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EVALUATING THE IMPACT OF STRESS-INDUCE CHANGES ON CAPROCK INTEGRITY IN THE SAN JUAN BASIN

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Acknowledgements

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Presentation Outline

Introduction → Site Description → Project Objectives

Methodology → Model Description and Setup → Results and Discussion

Conclusion and Recommendations → References

Introduction

- The caprock's geomechanical behavior affects the long-term integrity of storage reservoirs during CO_2 injection.
- Caprock stability depends on in-situ stress, pore pressure, rock strength, and mechanical failure from CO_2 injection.
- Increasing pore fluid pressure redistributes stress and causes geomechanical issues.

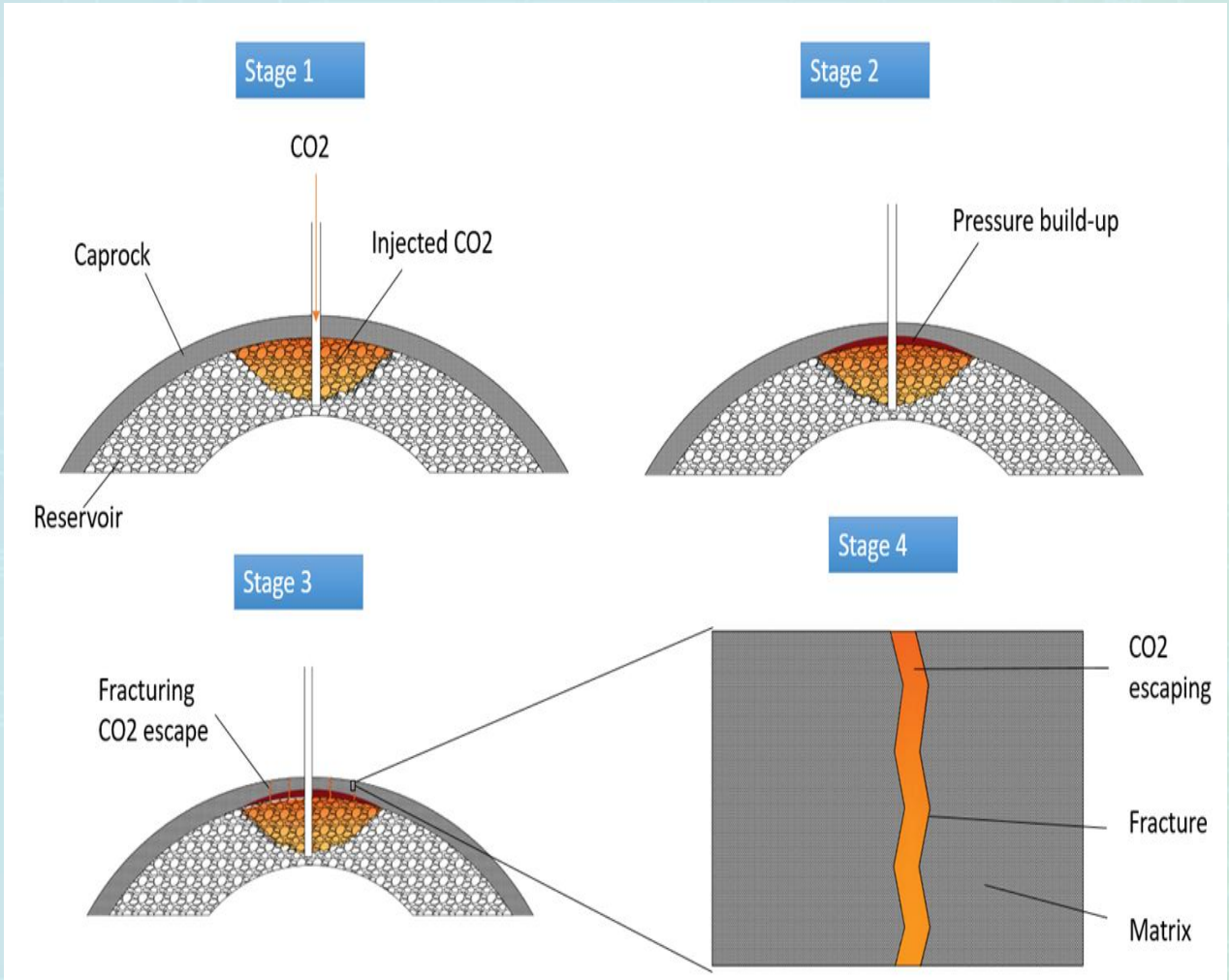


Fig.1: Illustrates CO2 injection and Caprock geomechanical response

Research Objectives

- To develop a coupled hydro-mechanical model incorporating information from the San Juan Basin storage complex.
- Calibrate the hydrodynamic model with historical water injection data from 22 SWD wells.
- Calibrate the coupled model with 1D MEM from the stratigraphic well.
- Evaluating the impact of stress-induced changes on cap-rock long-term structural stability.

Methodology

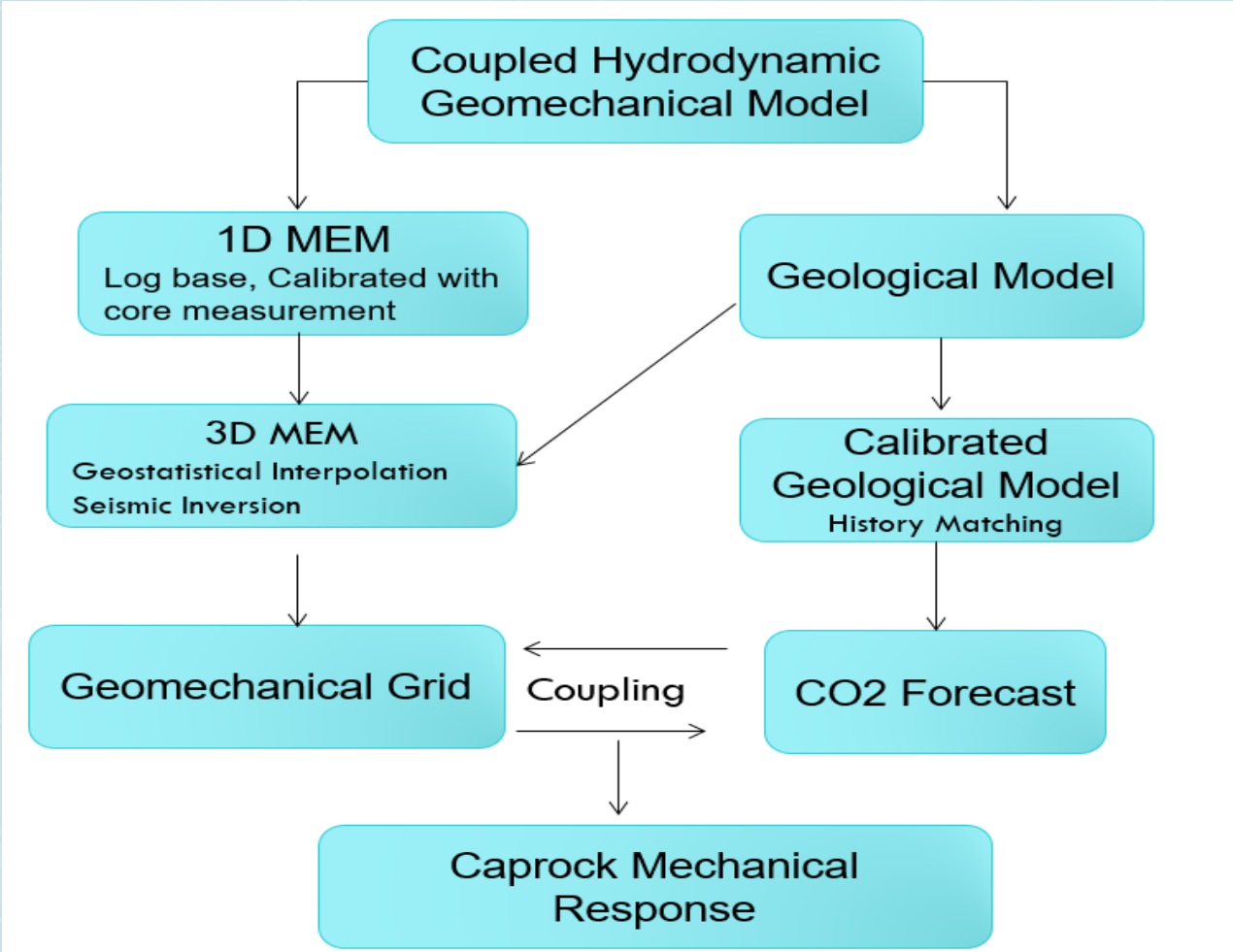


Fig.2 : Framework of Integrated coupled modeling

Site Description

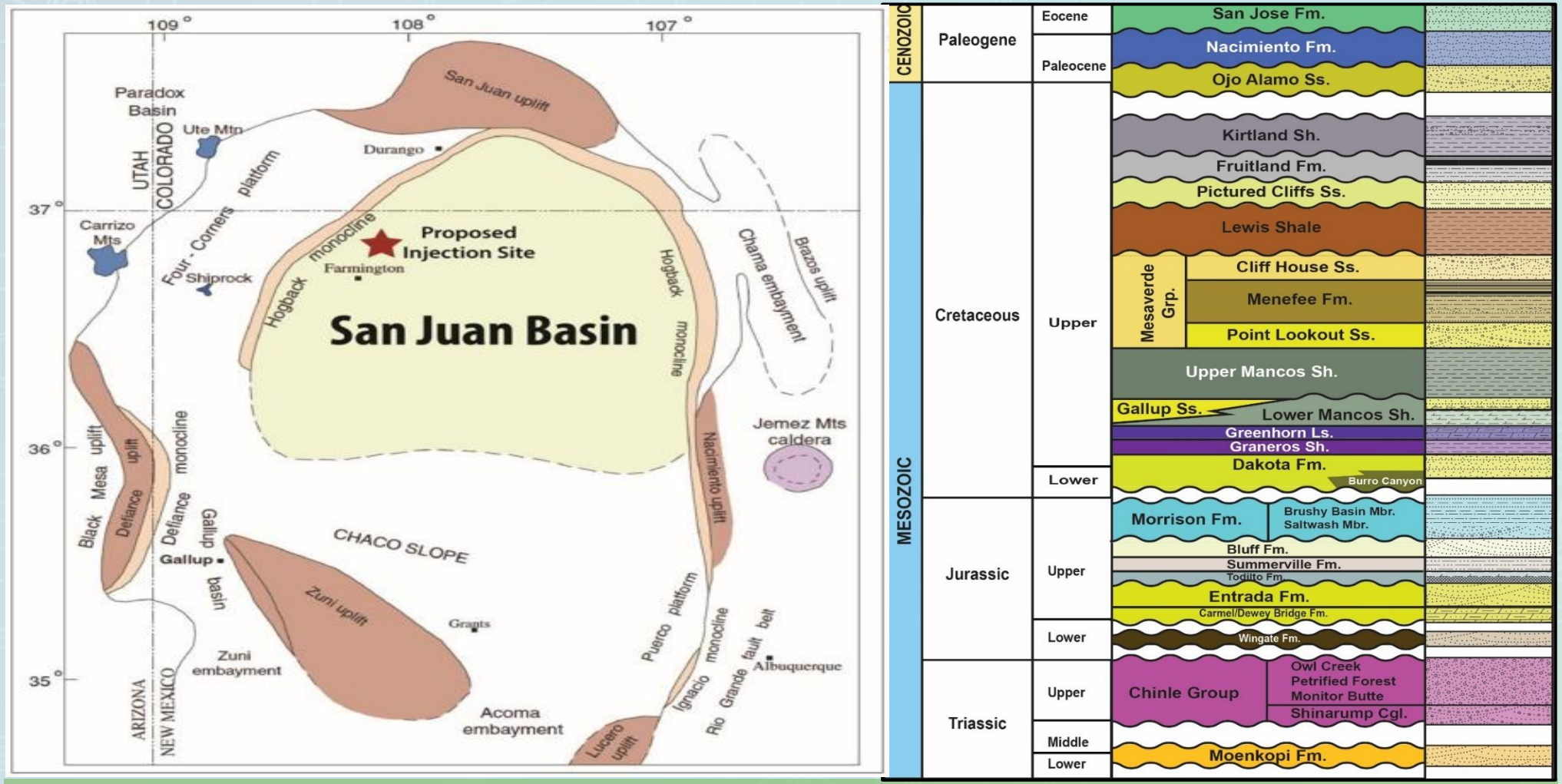


Fig.3: Location and Stratigraphic Section of San Juan Basin

Reservoir and Final Geomechanical grid

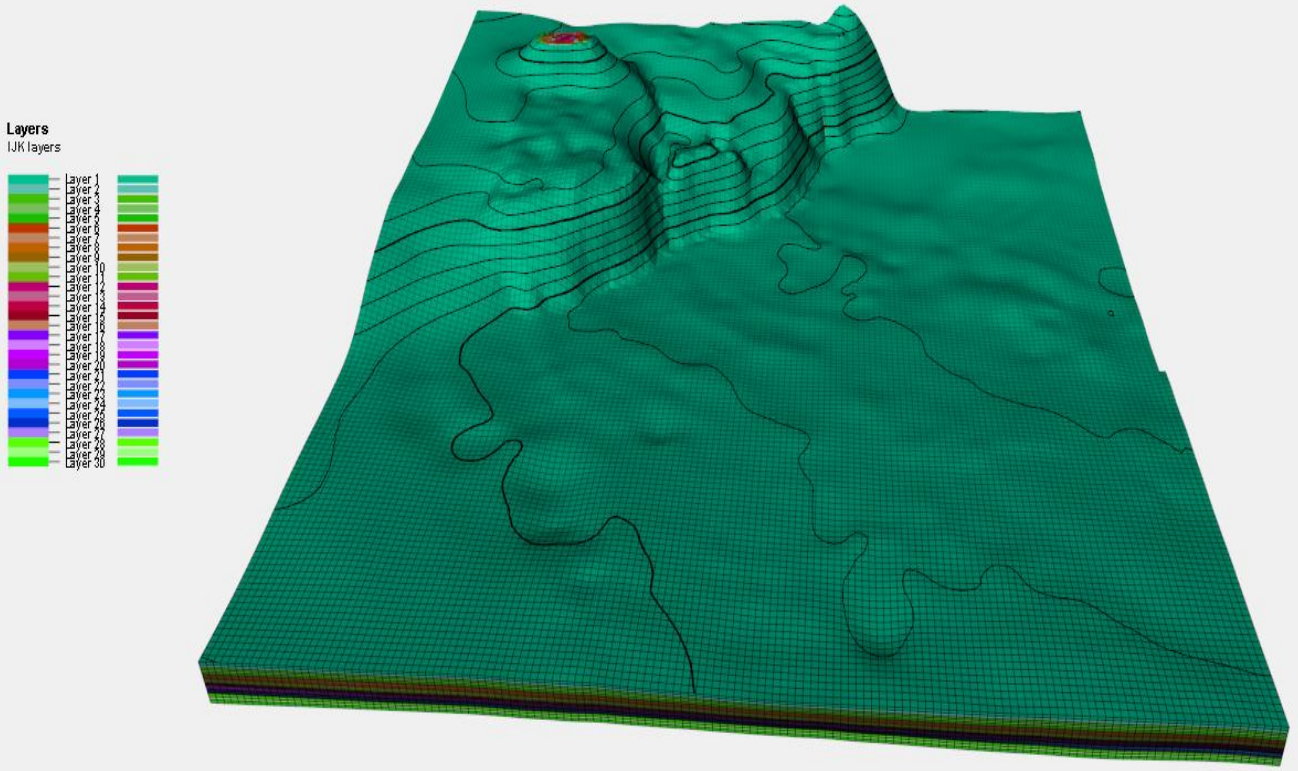


Fig.4: Main 3D Reservoir grid

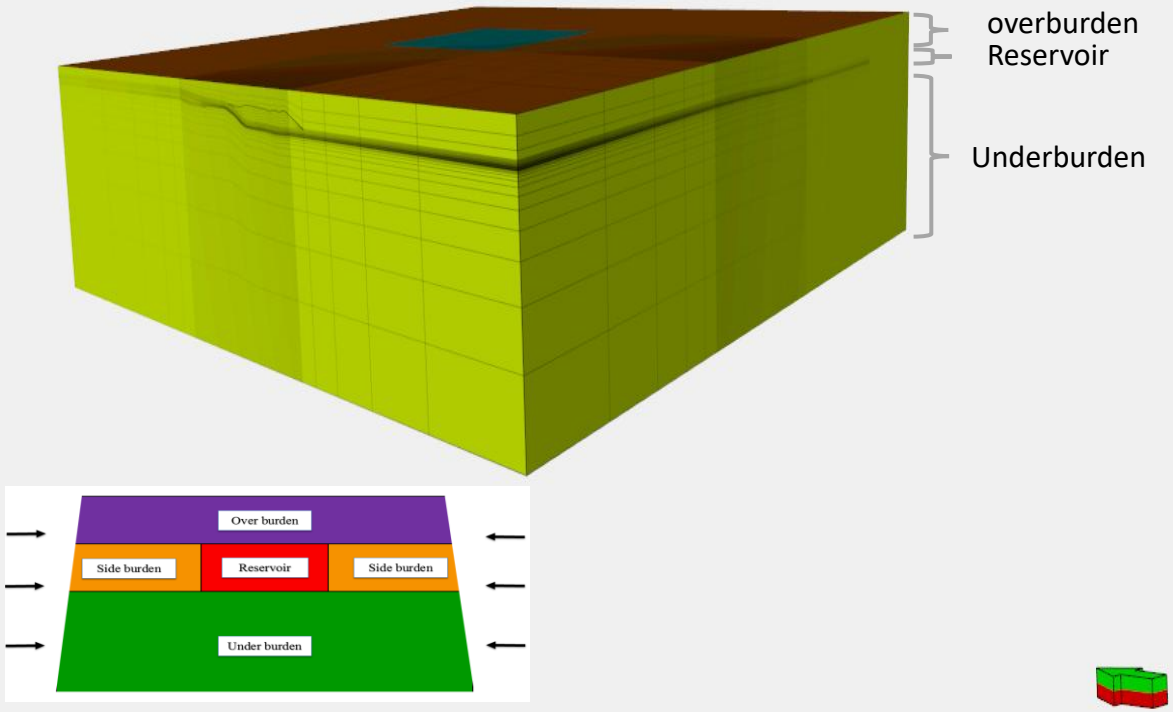


Fig.5: Final geomechanical grid

Model Description and Setup

Table 1: Shows Simulation setup	
Size	40x40 mile
Grid cells in (I,J,K) (ft)	143x144x37
Number of grid cells	761904
Dimension of a grid cell(ft)	1500x1500
Elevation(ft)	6223
Number of layers	30
Average thickness	139 ft
Permeability of caprock	3.9e-6 – 2.8e-5 mD
Porosity of caprock	0.3 – 0.8%
Pore pressure gradient	0.42 psi/ft
Formation fracture gradient	0.62 psi/ft
Formation temperature gradient	0.0194 F/ft
Water salinity	34000 ppm
Initial water saturation	100%

CO2 Injection Setup	
Bottom hole pressure	4680 psi(90% of fracture pressure)
Wellhead temperature	60F
Composition of injection fluid	100%CO2
Injection rate	20 MMSCFD over 30 years

Results for History Match

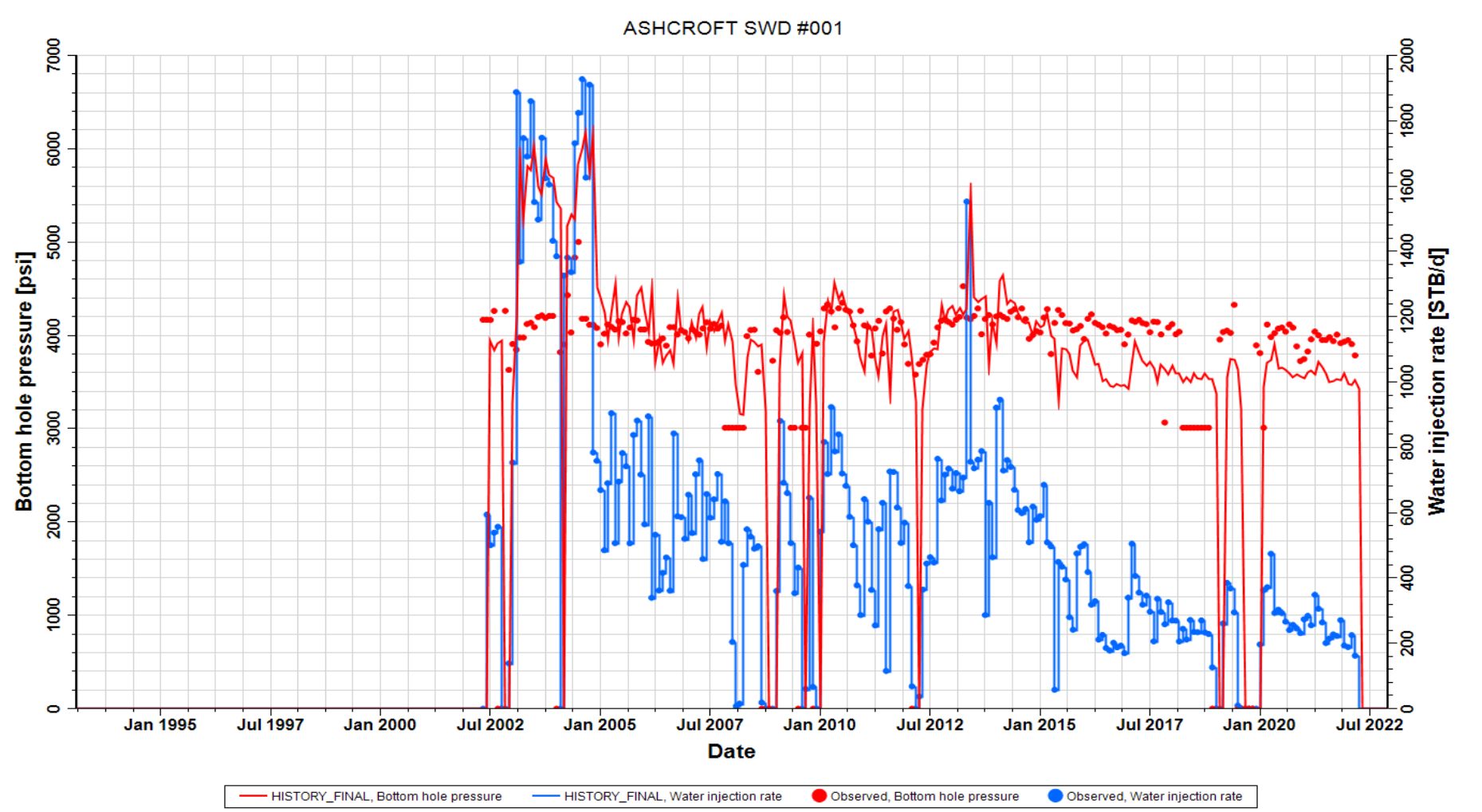


Fig.8 : BHP and Water injection rate of history matched results

Results for CO2 Forecast

Fig.10 : Illustrates CO2 plume after 30years of CO2 injection

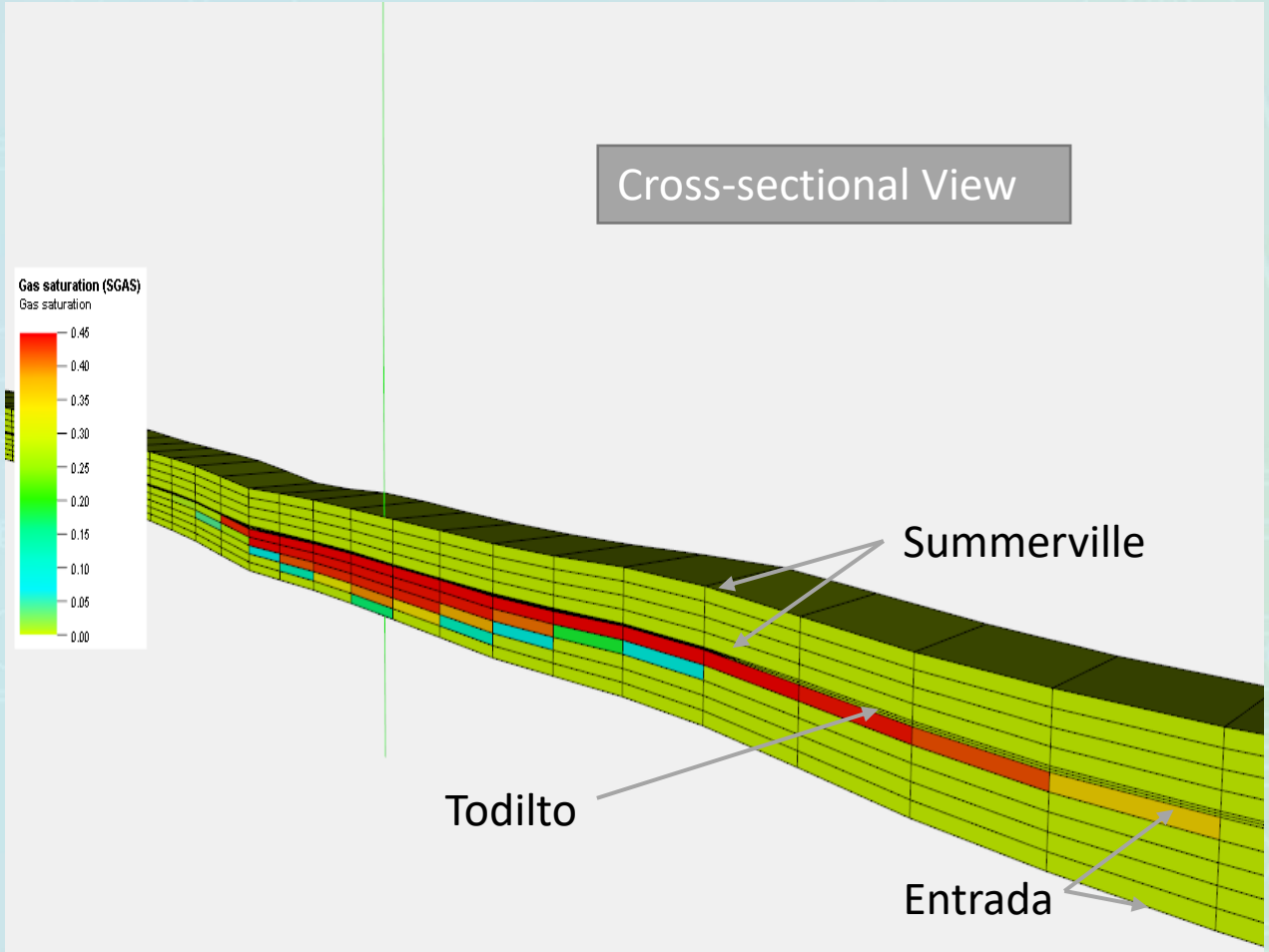


Fig.11 : Cross-sectional View of CO2 plume after 30years of CO2 injection

Results for CO2 Forecast

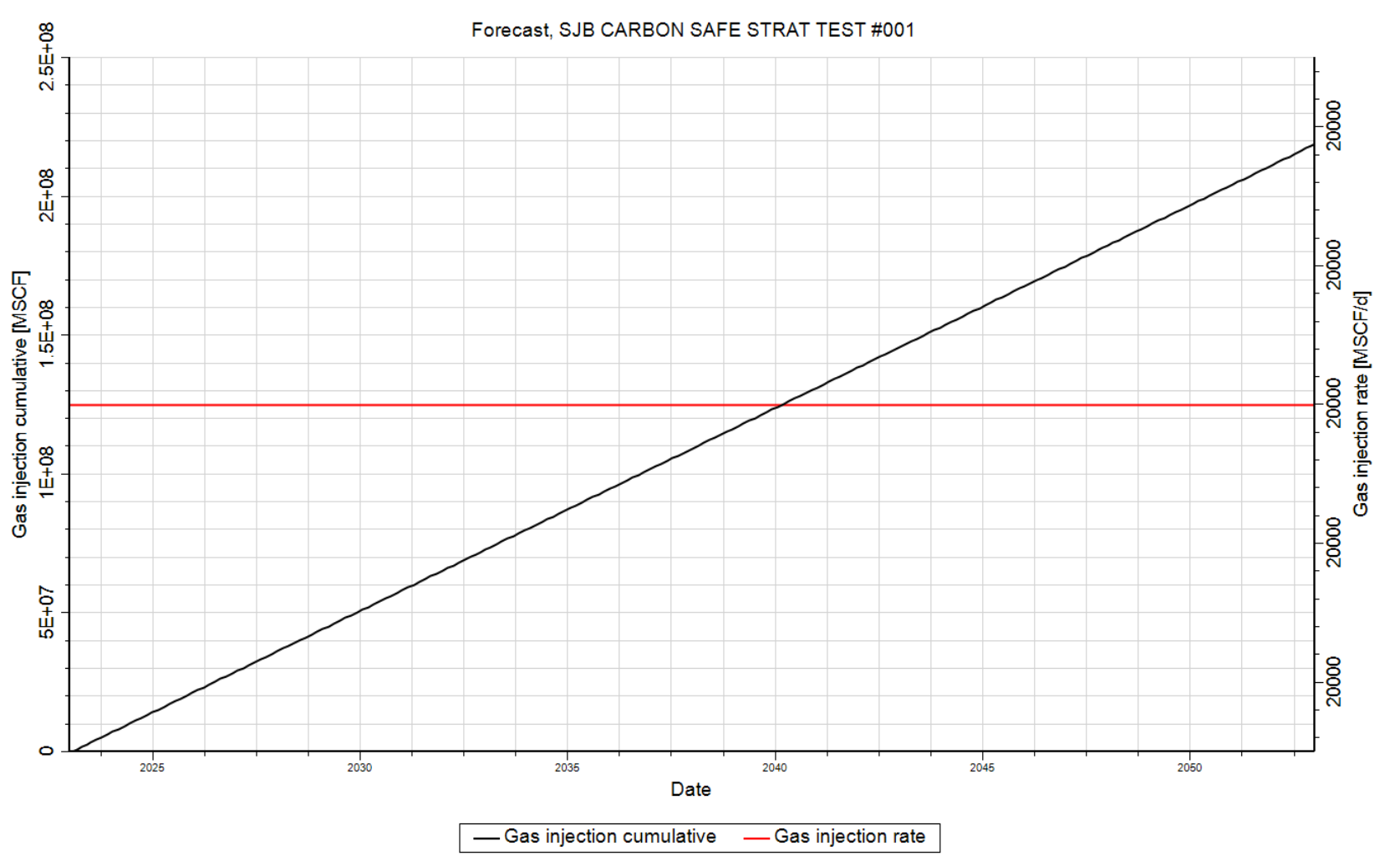


Fig.12 : Gas injection rate and gas injection cumulative

Results for CO2 Forecast

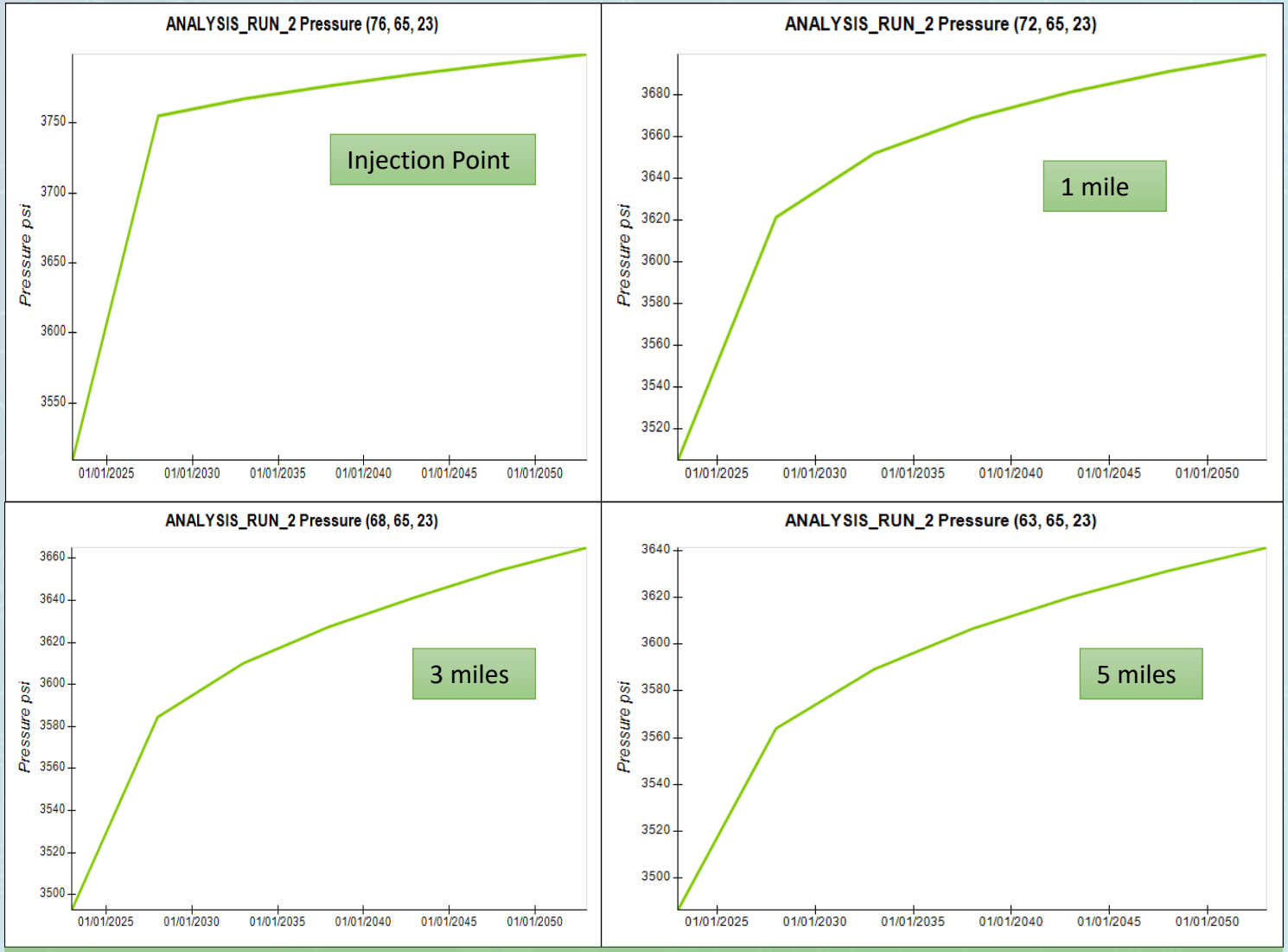


Fig.14 : Pressure evolution at different locations after 30years of CO2 injection

Investigation Point	Pressure difference (psi)
Injection point	300
1 mile	200
3 mile	160
5 mile	150

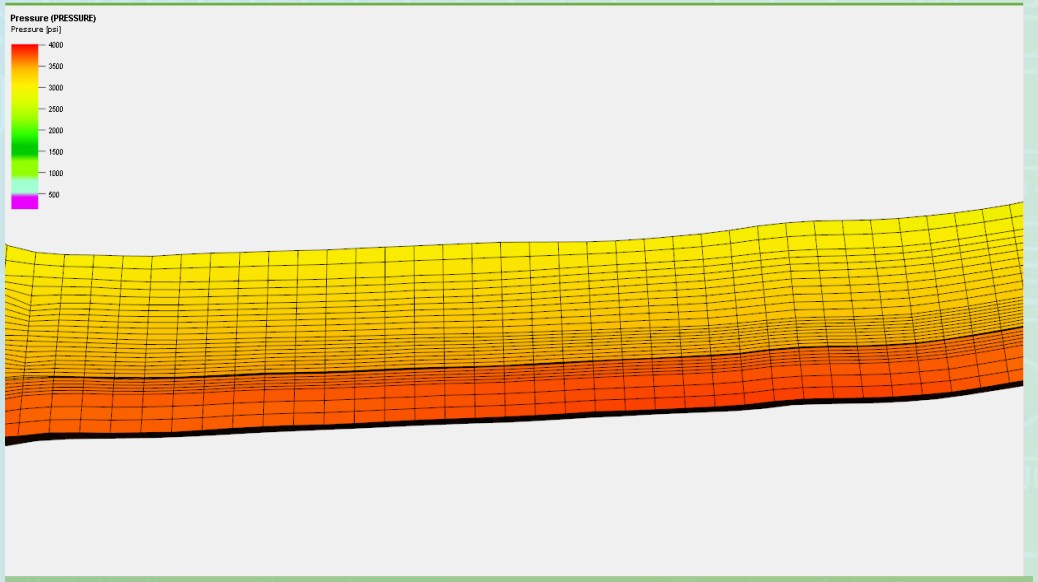


Fig.15 : Pressure front after 30years of CO2 injection

Results for CO2 Forecast

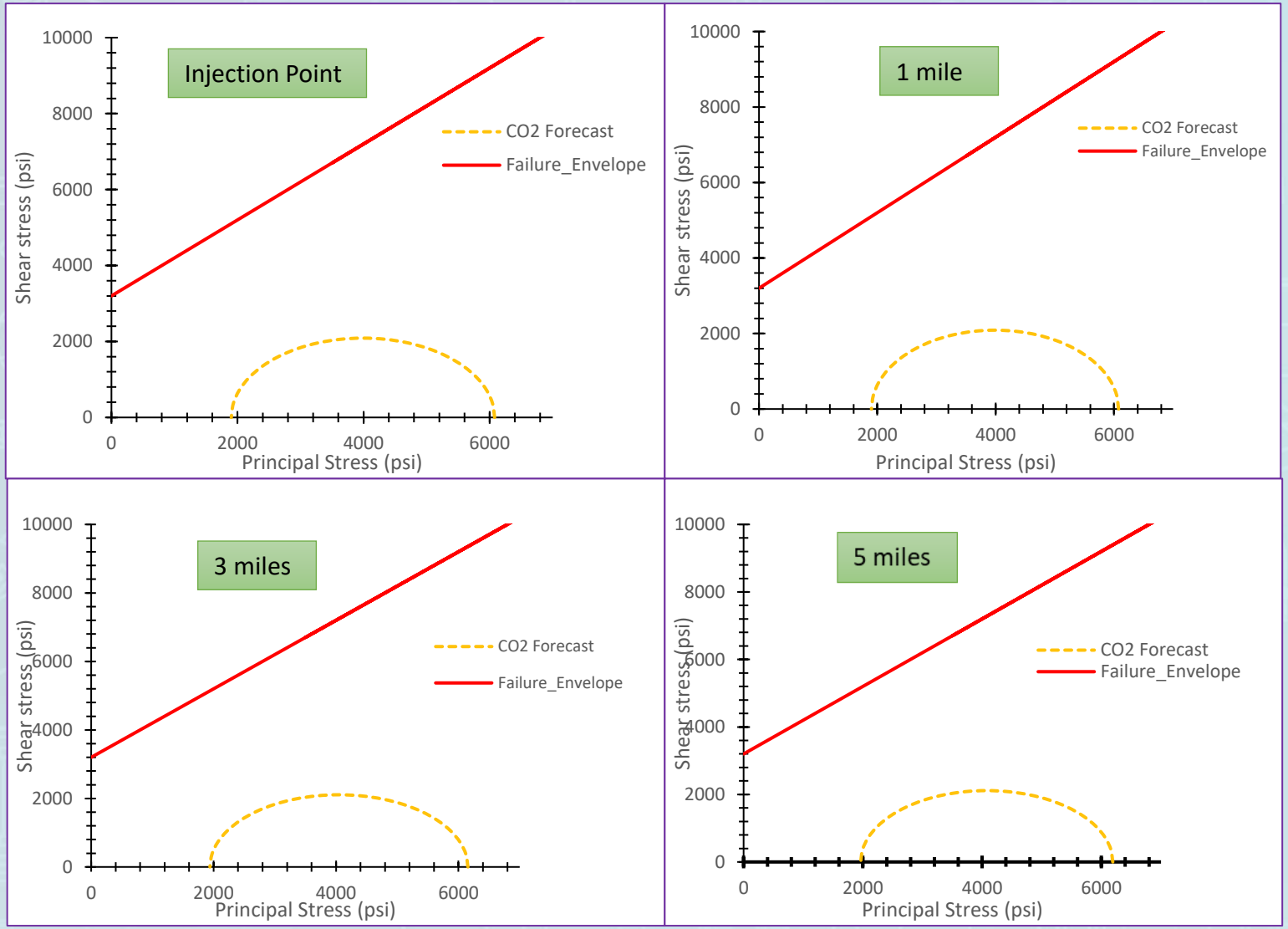
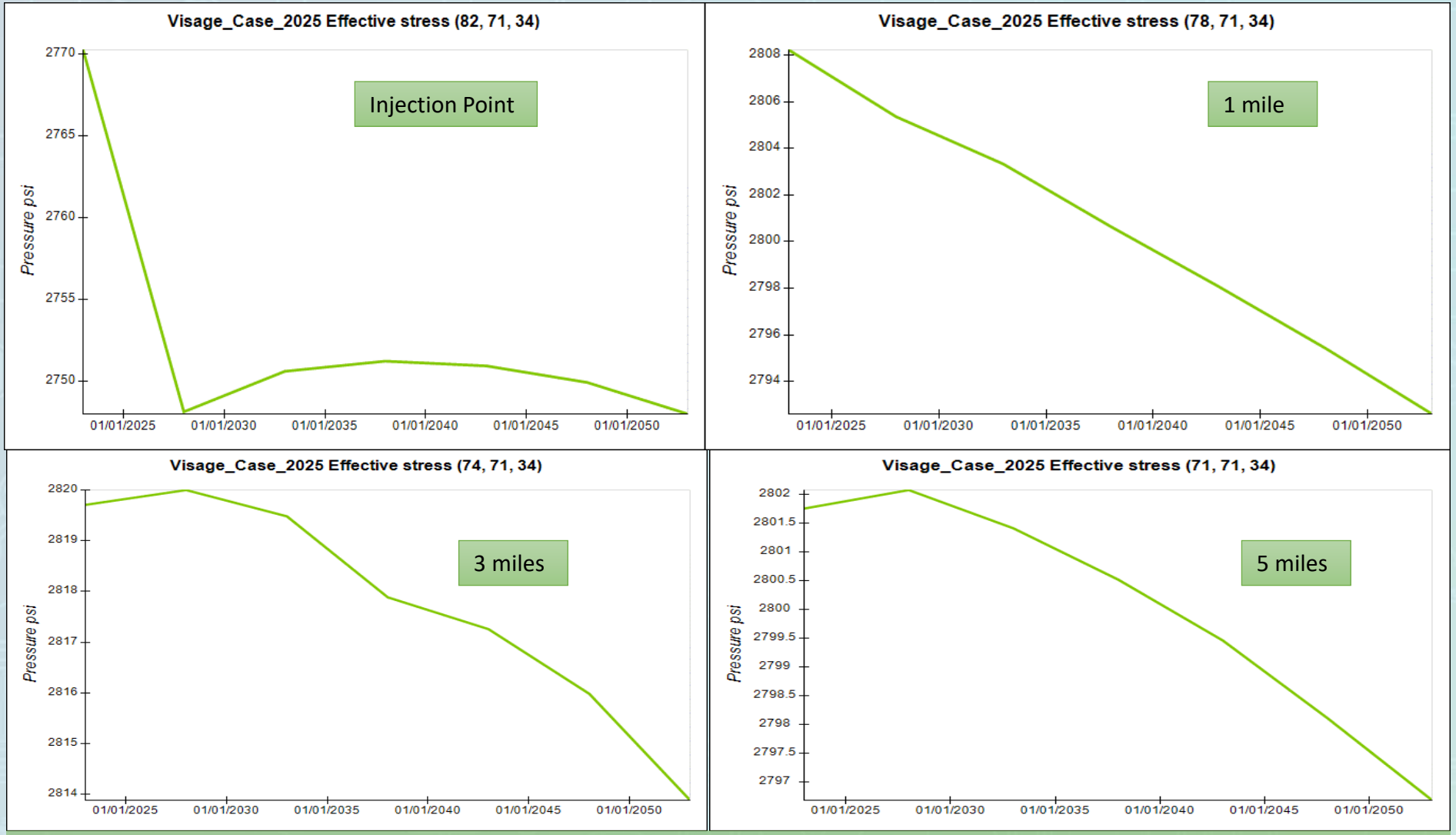


Fig.19 : Mohr-Coulomb at different locations after 30years of CO2 injection

Investigation Point(differences)	Difference (psi)	
	Minimum Principal stress	Maximum Principal stress
Injection point and 1 mile	47	72
Injection point and 3 mile	61	97
Injection point and 5 mile	84	134

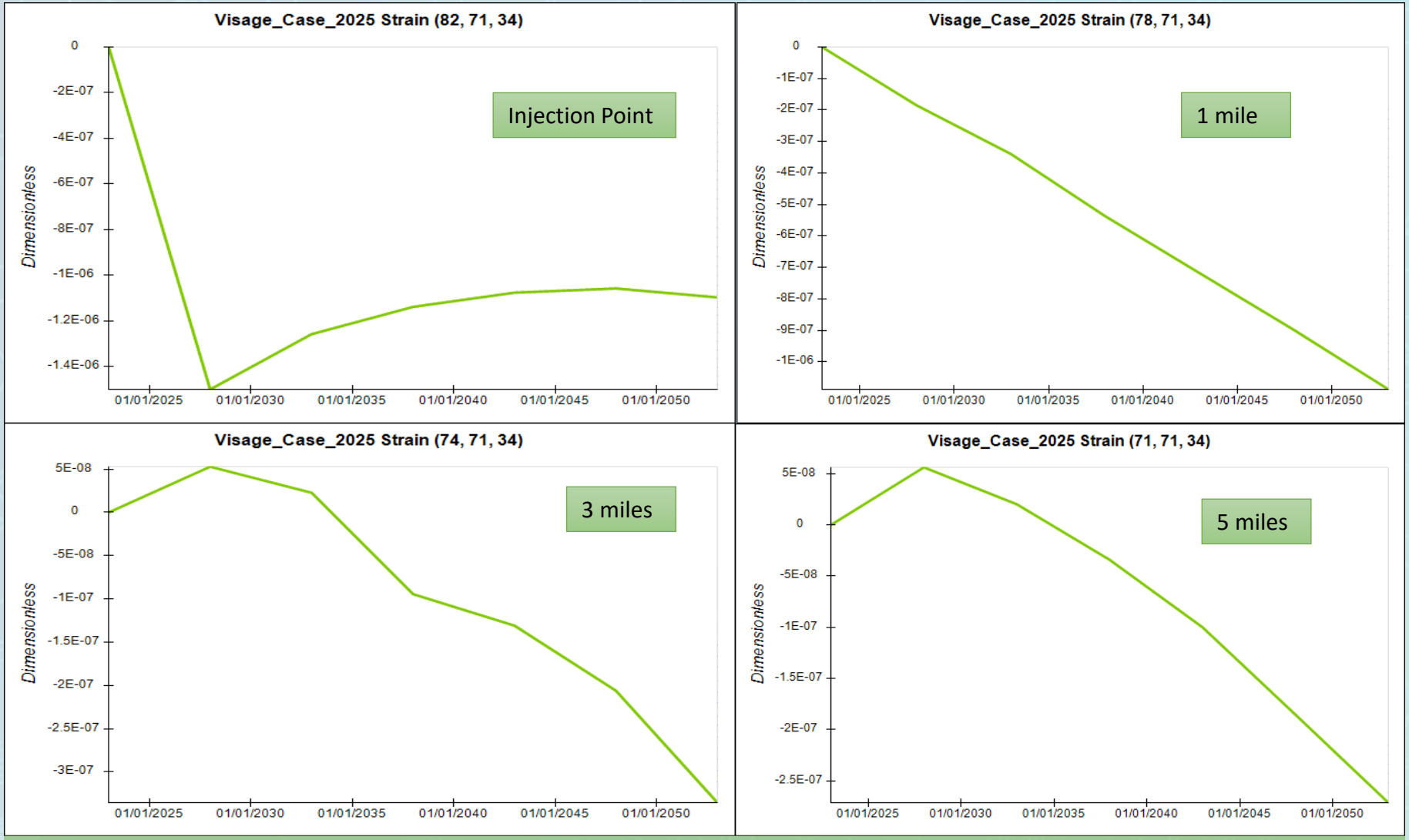
Results for CO2 Forecast



Investigation Point	Pressure difference (psi)
Injection point	20
1 mile	14
3 mile	6
5 mile	5

Fig.16 : Effective stress at different locations after 30years of CO2 injection

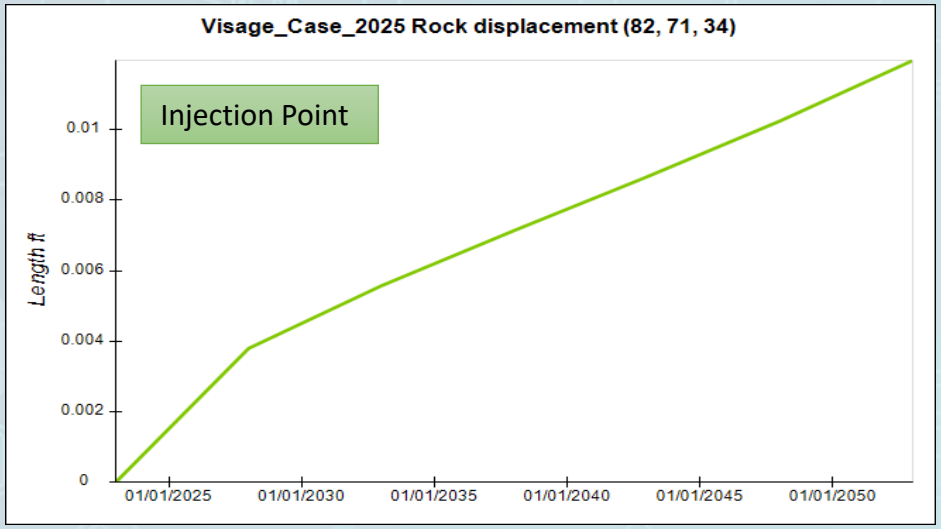
Results for CO2 Forecast

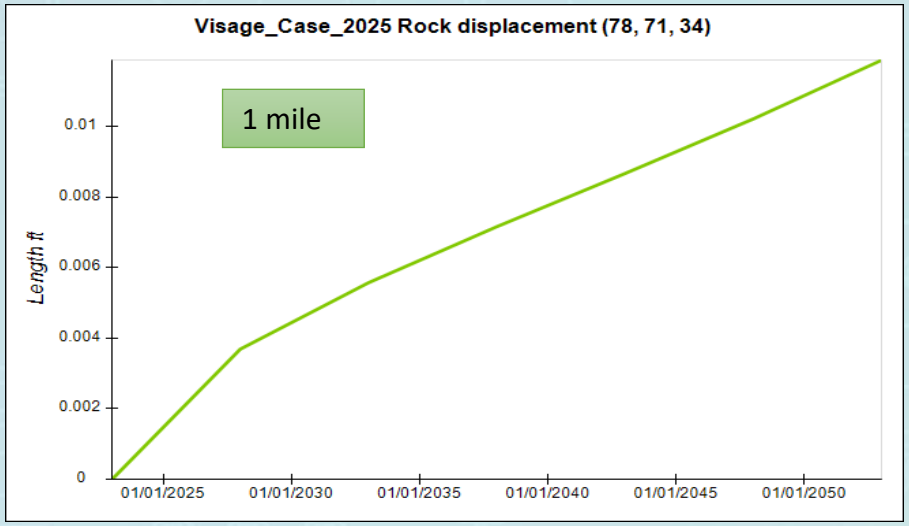


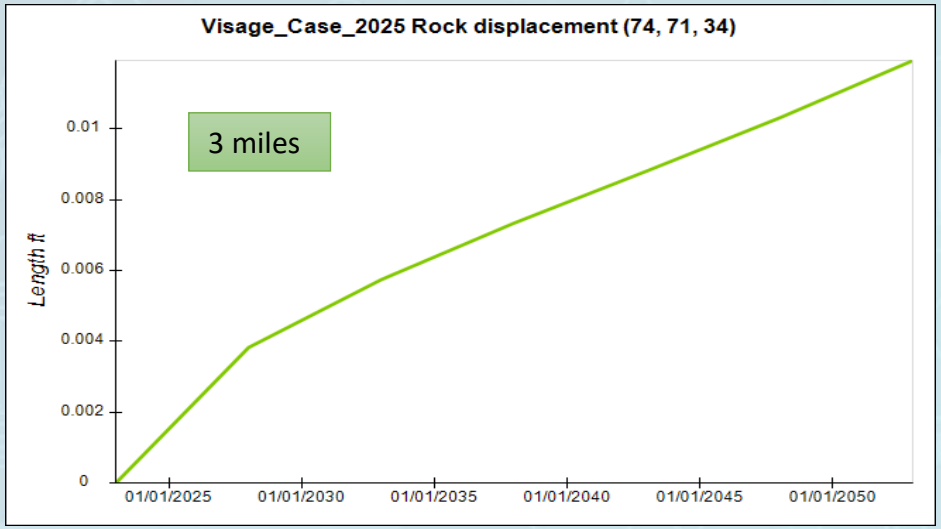
Investigation Point	Strain difference (Micro-strain)
Injection point	1.4
1 mile	1.0
3 mile	0.25
5 mile	0.2

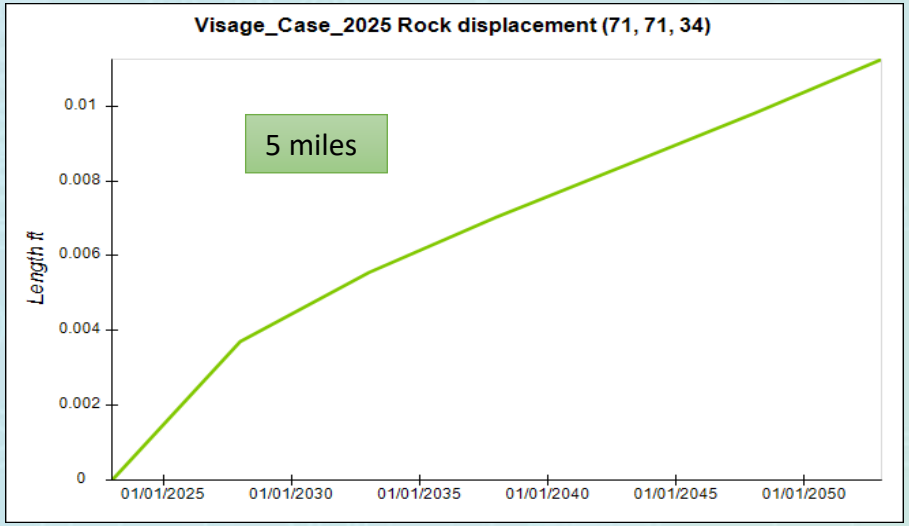
Fig.17 : Strain at different locations after 30years of CO2 injection

Results for CO2 Forecast









Investigation Point	Maximum difference (ft)
Injection point	0.01
1 mile	0.01
3 mile	0.01
5 mile	0.01

Fig.18 : Uplift at different locations after 30years of CO2 injection

Results for Post CO2 Injection

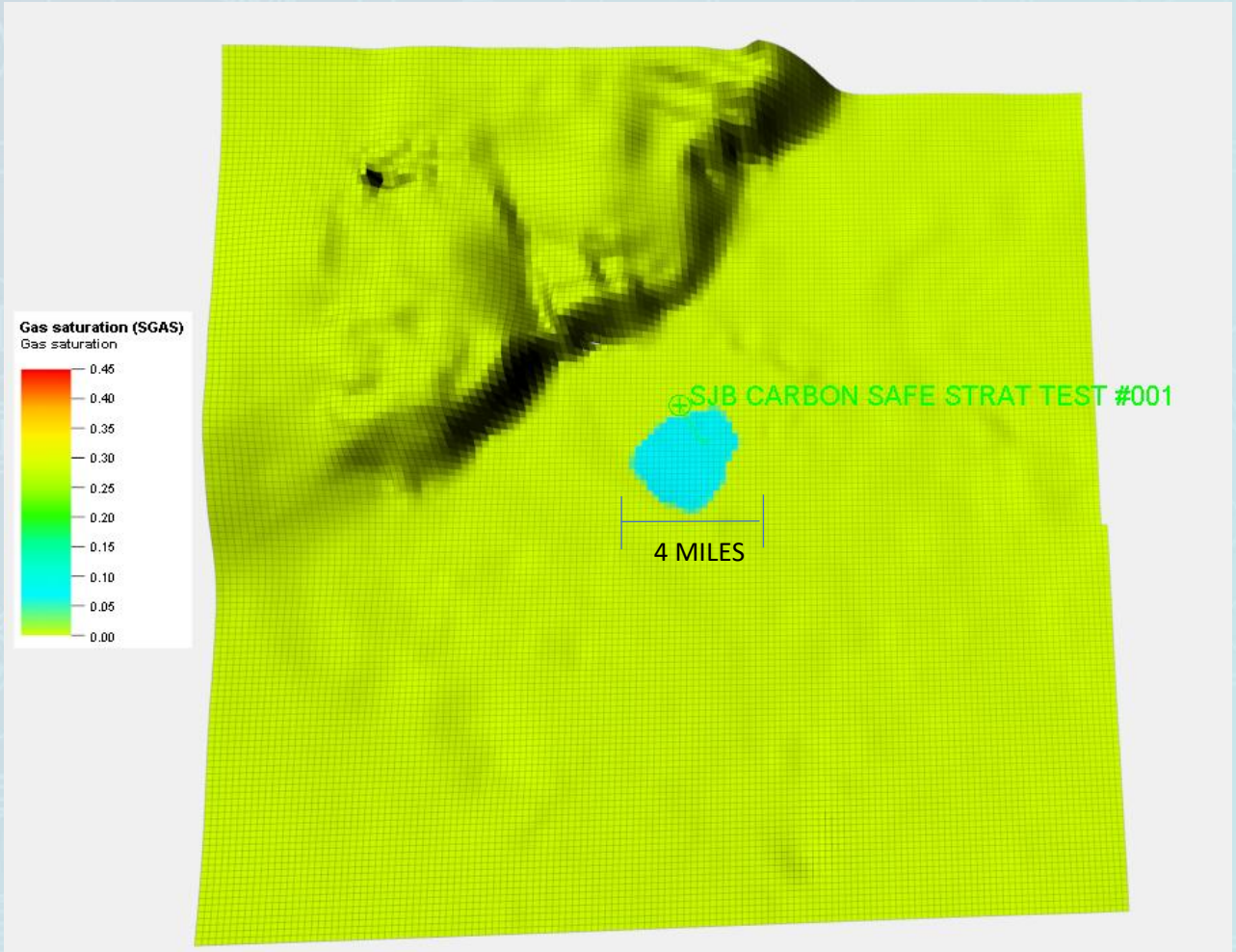


Fig.20 : Illustrates CO2 plume after 30years of CO2 injection

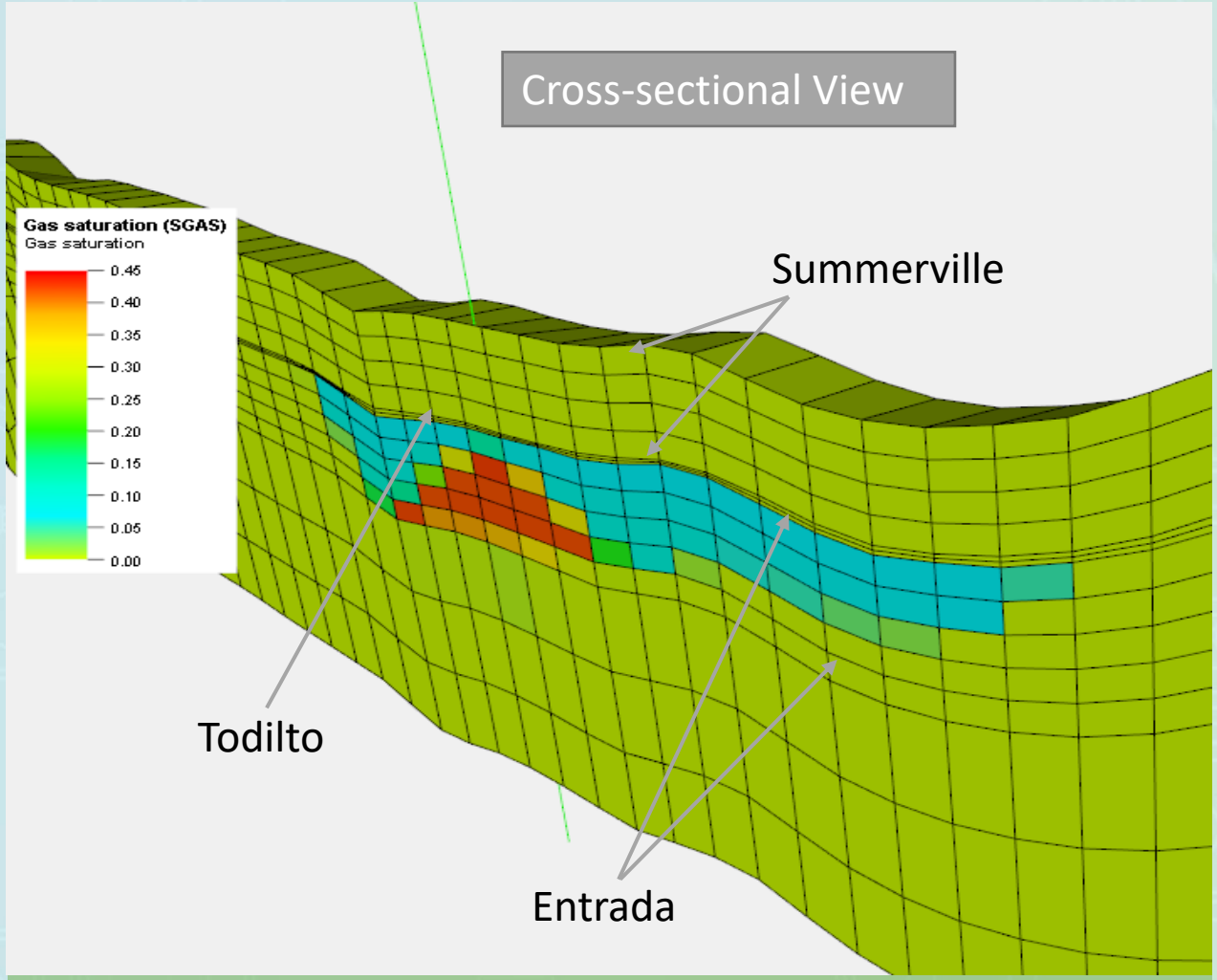
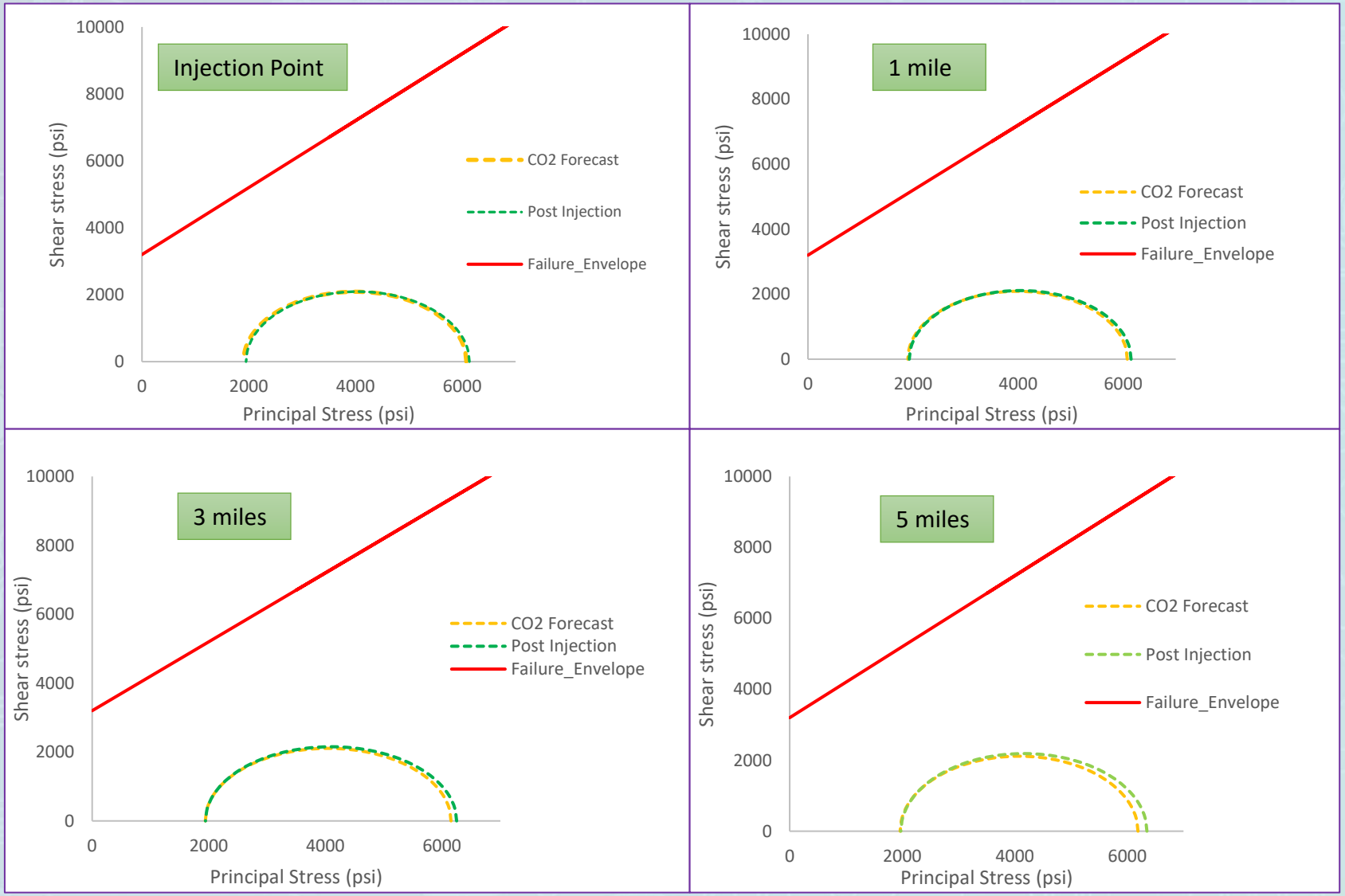


Fig.21 : Cross-sectional View of CO2 plume after 30years of CO2 injection

Results for Post CO2 Injection



Investigation Point(differences)	Difference (psi)	
	Minimum Principal stress	Maximum Principal stress
Injection point and 1 mile	51	86
Injection point and 3 mile	68	112
Injection point and 5 mile	87	162

Fig.22 : Mohr-Coulomb at different locations after 50 years of observation

Conclusion

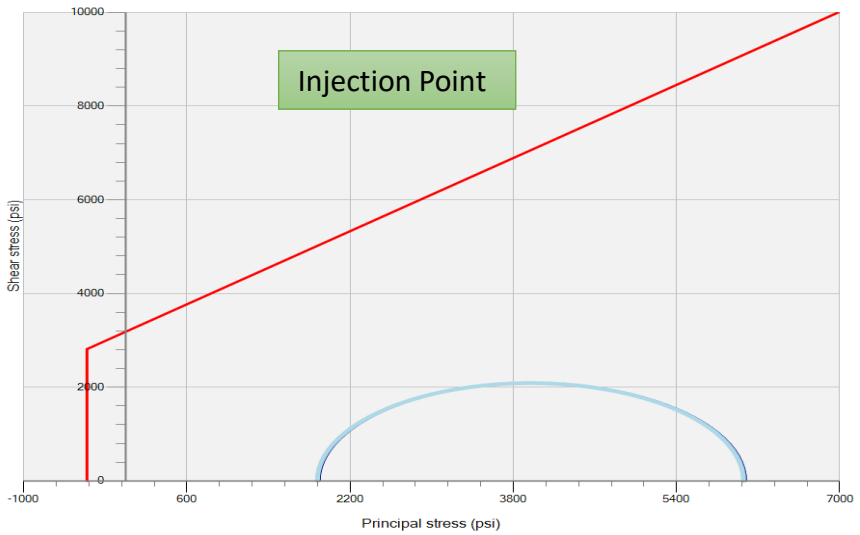
- Effective stress decreases due to pore pressure increase but the rate of reduction decreases moving away from the injection well.
- Strain recorded within and after the 30 years of injection is in micro-strain magnitude.
- There is permeability update within the caprock but the increase in permeability is very small and no change was seen moving away from the injection well.
- The analysis of the Mohr circle model shows a stable seal after 30 years of injection and 50 years of observation.
- Fifty years of monitoring the CO2 injection shows the seals is not compromised and the stress on the Caprock is reduced. This shows that the CO2 operation can be carried out without any geomechanically severe impact.

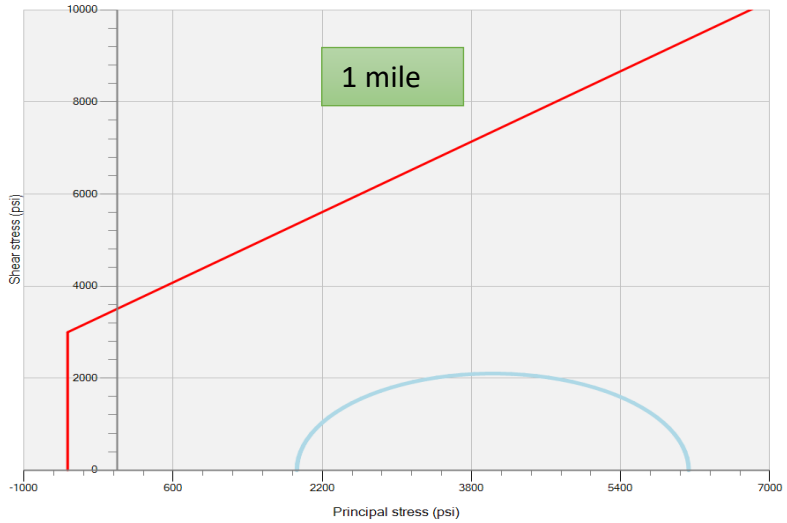
Thank you

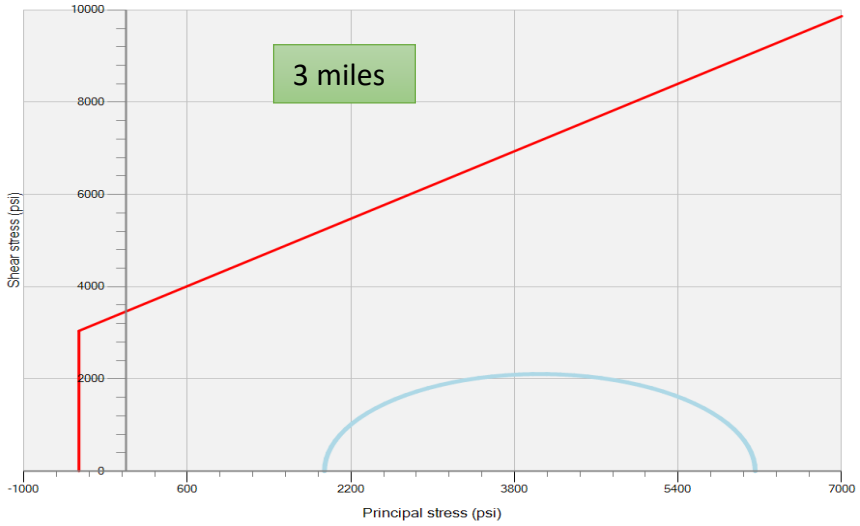
References

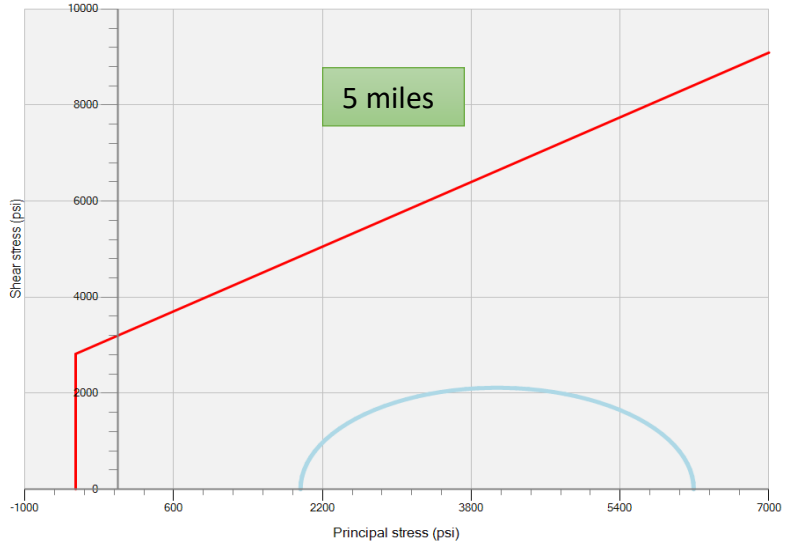
- Karimnezhad, M., Jalalifar, H., & Kamari, M. (2014). Investigation of caprock integrity for CO2 sequestration in an oil reservoir using a numerical method. *Journal of Natural Gas Science and Engineering*, *21*, 1127-1137.
- Shukla, R., Ranjith, P. G., Choi, S. K., & Haque, A. (2011). Study of caprock integrity in geosequestration of carbon dioxide. *International Journal of Geomechanics*, *11*(4), 294-301.
- Liu, H., Hou, Z., Were, P., Gou, Y., & Sun, X. (2016). Numerical investigation of the formation displacement and caprock integrity in the Ordos Basin (China) during CO2 injection operation. *Journal of Petroleum Science and Engineering*, *147*, 168-180.
- Zoback, M.D., 2010. *Reservoir geomechanics*. Cambridge university press.
- Bohloli, B., Skurtveit, E., Grande, L., Titlestad, G. O., Børresen, M., Johnsen, Ø., & Braathen, A. (2014). Evaluation of reservoir and cap-rock integrity for the Longyearbyen CO2 storage pilot based on laboratory experiments and injection tests.
- Han, Y., Liu, H. H., Alruwaili, K., & AlTammar, M. J. (2024, February). Wellbore and caprock integrity during CO2 injection in saline aquifer. In *International Petroleum Technology Conference* (p. D021S053R006). IPTC.
- Vilarrasa, V., & Makhnenko, R. Y. (2017). Caprock integrity and induced seismicity from laboratory and numerical experiments. *Energy Procedia*, *125*, 494-503.
- Busch, A., Amann, A., Bertier, P., Waschbusch, M., & Krooss, B. M. (2010, November). The significance of caprock sealing integrity for CO2 storage. In *SPE International Conference on CO2 Capture, Storage, and Utilization* (pp. SPE-139588). SPE.

Mohr–Coulomb diagram for matrix failure criteria









Investigation Point(differences)	Difference (psi)	
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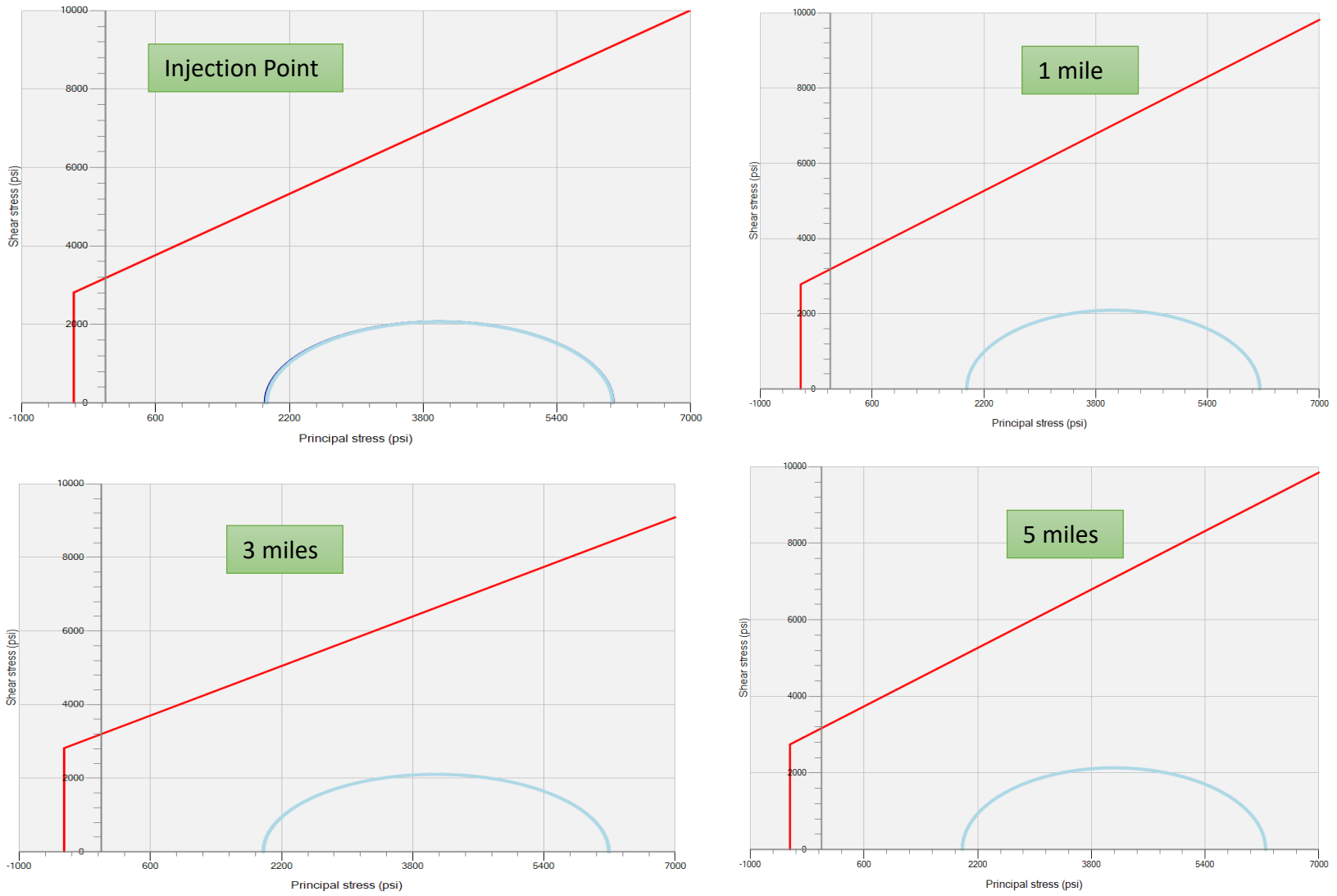
Injection point and 3 mile	61	97
Injection point and 5 mile	84	134

Fig.19 : Mohr-Coulomb at different locations after 30years of CO_2 injection

Post Injection analysis on the caprock



Investigation Point(differences)	Difference (psi)	
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Fig.22 : Mohr-Coulomb at different locations after 30years of CO_2 injection

Mohr–Coulomb diagram for matrix failure criteria on the reservoir

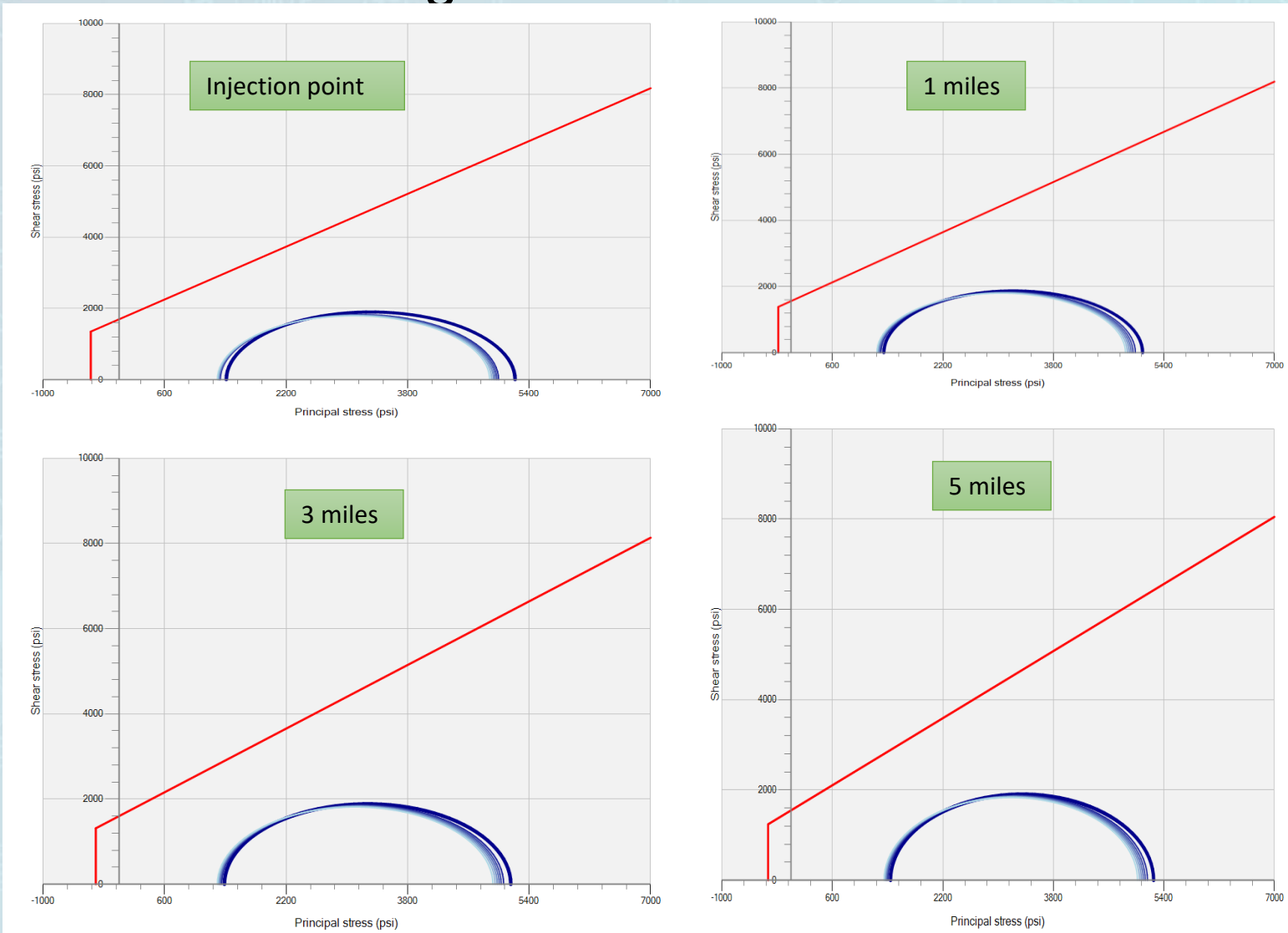

Fig.23 : Mohr-Coulomb at different locations after 30years of CO_2 injection(Reservoir)

Post Injection analysis on the Reservoir

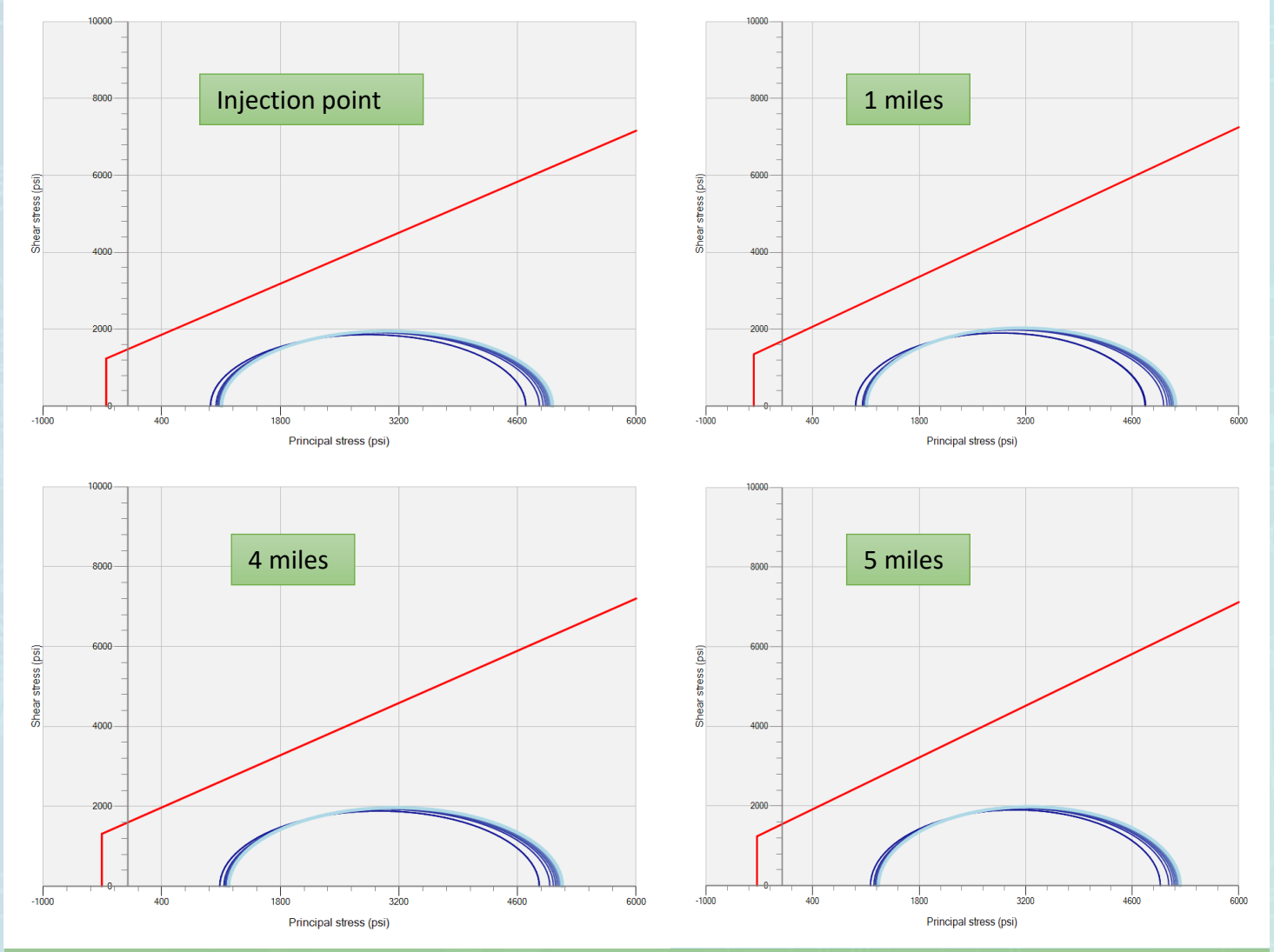

Fig.24 : Mohr-Coulomb at different locations after 50years of observation

Permeability evolution over time through 5 miles distance.