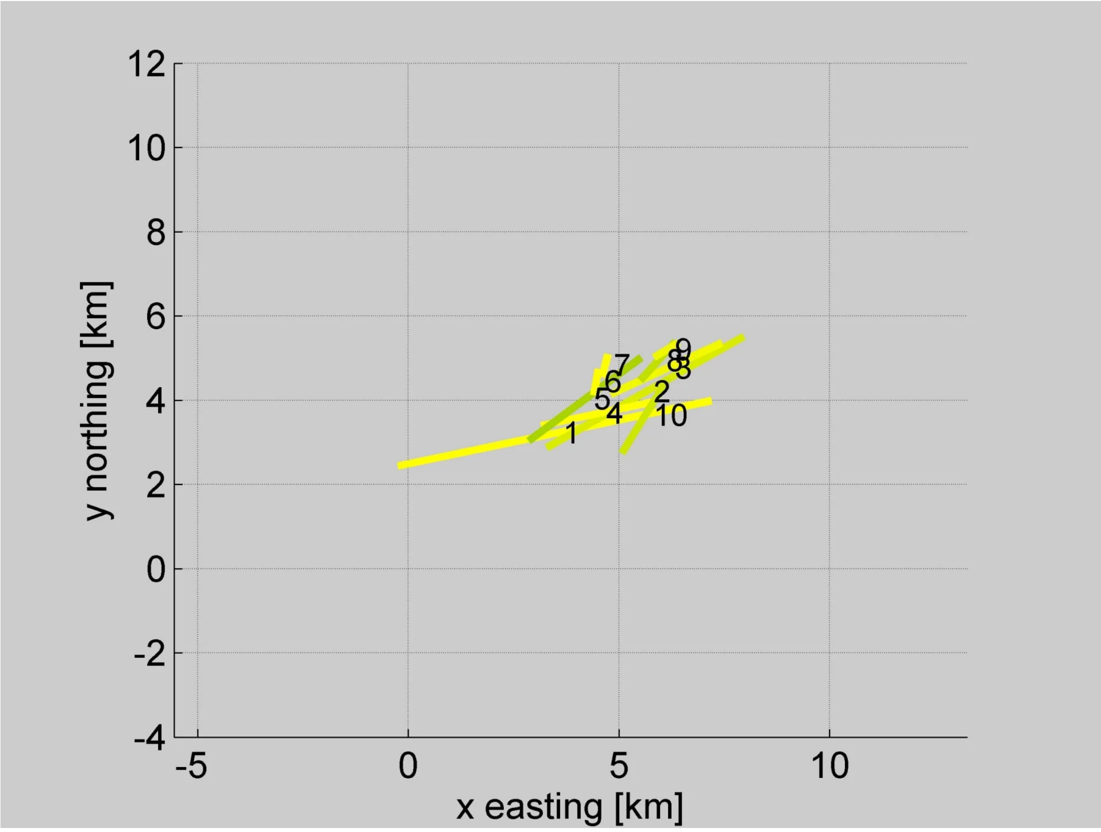
FAULT SLIP POTENTIAL ANALYSIS

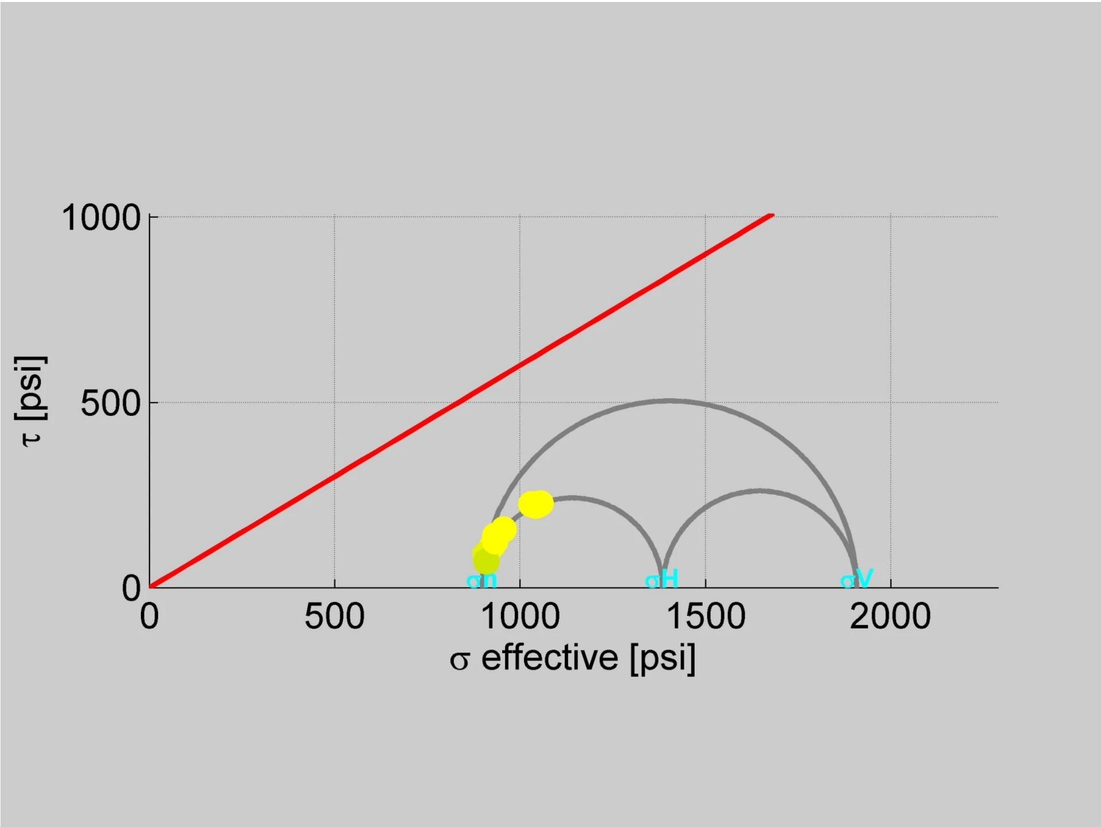
- We use the Fault Slip Potential (FSP) program (Walsh et al., 2017), to run a fault slip simulation using hydrologic and geomechanical parameters acquired from well logs as well as 3D seismic-based fault information.
- FSP employs both deterministic and probabilistic (stochastic) techniques.
- The deterministic technique uses the Mohr-Coulomb failure criterion to estimate the risk of fault slip.
- The probabilistic technique performs a Monte Carlo simulation on the model parameters, allowing for uncertainty using the tornado plot as input.

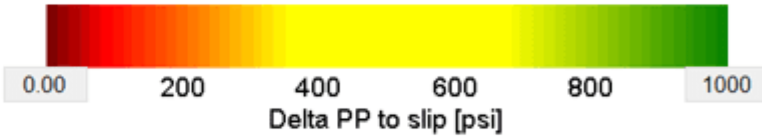
RESULTS

- The deterministic as well as probabilistic results show that Fault Slip Potential depends primarily on
  - Proximity of fault to injection well
  - Orientation of the fault
  - Length of the fault
- The Faults 5, 6, and 7 are all extremely close to the injection well and have similar orientations. However, Fault 5 has a quite low FSP compared to 6 and 7. The distinguishing factor is that length of fault 5 is quite significantly more than that of 6 and 7.

INITIAL STRESS STATE OF THE FAULTING SYSTEM







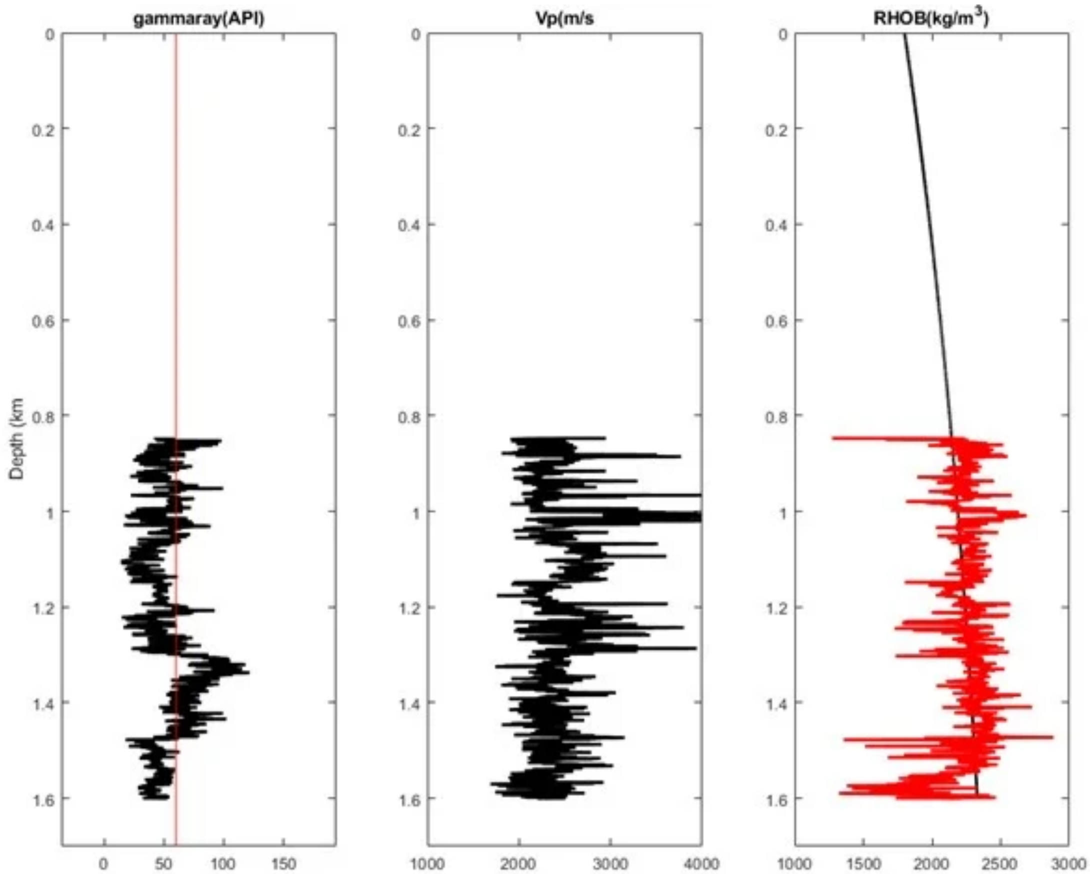
The reservoir fault model and initial stress regime of the field.

	X (Easting)	Y (Northing)	Strike	Dip	Length
1	3.473	3.217	258.2	90	7.609
2	5.626	4.194	60.6	90	5.371
3	6.127	4.755	245.2	90	2.908
4	4.500	3.684	258.0	90	2.754
5	4.192	4.027	233.5	90	3.321
6	4.456	4.431	190.3	90	0.630
7	4.669	4.821	14.4	85	0.557
8	5.919	4.931	222.3	85	1.234
9	6.122	5.197	238.7	85	0.678
10	5.617	3.638	211.7	88	2.098

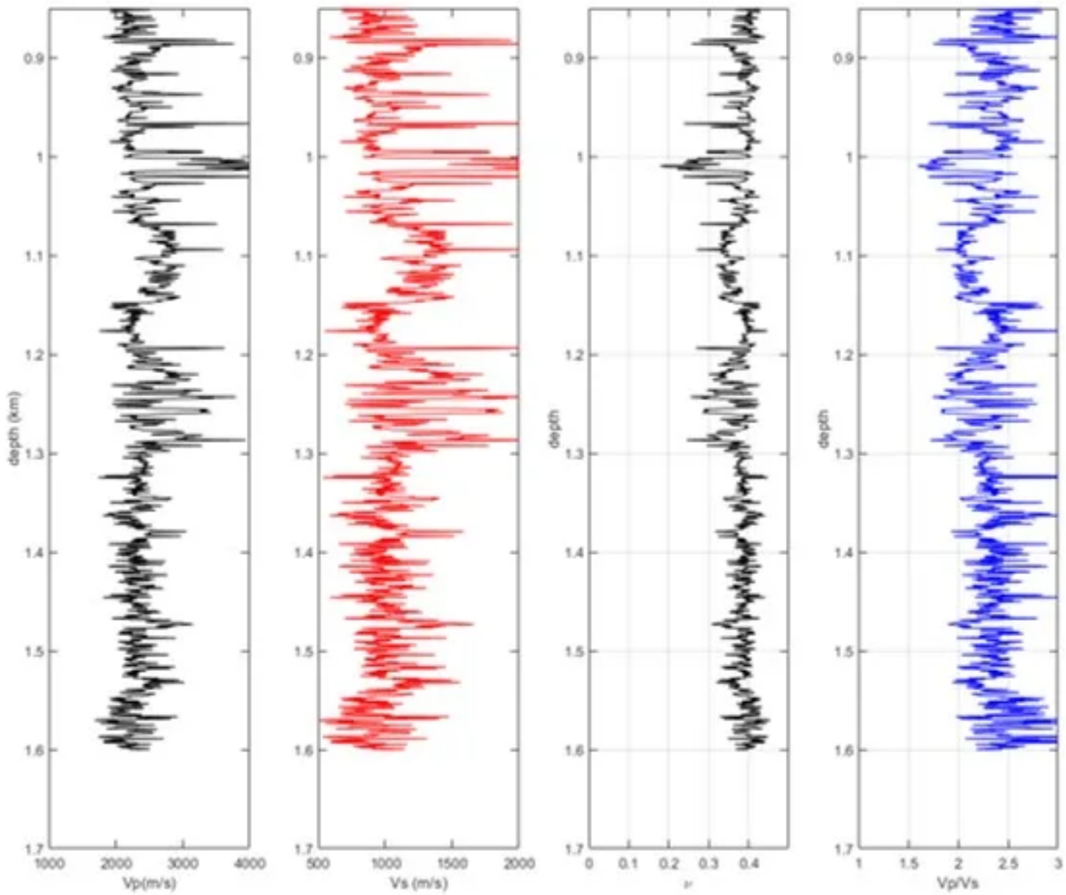
Fault parameters

1D GEOMECHANICAL MODELLING

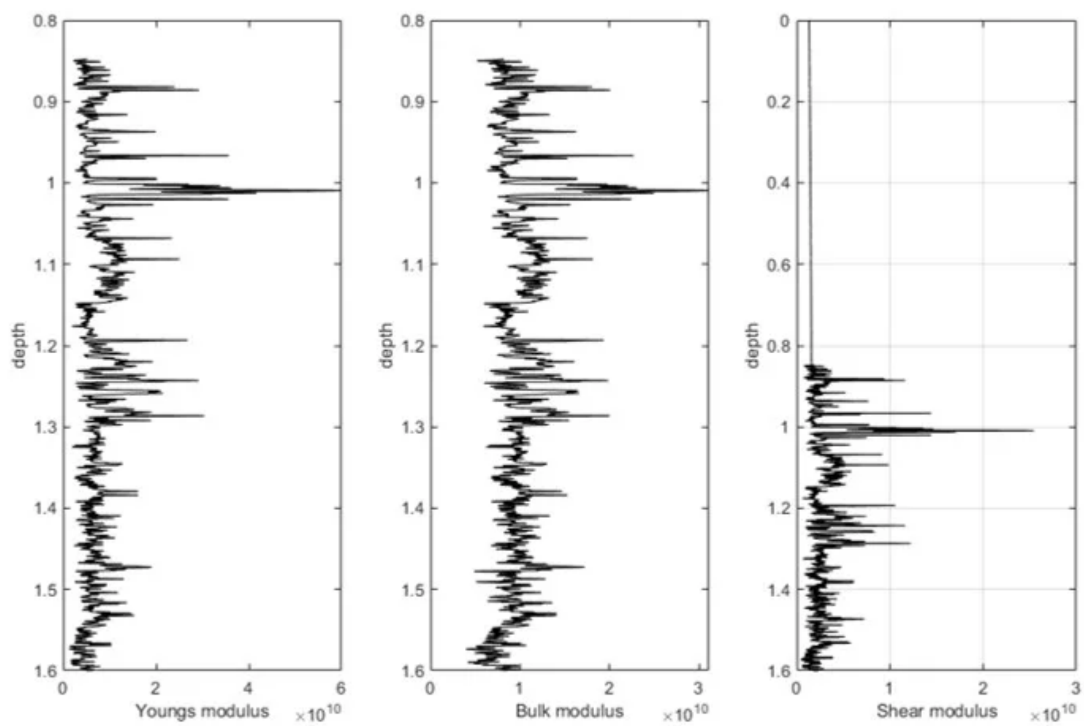
Petrophysical logs available for the field including a) Gamma ray b) Vp, and c) density log.



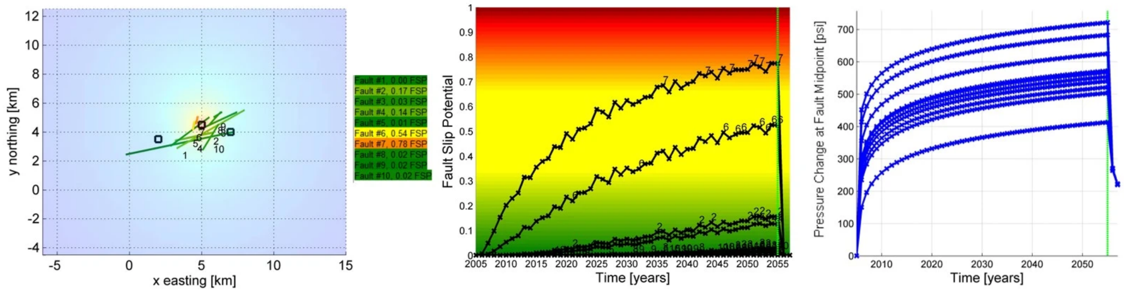
Elastic parameters (Vp, Vs, γ, Vp/Vs)



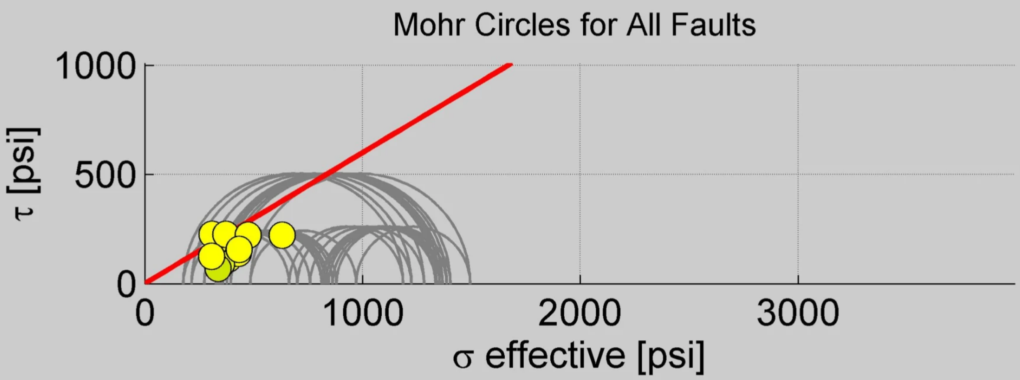
Geomechanical parameters (Y, K, S)



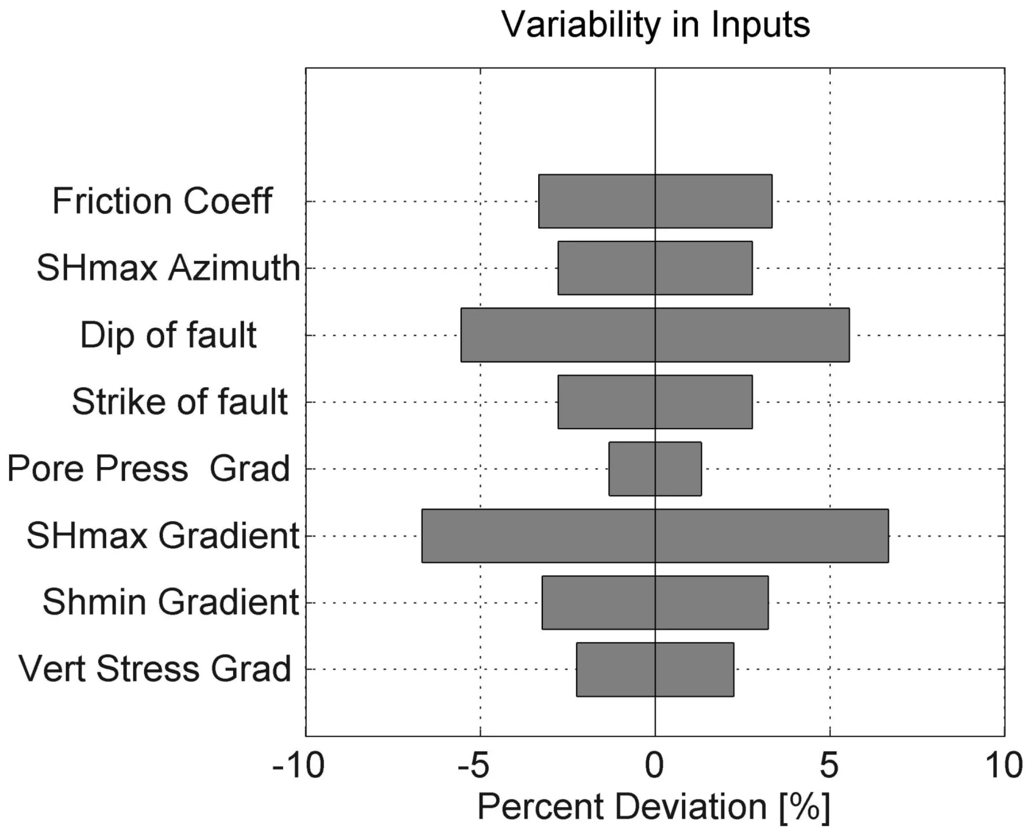
Fault Slip Potential (Probabilistic)



Fault Slip Potential (Deterministic)



FSP INPUT



Tornado plot showing input variation in FSP for probabilistic geomechanics

AUTHOR INFORMATION

Yashvardhan Verma is a PhD candidate at IITB-Monash Research Academy, which is a joint venture between the Indian Institute of Technology Bombay, Mumbai, and Monash University, Melbourne. His primary research area is the risk assessment of induced seismicity as a constraint in CO_2 storage. Prior to joining PhD, he worked with Schlumberger as a Research Geophysicist for 4 years.

Please feel free to contact Yash at yashvardhan.verma@monash.edu / yash.verma@iitb.ac.in

ABSTRACT

CO_2 enhanced oil recovery (EOR) is being increasingly deployed for the exploitation of depleted conventional oil and gas fields, due to the twofold benefit of improved recovery efficiency and reduction in carbon dioxide emissions. Geomechanics starts playing an increasingly important role with the injection of CO_2 in the subsurface and the subsequent pore pressure buildup. However, the release of pressure through oil production enables a higher amount of CO_2 to be introduced into the ground without causing undesirable effects. Understanding the stress perturbation due to fluid injection and withdrawal aids in comprehending the fault activation mechanism and the risks of induced seismicity. The current study evaluates the geomechanical influence of CO_2 injection for enhanced oil recovery in a depleted oil field and assesses the risk of injection and production induced seismicity as a constraint in the geologic containment of CO_2. The Cambay basin in western India is chosen for the study. A potential CO_2 EOR site has been identified in the basin due to its excellent permeability and recovery efficiency. **Coupled multiphase fluid flow modeling and geomechanical analysis** were carried out to study the hydro-mechanical characteristics of CO_2 injection and fluid production. The rise in pore pressure near the injection site induces stress changes even far away from the site of injection due to poroelastic coupling in rocks. The risk of induced seismicity was then analyzed through simulation of **fault slip potential (FSP)** in the field. FSP analysis suggests that along with **orientation of faults** and **proximity to the injection site**, **length of the fault** is also a key parameter influencing fault stability in the Cambay basin.