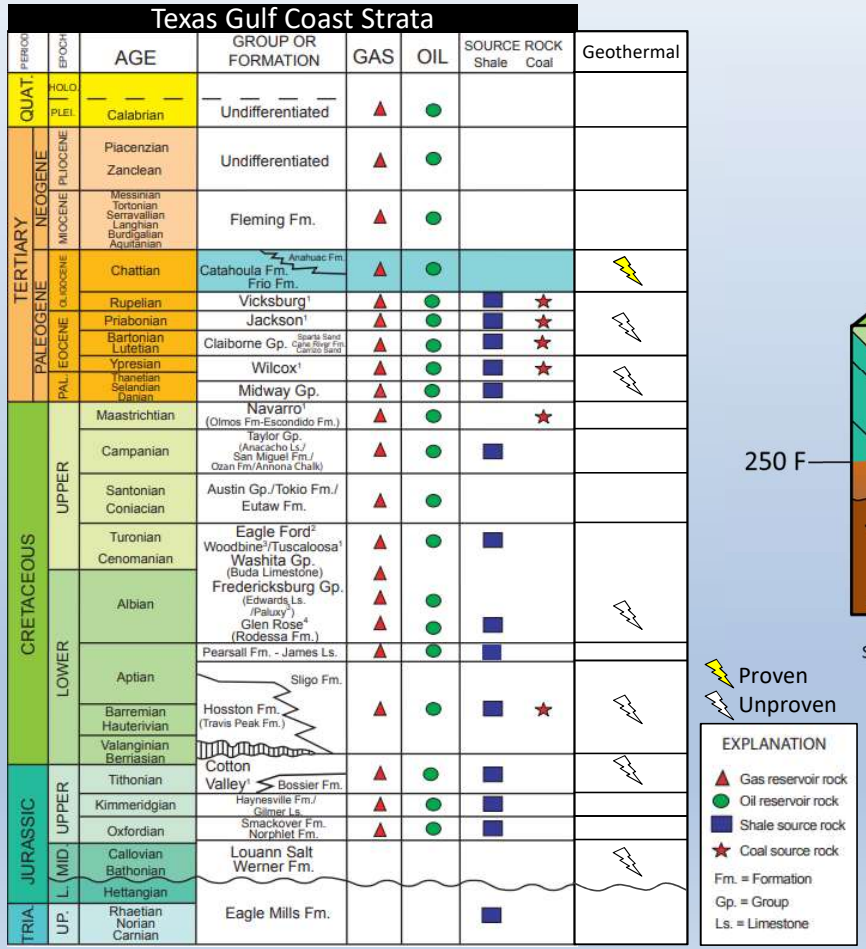
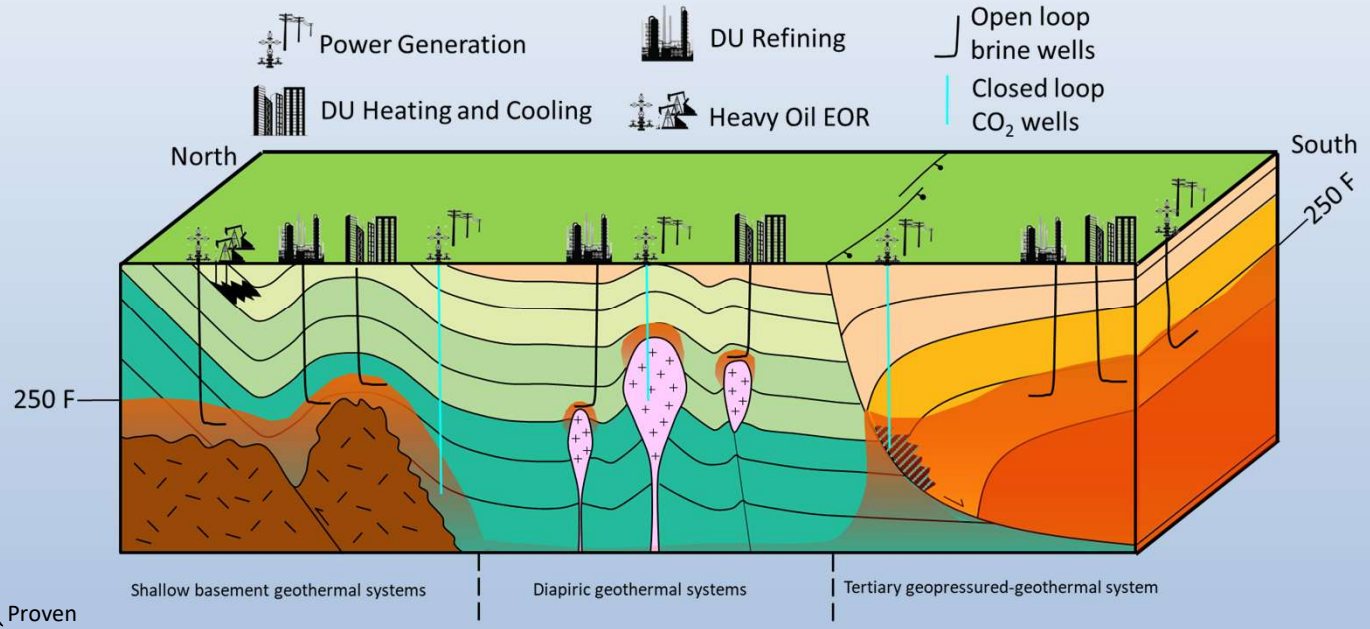
Eric Stautberg, PhD Candidate, 2024

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

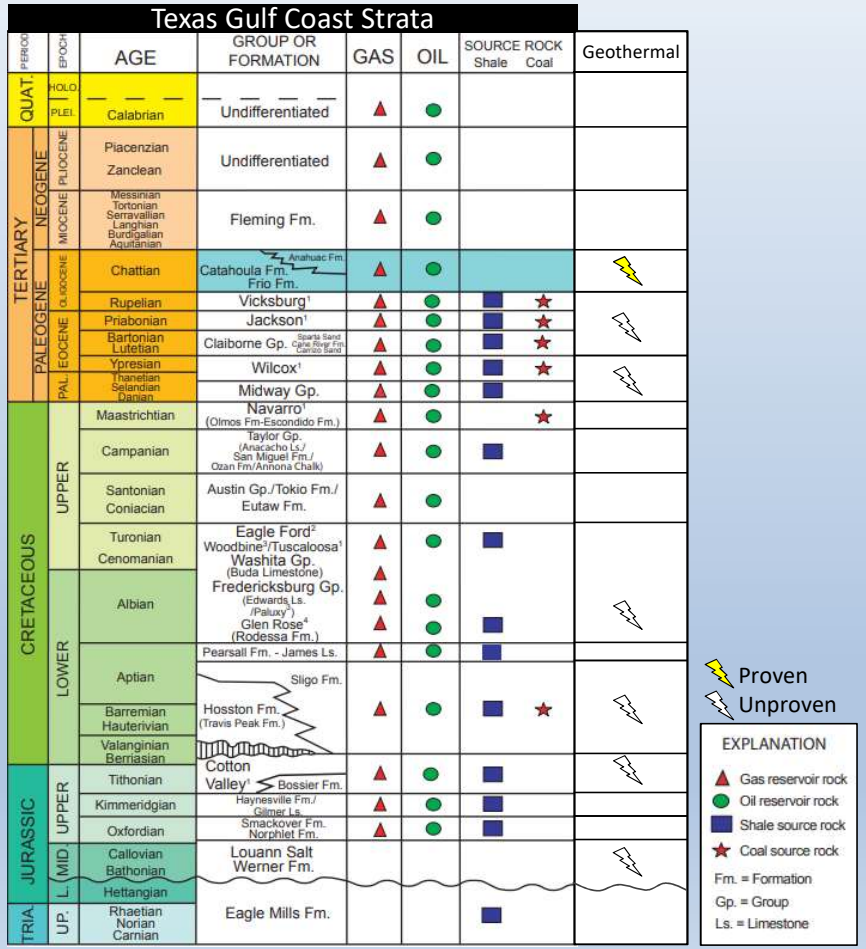
Potential Texas Gulf Coast Sedimentary Geothermal Play Types and Applications



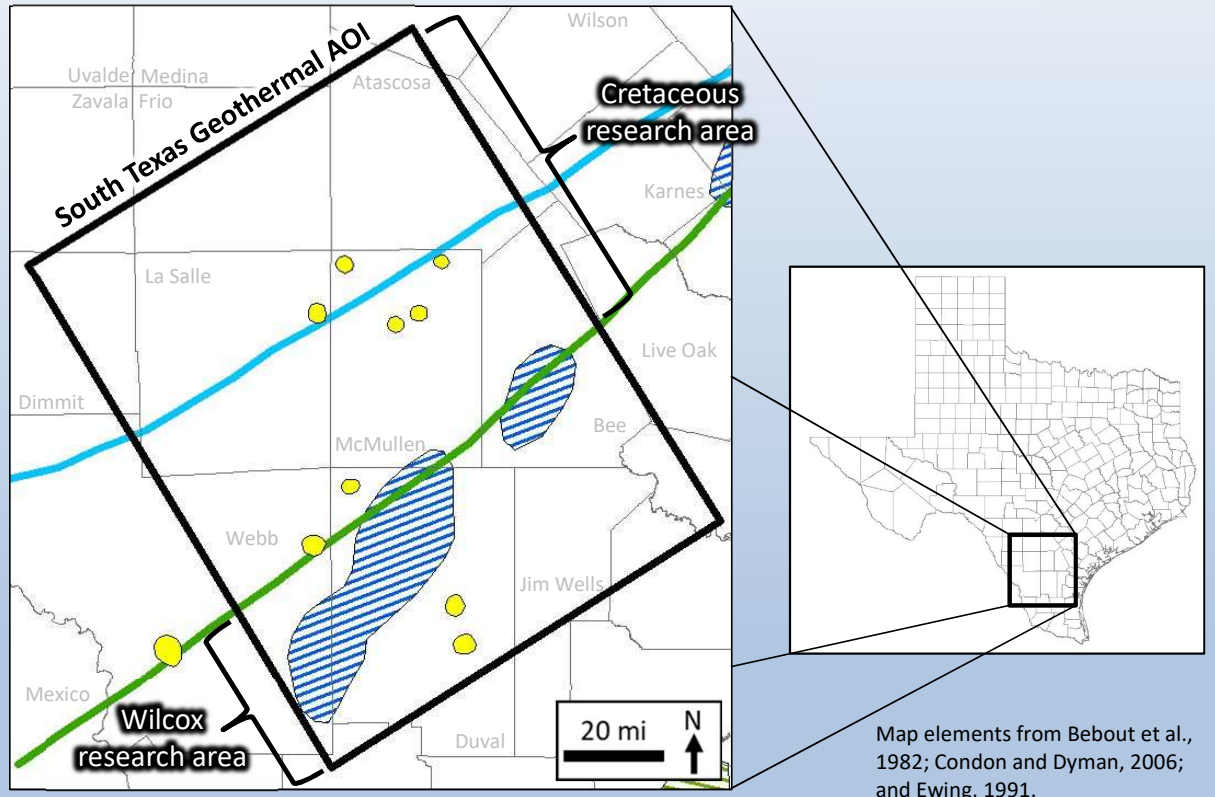
Modified From Swanson et al., 2013



South Texas Sedimentary Geothermal Research Area



Modified From Swanson et al., 2013



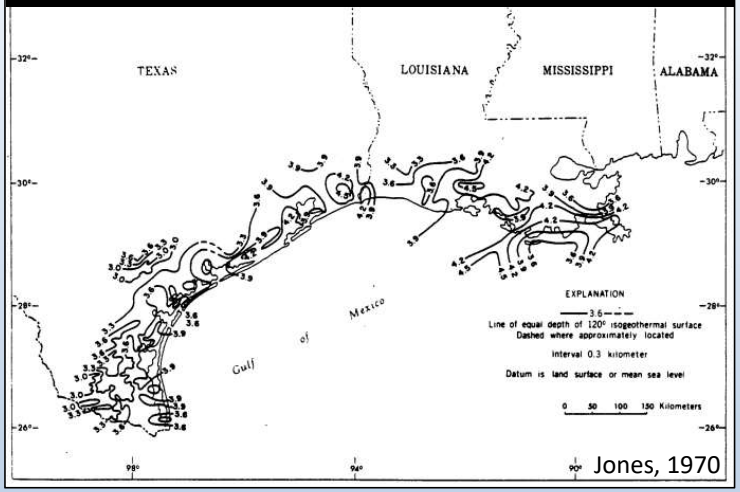
Map elements from Bebout et al., 1982; Condon and Dyman, 2006; and Ewing, 1991.

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)
  - Evaluated14 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)

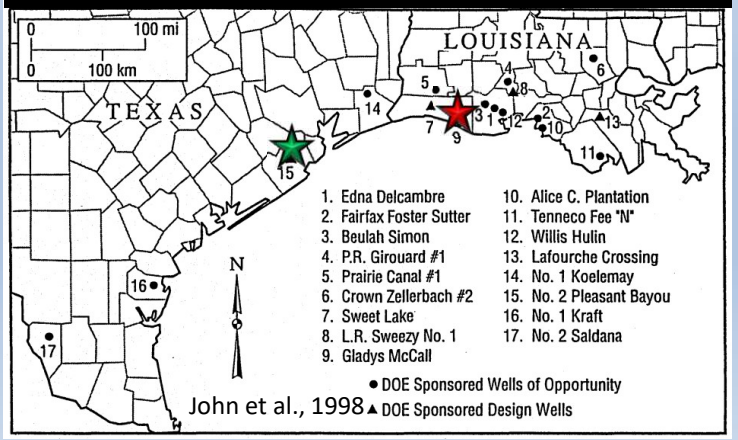
Has the energy environment changed enough since the mid-1990s to warrant developing these resources?

Depth to 120 C Isothermal Surface in the Northern Gulf of Mexico



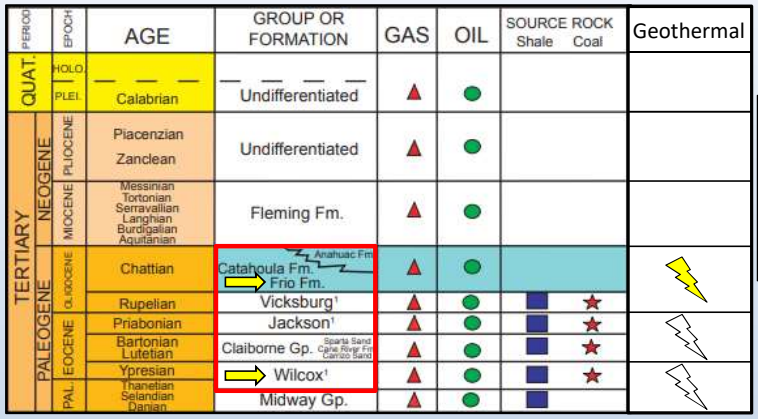
Jones, 1970

DOE 'Wells of Opportunity' Project 1978-1992



John et al., 1998

Tertiary Geopressured-Geothermal Systems



Modified From Swanson et al., 2013

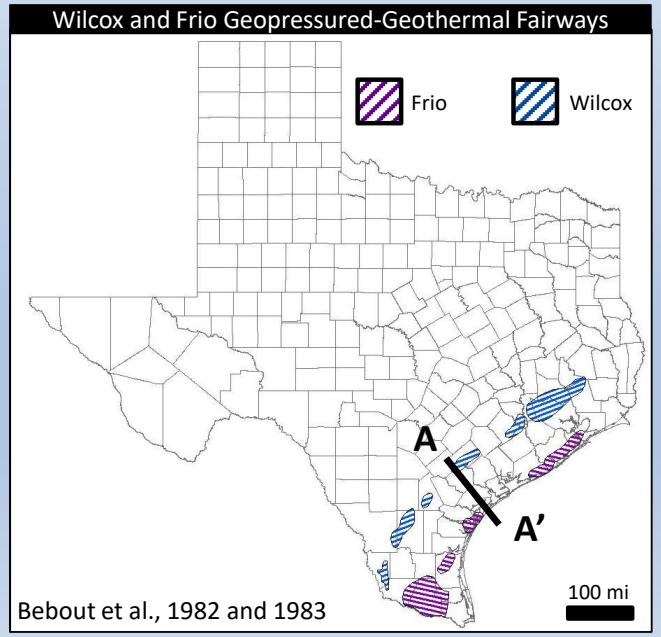
EXPLANATION
- Gas reservoir rock
- Oil reservoir rock
- Shale source rock
- Coal source rock

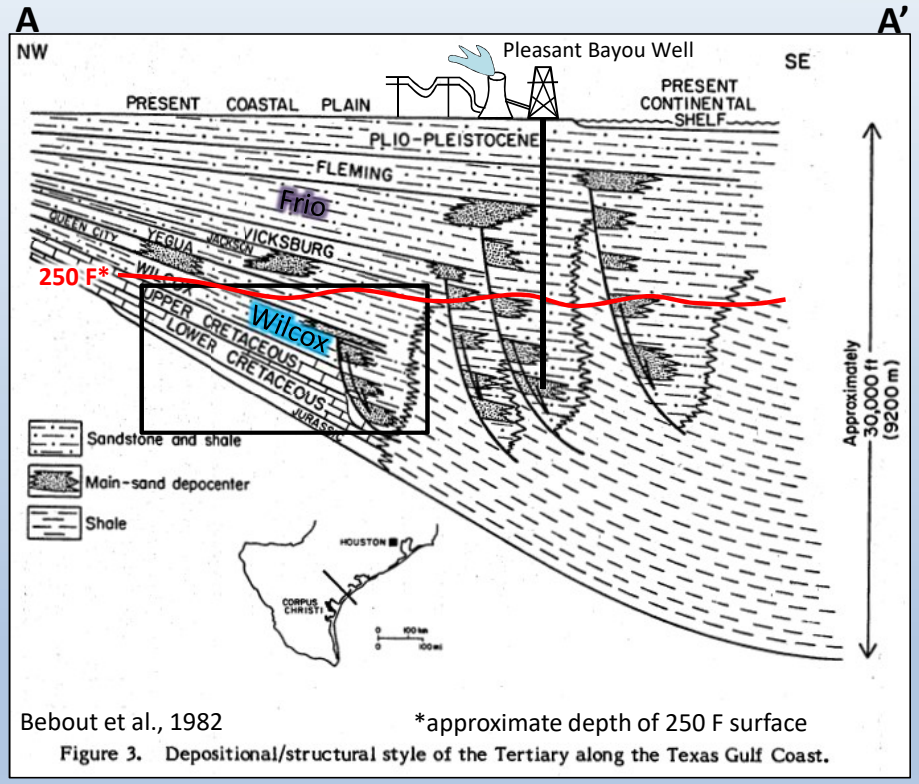
Fm. = Formation
Gp. = Group
Ls. = Limestone

Formations with geopressured zones

Proven

Unproven



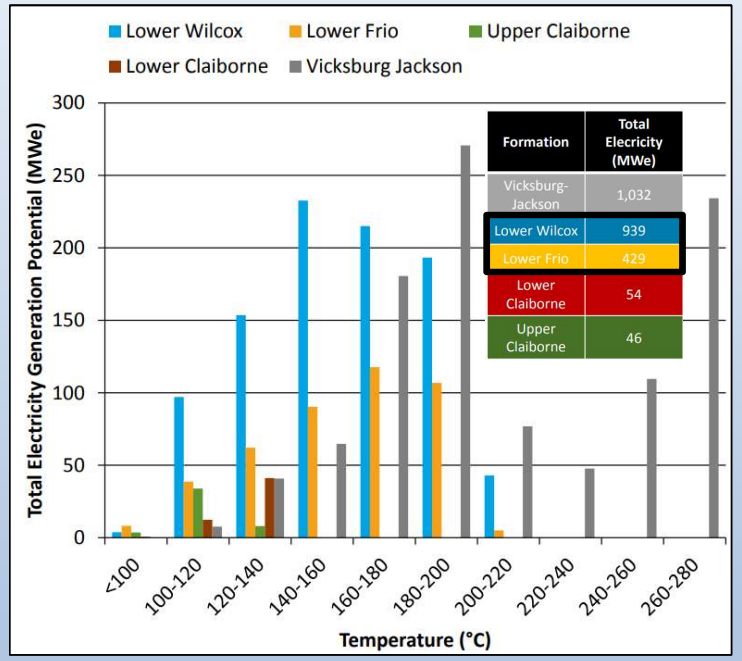


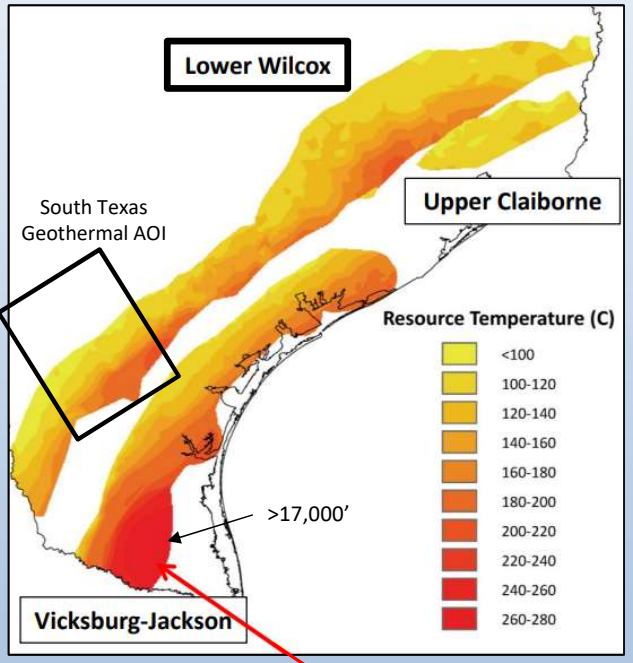
Bebout et al., 1982 *approximate depth of 250 F surface

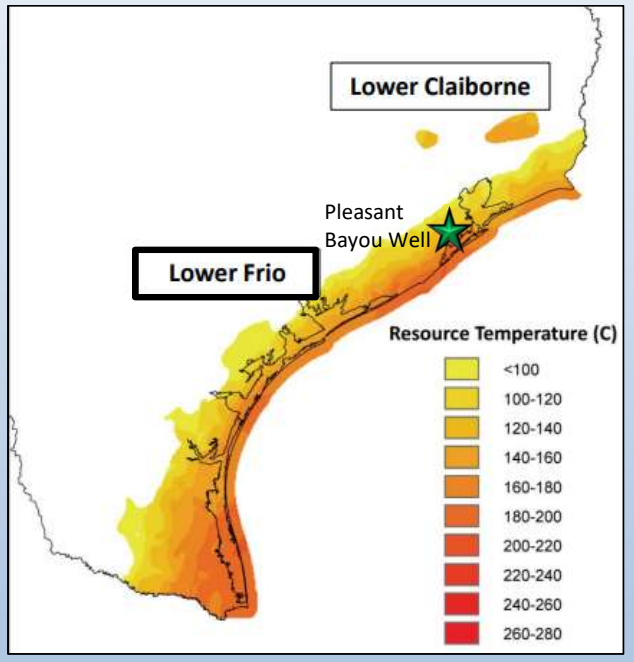
Figure 3. Depositional/structural style of the Tertiary along the Texas Gulf Coast.

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)







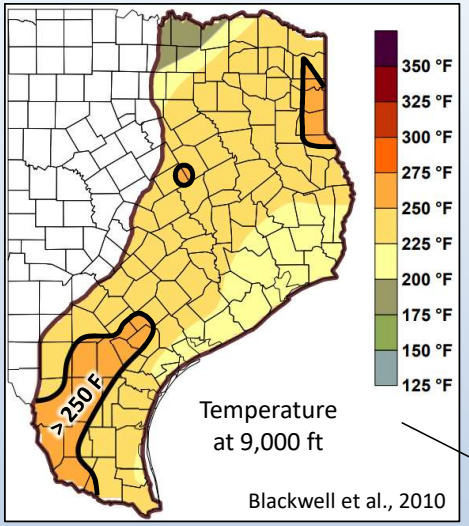
Maximum temperature of **273 C or 523 F** occurs in southern Vicksburg Jackson formations

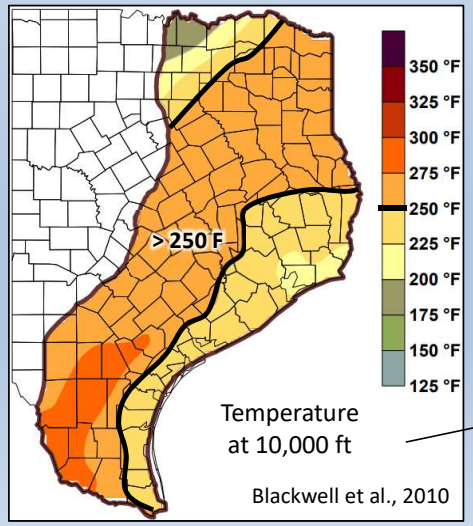
- 2.5 GW estimated recoverable electricity potential for Texas geothermal-geopressured Tertiary sand systems
- Equivalent to 7.8 million utility scale photovoltaic panels or about 1,000 utility scale wind turbines (Department of Energy, 2019)

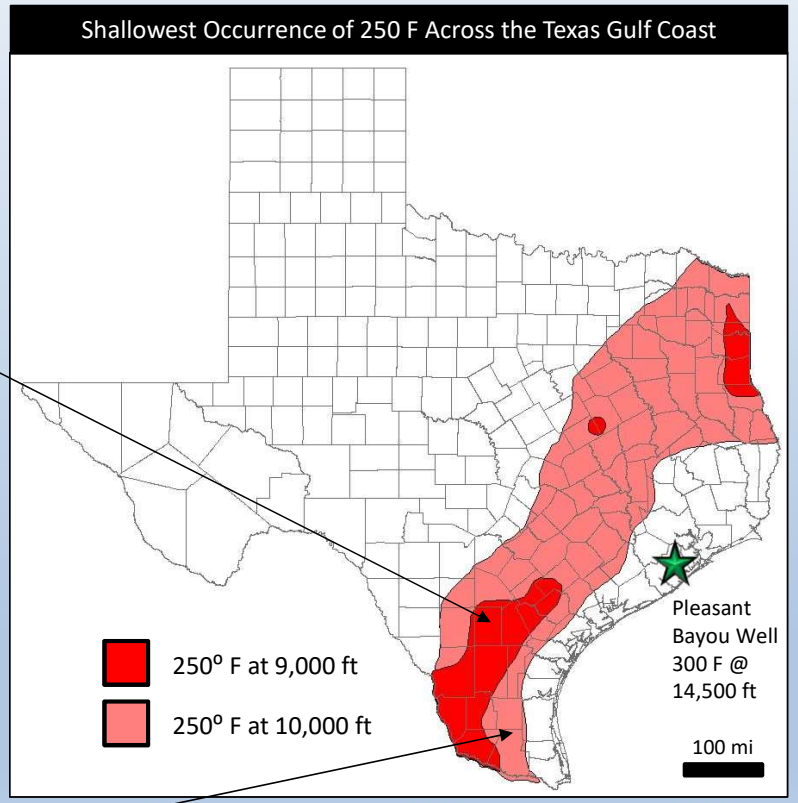
Temperature at Depth Mapping (SMU Geothermal Lab)

- 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?



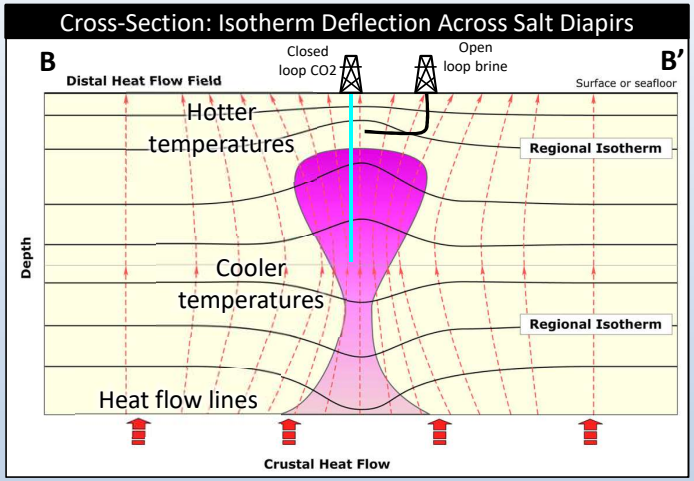




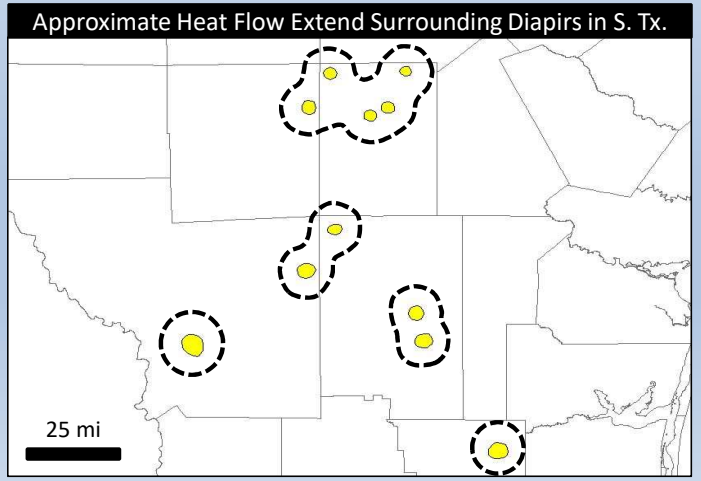
Geothermal Energy Potential of Salt Diapirs

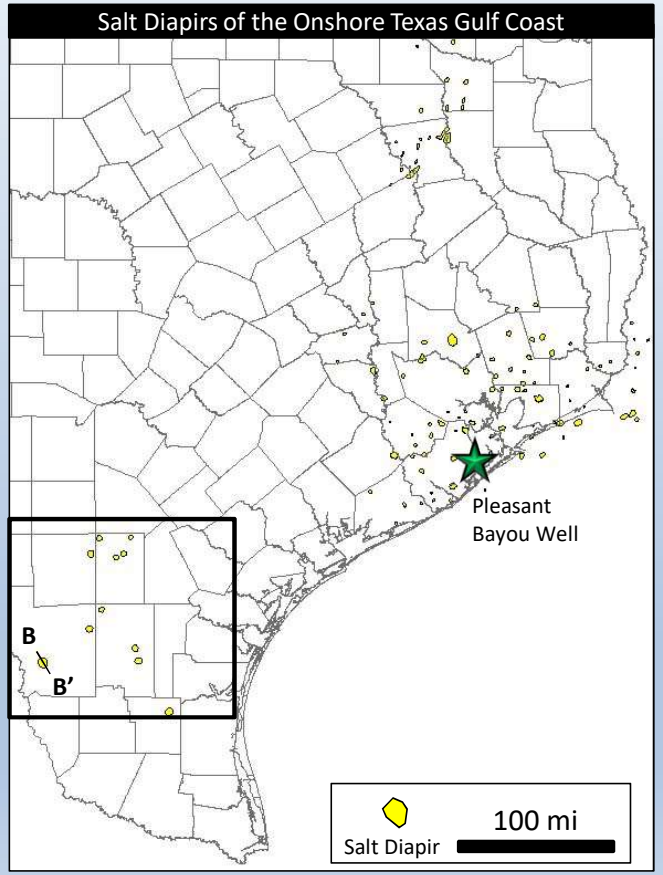
- Salt diapirs were first discussed as a source of geothermal energy in 1975
- High thermal conductivity of salt diapirs sets up two possible geothermal plays types
  1. Utilizing the salt diapir itself with closed loop well design
  2. Reservoirs above the salt diapir with elevated temperatures
- Anomalous 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



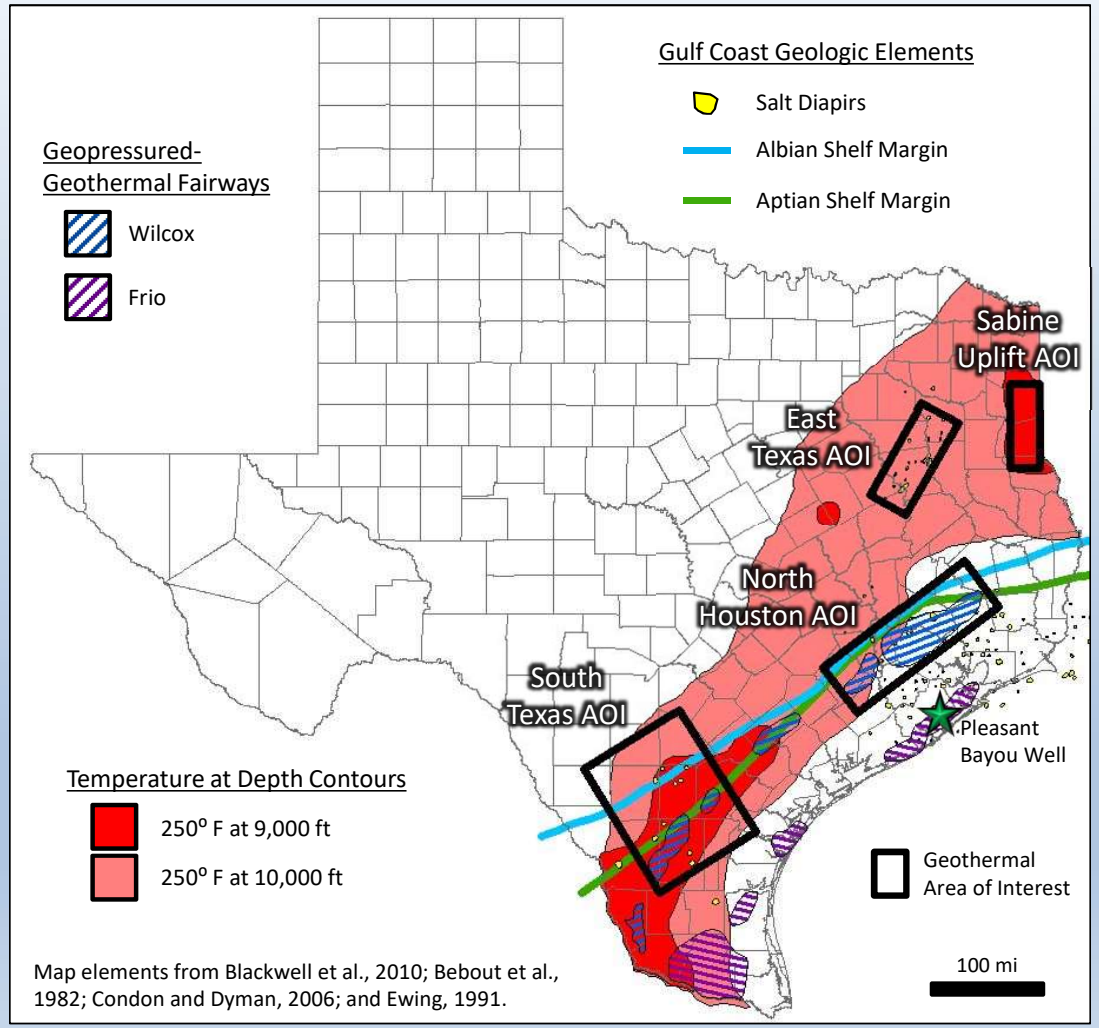


Diapir locations from Condon and Dyman, 2006

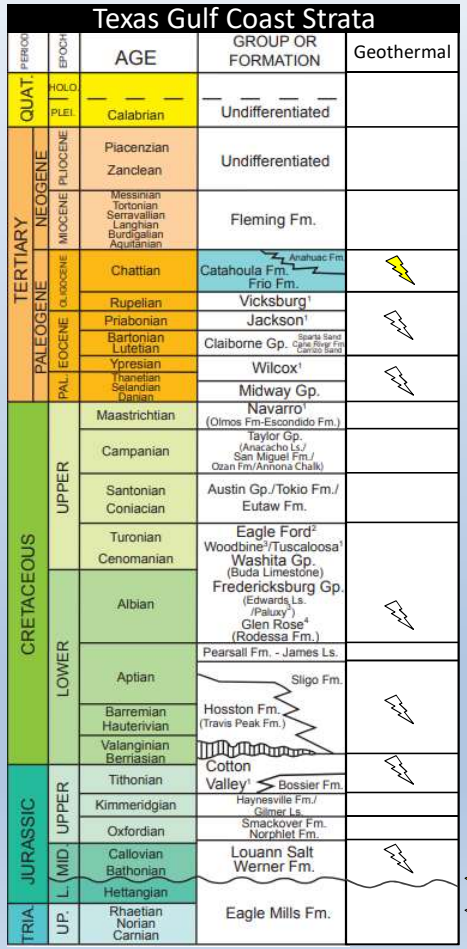
Texas Gulf Coast Sedimentary Geothermal Areas of Interest

- 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

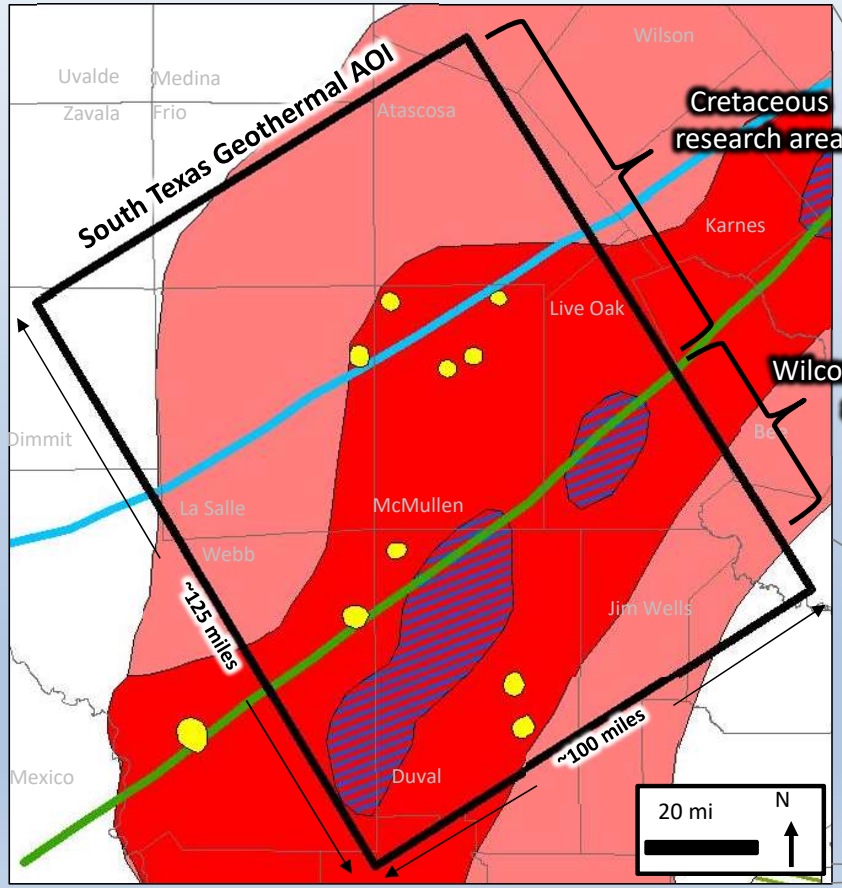
Key Project Characteristics	South Texas	North Houston	East Texas	Sabine Uplift
250 F @ 9,000'	✓	✗	✗	✓
Geopressure	✓	✓	✗	✗
K/Jr Formations	✓	✗	✓	✓
Salt Diapirs	✓	✓	✓	✗

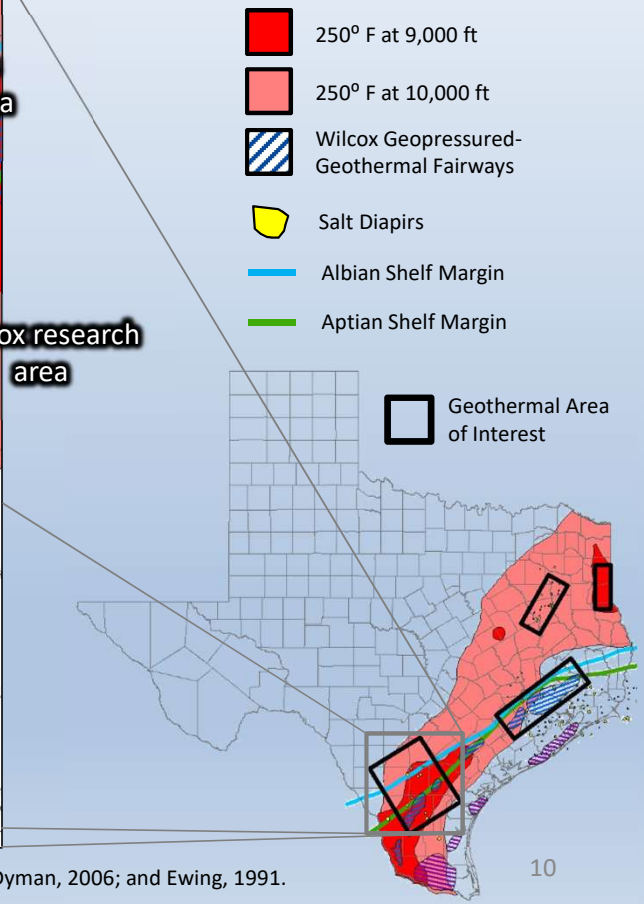


South Texas Geothermal Research Area



Modified From Swanson et al., 2013

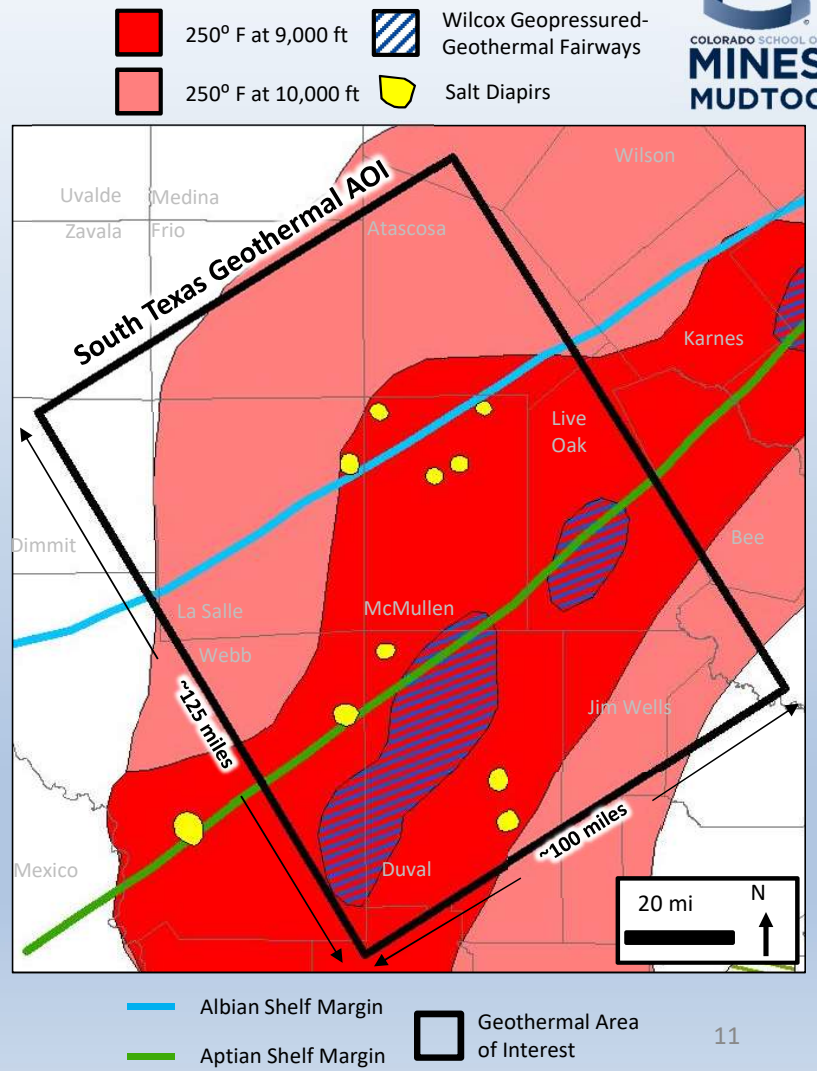




Map elements from Blackwell et al., 2010; Bebout et al., 1982; Condon and Dyman, 2006; and Ewing, 1991.

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	■			■	■	■	■



MUDTOC Consortium Sponsors
Spring 2022

Colorado School of Mines MUDTOC

Sponsoring Member Companies

Antero Resources

CIVITAS

Chevron

COTERRA

devon

ENVERUS

EOG Resources

GMT Exploration Company LLC

OXY

Red Willow Production Company

TGS

White Eagle Exploration

WHITING

In-Kind Supporting Companies

GeoMark

IHS

Mike Johnson & Associates

MJ Logs

PRA Platte River Associates, Inc.

Schlumberger

Stratum Reservoir

References

- Bebout, D.G., Weise, B.R., Gregory, A.R., and Edwards, M.B., 1982, Wilcox sandstone reservoirs in the deep subsurface along the Texas Gulf Coast: their potential for production of geopressured geothermal energy. Report of Investigations No. 117, DOE Technical Report DOE/ET/28461-T2, 193 p. OSTI # 6140725.
- Bebout, D.G., Loucks, R.G., and Gregory, A.R, 1983, Frio sandstone reservoirs in the deep subsurface along the Texas Gulf Coast: their potential for production of geopressured geothermal energy. Report of Investigations No. 91 Second Edition.
- Blackwell, D., Richards, M., and Stepp, P., 2010, Texas Geothermal Assessment for the I35 Corridor East, for Texas State Energy Conservation Office Contract CM709, Final Report.
- Condon, S.M and Dyman, T.S., 2006, 2003 Geologic assessment of undiscovered conventional oil and gas resources of the Upper Cretaceous Navarro and Taylor groups, Western Gulf Province, Texas: U.S. Geological Survey Digital Data Series DDS-69-H, Chapter 2, 42 p.
- Department of Energy, 2019, How Much Power is 1 Gigawatt?, https://www.energy.gov/eere/articles/how-much-power-1-gigawatt (accessed February 2022
- Ewing, T.E., and Lopez, R.F., compilers, 1991, Principal structural features, Gulf of Mexico Basin, in Salvador, A., ed., The Gulf of Mexico Basin: Boulder, Colorado, Geological Society of America, Geology of North America, Vol. J, Plate 2, Scale 1:2,500,000.
- Esposito, A. and Augustine, C., 2011, Geopressured geothermal resource and recoverable energy estimate for the Wilcox and Frio formations, Texas. GRC Transactions, Vol. 35, 2011.
- Jacoby, C.H. and Paul, D.K., 1975, Gulf Coast salt domes as possible sources of geothermal energy. Proceedings: Second United Nations Symposium on the Development and Use of Geothermal Resources. Vol. 3, p. 1673-1679.
- Jensen, P.K., 1990, Analysis of the temperature field around salt diapirs. Geothermics, Vol. 19, No. 3, p. 273-283.
- John C.J., Maciasz, G., and Harder, B.J., 1998 Gulf Coast geopressured-geothermal program summary report compilation: Volume 1 Executive Summary, p. 1-12.
- Jones, P.H., 1970, Geothermal resources of the northern Gulf of Mexico Basin, U.N. Symposium on the Development and Utilization of Geothermal Resources, Vol. 2, Part 1, p. 14-26.
- Petersen, K. and Lerche, I., 1994, Quantification of thermal anomalies in sediments around salt structures. Geothermics, Vol. 24, No. 2, p. 253-368.
- Swanson, S.M., Karlsen, A.W., and Valentine, B.J., 2013, Geologic assessment of undiscovered oil and gas resources – Oligocene Frio and Anahuac formations, United Sates Gulf of Mexico coastal plain and state waters: U.S. Geological Survey Open-File Report 2013 – 1257, p. 6.