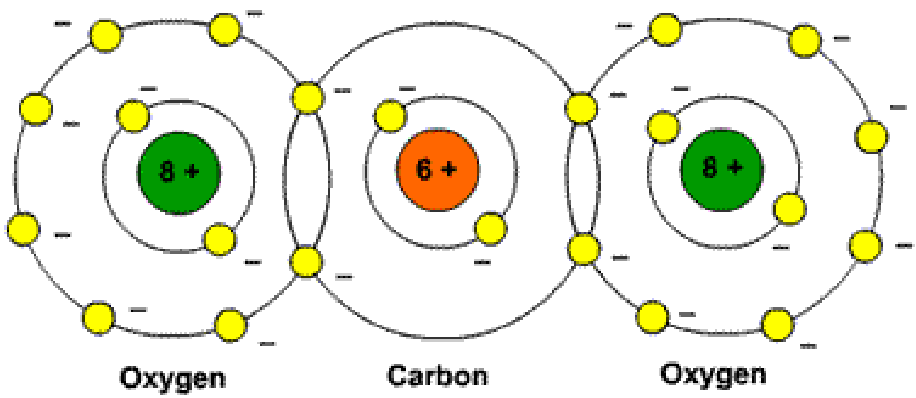
Land and Ocean Based Carbon Sequestration

海陆碳封存应用与研究



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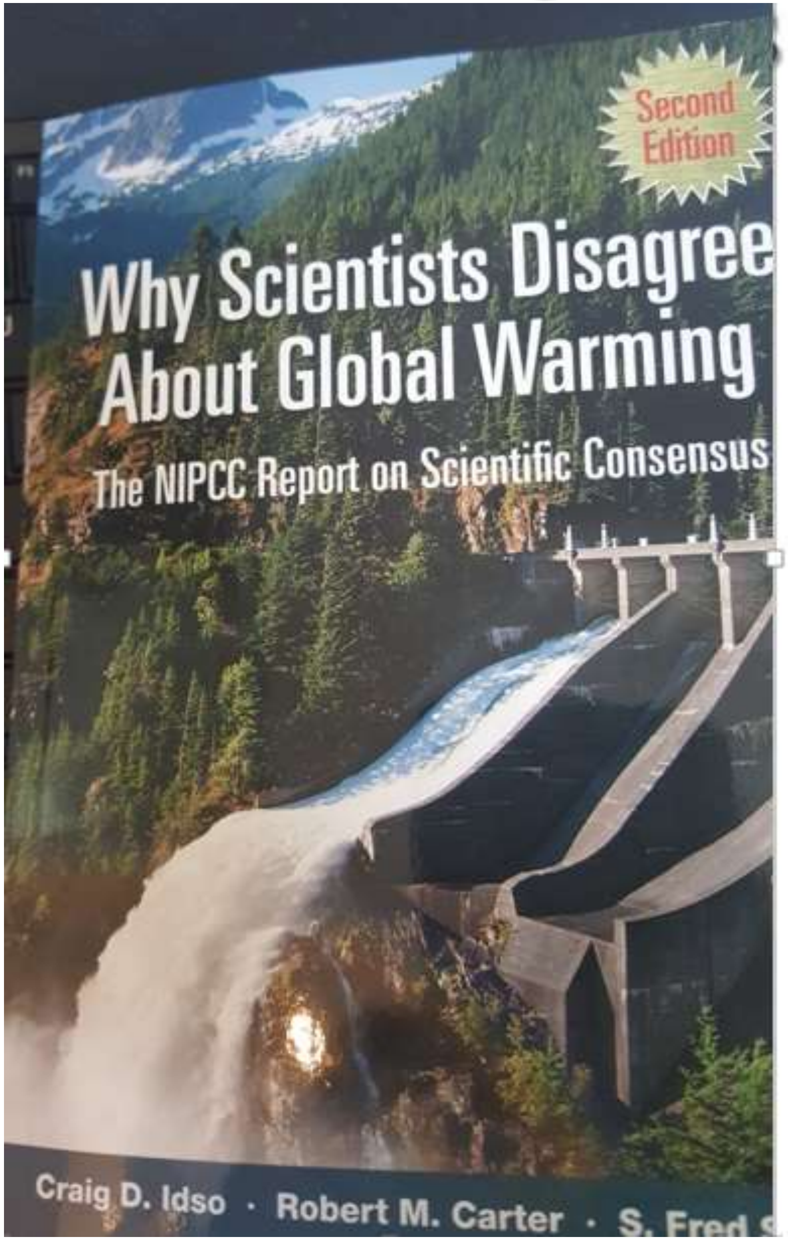
Initial Thoughts



Initial Thoughts

Foreword

President Barack Obama and his followers have repeatedly declared that climate change is "the greatest threat facing mankind." This, while ISIS is beheading innocent people, displacing millions from their homeland, and engaging in global acts of mass murder.

If it weren't so scary, it would be laughable. These statements should ring alarm bells in the minds of all Americans. They show how out of touch this president and the movement he leads are with reality and the American public.

Marita Noon, executive director, Citizen's Alliance for Responsible Energy

The global warming movement is the most extensive and most expensive public relations campaign in the history of the world. Nearly every government agency in the United States and many more around the world are promoting the manmade-climate-change-scare scenario. An entire generation has been brought up hearing and reading about it. Yet public concern about it peaked in 2000 and today, people are no more worried about it than they were 26 years ago when Gallup began polling this issue. They've seen through the rhetoric and exaggerations. They remember, even if journalists and politicians seem not to, that past sky-is-falling predictions failed to come true, and forecasts of a dire climate catastrophe are just as unlikely to come true.

More Information

- "Neither the rate nor the magnitude of the reported late twentieth century surface warming (1979-2000) lay outside normal natural variability.
- Historically, increases in atmospheric CO2 followed increases in temperature, they did not precede them. Therefore, CO2 levels cound not have forced them."

Presentation Focus

Land Based

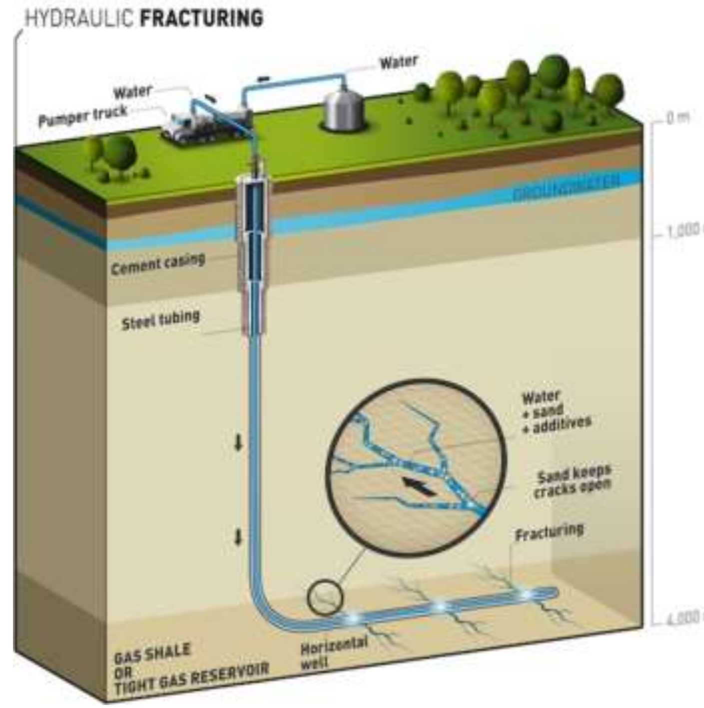
- Horizontal Fracturing
- Enhance Petroleum Recovery

Ocean Topics

- Gas Hydrates and Coastal Stability
- Ocean Modelling

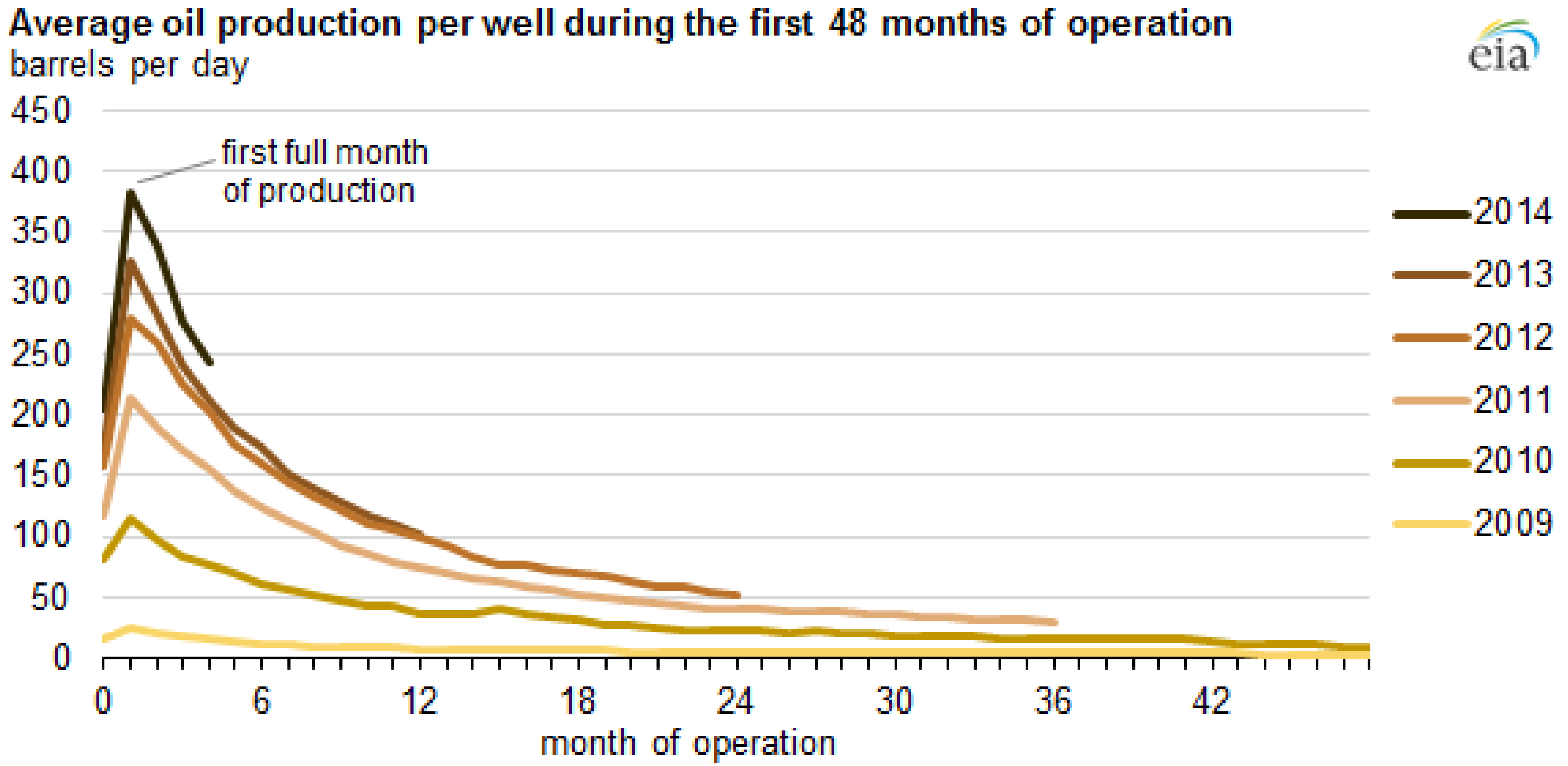
Rationale for Integration of CO_2 Sequestration and Petroleum Mining

"Currently the recovery factor for Eagle Ford Shale wells hovers at around 6%. This means that as much as 94% of the oil contained in the Eagle Ford Shale will remain there forever, unless some kind of unconventional method is used to help force it out of the formation. "



http://eaglefordshaleblog.com/2012/06/05/dry-gas-injection-in-the-eagle-ford-shale/

Well Operation Decline Overview



Economic Benefits

- Adding oil recovery methods adds to the cost of oil —in the case of CO_2 typically between 0.5-8.0 US$ per tonne of CO_2. The increased extraction of oil on the other hand, is an economic benefit with the revenue depending on prevailing prices.

- Onshore EOR has paid in the range of a net 10-16 US$ per tonne of CO_2 injected for oil prices of 15-20 US$/barrel.

- Prevailing prices depend on many factors but can determine the economic suitability of any procedure, with more procedures and more expensive procedures being economically viable at higher prices. Example: With oil prices at around 90 US$/barrel, the economic benefit is about 70 US$ per tonne CO_2.

- The Department of Energy estimates that 20 billion tons of captured CO_2 could produce 67 billion barrels of economically recoverable oil.

http://en.wikipedia.org/wiki/Enhanced_oil_recovery#Economic_costs_and_benefits

Example of a CO2 EOR Project

- **Boundary Dam, Canada** SaskPower's Boundary Dam project retrofitted its coal-fired power station in 2014 with Carbon Capture and Sequestration technology.

- The plant will capture 1 million tonnes of CO2 annually, which it will sell to Cenovus Energy for enhanced oil recovery at its Weyburn Oil Field.

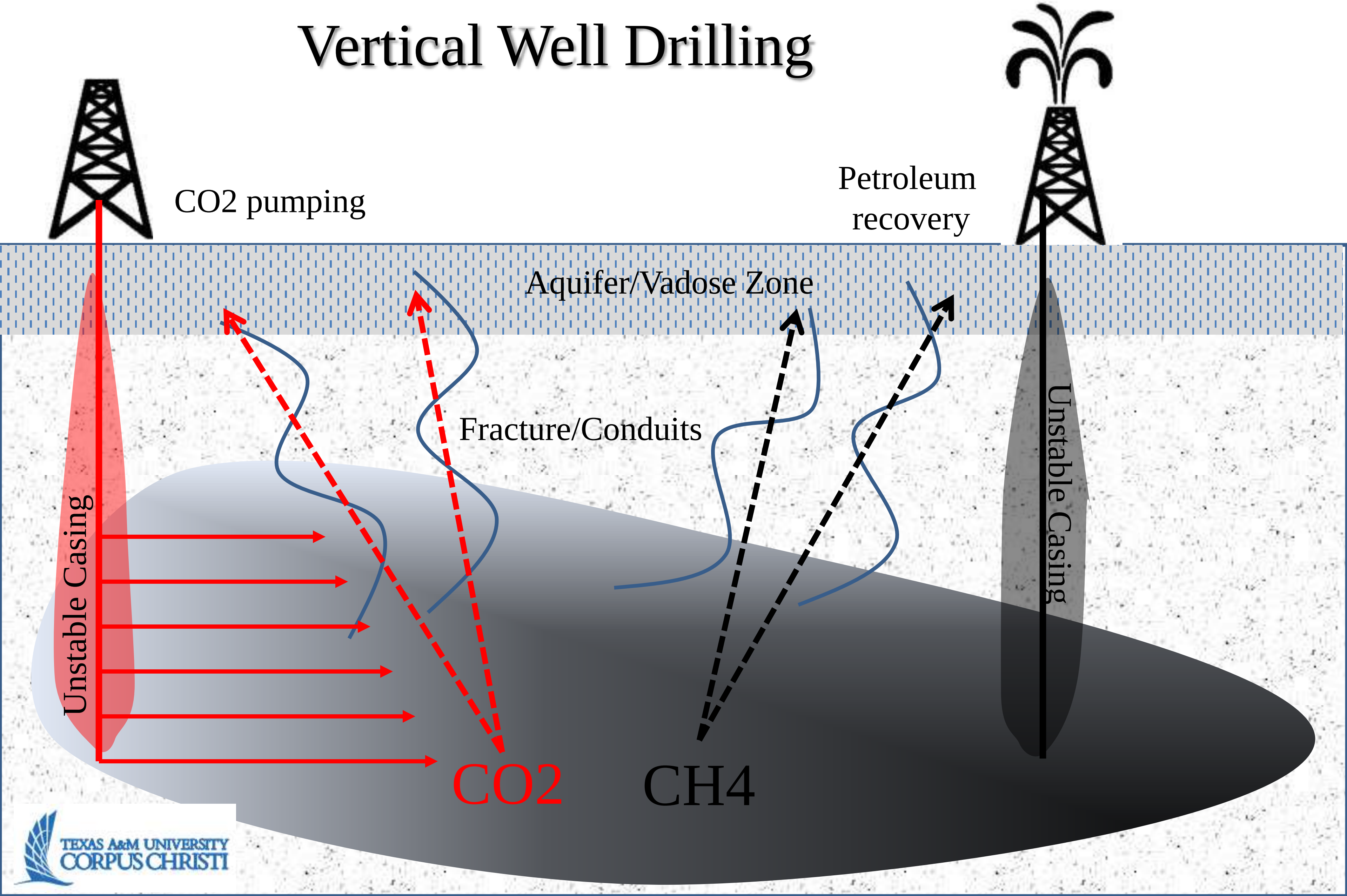
- The project is expected to inject a net 18 million ton CO_2 and recover an additional 130 million barrels (21,000,000 m^3) of oil, extending the life of the oil field by 25 years.

- There is a projected 26+ million tonnes (net of production) of CO2 to be stored in Weyburn, plus another 8.5 million tonnes (net of production) stored at the Weyburn-Midale Carbon Dioxide Project, resulting in a net reduction in atmospheric CO_2 by CO2 storage in the oilfield .

- That's the equivalent of taking nearly 7 million cars off the road for a year. Since CO_2 injection began in late 2000, the EOR project has performed largely as predicted. Currently, some 1600 m^3 (10,063 barrels) per day of incremental oil is being produced from the field.

http://en.wikipedia.org/wiki/Enhanced_oil_recovery#Economic_costs_and_benefits

Vertical Well Drilling



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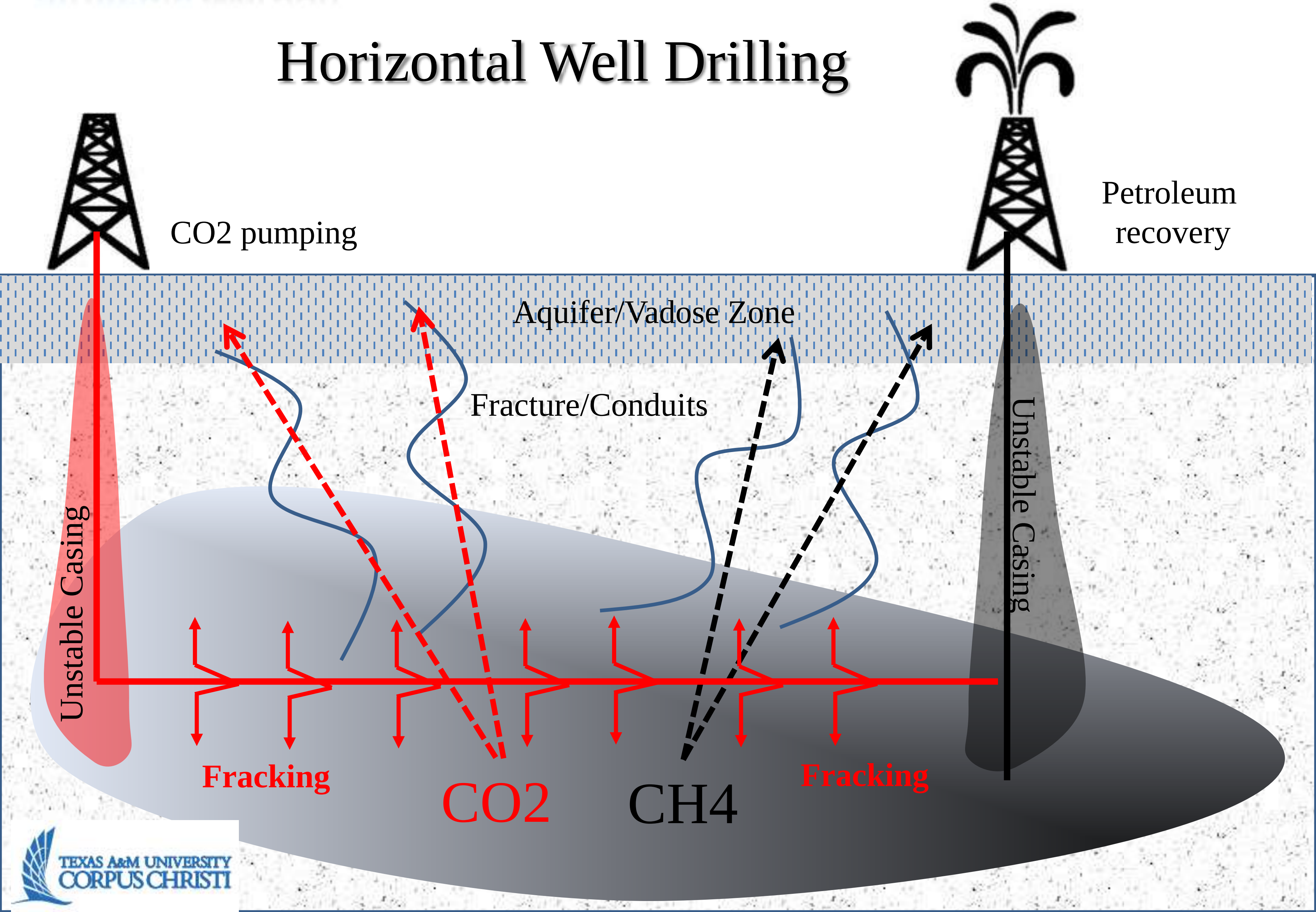
Horizontal Well Drilling



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Our Key Objectives

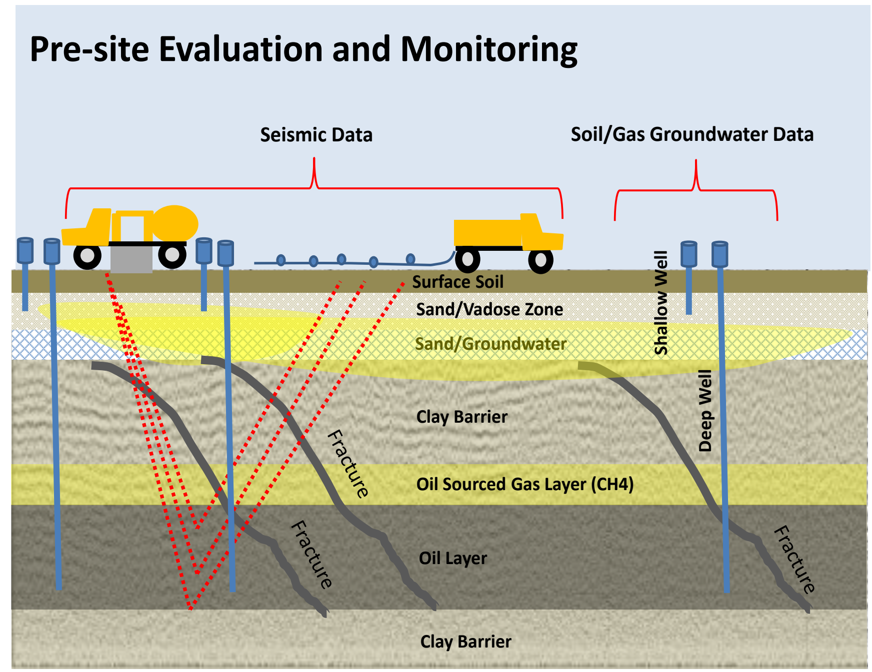
- Assessment of petroleum enhanced recovery levels using CO_2 pressurization in deep wells.

- Assess CO_2 geologic residence time to assess sequestration potential.

- Test CO_2 pressurization for horizontal fracturing in horizontal well operations.

- Evaluation of the economic issues related to materials, completion techniques and volume/value of commodities extracted or sequestered to determine the commercial feasibility of these activities.

- On a broader scale predict financial benefits for impeding leakage, tax write offs for sequestration, mitigating litigation also factor into the economics. Confirmation of geologic carbon sequestration capacity can be applied to evaluation of property value.



4-d seismic and radiocarbon natural abundance monitoring

Environmental Assessment

- Vertical fluid and gas migration
- Discrimination between petroleum and microbial gases

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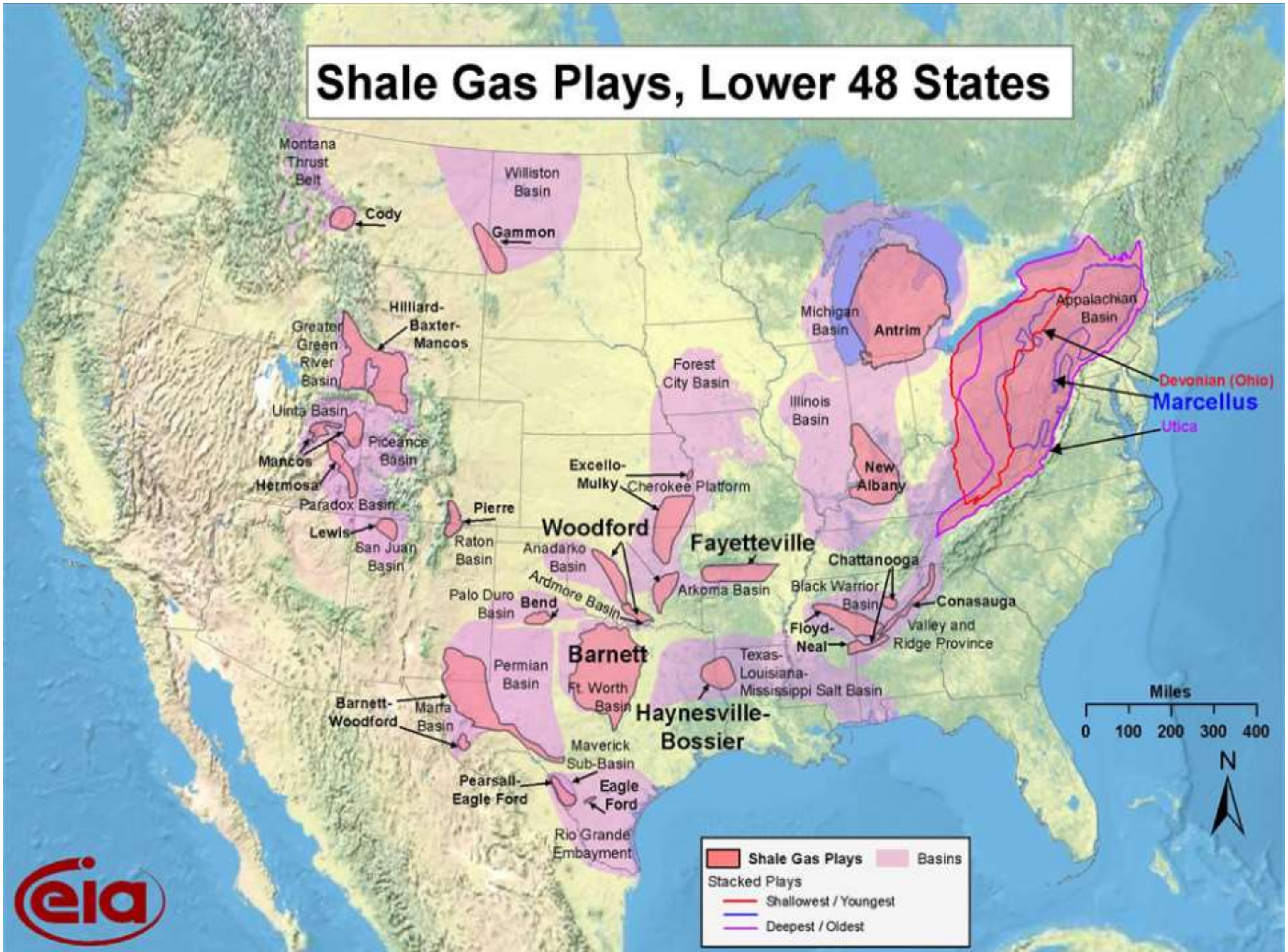

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Study Locations

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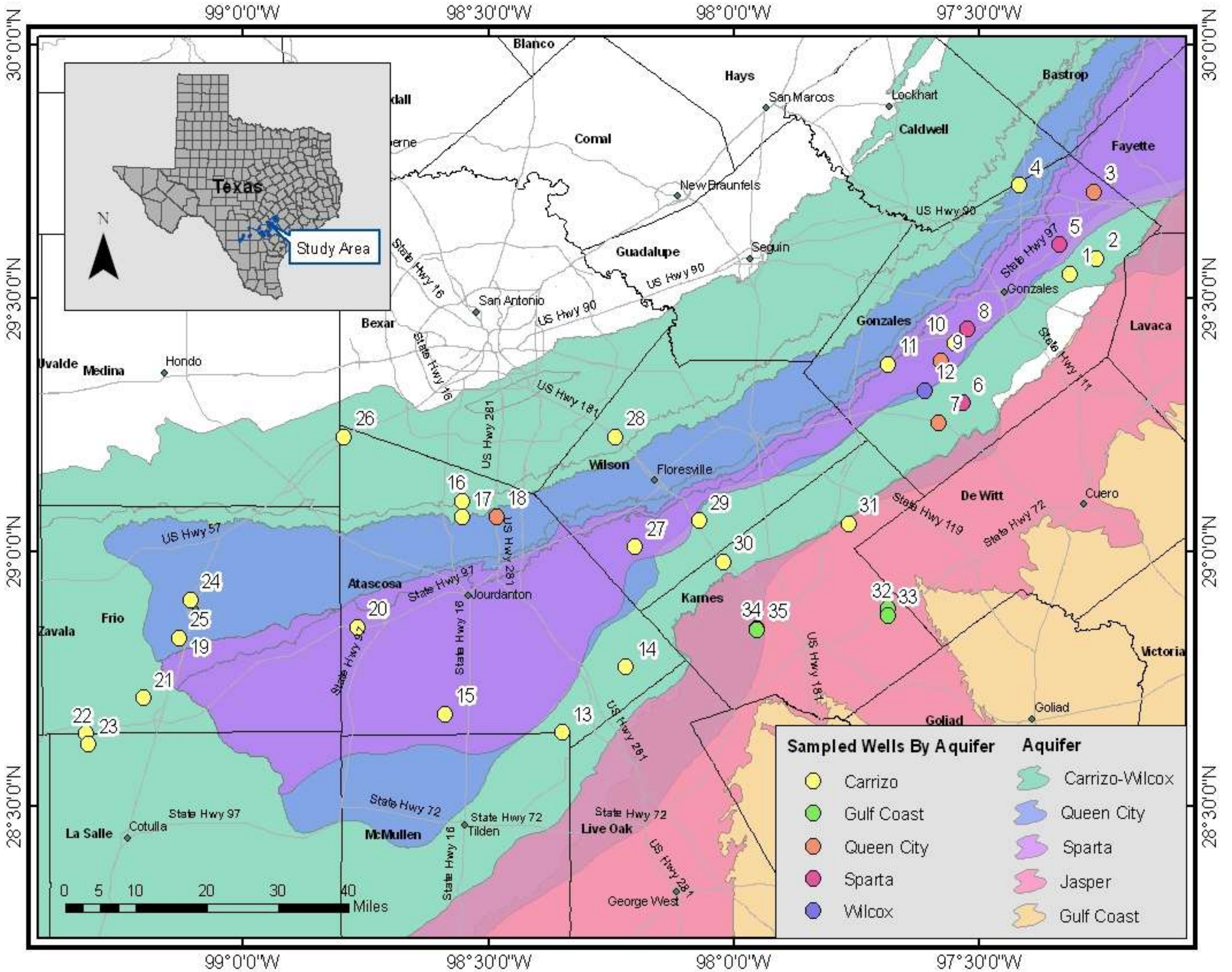

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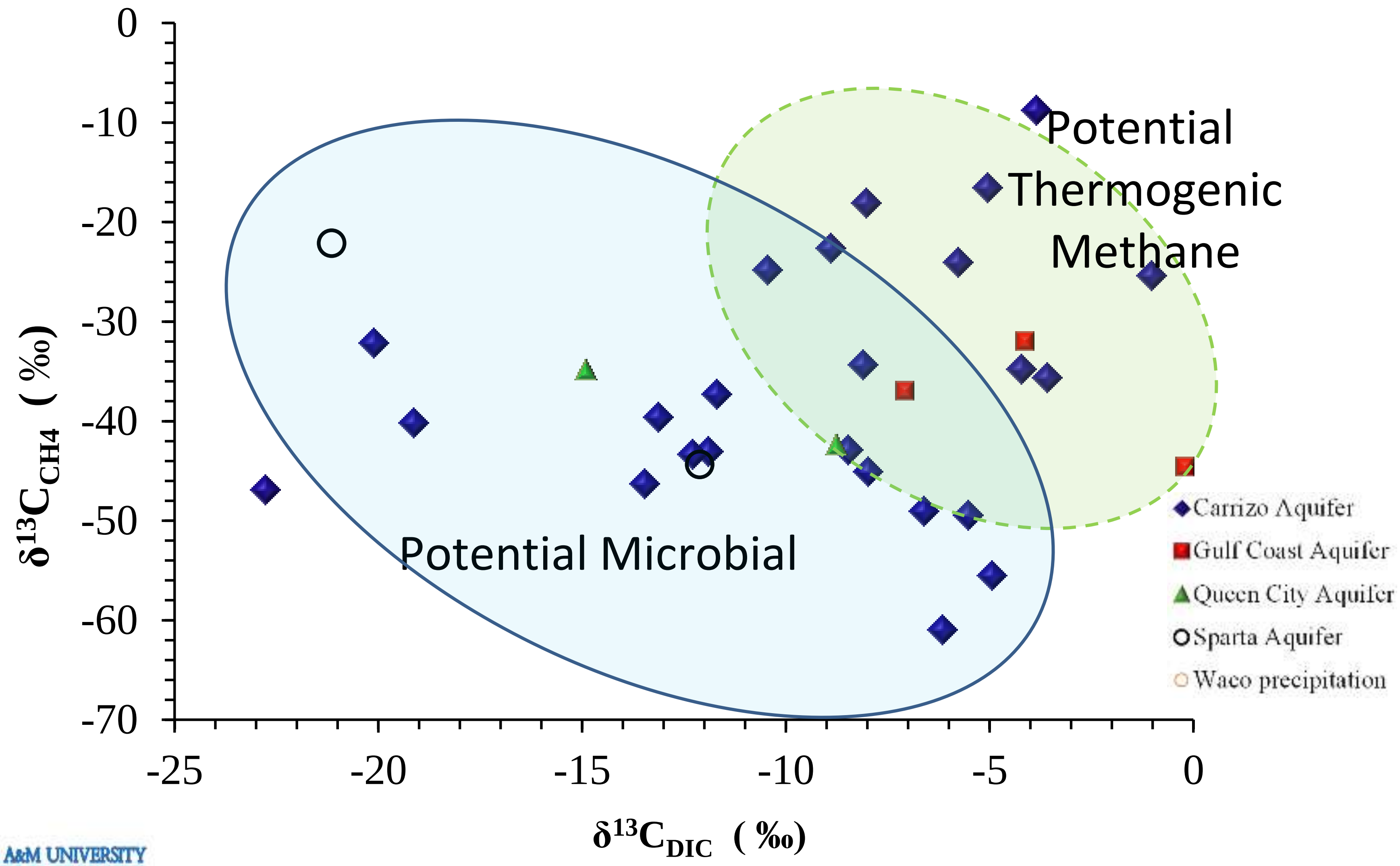
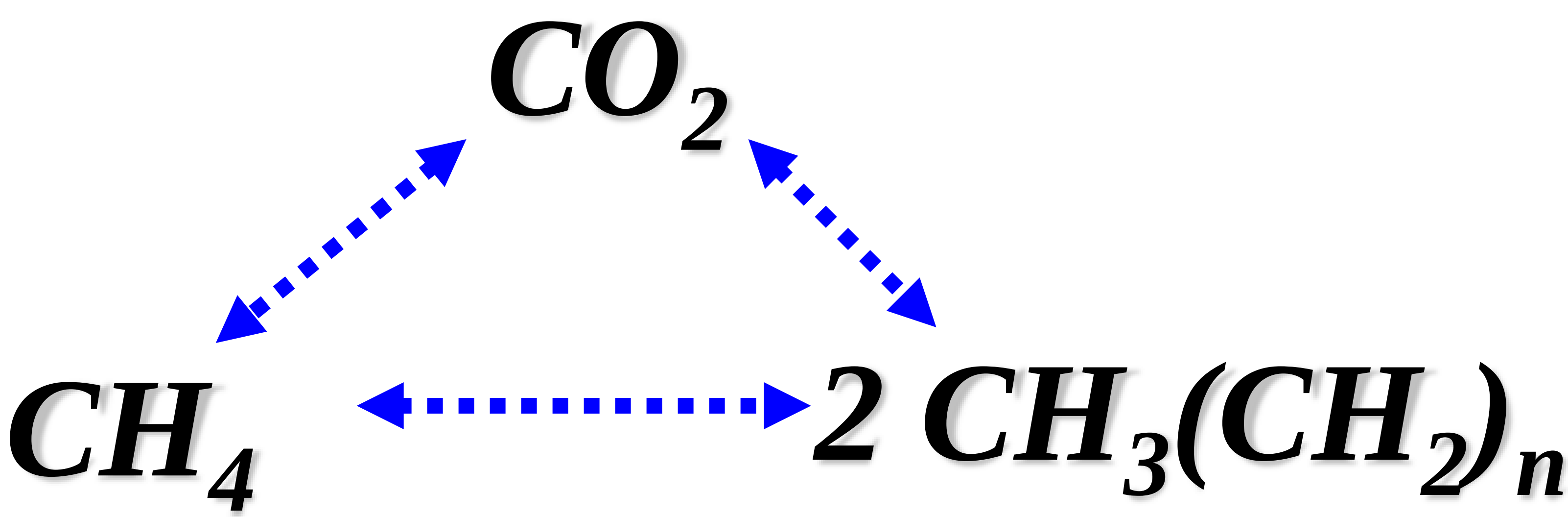
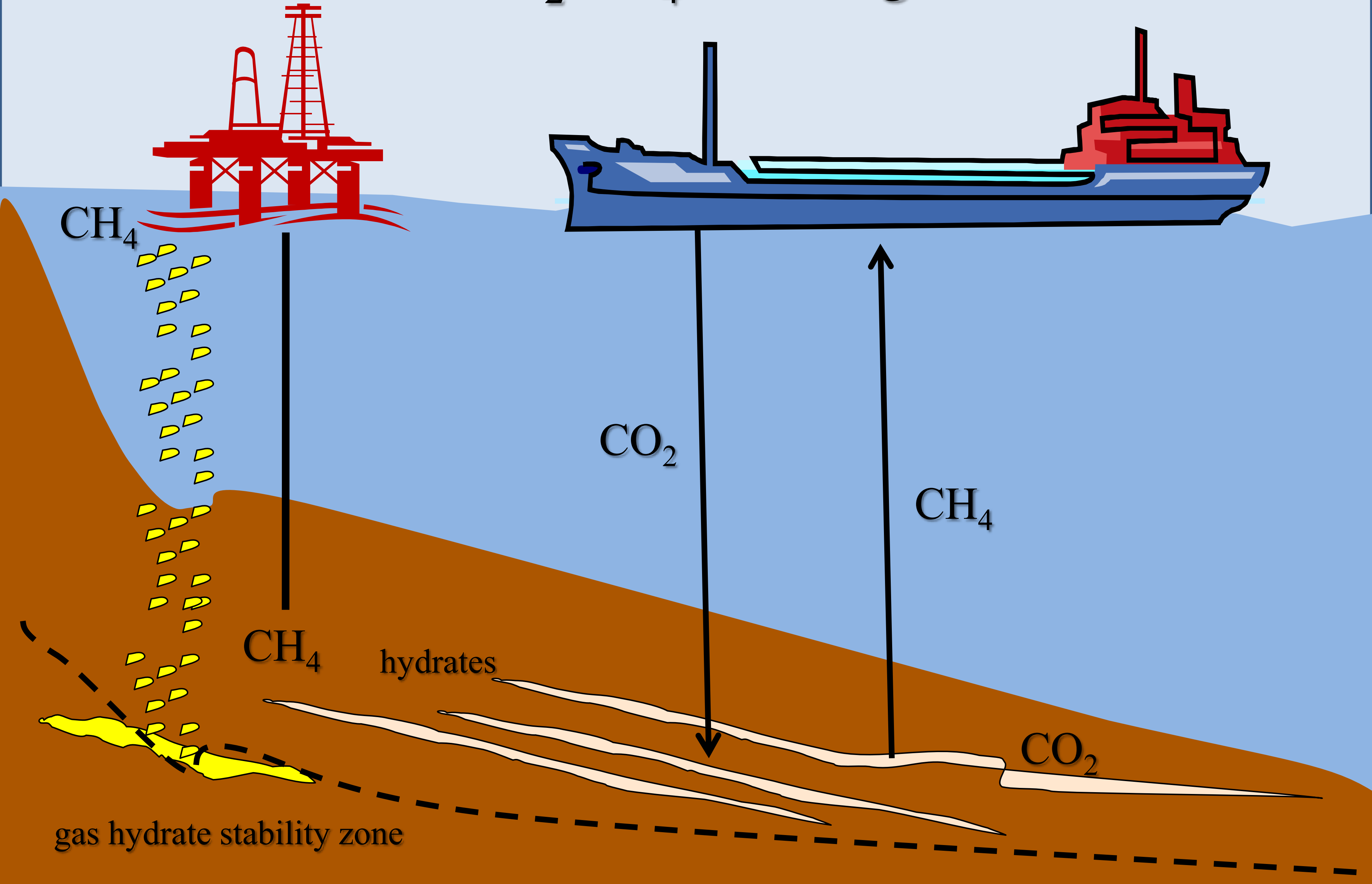
Methane Source Evaluation



Methane Hydrate Exploration Related to Deep Sediment Carbon Dioxide Sequestration



CO_2 CH_4 Exchange

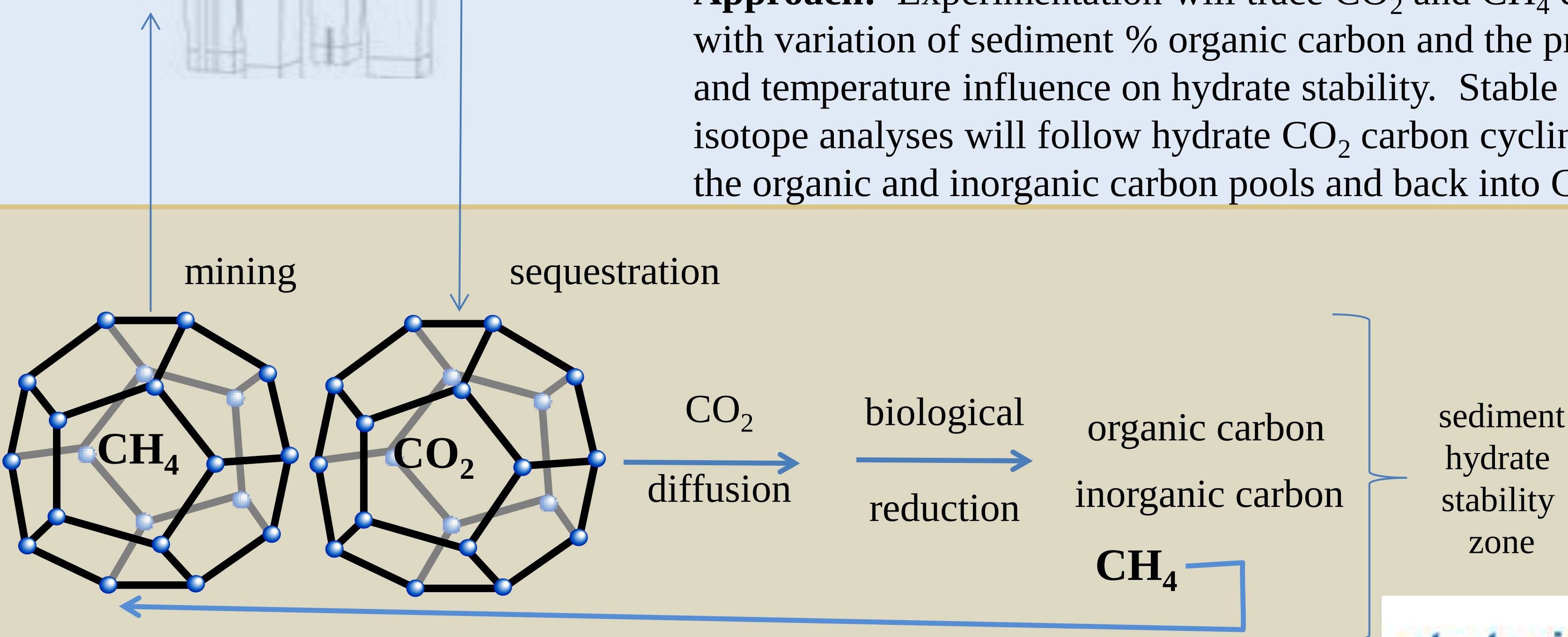


CO_2 Hydrate Stability

Objective: Determine the affect of sediment geologic and geochemical characteristics on the CO_2 hydrate residence time.

Rationale: CO_2 diffusion rates on a concentration gradient across the hydrate interface will vary in different geologic systems. The net residence time of sequestered CO_2 is a function of physical properties and geologic/geochemical influence on carbon cycles. While diffusion of CO_2 from hydrate will occur, geochemical cycles will contribute substantially to the residence time.

Approach: Experimentation will trace CO_2 and CH_4 cycling with variation of sediment % organic carbon and the pressure and temperature influence on hydrate stability. Stable carbon isotope analyses will follow hydrate CO_2 carbon cycling into the organic and inorganic carbon pools and back into CH_4.



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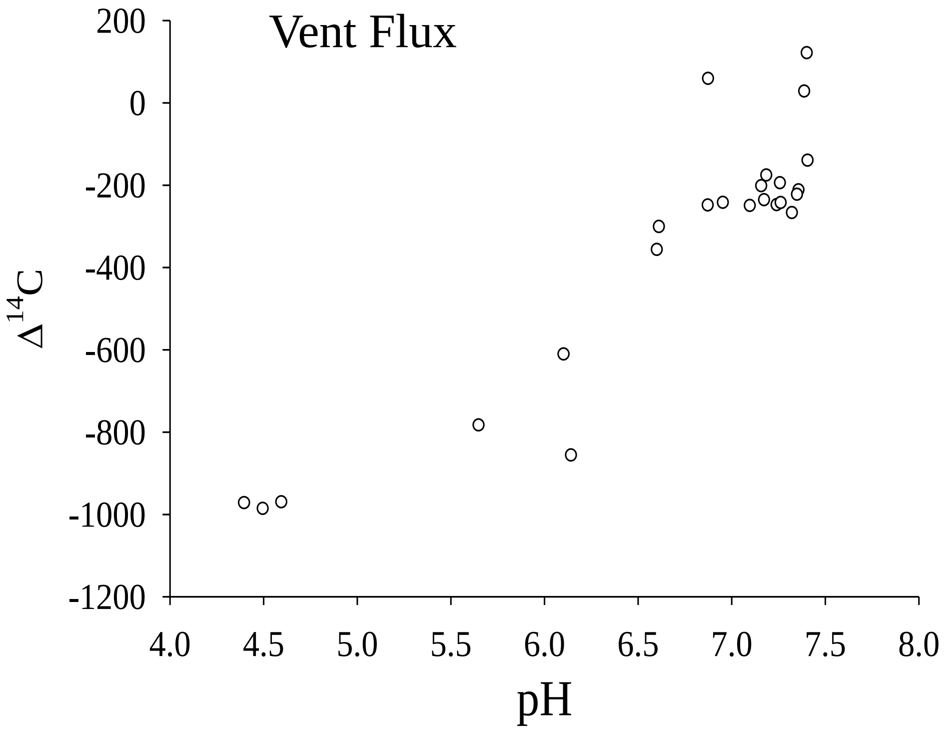
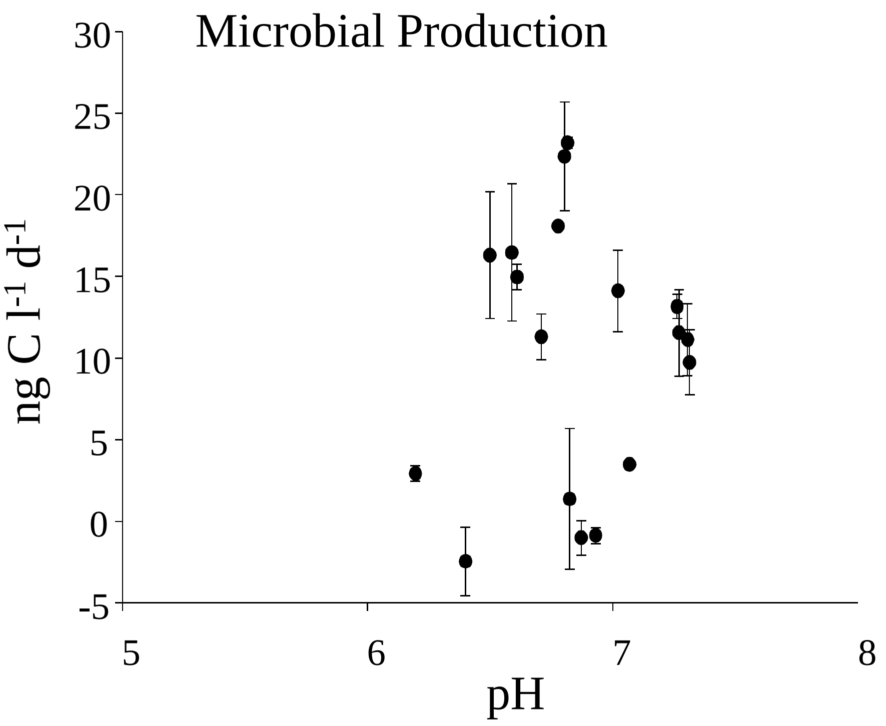
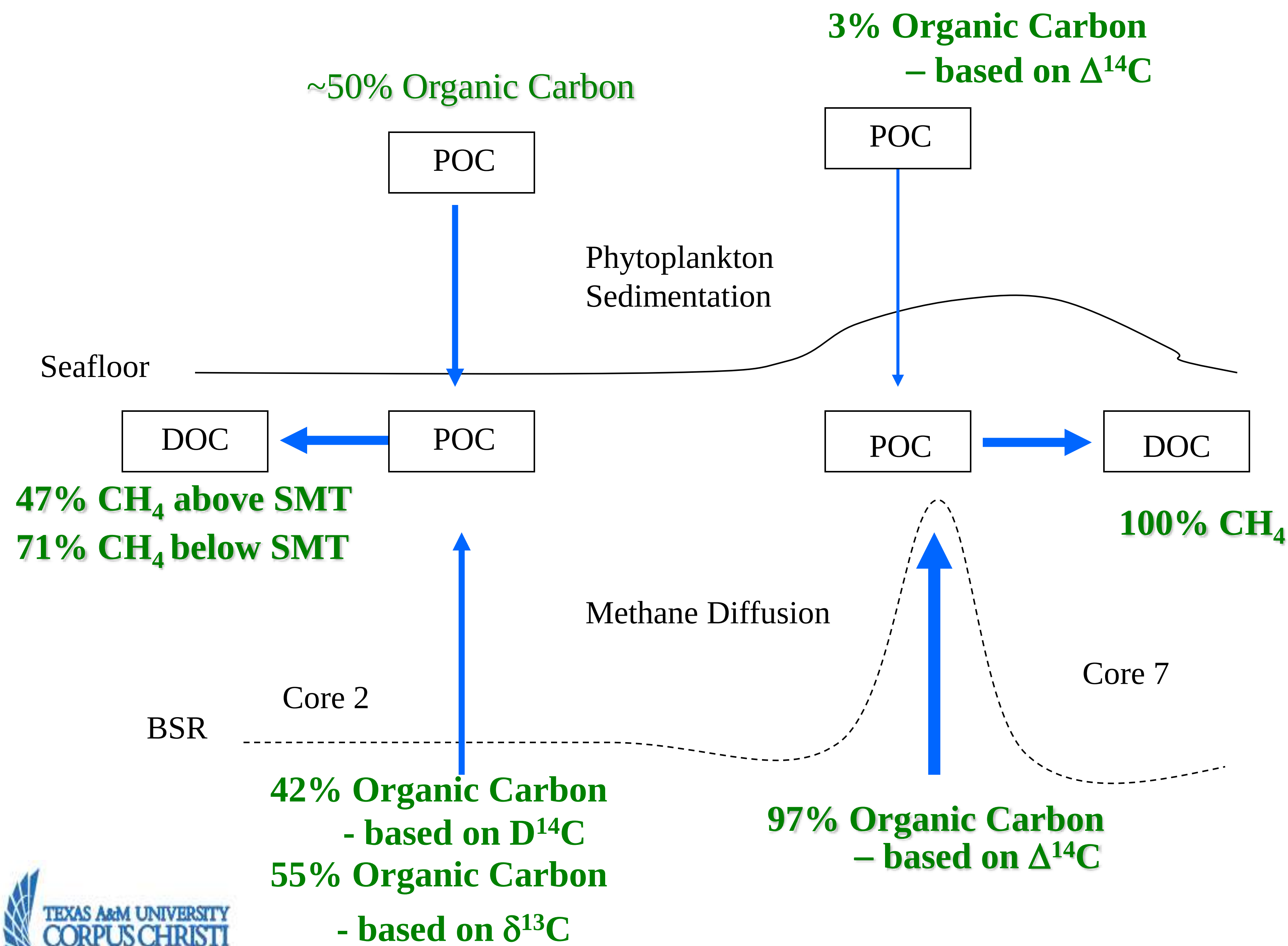
Loihi Vent Flux





Atwater Summary



Carbon Dioxide Vertical Migration in Sediments on the Chatham Rise, New Zealand

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Study Locations

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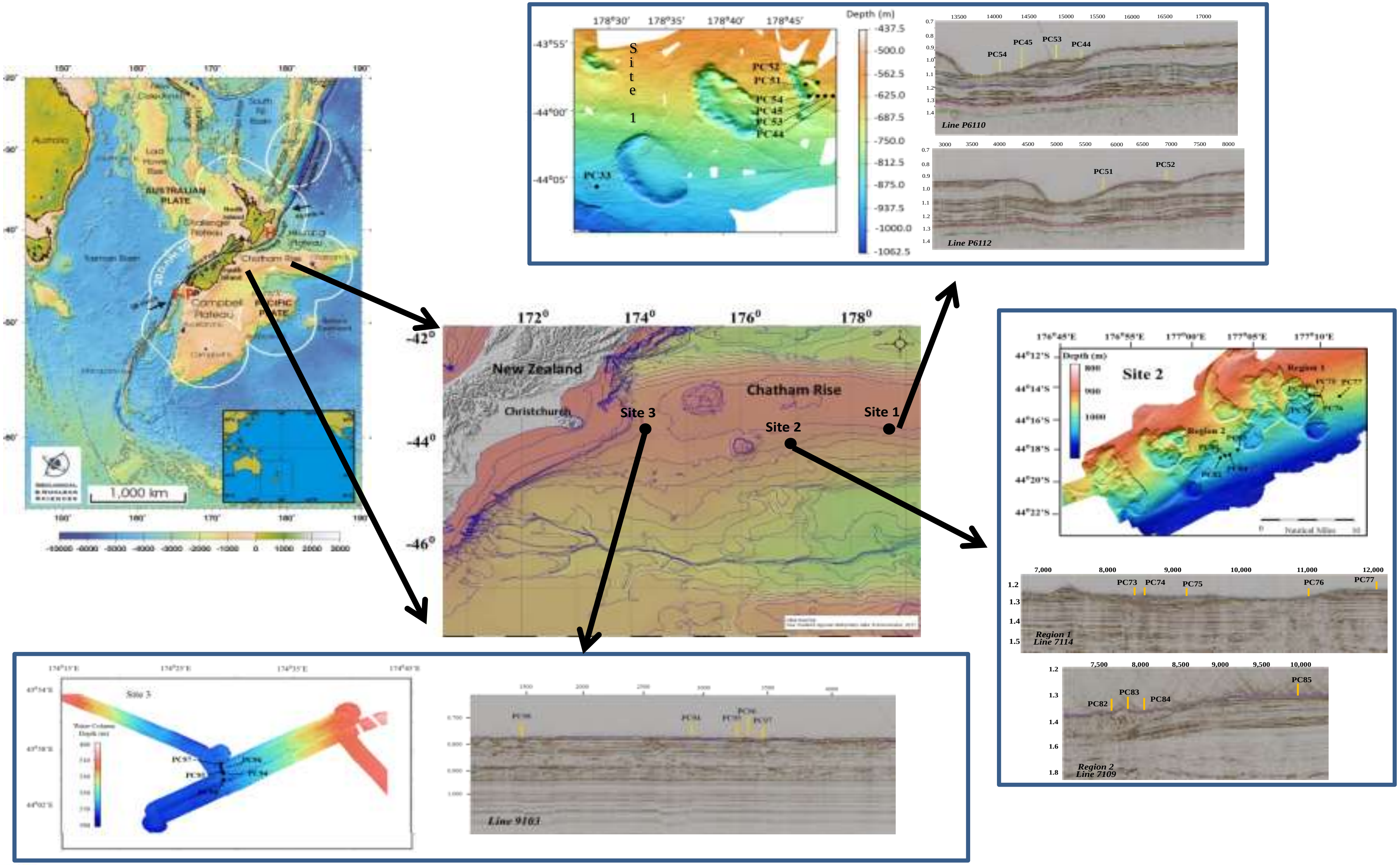

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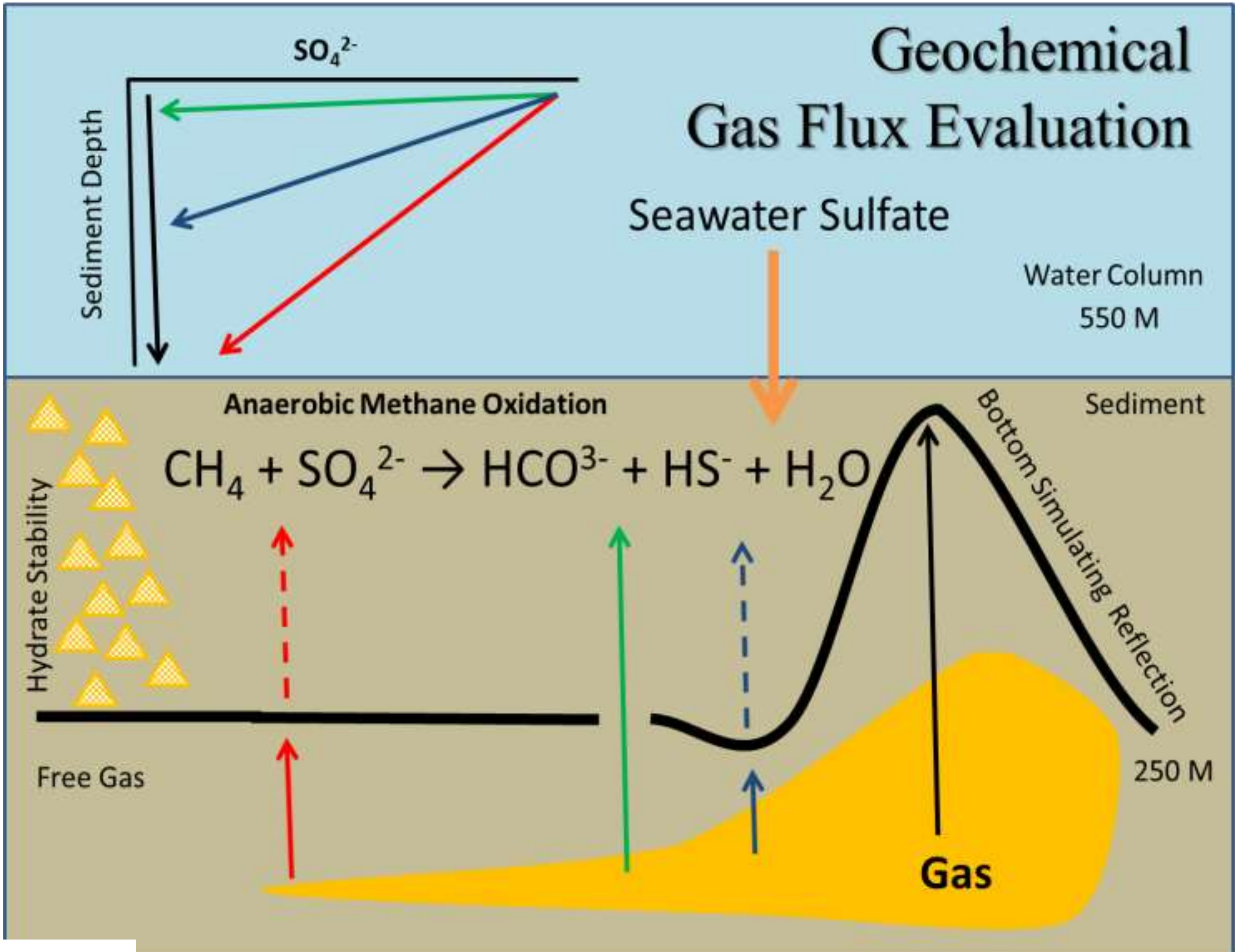
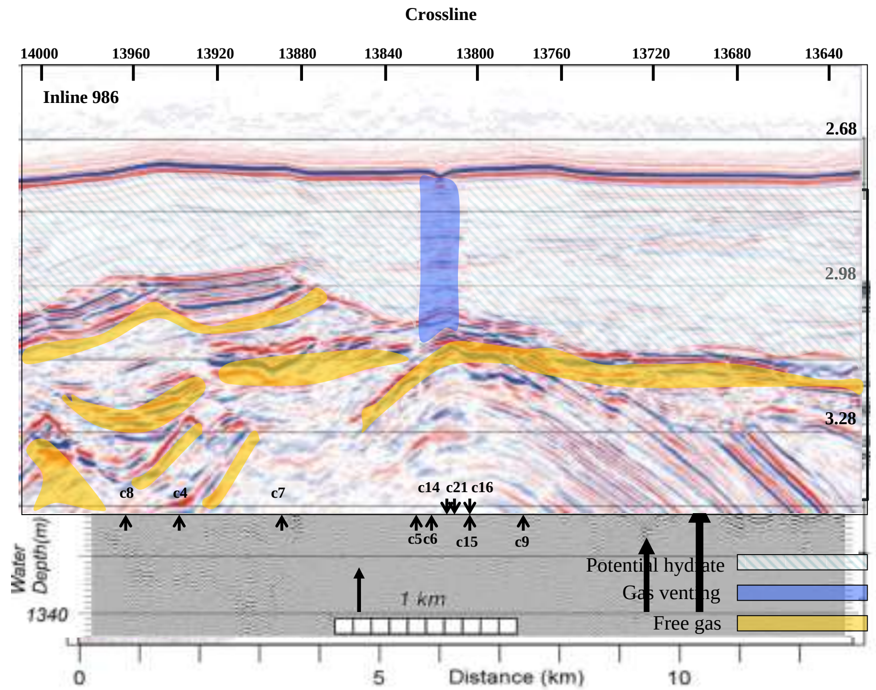


Geochemical
Gas Flux Evaluation
SO_4^{2-}
Sediment Depth
Seawater Sulfate
Water Column
550 M
Anaerobic Methane Oxidation
Sediment
$CH_4 + SO_4^{2-} \rightarrow HCO^{3-} + HS^- + H_2O$
Bottom Simulating Reflection
Hydrate Stability
Free Gas
250 M
Gas

Coastal SMT Summary

Chile Core	Chile SMT (cm)	New Zealand Core	New Zealand SMT (cm)	Atwater Valley Core	Atwater Valley SMT (cm)	Alaminos Can. Core	Alaminos Can. SMT (cm)
1	555	*2*	*3950*	1	288	1	633
13	733	3	1290	2	410	4	920
11	33.3	4	443	3	no SMI	5	800
10	189	11	309	4	no SMI	6	308
9	246	17	184	5	224	7	761
8	275	12	no SMI	6	45	8	949
6	235	18	806	7	no SMI	9	1550
5	248	8	357	8	59	10	469
2	212	7	211	9	291	11	621
3	194	14	381	10	385	12	672
7	292	10	87	11	246	13	995
12	266	13	268	12	317	14	642
14	*1011*	28	323	13	260	15	1793
		15	443	14	504	16	1242
		5	364	15	215	17	1628
						18	679
						19	828
						20	1107
						21	607
						22	589
	345		628		216		890



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Pore Water Profiles

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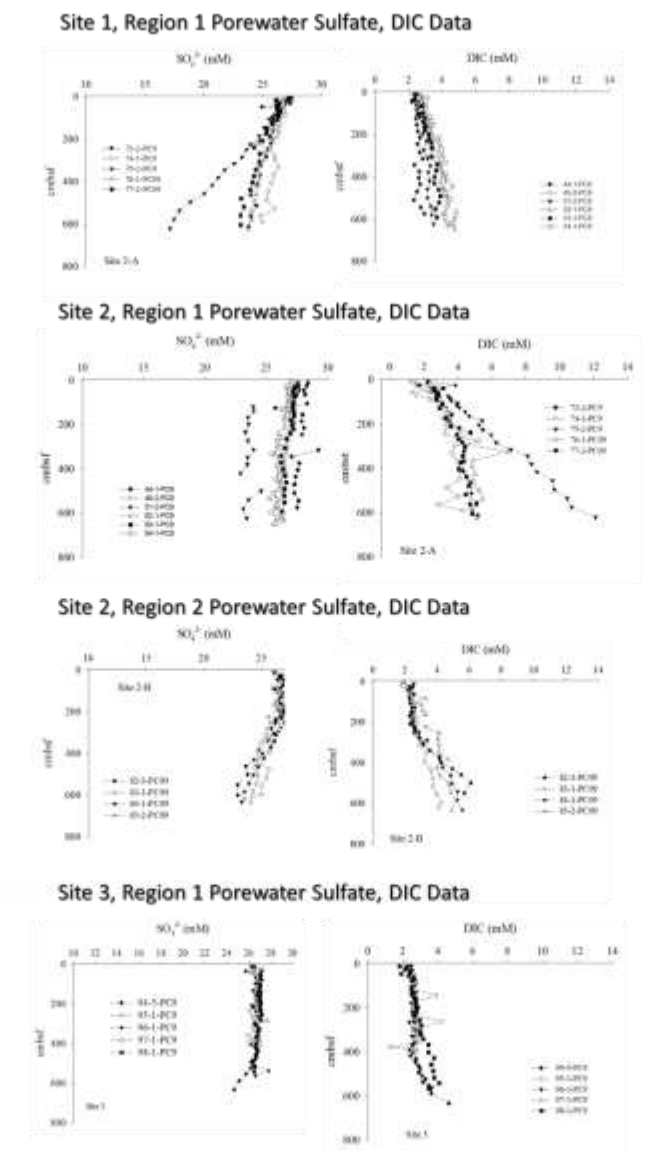
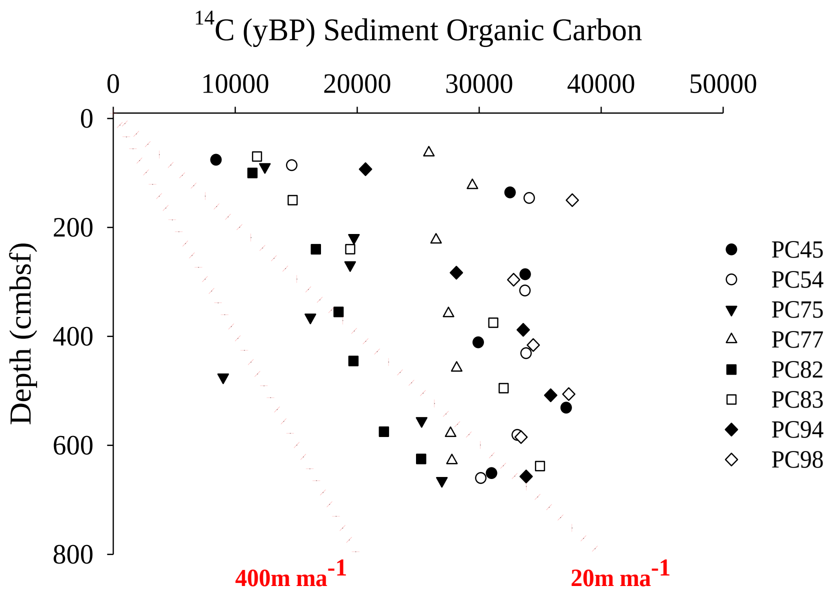
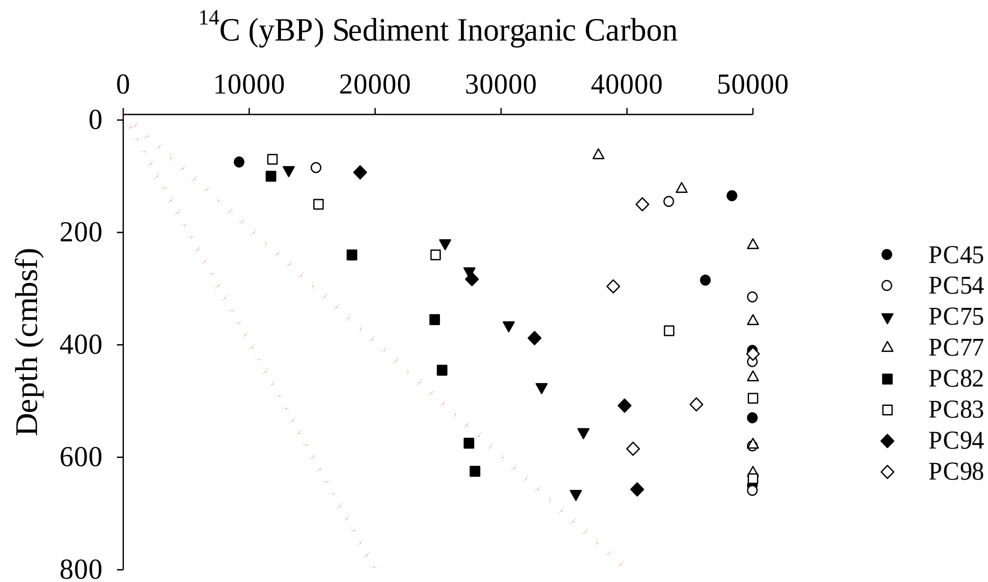


Figure 3: Sediment pore water profiles of sulfate and dissolved inorganic carbon (DIC) taken at Sites 1, 2 and 3.

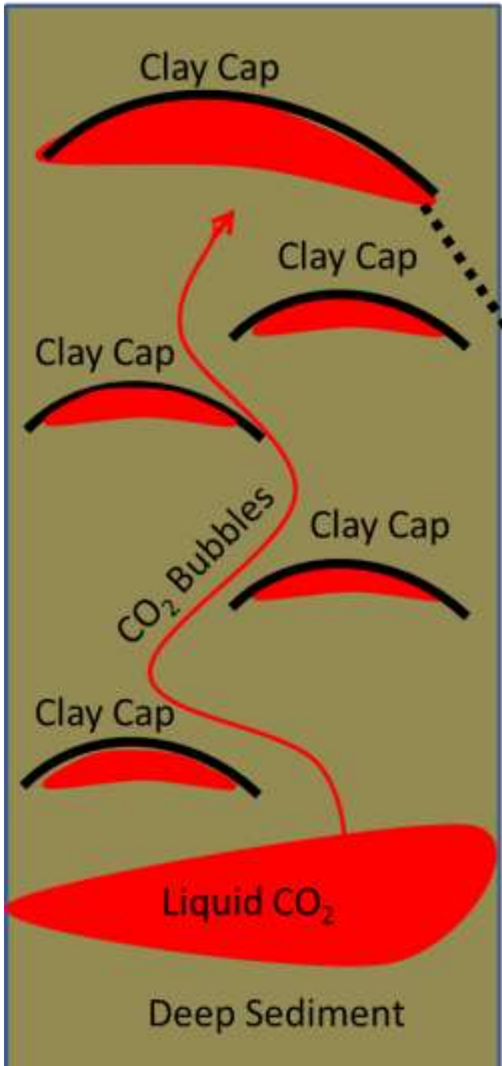
Site	Core ID	SO_4^{2-} Minimum (mbsf)	R2, N
1	44-1-PC9	34.4	0.140, 18
1	45-1-PC9	101.8	0.829, 25
1	51-1-PC9	22.1	0.549, 21
1	52-1-PC9	69.0	0.607, 22
1	53-1-PC9	103.3	0.774,25
1	54-1-PC9	100.2	0.763, 27
2A	73-2-PC9	51.5	0.955, 18
2A	74-1-PC9	77.2	0.936, 17
2A	75-2-PC9	16.2	0.988, 27
2A	76-1-PC9	50.5	0.962, 24
2A	77-2-PC9	37.5	0.920, 23
2B	82-3-PC9	23.5	0.958, 13
2B	83-1-PC9	38.0	0.760, 13
2B	84-1-PC9	33.6	0.957, 14
2B	85-2-PC9	51.6	0.859, 12
3	94-1-PC9	66.5	0.653, 24
3	95-1-PC9	55.4	0.201, 19
3	96-1-PC9	77.8	0.185, 21
3	97-1-PC9	no slope	n.d.
3	98-1-PC9	117.3	0.622, 18

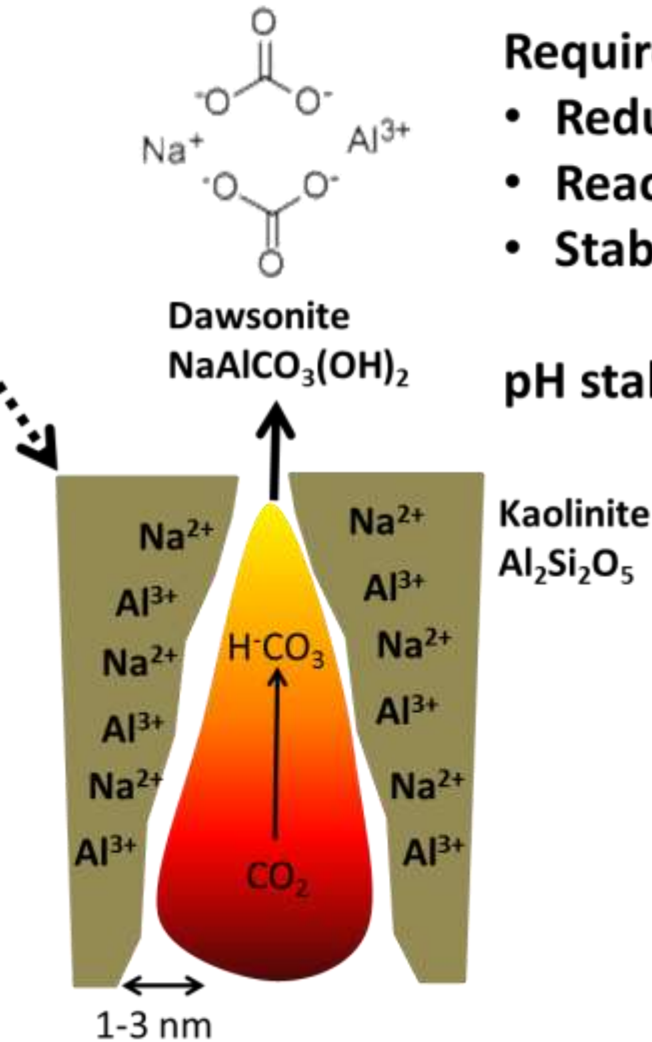
Sedimentation Relative to Carbon Age





Conclusions





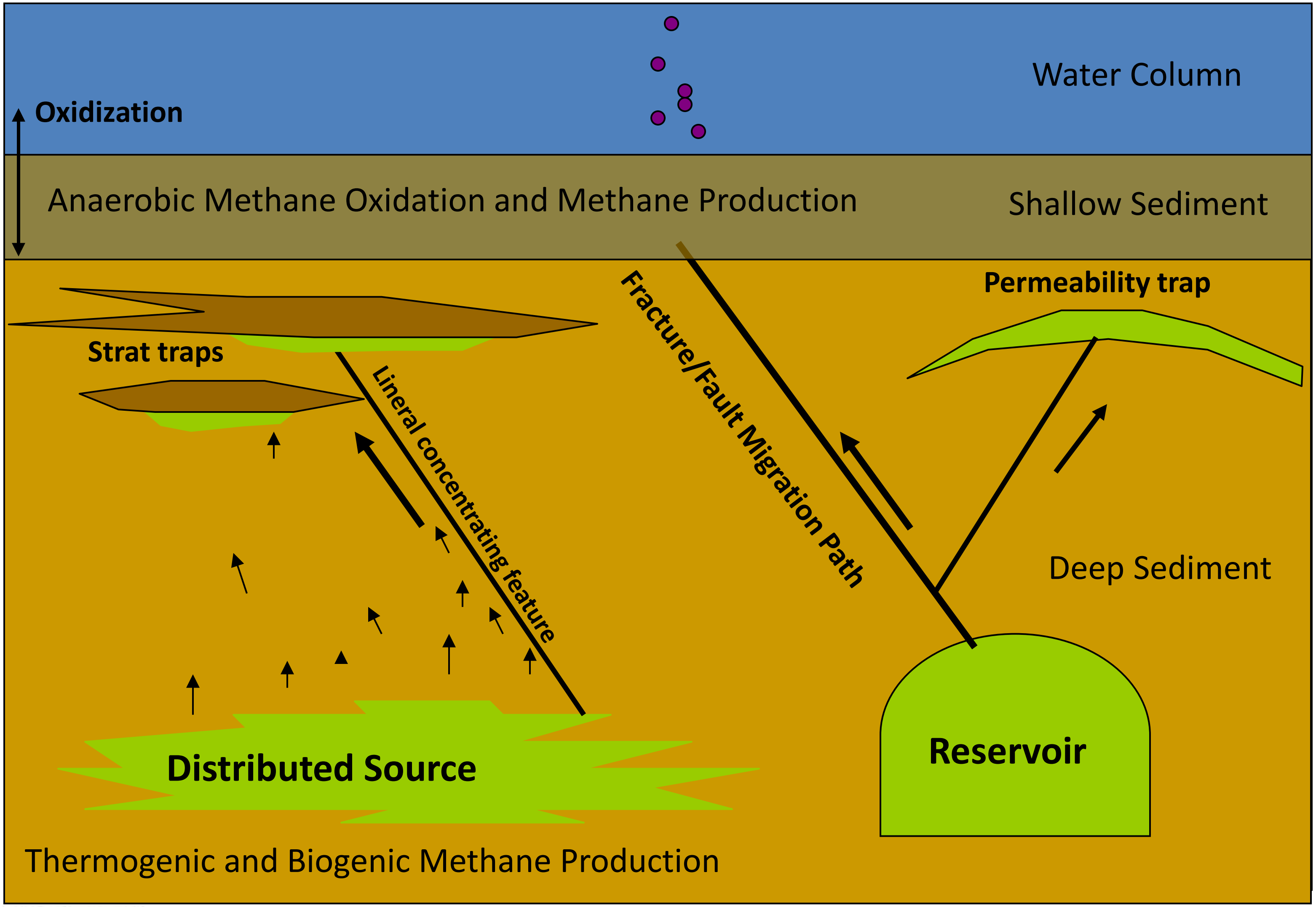
Key Points

Requirements for Formation Include:

- **Reduced CO2 solubility**
- **Reaction site for nucleation**
- **Stable CO2 concentration**

pH stability is 3-4

Vertical Gas Advection or Diffusion



Conclusions

- Land based CO_2 injection to geologic structures can be long term sequestration.
- Land based CO_2 injection needs to be considered for horizontal fracturing.
- Land based CO_2 injection can provide efficient fuel recovery in production declined wells.
- Ocean CO_2 injection can be used to recover gas hydrate methane and contribute to coastal stability.
- Ocean CO_2 sequestration needs to be monitored for environmental impact.