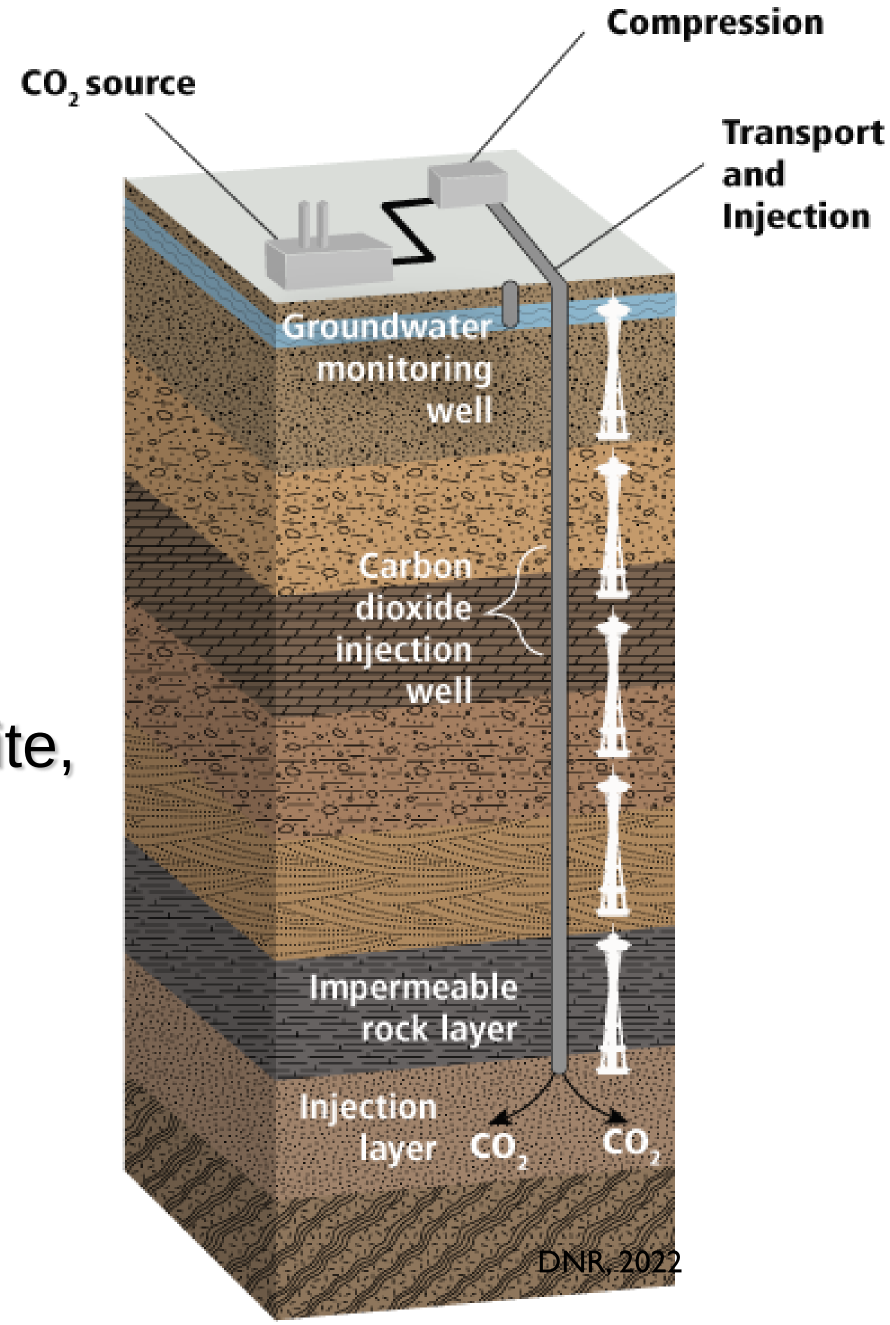
Investigating the CO_2 sequestration potential of the Morrow-B Sandstone in the Farnsworth, Texas hydrocarbon field through numerical models and experimental analysis



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Subsurface Modeling and Simulation Laboratory

Department of Geological Sciences

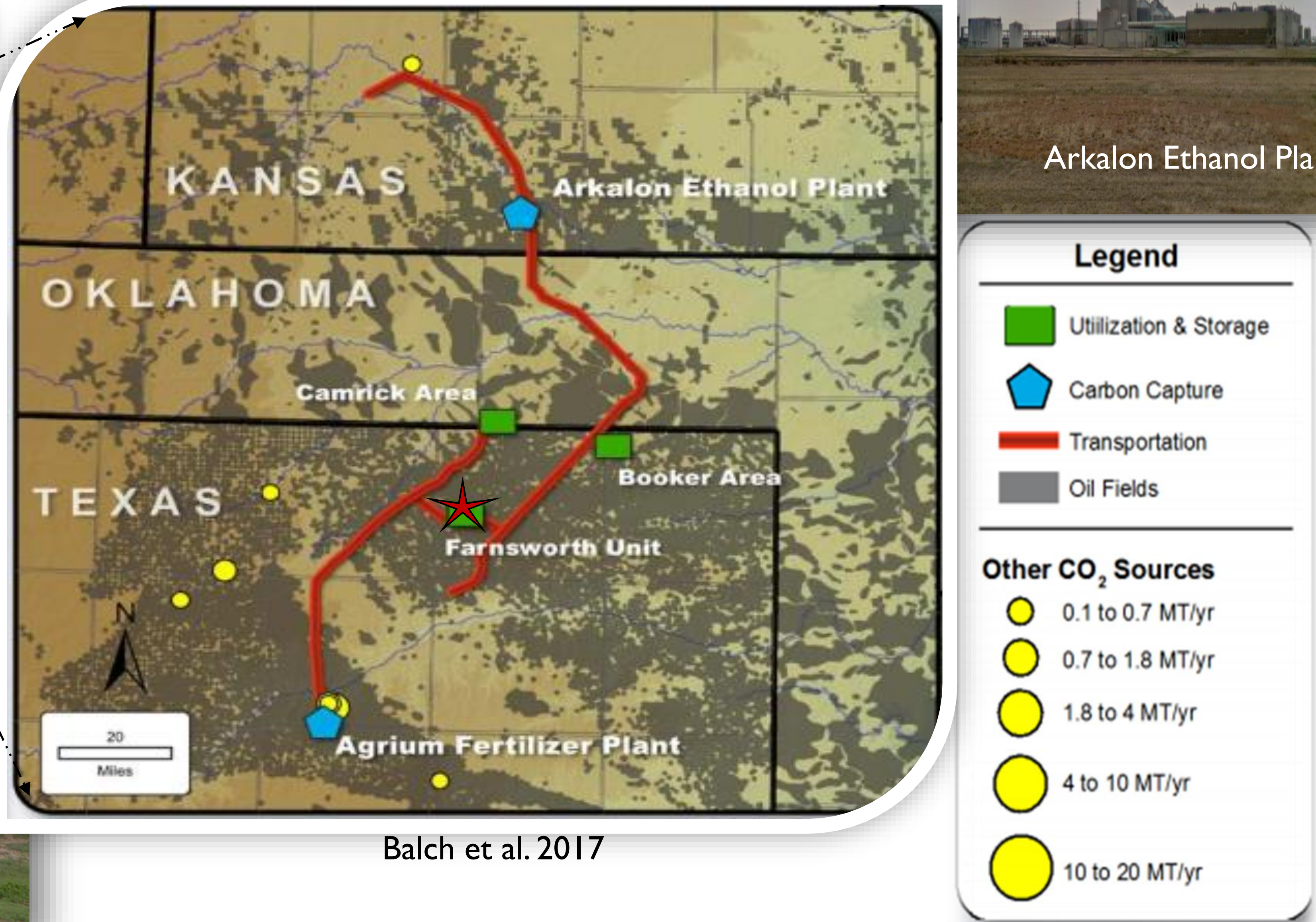
October 11, 2022

University of Missouri

Project Site: Farnsworth Unit (FWU)

Southwest Regional Partnership(SWP)

Carbon Dioxide (CO_2) Supply

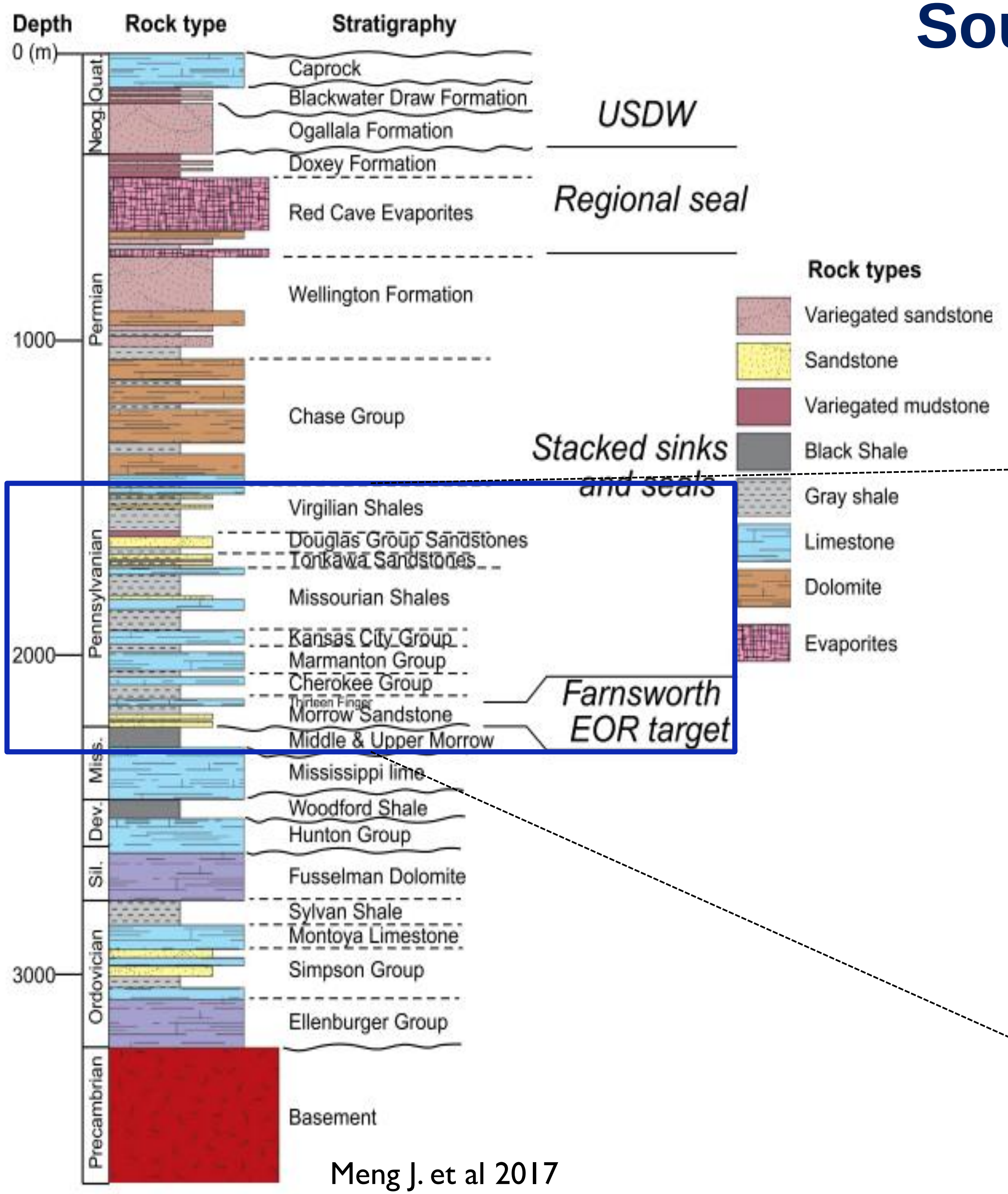


Balch et al. 2017

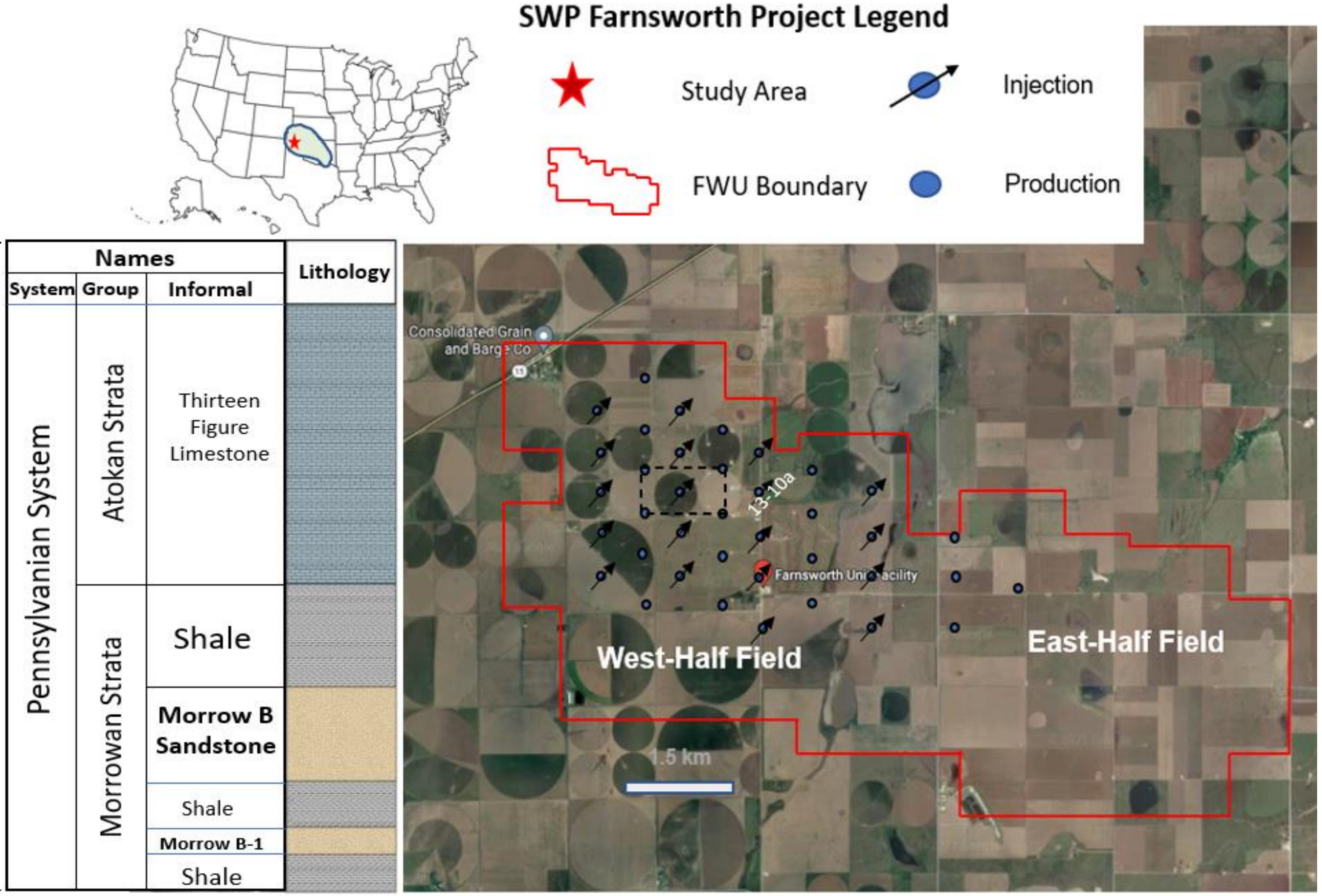
Arkalon Ethanol Plant

Agrium Fertilizer Plant

Southwest Regional Partnership(SWP) – Farnsworth Unit –



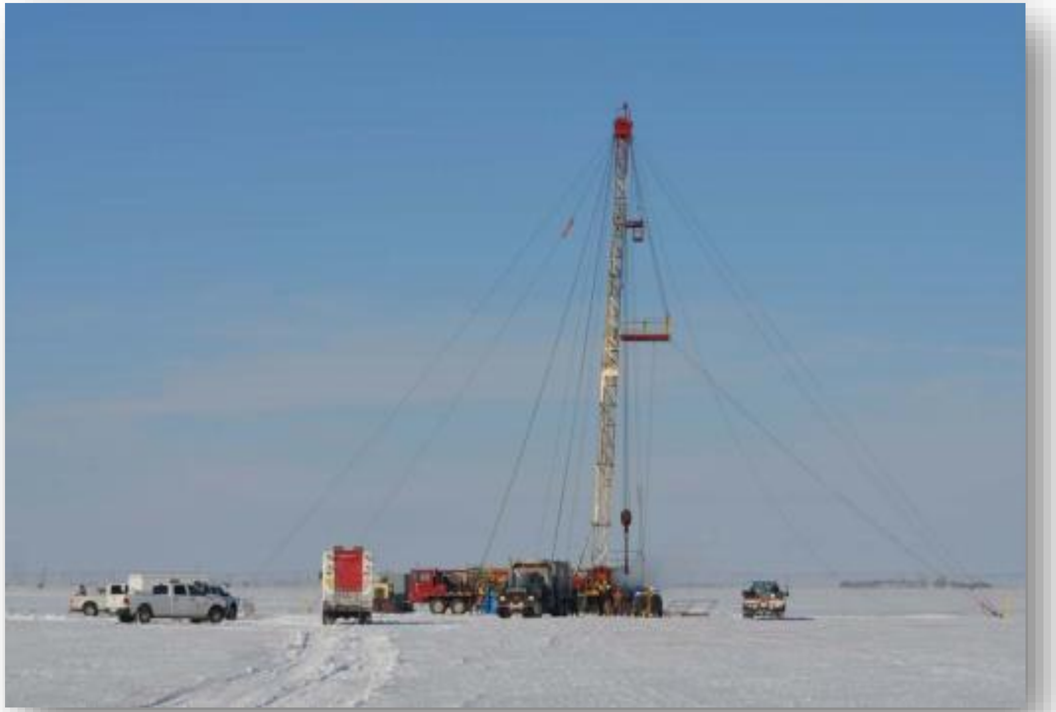
Meng J. et al 2017



Kutsienyo et al., 2022

Field History

- Field discovered in October 1955
  - Original oil in place ~120 million barrels
  - Original gas in place ~ 41.48 Bscf
- Morrow B thickness ~ 0-18 m
  - Porosity ~ 0.15
  - Permeability ~ 48 mD
- Primary recovery by solution gas ~ 1955
- Secondary recovery by waterflood ~ 1964
- Tertiary recovery by CO_2 flood ~ 2010
  - SWP partner in 2013 – focusing on geological characterization



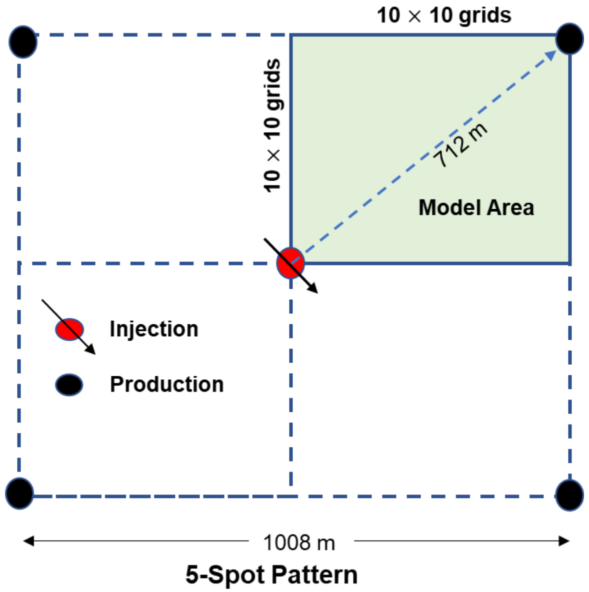
Research Objectives

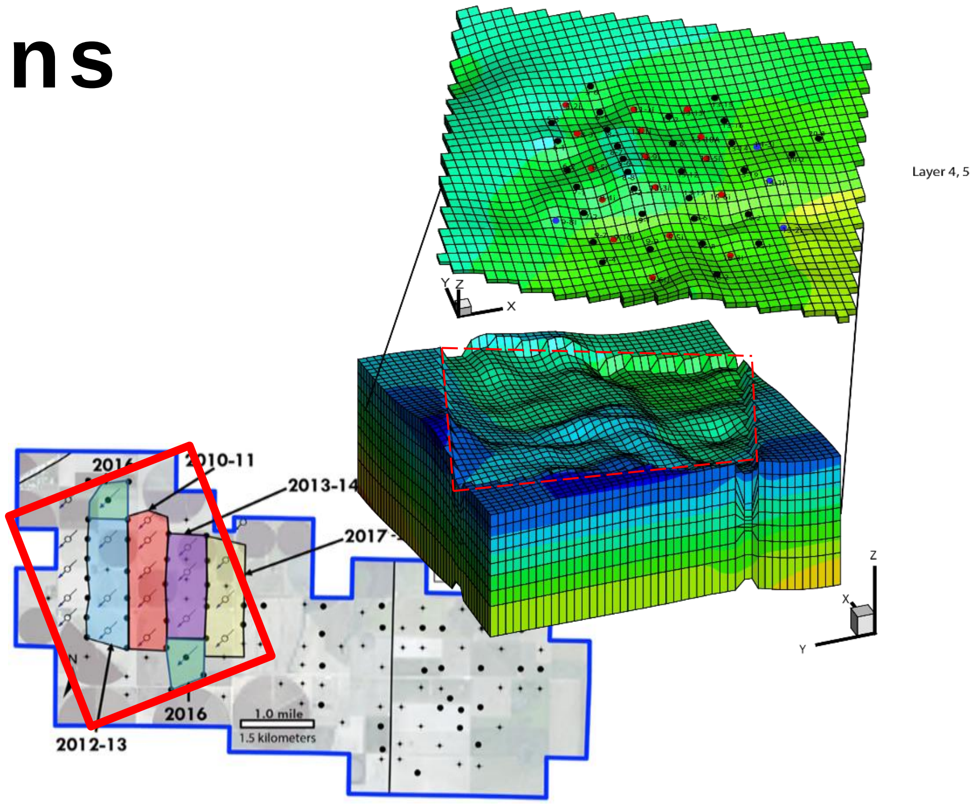
- To explore the feasibility of CO_2 storage in an active enhanced oil recovery (EOR) operation by understanding the behavior of CO_2 injected at the site.

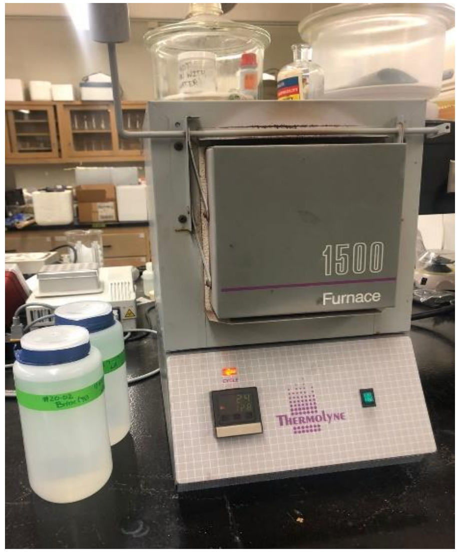
- Assessing the feasibility of large-scale CO_2 sequestration in the FWU, our studies seek to answer the following questions:
  - How far and how quickly the injected CO_2 migrate from its source?
  - How is the injected CO_2 partition among the formation water, petroleum, an immiscible gas phase, and carbonate minerals?
  - How is the mineralogy of the reservoir, and the reservoir's hydraulic properties change?

Our research employs **numerical reactive solute**, **heat**, and **multi-phase fluid transport** modeling at multiple spatial scales, and **laboratory experiments** designed to track changes in reservoir mineralogy and formation water chemistry as a result of chemical reaction with CO_2 **in order to answer the above questions**

Research Divisions







Part 1

Performance & comparison of the numerical simulators, TOUGHREACT, GEM, and STOMP-EOR on a five-spot well pattern in the FWU

Part 2

Field-scale numerical reactive transport simulations of CO_2 injection in the FWU

Part 3

Laboratory batch reaction experiments of the reaction of CO_2-saturated Morrow B formation water with the Morrow B Sandstone matrix

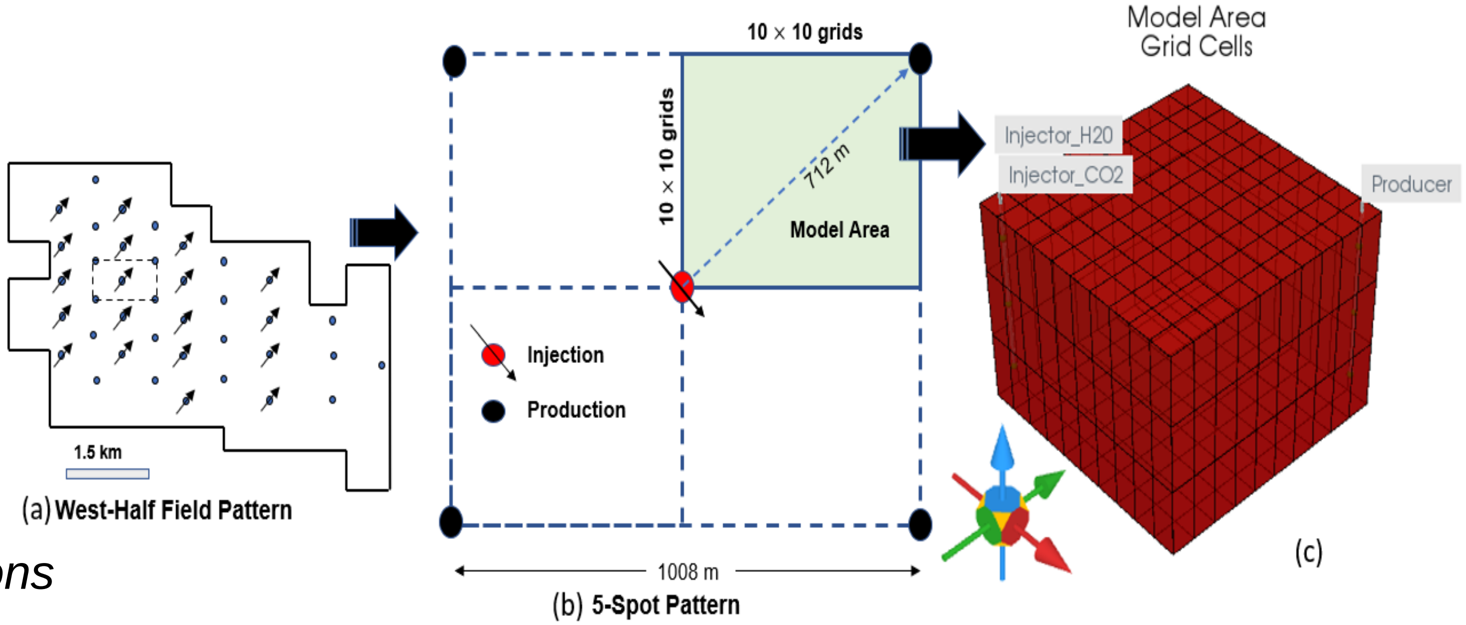
Each of the three **parts** in the research **coincides with a key deliverable in the grant** from the U.S. Department of Energy that is funding the project.

Modeling Workflow – Part I

Model spatial domains for present study

A. Model Design and Data

- *¼ -5 spot design (2010 – 3010) 13-10A*
- *Initial Morrow B pore water composition*
- *Initial mineral volume fractions*
- *Initial pressure and temperature distributions*
- *Multi-phase fluid flow, heat transport, reactive solute transport*

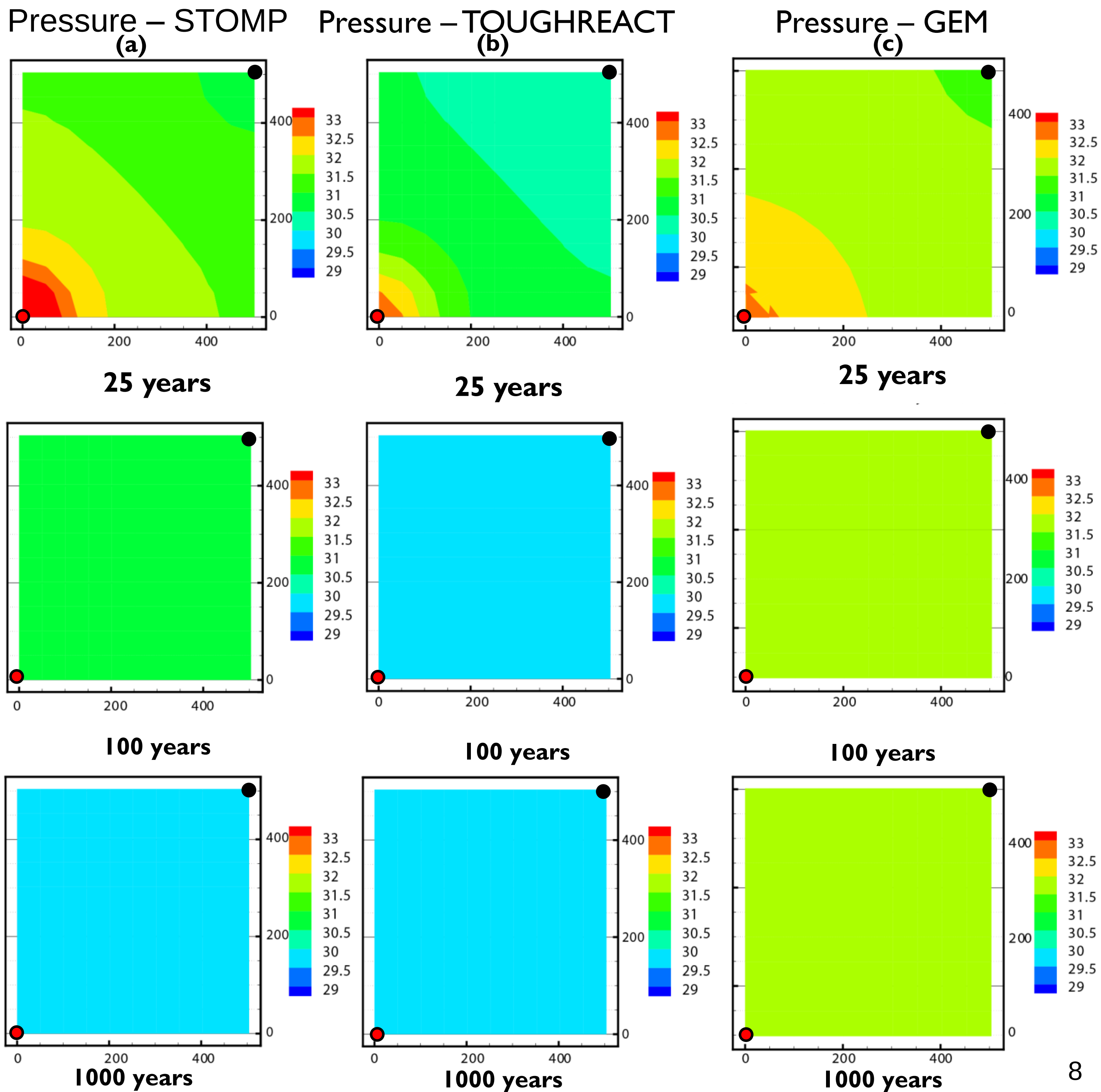


B. Model Scenarios

- Scenario 1 (*Saline Aquifer Model*) – **Two fluid phase system**
- Scenario 2 (*Hydrocarbon Reservoir Model*) – **Three fluid phase system**

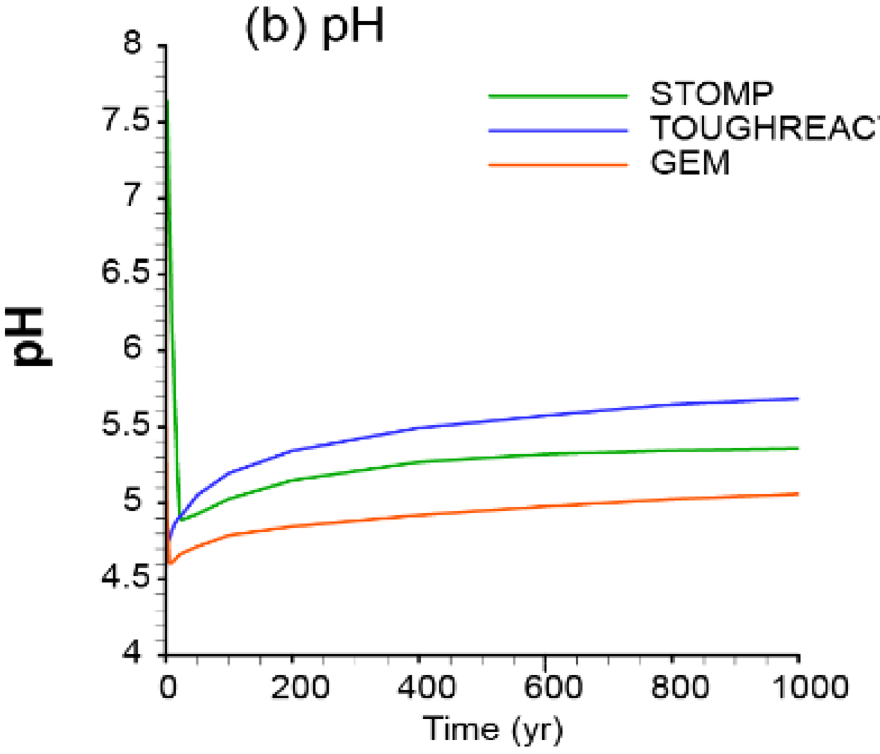
Results – Part I
Model Scenario 1

- Significant difference in pressure evolution
  - 25, 100, 1000 years
- Similar pattern of pressure distribution in Scenario 2

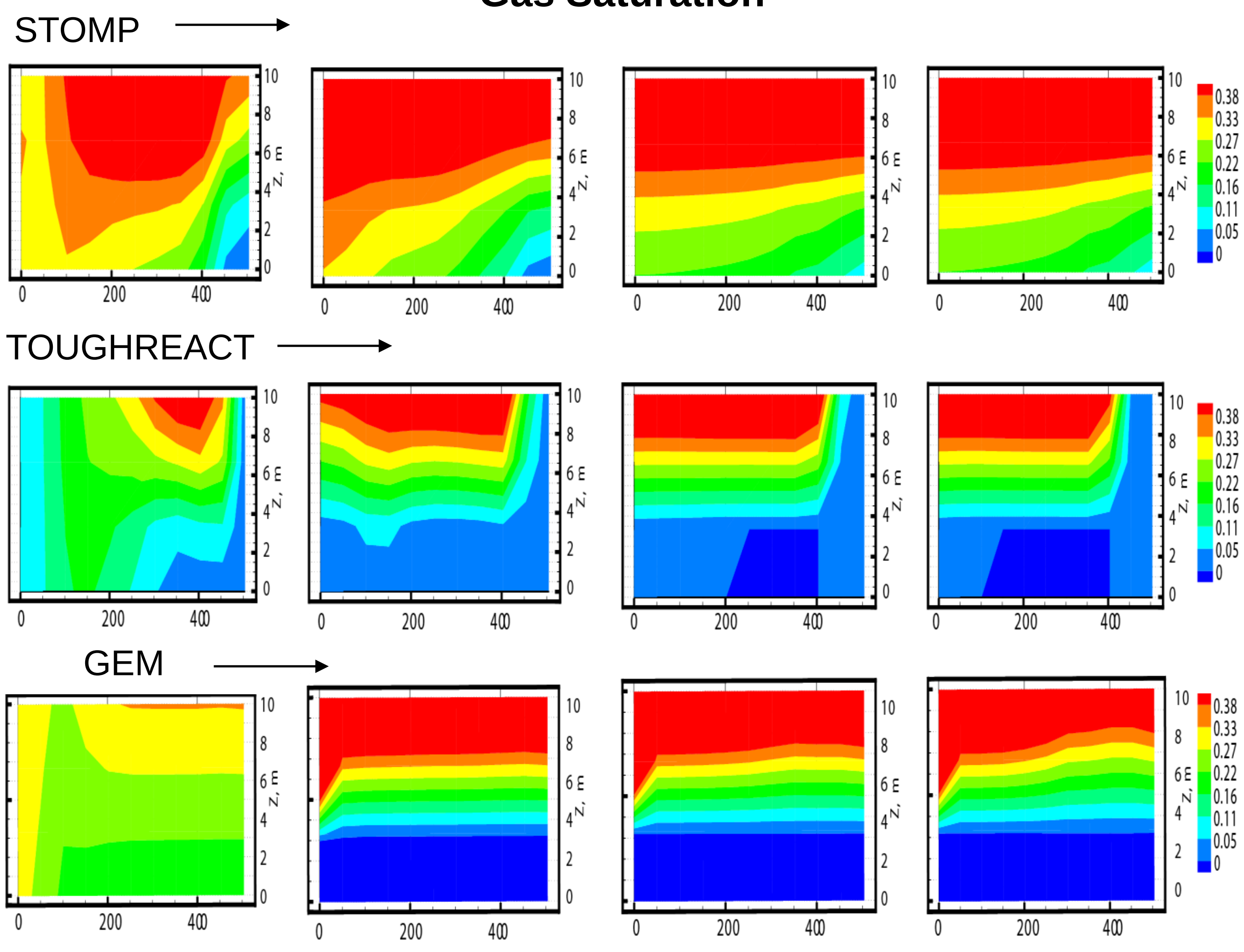


Results – Part I
Model Scenario 1

- Differences in immiscible CO_2 predicted is a function of the different CO_2 solubility functions that they employ
- Sharp initial drop in pH for the models
- Similar pattern Scenario 2 – except CO_2 in oil phase

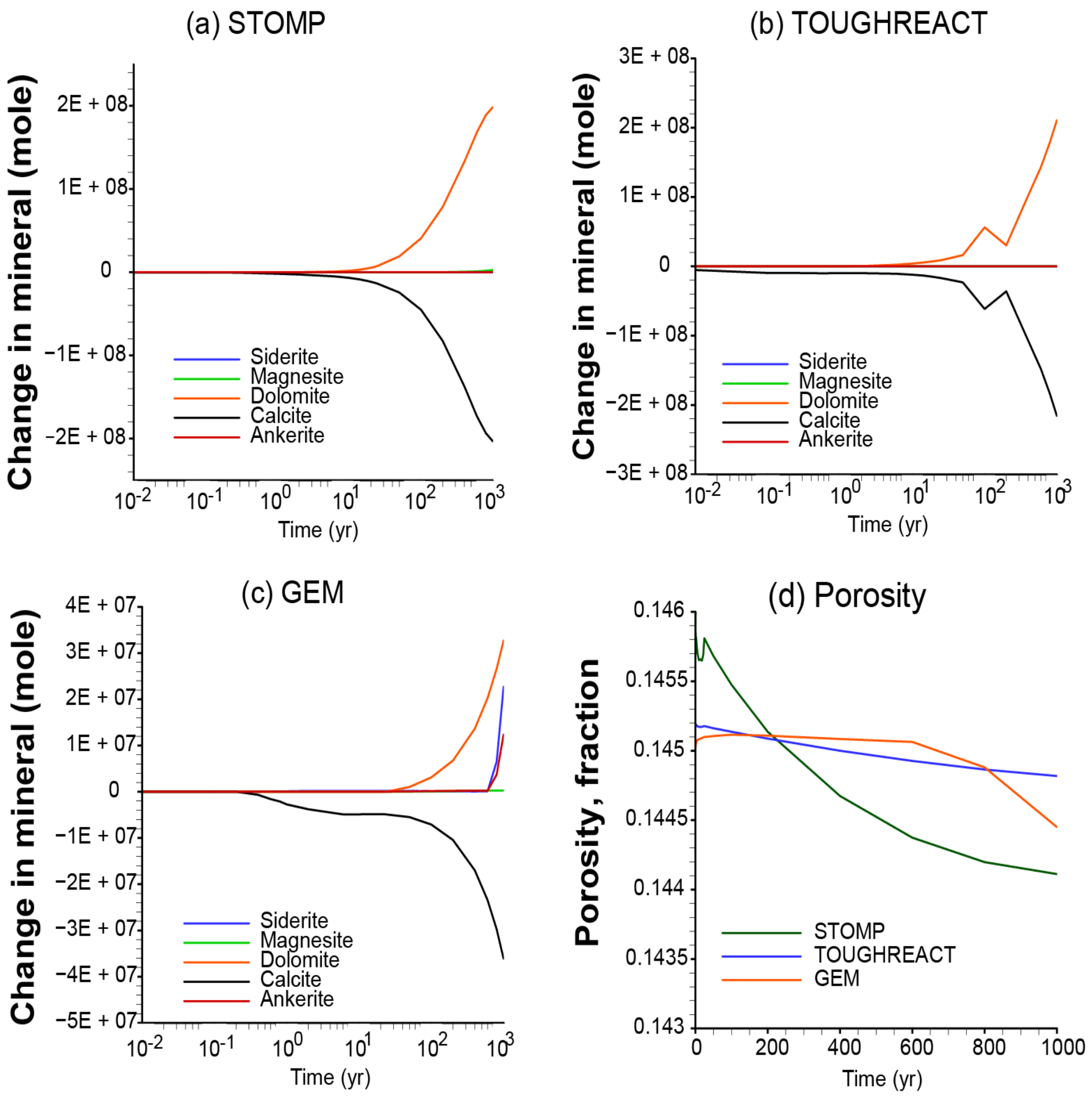


Gas Saturation

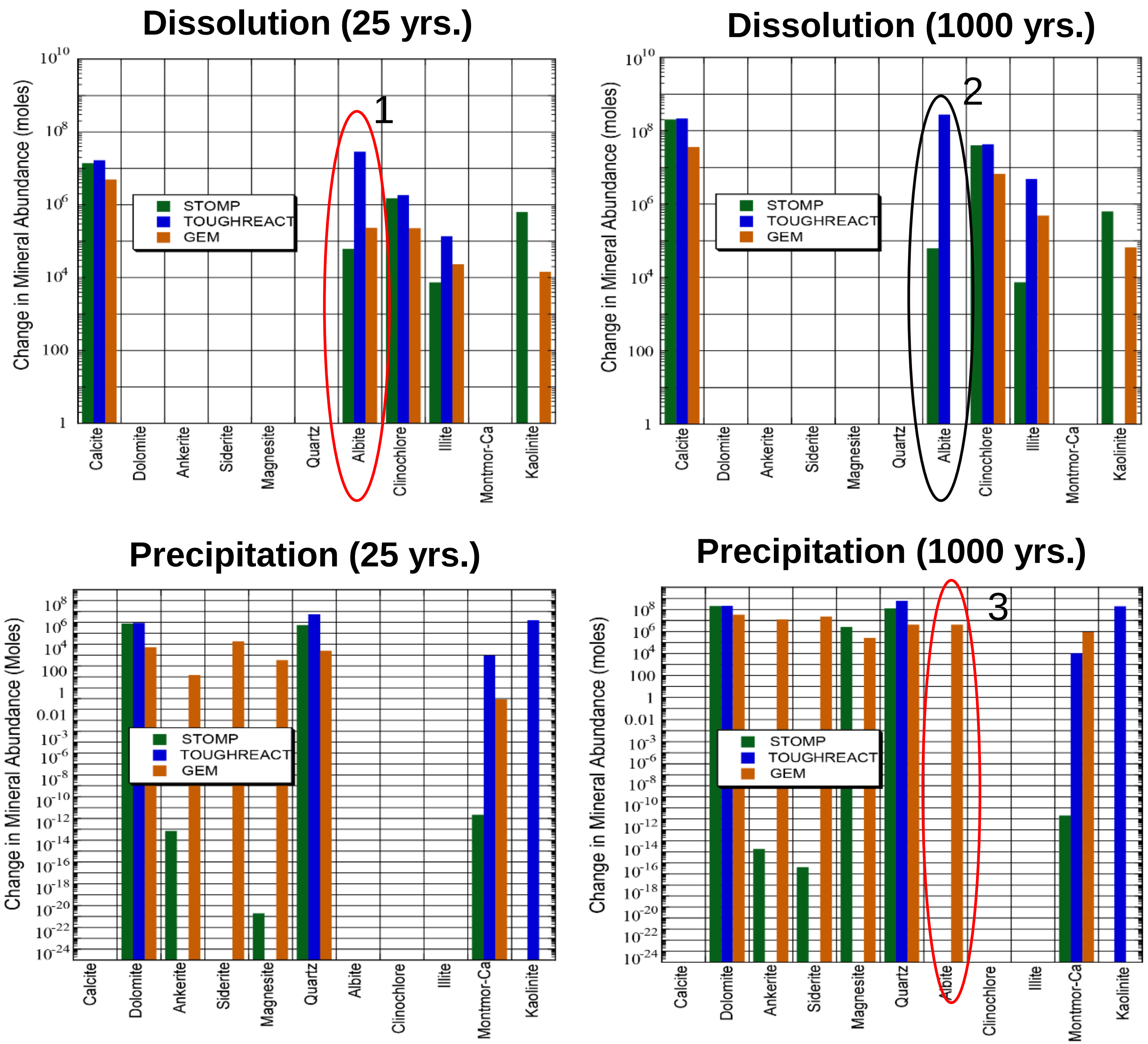


25 years **100 years** **600 years** **1000 years**

Results - Model Scenario 1 & 2

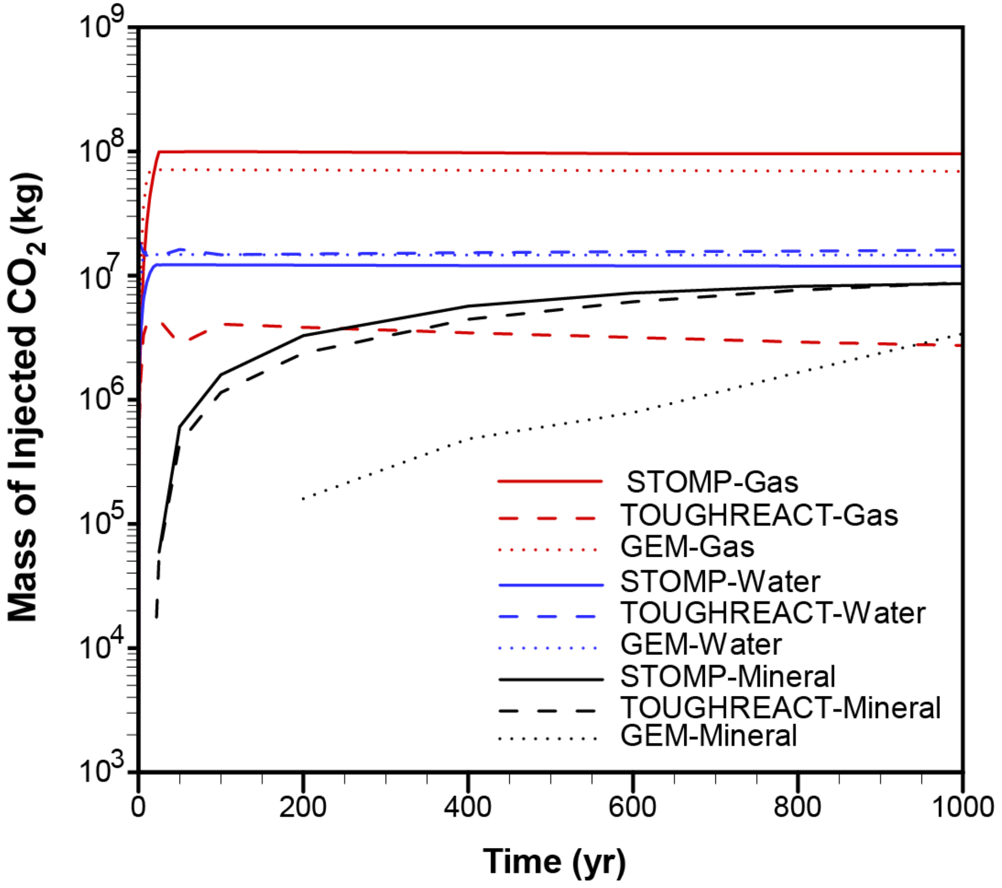


A

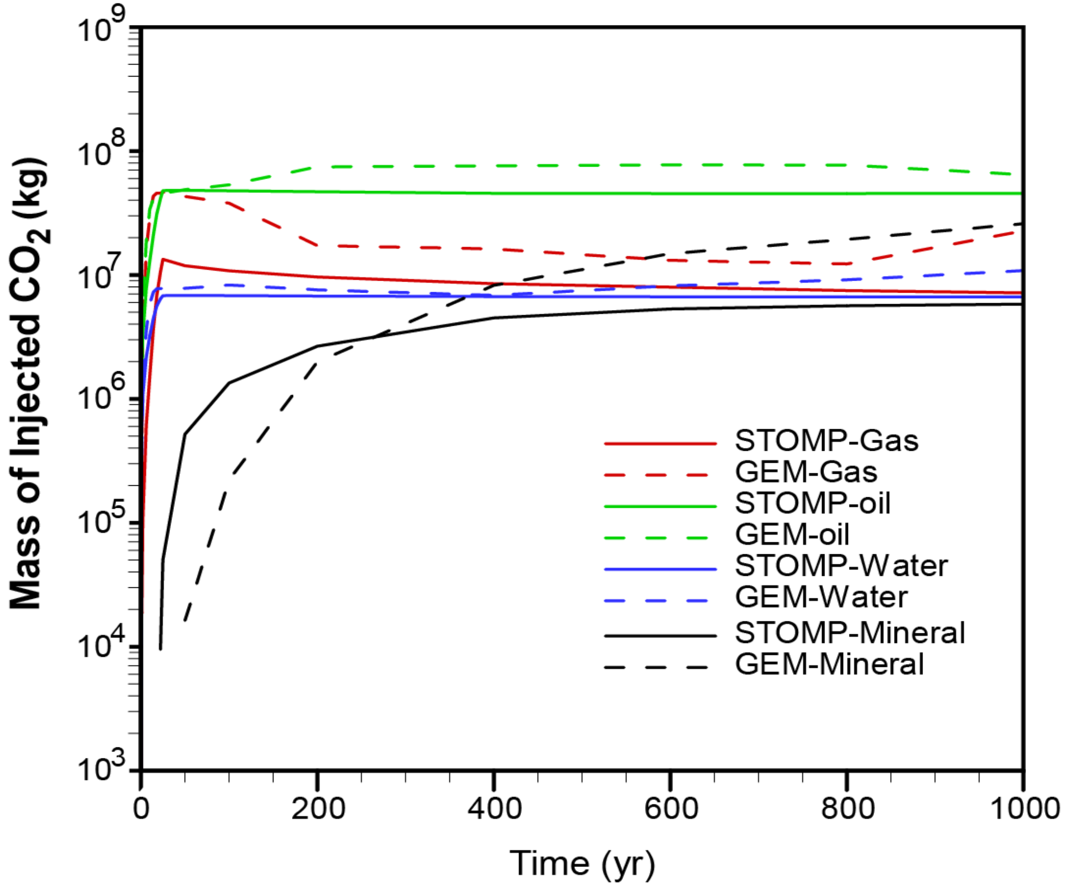


B

CO_2 Distribution and Storage



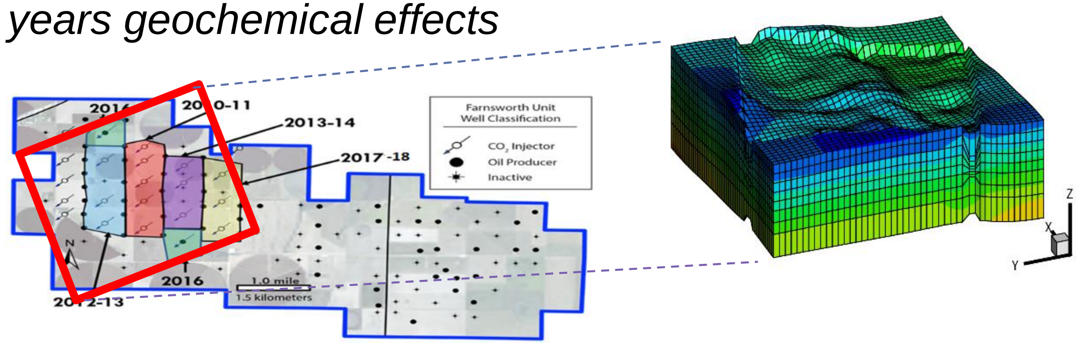
Two-phase fluid System

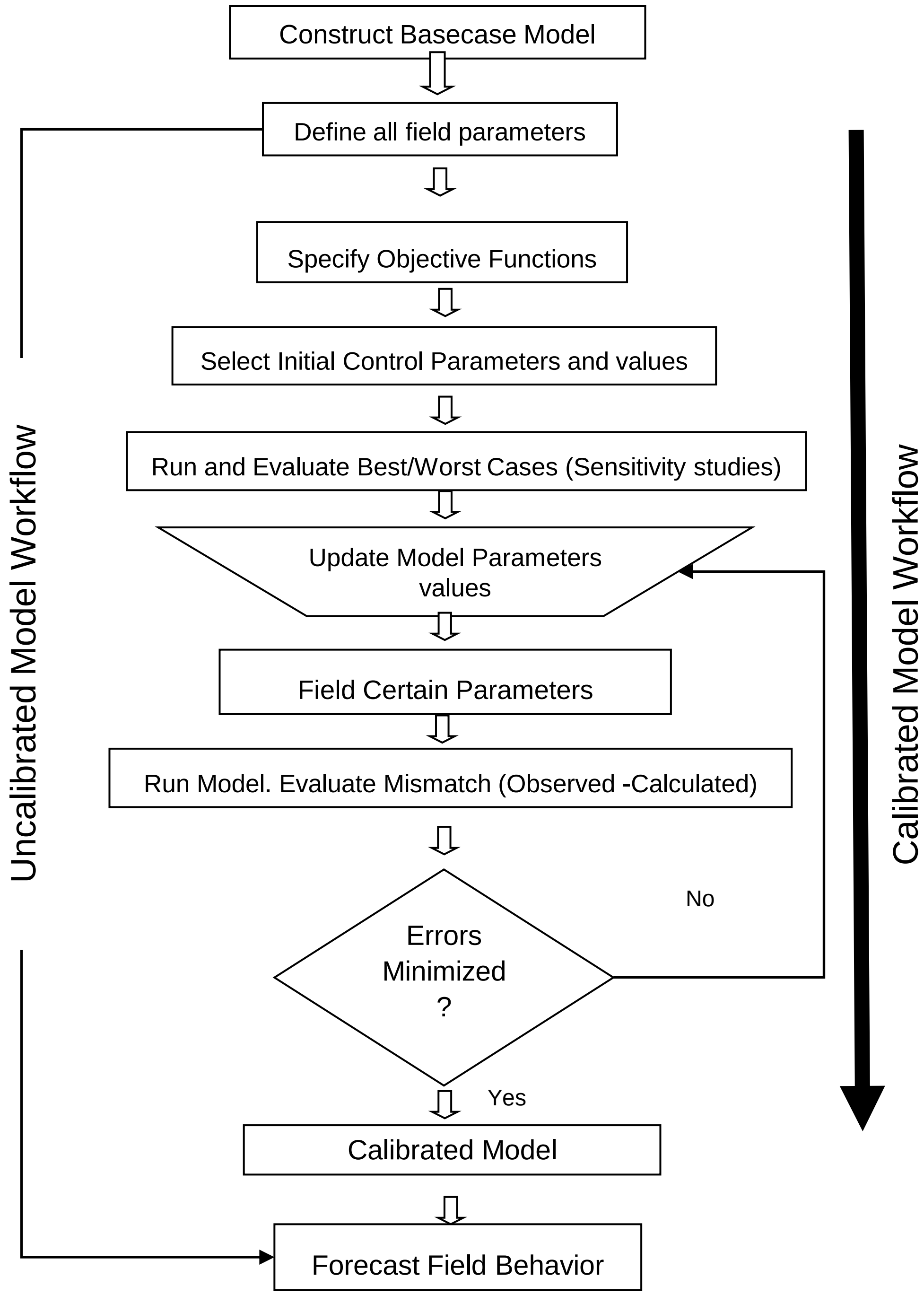


Three-phase system

Modeling Workflow – Part II

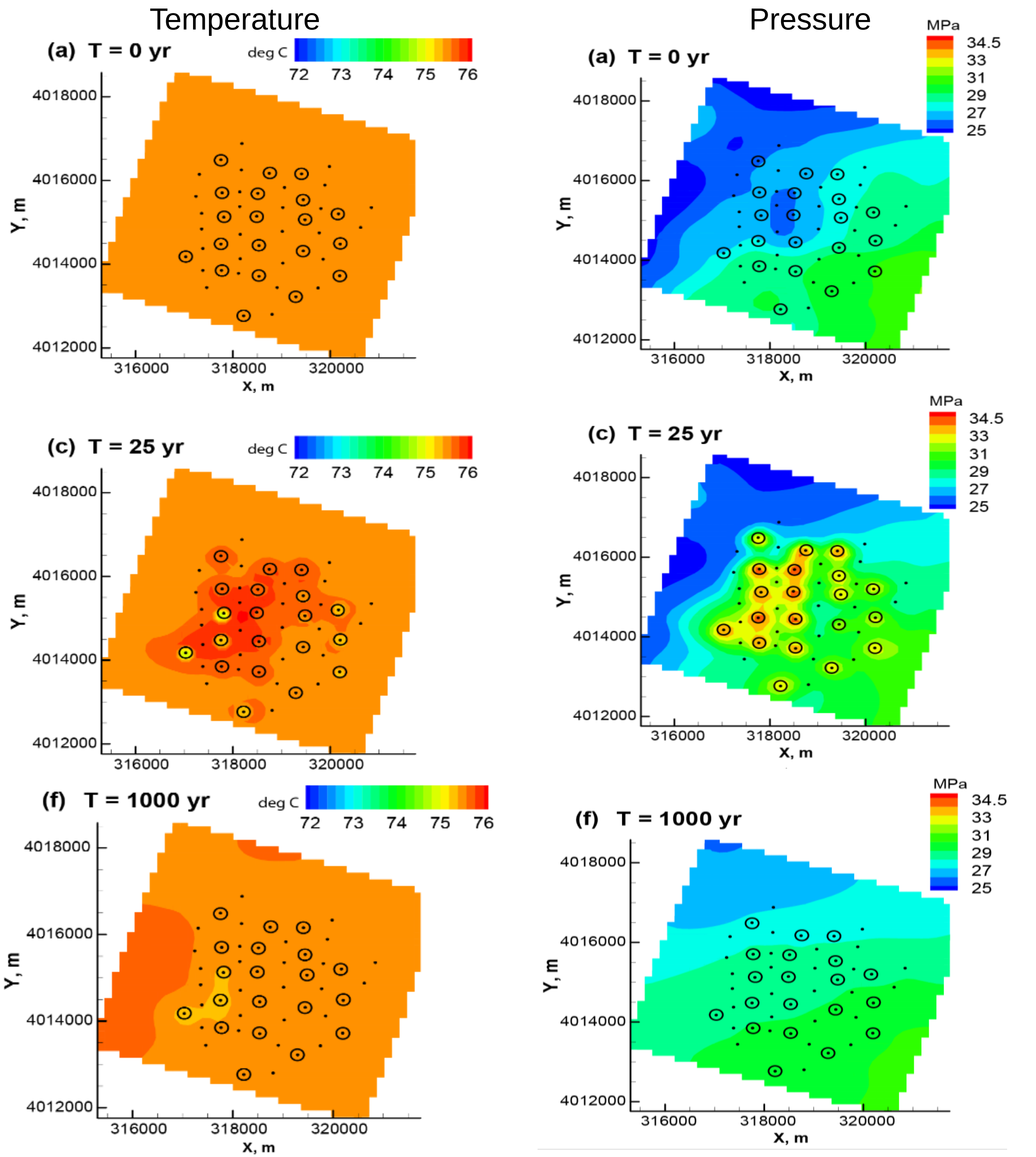
- *Baseline Model*
  - *Encompasses field collected data (2010 – 2018)*
- *Parametrizations through Sensitivity Studies:*
  - *Critical saturation endpoints*
  - *Permeabilities*
  - *Corey parameters*
- *History Match Tertiary Flood*
  - *CO_2-WAG (2010-2018)*
- *Prediction Studies*
  - *25 years of field operations*
  - *1000 years geochemical effects*





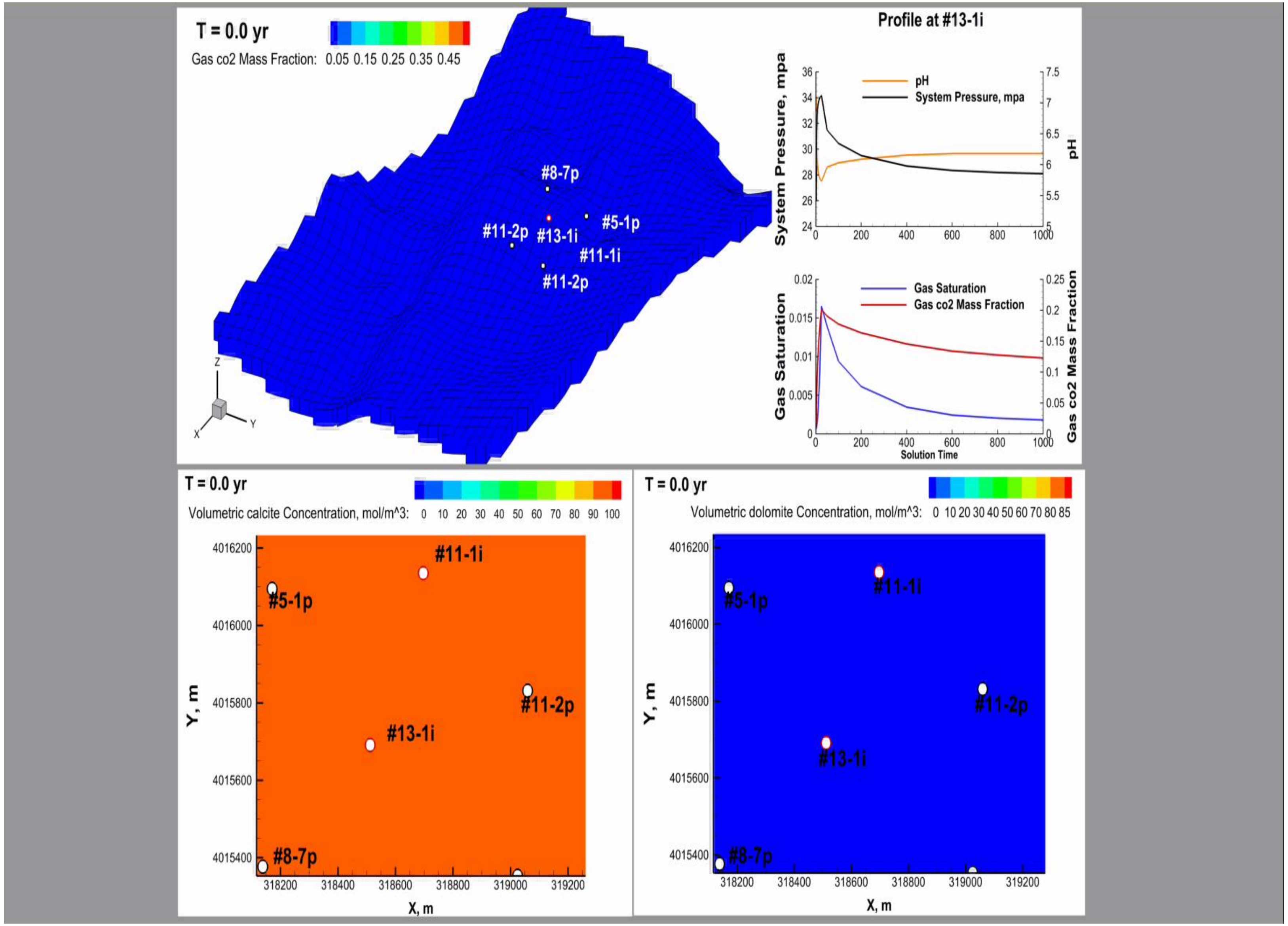
Results - Intensive Property Evolution

- We saw similar change in temperature
- Sharp decrease near wellbore, but slightly higher temperature towards highly impacted CO_2 region
- High pressure near wellbore
- Reservoir pressure decreasing to initial pressure over time

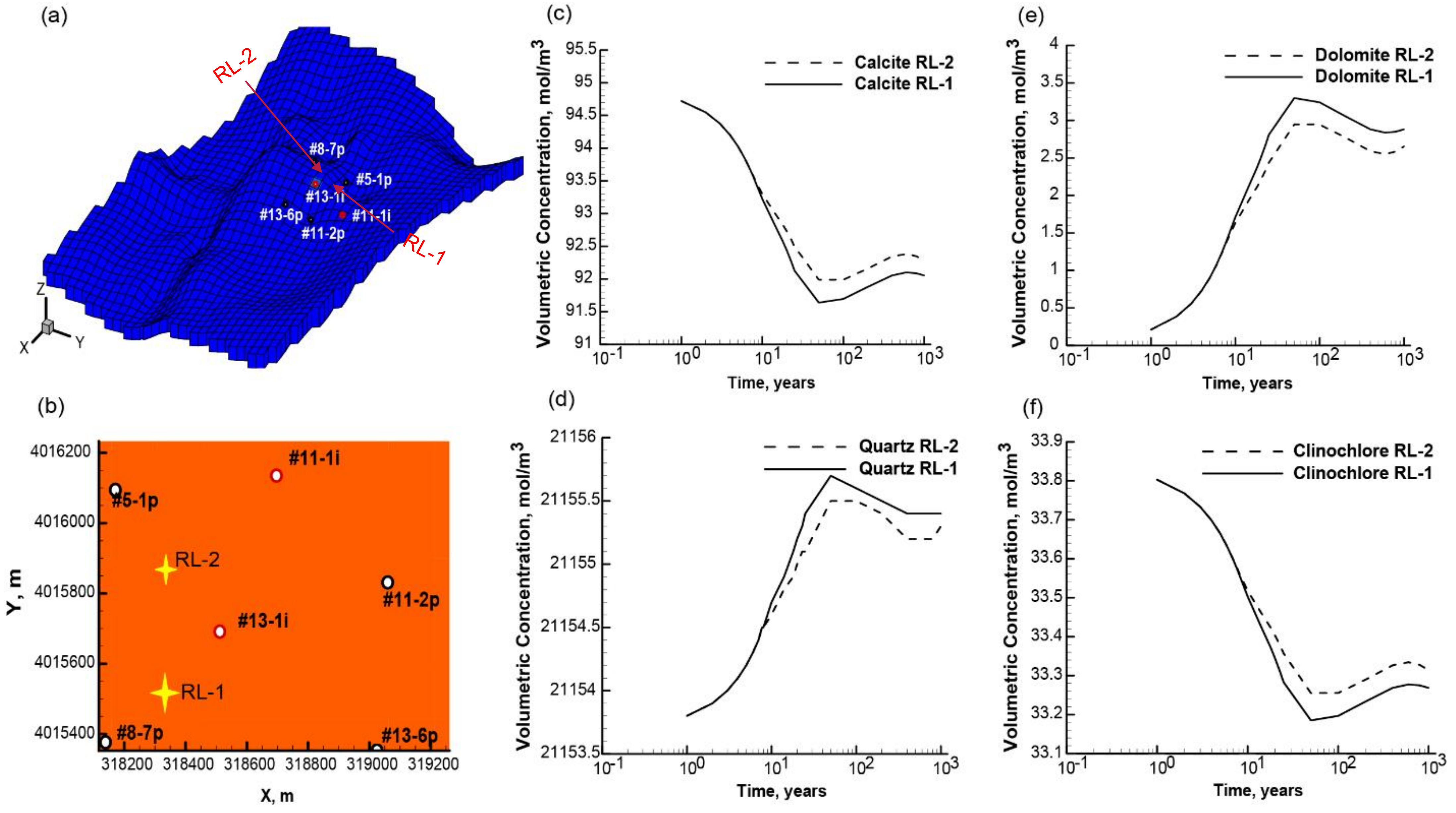


Results
Model Predictions

- Field show case the timeline of each injector
- Sharp initial drop in pH for the models
- System pressure above MMP
- Gas fraction of CO_2 decrease overtime



Tracking Mineral Change

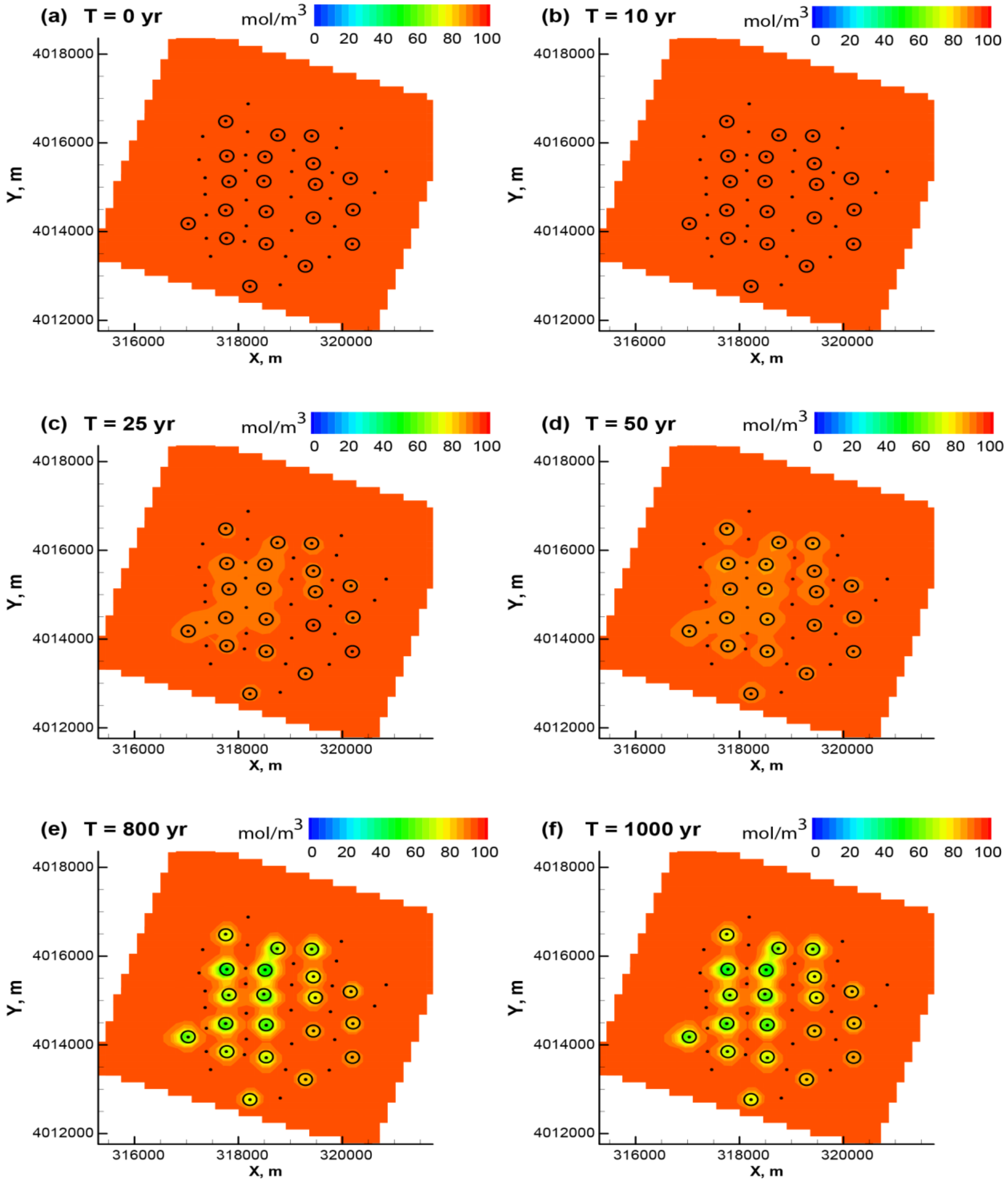


A

B

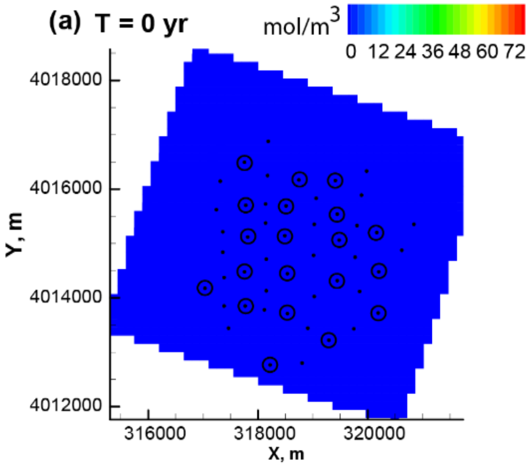
Primary Mineral Change

- Calcite dissolution is gradual
- Continuous increase in dissolution
  - Mostly in later part of the forecast

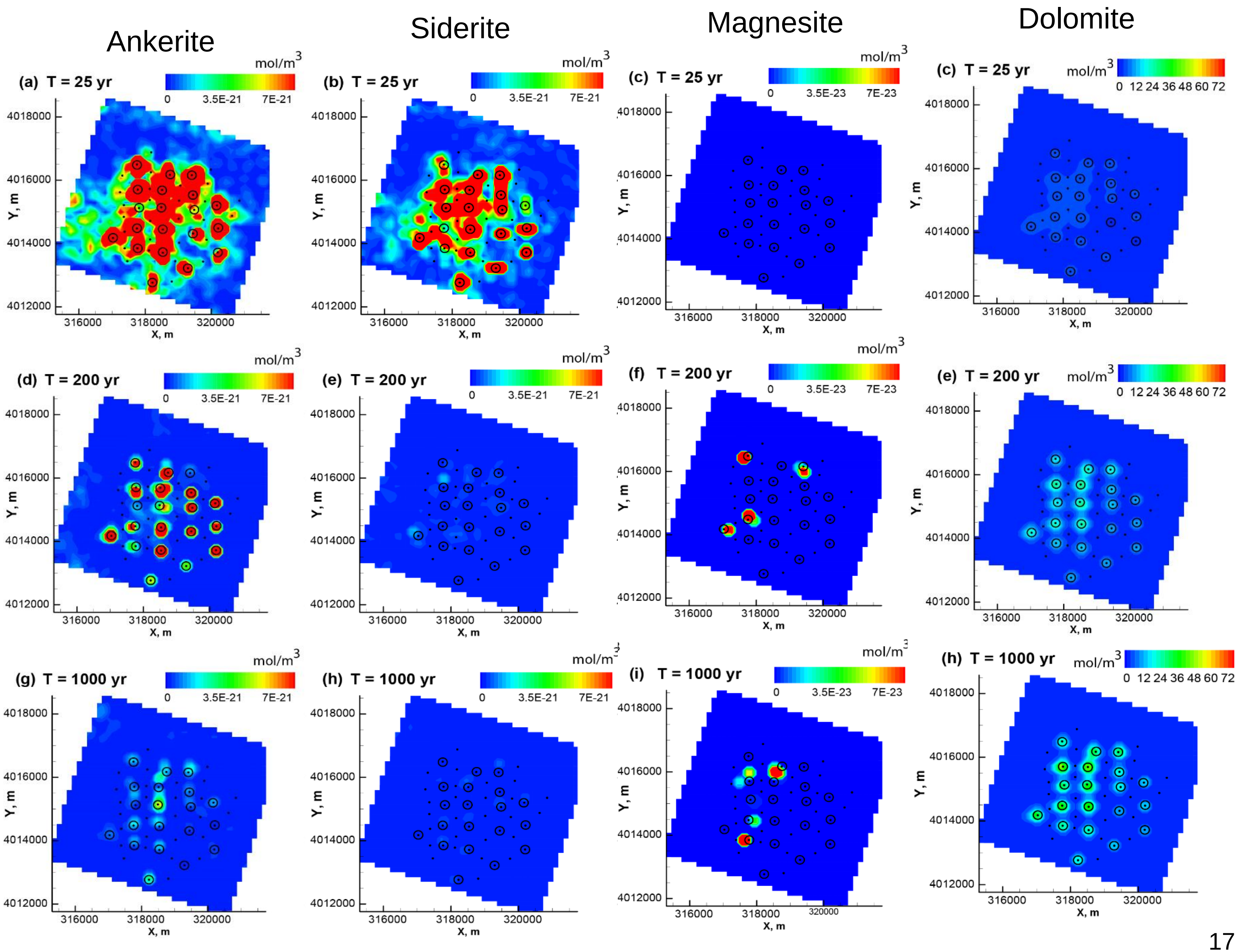


Secondary Mineral Changes

- Siderite and Ankerite show showed similar pattern
- Magnesite precipitation at late years
- Dolomite major form of CO_2 storage



Ankerite/Siderite/Magnesite

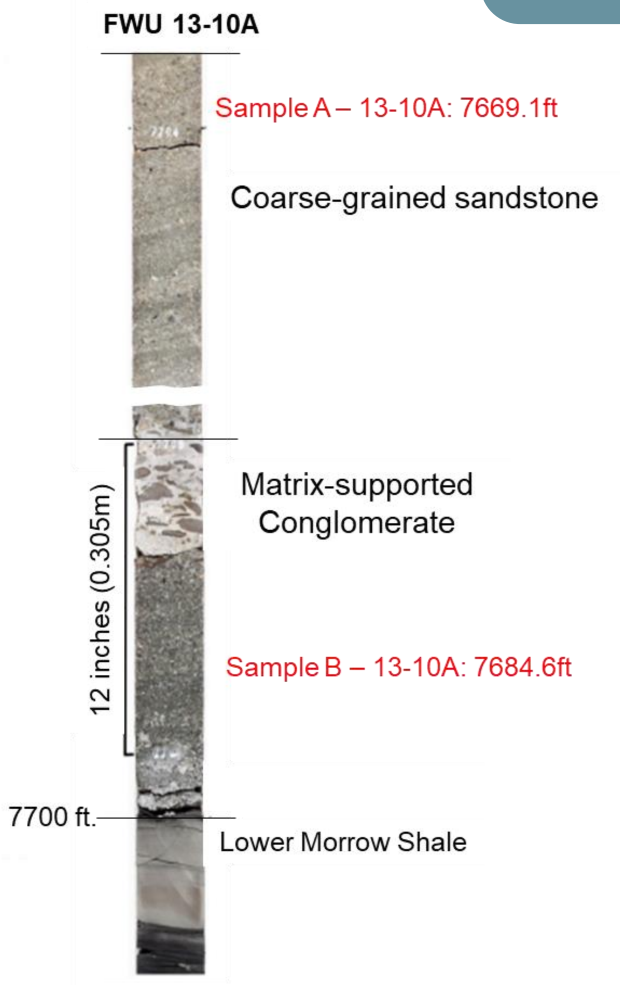


Part III Objectives

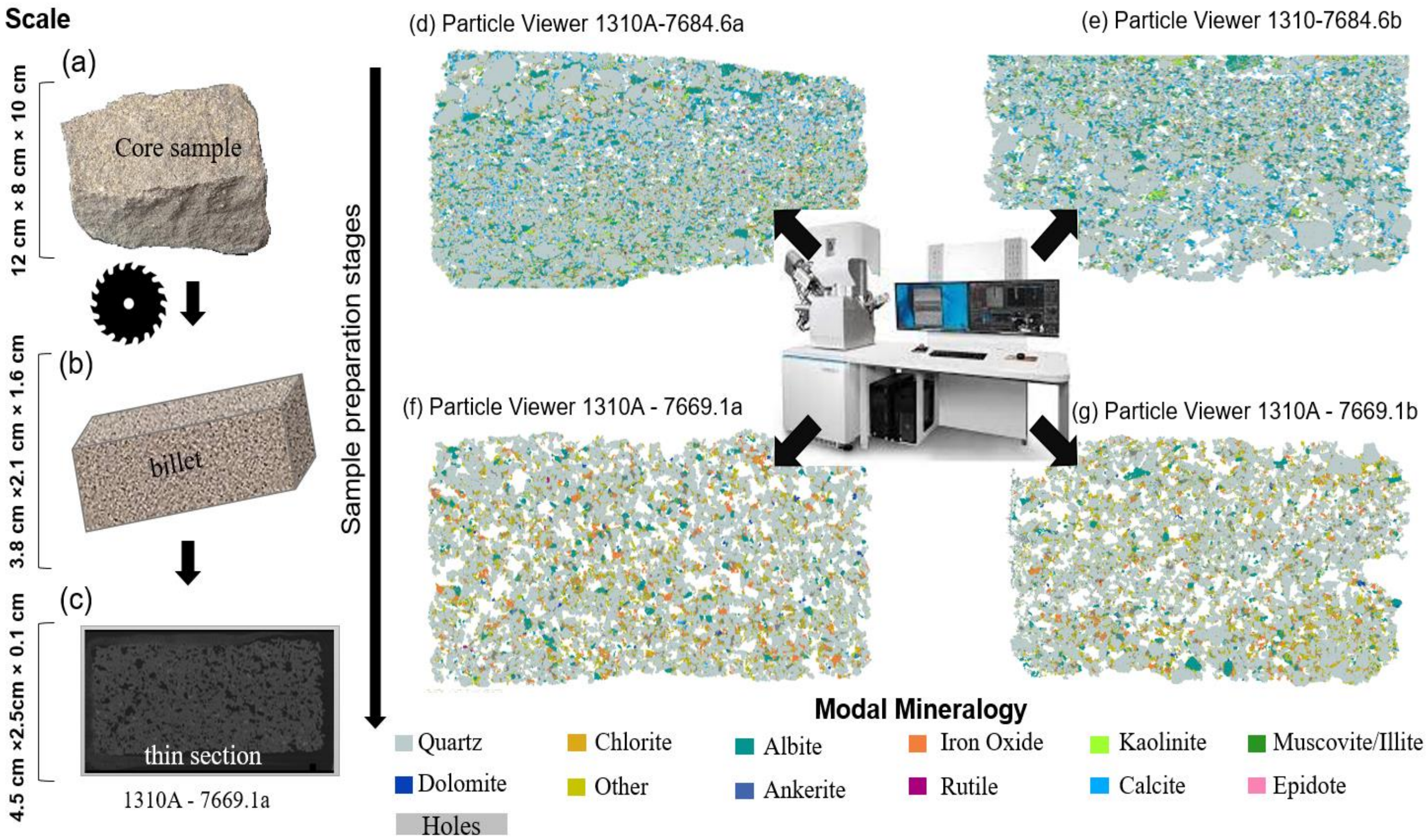
Corroborate the mineral evolution predicted by the numerical models in Parts I and II

Fulfilling Grants Subtask

Understand Geo-Chemo physical changes



Sample locations

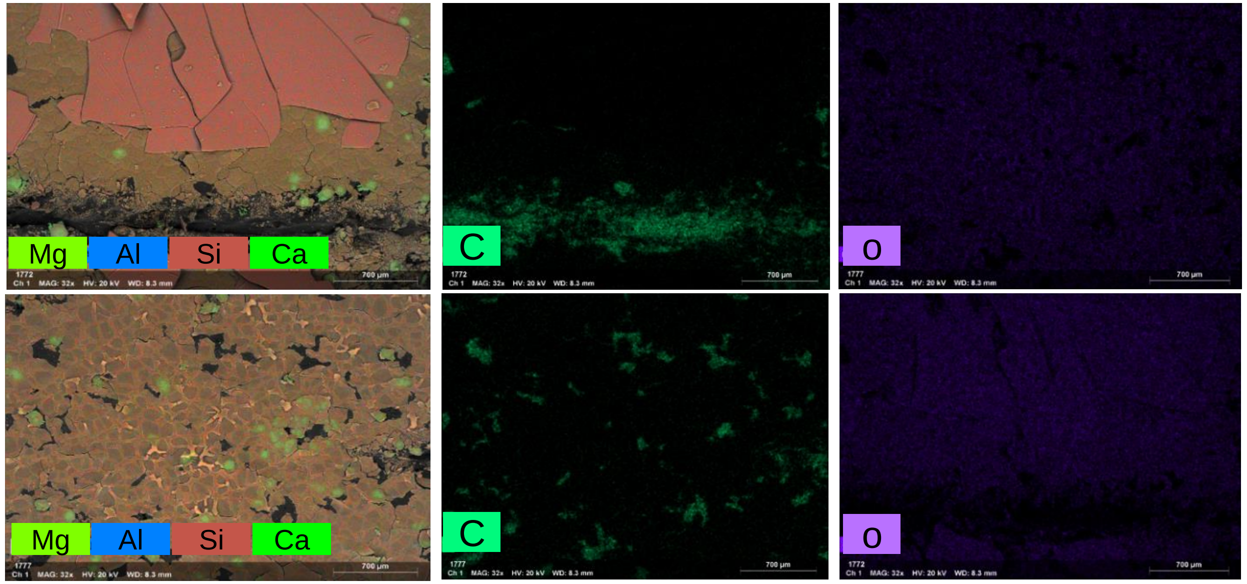


Batch Reaction and Observations – 61 days

- Reaction vessels and heat chamber
- Fluid analysis with ICP-AES
- Deposited particles on thin section – SEM

ICP-AES Analysis of the Elemental Composition of the Morrow B Formation Water

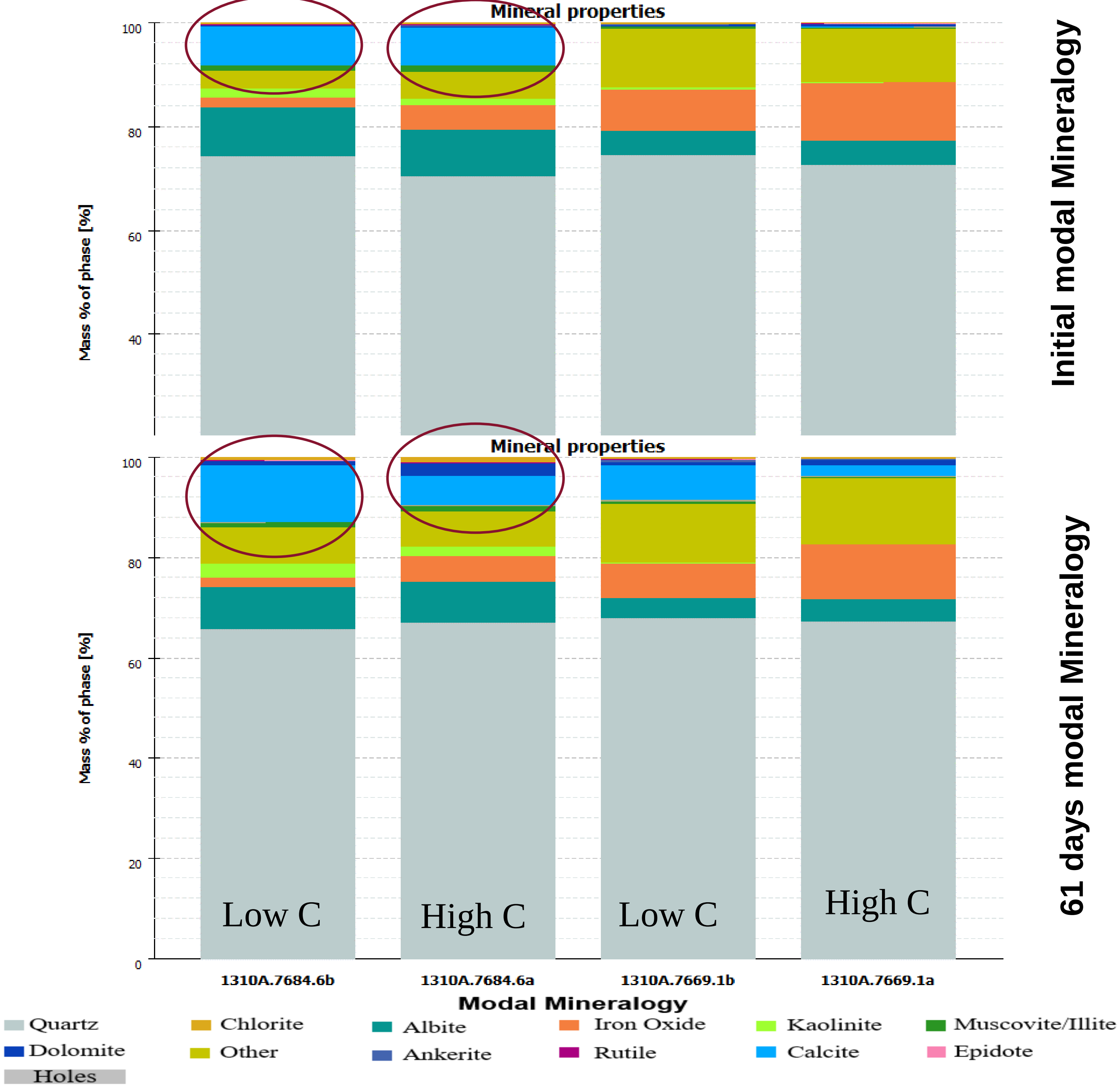
ESCL #	UMC ID	Elements	Concentrations (ppm)		
			Initial Conc.	Experiment 1	
				High Carbon	*Low Carbon*
11215	Well 20-02	S	7.76	8.45	8.4
		Ca	**42.3**	**4.1**	**3.5**
		K	12	37.3	45.2
		Na	1955	2550	2540
		Mg	**26.2**	**< 0.1**	**0.2**
		Fe	**< 0.4**	**< 0.4**	**< 0.4**
		Li	0.591	0.565	0.537
		Sr	**8.38**	**0.115**	**0.052**
		Ba	6.75	0.25	0.21
		Al	**0.226**	**< 0.13**	**< 0.13**
		pH	8.33	10.19	10.15



scanning electron microscope (SEM) Analysis

Thin Sections Observations – 61 days

- Less amount of calcite in High C modal analysis
- Rapid precipitation of calcite in Low C vessel thin section
- Dolomite significantly change from the initial modal analysis



Observations - Summary

- Modeling results:
  - The different models and codes yield some broadly similar results
  - Most of the injected CO_2 goes into the oil phase with successively smaller amounts into water, carbonate mineral, and immiscible gas phases
  - The long-term immiscible CO_2 gas phase will decrease as the other forms of storage increase
  - For the major native reservoir minerals, quartz is predicted to precipitate, and albite, calcite, and chlorite dissolve
  - Dolomite is the main mineral sink for the CO_2 in the FWU and increased in abundance over time
  - Changes in mineral abundances cause very small decreases in porosity
  - Predicted changes in reservoir pressure and immiscible gas abundance are too small to pose storage safety risks
- Experimental results:
  - Dolomite and silica are the main precipitated phases, consistent with numerical modeling results

Acknowledgements / Thank You / Questions

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University of Missouri

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