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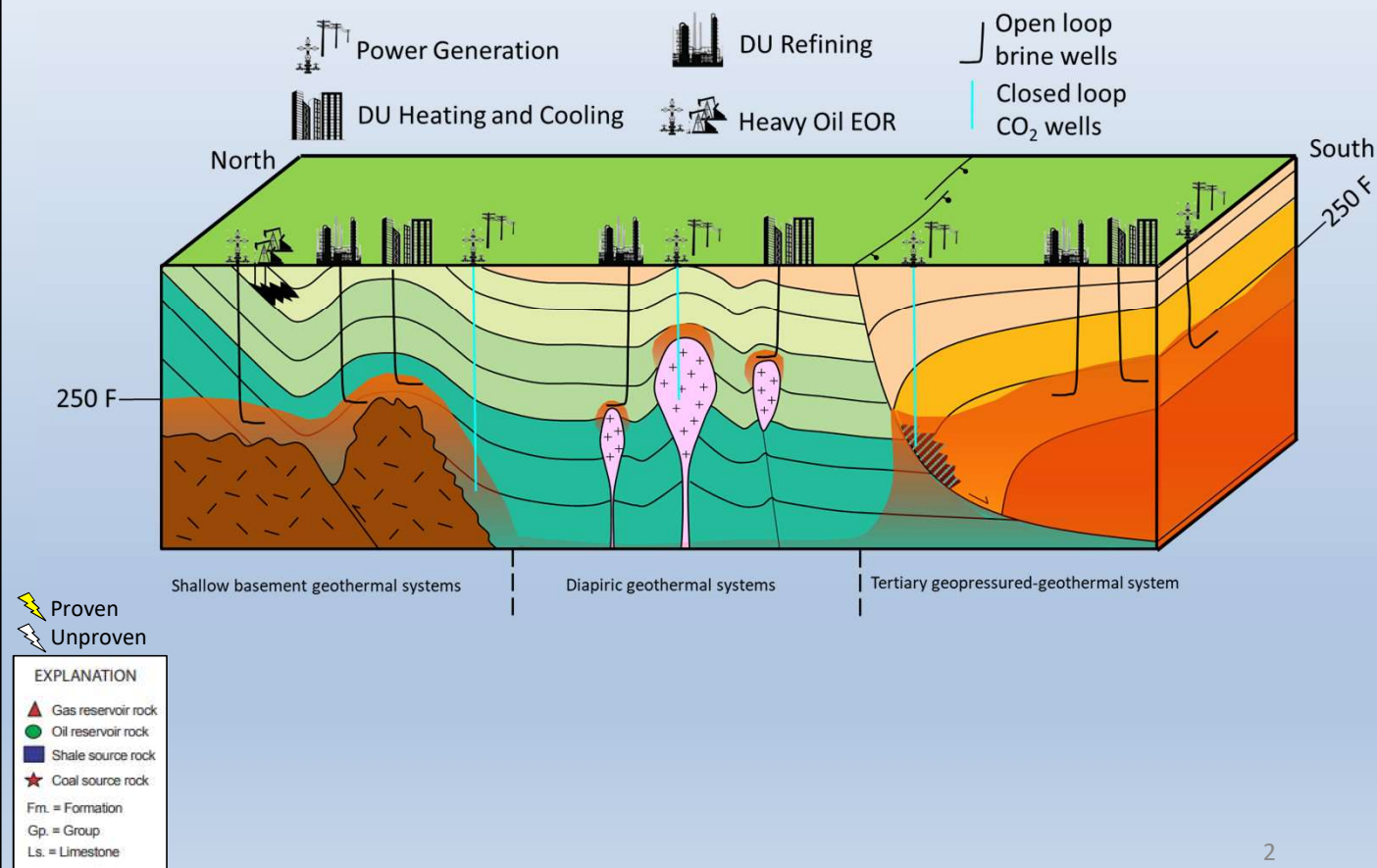
Eric Stautberg, PhD Candidate, 2024

IDENTIFICATION AND CHARACTERIZATION OF SEDIMENTARY GEOTHERMAL 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
QUAT.	HOLO.	—	—	—	—	—
	P.L.E.	Calabrian	Undifferentiated	▲	●	
TERTIARY	NEOGENE	Piacenzian	Undifferentiated	▲	●	
		Zanclean	Undifferentiated	▲	●	
	MIOCENE	Messinian	Fleming Fm.	▲	●	
		Tortonian				
		Serravallian				
	OLIGOCENE	Langhian				
		Burdigalian				
	PALEOGENE	Chattian	Catahoula Fm. Frio Fm.	▲	●	
		Rupelian	Vicksburg ¹	▲	●	★
CRETACEOUS	UPPER	Priabonian	Jackson ¹	▲	●	★
		Santonian	Claiborne Gp.	▲	●	★
		Lutetian	Wilcox ¹	▲	●	★
		Ypresian	Midway Gp.	▲	●	★
		Thamesian	Navarro ¹	▲	●	★
	LOWER	Selandian	(Olmec Fm.-Escondido Fm.)	▲	●	★
		Campanian	Taylor Gp. (Anascho Ls./ San Miguel Fm./ Ozan Fm./Anhona Chalk)	▲	●	★
		Santonian	Austin Gp./Tokio Fm./ Eutaw Fm.	▲	●	★
		Turonian	Eagle Ford ²	▲	●	★
		Cenomanian	Woodbine ² /Tuscaloosa ¹ Washita Gp. (Buda Limestone) Fredericksburg Gp. (Edwards Ls. Paluxy ³) Glen Rose ⁴ (Rodessa Fm.)	▲	●	★
JURASSIC	UPPER	Aptian	Pearsall Fm. - James Ls.	▲	●	★
		Barremian	Sligo Fm.	▲	●	★
		Hauterivian	Hosston Fm. (Travis Peak Fm.)	▲	●	★
		Valanginian	Cotton Valley ¹	▲	●	★
		Berriasian	Haynesville Fm. Glimmer Ls.	▲	●	★
	MID.	Tithonian	Smackover Fm. Norphlet Fm.	▲	●	★
		Kimmeridgian	Louann Salt Werner Fm.			
		Oxfordian				
		Callovian				
		Bathonian				
TRI.	UP.	Hettangian				
		Rhaetian	Eagle Mills Fm.			★

Modified From Swanson et al., 2013



South Texas Sedimentary Geothermal Research Area

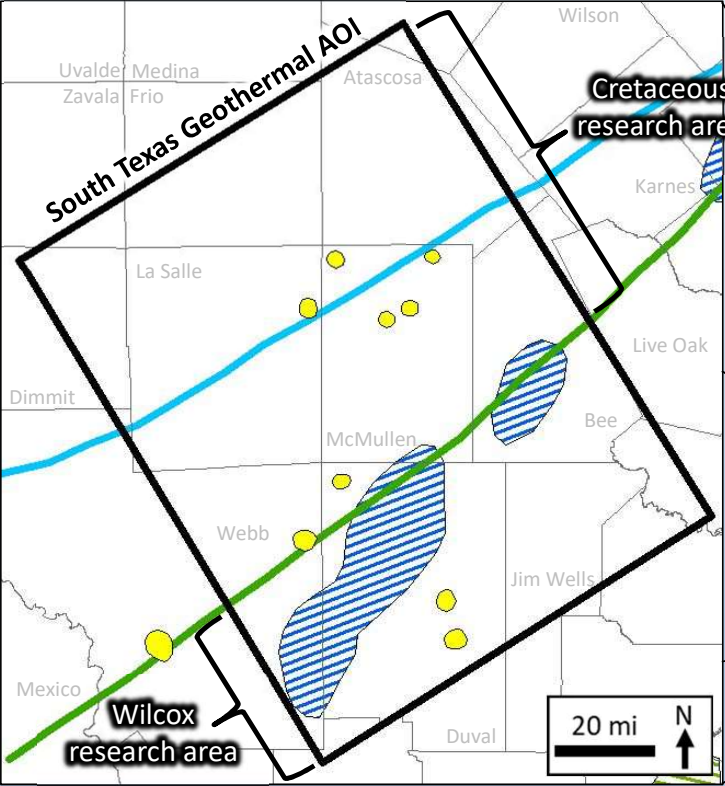
Texas Gulf Coast Strata						
PERIOD	EPOCH	AGE	GROUP OR FORMATION	GAS	OIL	SOURCE ROCK
						Shale Coal
QUAT.	Holo.	Calabrian	Undifferentiated	▲	●	
		Piacenzian	Undifferentiated	▲	●	
	Pleist.	Zanclean	Undifferentiated	▲	●	
		Messinian	Fleming Fm.	▲	●	
		Tortonian		▲	●	
	Pliocene	Serravallian		▲	●	
		Langhian		▲	●	
	Burdigalian	Aquitanian		▲	●	
				▲	●	
				▲	●	
TERTIARY	NEOGENE	Chattian	Catahoula Fm. / Frio Fm.	▲	●	
		Rupelian	Vicksburg ¹	▲	●	
	P. Eocene	Priabonian	Jackson ¹	▲	●	
		Santonian	Claiborne Gp.	▲	●	
	Paleocene	Lutetian	Wilcox ¹	▲	●	
		Ypresian	Midway Gp.	▲	●	
	Palaeocene	Thamesian	Navarro ¹	▲	●	
		Selandian	(Olmec Fm.-Escondido Fm.)	▲	●	
	Paleocene	Maastrichtian	Taylor Gp.	▲	●	
		Campanian	(Anascho Ls. / San Miguel Fm. / Ozan Fm./Annona Chalk)	▲	●	
CRETACEOUS	UPPER	Santonian	Austin Gp./Tokio Fm./Eutaw Fm.	▲	●	
		Turonian	Eagle Ford ²	▲	●	
		Cenomanian	Woodbine ² /Tuscaloosa ¹	▲	●	
			Washita Gp. (Buda Limestone)	▲	●	
			Fredericksburg Gp. (Edwards Ls. / Paluxy ³)	▲	●	
	LOWER	Albian	Glen Rose ⁴ (Rodessa Fm.)	▲	●	
			Pearsall Fm. - James Ls.	▲	●	
		Aptian	Sligo Fm.	▲	●	
		Barremian	Hosston Fm. (Travis Peak Fm.)	▲	●	
		Hauterivian	Cotton Valley ¹	▲	●	
JURASSIC	UPPER	Titthonian	Haynesville Fm. / Glimmer Ls.	▲	●	
		Kimmeridgian	Smackover Fm. / Norphlet Fm.	▲	●	
	MID.	Oxfordian	Louann Salt	▲	●	
		Callovian	Werner Fm.	▲	●	
	L.	Bathonian		▲	●	
		Hettangian		▲	●	
	UP.	Rhaetian	Eagle Mills Fm.	▲	●	
		Norian		▲	●	
	TRIA.	Carian		▲	●	
				▲	●	

Modified From Swanson et al., 2013

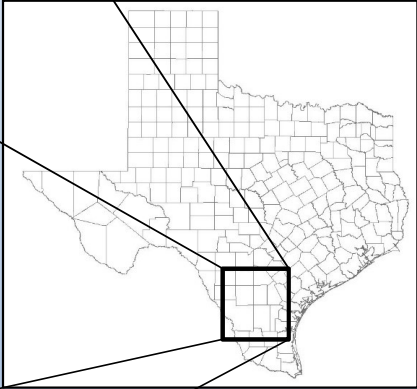
▲ Proven
 ● Unproven

EXPLANATION

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



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

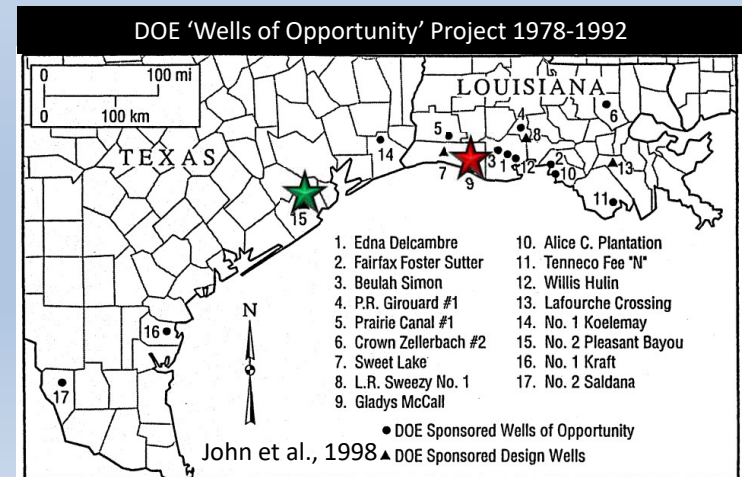
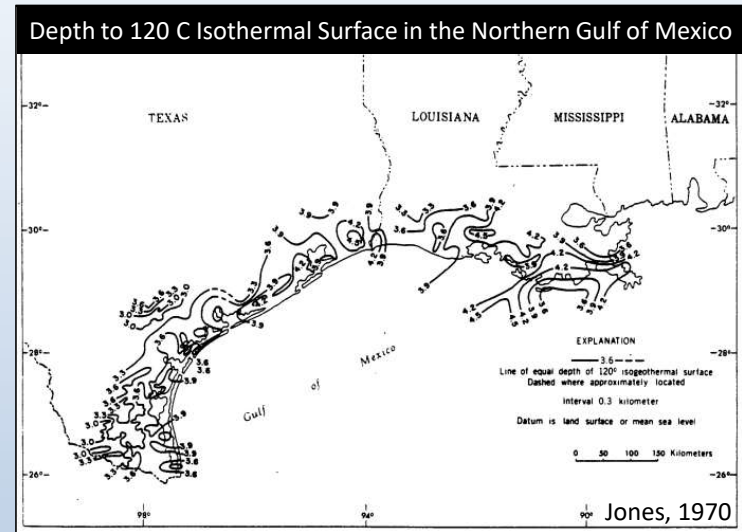


Map elements from Bebout et al., 1982; Condon and Dyman, 2006; and Ewing, 1991.

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

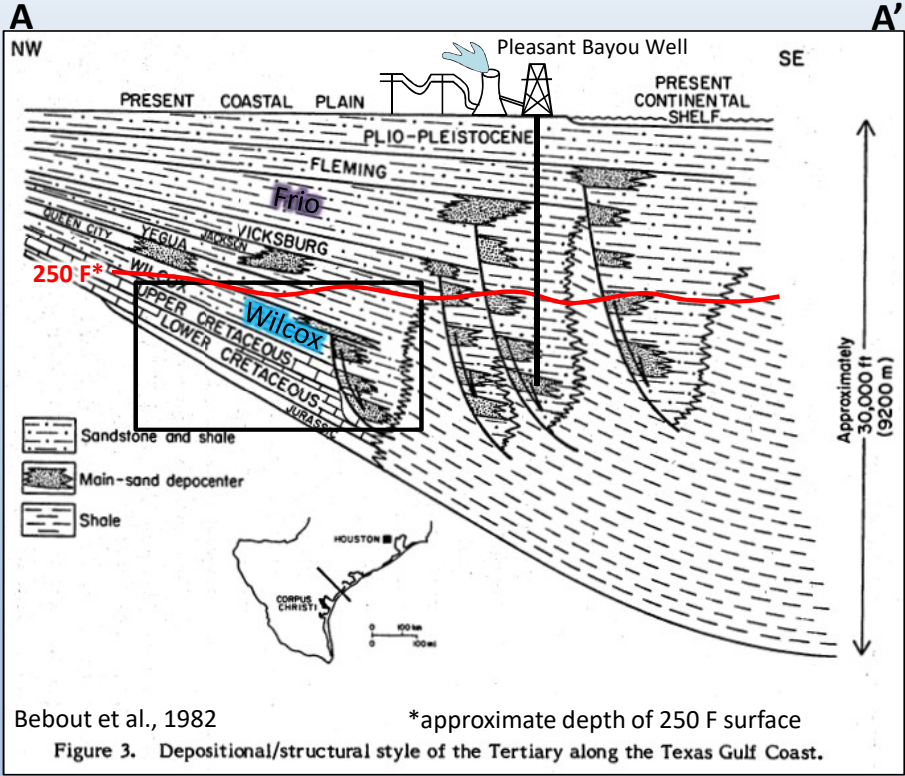
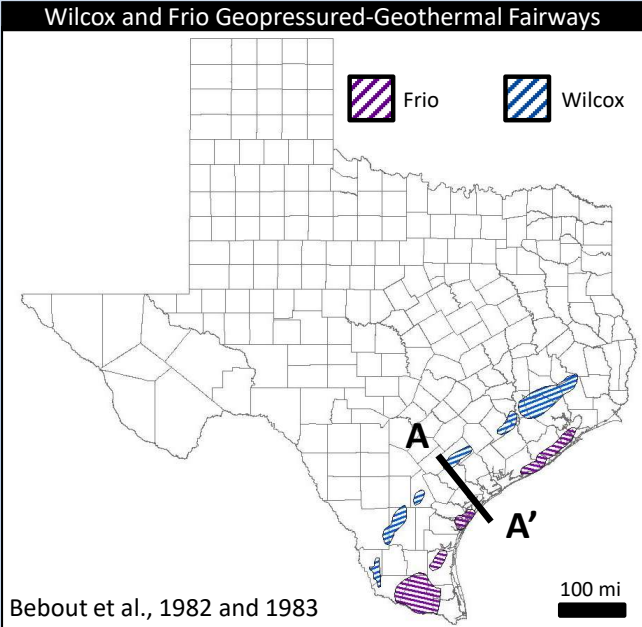
PERIOD	EPOCH	AGE	GROUP OR FORMATION	GAS	OIL	SOURCE ROCK Shale Coal	Geothermal
TERTIARY	QUAT.	HOLO.					
		PLEI.	Calabrian	Undifferentiated	▲	●	
	NEOGENE	Piacenzian	Undifferentiated	▲	●		
		Zanclean	Undifferentiated	▲	●		
		Messinian					
		Tortonian	Fleming Fm.	▲	●		
		Serravalian					
		Langhian					
		Burdigalian					
		Aquitanian					
	PALEOGENE	Chattian	Catahoula Fm. Frio Fm.	▲	●		⚡
		Rupelian	Vicksburg ¹	▲	●	★	
		Priabonian	Jackson ¹	▲	●	★	
		Bartonian	Claiborne Gp.	▲	●	★	
		Lutetian	Wilcox ¹	▲	●	★	
PAL.	Eocene	Ypresian		▲	●	★	
		Thamesian	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		

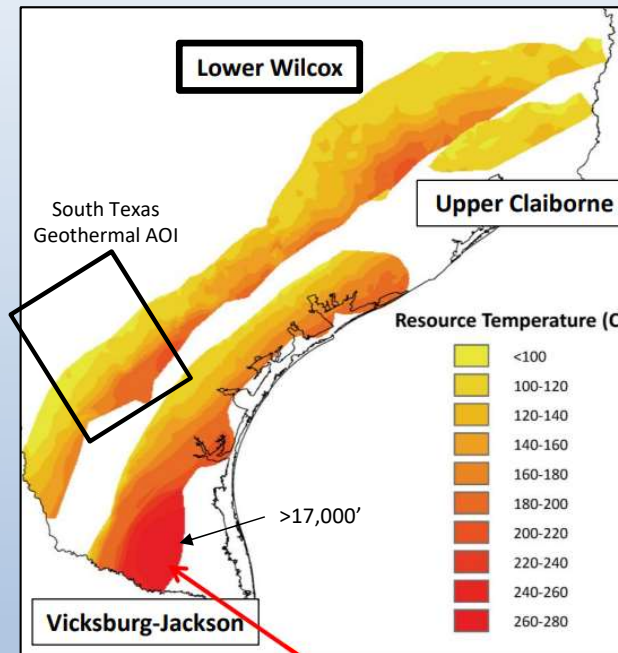
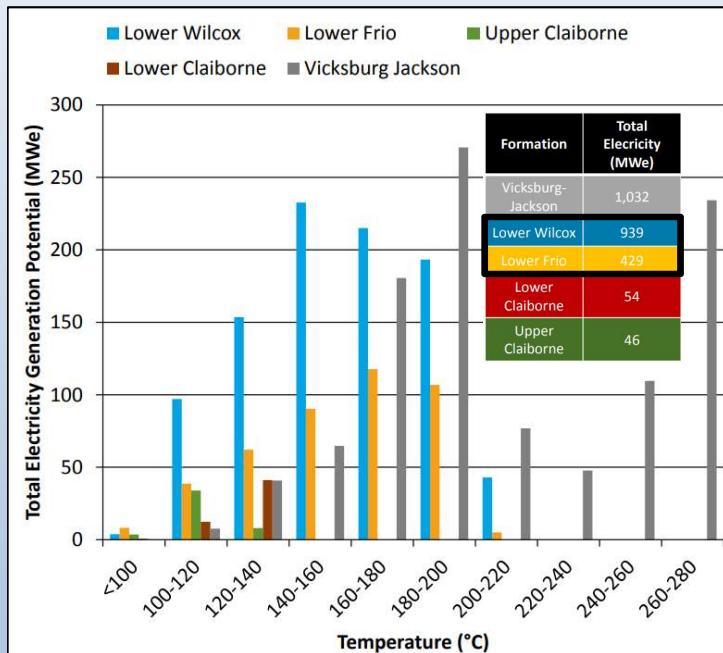
Formations with geopressured zones

⚡ Proven
⚡ Unproven

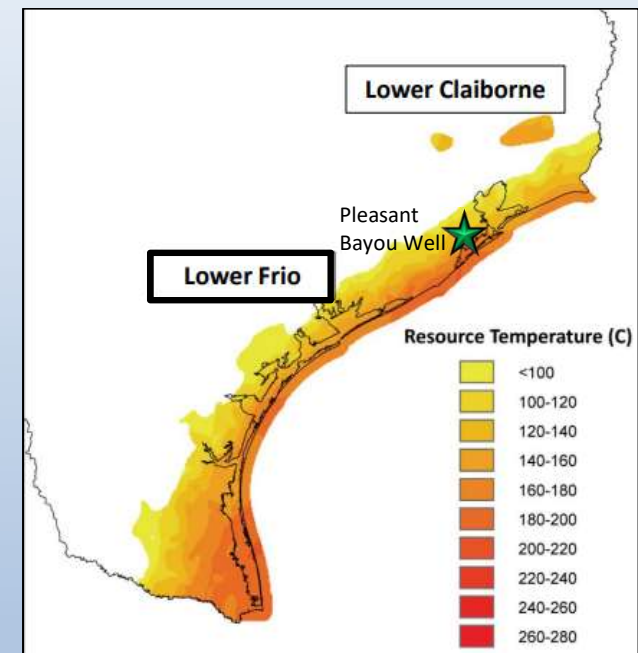


Producing depth (TVD)	Porosity and Perm.	Pressure (psi)	Temp. (F)	Salinity (ppm)
-16,465 ft	19% 200 mD	9,800	302	127,000

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

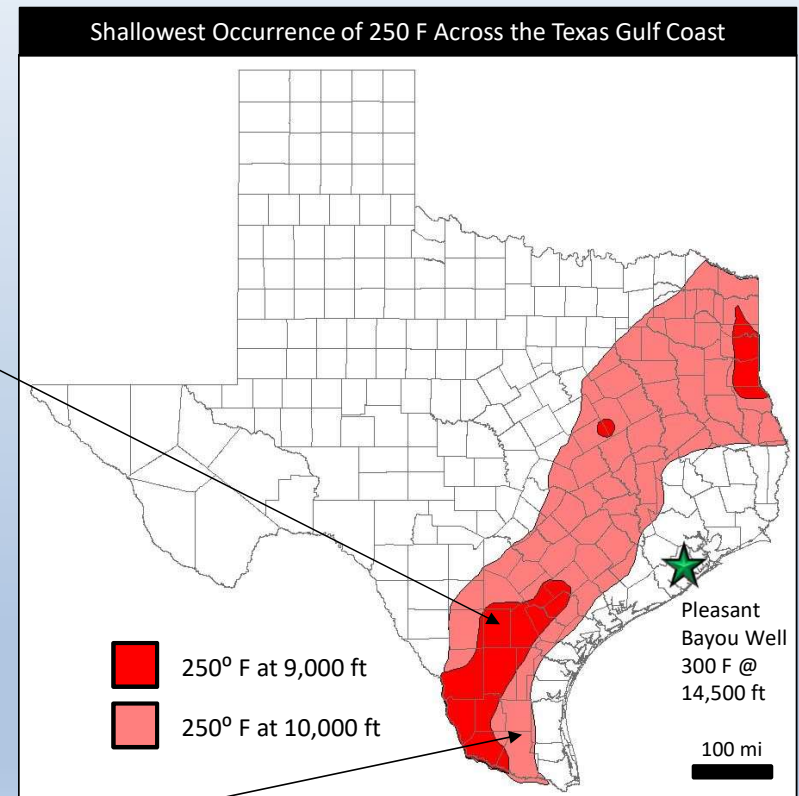
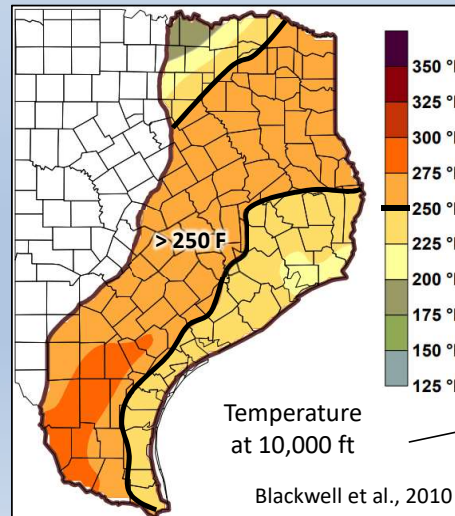
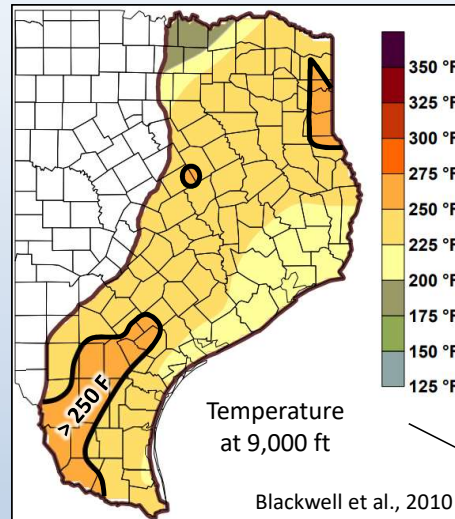


- 2.5 GW estimated recoverable electricity potential for Texas geothermal-geopressured Tertiary sand systems
- Equivalent to 7.8 million utility scale photovoltaic panels or about 1,000 utility scale wind turbines (Department of Energy, 2019)

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

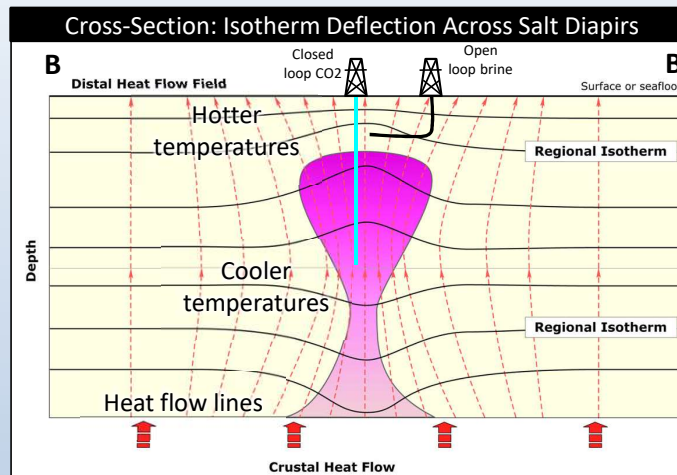
Key question: What formations are at these depths across Texas?



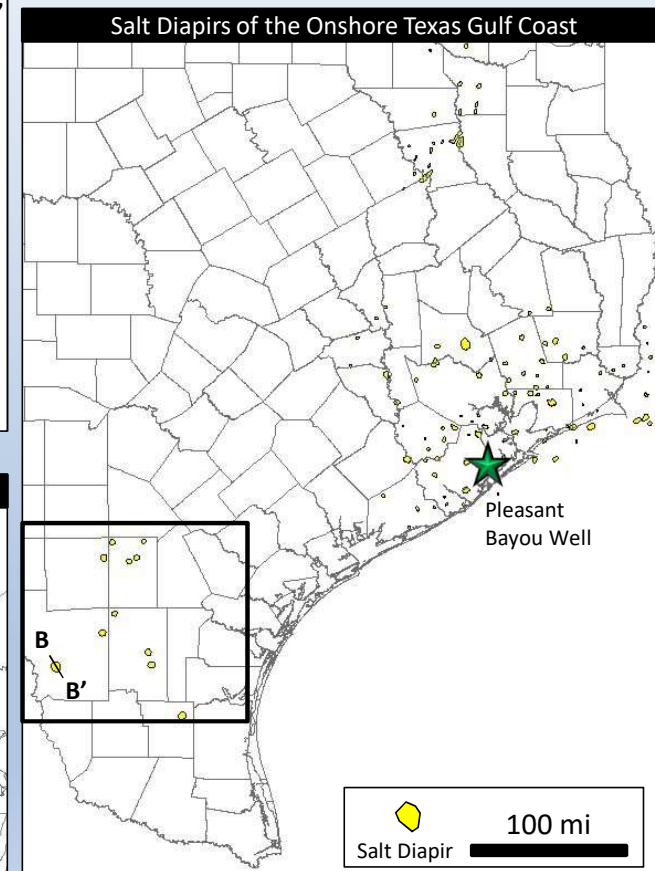
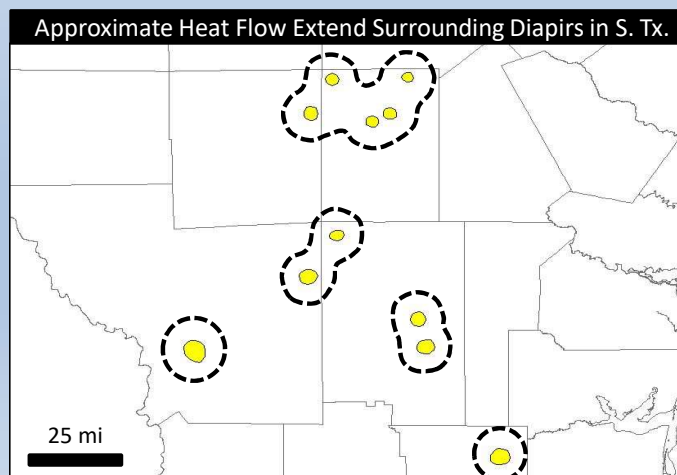
Geothermal Energy Potential of Salt Diapirs

- 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

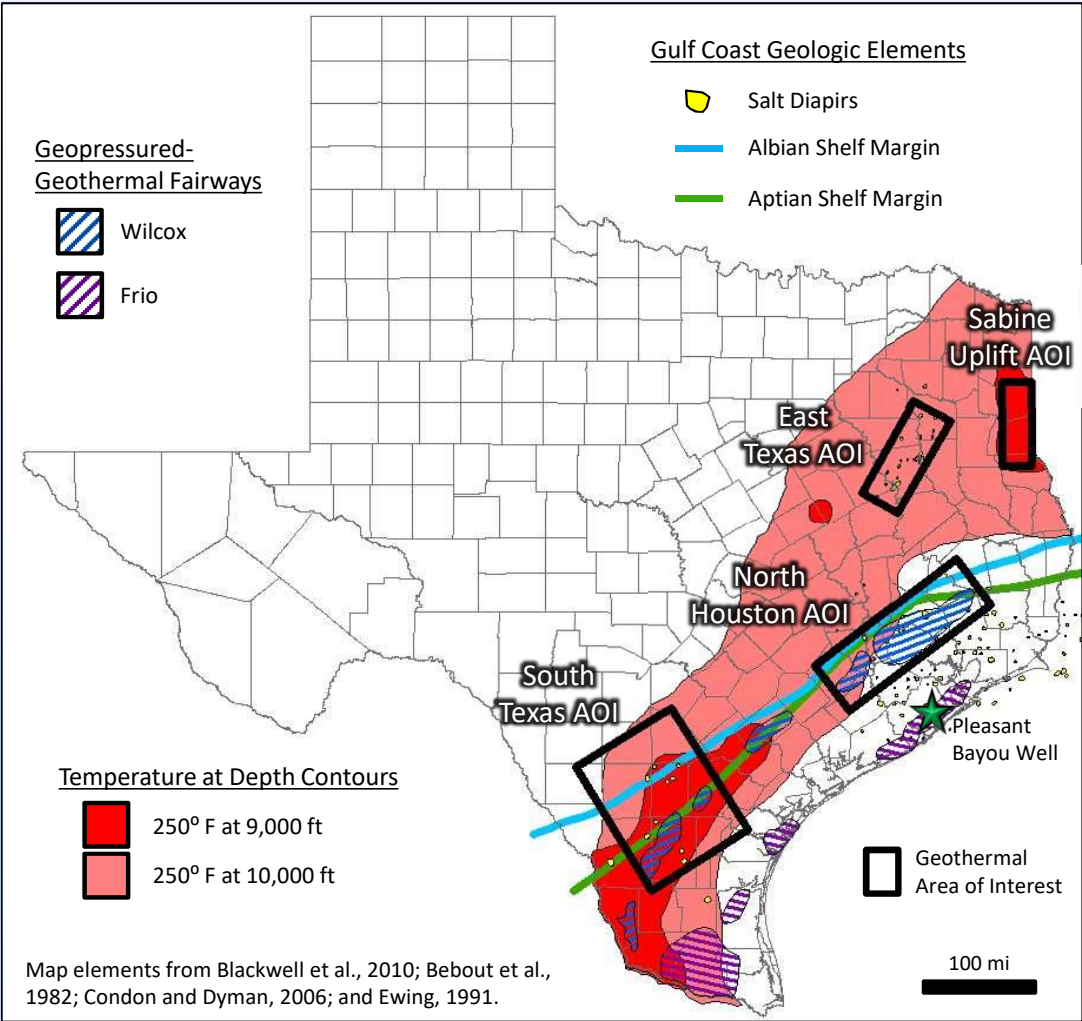


Diapir locations from Condon and Dyman, 2006

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	✓	✓	✓	✗



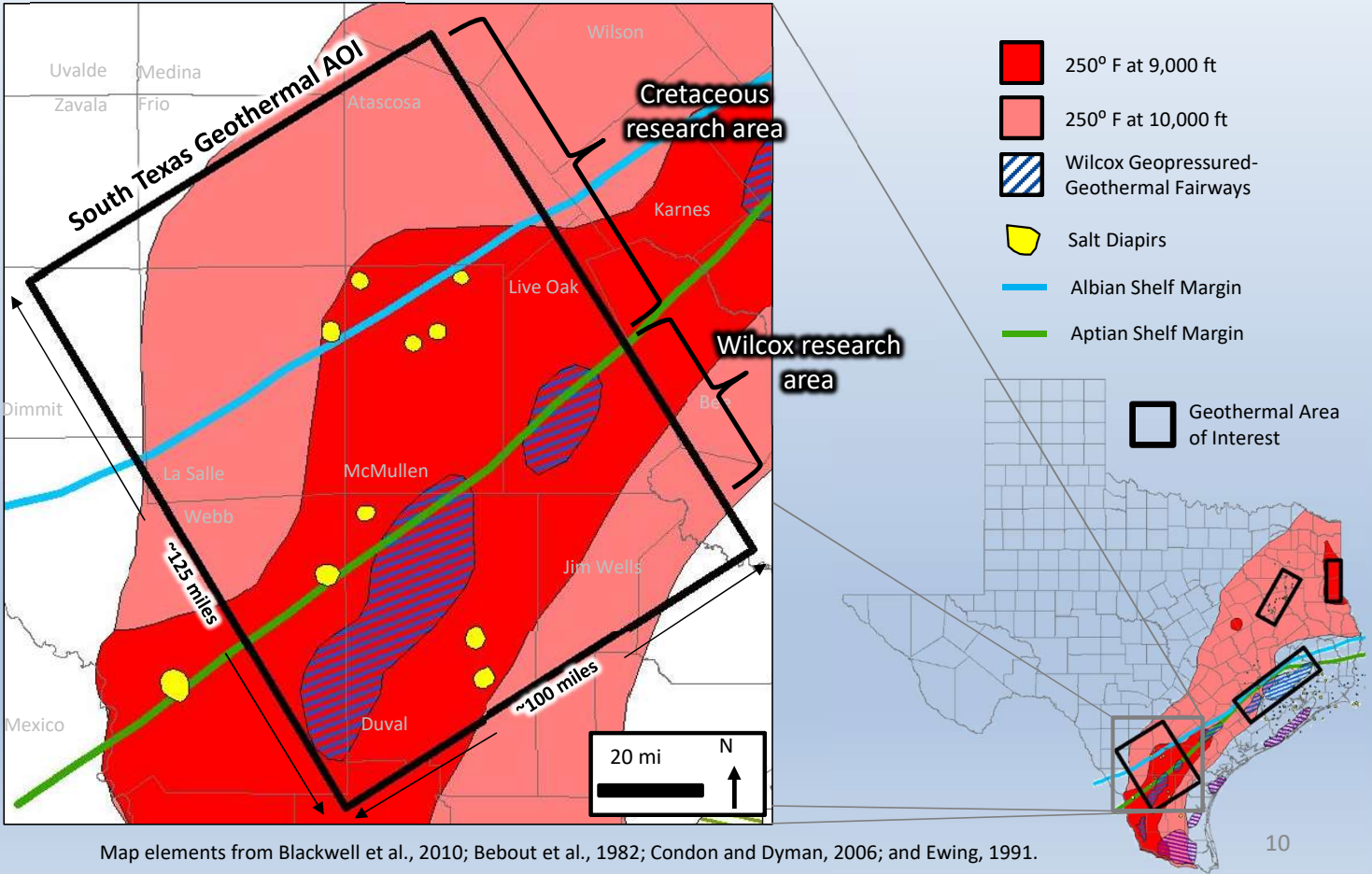
South Texas Geothermal Research Area



Texas Gulf Coast Strata				
PERIOD	EPOCH	AGE	GROUP OR FORMATION	Geothermal
QUAT.	HOLO.	—	—	Undifferentiated
	PLE.	Calabrian		
TERTIARY	NEOGENE	Piacenzian	Undifferentiated	
		Zanclean		
	MIOCENE	Messinian	Fleming Fm.	
		Tortonian		
	OLIGOCENE	Serravallian		
		Langhian		
	PALEOGENE	Burdigalian		
		Aquitanian		
	PAL. EOCENE	Chattian	Catahoula Fm. 	
		Rupelian	Vicksburg ¹	
CRETACEOUS	UPPER	Priabonian	Jackson ¹	
		Bartonian		
		Ypresian	Wilcox ¹	
		Thanetian	Midway Gp.	
		Selandian		
		Norian		
		Maastrichtian	Navarro ¹ (Olmec Fm.-Escondido Fm.)	
		Campanian	Taylor Gp. (Anacacho Ls./ San Miguel Fm./ Ozan Fm./Anhona Chalk)	
		Santonian	Austin Gp./Tokio Fm./ Eutaw Fm.	
		Turonian	Eagle Ford ² Woodbine ³ /Tuscaloosa ⁴	
	Albian	Washita Gp. (Buda Limestone)		
		Fredericksburg Gp. (Edwards Ls. /Paluxy ⁵) Glen Rose ⁶ (Rodessa Fm.)		
LOWER		Pearsall Fm. - James Ls.		
	Aptian			
		Sligo Fm.		
	Barremian	Hosston Fm. (Travis Peak Fm.)		
	Valanginian			
	Berriasian			
JURASSIC	UPPER	Titthonian	Cotton Valley ¹ 	
		Kimmeridgian	Haynesville Fm./ Glimmer Ls.	
	MID.	Oxfordian	Smackover Fm. Norphlet Fm.	
		Callovian	Louann Salt	
TRIA.	UP.	Bathonian	Werner Fm.	
		Hettangian		
		Rhaetian	Eagle Mills Fm.	
		Norian		
		Carrian		

⚡ Proven
⚡ Unproven

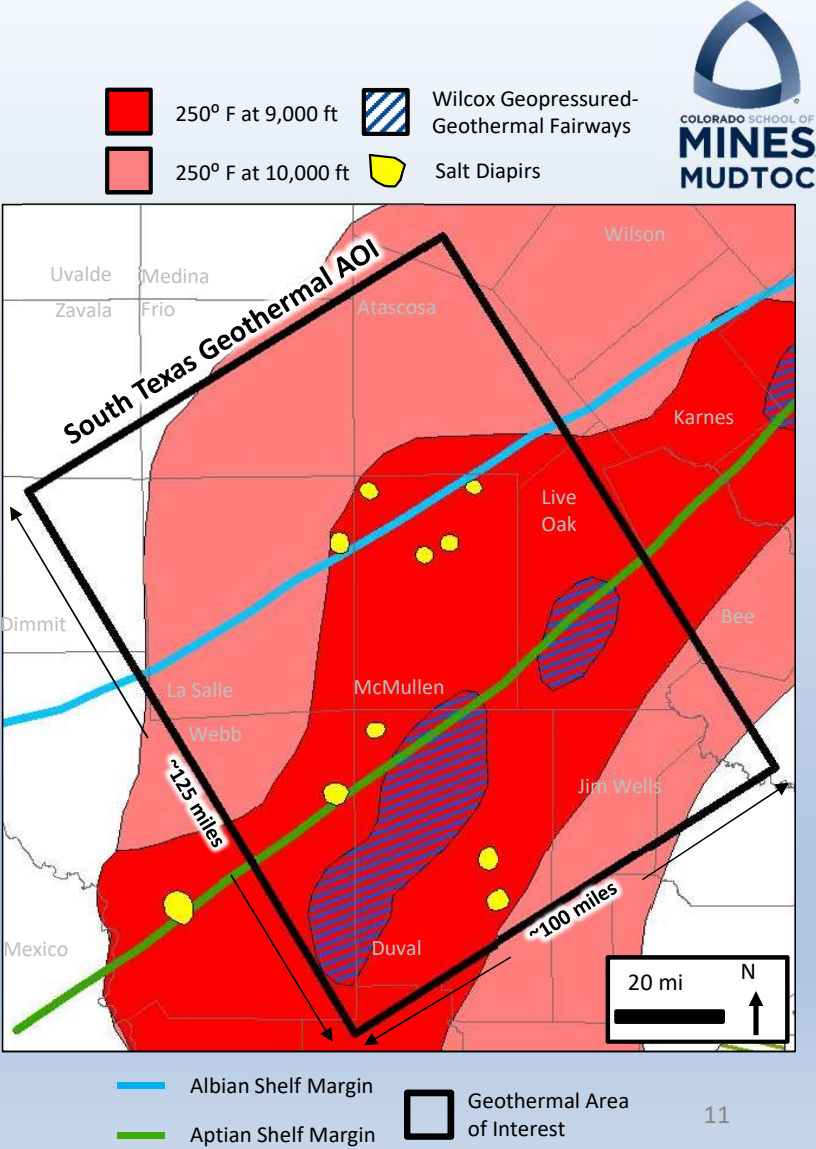
Modified From Swanson et al., 2013



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

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							
	Geothermal play fairway map							
	Reservoir characterization of each play type							
	Flow rate and power generation estimate							
	Subsurface risk assessment							
	Economic analysis and technology recommendation							



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Mike Johnson & Associates



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