Overview of Geological Carbon Sequestration Potential in Oklahoma: From Source to Sink

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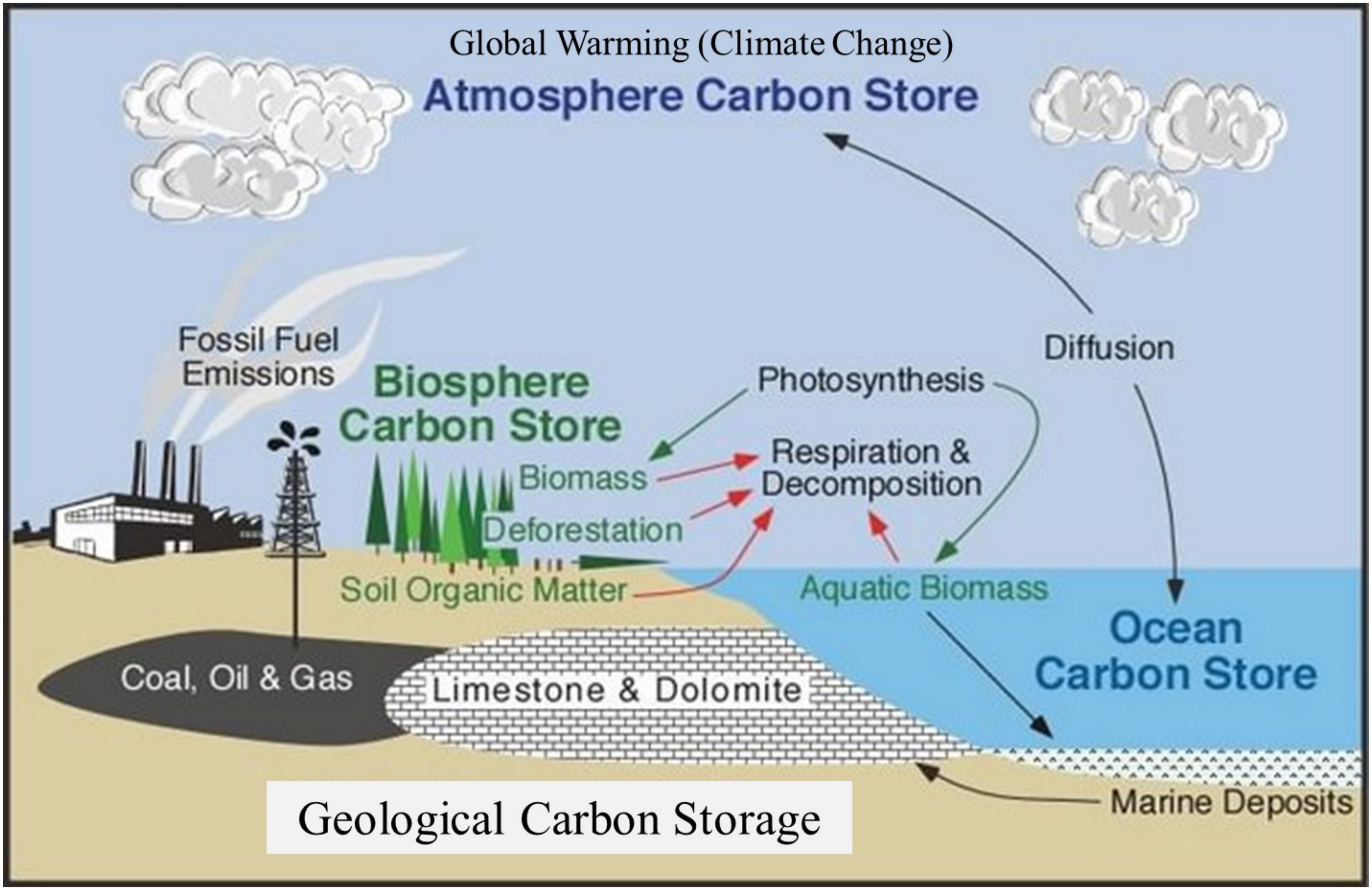
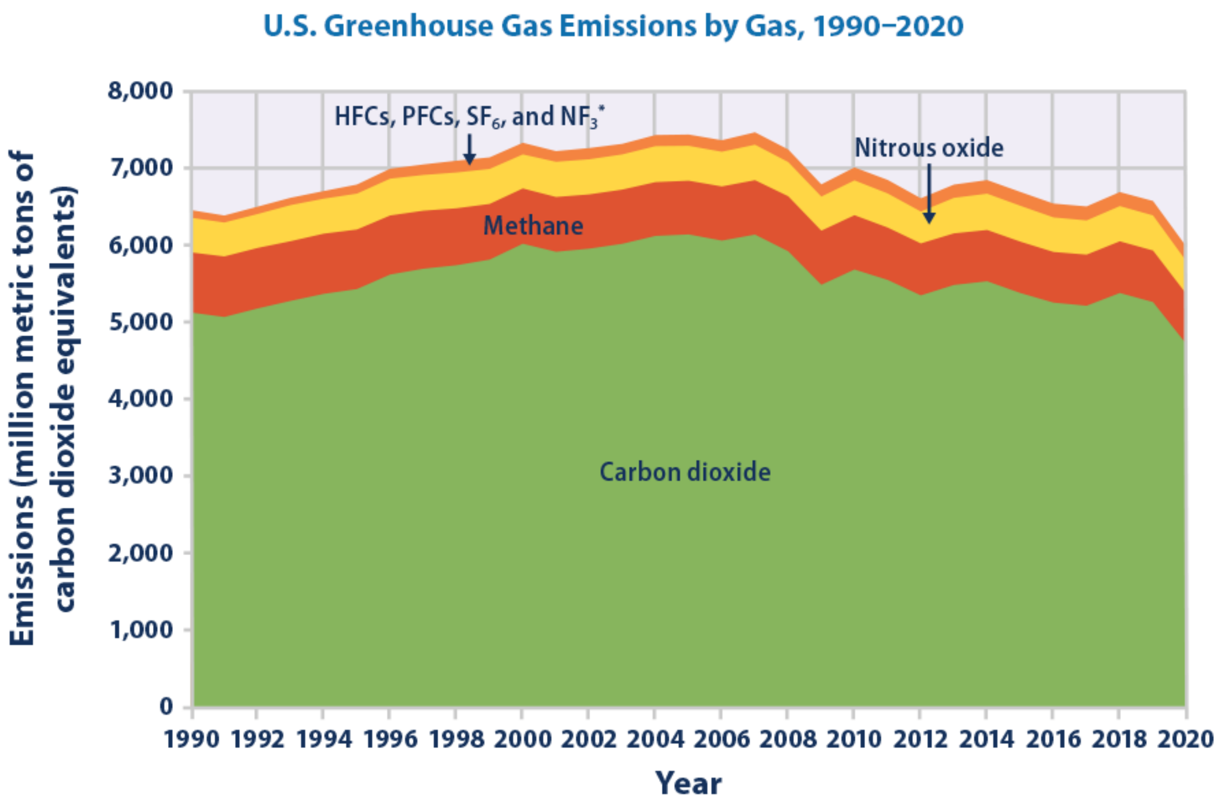
November 16, 2022

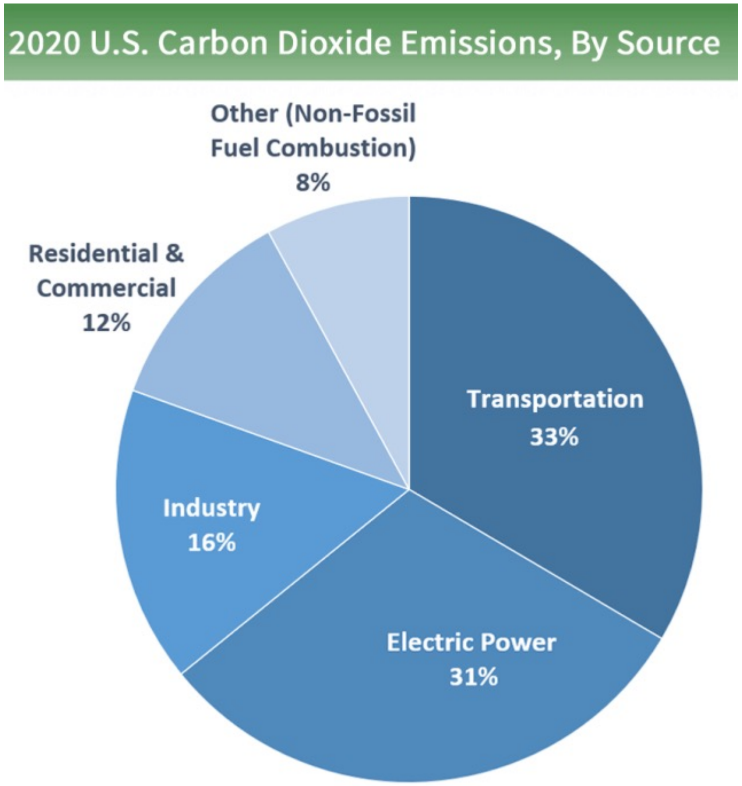
Context of the work



Modified from physicalgeography.net, accessed on Nov 2022

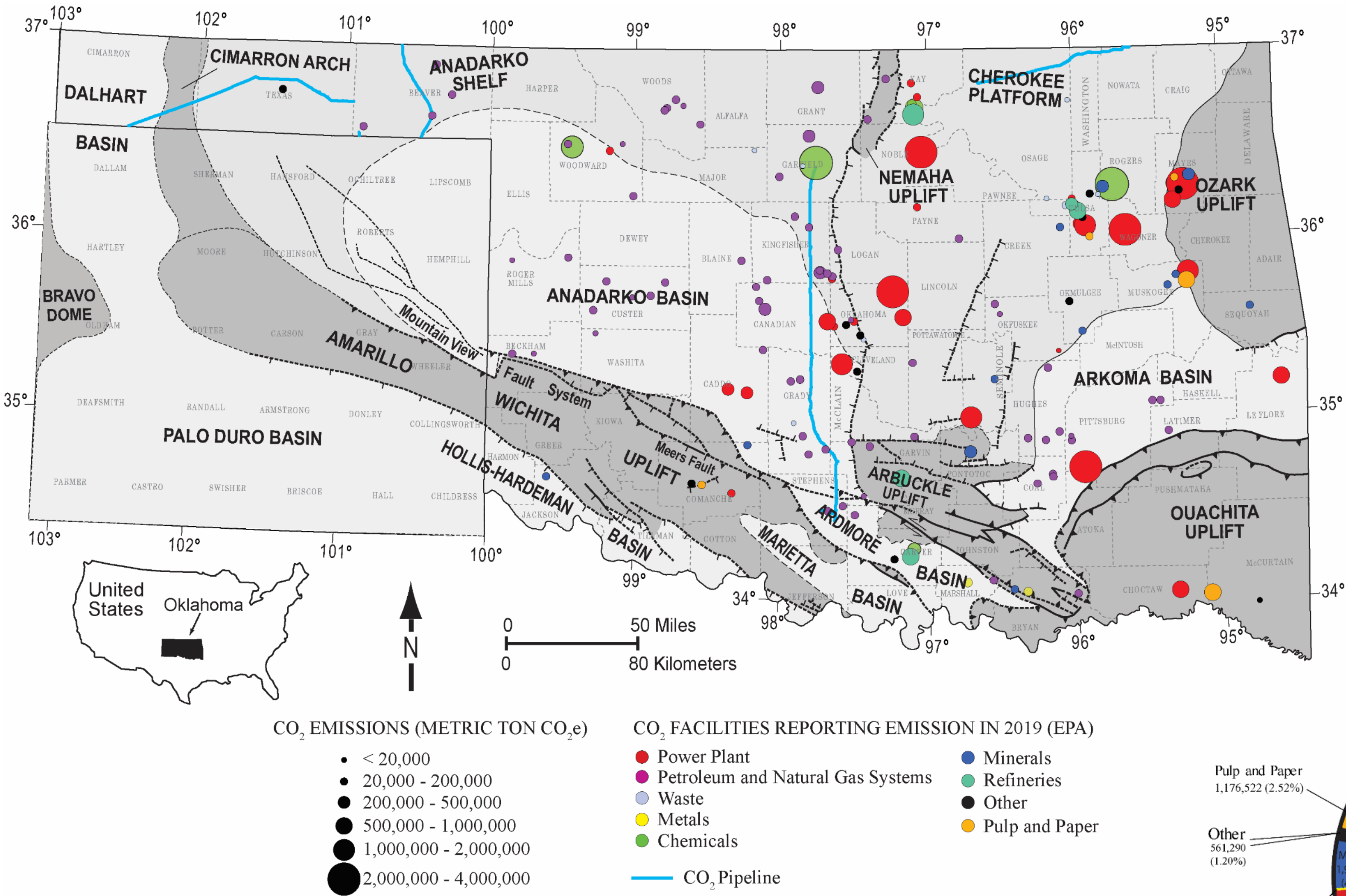
CO_2 Emissions in United States





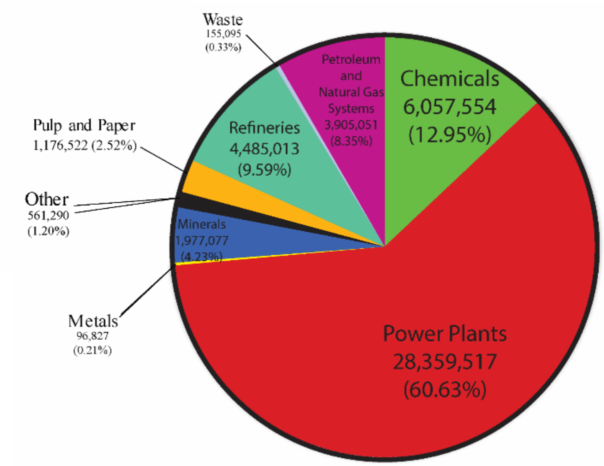
EPA, accessed on Nov 2022

CO_2 Emissions in Oklahoma



Oklahoma energy-related CO_2 Emission: 90.8 million metric ton (rank 23rd in the country).

Total Reported Emissions: 46,773,876 Metric ton CO_2e from 151 facilities.



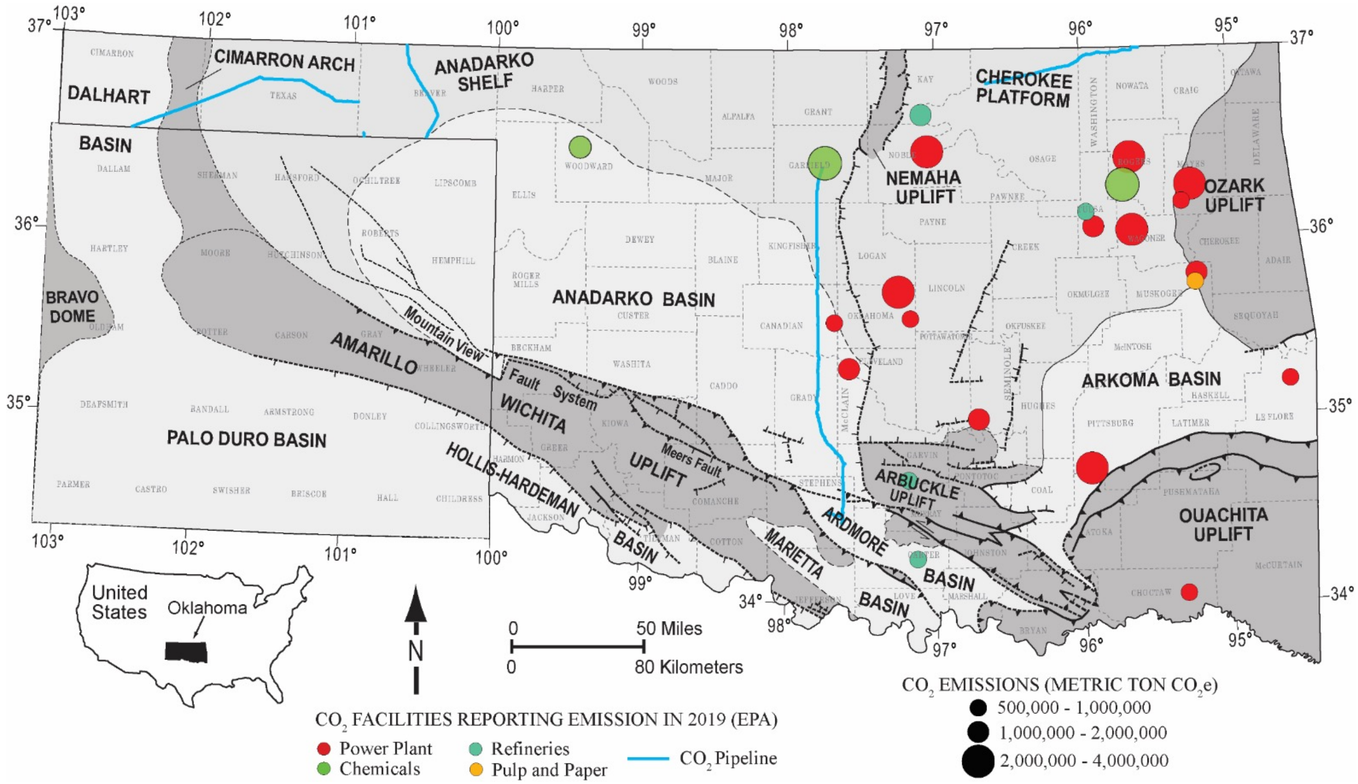
Modified after OGS fact sheet 1, 2021

45Q Qualified CO_2 Sources in Oklahoma

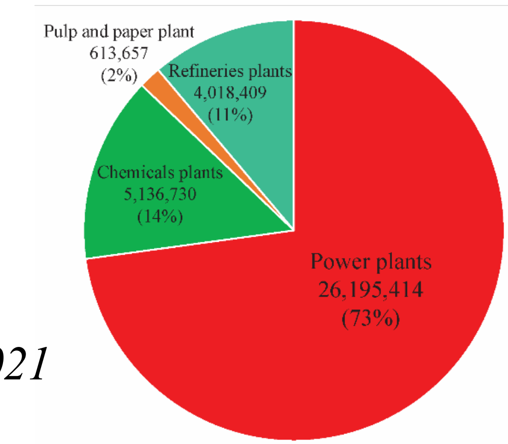
Key Elements of the Section 45Q Credit

Equipment Placed in Service Before 2/9/2018	Equipment Placed in Service on 2/9/2018 or Later
Credit Amount (per Metric Ton of CO_2)*	
Geologically Sequestered CO_2	
\$23.82 in 2020. Inflation-adjusted annually.	\$31.77 in 2020. Increasing to \$50 by 2026, then inflation-adjusted.
Geologically Sequestered CO_2 with EOR	
\$11.91 in 2020. Inflation-adjusted annually.	\$20.22 in 2020. Increasing to \$35 by 2026, then inflation-adjusted.
Other Qualified Use of CO_2	
None.	\$20.22 in 2020. Increasing to \$35 by 2026, then inflation-adjusted.
Claim Period	
Available until 75 million tons of CO_2 have been captured and sequestered.	12-year period once facility is placed in service.
Qualifying Facilities	
Capture carbon after 10/3/2008.	Begin construction before 1/1/2026.
Annual Capture Requirements	
Capture at least 500,000 metric tons.	*Power plants:* capture at least 500,000 metric tons. *Facilities that emit no more than 500,000 metric tons per year:* capture at least 25,000 metric tons. *DAC and other capture facilities:* capture at least 100,000 metric tons.
Eligibility to Claim Credit	
Person who captures and physically or contractually ensures the disposal, utilization, or use as a tertiary injectant of the CO_2.	Person who owns the capture equipment and physically or contractually ensures the disposal, utilization, or use as a tertiary injectant of the CO_2.

Source: CRS analysis of IRC Section 45Q.



Total Reported CO2 Emissions that qualified for 45Q: 35,964,210 Metric ton CO_2e from 23 facilities.



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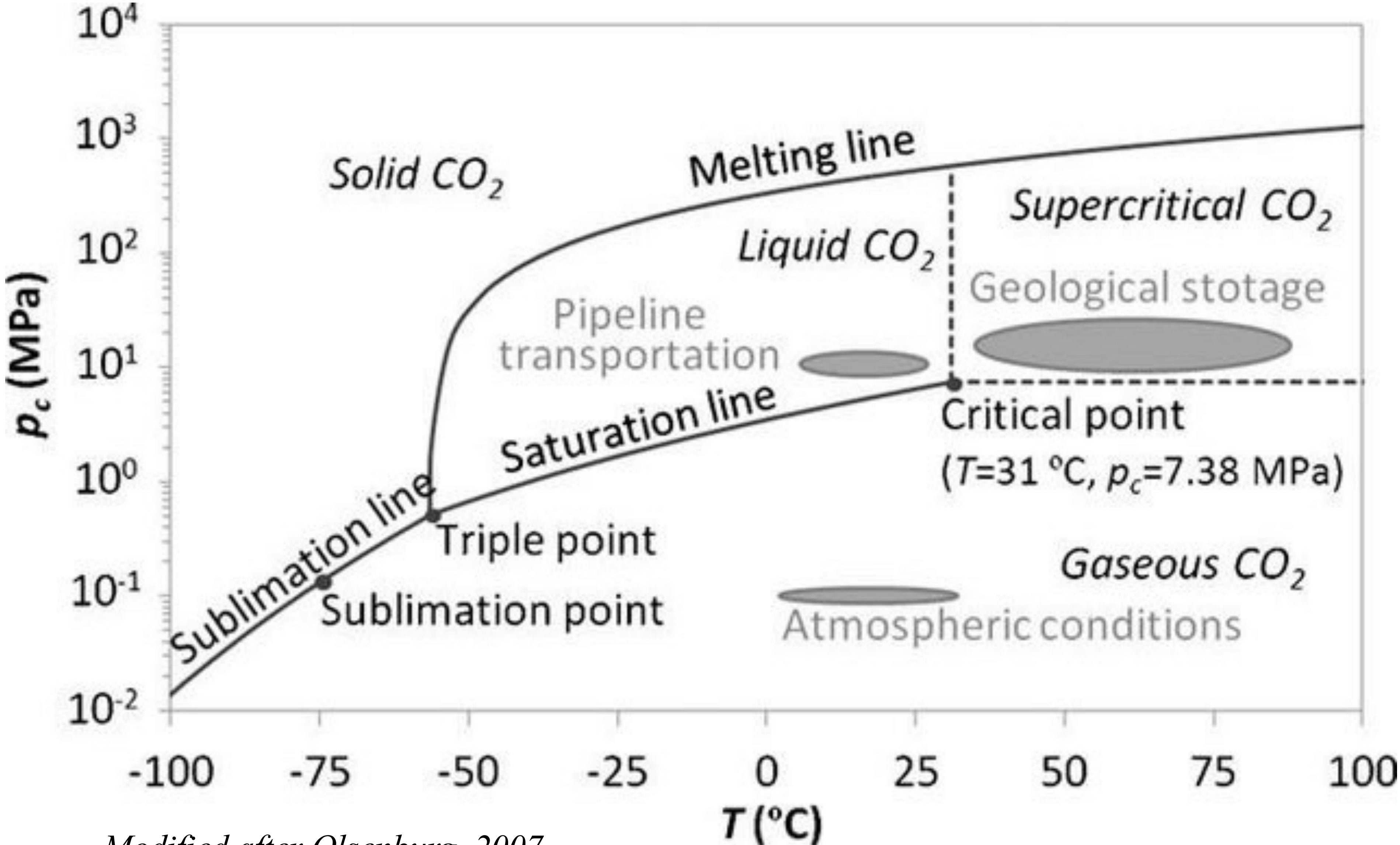
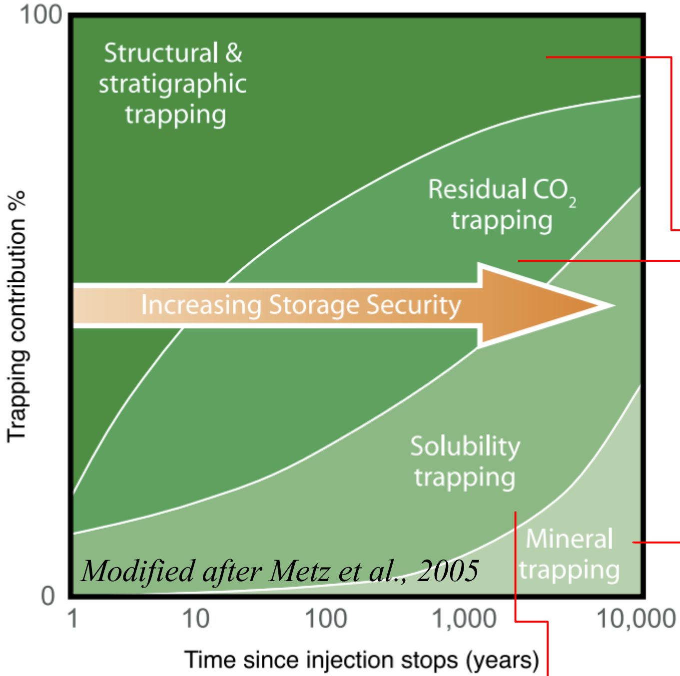
CO_2 Phase Diagram

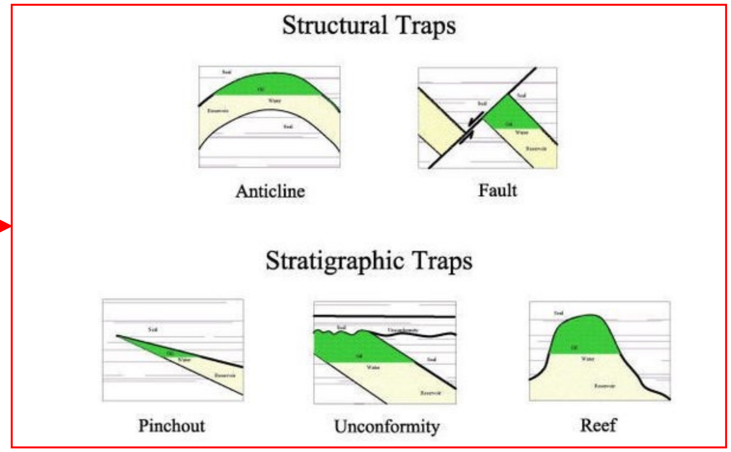


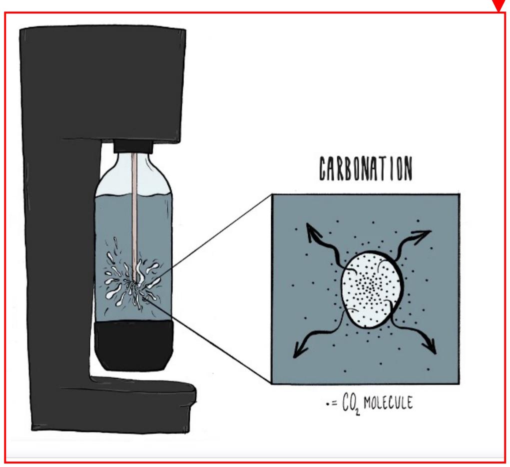
Modified after Olsenburg, 2007

Trapping Mechanisms



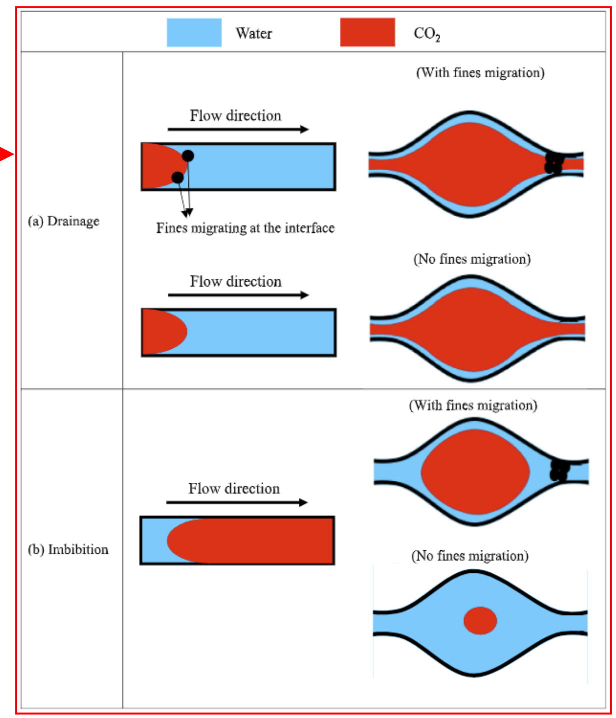
Modified after Metz et al., 2005





Mineral	Chemical composition	Vol.% of solid rock		Vol.% of medium	
		Sandstone	Shale	Sandstone	Shale
***Primary*:**					
quartz	SiO_2	58	19.22	40.6	17.3
kaolinite	$Al_2Si_2O_5(OH)_4$	2.02	4.37	1.41	3.95
calcite	$CaCO_3$	1.93	10.9	1.35	9.81
illite	$K_{0.6}Mg_{0.25}Al_{1.8}(Al_{0.5}Si_{3.5}O_{10})(OH)_2$	1.0	28.14	0.7	25.33
kerogen-OS	$C_{64}H_{102}O_{40}S_{10}$	0.0	2.0	0.0	1.8
oligoclase	$CaNa_4Al_6Si_{14}O_{40}$	19.8	5.28	13.86	4.75
K-feldspar	$KAlSi_3O_8$	8.2	4.74	5.74	4.27
Na-smectite	$Na_{0.290}Mg_{0.26}Al_{1.77}Si_{3.97}O_{10}(OH)_2$	4	23.0	2.8	20.7
chlorite	$Mg_{2.5}Fe_{2.5}Al_2Si_3O_{10}(OH)_8$	4.55	2.35	3.19	2.12
hematite	Fe_2O_3	0.5	0.0	0.35	0.0
porosity	----	----	----	30	10
***Secondary*:**					
anhydrite	$CaSO_4$				
magnesite	$MgCO_3$ ←				
low-albite	$NaAlSi_3O_8$				
siderite	$FeCO_3$ ←				
pyrite	FeS_2				
ankerite	$CaMg_{0.3}Fe_{0.7}(CO_3)_2$ ←				
dawsonite	$NaAlCO_3(OH)_2$ ←				
alunite	$KAl_3(OH)_6(SO_4)_2$				

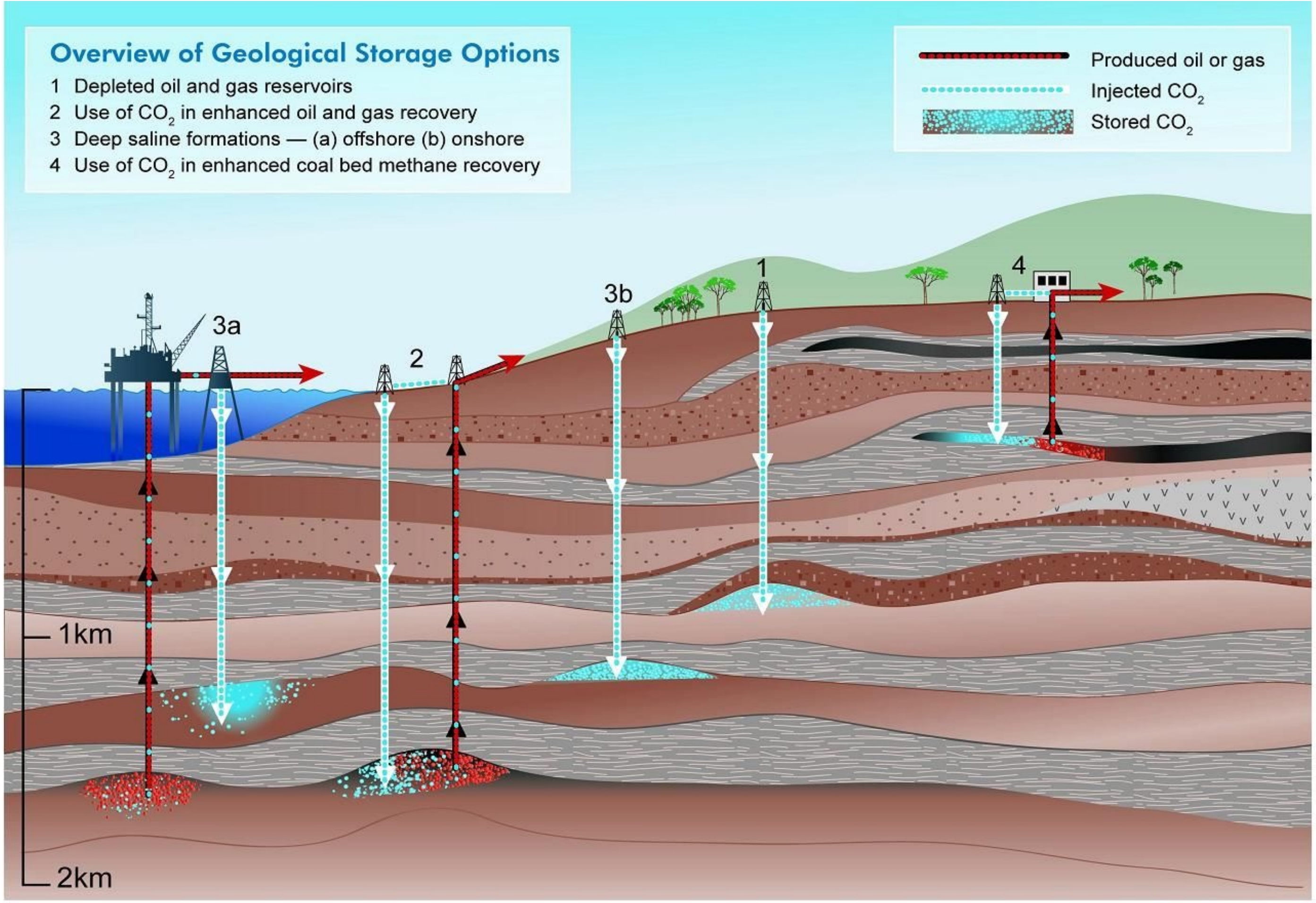
Modified after Xu et al., 2004



Modified after Ge et al., 2022

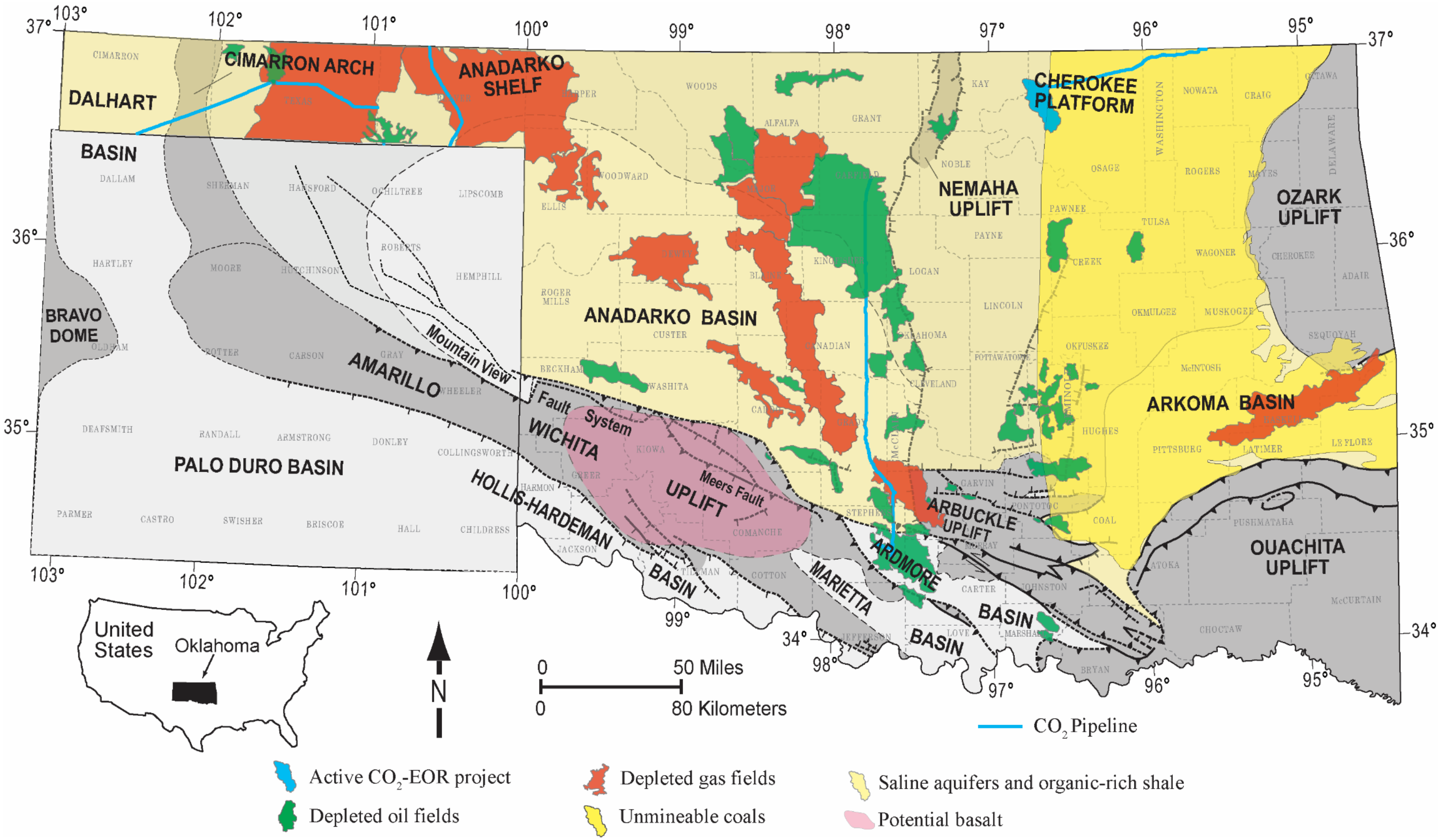
Carbon Capture, Utilization and Storage

Refers to **capture** of $CO2$ from large stationary sources (e.g. power plants, etc), and either **reuse** or **store** it in the deep subsurface (geologic sequestration).



Modified after Metz et al., 2005

Geological Carbon Storage Potential in Oklahoma

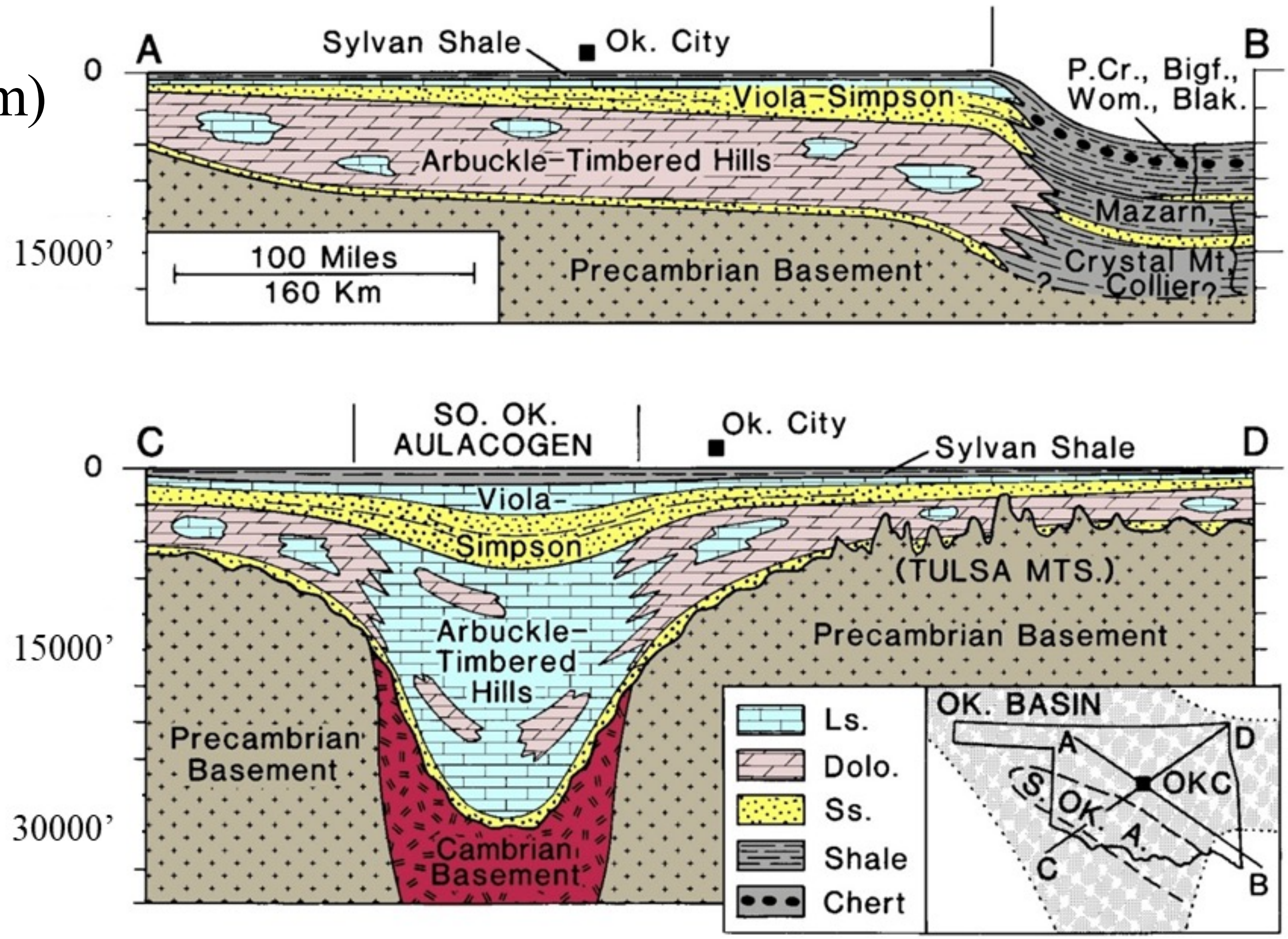


Modified after OGS fact sheet 1, 2021

Deep Saline Aquifers as Carbon Storage

<u>Criteria</u>:
Depth > 2500 ft (800 m)
TDS > 10,000 ppm

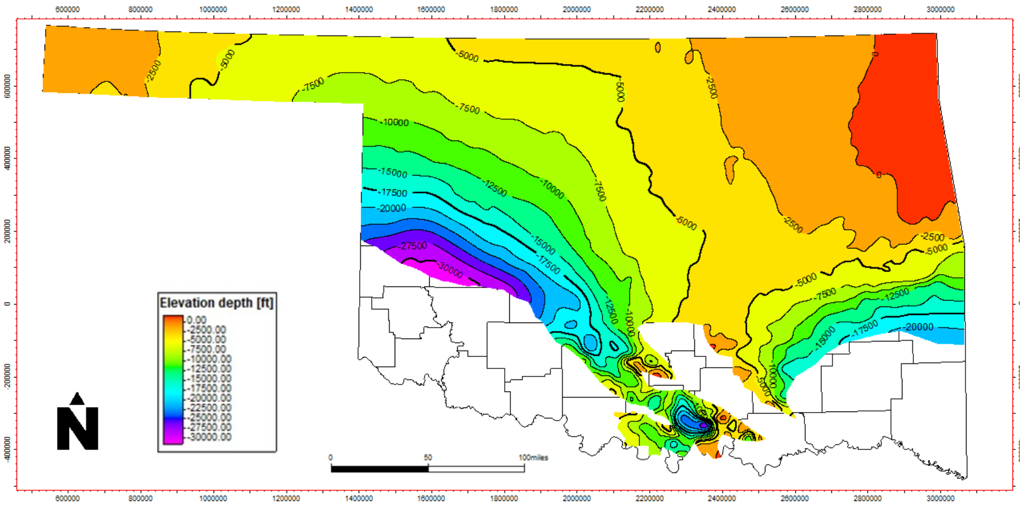
Arbuckle Group



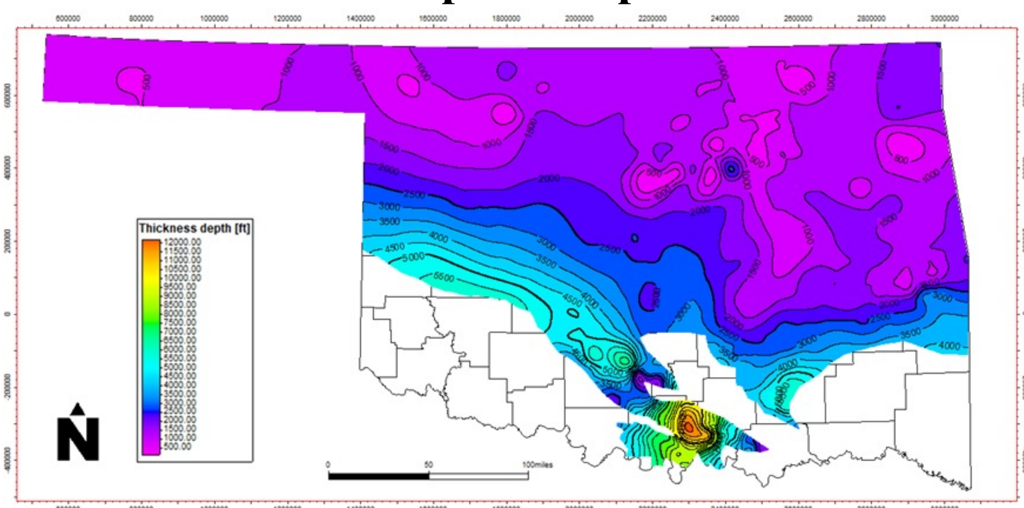
Schematic cross sections showing restored thickness of Late Cambrian and Ordovician strata in Oklahoma (based on data in Johnson and others, 1988).

Deep Saline Aquifers in Oklahoma

Depth Structure Map

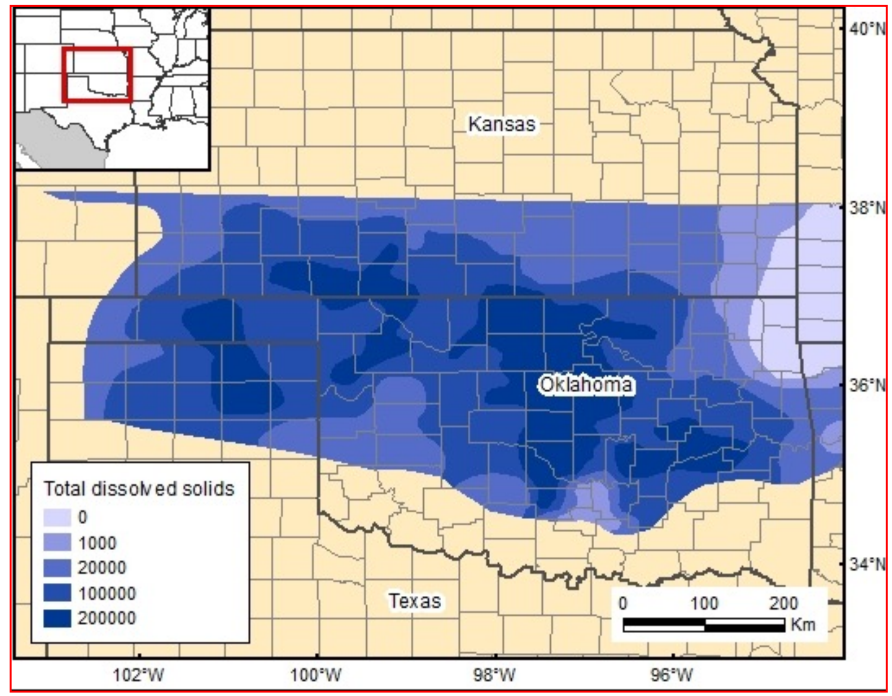


Isopach Map



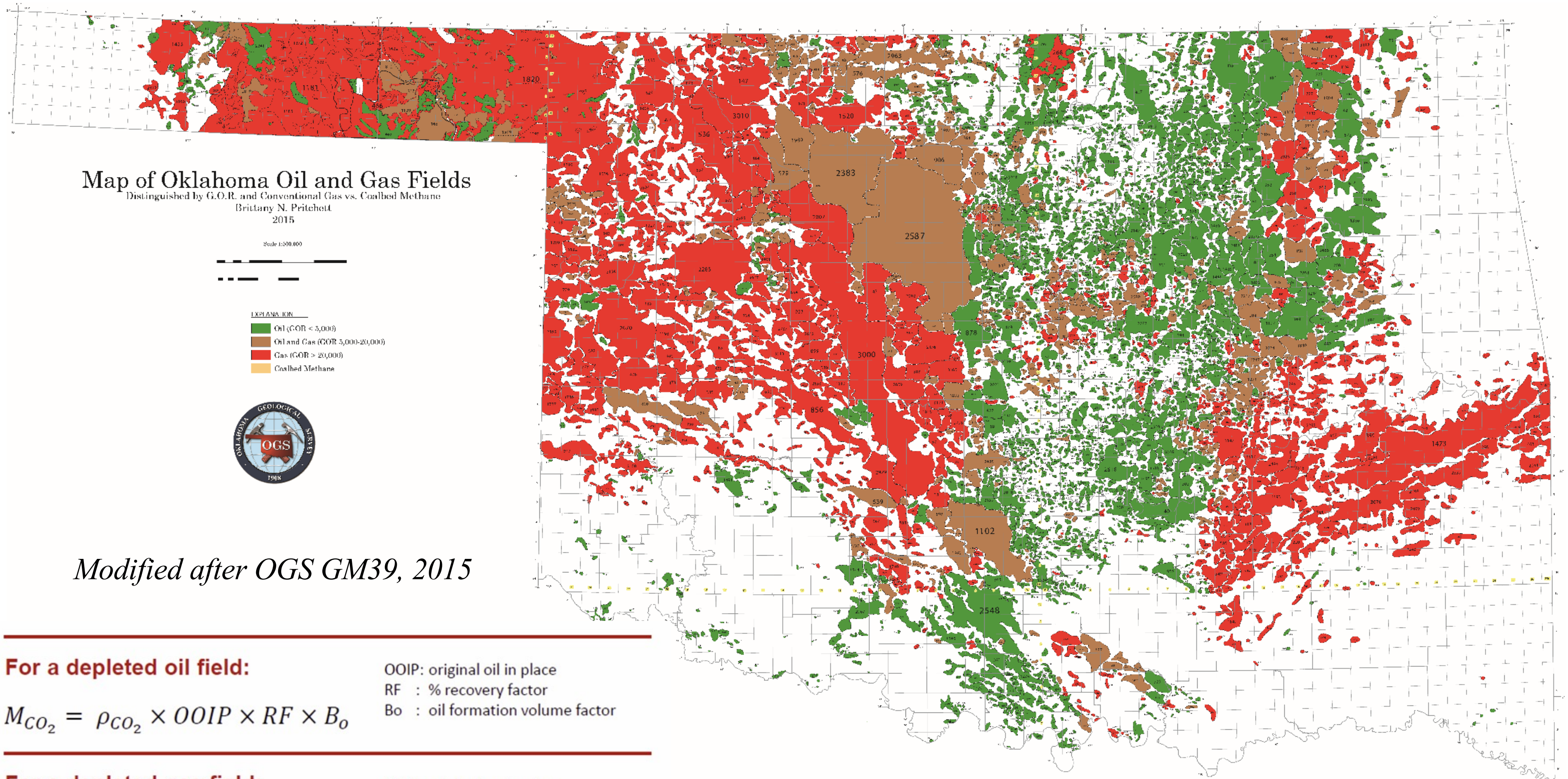
Suriamin et al., in prep

TDS Map



Modified after Jorgensen et al., 1996

Oil and Gas Fields in Oklahoma



Modified after OGS GM39, 2015

For a depleted oil field:

$$M_{CO_2} = \rho_{CO_2} \times OOIP \times RF \times B_o$$

OOIP: original oil in place
RF : % recovery factor
Bo : oil formation volume factor

For a depleted gas field:

$$M_{CO_2} = \rho_{CO_2} \times OGIP \times RF \times B_g$$

OGIP: original gas in place
Bg : gas formation volume factor

For a oil field due to CO_2-EOR:

$$M_{CO_2} = \rho_{CO_2} \times IOP \times B_o$$

IOP : incremental oil production
M_{CO2}: mega-tonnes CO_2

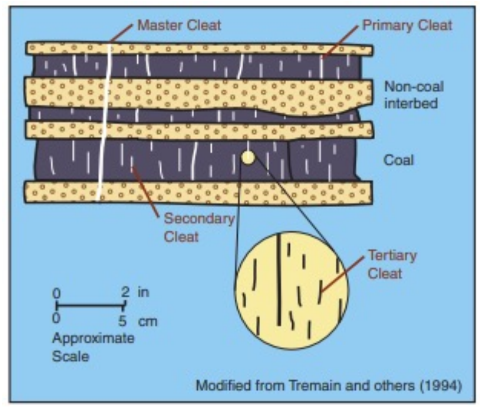
3192 big and small fields in total:
1803 oil fields
921 gas fields
439 mixed oil and gas fields

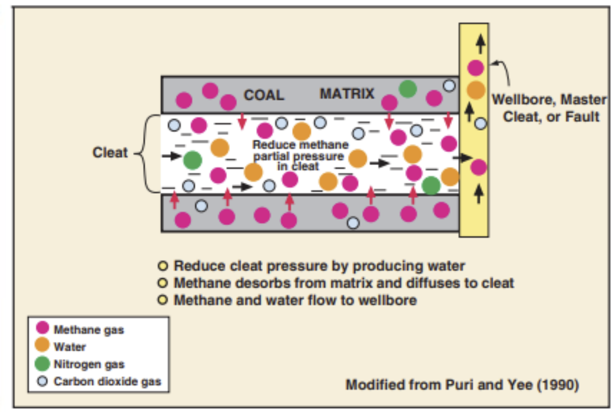
Unmineable Coal Beds as Carbon Storage

Definition: any coalbeds below economic mining depth could be used to store CO_2

Criteria:

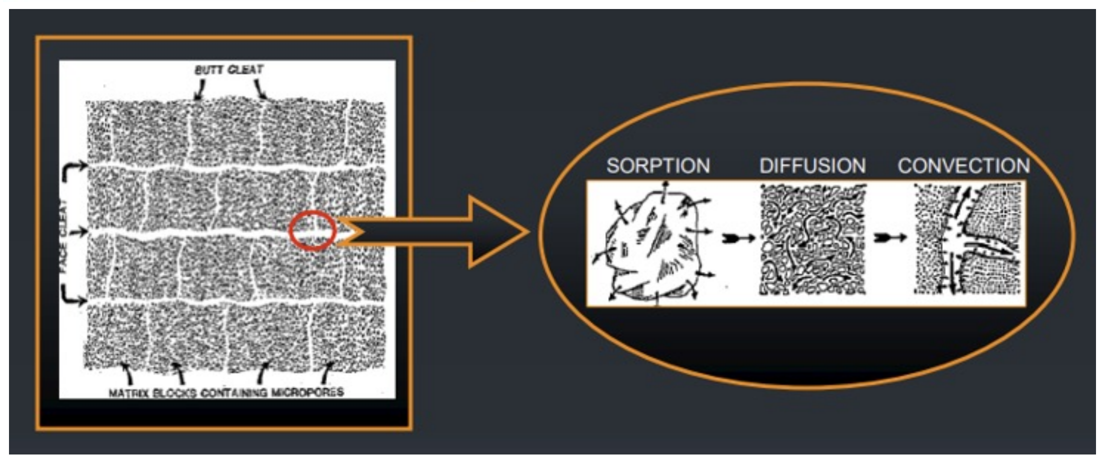
- Limited to a relatively narrow depth range (600 – 1000 m)



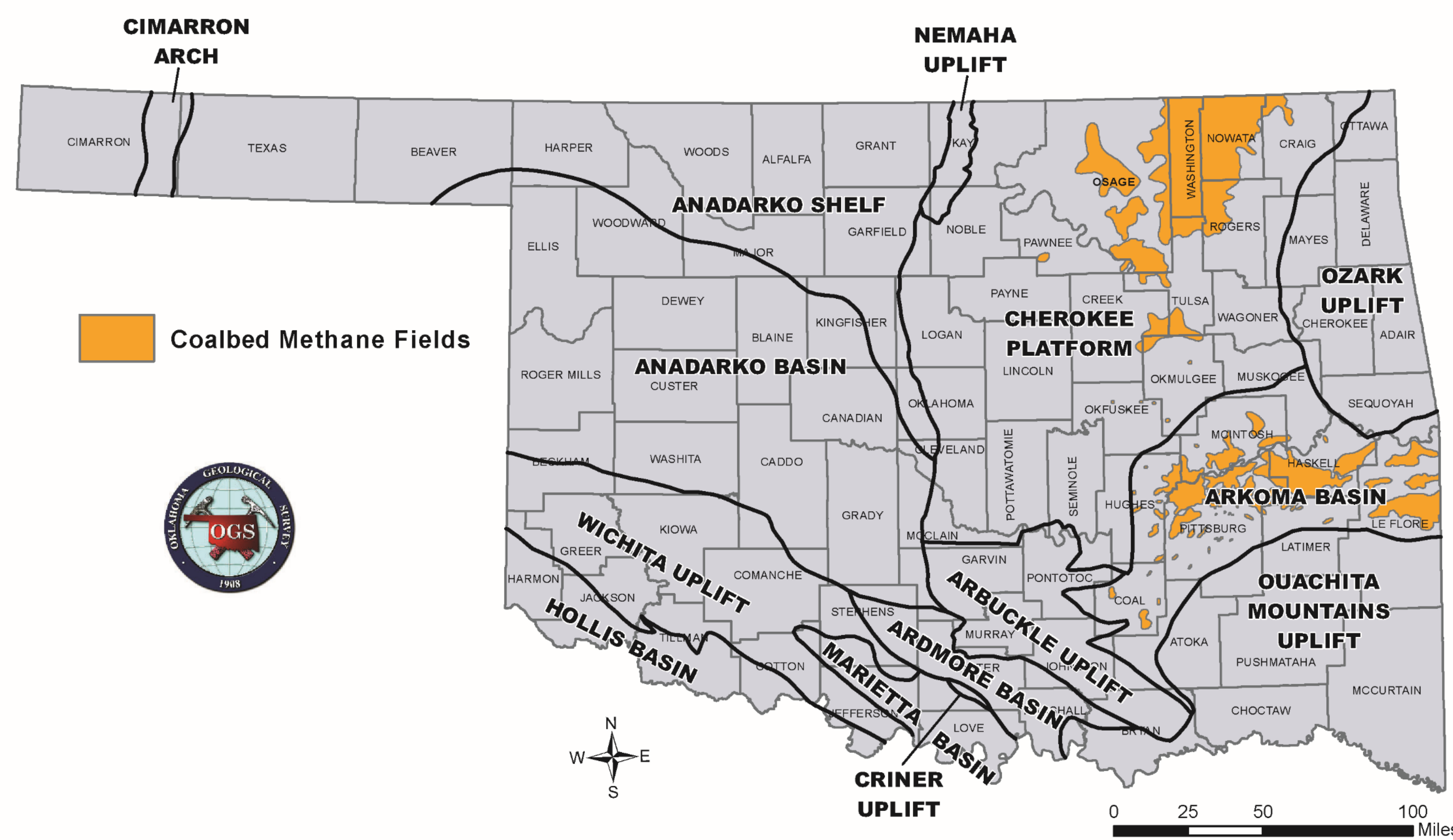


Why coalbeds?

- Large internal surface area
- CO_2 is more adsorbing than methane
- Dual role



Unmineable Coal Beds in Oklahoma



Suriamin et al., in prep

Unconventional Organic-Rich Shales as Carbon Storage

Criteria:

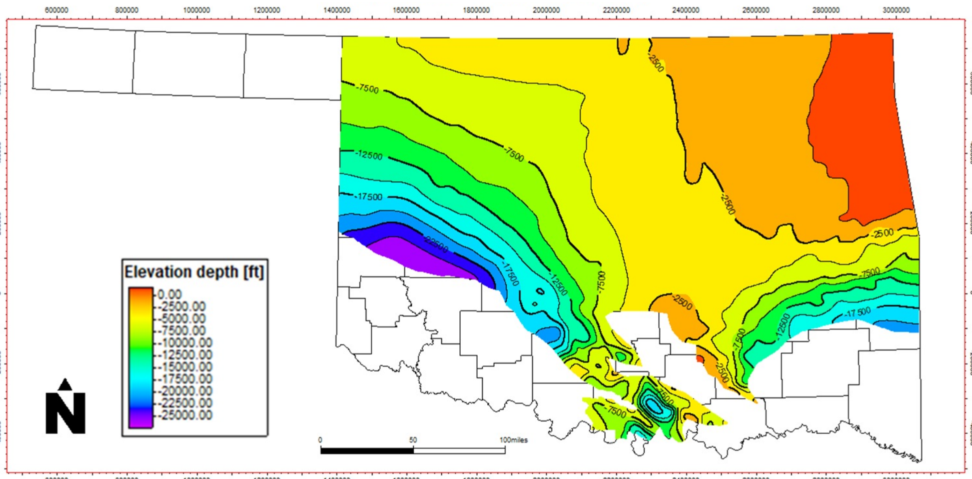
- Organic-rich shale > 2500 ft (800 m)
- TOC >= 2 wt%
- Methane-bearing
- Has been or will be stimulated for methane production before or during implementation of CO_2 storage

Why organic-rich shale?

- High certainty in the integrity of this class of reservoirs.
- Presence of an established network of fractures
- Potential to use injected CO_2 to enhance production of remaining hydrocarbons.

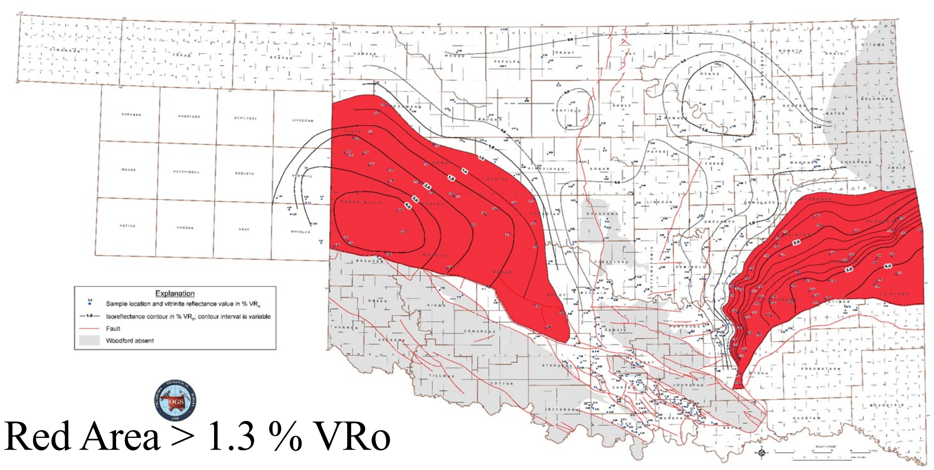
Unconventional Organic-Rich Shales in Oklahoma

Woodford Shale – Depth Structure Map



Suriamin et al., in prep

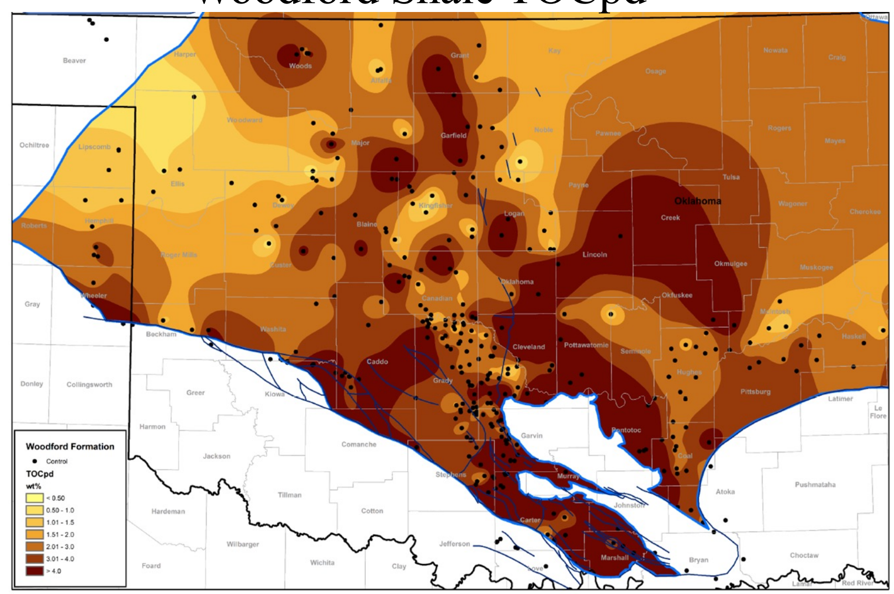
Vitrinite Isoreflectance Map of Woodford Shale in Oklahoma



Red Area > 1.3 % VRo
(gas window)

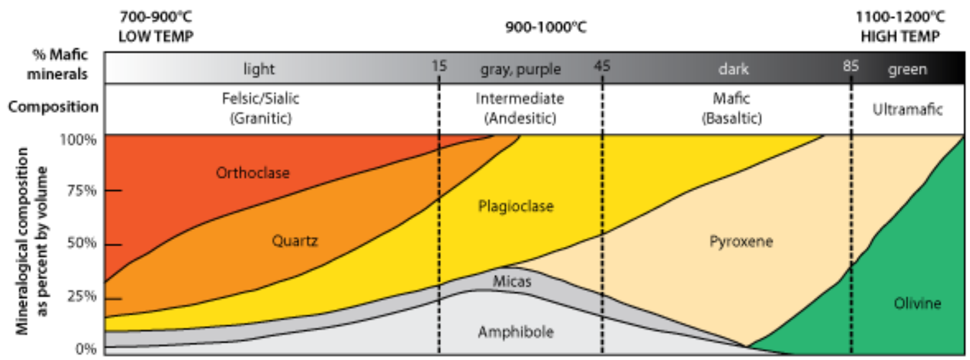
Modified after Cardott and Comer, 2021

Woodford Shale TOCpd

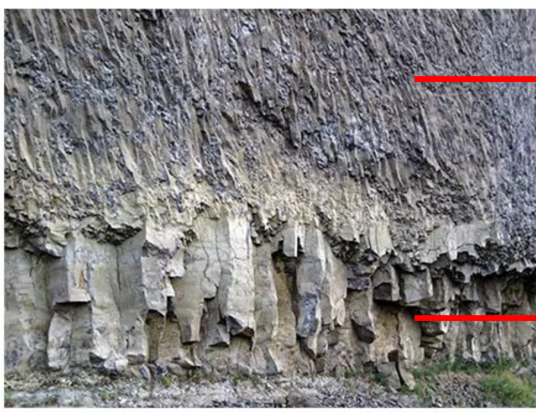


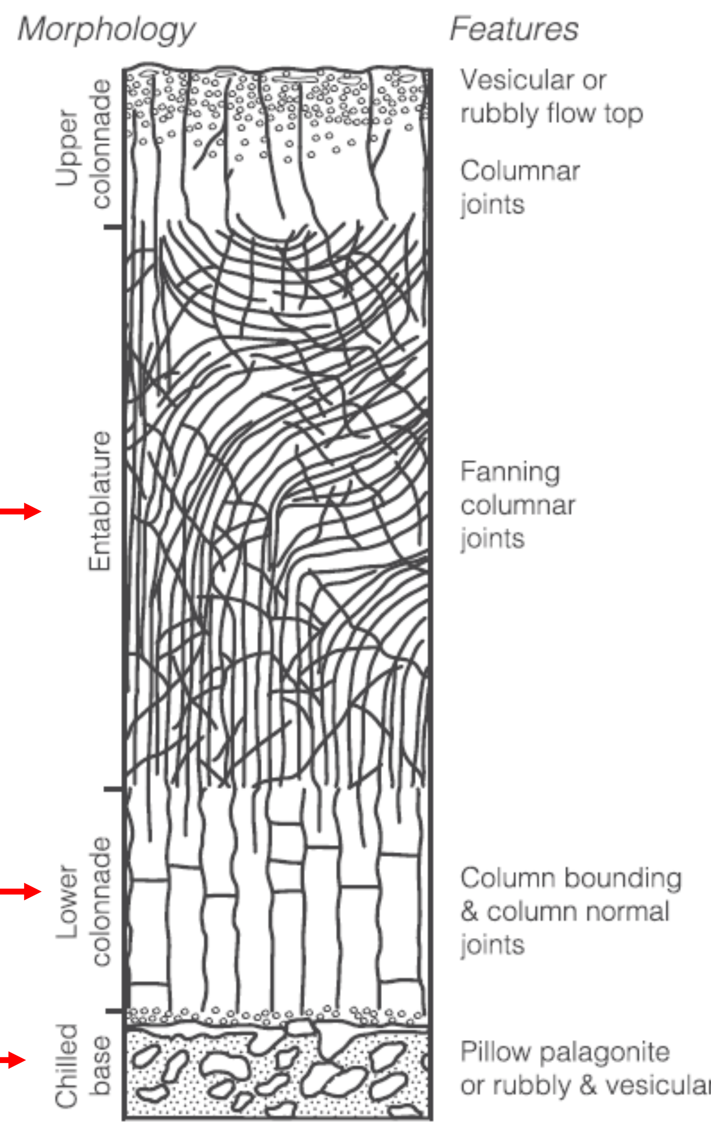
Curtis et al., 2020

Basalt



Texture	Rock names			
Coarse-grained	Granite	Diorite	Gabbro	Peridotite
Fine-grained	Rhyolite	Andesite	Basalt	Uncommon (rarely encountered)
Pyroclastic	Rhyolite Tuff	Andesite Tuff	Basalt Tuff	
Glassy	Obsidian			
Vesicular	Pumice (like meringue)		Scoria	

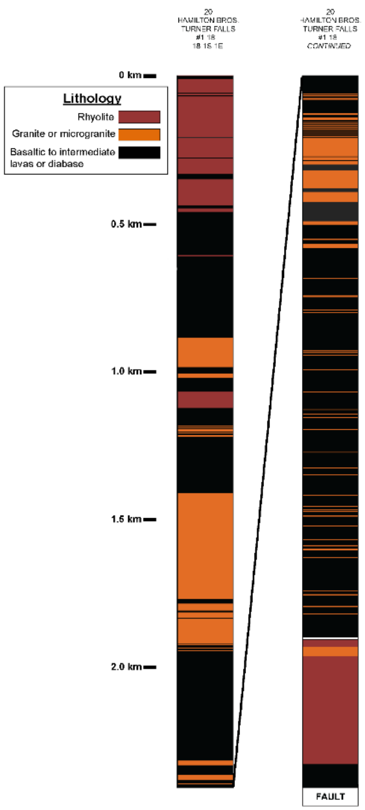


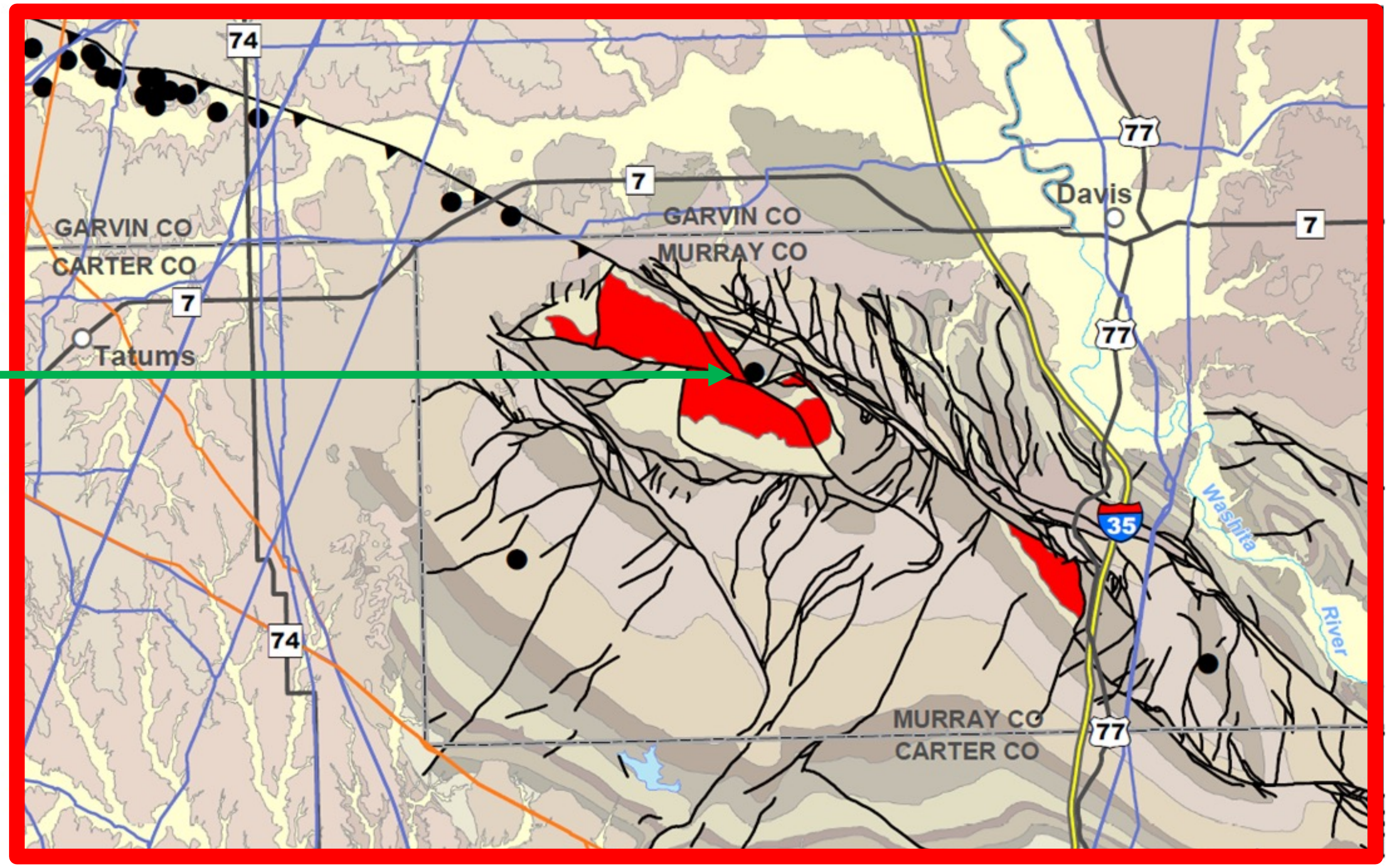


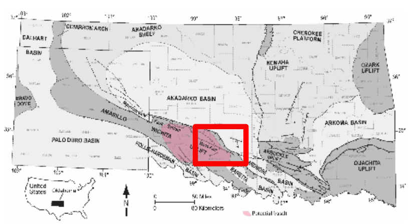
Gierzynski and Pollyea, 2017

Rapid mineralization reactions

Basalt in Oklahoma







Modified after OGS fact sheet 1, 2021

Gas pipeline transport

Liquid pipeline transport

0 1 2 4 6 8 Miles

● OGS core with mafic compostion

Fault, slip-sense not indicated

Thrust fault, sawteeth on overthrow block

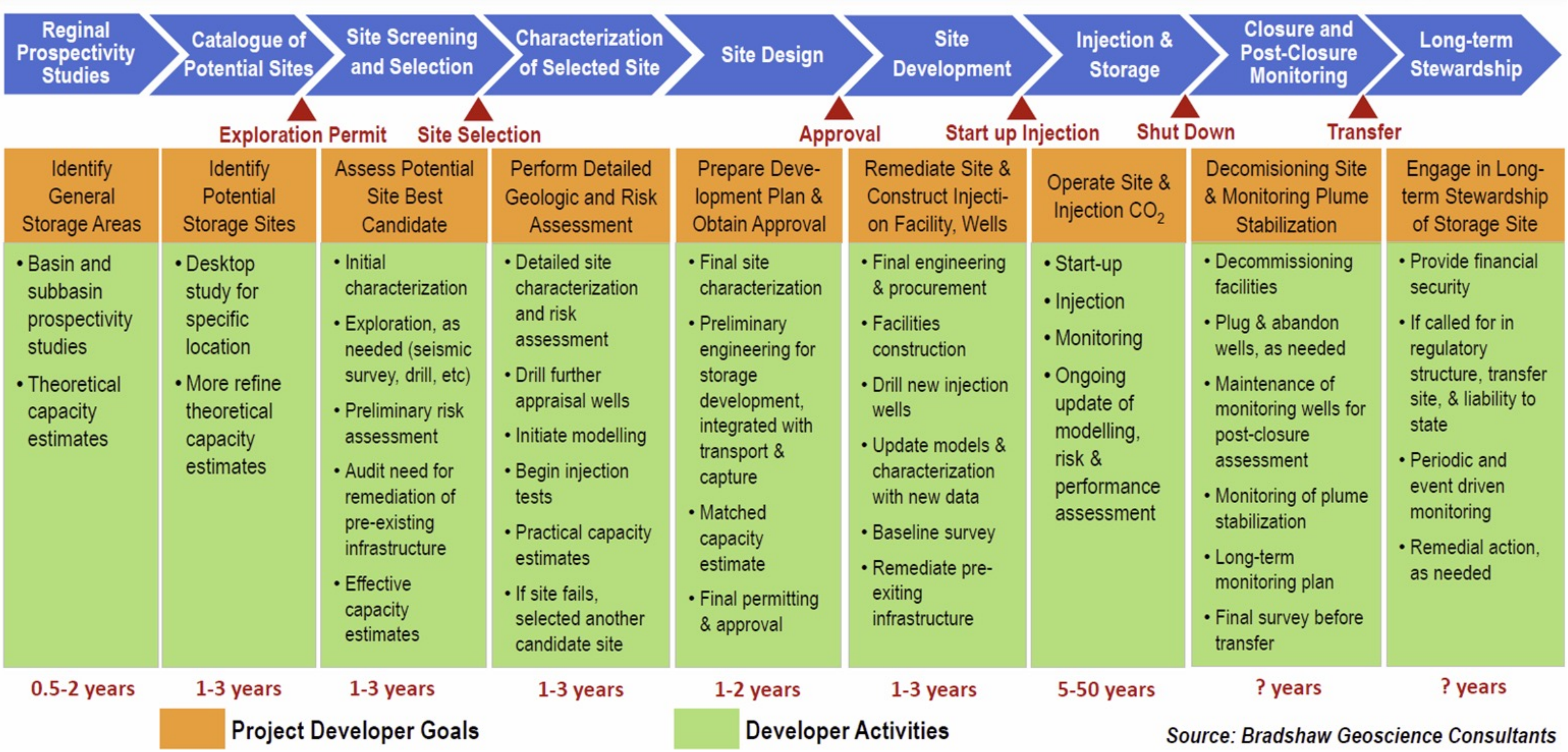
General Rock Type

Felsic igneous (Colbert Rhyolite)

Sedimenary alluvium, gravel, sandstones, shales, dolomite, and limestones

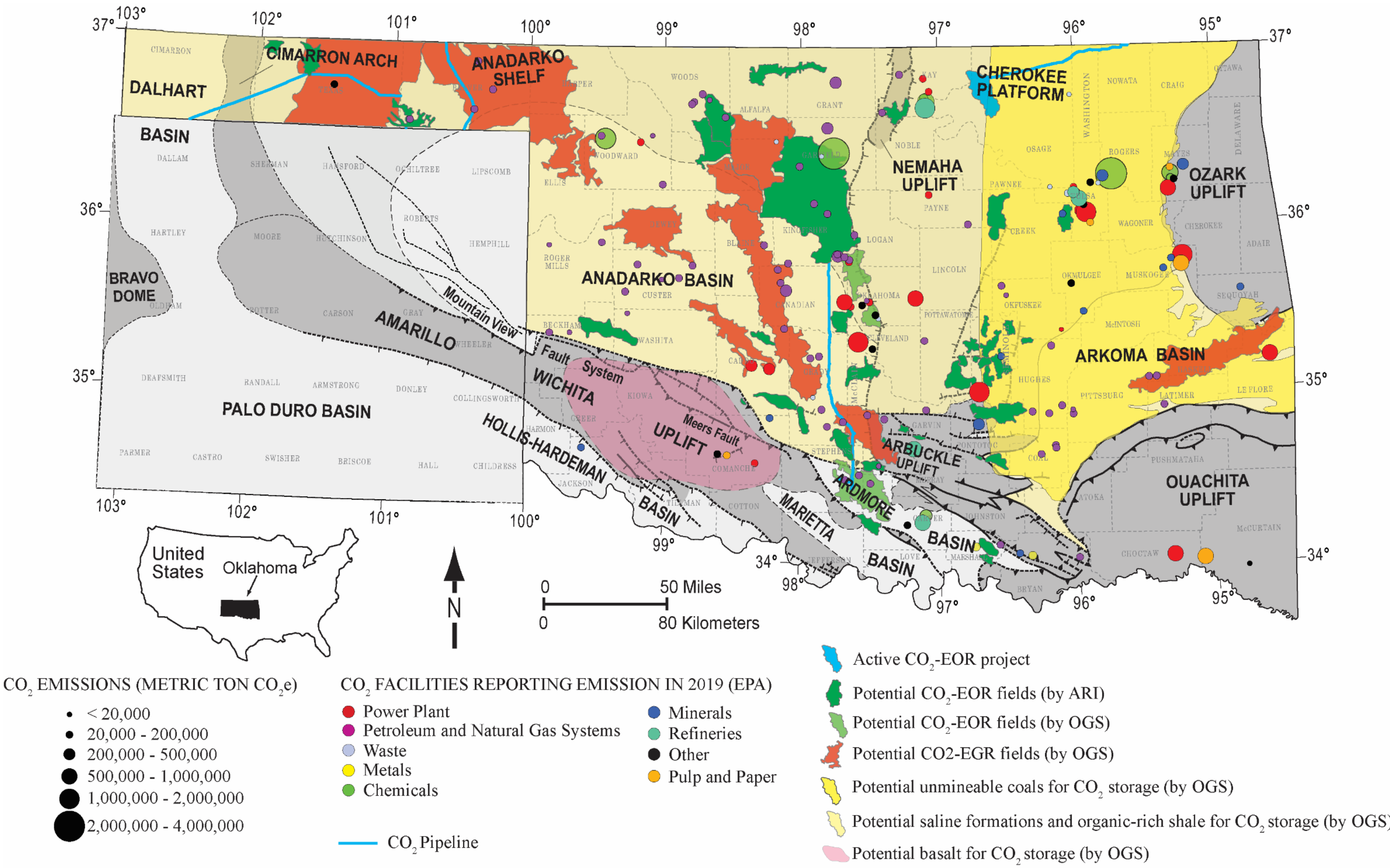
OGS Roles in Carbon Management in Oklahoma

- Geological Data Repository
- Geological and geophysical investigations



Conclusions

- Oklahoma's diverse and heterogeneous geology
- OGS strong experience in geological and geophysical investigation



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OGS CARBON MANAGEMENT