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Sedimentary Geothermal Play Types of the Texas Gulf Coast: Applications to Electrical Power Generation

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Keywords

Sedimentary geothermal, hot sedimentary aquifers, Texas, Gulf Coast, play types, salt diapirs, geopressure

ABSTRACT

Sedimentary basin geothermal is an emerging energy sector with the potential to provide renewable, dispatchable, baseload electricity to residential, commercial, and industrial markets above sedimentary basins. The Texas Gulf Coast contains the necessary reservoir temperatures required for electrical power generation (>250º F), and Texas is the largest consumer of electricity in the United States. Identifying and characterizing the major geothermal play types in this basin will help to reduce the exploration and development risks associated with these geothermal resources and encourage geothermal energy development in this region.

Previously, the main sedimentary geothermal play type identified on the Texas Gulf Coast was the Paleogene geopressured-geothermal sandstones of the Wilcox, Vicksburg, and Frio formations. However, Cretaceous and Jurassic formations in south and east Texas have the necessary reservoir properties to be used for electrical power generation but have not yet been investigated thoroughly. Additionally, salt diapirs across the Gulf Coast are a potential source of geothermal energy because of their high thermal conductivity, but this concept has yet to be evaluated for a resource potential.

Preliminary results show that south Texas is optimal for sedimentary geothermal exploration. Eocene Wilcox geopressured-geothermal sandstones are in relatively close proximity to multiple salt diapirs and Cretaceous formations with reservoir temperatures greater than 250º F. A data set of 3,407 wells with digital log suites and 1,590 wells with bottom hole temperature (BHT) measurements demonstrates that the Wilcox, Georgetown, Edwards, Glen Rose, Pearsall, and Sligo formations are the shallowest reservoirs across the research area that contain temperatures capable of electrical power generation.

Six potential sedimentary geothermal play types exist within these formations: 1) Paleocene and Eocene geopressured-geothermal deltaic and marine sandstones, 2) Aptian and Albian shelf-margin carbonates, 3) Aptian and Albian platform interior carbonate shoals, 4) Maastrichtian

deltaic and marine sandstones, 5) reservoirs of varying age located on the flanks of salt diapirs, and 6) repurposing existing oil and gas fields within these formations for geothermal energy. Further reservoir characterization and reservoir modeling of geothermal reservoirs within each play type will start to answer some of the key questions required to reduce the exploration and development risk associated with these resources. Identifying what geothermal play types exist in this basin is the first step towards developing renewable, dispatchable, baseload geothermal electricity in markets above sedimentary basins, further supporting the transition to green energy resources.

1. Introduction

Sedimentary basin geothermal and the use of hot sedimentary aquifers for electrical power generation is an emerging energy sector capable of providing stable, dispatchable, base load renewable energy to markets above sedimentary basins across the United States. To date, limited exploration and development of geothermal resources has been completed in sedimentary basins that lack substantial heat flow from volcanic activity or active crustal extension. Consequently, there are multiple sedimentary basins across the United States that are under explored regarding geothermal energy. The three main sedimentary basins in the contiguous United States with hot sedimentary aquifers capable of being exploited for low temperature power generation purposes are the Gulf Coast Basin, the Denver Basin, and the Williston Basin. These three basins have potential to provide an undefined amount of geothermal energy from hot sedimentary aquifers that have yet to be identified, characterized, drilled, or tested (Anderson, 2013; Doughty et al., 2018).

With the changing energy environment of the world, finding and developing renewable energy resources to fulfill the global energy demands is of upmost priority. To help achieve these increasing global energy demands, geothermal exploration needs to occur in basins that lack significant heat flow from active volcanism or ongoing crustal extension. This project is focused at using one of these basins, the Texas Gulf Coast region of the Western Gulf Basin (Figure 1), to encourage geothermal exploration by first identifying what sedimentary geothermal play types exist across the basin. Exploration methods and results from this research can be applied to other basins in the United States and internationally, ultimately helping to discover the energy resources necessary to keep up with increasing global energy demands.

2. Geothermal Elements of the Texas Gulf Coast

In the Western Gulf Basin, limited research has been completed on identifying different geothermal play types and geothermal play fairways, as compared to a century's worth of oil and gas exploration and development. To date, the only geothermal play type identified in this basin are the geopressured-geothermal sandstones of the Paleogene Wilcox, Vicksburg, and Frio formations (Bebout et al., 1978; Loucks et al., 1978; Bebout et al., 1979; Bebout et al., 1982; Esposito and Augustine, 2011, and others). These geopressured-geothermal systems are highly over-pressured sandstones that extend regionally across the basin and were originally identified in the late 1970s for their geothermal resource potential. However, the abundance of oil and gas data and development within this basin suggests that other geothermal play types exist in Jurassic, Cretaceous, and additional Paleogene formations. This project has identified the Rio Grande Embayment subdivision of the Western Gulf Basin (Figure 1) as a location that contains multiple different sedimentary geothermal play types that can be used as a case study for identifying and characterizing hot sedimentary aquifers associated with different geothermal play type.

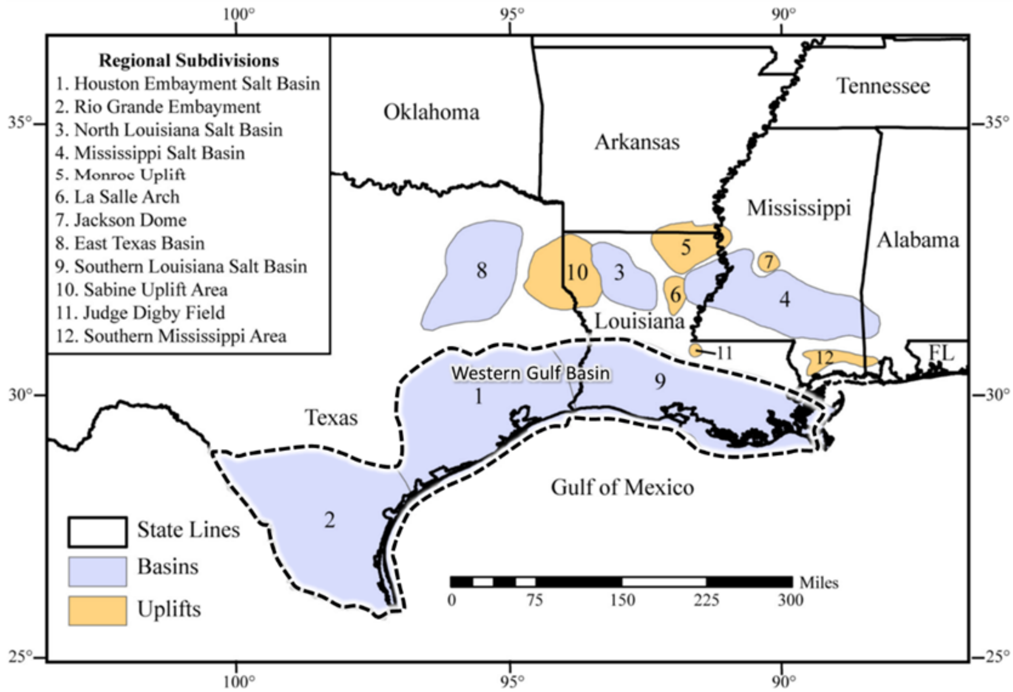

Figure 1: Basins and uplifts of the onshore Gulf of Mexico region showing basins in blue and uplifts in yellow. This project is focused on the Rio Grande Embayment (2) part of the Western Gulf Basins for its sedimentary geothermal energy potential. Modified from Ewing, 1991.

Sedimentary formations of the Texas Gulf Coast span from Triassic through the Holocene and record rifting and passive margin tectonism, regionally extensive carbonate platform development, and deposition of thick siliciclastic depositional environments across the entire Western Gulf Basin. Consequently, numerous types of sedimentary geothermal play types exist, both spatially and temporally, where different aged formations are at temperatures greater than 250° F. To determine the location of geothermal research areas across this basin, four main geologic factors were considered: 1) the location of geopressured-geothermal zones in Paleogene formations, 2) the shallowest depth to find reservoirs temperatures of 250° F, 3) the location of Cretaceous shelf margins, and 4) the location of salt diapirs.

2.1 Paleogene Geopressured-Geothermal Systems

Geothermal research on the Gulf Coast dates to 1970, when the first discussion of the geothermal potential in this basin occurred at the U.N. Symposium on the Development and Utilization of Geothermal Resources. At this meeting, P.H. Jones from the U.S. Geological Survey (USGS) suggested there was enormous geothermal potential here based on isotherm mapping, the large volume of water stored in deep aquifers, and geopressured zones encountered in the Paleogene sandstones of the Wilcox and Frio formations (Jones, 1970). The Bureau of Economic Geology at the University of Texas at Austin (BEG) started investigating the geothermal resources of Texas in 1974 and concluded that the Trans-Pecos and Gulf Coast regions have potential to supply undetermined amounts of geothermal energy to Texas (Dorfman and Kehle, 1974).

In 1975, the BEG evaluated the regional sand distribution of the Frio Formation and identified two potential geothermal fairways in Texas (Bebout et al., 1975). Research continued throughout the late 1970s and early 1980s, also evaluating the Wilcox and Vicksburg formations. Zones of hard over-pressure (>0.7 psi/ft) exist in these Paleogene formations along the Texas Gulf Coast and were identified as potential geothermal fairways because of the high over-pressure, hot reservoir temperatures (>250º F), and the superb reservoir quality preserved in these sandstones (Loucks et al., 1978; Bebout et al, 1982). Additionally, the geopressured-geothermal fairways in the Wilcox and Frio formations extend regionally across the Texas Gulf Coast and are important geothermal play types because of the enormous volume of hot brine and dissolved methane stored in these hot sedimentary aquifers.

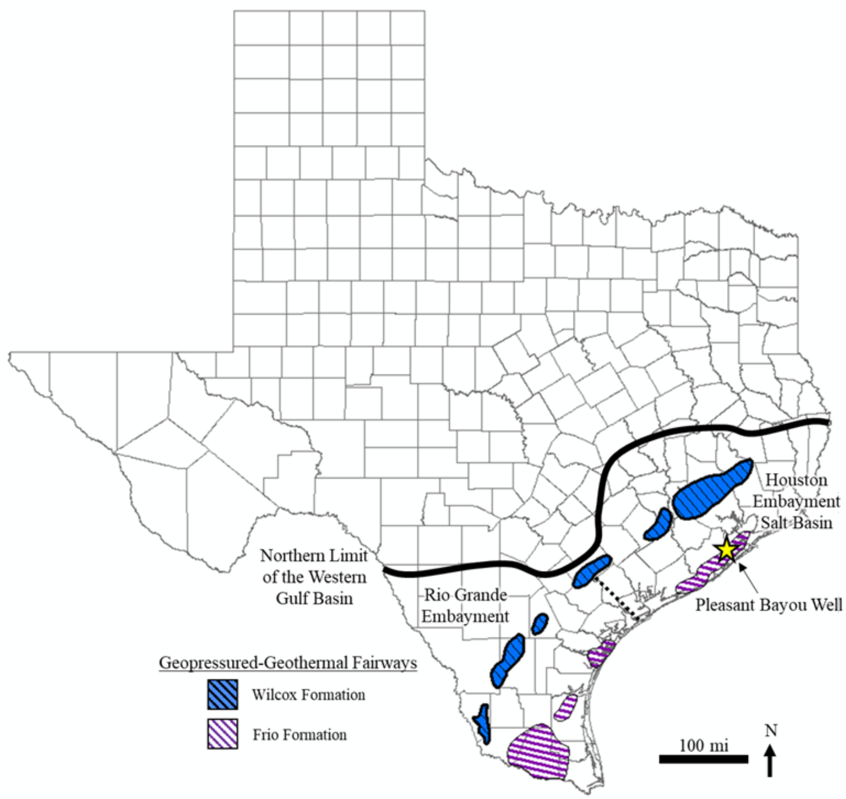

Figure 2: Location of geopressured-geothermal fairways in the Wilcox and Frio formations along the Texas Gulf Coast. The location of the Pleasant Bayou #2 well is shown by the yellow star. Modified from John et al., 1998 and Ewing, 1991.

Over-pressure in these formations is driven by rapid deposition and burial of wet sandstones and shales on the downthrown side of listric growth faults (Figure 3). Growth faults developed because of rapid loading from large quantities of sands and mud that were deposited on top of the low-density shales of the previous sequence (Bebout et al, 1979). Salt mobilization from this loading also contributed to growth fault development in these Paleogene formations. Some sandstones are fully encased in shales causing fluid trapped in the sandstones to develop high over pressure as they were buried (Bruce, 1973).

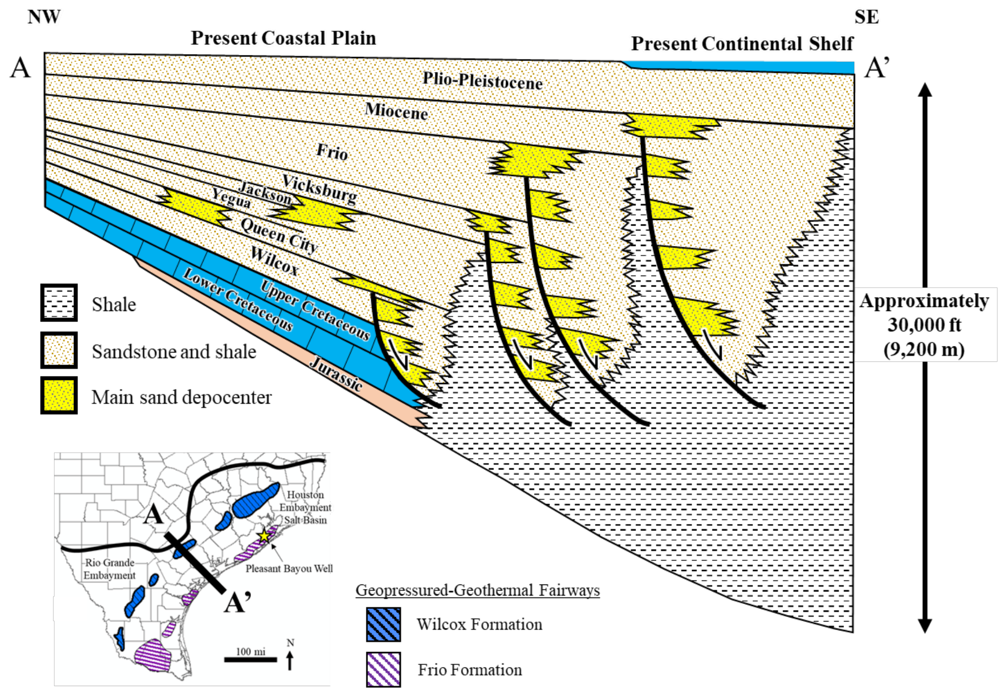

Figure 3: Schematic cross section showing how the Paleogene geopressured-geothermal reservoirs are distributed throughout the stratigraphic framework of the Gulf Coast. Syn-depositional growth faults caused large volumes of sediment to be deposited on the downthrown side of the fault systems, resulting in the rapid burial of wet sandstones encased in low permeability shales, allowing high pressure to develop in some of the sandstones. Modified from Bebout et al., 1982.

2.1.1 The Pleasant Bayou Geopressured-Geothermal Well

In 1978 the BEG and U.S. Department of Energy (DOE) started an exploration drilling project to test the geothermal energy potential stored in a geopressured reservoir of the Oligocene Frio Formation. Under contract from the DOE, the BEG selected a well site in Brazoria County, Texas to drill the first geopressured-geothermal well in the United States (Figure 2). This location was specifically chosen because it contained the required reservoir properties to make electricity from brine stored in a hot sedimentary aquifer. The distributary-mouth bar and delta-plain sandstones of the Frio Formation C-zone here are 250-350 feet thick with reservoir temperatures greater than 300º F and 30-40 millidarcys (mD) of permeability. Brine salinities range from 40,000 to 80,000 parts per million (ppm) total dissolved solids (TDS) and methane content ranges from 25 to 45 cubic feet per barrel of brine (Bebout et al., 1978).

The following year, the Pleasant Bayou No. 2 well was drilled to a total depth of 16,500 feet and completed over a 60-foot perforation in the Frio Formation C-zone at a depth of 14,644 feet (Riney, 1991). Preliminary testing of this well took place during 1979 and a long-term flow test occurred between 1981 and 1983. During this time, the well achieved flow rates of approximately 20,000 barrels per day of brine, however many production and mechanical problems occurred. Well testing was suspended in 1983 when the production tubing parted and the project was temporarily shut down (Rodgers, 1982).

In 1987, the well was cleaned out, recompleted, and a long-term production test began in 1988. During this time, downhole pressure and temperature measurements showed stable pressure values exceeding 9,800 pounds per square inch absolute (psia) and stable reservoir temperatures ranging from 293º F to 307º F (Riney, 1991). Flow testing continued for two more years, flowing approximately 12 million barrels of brine and 231,000 MCF of gas over the life of the well. A binary cycle hybrid power electrical generation system (HPS) operated at the site for several months and successfully demonstrated that geopressured geothermal reservoirs could be used to generate electricity (John et al., 1998). After this successful demonstration, the Pleasant Bayou #2 well was plugged and abandoned in 1994. In the final report of this project, it was concluded that developing these resources was not commercially profitable at the time but a rapid advance in different technologies used in this project could make these resources more attractive in the future (John et al., 1998). While the Pleasant Bayou operations were being conducted, the BEG was also investigating the geothermal potential of the Wilcox and Vicksburg formations and identified seven additional geothermal fairways across the Texas Gulf Coast (Figure 2) (Loucks et al., 1978; Bebout et al., 1982). Each one of these geopressured zones contains thick, porous, permeable sandstones with reservoir temperatures that exceed 300º F.

2.2 Previous Temperature at Depth Mapping

In 2010, the Geothermal Lab at Southern Methodist University (SMU) constructed a series of regional temperature at depth maps for the Texas Gulf Coast. Maps produced from this study used 9,549 corrected bottom hole temperature (BHT) measurements to determine reservoir temperatures at 1,000 ft depth increments from 7,000 ft to 14,000 ft across the entire Texas Gulf Coast (Blackwell et al., 2010). Based on these maps, in both east and south Texas, 250º F occurs at an approximate depth of 9,000 ft. However, across the rest of the Texas Gulf Coast, 250º F is encountered at a depth of approximately 10,000 ft (Figure 4). Focusing on the areas in south and east Texas where 250º F is encountered at a shallower depth will ensure that more subsurface data is available for this study, as the amount of subsurface data decreases with depth across the basin. For this project, 250 º F was chosen as the minimum temperature use to identify geothermal play types across the Texas Gulf Coast because it is approximately the minimum temperature required for generating electricity with binary cycle power plants.

2.3 Paleogeographic Shelf Margins

The location of paleogeographic-shelf margins are also important geologic features in the Western Gulf Basin (Figure 4). In particular, the Lower Cretaceous (Aptian and Albian) Sligo and Edwards/Stuart City shelf margins extend from Mexico to Florida and represent the southern and down-dip depositional limit of widespread, porous, and permeable reservoirs during Lower Cretaceous (Ewing et al., 1991). These shelf margins also divide the region into a Mesozoic geothermal study area to the north and a Paleogene geothermal study area to the south (Figure 5). North of the shelf margins, Paleogene formations are too cool for geothermal energy development and south of the shelf margins the Mesozoic formations are very deep (>18,000 ft), making them a challenge to develop economically.

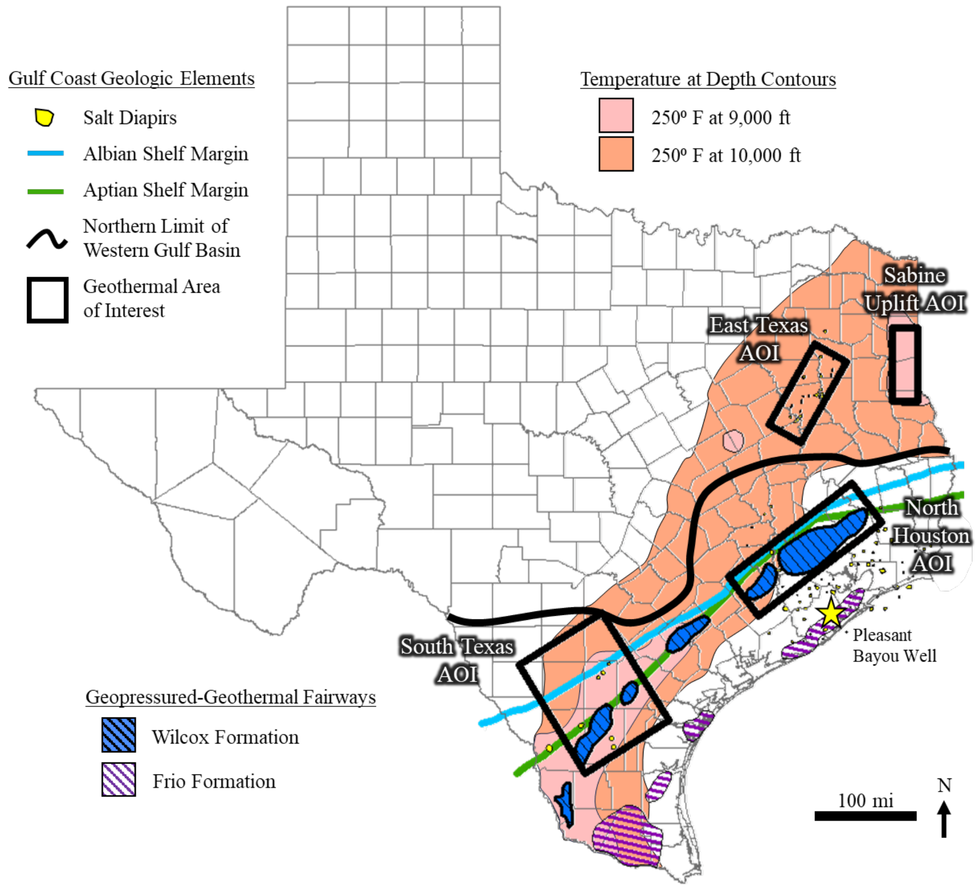

Figure 4: The location of key geologic features for geothermal exploration on the Texas Gulf Coast. 250º F occurs at a depth of approximately 9,000 ft in both east and south Texas and at approximately 10,000 ft across the rest of the region. Salt diapirs are mainly located in south Texas, the southeastern coast near Houston, and in the East Texas Salt Basin. Over pressured Paleogene sandstones extend across the Western Gulf Basin as northeast-southwest trending pressure cells that roughly follow strike of these systems. Map elements are from Blackwell et al., 2010; Bebout et al., 1982; Condon and Dyman, 2006; and Ewing, 1991.

2.4 Salt Diapirs

Salt diapirs were first considered as a geothermal resource in the 1970s and are important geologic features for sedimentary geothermal exploration in this region. The high thermal conductivity of halite (4.250 W/m-K at 250º F), which is the main constituent of these diapirs, causes thermal anomalies in the reservoirs adjacent and above them and it was suggested that salt domes could be a virtually inexhaustible source of geothermal energy (Jensen, 1990; Petersen and Lerche, 1995; Urquhart and Bauer, 2015; Daniilidis and Herber, 2017). Consequently, elevated reservoir temperatures in the reservoirs above salt diapirs could be a source of geothermal energy and a play type not yet identified or characterized. Another sedimentary geothermal play type associated with salt diapirs is the diapir itself. Higher than normal temperatures based on reservoirs at similar depths have been documented inside salt diapirs and closed loop wells could be drilled directly into the salt to extract heat for electrical power generation. Only a few studies have considered this play type before, but no geothermal resource estimates have been calculated for salt diapirs (Jacoby and Paul, 1975; Hickerson and Hickerson, 1997). Understanding the geothermal potential from salt diapirs and the heat anomalies associated with them will be an important part of geothermal exploration in the Western Gulf Basin. The location of salt diapirs on the Texas Gulf Coast is shown in Figure 4 and their location in south Texas is shown in Figure 5.

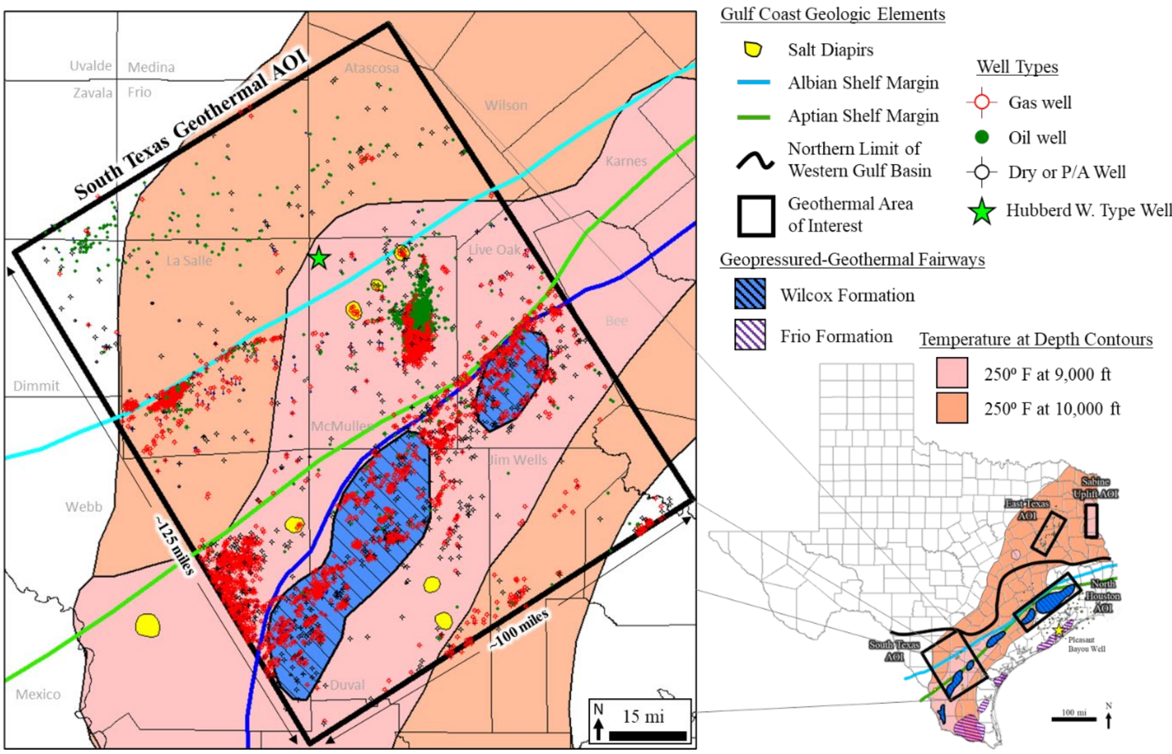

Figure 5: Location of the South Texas Geothermal AOI for this project which covers parts of 10 different counties and overlies the Eagle Ford, Austin Chalk, and Paleogene oil and gas trends. This area contains all the major sedimentary geothermal play types present in the Western Gulf Basin including Paleogene geopressured-geothermal reservoirs, salt diapirs, and porous Cretaceous formations. The location of vertical wells with digital logs used in this project are displayed in red, green, and black well symbols. Map elements are from Blackwell et al., 2010; Bebout et al., 1982; Condon and Dyman, 2006; and Ewing, 1991.

2.6. South Texas Geothermal Research Area

Combining these geologic elements together shows four main geothermal exploration areas across the Texas Gulf Coast. However, the South Texas Geothermal Area of Interest (AOI) is the only one that contain all four key geologic elements: the shallowest depth to 250º F, multiple salt diapirs, over-pressure fairways in the Wilcox Formation, and Cretaceous formations north of the shelf margins with reservoir temperatures greater than 250º F (Figure 5). Like the South Texas AOI, 250º F is encountered at a depth of 9,000 ft in the Sabine Uplift AOI but no geopressured zones or salt diapirs are present in this area. The East Texas AOI contains numerous salt diapirs in the East Texas Salt Basin but the depth to 250º F occurs at 10,000 ft and this area does not contain any geopressured zones. The North Houston AOI contains a large geopressured zone in the Wilcox Formation but 250º F is not encountered until depths greater than 10,000 ft, and this area is south of both Lower Cretaceous shelf margins. Consequently, this project is focused on identifying geothermal play types in the South Texas Geothermal AOI because of the diversity of geothermal elements in this area. However, more geothermal research needs to be completed within the other AOIs and across the entire Western Gulf Basin.

3. Data and Methods

Oil and gas exploration and development over the past century has led to a robust subsurface dataset across the basin that can be used for geothermal exploration. Within the South Texas Geothermal AOI, over 93,000 vertical, deviated, and horizontal wells have been drilled in search for hydrocarbons, with close to 50,000 of these wells containing some form of digital log data. For this project, 3,407 vertical wells with digital log data below 9,000 ft were provided by TGS for the purpose of identifying and characterizing hot sedimentary aquifers associated with the different sedimentary geothermal play types within the research area (Figure 5 and Figure 6). Digital well log data ranges from wells with Quad Combo and specialty logs to wells with only spontaneous potential (SP) and resistivity logs. Log interpretation, log correlation, and subsurface mapping using this dataset has been completed using Petra.

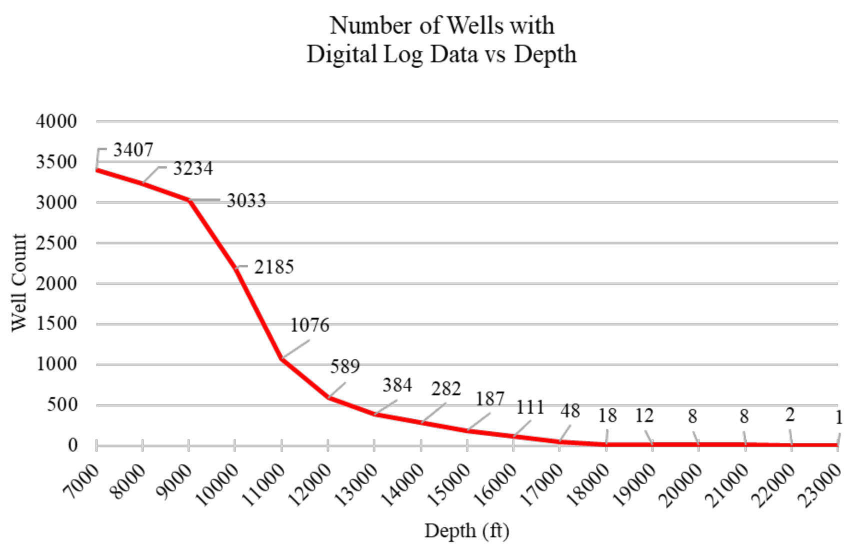

Figure 6: Cross plots showing the distribution of vertical wells with digital log data versus depth for the South Texas Geothermal AOI.

Digital log data were used to create a stratigraphic framework across the South Texas Geothermal AOI that spans from the Lower Cretaceous Sligo Formation to the Oligocene Frio Formation (Figure 7). The major formation tops were defined by gamma ray, resistivity, and bulk density log characteristics and petrophysical relationships. Eight major formation tops were picked and used to make regional structure maps across the AOI which from deepest to shallowest include: 1) the Sligo Formation, 2) the Pearsall Formation, 3) the Glen Rose Formation, 4) Edwards Limestone, 5) Buda Limestone, 6) the Austin Chalk, 7) the Olmos Formation, and 8) the Wilcox Formation (Figure 7). Regional depth structure maps were then compared to the depth to 250º F maps created by SMU (Blackwell et al., 2010) to determine the spatial distribution of formations with reservoir temperatures greater than 250º F. Combining these two sets of maps demonstrates that the Wilcox, Georgetown, Edwards, Glen Rose, Pearsall, and Sligo formations are the shallowest reservoirs across the research area that have reservoir temperatures capable of electrical power generation

(Figure 8). Consequently, multiple different geothermal play types are present across the South Texas Geothermal AOI based on the depositional trends within each of these formations.

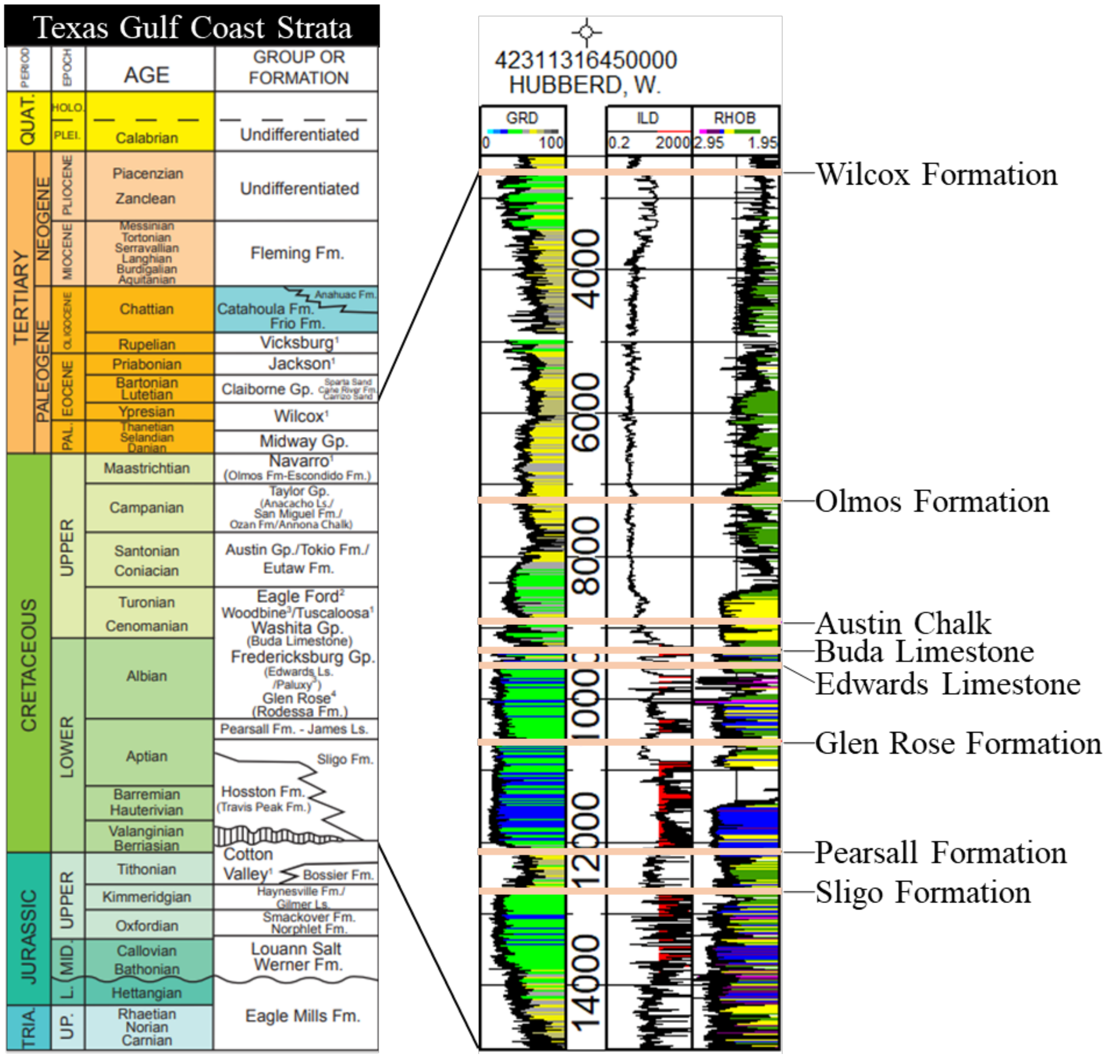

Figure 7: Stratigraphic column and type log for the South Texas Geothermal AOI showing the major formation tops that were correlated and mapped for the purpose of identifying what formations have reservoir temperatures greater than 250° F. Track 1 of the log display shows the gamma ray curve displayed from 0-100 API, where dark blue and green are lower API and yellow and gray are higher API. Track 2 shows the deep resistivity log on a logarithmic scale from 0.2-2000 ohms and shaded red for values greater than 50 ohms. Track 3 is the bulk density (RHOB) log scaled from 1.95-2.95 g/cm^3 where green and yellow are lower density formations (<2.65 g/cm^3) and blue, purple, and pink are high density formations (>2.71 g/cm^3). Stratigraphic column is modified from Swanson et al., 2013.

4. Geothermal Play Types of South Texas

Reservoir temperatures greater than 250° F, regional depth structure, and porosity greater than 10% are the three main geologic elements used to identify geothermal play types within the South Texas Geothermal AOI. Based on these three geologic elements, six geothermal play types were identified within the South Texas Geothermal AOI that span from the Early Jurassic strata through the Paleogene. Details of each geothermal play type are discussed below.

4.1 Aptian and Albian Shelf Margin Carbonates

The Lower Cretaceous of the Western Gulf Basin is dominated by multiple episodes of carbonate platform development that span across the entire basin leading to the deposition of the Albian Edwards and Glen Rose formations and the Aptian Sligo Formation. Carbonate platform morphology is one of the main controls on the spatial and temporal distribution of porous facies in these formations and the current depth of each formation controls the reservoir temperature. The shelf margin for the Edwards, Glen Rose, and Sligo are buried at depths of approximately 9,000 ft, 12,000 ft, and 16,000 ft, respectively and all have reservoir temperatures above 250º F. Additionally, density porosity calculations in each of these formations at their respective shelf margins show multiple intervals with porosity greater than 10% porosity, with some intervals approaching 20%. Consequently, the shelf margins for each of these formations contain the necessary requirements to be a potential geothermal target across the South Texas Geothermal AOI (Figure 9).

There are three key advantages to the Aptian and Albian shelf margin geothermal play types that will assist in exploring for prospects within these play fairways. First, the shelf margins follow well documented linear trends that have been defined by decades of oil and gas exploration across the research area (Ewing, 1991; Scott, 1990). Additionally, these shelf margin reefs and shoals have potential to have high permeability based on the types of lithologies deposited at the shelf margin. Lastly, these three shelf margins are all at temperatures above 250º F so brine production from each formation can be used for electrical power generation. However, some disadvantages exist to this geothermal play type, one of which is the unpredictable porosity and permeability relationships in shelf margin reefs and shoals that might be exacerbated based on diagenesis at the depths the shelf margins are buried at. For example, the top of the Sligo shelf margin is buried at a depth of approximately 16,000 ft across the research area, leading to challenges from both a drilling and economic standpoint. Despite these disadvantages, the Aptian and Albian shelf margins should be considered geothermal play types both within the research area and across the Western Gulf Basin.

4.2 Aptian and Albian Platform Interior Shoals

Also within the Aptian and Albian carbonate formations, platform interior shoals have the potential to be a geothermal target across the South Texas Geothermal AOI (Figure 9). Like the shelf margin facies, the spatial distribution of these depositional facies is controlled by the carbonate platform morphology and the reservoir temperatures are controlled by depth. The top of the platform interior facies of the Edwards, Glen Rose, and Sligo formations range in depths of approximately 5,900-9,000 ft, 7,400-11,800 ft, and 9,200-16,500 ft, respectively. Reservoir temperatures are greater than 250º F in both the Glen Rose and Sligo platform interior facies but are less than 250º F in the Edwards platform interior facies.

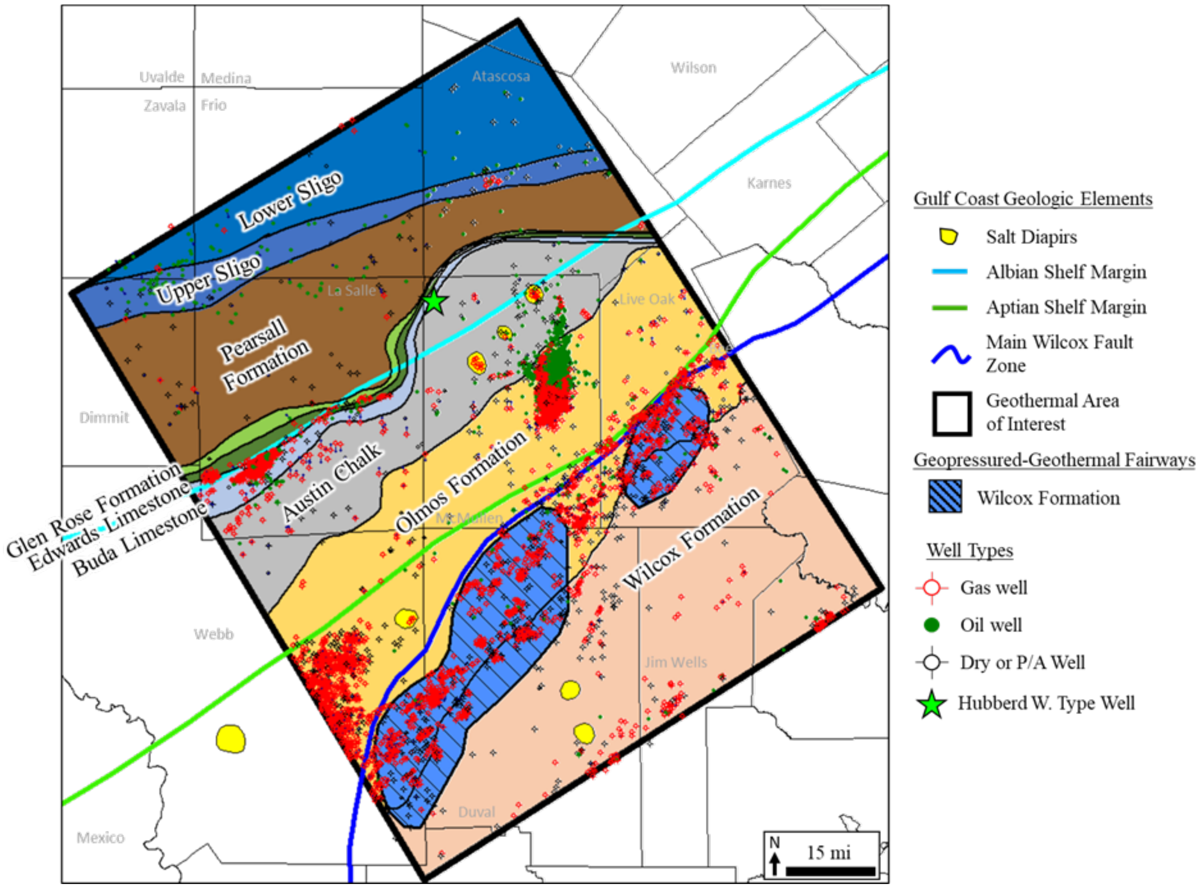

Figure 8: Geothermal play fairway map for the South Texas Geothermal AOI showing the location where the top of Cretaceous and early Paleogene formations first reach reservoir temperatures of 250° F based on the intersection between depth structure maps and the depth to the 250° F isotherm. The northern limit of each fairway denotes when that formation first intersects the 250° F isotherm. Location of salt diapirs from Condon and Dyman, 2006. Paleocene to Eocene geopressured fairways from Bebout et al., 1982. Aptian and Albian shelf margins from Ewing, 1991.

Density porosity calculations in these facies show multiple intervals with greater than 10% porosity, with some intervals approaching 20%. However, there are multiple intervals with wellbore washout in these facies so careful petrophysical analysis is needed here to correctly calculate porosity. Despite this, there are still multiple intervals in both the Glen Rose and Sligo formations that have reservoir temperatures and porosities suitable for electrical power generation. However, the Edwards platform interior is too shallow and cool across the research area to be used for electrical power generation but could still be considered a potential direct use application.

Similar advantages exist in this play type as in the shelf margin play type. The nature of platform interior shoals can lead to high permeability facies here and across most of the research area and the platform interiors of these formations exceeds 250° F. Also, the platform interior of the Aptian and Albian carbonates are at shallower depths as compared to their respective shelf margins, which will be favorable for drilling and economics. However, unlike the shelf margins, the spatial and temporal distribution of platform interior shoals is less predictable and unlikely to follow specific linear trends. Determining the location and areal extent of platform interior shoals is more challenging and they are likely to have unpredictable porosity and permeability trends. Despite these disadvantages, Aptian and Albian platform interior shoals should be considered a geothermal play type across both the South Texas Geothermal AOI and the Western Gulf Basin.

4.3 Maastrichtian Deltaic Sandstones

Depositional trends of the Upper Cretaceous Maastrichtian in south Texas are dominated by deltaic and marine sandstones of the Olmos Formation. In parts of the research area, the Olmos Formation has reservoir temperatures between 250º F and 280º F (uncorrected BHTs) and is buried at depths between 9,000 and 12,000 ft. Density porosity calculations show that some locations have over 100 ft of porosity greater than 10% and those areas are shown on Figure 9. Depositional facies described by Hamilton and Gottardi (2017) show that oil and gas production in the Olmos Formation within the research area mainly comes from delta front and slope deposits which suggests that off structure and along trend from these fields could have geothermal potential where temperature is greater than 250º F and porosities are greater than 10%. The main advantages of this play type are that it is buried shallower than the Aptian and Albian carbonates and the sandstones are likely to have more predictable porosity and permeability relationships. However, reservoir temperatures barely reach 250º F across most of the research area which might cause challenges for electrical power production.

4.4 Paleocene-Eocene Geopressured-Geothermal Systems

As discussed previously, the Paleocene geopressured-geothermal systems are important geothermal play types across the Texas Gulf Coast and the entire Western Gulf Basin. In the South Texas Geothermal AOI, two Wilcox geopressured-geothermal areas were identified by the BEG in the late 1970s and early 1980s (Bebout et al., 1982). The Wilcox Formation here was deposited across the entire research area and ranges in thickness from 450 ft to over 4,000 ft thick, where sandstones and shales were deposited on the downthrown side of large growth faults. In the northern part of the AOI, the Wilcox is buried at depths between 2,000 and 8,000 ft. However, south of the main Wilcox Fault Zone (Figure 9) the Wilcox is buried at depths from 9,000 to 15,000 ft and has reservoir temperatures over 300º F. Density porosity calculations show that most of the sandstone beds have porosities greater than 10%, with some beds close to 20%. For these reasons and the reasons defined by the BEG, the Wilcox geopressured-geothermal reservoirs are important geothermal play types both within the research area and across the Western Gulf Basin.

4.5 Salt Diapirs

Another important geothermal play type across the Western Gulf Basin and within the South Texas Geothermal AOI are salt diapirs because of their high thermal conductivity (4.250 W/m-K at 250º F) (Urquhart and Bauer, 2015). There are over 85 salt diapirs across the Texas Gulf Coast alone (Seni et al., 1985) and six within the research area (Figure 5 and Figure 9). Within the AOI, the depth to the crest of each diapir ranges from only 900 ft below the surface to over 7,000 ft. According to Jacoby and Paul (1975), the internal temperatures of Gulf Coast diapirs can range from 300º F to 580º F however, further research needs to be completed to determine the actual internal temperatures of diapirs within the AOI. However, the high thermal conductivity of halite suggests that salt diapirs could be a source of geothermal energy from two different play types. The first play type would be the diapir itself if closed loop wells could be used to extract heat directly from the diapir. Additionally, the second play type associated with salt diapirs would be targeting any heat anomalies in the reservoirs above them because of the high thermal conductivity of the diapir. Salt diapirs are complex structural and stratigraphic features, thus more research needs to be completed to understand their geothermal resource potential.

4.6 Repurposing Existing Oil and Gas Fields

Oil and gas fields that produce from formations south of the Albian (Edwards) shelf margins have potential to be repurposed for geothermal energy based on their reservoir properties, reservoir temperatures, and depths. Along the Edwards shelf margin, multiple gas fields are nearing the end of their production life and have repurposing potential for either electrical power generation or direct use applications (Figure 9). Additionally, AWP Field is the largest vertical oil and gas field within the research area and produces mainly from the Olmos Formation. This field contains over 1,000 wells that are nearing the end of their production life and could be repurposed for geothermal energy based on their reservoir characteristics, reservoir temperatures, and depths.

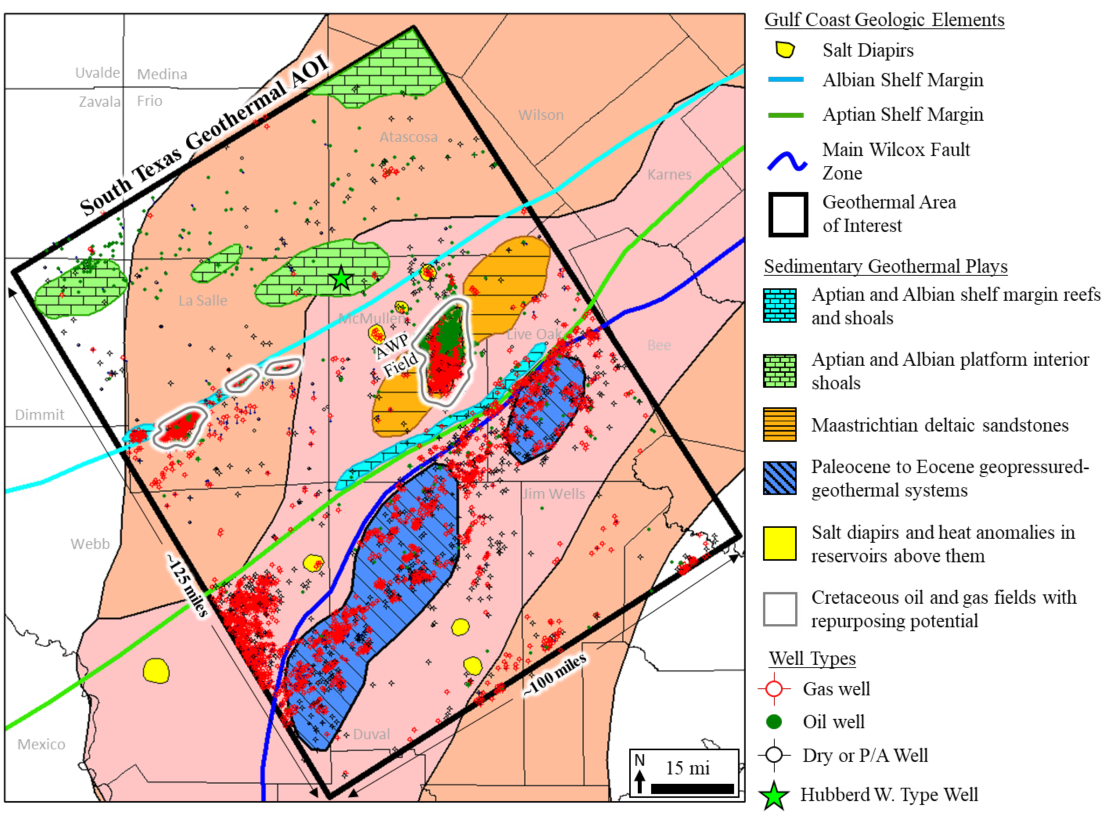

Figure 9: Geothermal play type map for the South Texas Geothermal AOI showing the location of different play types based on the criteria defined above. Temperature at depth contours from Blackwell et al., 2010. Location of salt diapirs from Condon and Dyman, 2006. Paleocene to Eocene geopressured fairways from Bebout et al., 1982. Aptian and Albian shelf margins from Ewing, 1991.

Lastly, numerous Wilcox fields south of the Aptian shelf margin also have hundreds of gas wells that are nearing the end of their production life and the necessary reservoir properties and temperatures for geothermal energy. However, extensive research needs to be completed in all these fields to determine what wells could be viable for geothermal energy based on wellbore integrity, fluid production, temperature, depth, and other variables. Wells within these fields could be converted to closed loop well designs, co-produced brine might be an option for geothermal energy, or some wells may even be able to be deepened to target geothermal play types in the Aptian and Albian carbonate systems.

5. Conclusions and Future Work

Based on previous research and subsurface data from this project, south Texas contains more geothermal play types than previously considered. Two Wilcox geopressured-geothermal systems are in close proximity to six salt diapirs and four Cretaceous formations with reservoir properties and temperatures capable of electrical power generation (Figure 10). Along with the play types associated with the Cretaceous and Paleogene formations, multiple oil and gas fields also have the potential to be repurposed for geothermal energy, either for electrical power generation or direct use applications. For these reasons, the Rio Grande Embayment subdivision of the Western Gulf Basin is an important research area for understanding what geothermal play types exist across the rest of the Texas Gulf Coast and the entire Western Gulf Basin. Beyond electrical power generation, the geothermal play types here also have direct use applications that range from assisting heavy oil extraction (Seni et al., 1994)) and refining, to providing power for green hydrogen production, or residential and commercial heating and cooling where markets overlap with the different play types (Figure 10). For these reasons, the geothermal energy potential of the Western Gulf Basin is only barely beginning to be understood.

5.1 Future Work

Now that these sedimentary geothermal play types have been identified, the next phase of this research project is to characterize a hot sedimentary aquifer associated with each play type. This will include petrophysical modeling, core description, and reservoir modeling to determine fluid production rates along with estimating the thermal depletion and recharge of each hot sedimentary aquifer. The final phase of this project will be combining all these elements into a techno-economic evaluation to determine the economic feasibility of developing these geothermal resources. These results will help to reduce some of the key risks associated with exploring for and developing geothermal resources in sedimentary basins. By identifying and characterizing the major geothermal play types in sedimentary basins, the geothermal energy sector becomes one step closer to delivering clean, renewable, baseload electricity to new regions of the United States not previously considered to have geothermal resources. Developing geothermal energy resources in these sedimentary basins will ultimately help to fight climate change by reducing greenhouse gas emissions from fossil fuel based electrical power generation as global energy demands continue to grow.

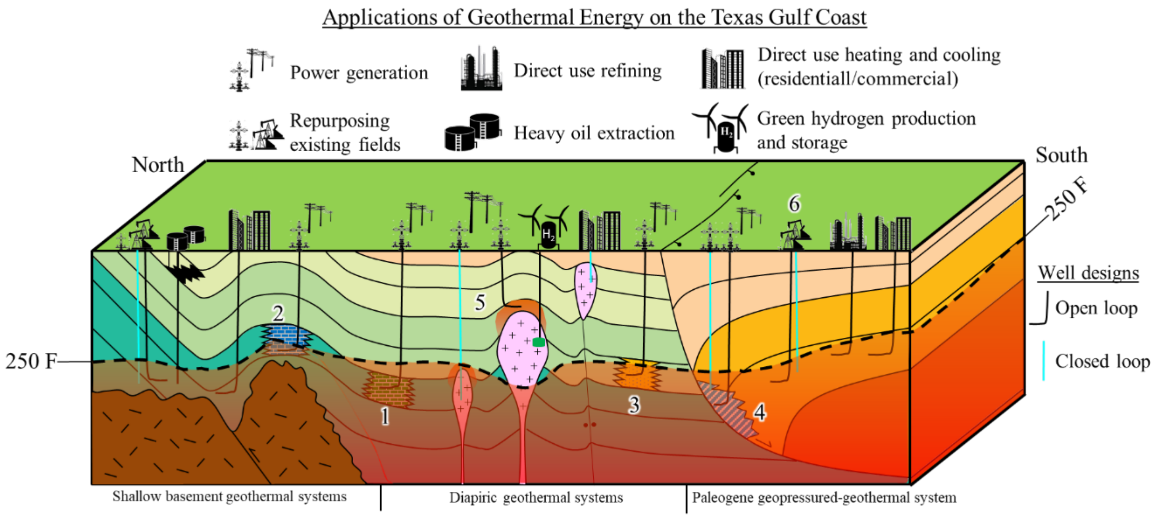

Figure 10: Schematic block diagram showing the distribution of sedimentary geothermal play types of the Rio Grande Embayment and the South Texas Geothermal AOI. 1) Aptian and Albian shelf margin reefs and shoals. 2) Aptian and Albian platform interior reefs and shoals. 3) Maastrichtian deltaic and marine sandstones. 4) Paleogene geopressured-geothermal systems. 5) Salt diapirs and heat anomalies in reservoirs above them. 6) Repurposing existing oil and gas fields for geothermal energy.

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