UQ Gas & Energy Transition Research Centre

Assessing Fault Reactivation and Surface Uplifting Risk in CO_2 Geological Sequestration

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Introduction

Carbon Capture and Storage (CCS) plays a pivotal role in mitigating CO_2 emissions. Implementing large-scale CCS projects can encounter critical geomechanical challenges, such as induced fault reactivation, surface uplifting and seismic activities. Geomechanical issues associated with CO_2 storage can include fault re-activation, induced seismicity, surface uplifting, fault sealing failure, borehole instability, caprock failure, and even seismic events (Cappa & Rutqvist, 2012; Rutqvist, 2012; Rutqvist et al., 2013).

Among these, fault reactivation, induced seismicity and surface uplift stand out as important factors in determining the success or failure of CO_2 storage projects. These factors can result in a range of other issues, including failure of the bottom hole assembly, casing, drill pipe, fault gouge failure, and potential CO_2 escape, among others. A comprehensive understanding of the conditions under which faults may re-activate due to gas injection can significantly influence operational parameters.

Methodology

To investigate the geomechanical risks of CO_2 injection, integrating geology, reservoir and geomehcanics simulation software packages, we carried out a comprehensive numerical simulation study to investigate fault and reservoir behaviours associated with CO_2 injection. By integrating JewelSuite, IMEX, and ABAQUS software, a field-scale reservoir geo-mechanical model was developed.

The research mainly investigated the impact of well placement, perforation length and bottom hole injection pressure (BHIP) on a range of geomechanical risks, such as fault reactivation, zone of failure, surface uplifting, seismic activity and fault slip during CO_2 injection.

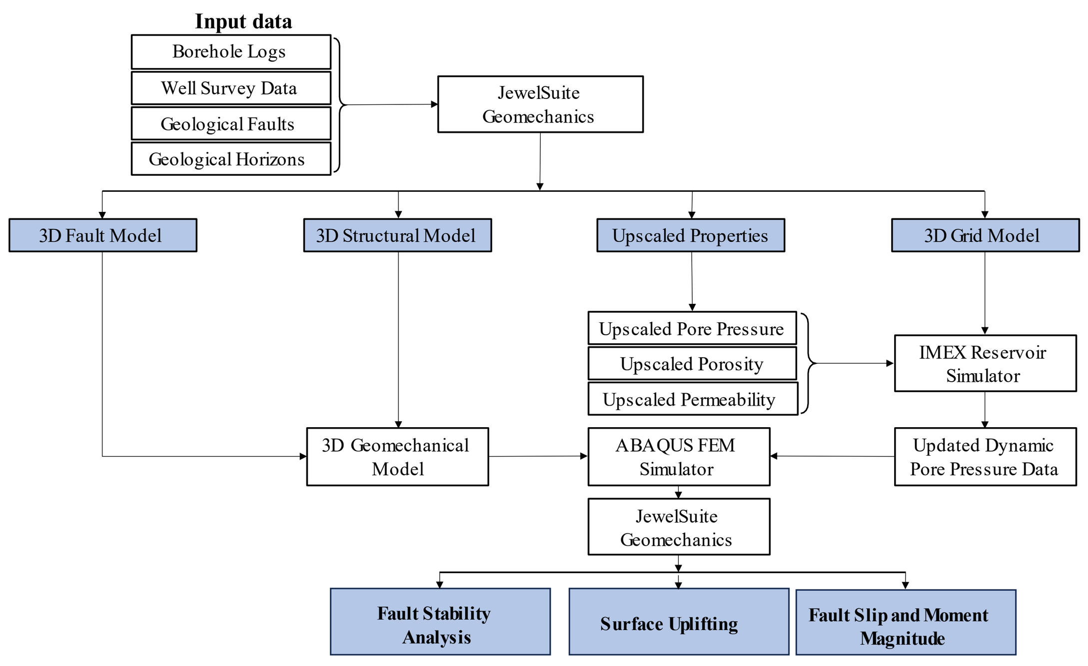

Figure 1: Detailed workflow for 3D integrated geo-mechanical modelling of fault stability analysis

Results

Impact of perforation length on fault reactivation risk

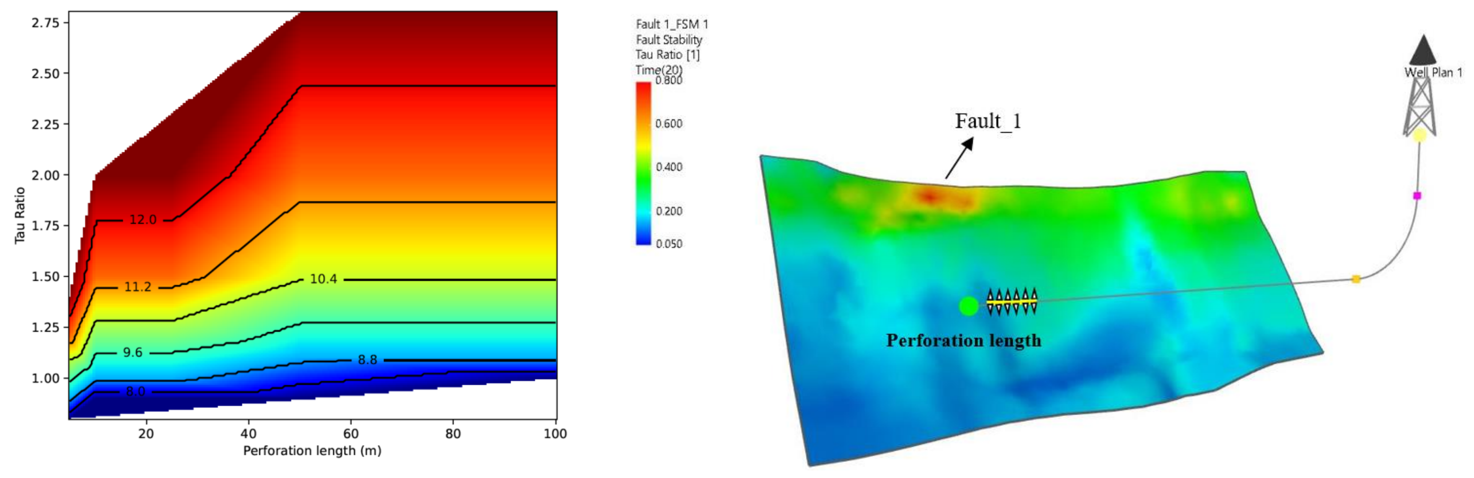

Figure 2: Tau ratio change versus perforation length on the surface of fault_1

Impact of well azimuth on fault reactivation and Zone of Failure

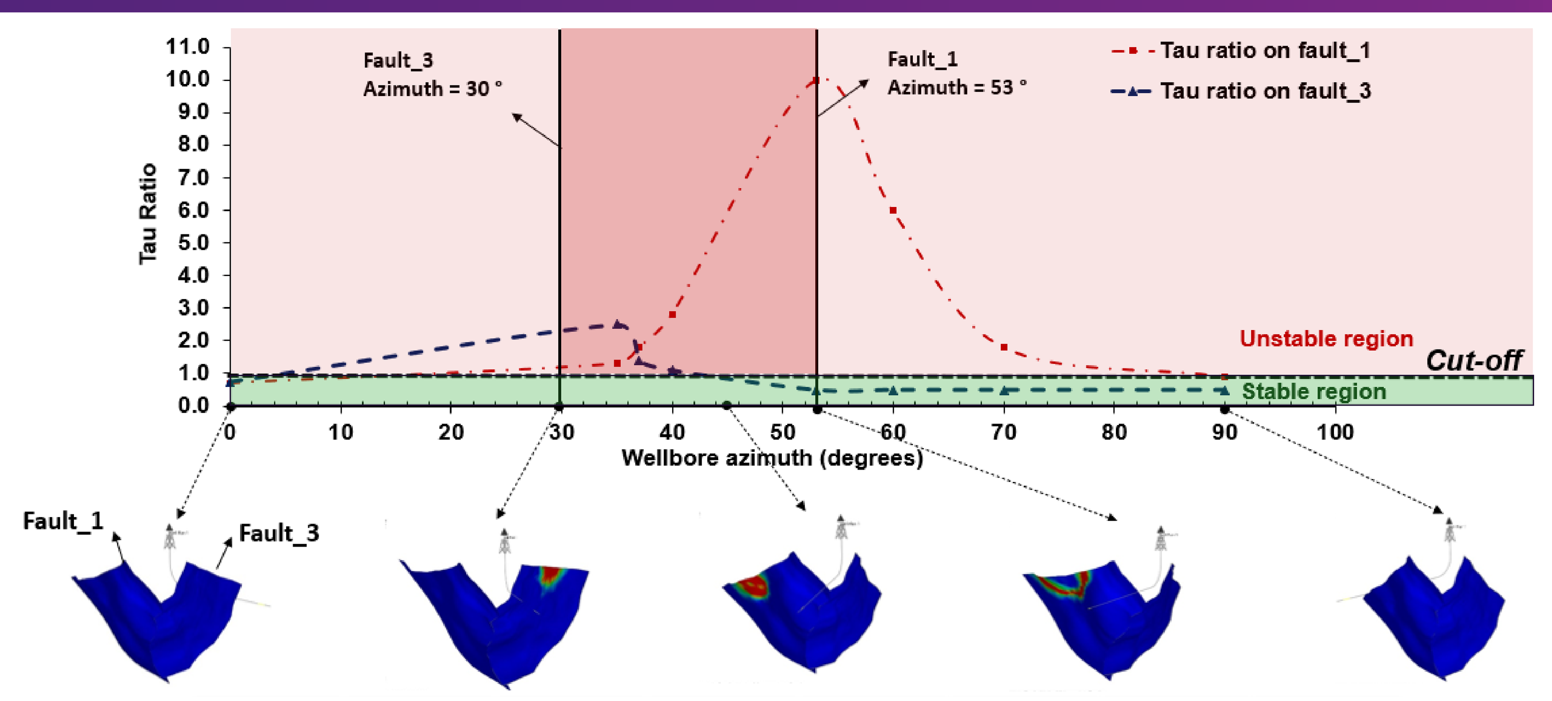

Figure 3: Tau ratio changes versus different wellbore azimuth angles

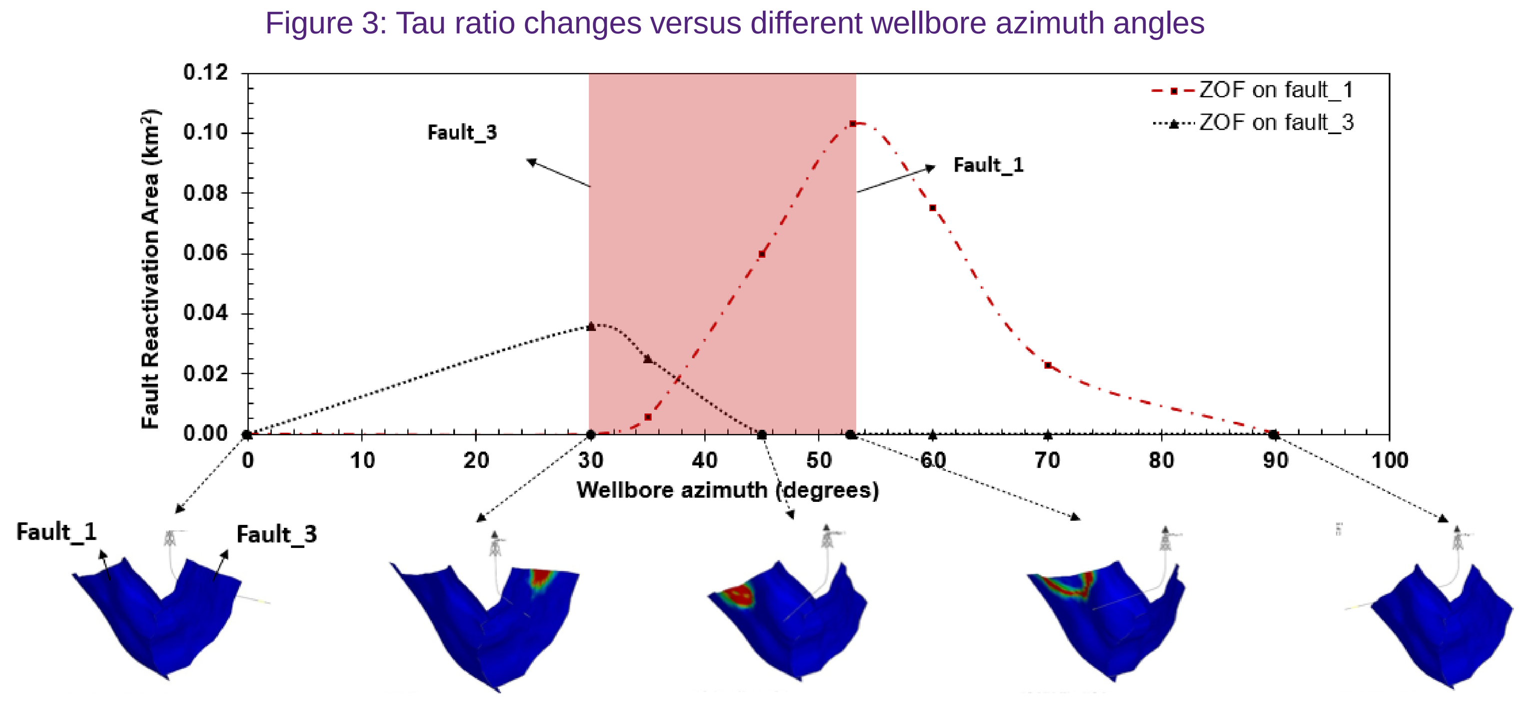

Figure 4: Zone of Failure area change versus different wellbore azimuth angles

Impact of bottom hole injection pressure on fault reactivation

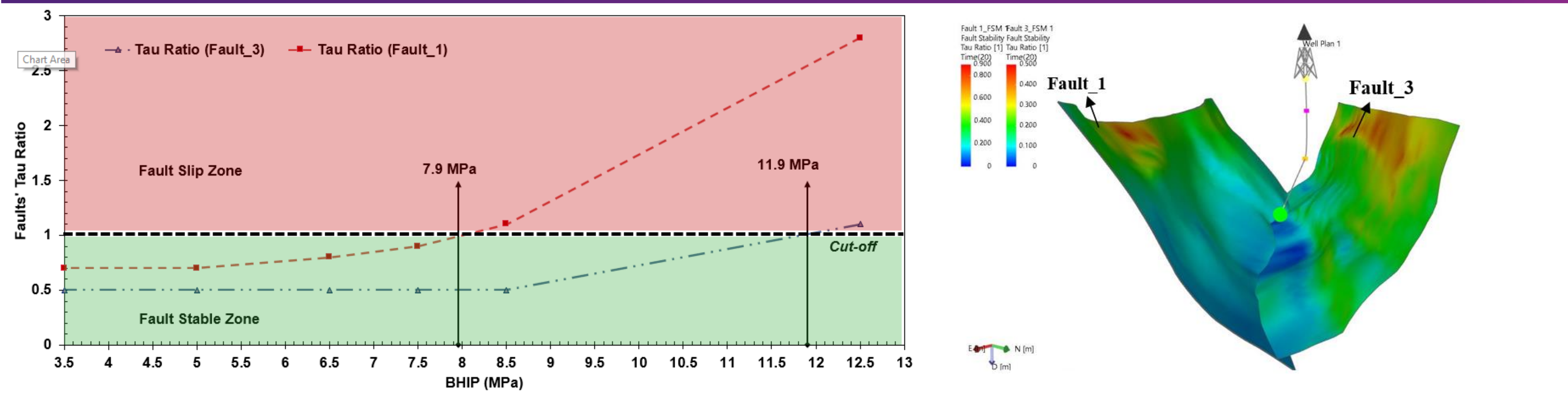

Figure 5: Faults' Tau ratio versus bottom hole injection pressure change during 20 time-steps of CO_2 injection

Impact of well azimuth and BHIP on surface uplifting

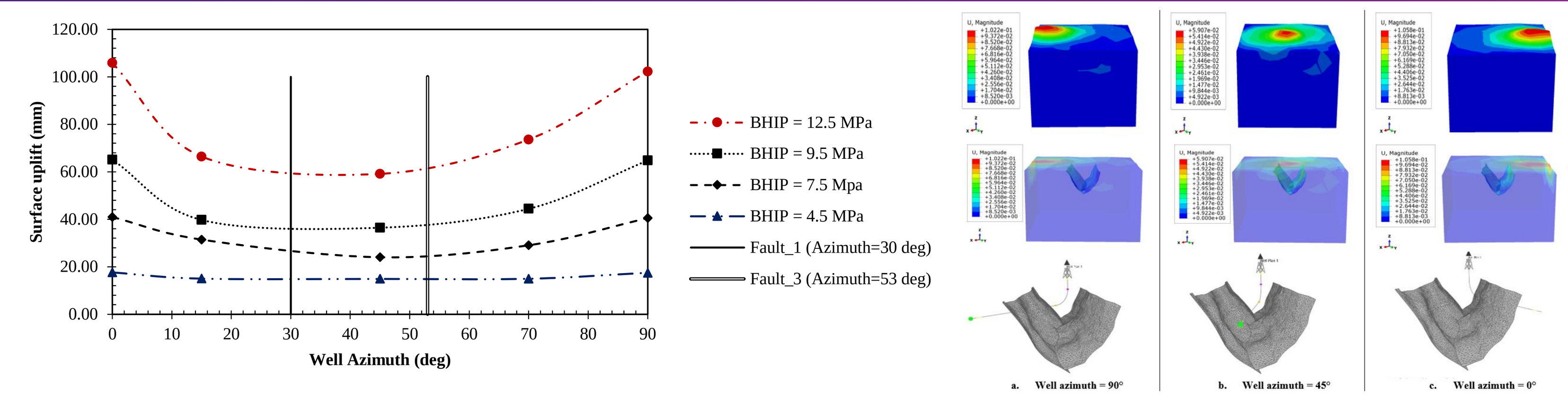

Figure 6: Surface uplifting changes in different well azimuth and BHIP

Impact of well azimuth and BHIP on fault slip

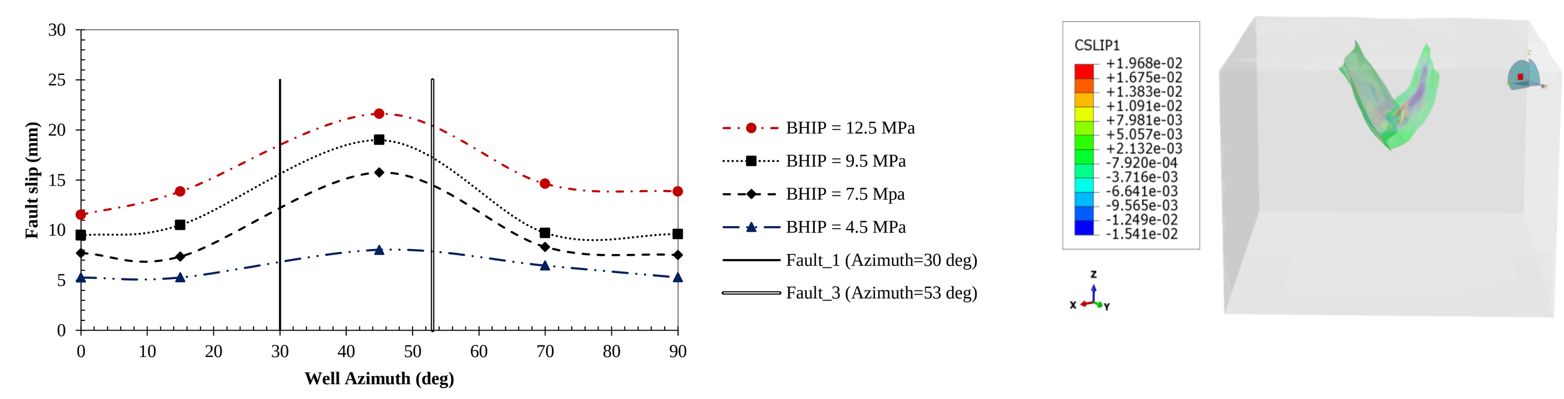

Figure 7: Fault slip versus different well azimuth and BHIP

Impact of well azimuth and BHIP on moment magnitude

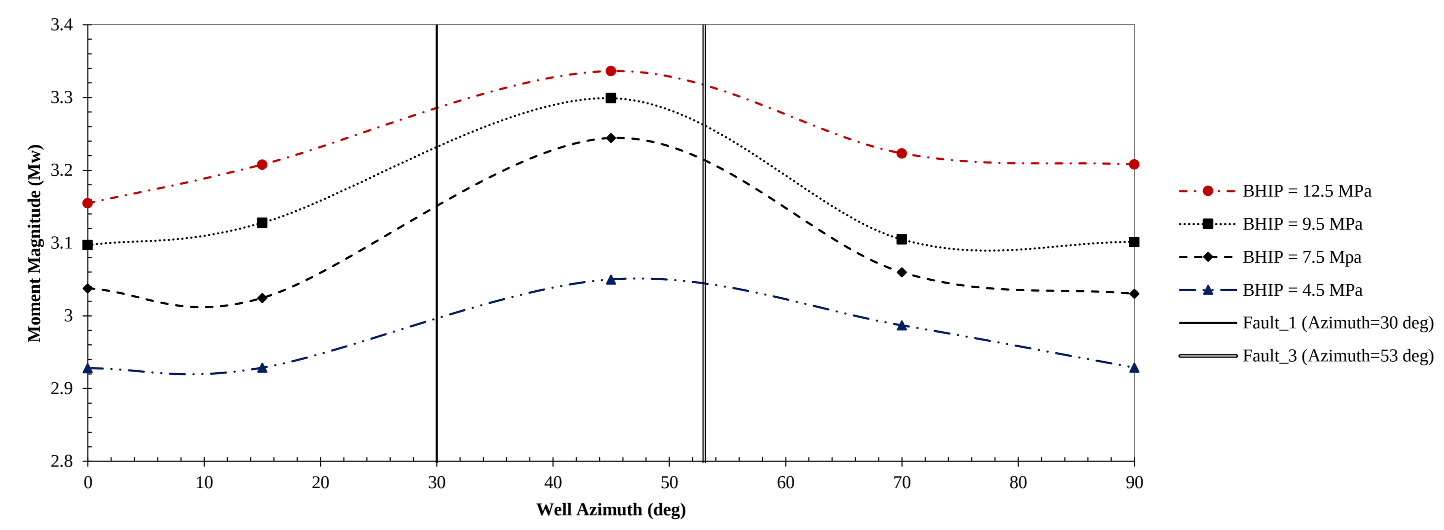

Figure 8: Generated moment magnitude of faults versus different well azimuth and BHIP

Conclusions

(i) Positioning of horizontal wellbores significantly influences fault stability. When placed within a specific azimuth range (30° to 53°) between faults, a substantial risk of fault slip and reactivation ranging from Tau ratio of 2 to 10 is observed.

(ii) The Zone of Failure expands notably when wellbores intersect fault surfaces within the middle zone of faults. The size of ZOF varies from around 0.04 km^2 to 0.1 km^2 with well azimuth angles ranging from 30° to 53°.

(iii) BHIP plays a crucial role in fault stability. Elevated BHIP levels increase the Tau ratio, signifying a higher risk of fault reactivation. Higher BHIP values ranging from around 8 MPa to 12.5 MPa exacerbate the potential for fault reactivation across a range of perforation lengths from 5 m to 100 m.

(iv) Higher BHIP values ranging from 4.5 MPa to 12.5 MPa, lead to increased surface uplift from 14 mm to 60 mm when the well is drilled in the middle zone of faults and around 17 mm to 102 mm when the well is along azimuths of 0° or 90° for the same BHIP increase.

(v) Higher BHIP levels from 4.5 MPa to 12.5 MPa and azimuth angles specifically between 30° to 53° in this case study, contribute to increased fault slip from around 8 mm to 21.6 mm in the fault middle zone. Additionally, seismic moment increased from around 3.0 to 3.3 by raising BHIP from 4.5 MPa to 12.5 MPa.

References

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