Refining Storage Efficiency Factors in Saline Systems (CO_2-SCREEN)

FWP-1022403

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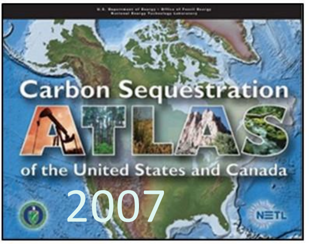
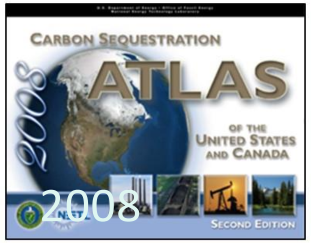
National Energy Technology Laboratory

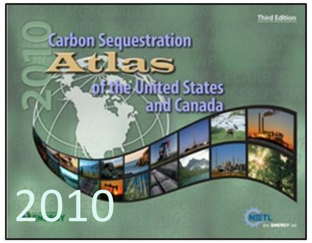
U.S. Department of Energy
National Energy Technology Laboratory
Carbon Management Project Review Meeting
August 15 - 19, 2022

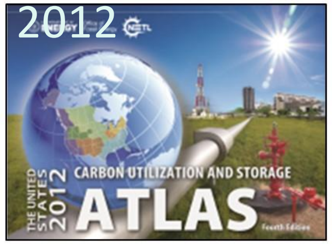
Prospective CO_2 Storage Quantification

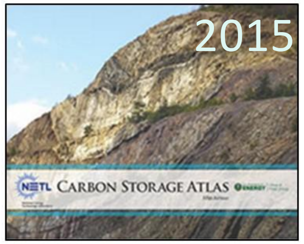
Carbon Storage Atlases



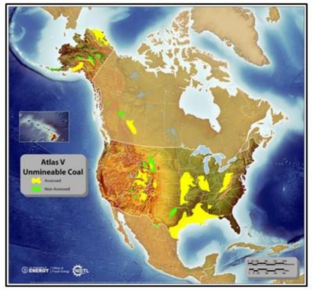








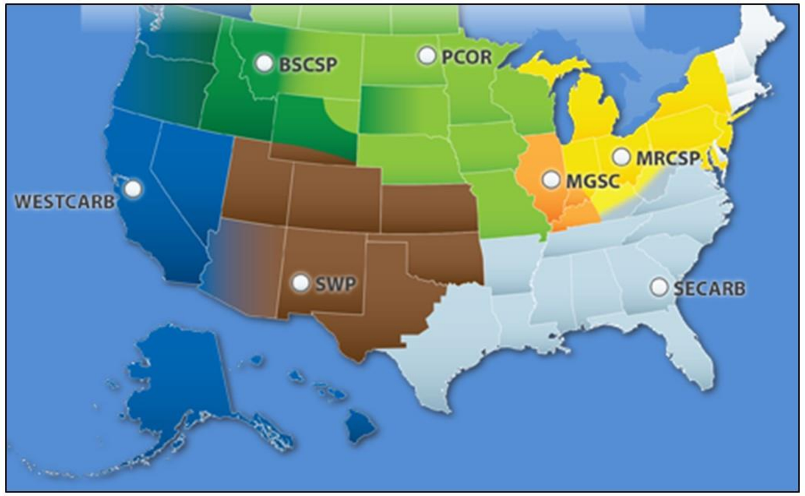
186 - 232 GT



54 - 113 GT

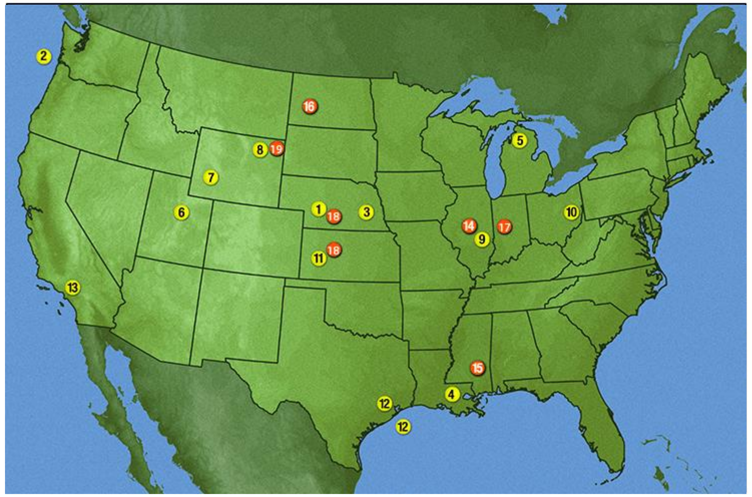
2,379 - 21,633 GT

NETL's Regional Carbon Sequestration Partnership (RCSP)



BSCSP: Big Sky Carbon Sequestration Partnership
MGSC: Midwest Geological Sequestration Consortium
MRCSP: Midwest Regional Carbon Sequestration Partnership
PCOR: The Plains CO_2 Reduction Partnership
SECARB: Southeast Regional Carbon Sequestration Partnership
SWP: Southwest Partnership on Carbon Sequestration
WESTCARB: West Coast Regional Carbon Sequestration Partnership

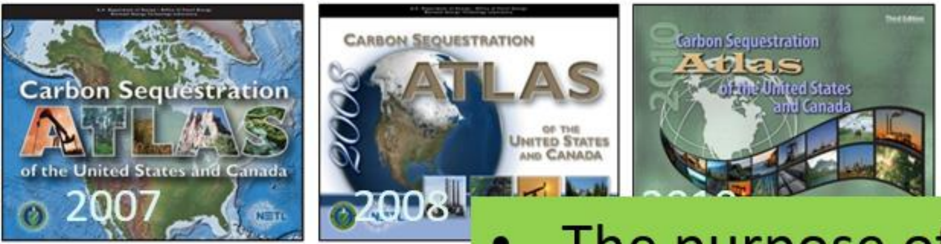
Carbon Storage Assurance Facility Enterprise (CarbonSAFE)

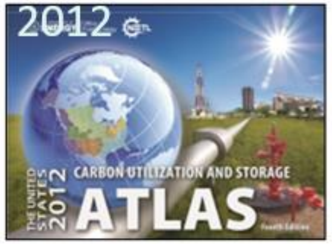


- Geologic storage of 50+ million metric tons of CO_2
- 13 Pre-feasibility projects
- 6 feasibility projects

Prospective CO_2 Storage Quantification

Carbon Storage Atlases





186 - 232 GT

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2,379 - 21,633 GT

NETL's Regional Carbon Sequestration Partnership (RCSP)

SECARB: Southeast Regional Carbon Sequestration Partnership
SWP: Southwest Partnership on Carbon Sequestration
WESTCARB: West Coast Regional Carbon Sequestration Partnership

Carbon Storage Assurance Facility Enterprise (CarbonSAFE)

f 50+ million metric

rojects

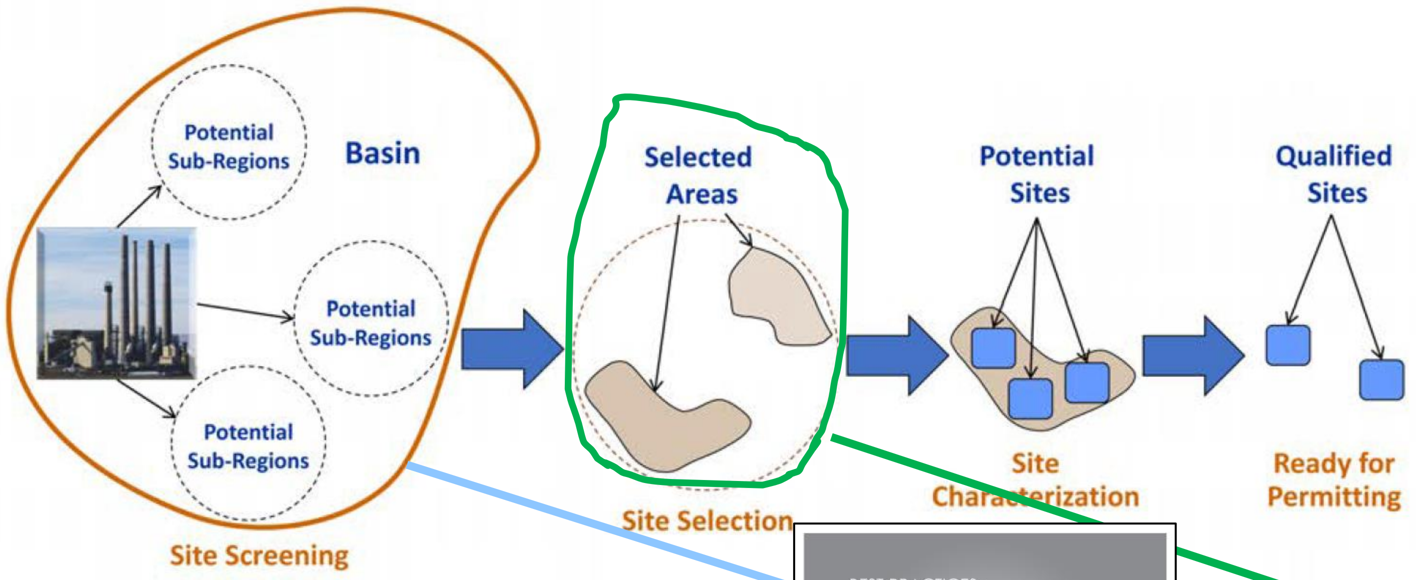
- 6 feasibility projects

- The purpose of storage estimates developed using these methodologies is to provide a high-level inventory of the subsurface volume to store CO_2 in the United States and Canada.

- This information can be used by the general public, elected officials, and planners

Methods Based on NETL's Best Practice Manuals

"Project Site Maturation" through the Exploration Phase.




BEST PRACTICES:
Site Screening, Site Selection, and Site Characterization for Geologic Storage Projects
2017 REVISED EDITION
NETL
NATIONAL ENERGY TECHNOLOGY LABORATORY

CO_2 Classification Table

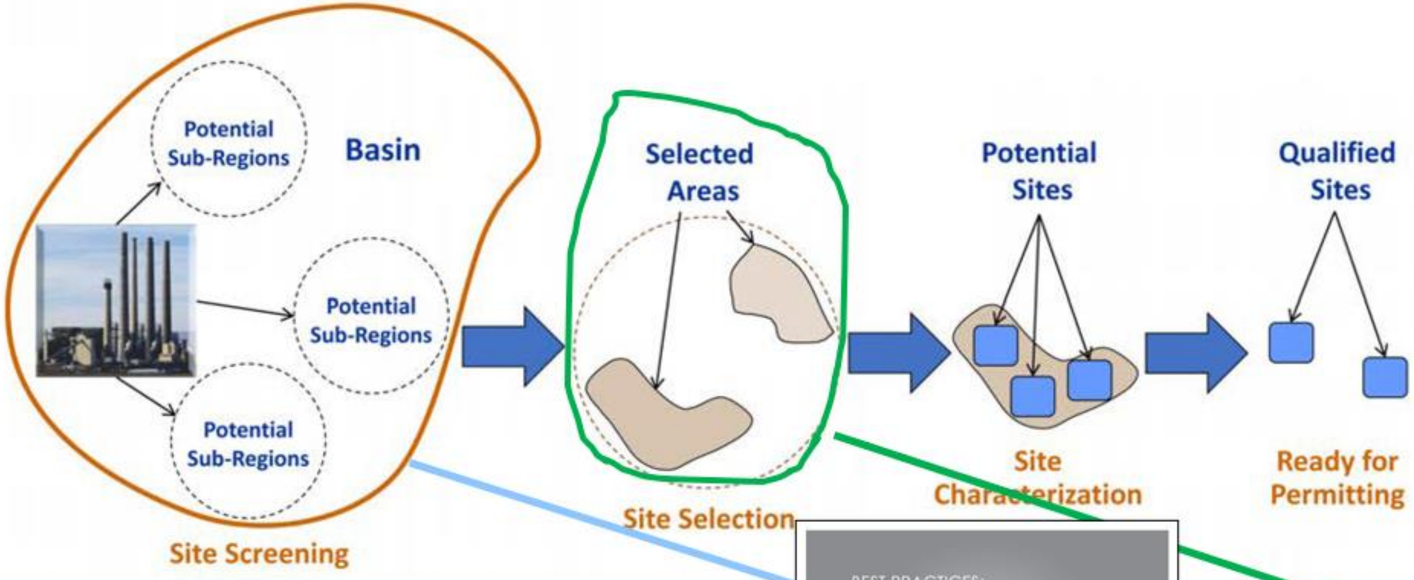
Petroleum Industry	CO_2 Geological Storage
Reserves	**Storage Capacity**
On Production	Active Injection
Approved for Development	Approved for Development
Justified for Development	Justified for Development
Contingent Resources	**Contingent Storage Resources**
Development Pending	Development Pending
Development Unclarified or On Hold	Development Unclarified or On Hold
Development Not Viable	Development Not Viable
Prospective Resources	**Prospective Storage Resources**
Prospect	Qualified Site(s)
Lead	Selected Areas
Play	Potential Sub-Regions

Prospective Storage Resources	
Project Sub-Class	**Evaluation Process**
Qualified Site(s)	Site Characterization
Selected Areas	Site Selection
Potential Sub-Regions	Site Screening

https://www.netl.doe.gov/sites/default/files/2018-10/BPM-SiteScreening.pdf

Methods Based on NETL's Best Practice Manuals

"Project Site Maturation" through the Exploration Phase.



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Prospective Storage Resources

- Selected Areas
- Potential Subregions

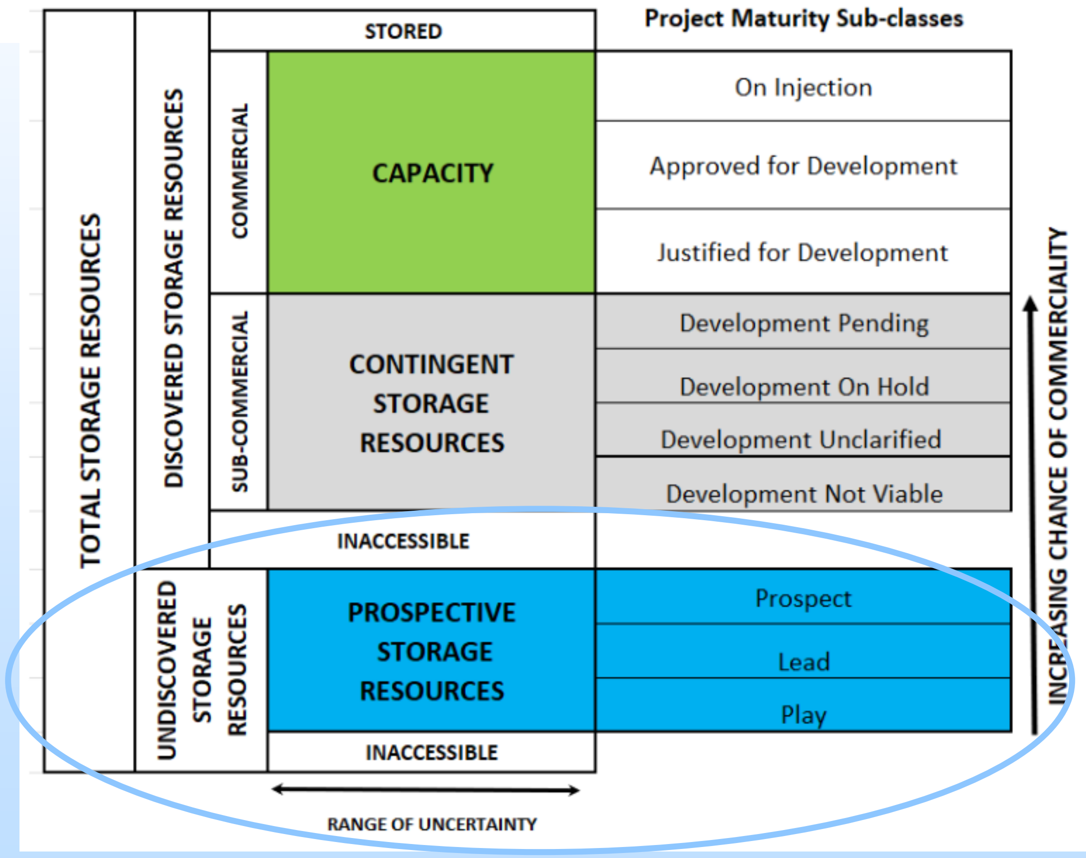
https://www.netl.doe.gov/sites/default/files/2018-10/BPM-SiteScreening.pdf

Society of Petroleum Engineers' Storage Resources Management System

https://experts.illinois.edu/en/publications/the-co2-storage-resources-management-system-srms-toward-a-common-

Classification: Prospective Storage Resources(*Undiscovered* Storage Resources)

https://www.spe.org/en/industry/co2-storage-resources-management-system/



<u>Well does not exist or not assessed</u>

Play: A project associated with a prospective trend of potential prospects, but that requires more data acquisition and/or evaluation to define specific leads or prospects.

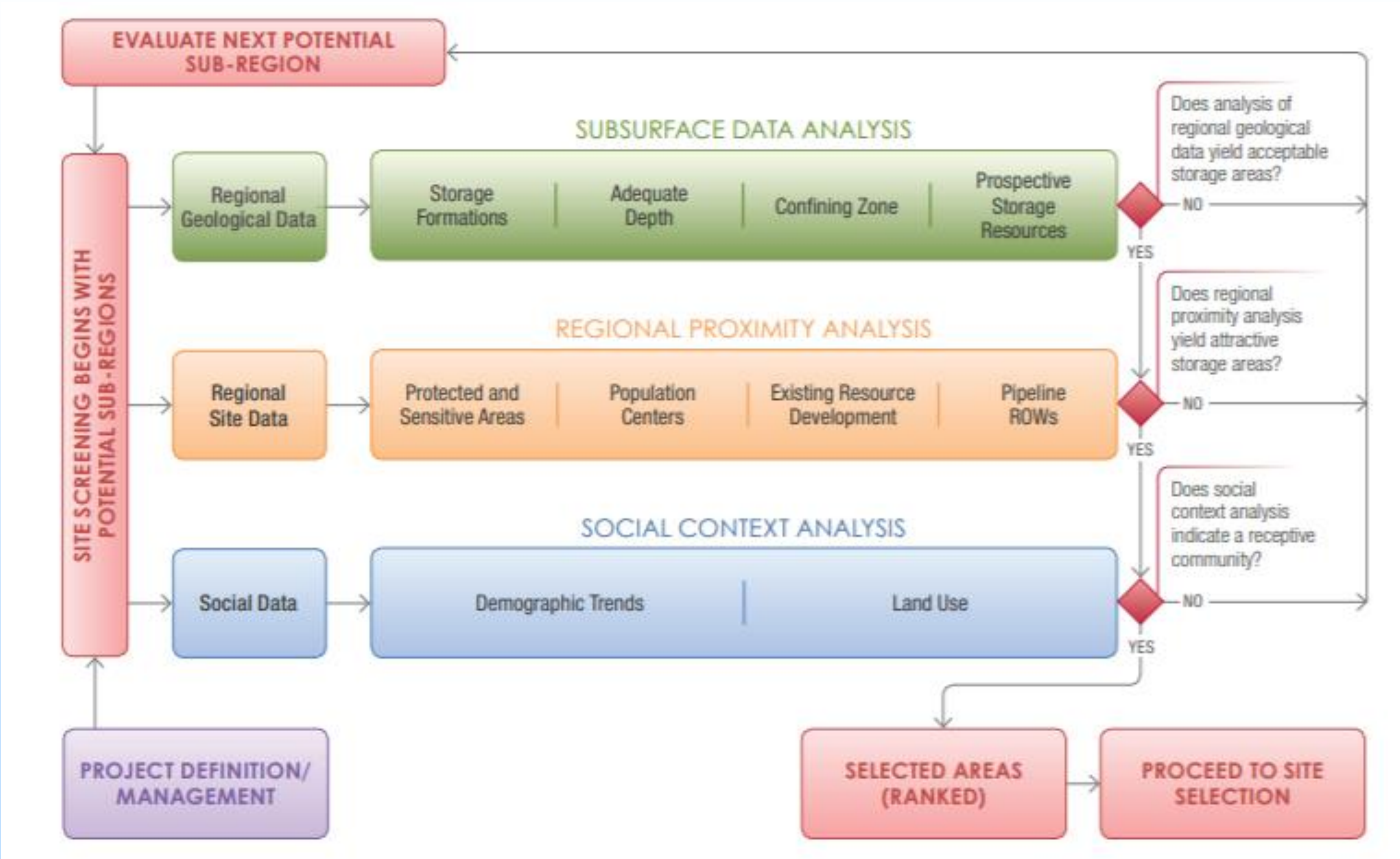
Lead: A project associated with undiscovered storable quantities that is currently poorly defined and requires more data acquisition and/or evaluation to be classified as a prospect.

Prospect: A project associated w/ undiscovered storable quantities sufficiently defined to represent a viable drilling target

Ends with a drilling prospect or existing well identified to assess

PROCESS FLOWCHART FOR SITE SCREENING

Guidelines for Site Screening



Saline Methodology Equation

Subsurface Data Analysis

i. Injection Formation

- Saline Formations, TDS > 10,000 ppm

ii. Adequate Depth

- Sufficient depth to maintain injected CO_2 in the supercritical state ~800 m

iii. Confining Zone

- Contain injected CO_2

iv. Prospective Storage Resources

- Sufficient pore volumes and can accept the change in pressure to accommodate planned injection volumes

Parameter	Units[a]	Description
G_{CO_2}	M	Mass estimate of saline formation CO_2 storage resource.
A_t	L^2	Geographical area that defines the basin or region being assessed for CO_2 storage.
h_g	L	Gross thickness of saline formations for which CO_2 storage is assessed within the basin or region defined by A.
ϕ_{tot}	L^3/L^3	Total porosity in volume defined by the net thickness.
ρ	M/L^3	Density of CO_2 evaluated at pressure and temperature that represents storage conditions anticipated for a specific geologic unit averaged over h_g and A_t.
E_{saline}	L^3/L^3	CO_2 storage efficiency factor that reflects a fraction of the total pore volume that is filled by CO_2.

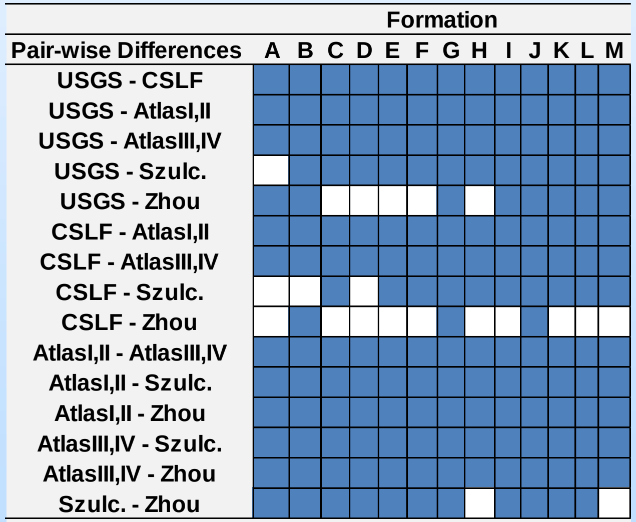
- **Potential Sub-Regions**
  - limited or unavailable geologic data

$$G_{CO_2} = \mathrm{A_t h_g \phi_t \rho E_{saline}}$$

- **Selected Areas**
  - increased data availability and adv. geologic interpretation

$$G = A^d h^s \phi^s \rho^s E_{saline}{}^s$$
$$E_{saline}{}^s = E_A{}^s E_h{}^s E_\phi{}^s E_V{}^s E_d{}^s$$

1. CSLF
2. US-DOE[1]
3. US-DOE[2]
4. USGS
5. Szulczewski (MIT)
6. Zhou (LBNL)



*white boxes represent statistical differences

Saline Methodology Efficiency

Potential Sub-Regions

Saline formation efficiency factors for geologic and displacement terms.

$E_{saline} = E_{An/At}\, E_{hn/hg}\, E_{\phi e/\phi tot}\, E_V\, E_d$

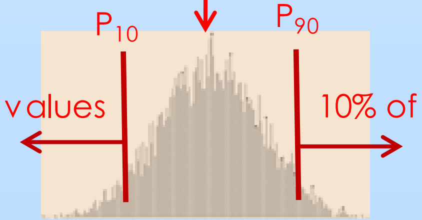
Lithology	P_{10}	P_{50}	P_{90}
Clastics	0.51%	2.0%	5.4%
Dolomite	0.64%	2.2%	5.5%
Limestone	0.40%	1.5%	4.1%

Log-odds stochastic approach

$$E_{saline} = E_A E_h E_\phi E_V E_d$$

E_A E_h E_ϕ E_v E_d

$$\frac{1}{\left(1+e^{(-E_A)}\right)} * \frac{1}{\left(1+e^{(-E_h)}\right)} * \frac{1}{\left(1+e^{(-E_\phi)}\right)} * \frac{1}{\left(1+e^{(-E_V)}\right)} * \frac{1}{\left(1+e^{(-E_D)}\right)}$$



Term	Symbol	P_{10}/P_{90} Values by Lithology			Description
		Clastics	Dolomite	Limestone	
Geologic terms used to define the entire basin or region pore volume					
Net-to-Total Area	$E_{An/At}$	0.2/0.8	0.2/0.8	0.2/0.8	Fraction of total basin or region area with a suitable formation.
Net-to-Gross Thickness	$E_{hn/hg}$	0.21/0.76*	0.17/0.68*	0.13/0.62*	Fraction of total geologic unit that meets minimum porosity and permeability requirements for injection.
Effective-to-Total Porosity	$E_{\phi e/\phi tot}$	0.64/0.77*	0.53/0.71*	0.64/0.75*	Fraction of total porosity that is effective, i.e., interconnected.
Displacement terms used to define the pore volume immediately surrounding a single well CO_2 injector.					
Volumetric Displacement Efficiency	E_V	0.16/0.39*	0.26/0.43*	0.33/0.57*	Combined fraction of immediate volume surrounding an injection well that can be contacted by CO_2 and fraction of net thickness that is contacted by CO_2 as a consequence of the density difference between CO_2 and in-situ water.
Microscopic Displacement Efficiency	E_d	0.35/0.76*	0.57/0.64*	0.27/0.42*	Fraction of pore space unavailable due to immobile *in-situ* fluids.

*Values from IEA (2009)/Gorecki (2009)

Energy & Environmental Research Center

CO_2-SCREEN

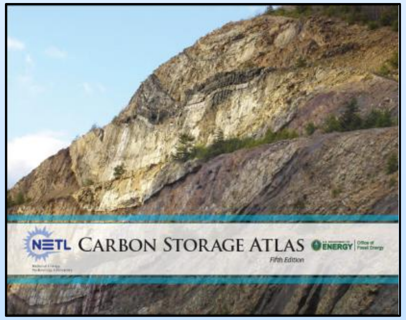
CO_2 Storage prospeCtive Resource Estimation Excel aNalysis

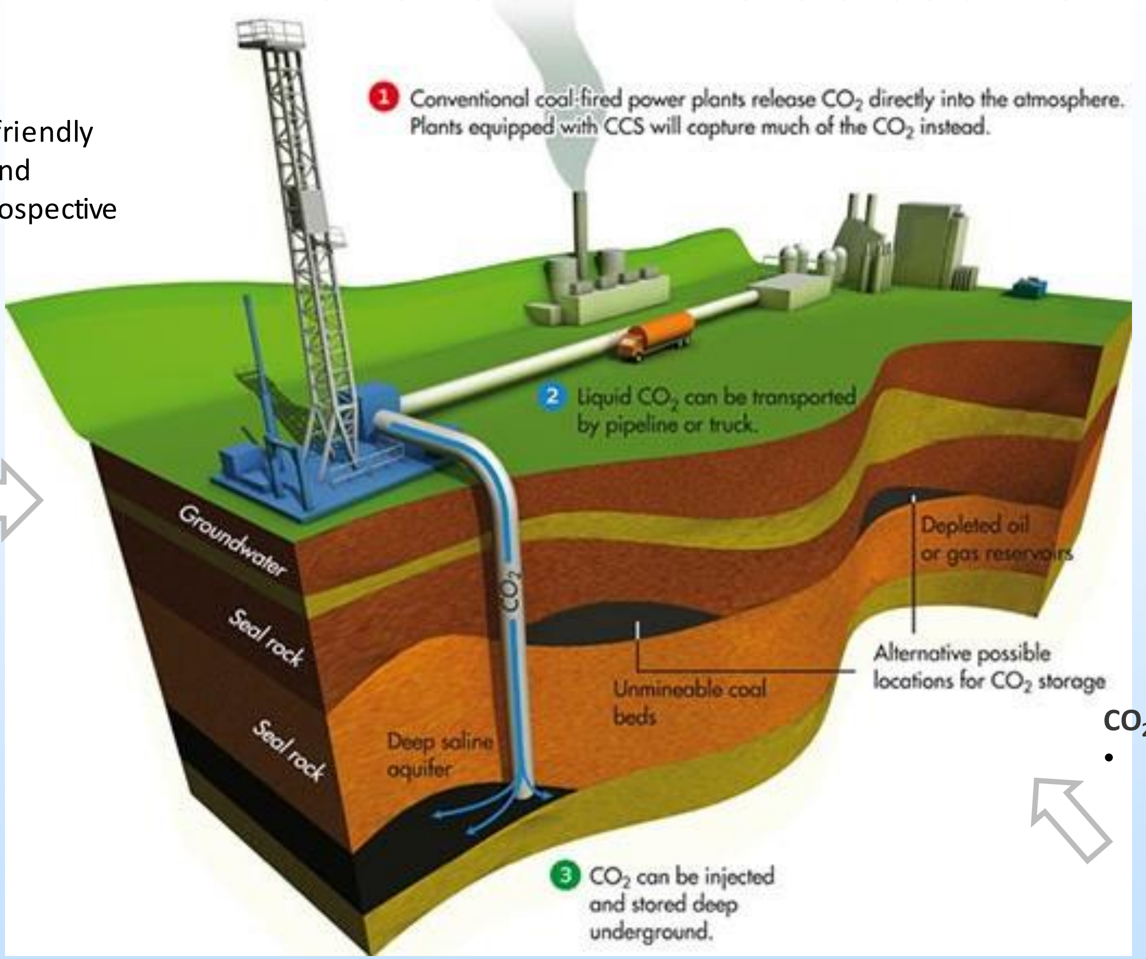
How Much CO_2 Can be Stored in the Subsurface?

2021: Nominated for R&D 100 award
2019: ICHEME finalist

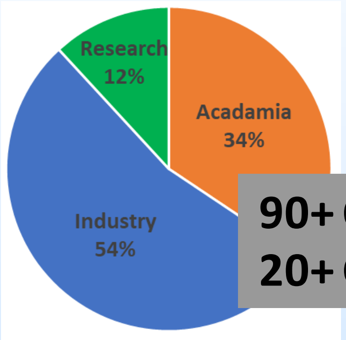
CO_2-SCREEN is a user-friendly tool that allows quick and reliable estimates of prospective CO_2 storage sites

CO_2-Screen establishes the scale of carbon capture and storage activities for governmental policy and commercial project decision-making





CO_2-SCREEN has been downloaded more than 600 times and cited 194 times in peer-reviewed journals.



90+ Organizations
20+ Countries

CO_2-Screen supports Carbon Storage field tests

- Provides prospective carbon storage resource estimates in subsurface formations
  - saline formations
  - shale formations
  - residual oil zones

CO_2-SCREEN was developed by the United States Department of Energy's National Energy Technology Laboratory with partners at the Carbon Storage Assurance Facility Enterprise (CarbonSAFE), Illinois State Geological Survey, Energy & Environmental Research Center, United States Geological Survey

NATIONAL ENERGY TECHNOLOGY LABORATORY
USGS science for a changing world
EERC Energy & Environmental Research Center Putting Research into Practice
ILLINOIS STATE GEOLOGICAL SURVEY PRAIRIE RESEARCH INSTITUTE

CO_2-Screen can be accessed at:

- **NETL's EDX** https://edx.netl.doe.gov/dataset/co2-screen
- **YOUTUBE** https://www.youtube.com/watch?v=Ihakk-HYfOI

EDX Energy Data eXchange

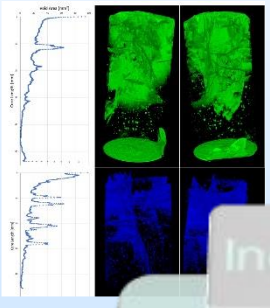
Next Steps: Update Efficiency with New Relative Permeability Data

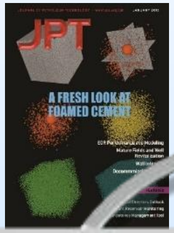
CO_2BRA Database

- An open dataset of unsteady state relative permeability measurements of supercritical CO_2 displacing brine in 12+ rock types. https://edx.netl.doe.gov/hosting/co2bra/

Capabilities at NETL

Four computed tomography scanners with 3D resolution from microns to millimeters, all with ancillary core flow capabilities, used for examining real rocks under real conditions applicable to storage and production.





Micro-CT

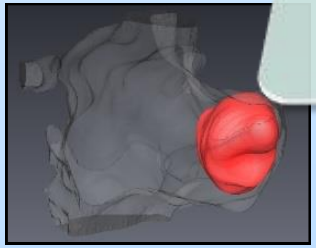
- Pore Scale
- Small Samples
- Dynamic Flooding

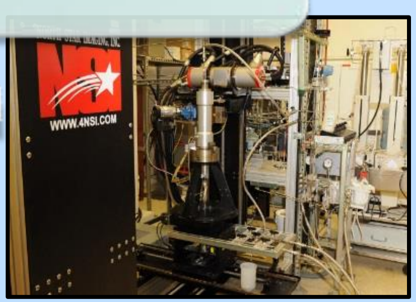
Industrial CT

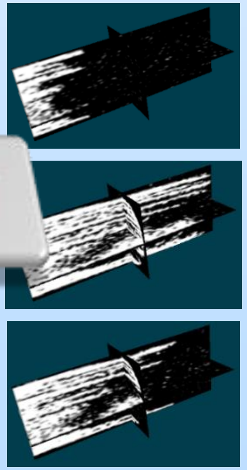
- Pore & Core scale
- 1" Diameter plus Samples
- Highest Pressures

Medical CT

- Core Scale
- Large Samples
- Dynamic Flooding







Experimental details in:
Moore, et al., 2021,
Advance Water Resources

Homogenous models - Reservoir Modeling

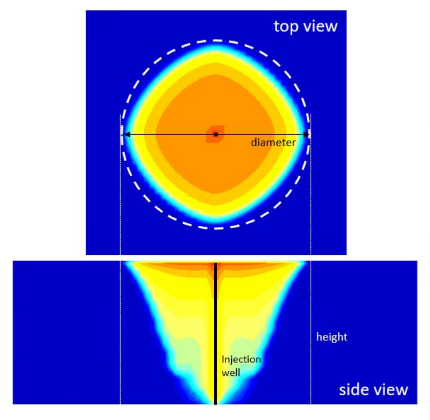
Homogenous models

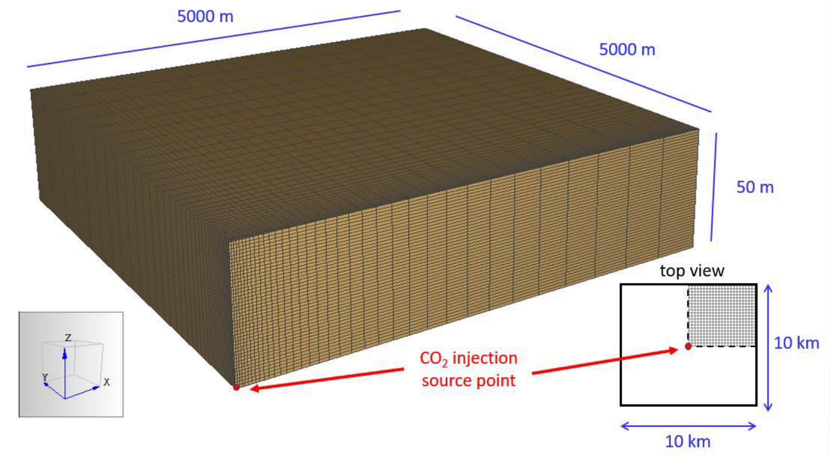
Model dimensions		
Width	5,000	m
Length	5,000	m
Thickness	50	m
Domain discretization	35×35×43	
Number of grids	52,675	
Rock properties		
Porosity	variable*	
Permeability (lateral)	variable*	
Permeability anisotropy	variable*	
Relative permeability	variable*	
Capillary pressure	variable*	
Reservoir properties		
Initial pressure	variable*	
Pressure gradient	10.14	kPa/m
Initial temperature	variable*	
Temperature gradient	0.02	°C/m
Brine concentration	8	%
Pore compressibility	4.5E-10	Pa^{-1}
Operation properties		
Injection rate	variable*	
Injection period	30	years
Perforation	bottom source point	

*Varies based on modeling cases

$$E_{saline}{}^{s} = E_A{}^{s} E_h{}^{s} E_\phi{}^{s} E_V{}^{s} E_d{}^{s}$$

Minimum-area-circle approach





TOUGH3-ECO2M

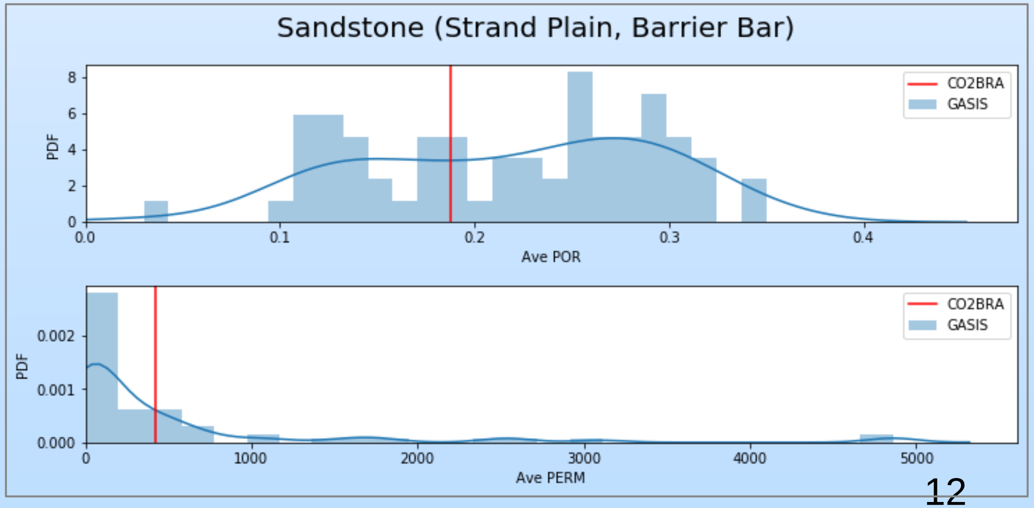
$$E_V = \frac{V_i}{Ah\rho\phi(1 - S_{w_{irr}})}$$

$$E_d = 1 - S_{w_{ave}}$$

CO$_2$BRA Database | GASIS Database

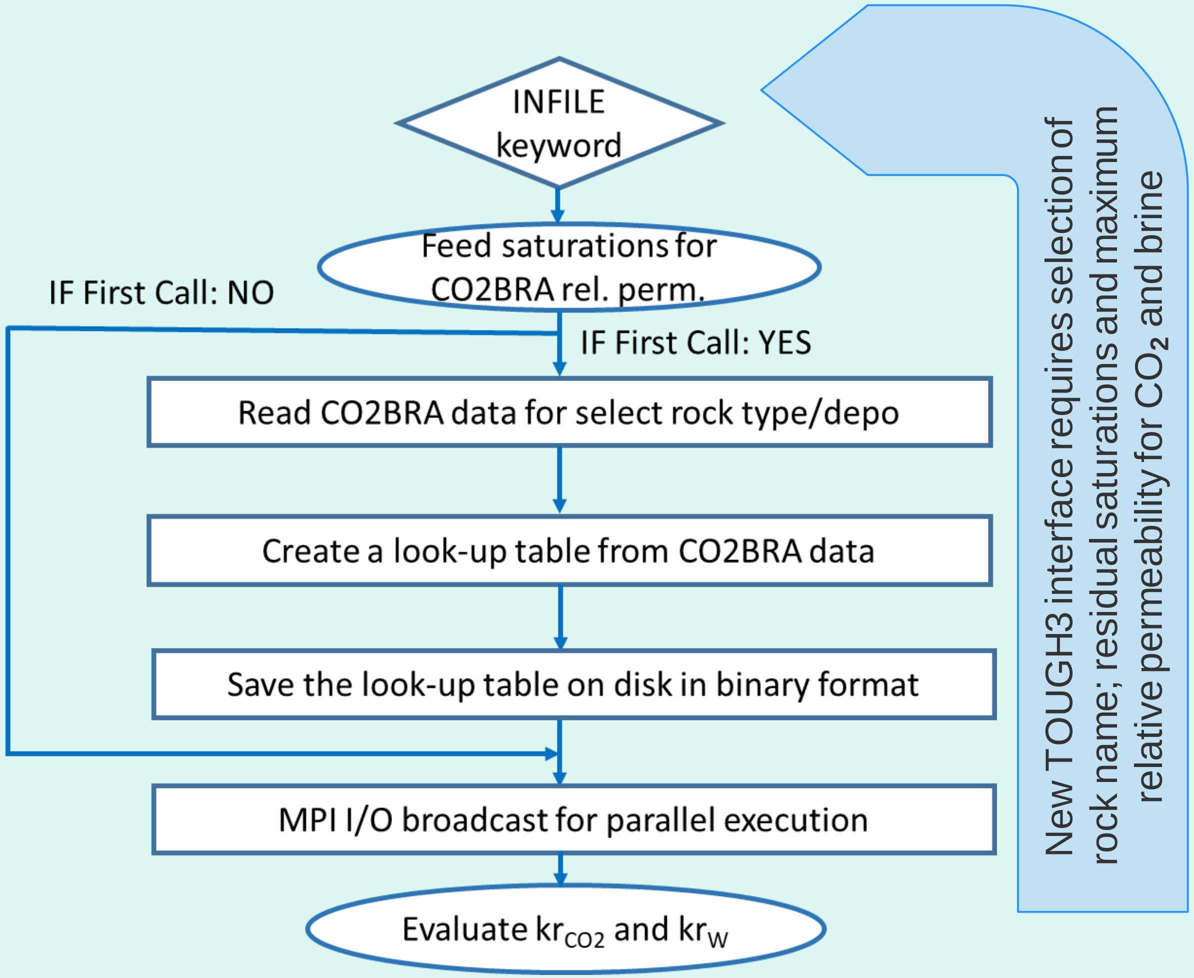
	Lithology	Depositional Environment	Sample Name	Min Por	Min Por	Min Perm mD	Max Perm mD
1	Sandstone	Marginal Marine	Bandera Brown A	0.1	0.3	50	350
2		Strand Plain, Barrier Bar	Berea	0.1	0.3	100	700
3		Deltaic Complex Fluvial	Castlegate	0.1	0.3	200	1000
4		Aeolian	Navajo	0.15	0.25	20	800
5	Limestone	Shallow Marine	Austin Chalk	0.1	0.3	50	150
6		Reef	Edwards Yellow	0.1	0.25	50	110
7	Dolomite	Reef	Silurian	0.1	0.3	100	400

GASIS: Gas Information System (Hugman et al., 2016)

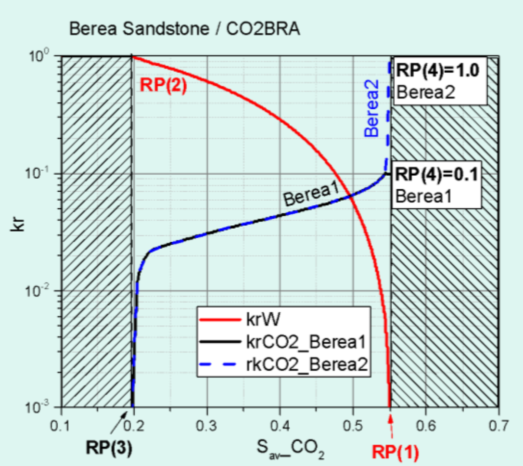


Homogenous models - Reservoir Modeling

Coupling CO_2BRA and TOUGH3 using a lookup table

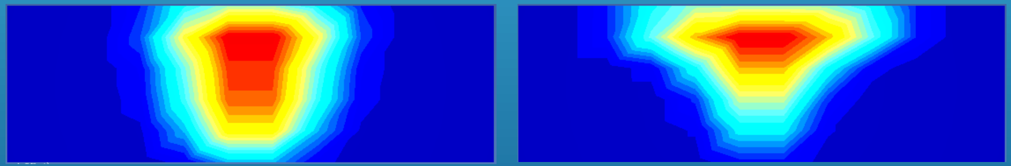


CO_2BRA relative permeability for carbon dioxide approaching residual brine saturation

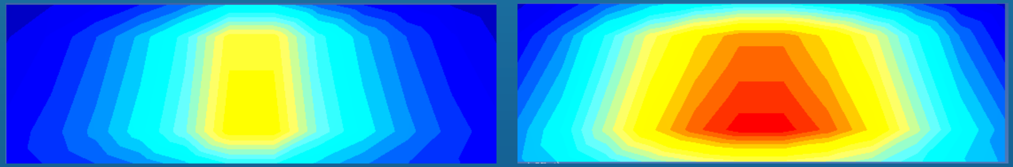


Berea1 **Berea2**

CO_2 saturations depicted using a vertical cross-section along a well



Pressure distributions depicted using a vertical cross-section along a well

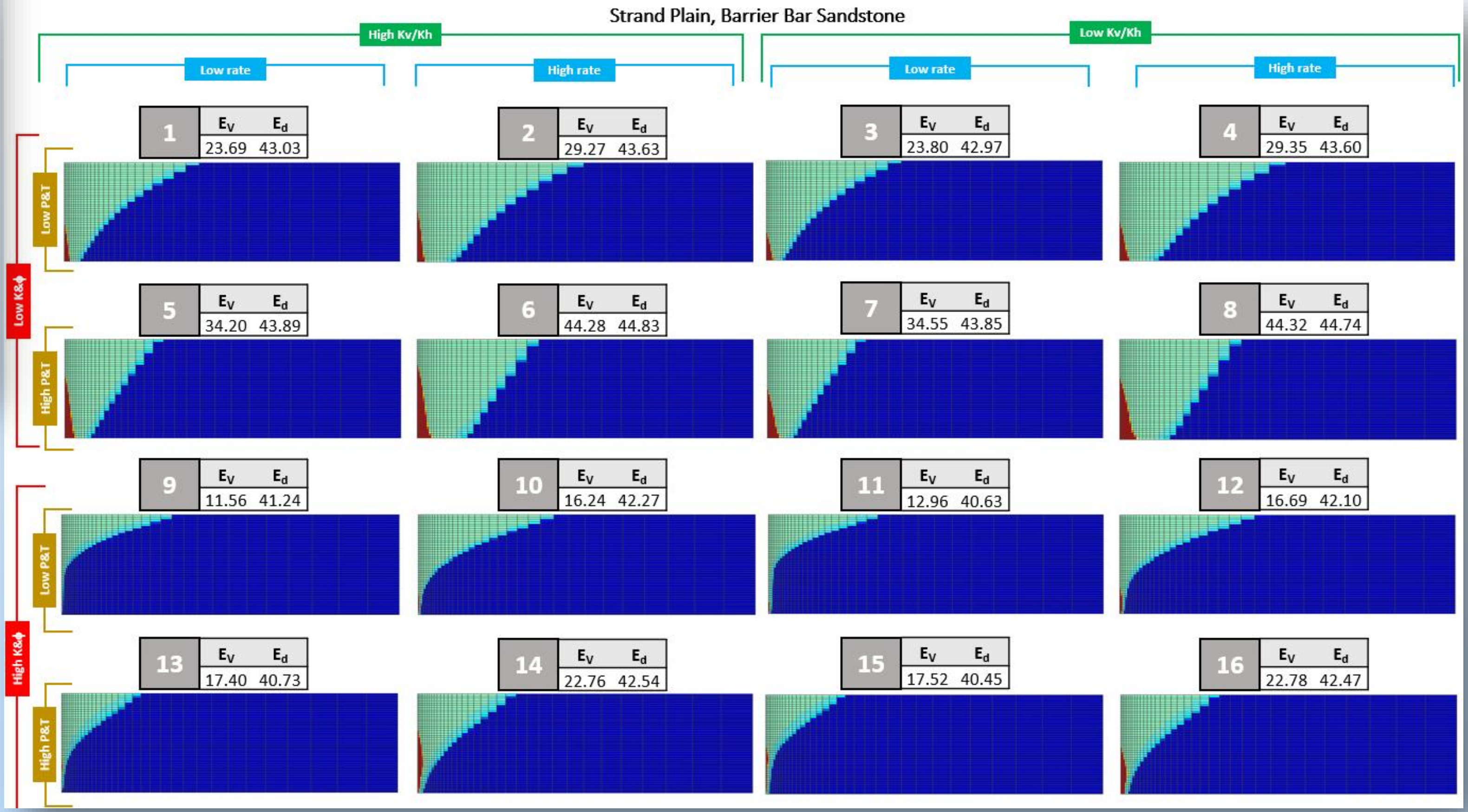


Homogenous models - Simulation Results

Modeling Cases							Storage Efficiencies (%)	
Case No.	Porosity	Permeability (mD)	Temperature (°C)	Pressure (MPa)	Kv/Kh	Rate (tons/day)	E_V	E_d
1	0.1	100	43.3	9.65	0.5	400	23.69	43.03
2	0.1	100	43.3	9.65	0.5	800	29.27	43.63
3	0.1	100	43.3	9.65	0.1	400	23.80	42.97
4	0.1	100	43.3	9.65	0.1	800	29.35	43.60
5	0.1	100	87.8	27.6	0.5	400	34.20	43.89
6	0.1	100	87.8	27.6	0.5	800	44.28	44.83
7	0.1	100	87.8	27.6	0.1	400	34.55	43.85
8	0.1	100	87.8	27.6	0.1	800	44.32	44.74
9	0.3	700	43.3	9.65	0.5	400	11.56	41.24
10	0.3	700	43.3	9.65	0.5	800	16.24	42.27
11	0.3	700	43.3	9.65	0.1	400	12.96	40.63
12	0.3	700	43.3	9.65	0.1	800	16.69	42.10
13	0.3	700	87.8	27.6	0.5	400	17.40	40.73
14	0.3	700	87.8	27.6	0.5	800	22.76	42.54
15	0.3	700	87.8	27.6	0.1	400	17.52	40.45
16	0.3	700	87.8	27.6	0.1	800	22.78	42.47
						P_{10}	14.60	40.68
						P_{50}	23.24	42.76
						P_{90}	39.42	44.32

Modeling cases used for Strand Plain Sandstone

Impact of injection rate, pressure & temperature, porosity & permeability, and permeability anisotropy on CO_2 plume shape and storage efficiency factors



Homogenous models - Simulation Results

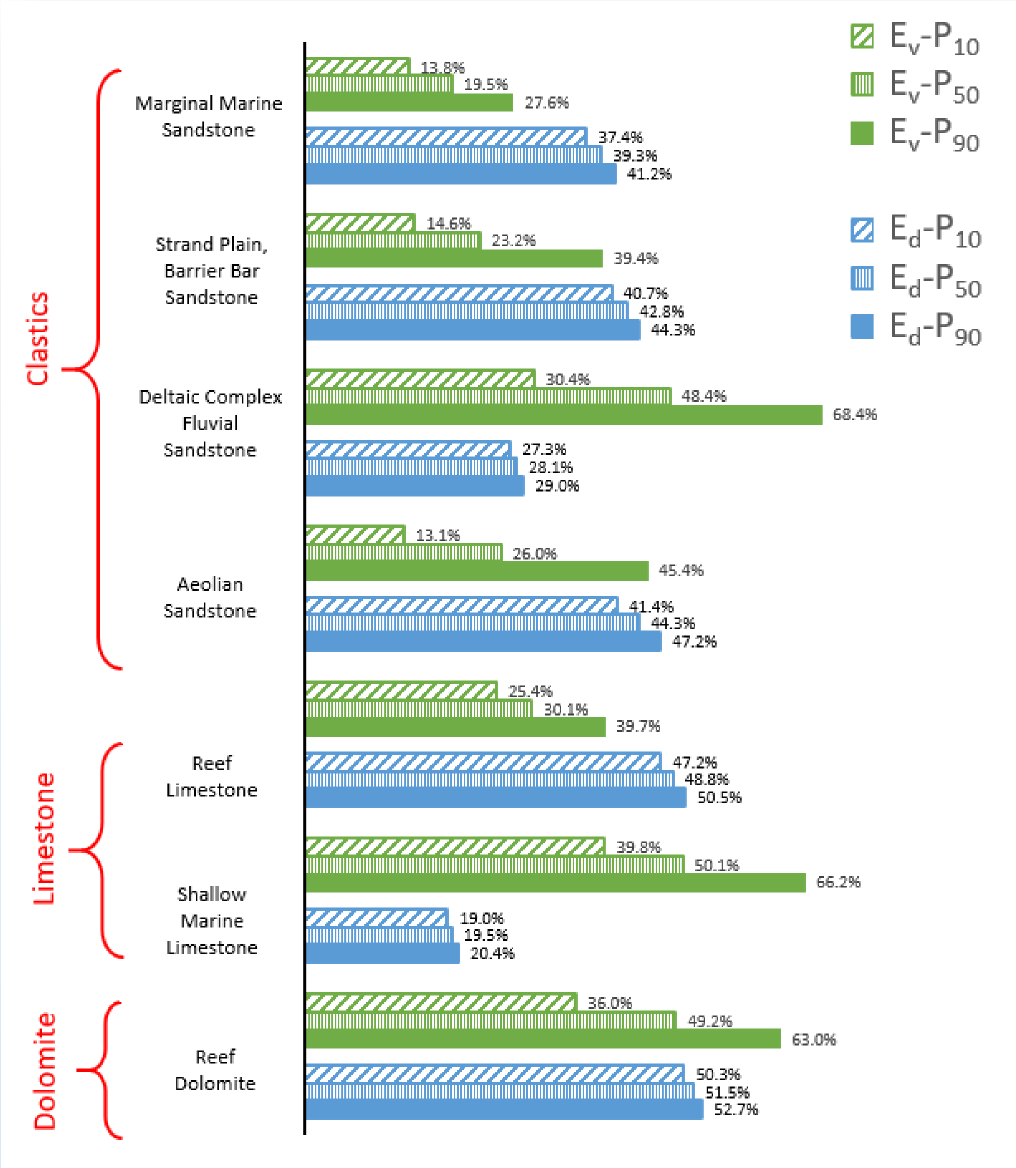


Table 5 – Saline formation efficiency factors (%) using homogenous models.

Lithology	E_{saline} (Goodman et al, 2011) P10	P50	P90	E_{saline} (This study) P10	P50	P90
Clastics	7.4	14.0	24.0	4.5	10.0	19.1
Limestone	10.0	15.0	21.0	6.8	13.6	24.2
Dolomite	16.0	21.0	26.0	18.4	25.6	32.5

- In both studies, dolomite followed by limestone had the highest values
- Refinements to previous storage efficiency factors:
  - narrower range for clastics
  - wider range for limestone
  - higher P10 and P90 for dolomite

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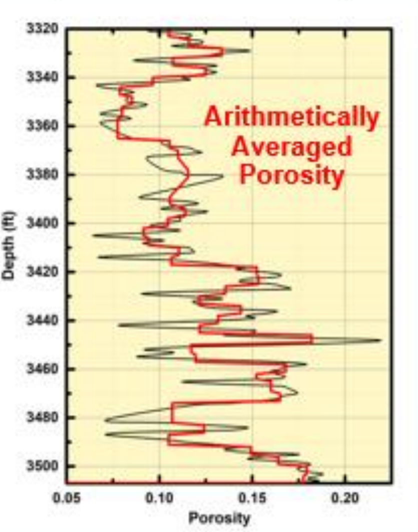
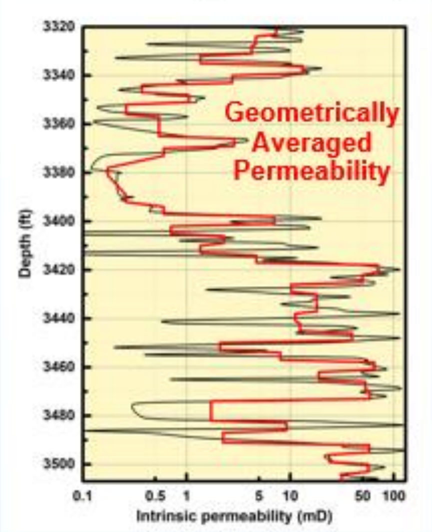
Simulated CO_2 storage efficiency factors for saline formations of various lithologies and depositional environments using new experimental relative permeability data

Foad Haeri [a,b,*], Evgeniy M. Myshakin [a,b], Sean Sanguinito [a,b], Johnathan Moore [a,b], Dustin Crandall [a], Charles D. Gorecki [c], Angela L. Goodman [a]

Heterogeneous models (Vertical)

Lower Mt. Simon Sandstone Shallow Marine
3,320 - 3,507 TVD bgs (164 ft)
at Duke Energy #1 Well
(East Bent Field, Boone County, Kentucky)





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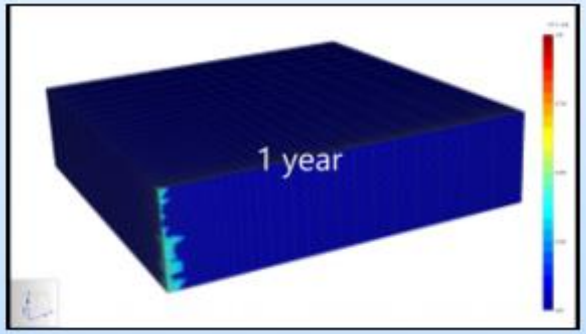

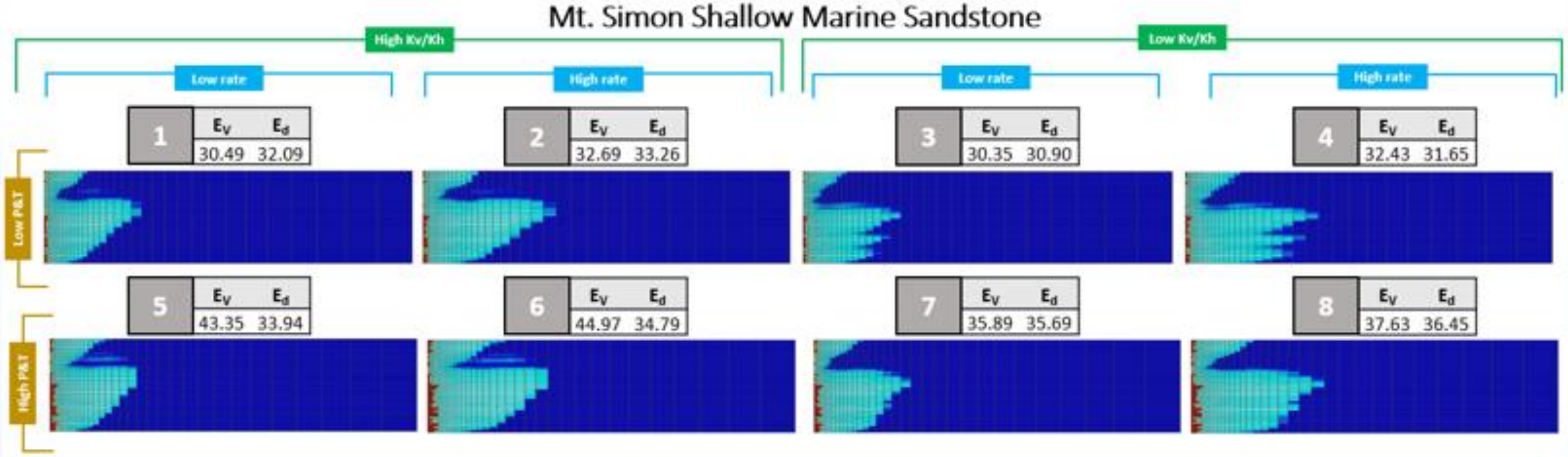

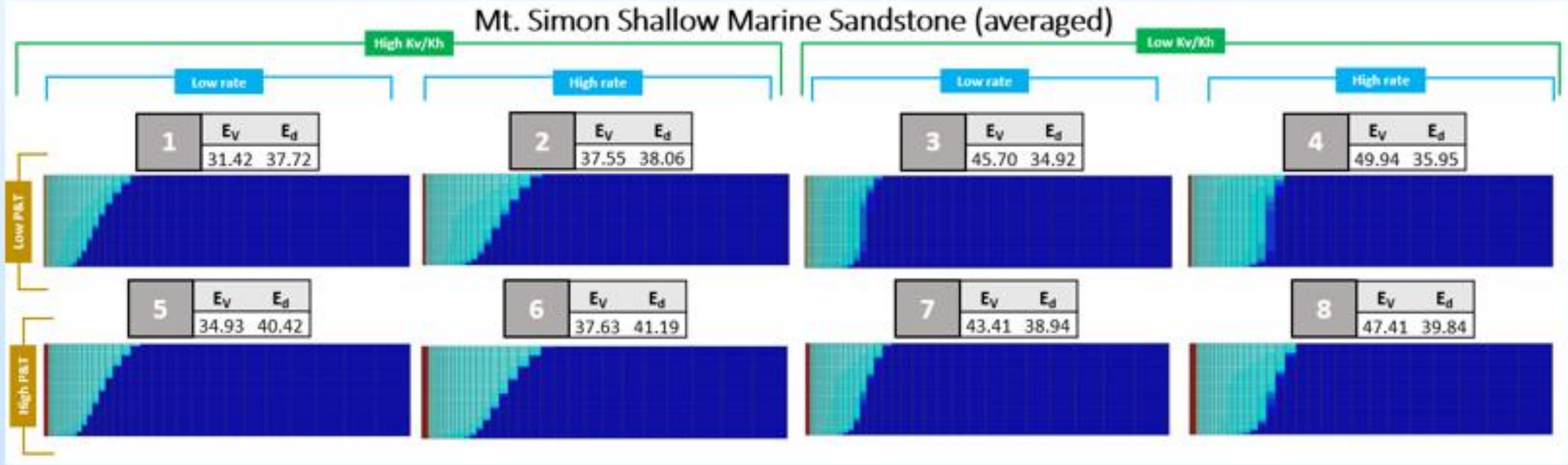

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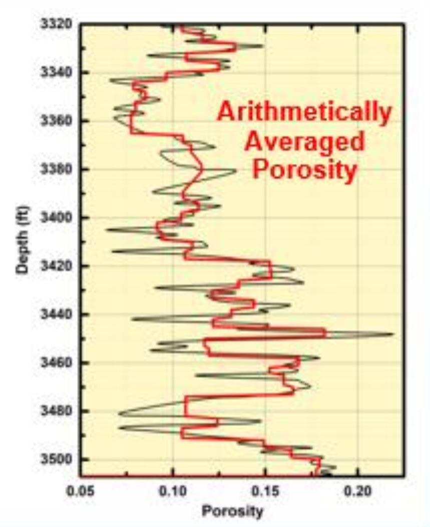

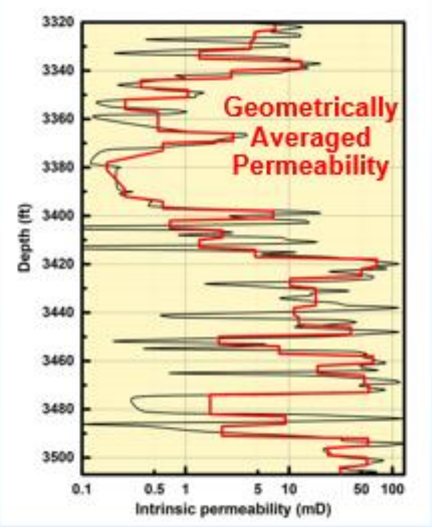

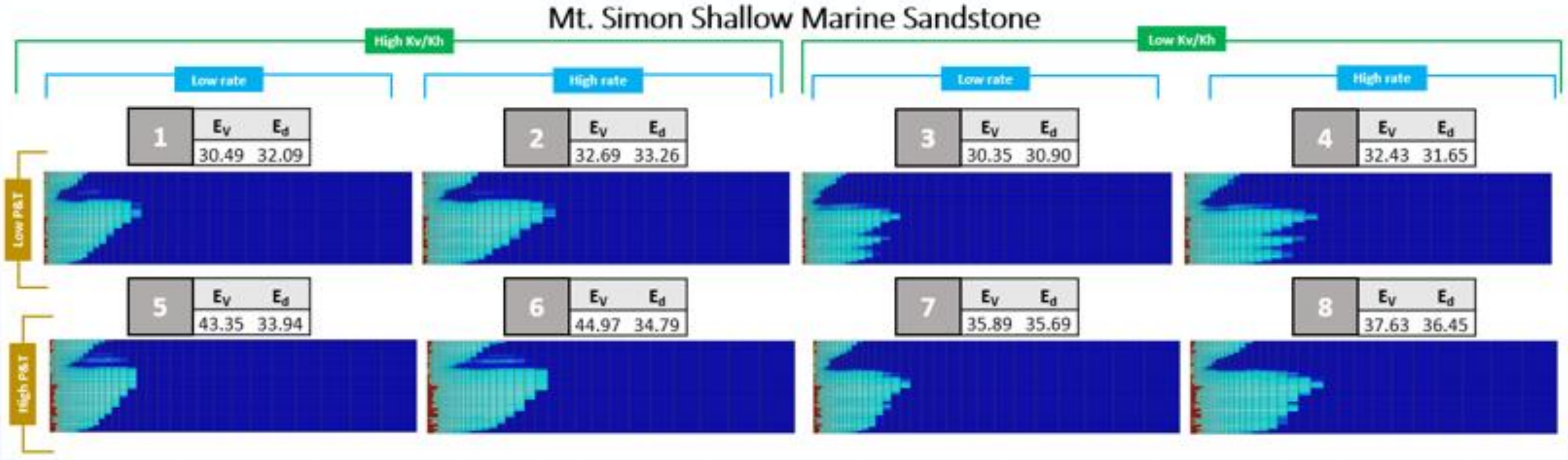

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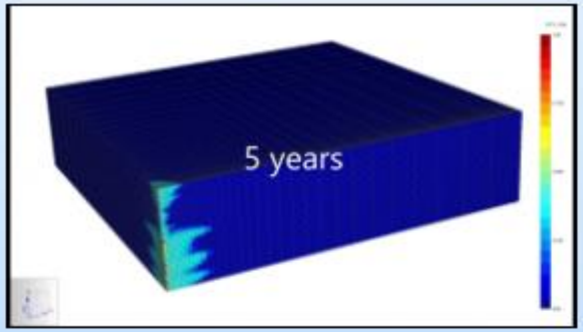

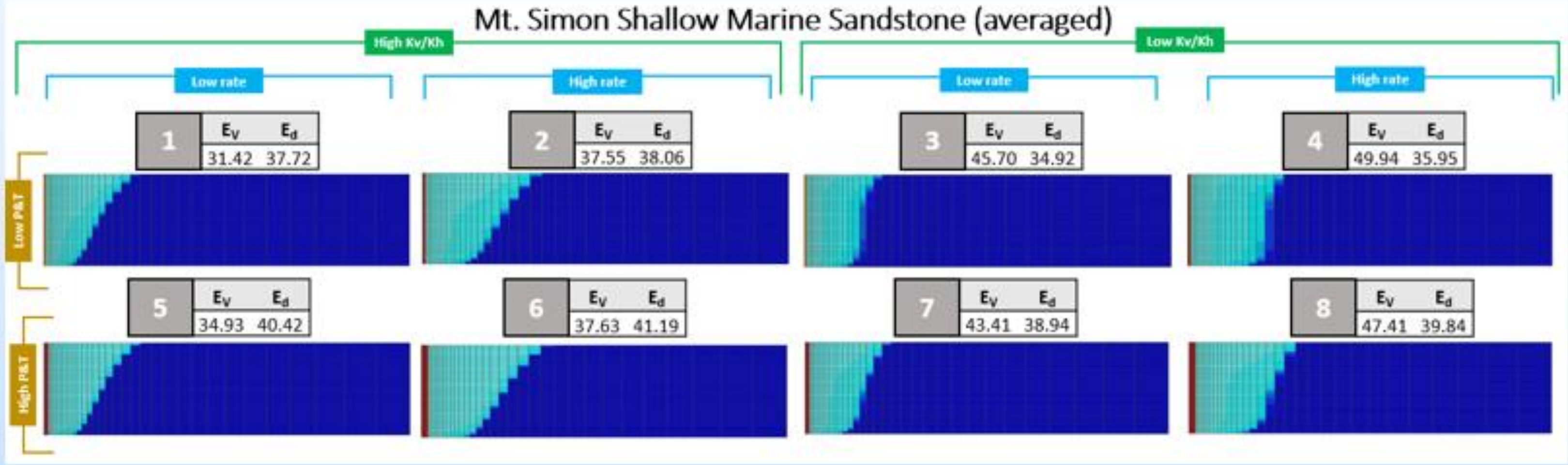

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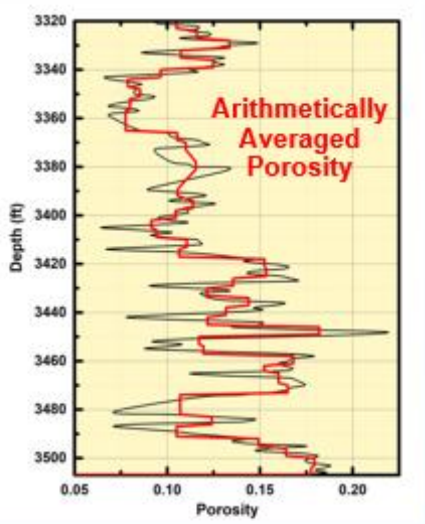

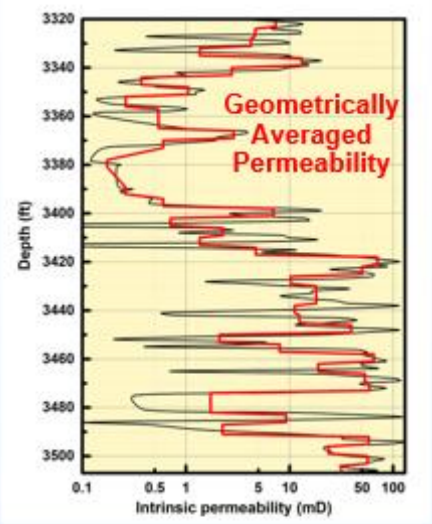

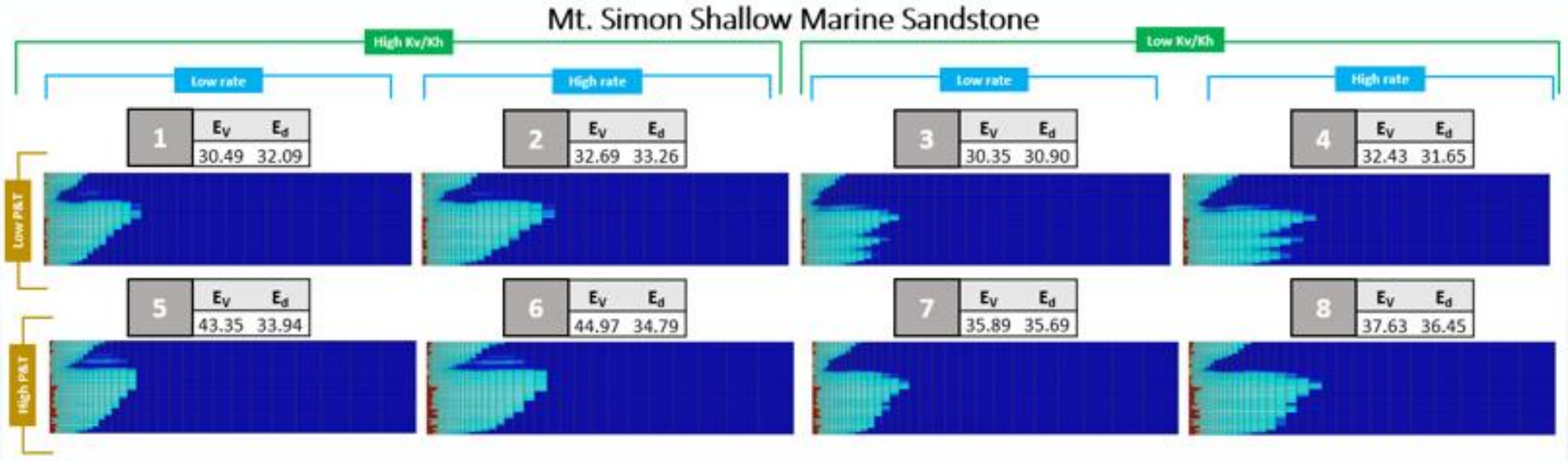

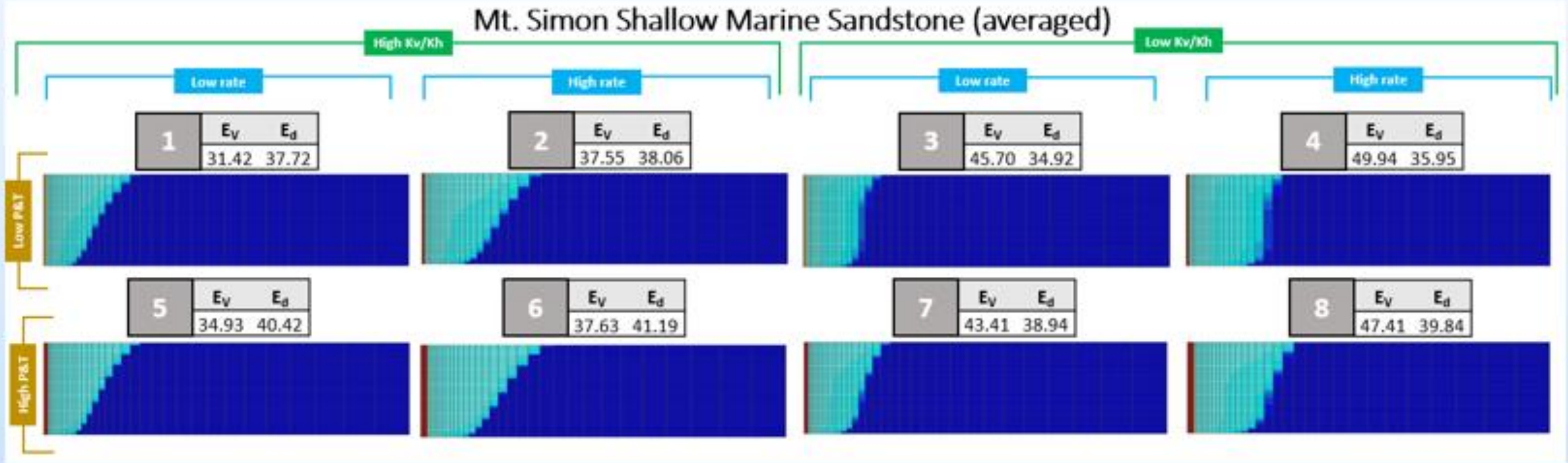

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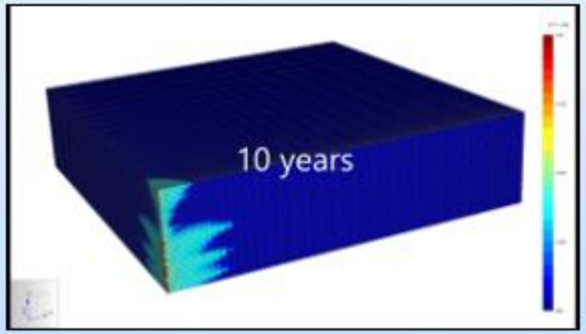

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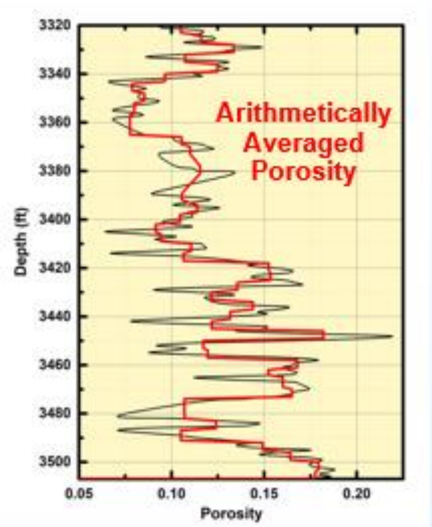

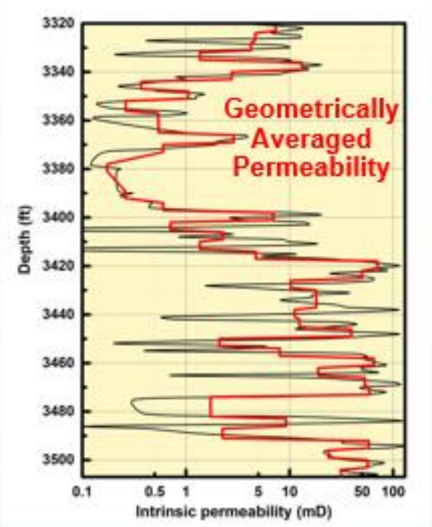

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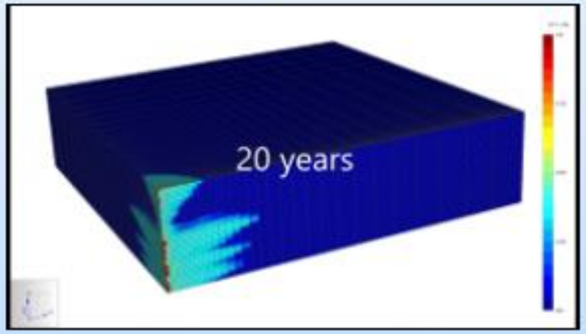

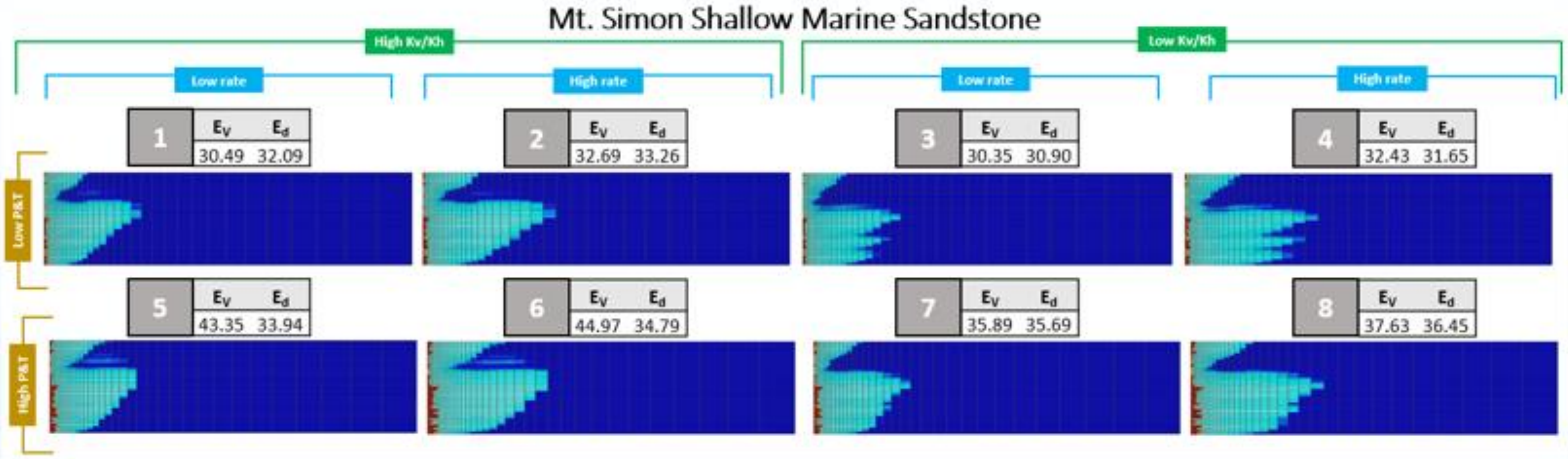

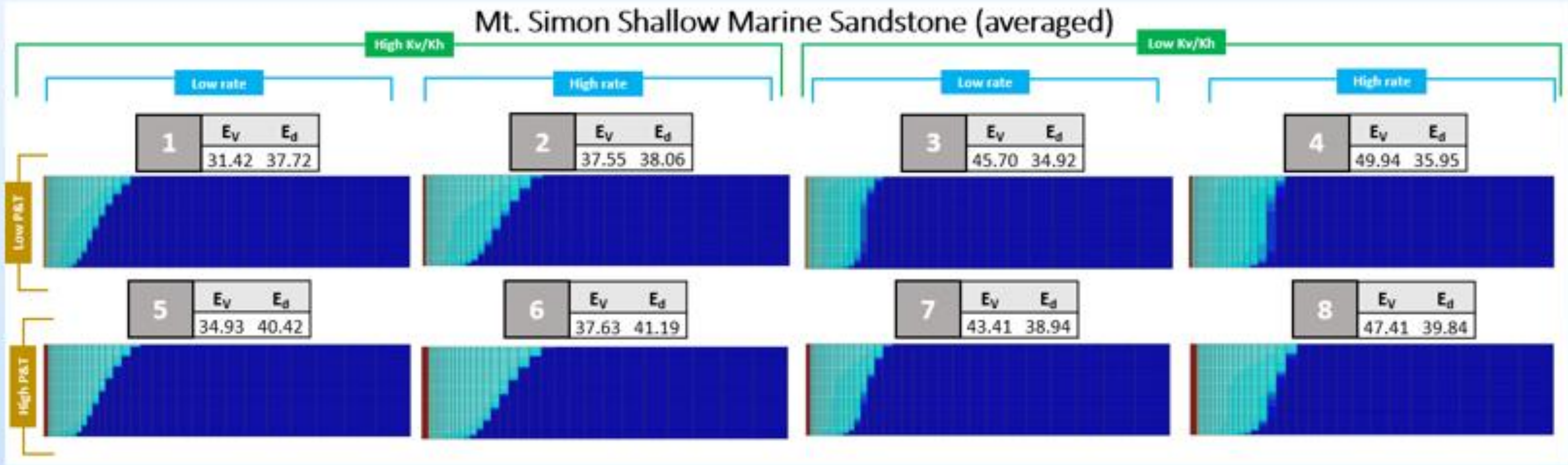

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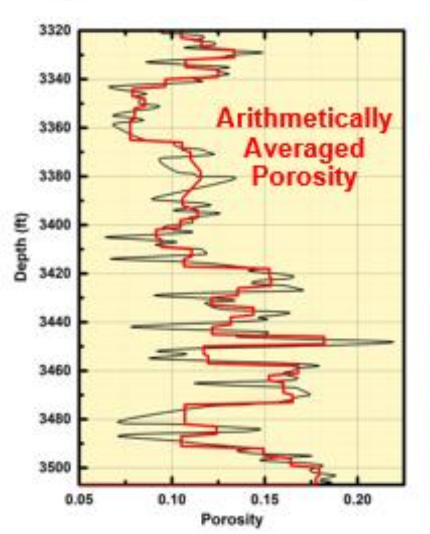

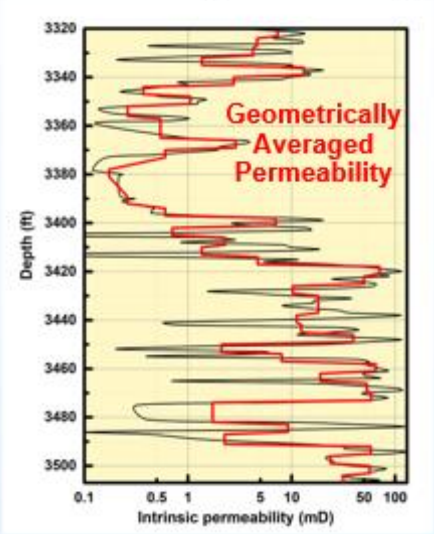

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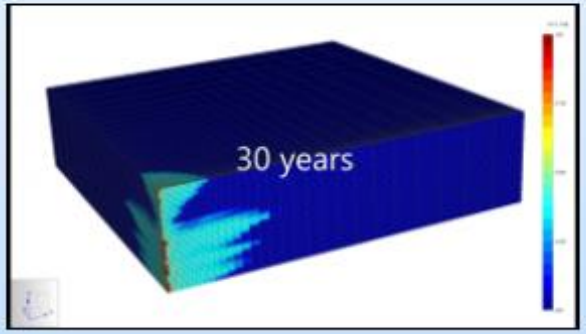

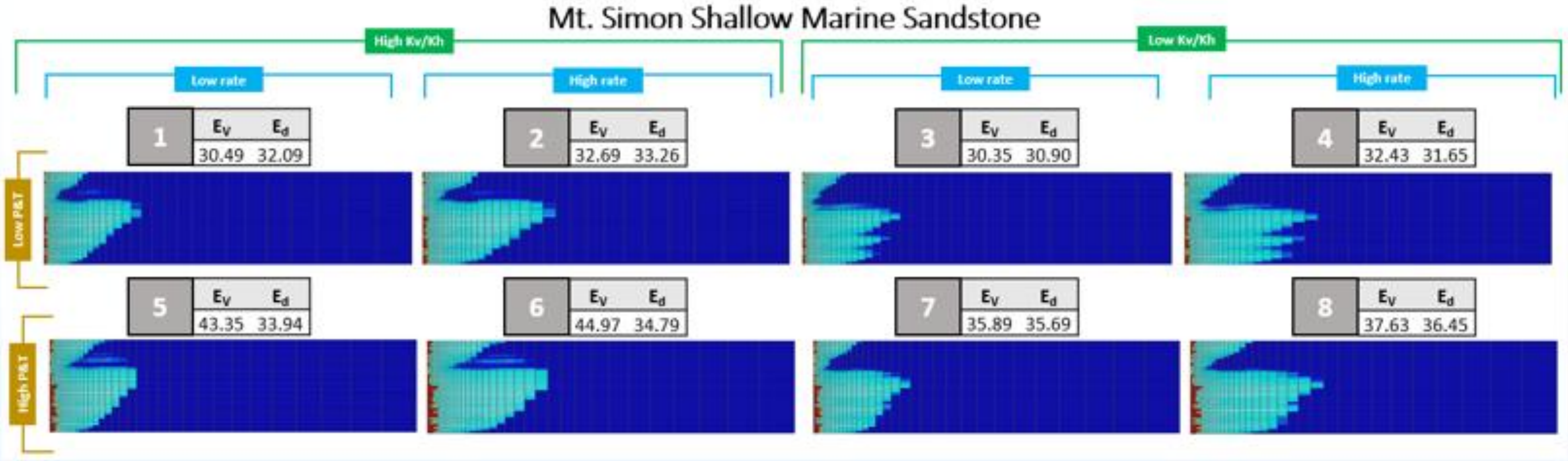

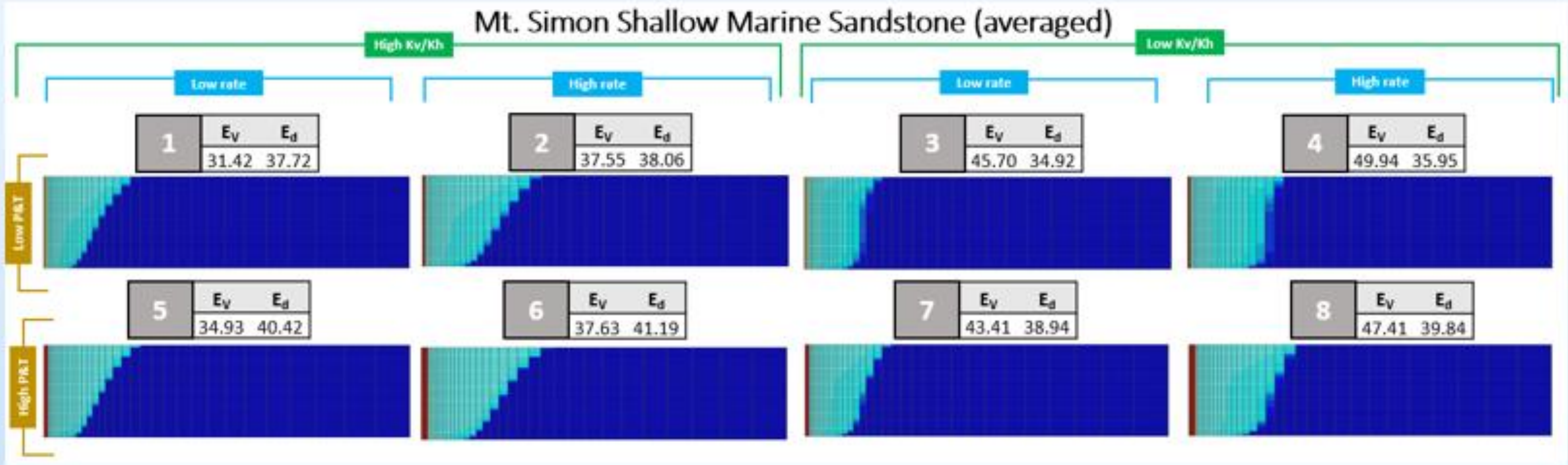

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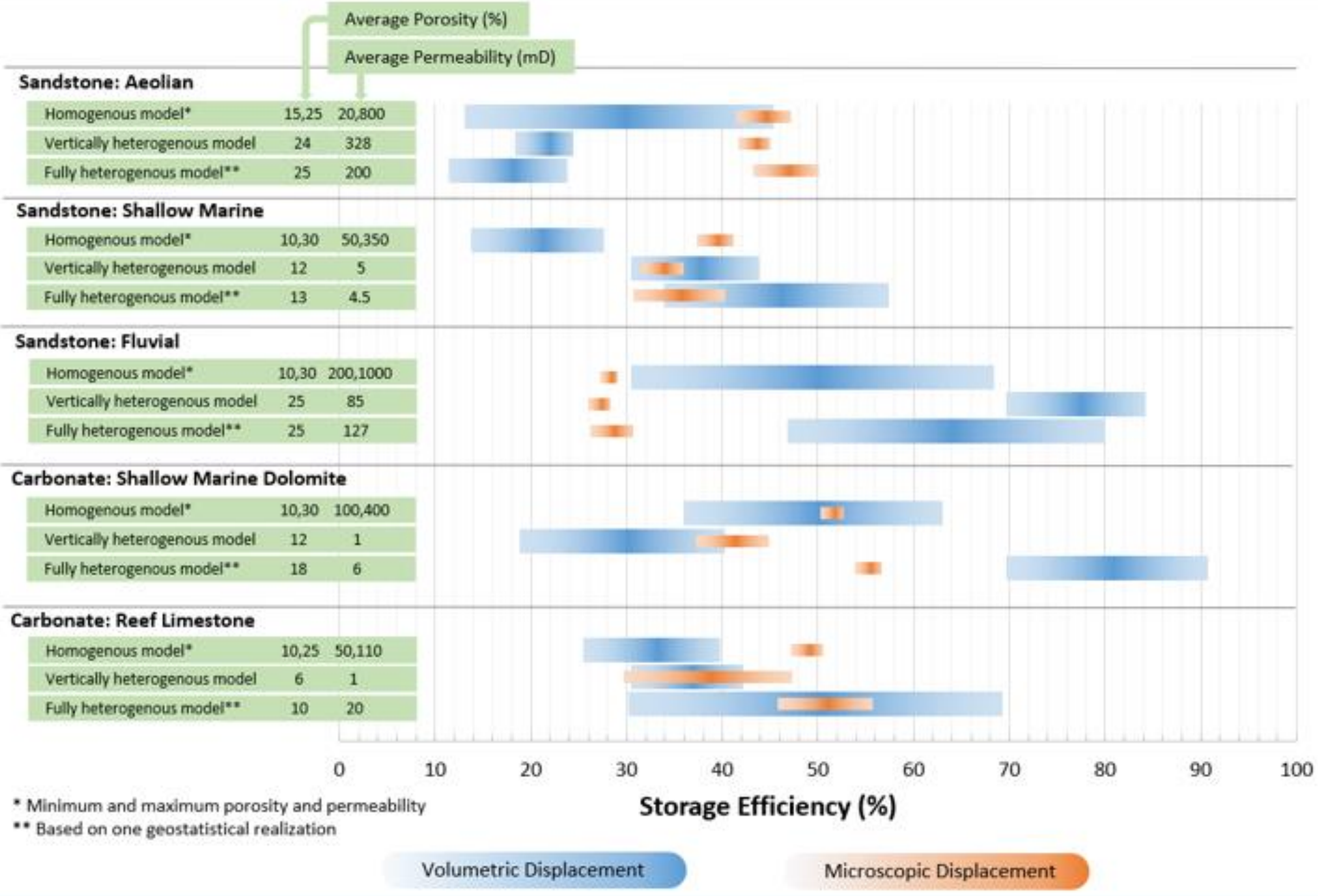
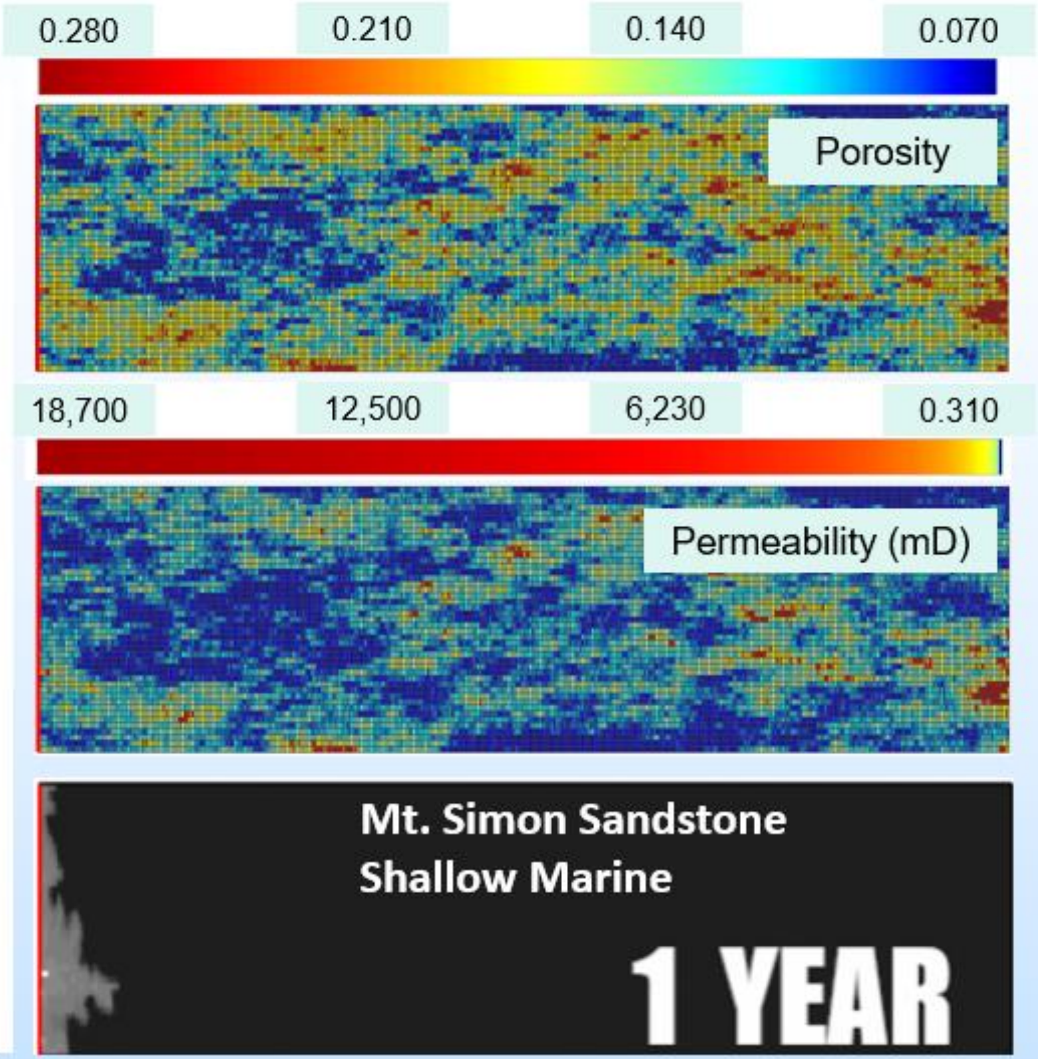
Impact of heterogeneity on volumetric and microscopic efficiencies after 30 years of CO_2 injection in different depositional environments





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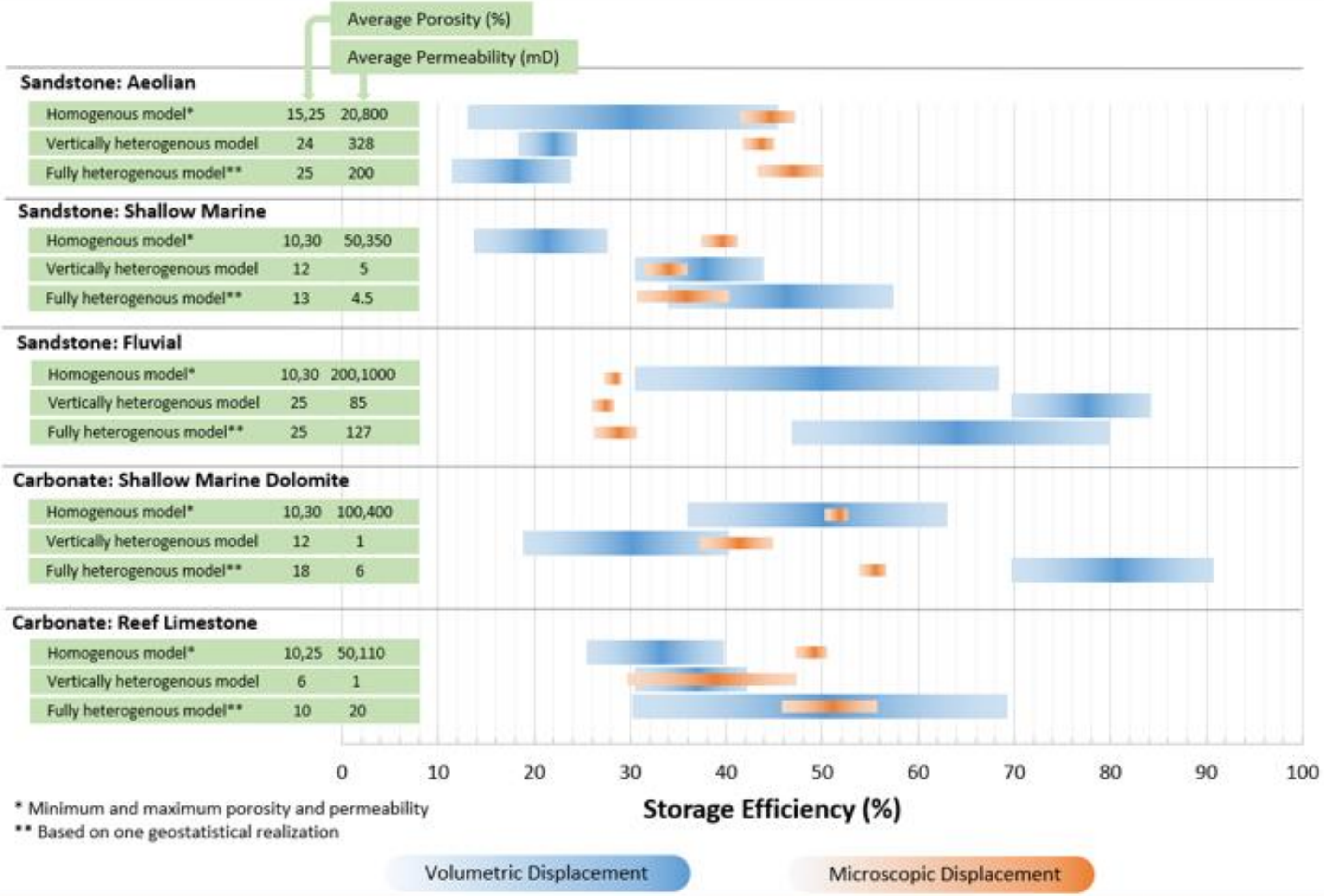

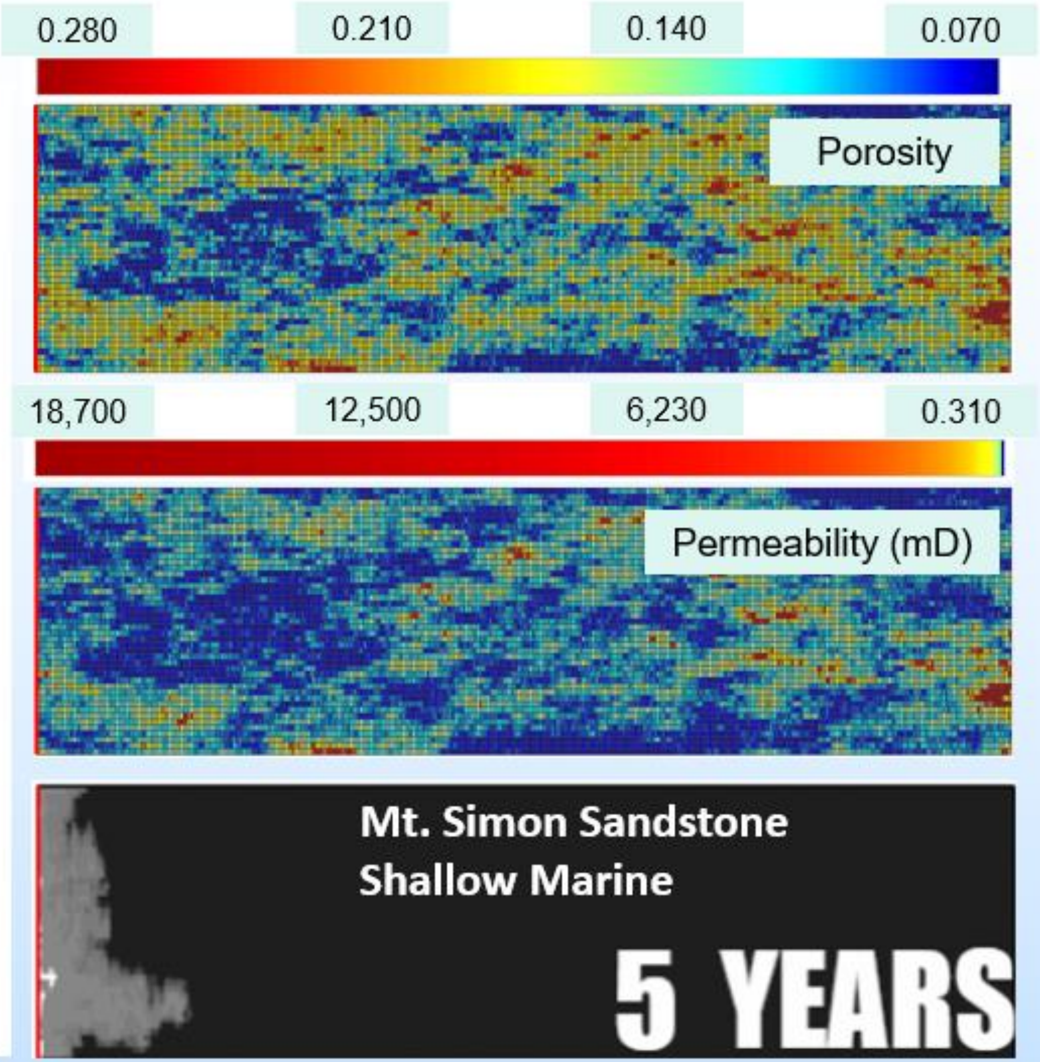

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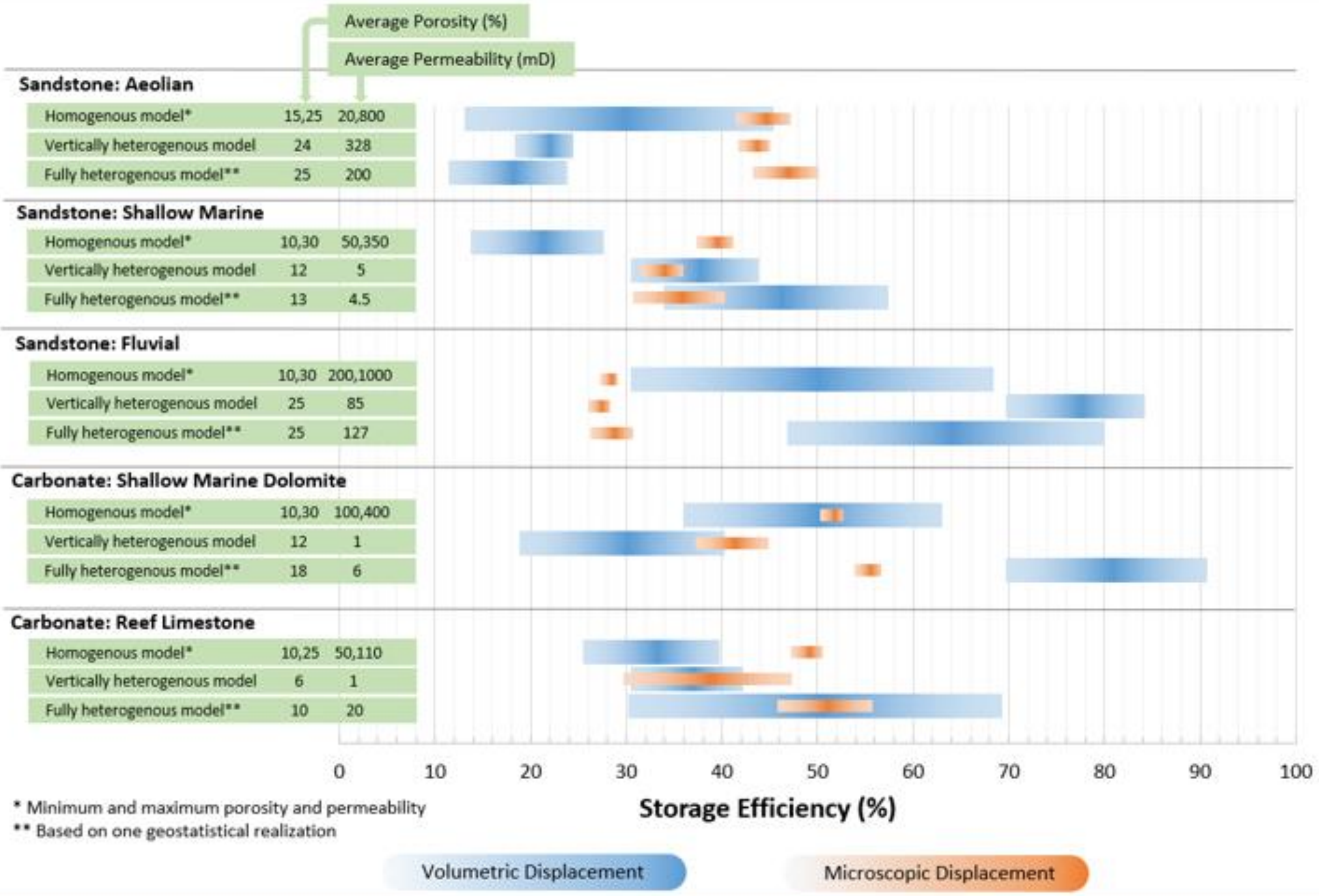

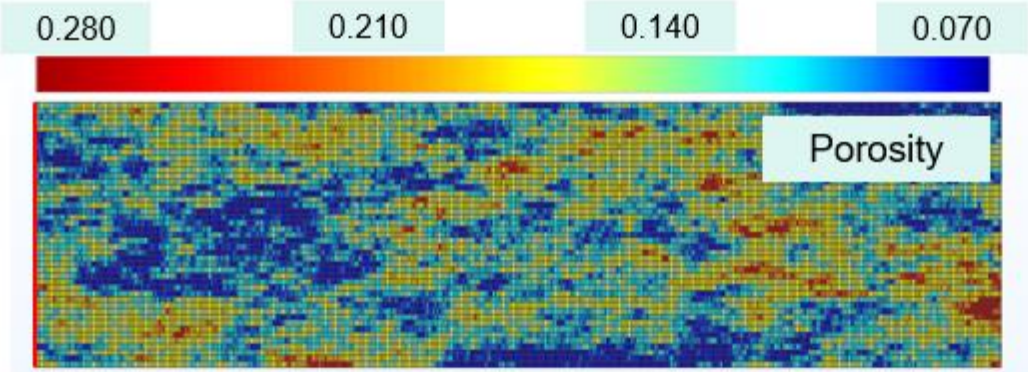

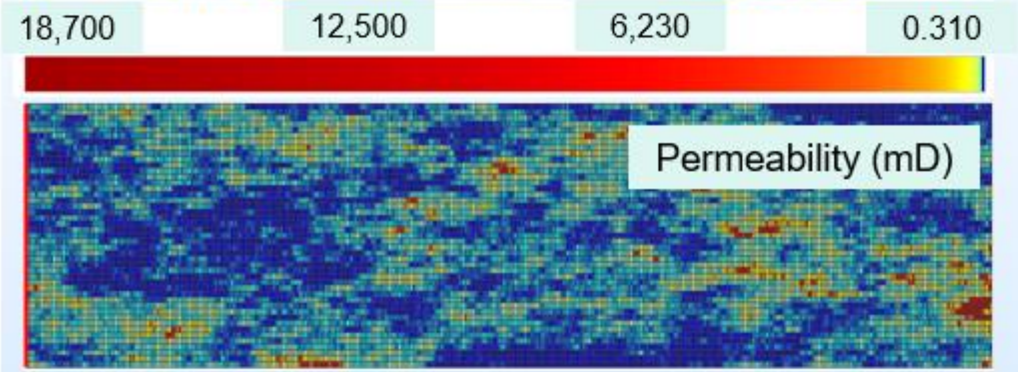

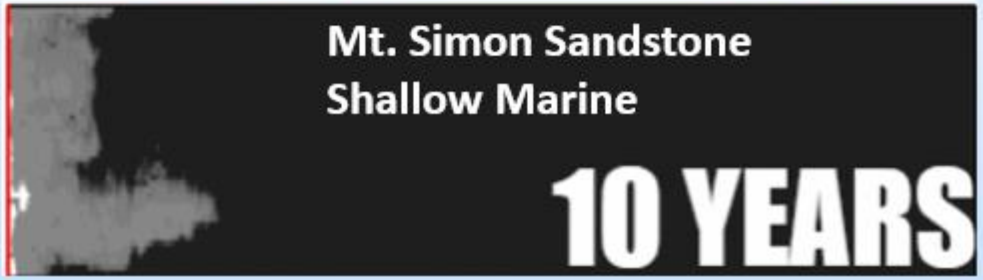

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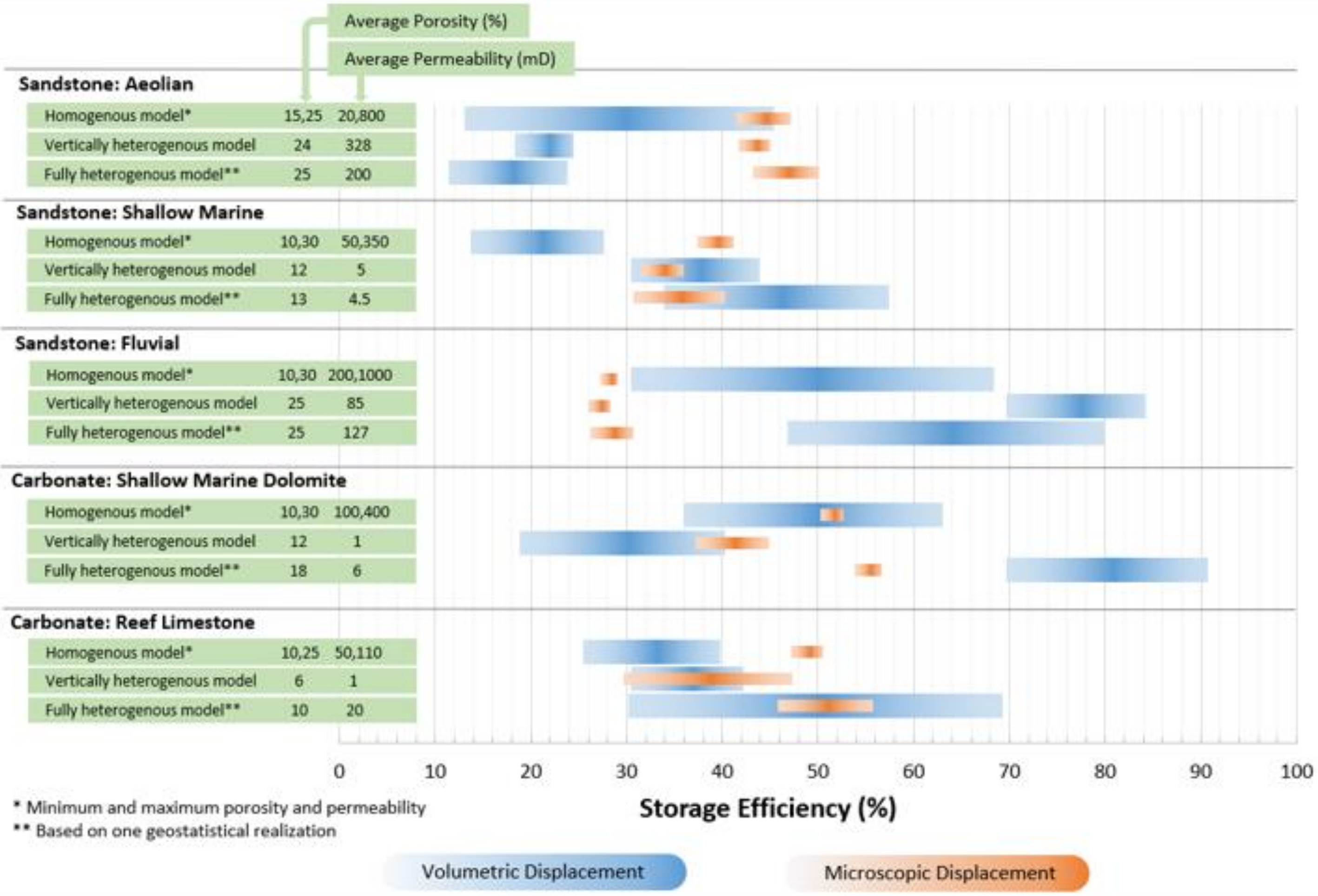

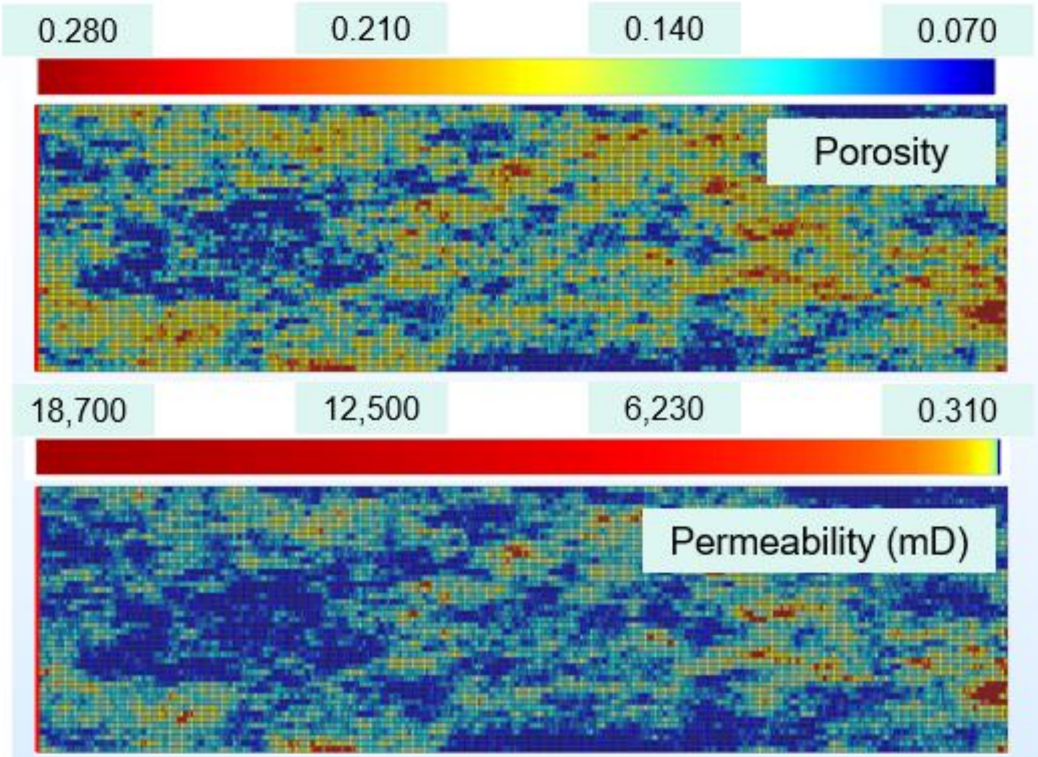

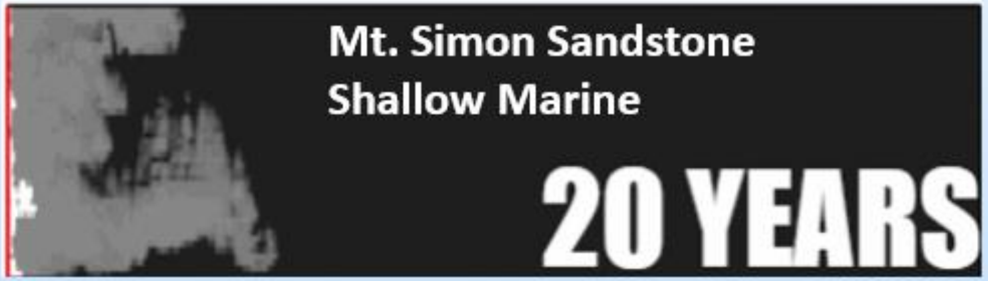

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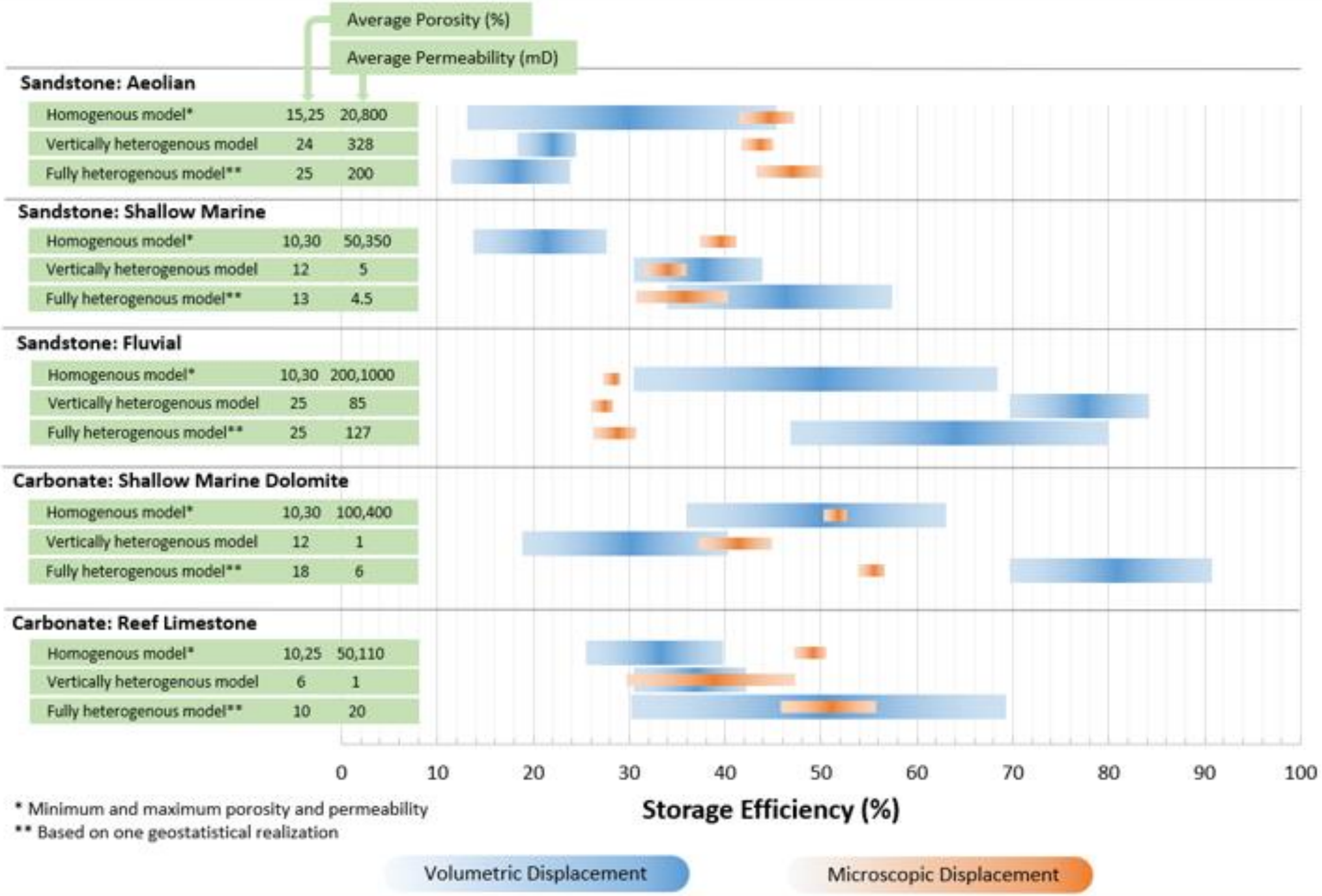

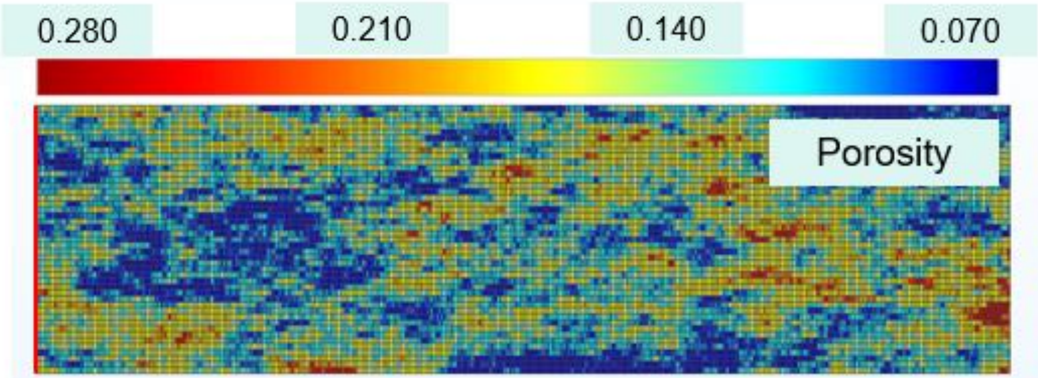

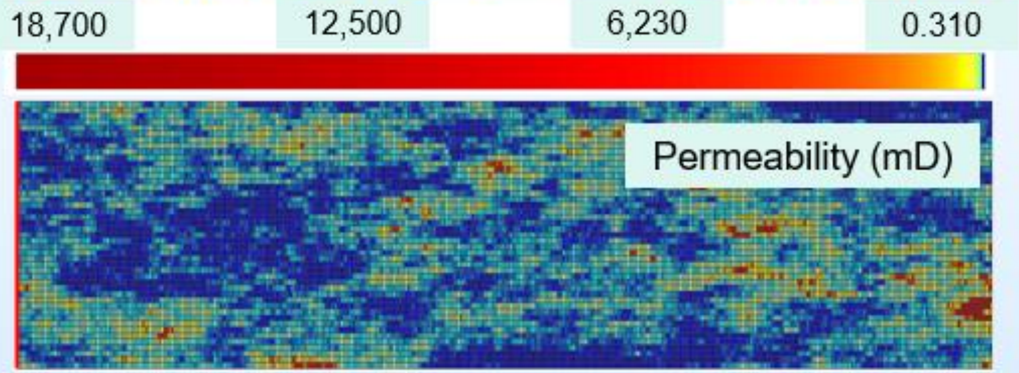

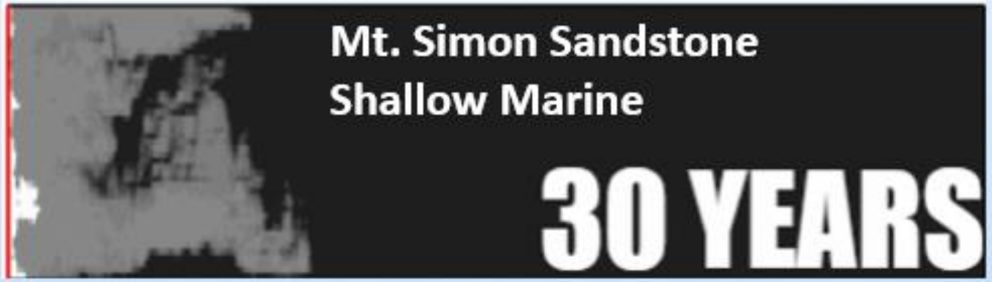

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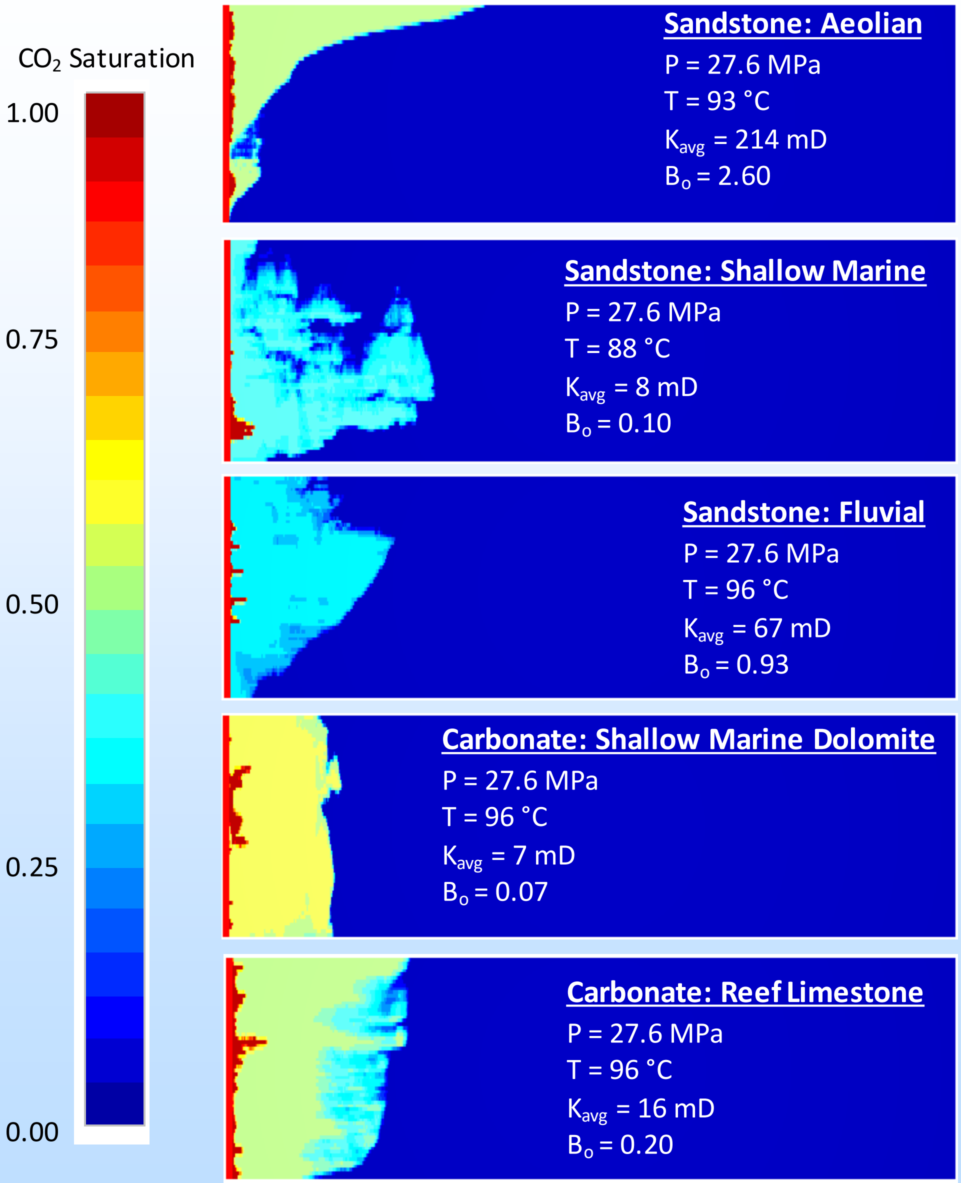


Variation of CO_2 plume shape impacted by the ratio of buoyancy to capillary force expressed by Bond number

(Based on one geostatistical realization)

Assumptions:

Constant injection rate = 800 t/d

Injection duration = 30 years

Permeability anisotropy = 0.1

B_o: Bond number = Buoyancy force/Capillary force

$$B_o = \frac{\Delta\rho g k_V}{\sigma \cos\theta}$$

$\Delta\rho$: Brine-CO_2 density difference

k_V: Vertical permeability

Interfacial tension ≈ 27 mN/m

Contact angle ≈ 22°

$B_o > 1$: Buoyancy dominates

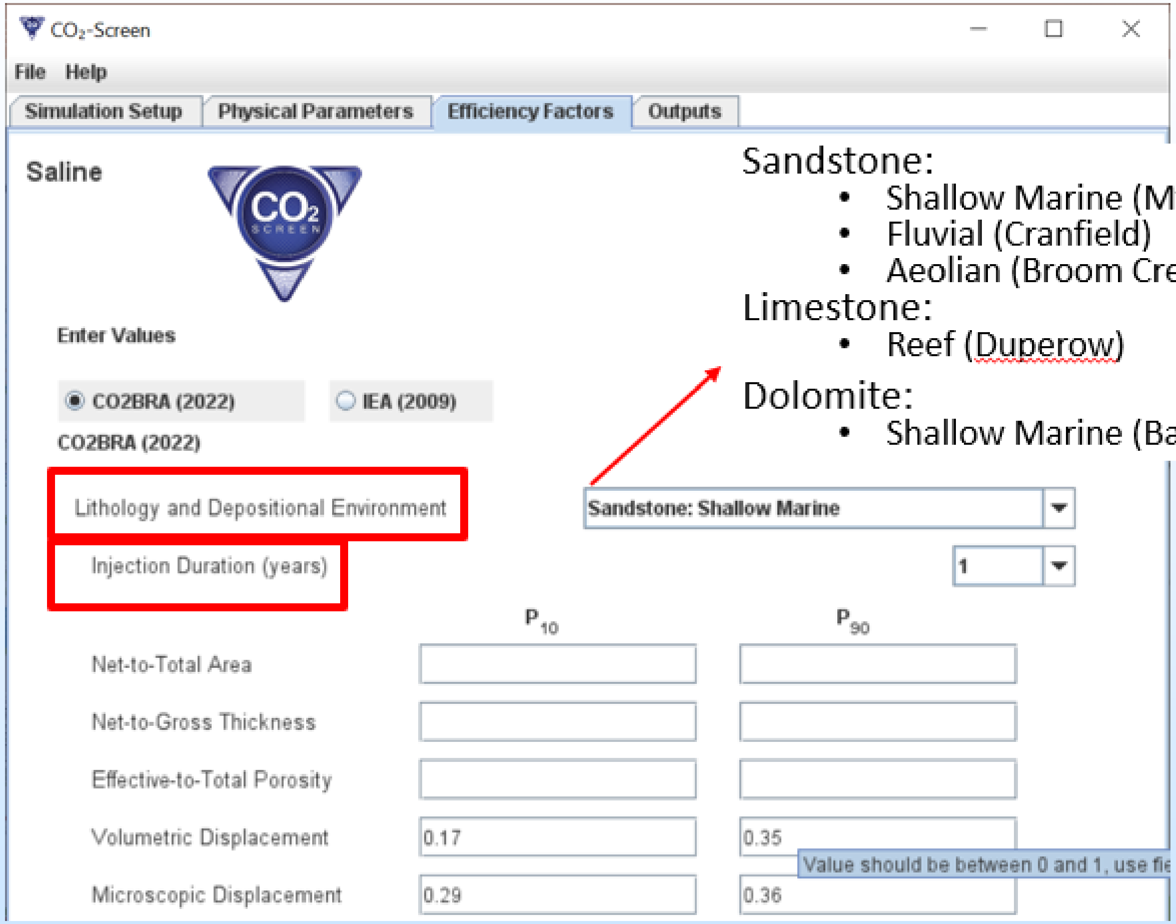
$B_o < 1$: Capillarity dominates

26

Saline Methodology Efficiency

Selected Areas

$$E_{saline}{}^{s} = E_A{}^{s} E_h{}^{s} E_\phi{}^{s} E_V{}^{s} E_d{}^{s}$$



Sandstone:

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- Fluvial (Cranfield)
- Aeolian (Broom Creek)

Limestone:

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Dolomite:

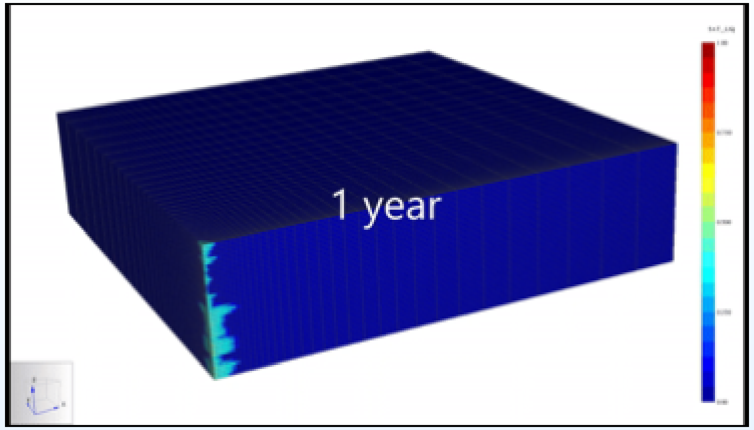
- Shallow Marine (Bass Island)

CO$_2$BRA Database

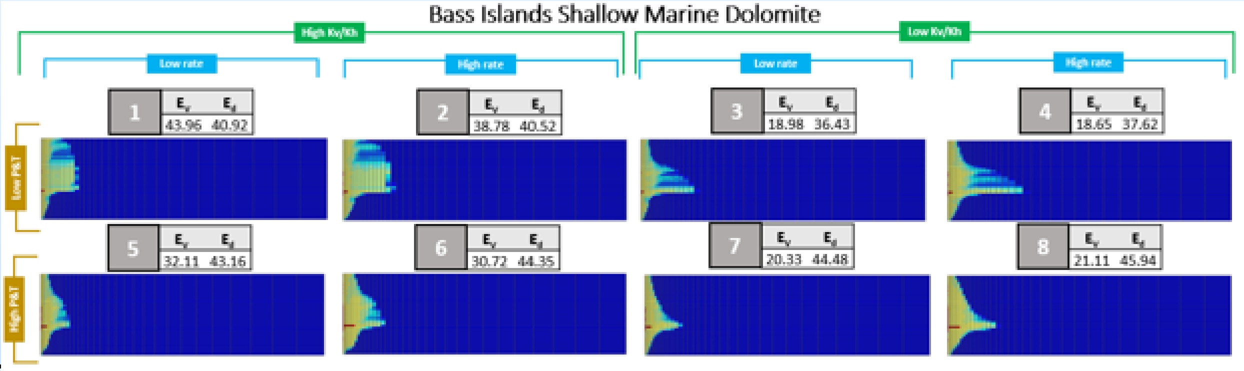
CO$_2$ Brine **R**elative Permeability **A**ccessible Database

https://edx.netl.doe.gov/dataset/co2_brine_relative_permeability_database

Dynamic variation of plume shape and efficiencies (Mt. Simon)



Impact of different properties on CO$_2$ plume shape and storage efficiency factors



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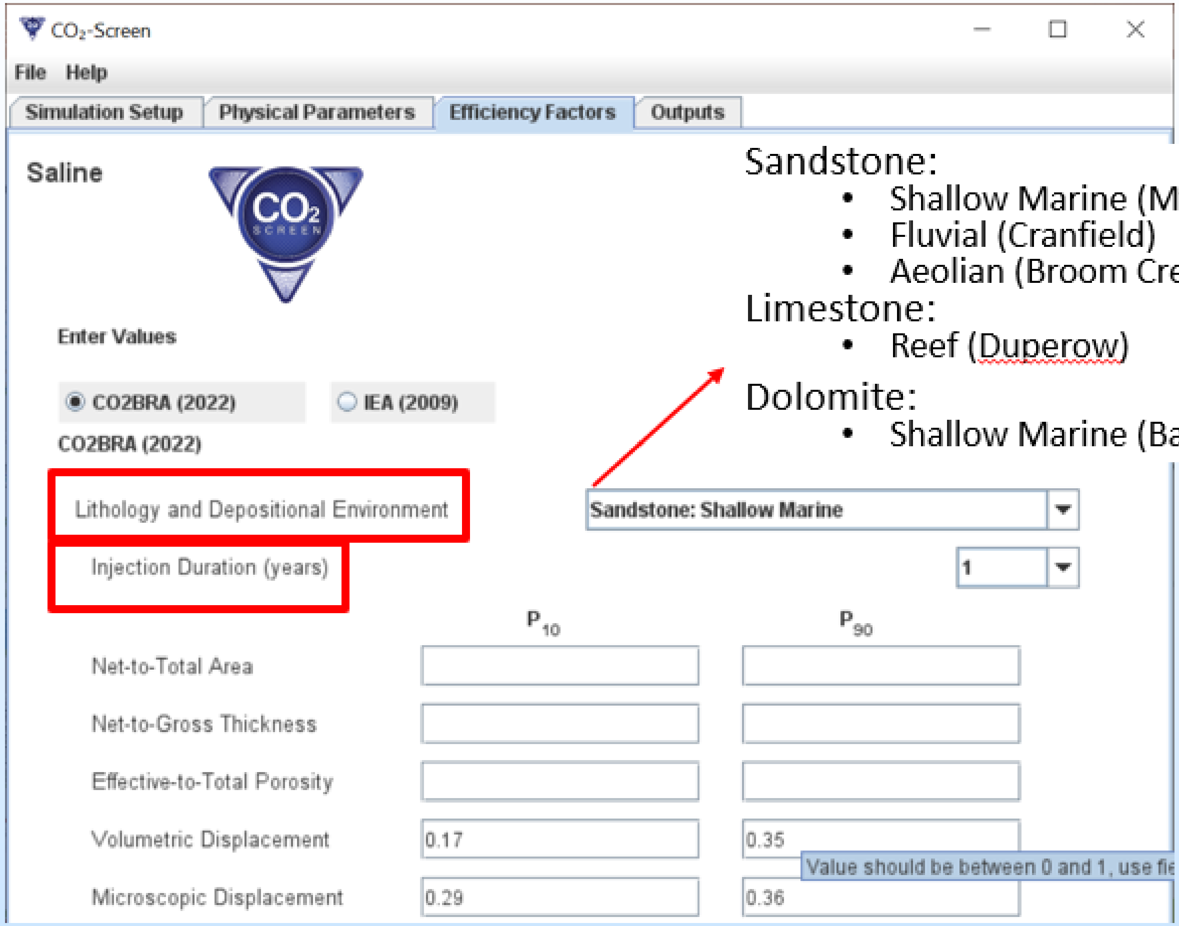

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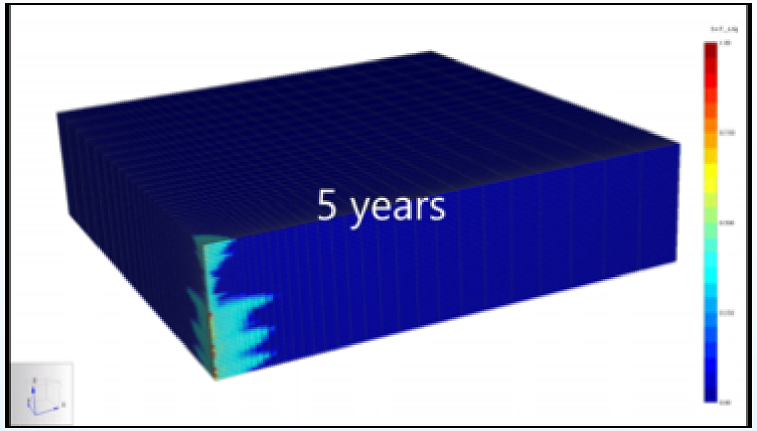

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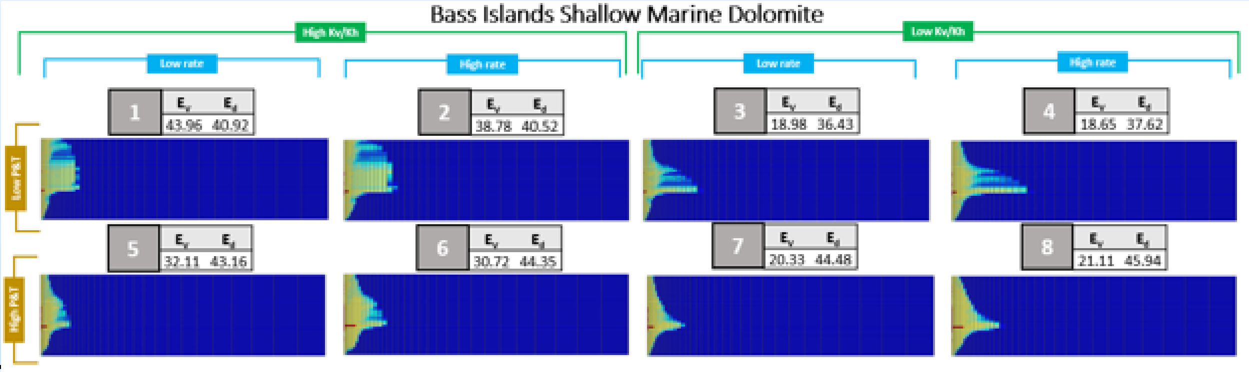

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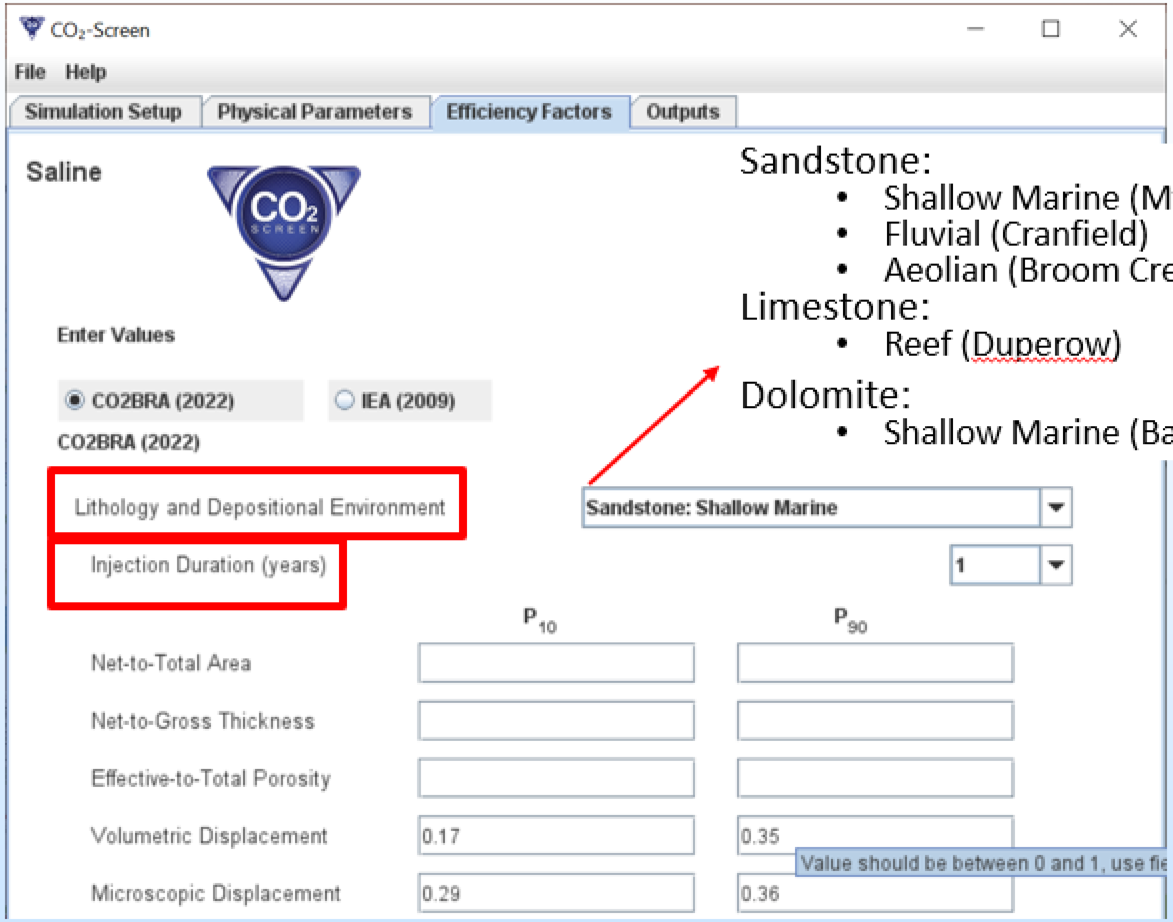

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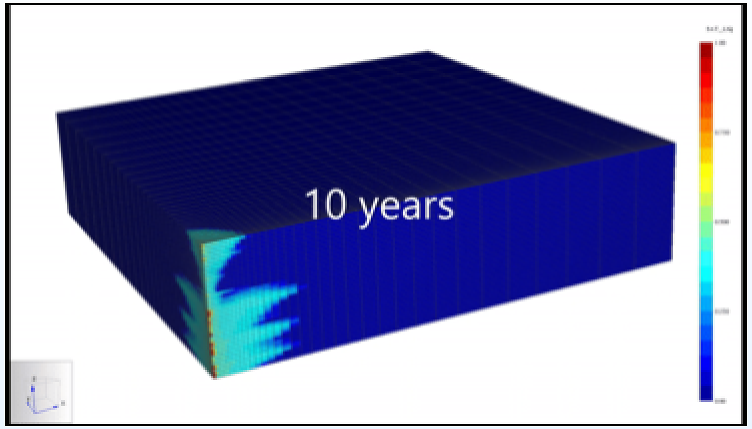

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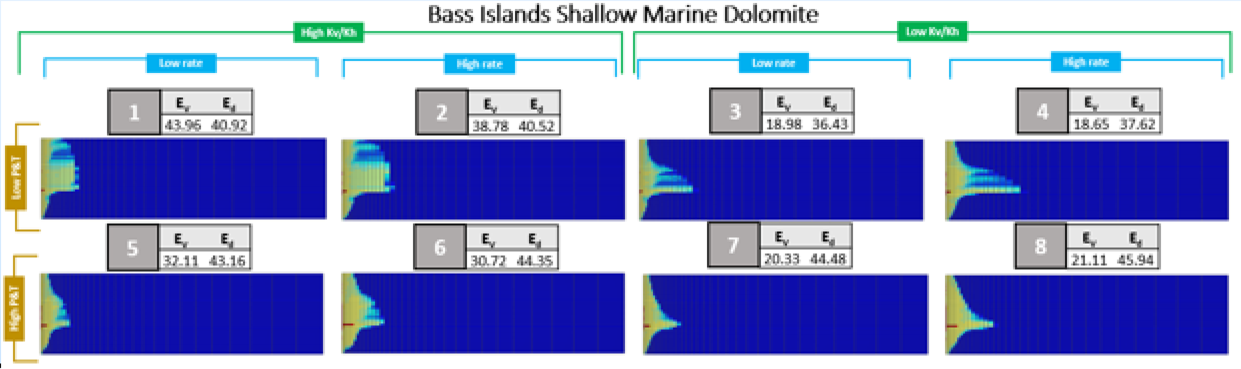

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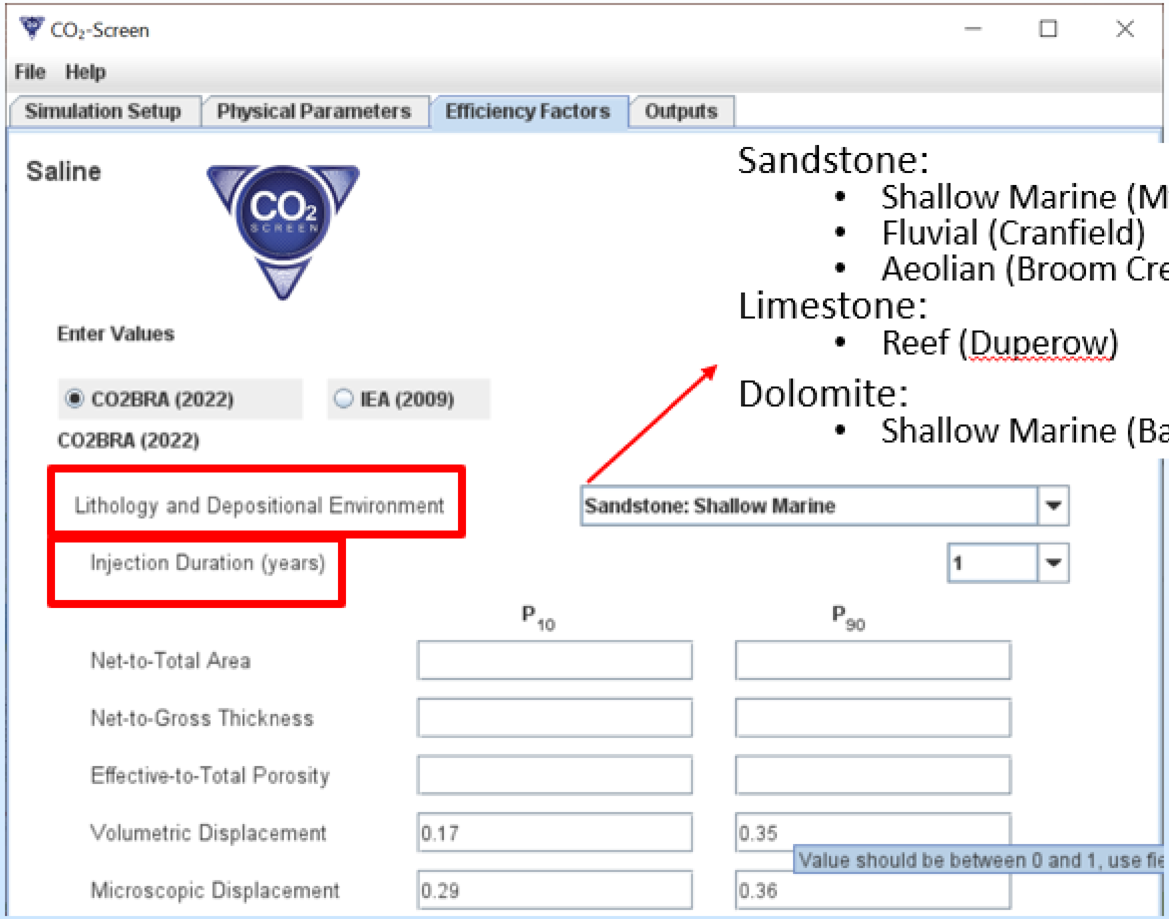

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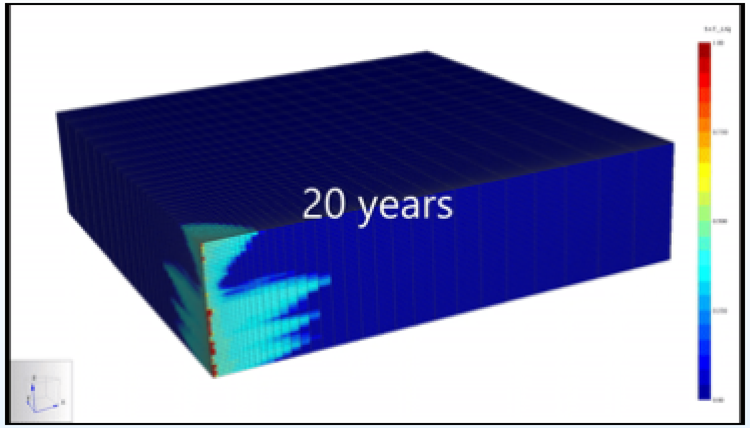

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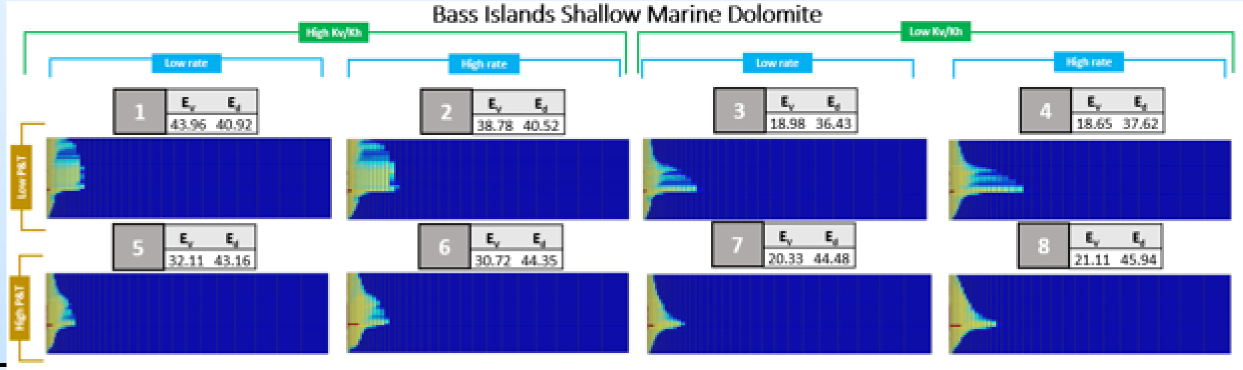

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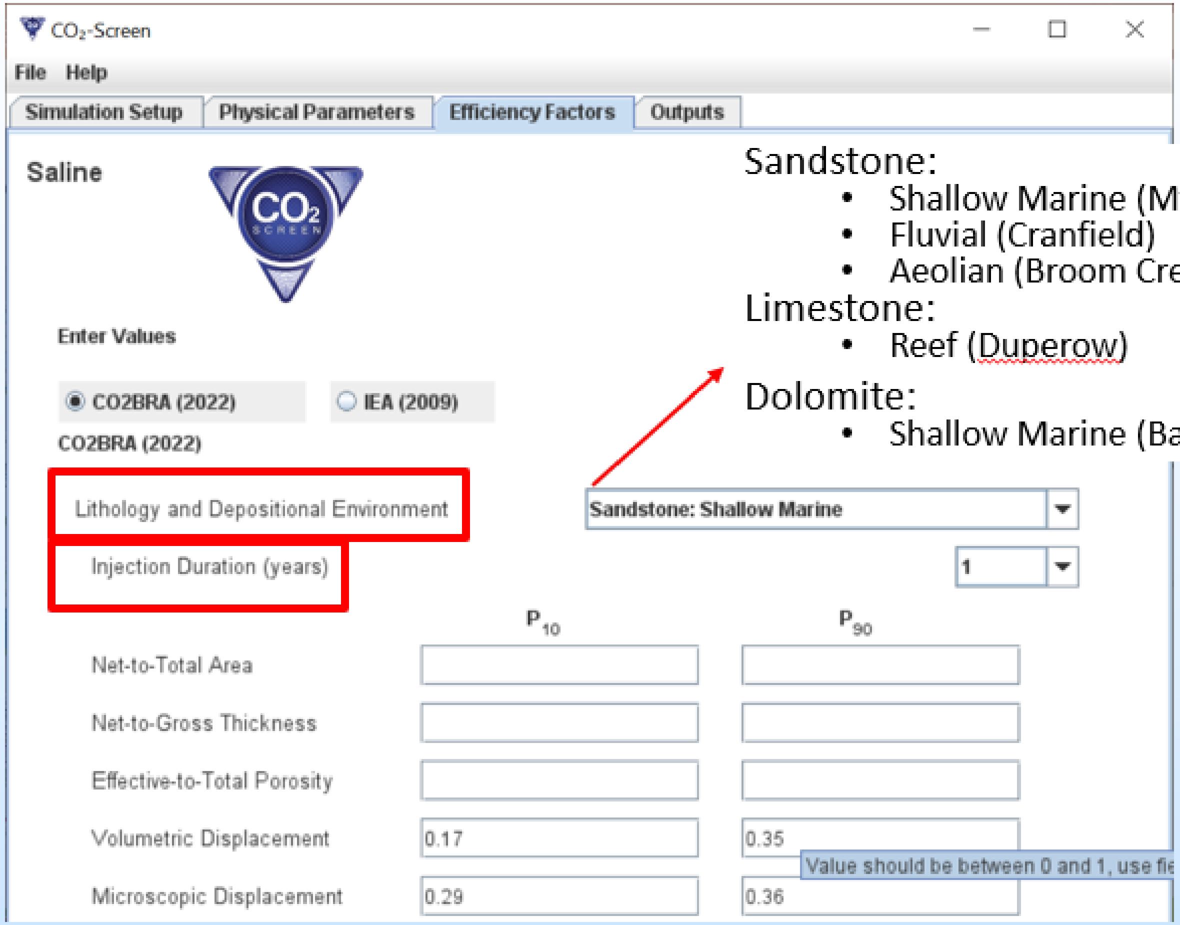

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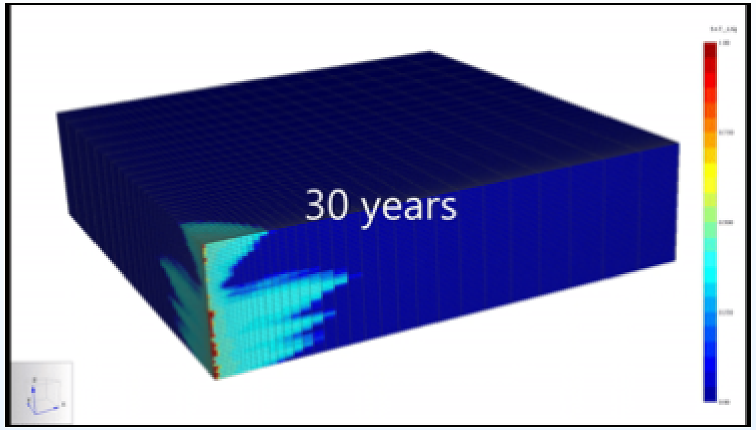

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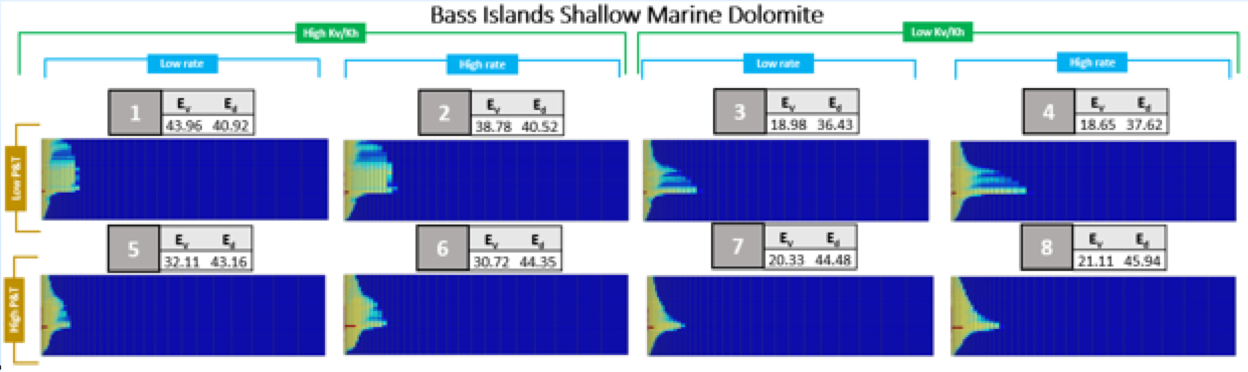


Shale Methodology Equation

$$G_{CO_2} = A_t E_A h_g E_h \left[\rho_{CO_2} \phi E_\phi + \rho_{sCO_2} (1-\phi) E_S\right]$$

Net effective formation volume

Efficiency of storage as free gas

Efficiency of storage in sorbed phase

E_ϕ: P_{10} to P_{90} range of 0.15 to 0.36

E_S: P_{10} to P_{90} range of 0.11 to 0.24

ROZ Methodology Equation

$$G_{CO_2} = A_t E_A h_g E_h \phi_{tot} E_\phi \left[(1 - S_{wirr} - S_{or})\rho_{CO_2} E_v + S_{or} R_{C/O} E_{Ds}\right]$$

Net effective formation volume

Sweep Efficiency

CO_2 dissolution in oil

E_{ROZ}: P_{10} to P_{90} range of 0.6 to 7.0

Notable groups that have used CO_2-SCREEN

Academia

USA Groups

- Carnegie Melon University (PA, USA)
- Colorado School of Mines (CO, USA)
- Louisiana State University (LA, USA)
- New Mexico Tech (NM, USA)
- Oklahoma State University (OK, USA)
- Texas A&M University (TX, USA)
- The University of North Dakota (ND, USA)
- The University of Texas at Austin (TX, USA)
- The University of Oklahoma (OK, USA)
- The University of Wyoming (WY, USA)

Non-USA Groups

- Carleton University (Canada)
- Central University of Ecuador (Ecuador)
- Chinese Academy of Sciences (China)
- Heriot Watt University (UK)
- Ho Chi Minh City University of Technology (Vietnam)
- Indian Institute of Technology Bombay (India)
- King Abd. Univ. of Science and Technology (Saudi Arabia)
- King Juan Carlos University (Spain)
- La Universidad Nacional de Ingenieria (Peru)
- National University of Singapore (Singapore)
- Pandit Deendayal Petroleum University (India)
- Seoul National University College of Medicine (South Korea)
- Silesian University of Technology (Poland)
- The Universidad de Monterrey (Mexico)
- The University of Trinidad and Tobago (Trinidad and Tobago)
- Tsinghua University (China)
- Universidad Estatal Peninsula de Santa Elena (Ecuador)
- Universidad Nacional de Colombia (Colombia)
- University College of London (UK)
- University of Alberta (Canada)
- University of Calgary (Canada)
- Xi'an Shiyou University (China)

Notable groups that have used CO_2-SCREEN

Industry

USA Groups

- Advanced Resources Int. (VA, USA)
- Battelle (OH, USA)
- BP (British Petroleum) (TX, USA)
- Burns McDonnel (MI, USA)
- Central Resources INC (CO, USA)
- Chevron (TX, USA)
- Dale Operating Company (TX, USA)
- DeGolyer and MacNaughton (TX, USA)
- Elysian (CT, USA)
- EOG Resources (TX, USA)
- Evolved Energy Research (CA, USA)
- Exxon Mobile (TX, USA)
- Jupiter Oxygen (IL, USA)
- Lonquist & Co. LLC (USA)
- Merchang Consulting (TX, USA)
- Mitre (MA, USA)
- Mitsubishi Corp. (TX, USA)
- Nanoswitch (TX, USA)
- Oceanit (TX, USA)
- Ocelot Consulting (MO, USA)
- Optimal Energy (VT, USA)
- Oxy (TX, USA)
- Pelican Energy (LA, USA)
- Roil Energy (FL, USA)
- Rose & Associates (TX, USA)
- RZG LLC (OK, USA)
- Samuel Gary Jr. & Associates (CO, USA)
- SCS Engineers (CA, USA)
- Talos Energy (TX, USA)
- Weyerhaeuser (WA, USA)

Non-USA Groups

- Advantage Energy LTD (Canada)
- Baker Hughes (UK)
- Beicip-Franlab (Napoleon Bonaparte, France)
- Egyptian General Petroleum Corp. (Egypt)
- Enquest (UK)
- Fenix Consulting Delft (Netherlands)
- Gassnova (Trondheim, Norway)
- Geogreen (France)
- Kiwetinohk Energy (Canada)
- Lloyd's Register (Great Britain)
- Molyneux Advisors (Australia)
- Origin (Australia)
- Reliance Industries Limited (India)
- Repsol (Norway)
- SI-SRL (Italy)
- SK (South Korea)
- Soluzioni Indrocarburi (Italy)
- Volta Oil & Gas (UK)
- WSP (Chili)
- YPF Technology (Chili)

Notable groups that have used CO_2-SCREEN

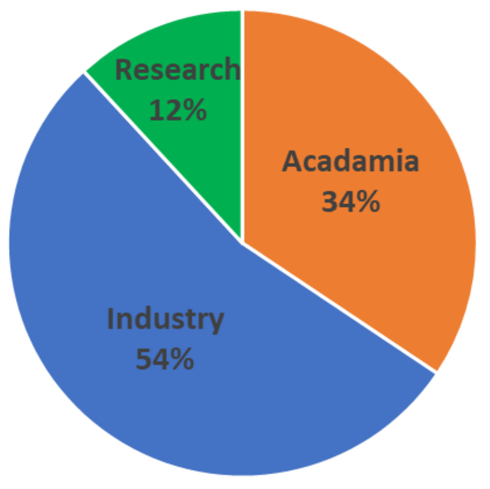
Research

USA Groups

- Battelle (OH, USA)
- Bureau of Ocean Energy Management (USA)
- CarbonSafe (USA)
- Department of Interior (USA)
- Energy & Environmental Research Center (ND, USA)
- Lawrence Livermore National Laboratory (CA, USA)
- Petroleum Recovery Research Center (NM, USA)
- Indiana Geological & Water Survey (IN, USA)

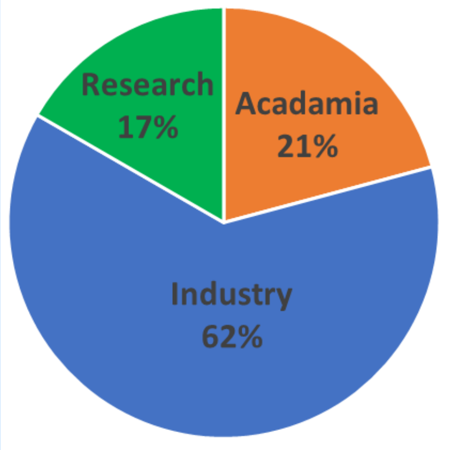
Non-USA Groups

- The French Institute of Petroleum (IFPEN) (France)
- Petroleum Learning Centre (UK)
- The Geological and Mining Institute of Spain (Spain)



90+ Organizations
20+ Countries

USA



Non-USA