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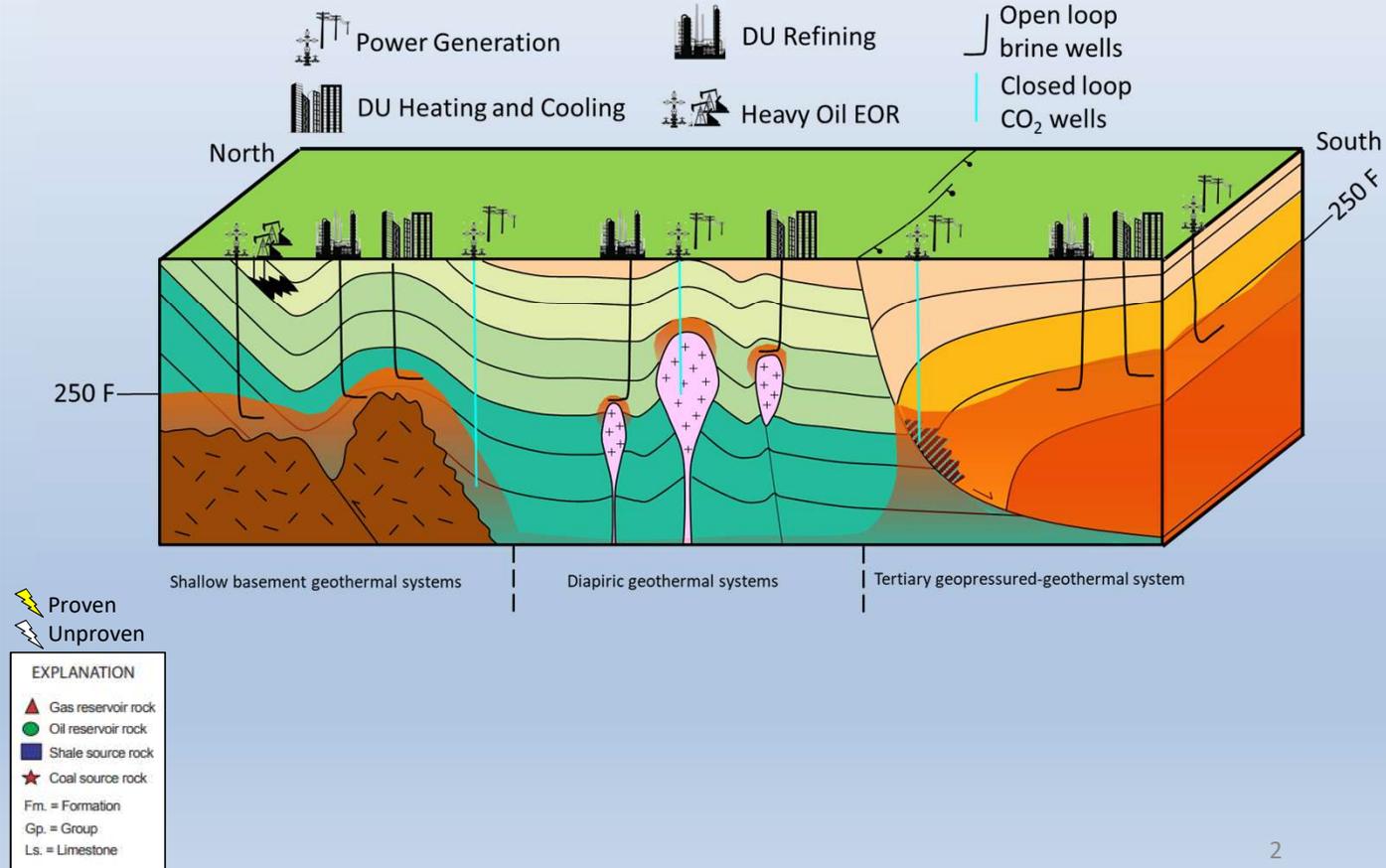
Eric Stautberg, PhD Candidate, 2024

**IDENTIFICATION AND CHARACTERIZATION OF SEDIMENTARY
GEOHERMAL PLAY TYPES IN SOUTH TEXAS FOR ELECTRICAL
POWER GENERATION**

Potential Texas Gulf Coast Sedimentary Geothermal Play Types and Applications

Texas Gulf Coast Strata								
PERIOD	EPOCH	AGE	GROUP OR FORMATION	GAS	OIL	SOURCE ROCK Shale Coal	Geothermal	
QUAT.	HOLO.	Calabrian	Undifferentiated	▲	●			
	P.L.							
TERTIARY	NEOGENE	Piacenzian	Undifferentiated	▲	●			
		Zanclean	Undifferentiated	▲	●			
	MIOCENE	Messinian	Fleming Fm.	▲	●			
		Tortonian						
		Serravallian						
	PALEOGENE	Chattian	Catahoula Fm. Frio Fm.	▲	●		⚡	
		Rupelian	Vicksburg ¹	▲	●	■	★	
	PALEOGENE	E.O.	Priabonian	Jackson ¹	▲	●	■	★
			Bartonian	Claiborne Gp. <small>(Gardali Sand, Cape Fear Fm., Wilcox Sand)</small>	▲	●	■	★
		YPR.	Ypresian	Wilcox ¹	▲	●	■	★
Thanetian			Midway Gp.	▲	●	■	★	
CRETACEOUS		UPPER	Maastrichtian	Navarro ¹ <small>(Olmos Fm.-Escondido Fm.)</small>	▲	●	■	★
			Campanian	Taylor Gp. <small>(Anascho Ls., San Miguel Fm., Ozan Fm./Annona Chalk)</small>	▲	●	■	
		LOWER	Santonian	Austin Gp./Tokio Fm./Eutaw Fm.	▲	●		
			Turonian	Eagle Ford ² Woodbine ² /Tuscaloosa ¹	▲	●	■	
	Cenomanian		Washita Gp. <small>(Buda Limestone)</small>	▲	●			
	Albian		Fredericksburg Gp. <small>(Edwards Ls., Paluxy³, Glen Rose⁴, Rodessa Fm.)</small>	▲	●	■	⚡	
JURASSIC	UPPER	Aptian	Pearsall Fm. - James Ls. Sligo Fm.	▲	●	■		
		Barremian	Hosston Fm. <small>(Travis Peak Fm.)</small>	▲	●	■	★	
	MID.	Berriasian	Cotton Valley ¹	▲	●	■	⚡	
		Tithonian	Bossier Fm. <small>Haynesville Fm., Gilmer Ls.</small>	▲	●	■		
		Kimmeridgian	Smackover Fm. Norphlet Fm.	▲	●	■		
TRI.	UP.	Oxfordian	Louann Salt Werner Fm.				⚡	
		Callovian	Eagle Mills Fm.			■		

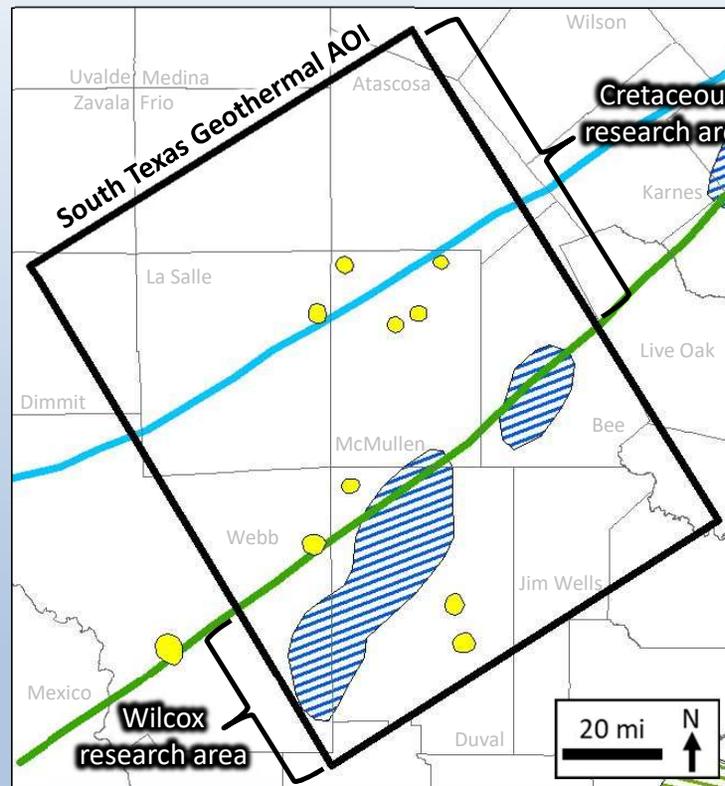
Modified From Swanson et al., 2013



South Texas Sedimentary Geothermal Research Area

PERIOD		EPOCH		AGE		GROUP OR FORMATION	GAS	OIL	SOURCE ROCK		Geothermal
PERIOD	EPOCH	AGE	AGE	GROUP OR FORMATION	GAS	OIL	Shale	Coal			
QUAT.	HOL.	CAL.	B.	Undifferentiated	▲	●					
				Undifferentiated	▲	●					
TERTIARY	NEOGENE	PLIOCENE	Z.	Undifferentiated	▲	●					
				Undifferentiated	▲	●					
	MIOCENE	SERRAVALLIAN	F.	Fleming Fm.	▲	●					
				Messinian	▲	●					
	PALEOGENE	OLIGOCENE	C.	Catahoula Fm. Frio Fm.	▲	●				⚡	
				Chatian	▲	●					
	PAL.	E.	M.	Rupelian	▲	●	■	★		⚡	
				Priabonian	▲	●	■	★		⚡	
	M.	L.	U.	Bartonian	▲	●	■	★			
				Lutetian	▲	●	■	★			
M.	L.	U.	Ypresian	▲	●	■	★				
			Therapsid	▲	●	■	★				
CRETACEOUS	UPPER	U.	M.	Midway Gp.	▲	●	■	★		⚡	
				Navarro ¹	▲	●		★			
	M.	U.	M.	Maastrichtian	▲	●		★			
				Campanian	▲	●	■				
	M.	L.	U.	Santonian	▲	●					
				Coniacian	▲	●					
	M.	L.	U.	Turonian	▲	●	■				
				Cenomanian	▲	●	■				
	M.	L.	U.	Albian	▲	●	■			⚡	
				Albian	▲	●	■				
M.	L.	U.	Aptian	▲	●	■					
			Aptian	▲	●	■					
M.	L.	U.	Barremian	▲	●	■	★		⚡		
			Hauterivian	▲	●	■					
M.	L.	U.	Valanginian	▲	●	■					
			Bermsian	▲	●	■					
JURASSIC	UPPER	U.	M.	Tithonian	▲	●	■			⚡	
				Kimmeridgian	▲	●	■				
M.	L.	U.	M.	Oxfordian	▲	●	■				
				Callovian	▲	●	■				
M.	L.	U.	M.	Bathonian	▲	●	■			⚡	
				Hettangian	▲	●	■				
TRI.	UP.	M.	L.	Rhaetian	▲	●	■				
				Norian	▲	●	■				
M.	L.	U.	M.	Carinian	▲	●	■				
				Eagle Mills Fm.	▲	●	■				

Modified From Swanson et al., 2013

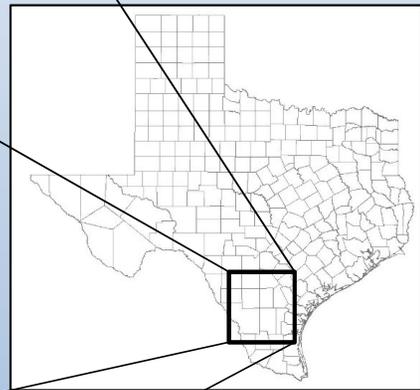


⚡ Proven
⚡ Unproven

EXPLANATION

- ▲ Gas reservoir rock
- Oil reservoir rock
- Shale source rock
- ★ Coal source rock
- Fm. = Formation
- Gp. = Group
- Ls. = Limestone

- ▨ Wilcox Geopressured-Geothermal Fairways
- ▨ Salt Diapirs
- Albian Shelf Margin
- Aptian Shelf Margin

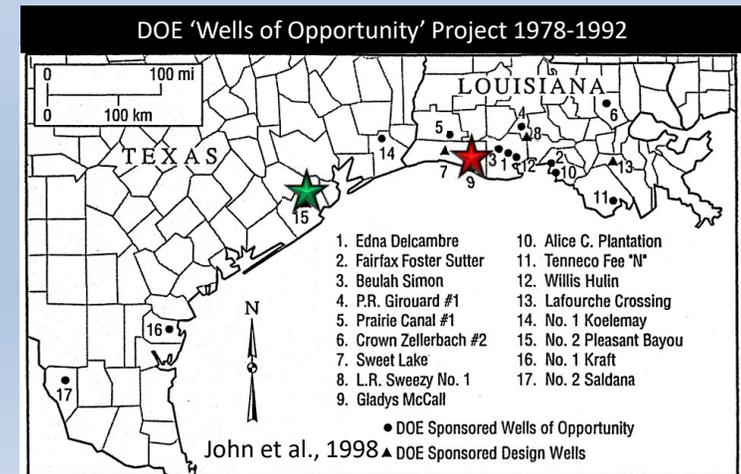
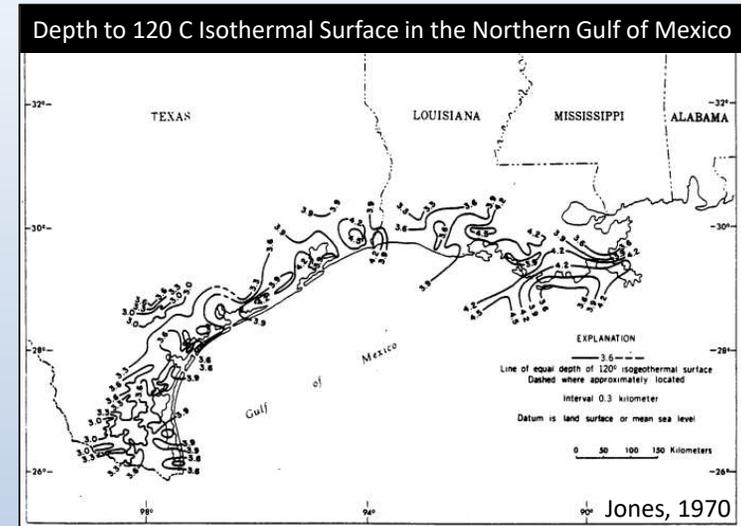


Map elements from Bebout et al., 1982; Condon and Dyman, 2006; and Ewing, 1991.

Tertiary Geopressured-Geothermal Systems

- First considered for geothermal energy in 1970 (Jones, 1970)
- Initial fairway mapping and geopressured reservoir identification 1975-1979 (Wilcox, Frio, and Vicksburg formations)
- DOE funded 'Wells of Opportunity' exploration project began in 1978
 - Three new wells drilled (1 in Texas, 2 in Louisiana)
 - Evaluated 14 existing deep oil/gas wells
- Two wells achieved flowback of ~20,000 barrels of water per day
 - Pleasant Bayou #2 – Brazoria County, Texas
 - Gladys McCall #1 – Cameron Parish, Louisiana
- Hybrid binary cycle power plant at the Pleasant Bayou location produced 1 MW of electricity
- Continued evaluation through 1980s and early 1990s investigating Frio and Vicksburg formations
- Concluded that “commercial production of geopressured-geothermal aquifers is feasible under reasonable assumptions of gas and electricity price. However, the near-term likelihood of large-scale developments of geopressured aquifers is low” (John et al., 1998)

Has the energy environment changed enough since the mid-1990s to warrant developing these resources?



Tertiary Geopressured-Geothermal Systems

PERIOD	EPOCH	AGE	GROUP OR FORMATION	GAS	OIL	SOURCE ROCK		Geothermal
						Shale	Coal	
QUAT.	HOLO.	Calabrian	Undifferentiated	▲	●			
	PLEI.							
TERTIARY	NEOGENE	Piacenzian	Undifferentiated	▲	●			
		Zanclean						
	Messinian	Fleming Fm.	▲	●				
	Tortonian							
	Serravallian							
PALEOGENE	OLIGOCENE	Chatthian	Catahoula Fm. Frio Fm.	▲	●			⚡
		Rupelian	Vicksburg ¹	▲	●	■	★	
PALEOGENE	Eocene	Priabonian	Jackson ¹	▲	●	■	★	
		Bartonian	Claiborne Gp.	▲	●	■	★	
		Lutetian	Wilcox ¹	▲	●	■	★	
		Ypresian		▲	●	■	★	
		Thanetian	Midway Gp.	▲	●	■	★	

Modified From Swanson et al., 2013

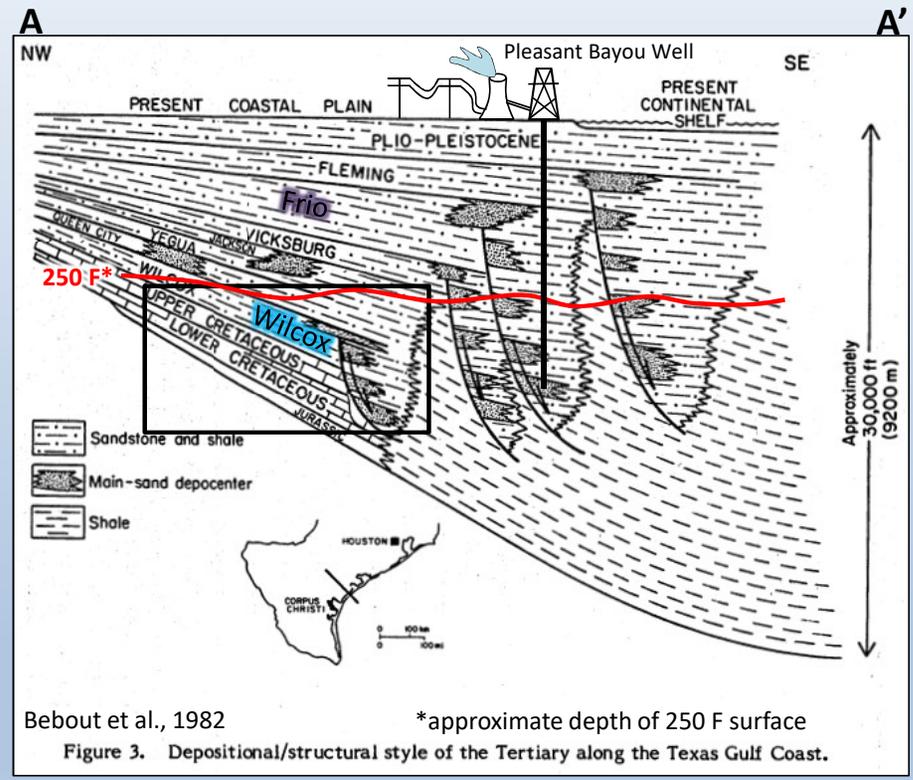
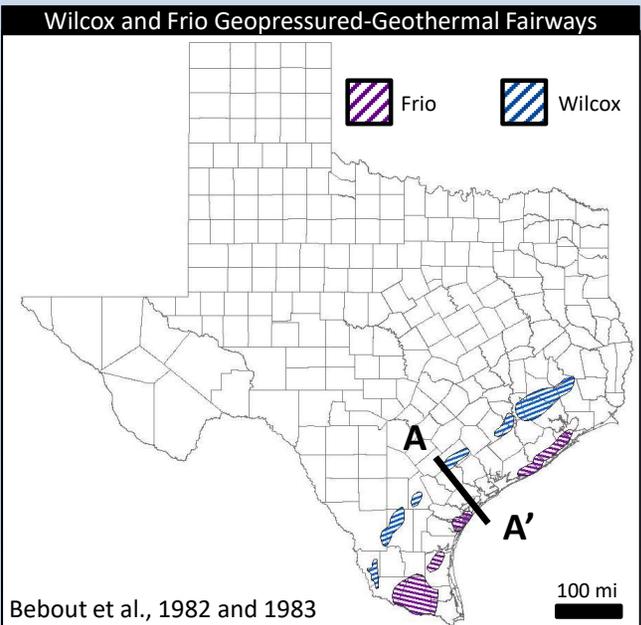
EXPLANATION

- ▲ Gas reservoir rock
- Oil reservoir rock
- Shale source rock
- ★ Coal source rock

Fm. = Formation
Gp. = Group
Ls. = Limestone

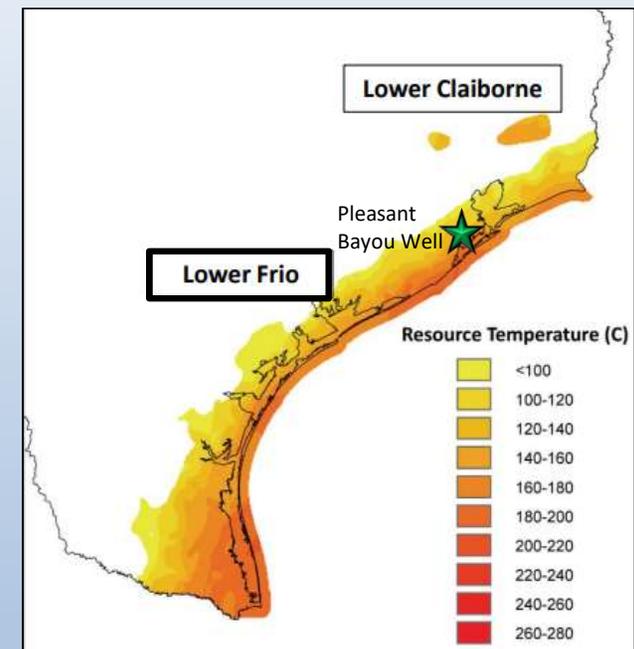
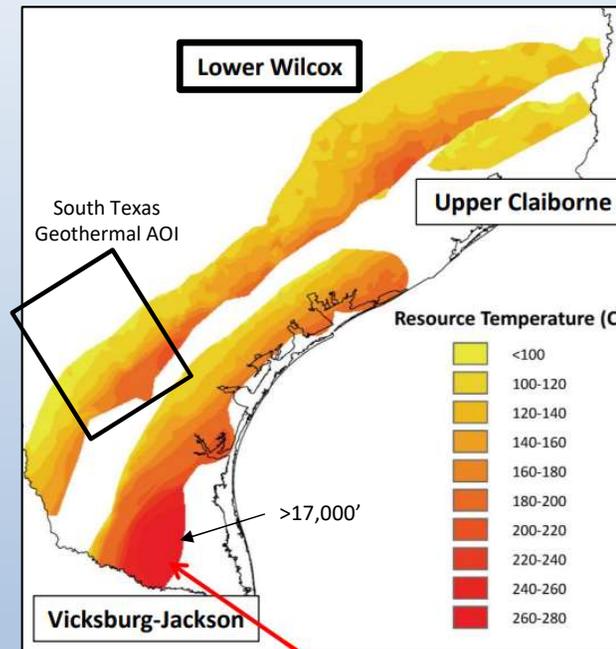
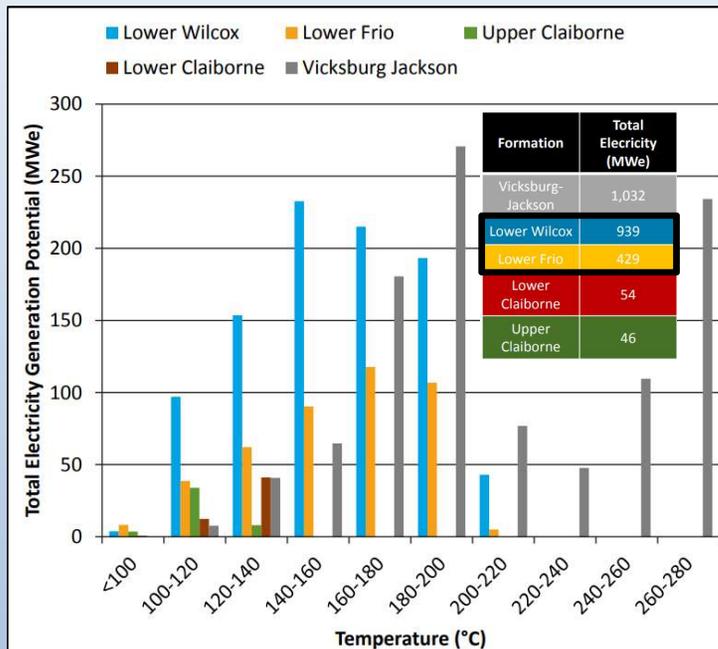
□ Formations with geopressured zones

⚡ Proven
⚡ Unproven



Producing depth (TVD)	Porosity and Perm.	Pressure (psi)	Temp. (F)	Salinity (ppm)
-16,465 ft	19% 200 mD	9,800	302	127,000

Resource Estimate for Texas Geothermal-Geopressured Sands (Esposito and Augustine, 2011)



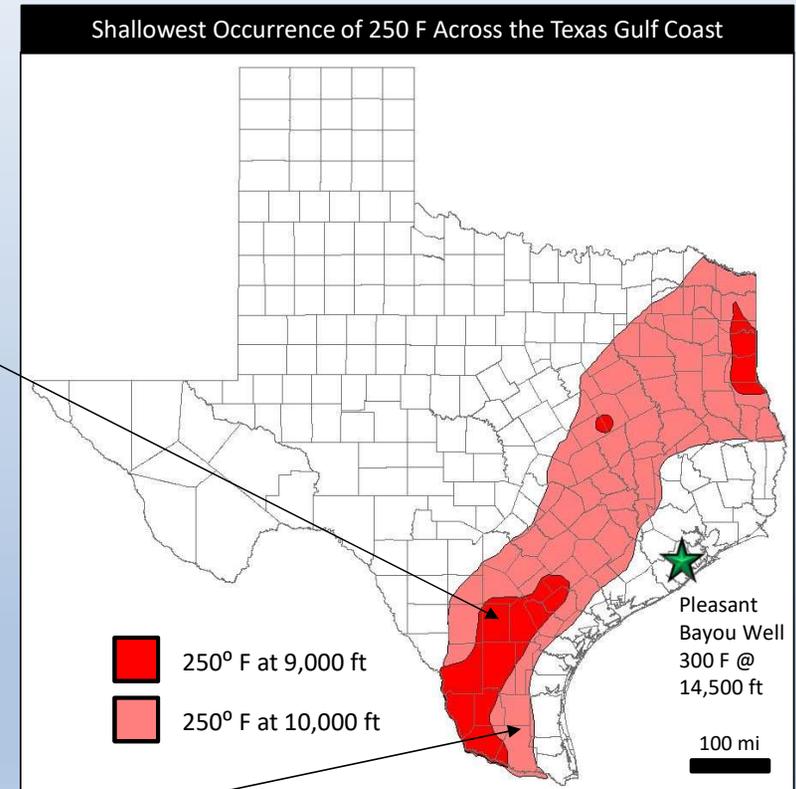
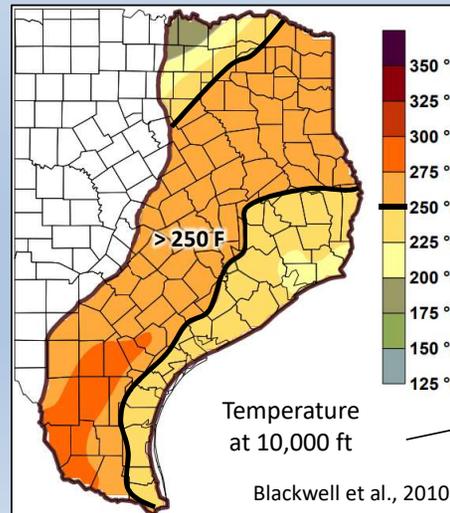
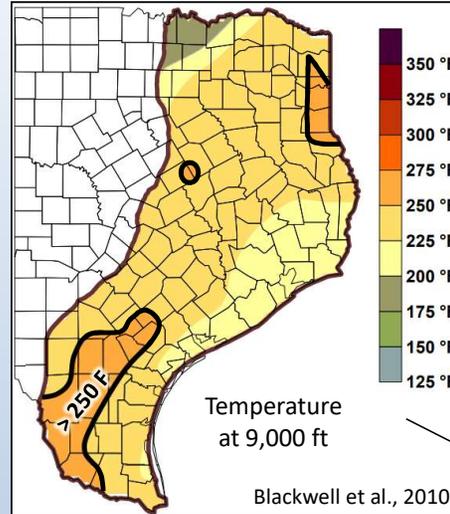
Maximum temperature of **273 C or 523 F** occurs in southern Vicksburg Jackson formations

- 2.5 GW estimated recoverable electricity potential for Texas geothermal-geopressured Tertiary sand systems
- Equivalent to 7.8 million utility scale photovoltaic panels or about 1,000 utility scale wind turbines (Department of Energy, 2019)

Temperature at Depth Mapping (SMU Geothermal Lab)

- Maps made from 9,500+ wells with corrected BHT measurements using the SMU-Harrison temperature correction equation
- Temperature depth maps made every 1,000 ft between 8,000 ft and 14,000 ft
- 250° F is approximately the minimum temperature suitable for electrical power generation

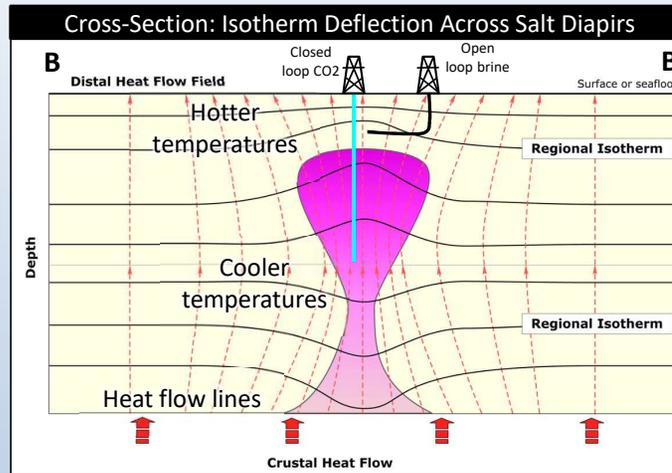
Key question: What formations are at these depths across Texas?



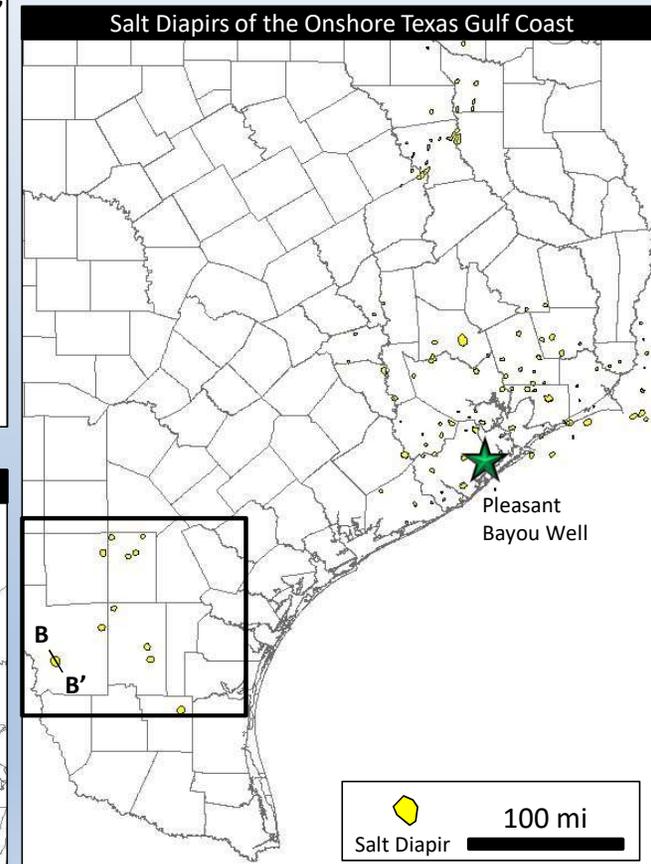
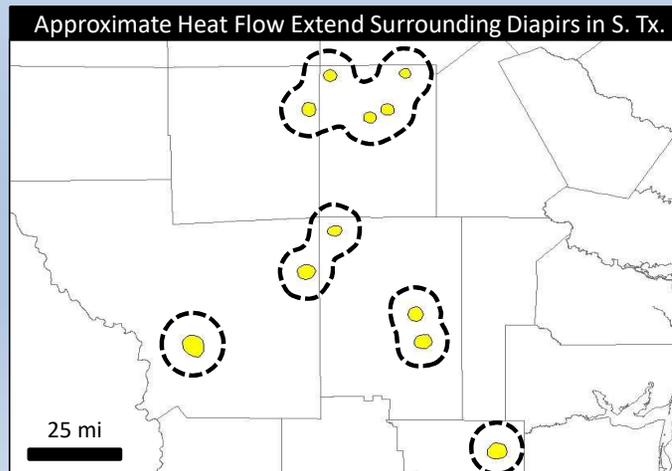
Geothermal Energy Potential of Salt Diapirs

- Salt diapirs were first discussed as a source of geothermal energy in 1975
- High thermal conductivity of salt diapirs sets up two possible geothermal plays types
 1. Utilizing the salt diapir itself with closed loop well design
 2. Reservoirs above the salt diapir with elevated temperatures
- Anomalous temperature field extends a lateral distance of about 3 diapir radii from the center (Jensen, 1989)
- Internal diapir temperatures can range from 330 F at 10,000 ft to 580 F at 20,000 ft (Jacoby and Paul, 1975)
- Targeting hot reservoirs above diapirs could reduce drilling costs by ~30% when targeting similar temperatures at deeper depths (Jensen, 1989)

How do we characterize and test the energy potential in these diapirs?



Courtesy of C. Rivera from Mark Rowan, personal communication

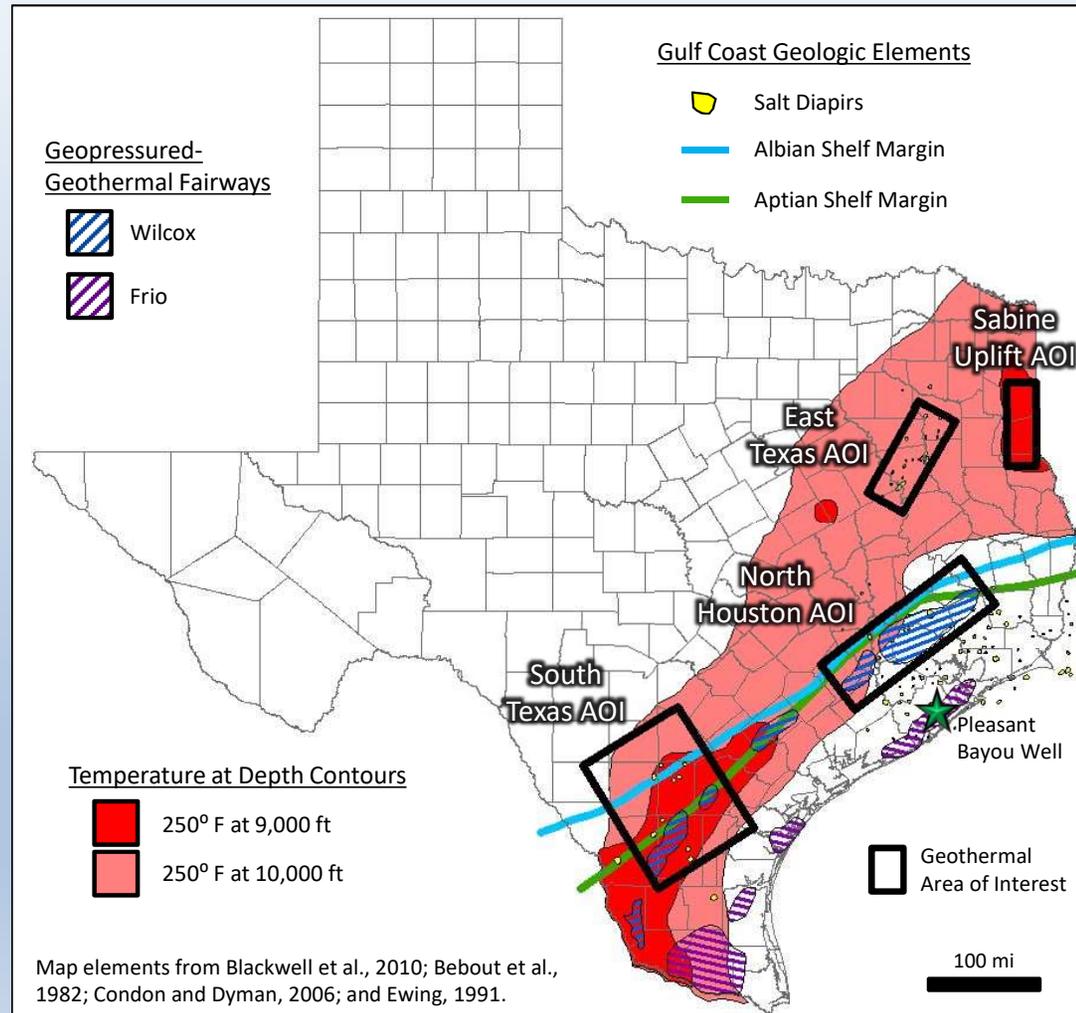


Diapir locations from Condon and Dyman, 2006

Texas Gulf Coast Sedimentary Geothermal Areas of Interest

- Four areas identified for potential sedimentary geothermal research project
- South Texas contains the most elements for a research project
- North Houston has a large Wilcox fairway directly under a major metropolitan area
- East Texas has highest concentration of salt domes
- Sabine Uplift has heat anomalies in Jurassic formations which are likely too deep to study in South Texas

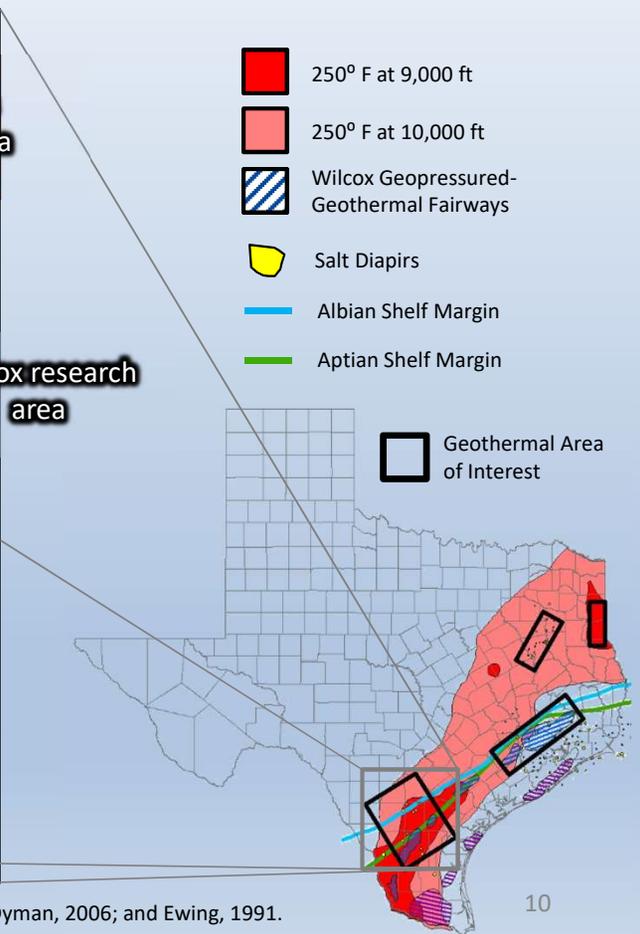
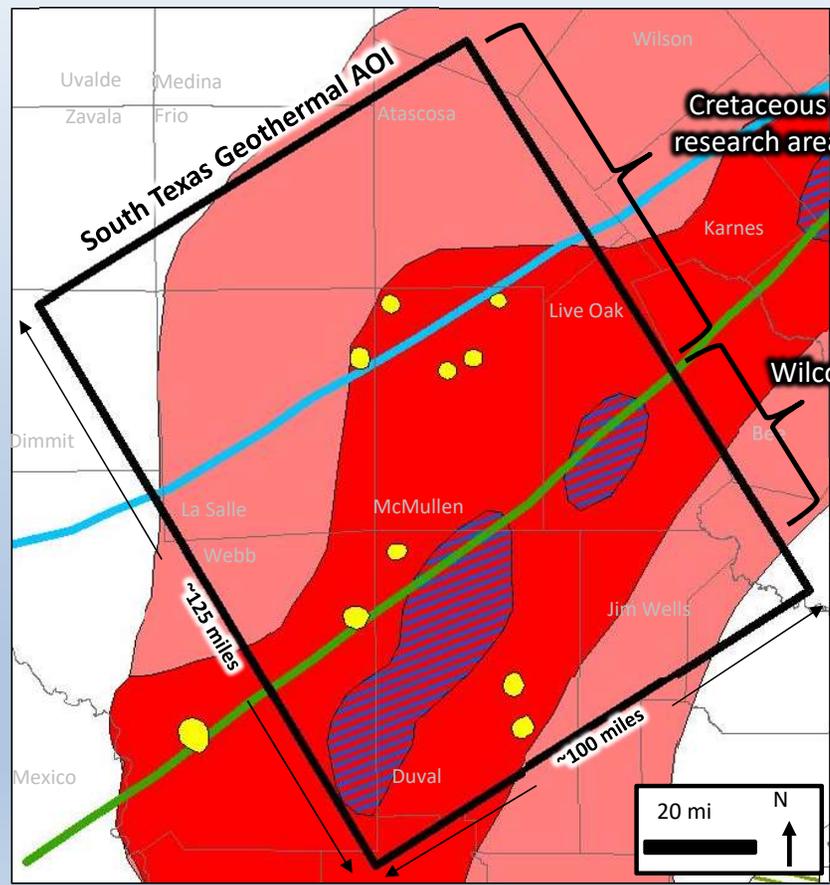
Key Project Characteristics	South Texas	North Houston	East Texas	Sabine Uplift
250 F @ 9,000'	✓	✗	✗	✓
Geopressure	✓	✓	✗	✗
K/Jr Formations	✓	✗	✓	✓
Salt Diapirs	✓	✓	✓	✗



South Texas Geothermal Research Area

Texas Gulf Coast Strata				
PERIOD	AGE	GROUP OR FORMATION	Geothermal	
QUAT.	Calabrian	Undifferentiated		
	Piacenzian	Undifferentiated		
TERTIARY	Messinian	Fleming Fm.		
	Tortonian			
	Serravallian			
	Langhian	Chattian	⚡	
	Burdigalian			
	Agulthian			
	PALEOGENE	Rupelian	Vicksburg'	
		Priabonian	Jackson'	⚡
		Bartonian	Claiborne Gp.	
		Lutetian		
Ypresian		Wilcox'		
Thanetian		Midway Gp.	⚡	
Selandian				
CRETACEOUS		Maastrichtian	Navarro'	
		UPPER	(Olmos Fm-/Escondido Fm.)	
			Campanian	Taylor Gp. (Anascho Ls./ San Miguel Fm./ Ozan Fm./Anhona Chalk)
	Santonian		Austin Gp./Tokio Fm./ Eutaw Fm.	
	LOWER	Turonian	Eagle Ford'	
		Cenomanian	Woodbine'/Tuscaloosa' Washita Gp. (Buda Limestone)	
		Albian	Fredericksburg Gp. (Edwards Ls. Paluxy') Glen Rose' (Rodessa Fm.)	⚡
		Aptian	Pearsall Fm. - James Ls. Sligo Fm.	
		Barremian	Hosston Fm. (Travis Peak Fm.)	⚡
	JURASSIC	Hauterivian	Valanginian	
Berriasian		Cotton Valley'	⚡	
Tithonian		Bossier Fm.		
UP. L. MID. UPPER		Haynesville Fm./ Glimmer Ls. Smackover Fm. Norphlet Fm.		
TRIA.	Oxfordian	Louann Salt		
	Callovian	Werner Fm.	⚡	
	Bathonian	Eagle Mills Fm.		
UP. L. MID. LOWER	Rhaetian			
	Norian			
	Carnian			

⚡ Proven
⚡ Unproven



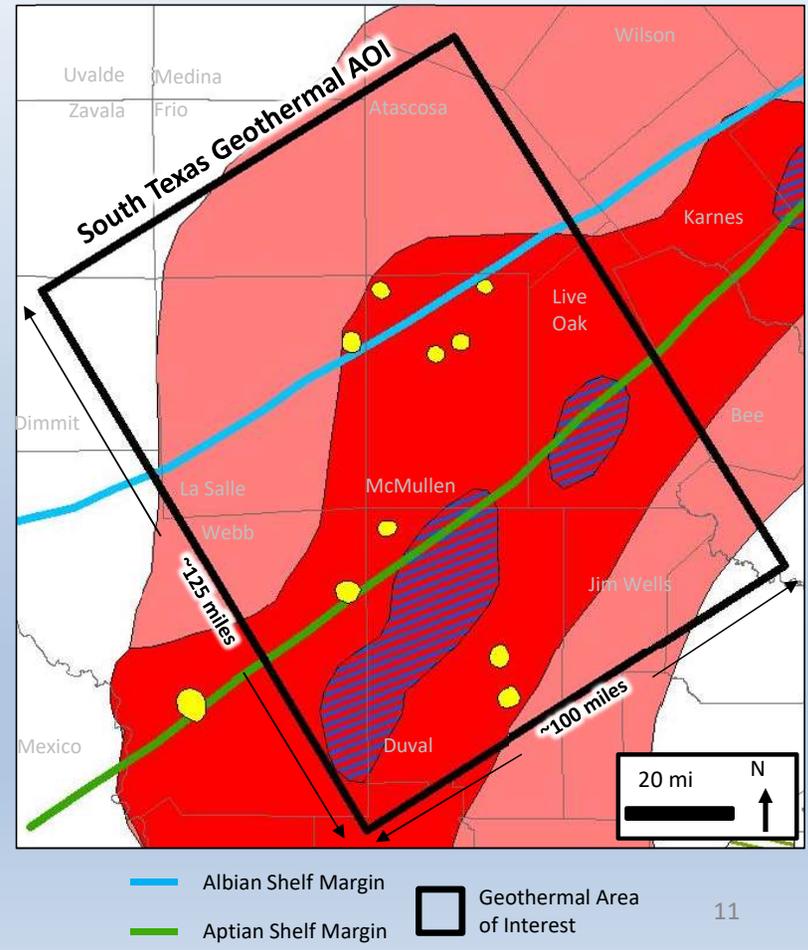
Map elements from Blackwell et al., 2010; Bebout et al., 1982; Condon and Dyman, 2006; and Ewing, 1991.

Modified From Swanson et al., 2013

Data and Deliverables



	Data Requirements	Well log data	Seismic data	Core data	Corrected BHTs	Produced fluid	Water chemistry	Cost estimates for DCE
Project Deliverables	Petrophysical analysis of type well in each play type	Green	Light Blue	Green	Light Blue	Light Blue	Light Blue	Light Blue
	Geothermal play fairway map	Green	Green	Green	Green	Light Blue	Light Blue	Light Blue
	Reservoir characterization of each play type	Green	Green	Green	Green	Green	Green	Light Blue
	Flow rate and power generation estimate	Green	Light Blue	Green	Green	Green	Light Blue	Light Blue
	Subsurface risk assessment	Green	Green	Light Blue	Green	Green	Green	Light Blue
	Economic analysis and technology recommendation	Green	Light Blue	Light Blue	Green	Green	Green	Green



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