Eastern Texas Geothermal Mapping

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ABSTRACT

The idea of using oil and gas wells for geothermal energy production was brought to the forefront in 2005 and 2006 (McKenna et al., 2005; SMU Geothermal Energy Utilization Conference, 2006; Erdlac et al., 2006). This concept has prompted a review of existing research in Texas from the 1970s to 1990s on geopressure and a new resource assessment based on oil and gas well data. Through the combination of new and previous data sets, a series of temperature maps at depths ranging from 7000 to 14,000 feet for eastern Texas have been created. South Texas has the highest temperatures (420°F). The Gulf Coast geopressure resource is best defined and closest to electric markets, making this an initial first choice for development.

Introduction

A geothermal assessment for eastern Texas focused on the interpretation of temperatures for depths ≥7,000 feet, capable of electrical generation or high temperature direct-use applications (Richards et al., 2009). The research is based on wells and geology in the eastern half of Texas located between interstate I-35 and the eastern border of Texas. This area covers North Texas, East Texas, the Gulf Coast and South Texas. This regional focus was chosen because of the collocation of existing oil and gas fields and the higher heat flow shown on the Geothermal Map of North America (Figure 1.) (Blackwell and Richards, 2004a) and regional temperature at depth maps by Blackwell et al., (2006). This review of existing and new temperature data illustrates the compelling reasons Texas has to develop its geothermal resources.

Generalized Regional Geology

The geology of Texas is defined by numerous periods of uplift and regional seas creating numerous layers of sediments. The eastern and southern halves of the state were part of the collision of the European-African-South American plates forming Pangaea. As North America rifted away along the Texas Craton edge, the formation of the Balcones - Luling - Mexia fault zones were created allowing warm fluids to rise quickly along them and sustain elevated temperatures in the fresh water aquifers, such as the Trinity, Hosston, and Edwards. During the Middle Jurassic the East Texas and Gulf Coast basins started filling in with deposits of marine salt and sand/shale sediments which continues to build new land mass towards the Gulf of Mexico. Initially the sediment flow was dominated from the western side of the Gulf Coast (now South Texas and Central Gulf Coast) during the Eocene and Oligocene; deposition gradually shifted eastward, where it is today, with sediment primarily from the North and East (Mississippi Delta) (Salvador, 1991). The older sediments

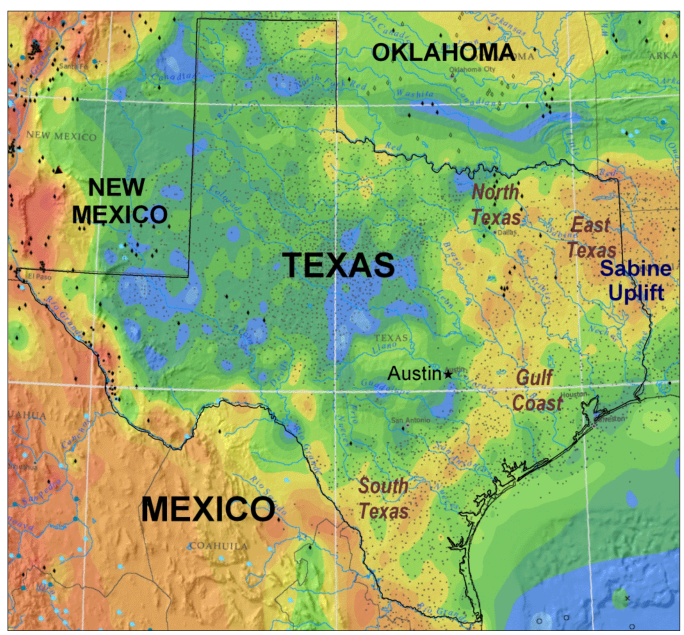


Figure 1. South-central portion of the Geothermal Map of North America (Blackwell and Richards, 2004a) with the Texas State boundary, and regional areas highlighted.

have equilibrated to the background geothermal gradient associated with the basement rocks below. These gradients are associated with increased temperatures on the western side of the Gulf Coast (South Texas) and in bands following the current shoreline according to sediment age.

The East Texas embayment and the Sabine Uplift dominate East Texas and into Louisiana. The overlying sediments are similar in age to the Gulf Coast. The Sabine uplift is basement rock with a unique composition which contains higher levels of natural radioactive decay than other basement rocks in the region. This impacts the sediments in the vicinity of the Sabine Uplift and increases the geothermal gradient and heat flow for the area (Figure 1).

Data Collection Methodology

The geothermal temperature data used in this assessment consists of five data sets (Figure 2). The newest is the SMU Geothermal Laboratory Texas Oil/Gas Temperature database (SMU-TOGT) extracted from well log headers from the Railroad Commission Districts 1 to 6 [4887 wells]. The second largest dataset is the Texas subset of the American Association of Petroleum Geologist Geothermal Survey Well Data (AAPG-GSW) (AAPG COSUNA Data_ROM, 1994) [2498 wells]. Thsee data were collected as part of the Geothermal Gradients Map of North America (DeFord and Kehle, 1976) from oil and gas wells. Other data sets in this assessment are the Gulf Coast Gregory et al. (1980) data which focused on geopressure data [654 wells]. The Fairway Field dataset was from collaboration with the Hunt Oil Company to review wells drilled over a 40 year period from 1965 to 2005 [148 wells]. Lastly, data from a previously detailed thermal study for Freestone County (Burns, 2004) used oil and gas well log headers [174 wells].

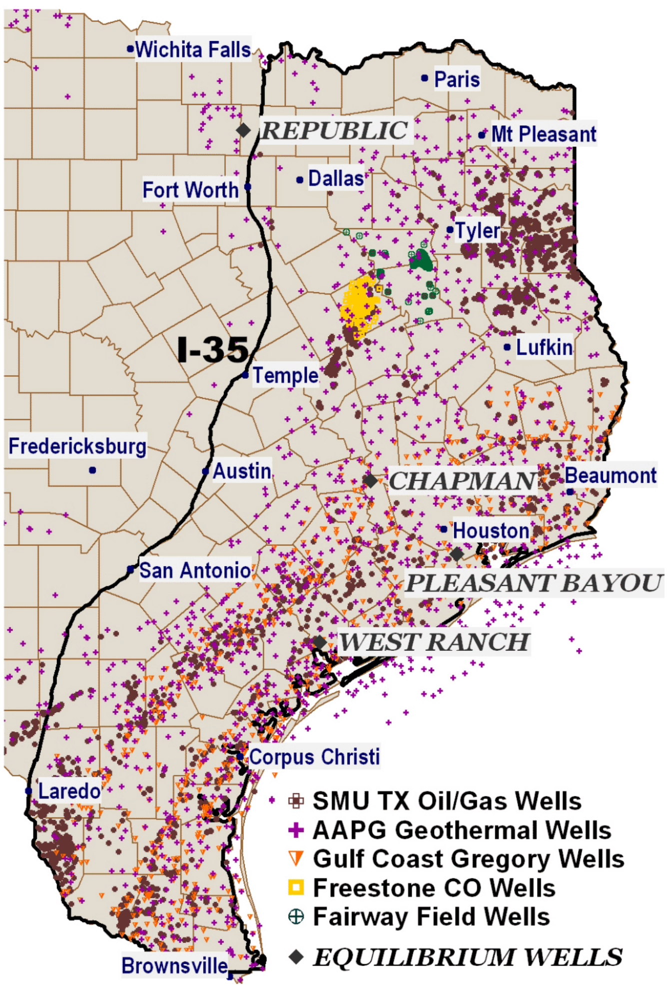


Figure 2. Location of data used in this report: SMU Texas Oil/Gas Temperature Database brown cross symbols, AAPG Geothermal Survey Well Data pink cross symbols, the Gulf Coast Gregory et al. (1980) data orange triangle symbols, the Freestone County (Burns, 2004) data yellow square symbols, and the Fairway Field (Hunt Oil and Kweik, 2009) green round symbols. The locations of equilibrium wells are shown as black diamonds.

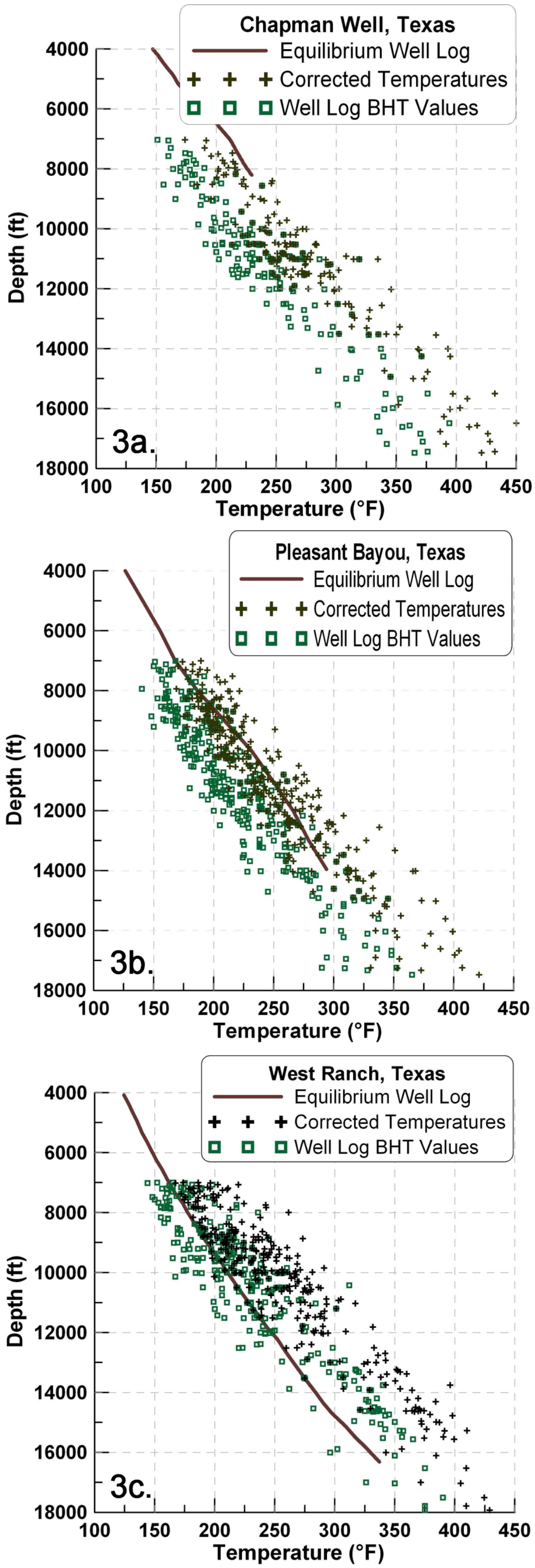
Data Corrections

When drilling a well, fluid is injected and circulated to the drill head to cool the bit, stabilize the walls, and clear the cuttings from the borehole. The mud and fluids impregnate the surrounding rock formations, thereby cooling the borehole at the deeper depths according to the surface air temperature, drilling speed, type of drilling fluid, etc. Many factors affect the time needed for a well to return to the in-situ temperature (equilibrium) including the thermal conductivity of the rock formations, pore fluid movement, and drilling conditions. This process of reequilibrating usually takes a few months depending on the post-drilling activities (Harrison and Luza, 1985).

To adjust for the difference in temperature, the well log header temperatures (BHT) are given a correction. There are various types of temperature corrections that can be applied to the BHT value to calculate the approximate equilibrium temperature. This is usually done based on the time since circulation recorded with the BHT reading, or derived from an empirical correction for the depth. The correction used by Harrison is a second order polynomial correlated to depth (Blackwell and Richards, 2004b; Harrison et al, 1983; Harrison and Luza, 1985). This correlation of temperature changes as a function of depth. It was applied to the raw well log data in the SMU TOGT, Fairway Field, and Freestone County.

In order to assess the validity of the calculated equilibrium temperature, the new values were checked against equilibrium well logs. The well locations (Chapman #1, Republic, and West Ranch 496) were previously logged using high-accuracy temperature logging gear (Wisian et al., 1996; and Negraru et al., 2008). An additional temperature log from the Pleasant Bayou well was used (Institute of Gas Technology, 1992). The equilibrium wells and their surrounding area wells are shown in Figure 2. Example plots of the Chapman and Pleasant Bayou wells show the difference between the well log data values and the corrected equilibrium values (Figure 3 a, b, c). The data shown are plotted according to their location being within ±0.5° of latitude and longitude around the primary equilibrium well location.

The equilibrium temperature graphs show how the log header data is generally too cold in comparison to the calculated equilibrium temperature for each site. The West Ranch well has the least correlation to the corrected data. This may be from the water flooding of the field to increase hydrocarbon production, cooling the original deeper formation temperatures.



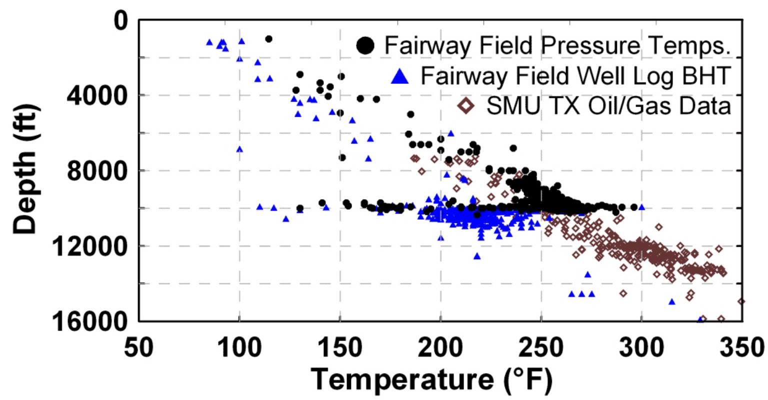


Figure 4. SMU Texas oil/gas temperature data locations within or near the Fairway Field showing the corrected values versus the averaged Fairway Field pressure data temperatures.

The Fairway Field pressure data were used to review the application of the Harrison Correction on the raw BHT values from the production well drilling records (Figure 4). Pressure data are collected with a temperature value throughout the life of a well. These are not considered equilibrium temperature measurement because the well is active and has been flowing. They represent values not influenced by drilling fluids, so are considered close to equilibrium. The pressure data has differing values for a specific well which can be used to indicate a reasonable spread of temperatures at that depth. These temperatures usually vary 10 to 25°F for a similar depth measurement as shown by the sample set of wells in Figure 5.

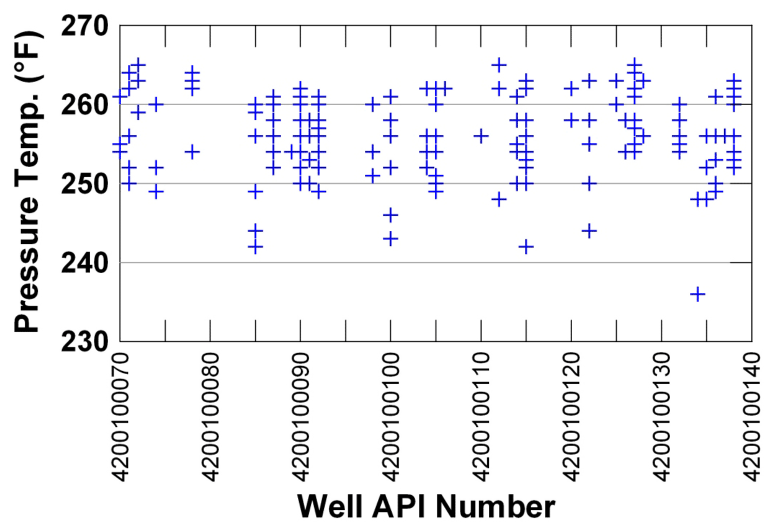
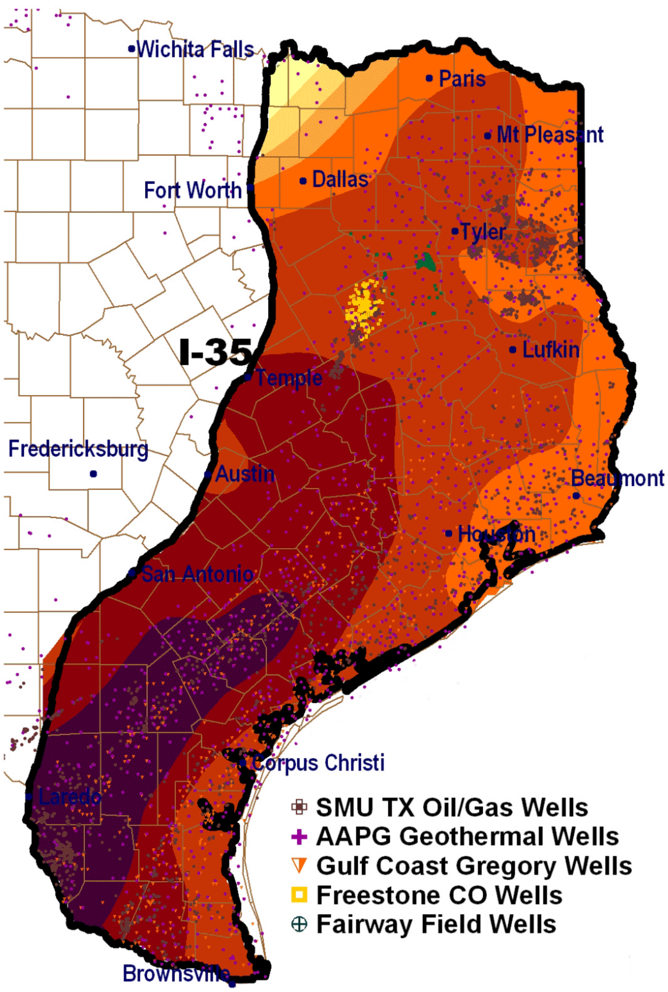


Figure 5. Fairway Field temperatures from pressure logs. Individual well sites are shown with the temperature readings over time. Each vertical line of data represents one well listed by API number along bottom axis and temperature °F on vertical axis.

Mapping the Data

Maps were produced from 3-Dimensional lattices and 2-Dimensional grids. The 3-Dimensional lattices are able to take into consideration the gradients of data in all directions and use it to create smooth contour

Figure 3 a, b, c. Equilibrium temperature well log shown as a brown line with the original BHT values shown as green square symbols and the final corrected equilibrium data shown with black cross symbols.



Figures 6. Example of 3-Dimensional temperature grid at 14,000 feet depth.

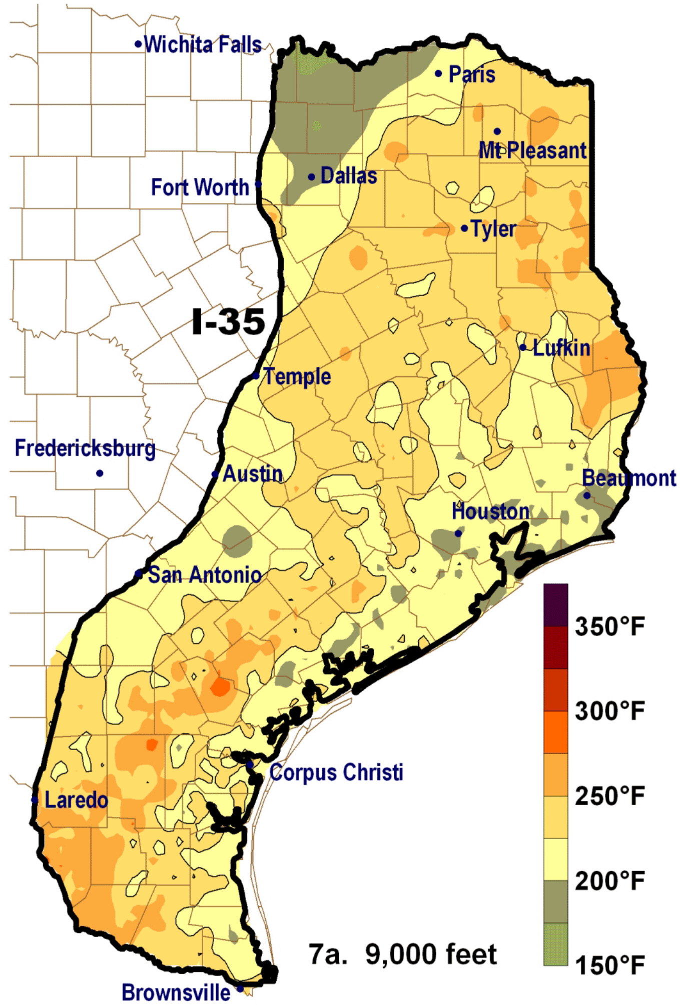


Figure 7a. Map of temperatures at 9,000 feet detailed at the county level.

maps of temperature at any depth slice between 7,000 and 14,000 feet (Figure 6). The maps show the general regional trend of the data temperatures.

Next the data were used to generate a 2-Dimensonal set of maps at 9,000 and 12,000 feet focused on the county level (Figure 7 a, b). To generate a map for 9,000 and 12,000 feet, only the wells with depth values of ± 2000 feet from the mapped depth were selected. At this detail the location of data points is clearly shown. Although there are counties with little to no data, it is helpful to see where the county sits within the larger temperature trends for the region. Where there is data, it is relatively densely located; therefore the average distance between data points is approximately 3.6 square miles. The depths of 9,000 and 12,000 feet were chosen for the 2-Dimensional detailed maps because 9000 feet is the initial depth where most of eastern Texas is near 200°F. Temperatures at 12,000 feet were chosen because the majority of deep oil and gas wells in this area are completed between 12,000 and 13,000 feet. This depth range is representative of what is currently available to use as a geothermal power exploration tool.

The corrected temperature data show that by 9000 feet, the majority of the area east of the Interstate I-35 corridor is at 200°F or hotter (Figure 7a). The two primary areas with a concentration of temperatures less than 200°F is North Texas where values are in the 150-175°F range, and the first coastal band along the Gulf Coast intermixed with temperatures of 175°F to over 200°F. The hottest areas at 9000 feet are located in East and South Texas with temperatures reaching 250°F to over 275°F.

At 12,000 feet (Figure 7b), throughout the entire area, temperatures reach at least 200°F and more are often at or above 250°F. The hottest area is East and South Texas with temperatures commonly over 300°F, some measuring as high as 350°F.

Values continue to increase with depth such that at 13,500 feet the corrected temperatures are consistently over 300°F. At 14,500 feet the average corrected temperature value is almost 350°F. This assessment's deepest well drilled is in South Texas along the Gulf Coast, in Brooks County, reaching depths of 19,829 feet with a temperature of 404°F. The hottest well is in Duval County, also South Texas, at 420°F measured from 17,030 feet deep.

It should be noted that the deeper temperatures in East Texas are predicted to be hotter than South Texas and the Gulf Coast areas due to the basement rock of the Sabine Uplift having high heat flow due to high levels of natural radioactivity. East Texas has limited accuracy for depths >12,000 feet since oil and gas fields

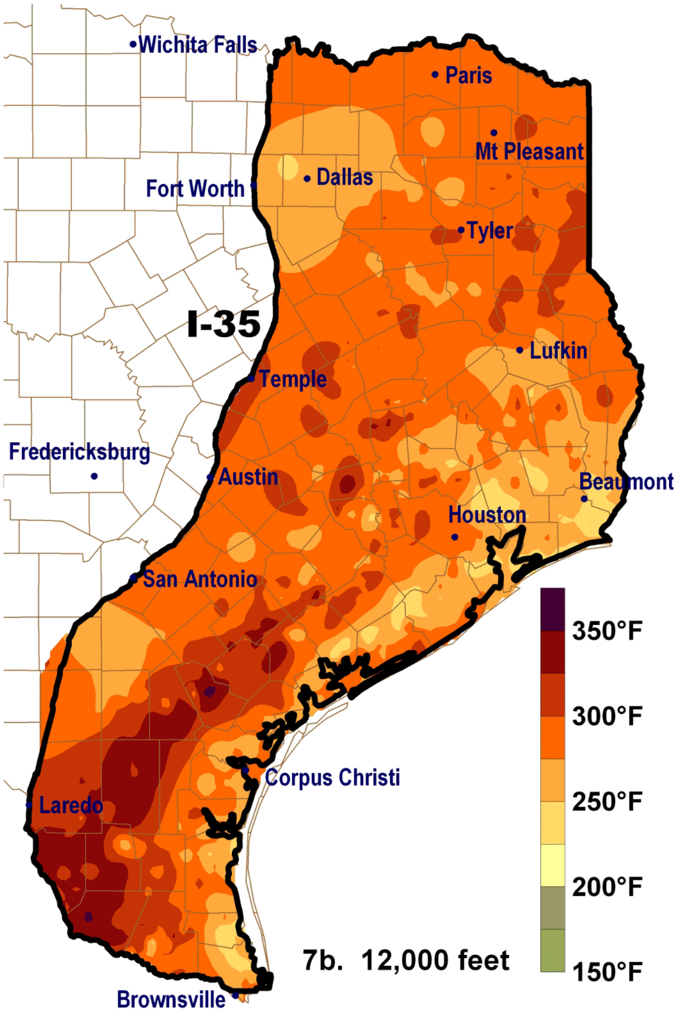


Figure 7b. Map of temperatures at 12,000 feet detailed at the county level.

are usually more shallow in this area. At 9,000 feet East Texas is warmer than North Texas and similar to South Texas.

Geothermal Resource Utilization

This eastern Texas Geothermal Assessment used the resources accessible through reasonable drilling depths associated with oil and gas wells. The advantage of this method is the ability to review the Earth at depth, reducing exploration costs. When working with existing oil and gas fields, there is existing infrastructure necessary for geothermal project development, i.e., roads, well pads, electrical connections to the grid, etc. There are hundreds of thousands of exajoules of thermal energy to be extracted under Texas (Tester et al., 2006, Richards et al., 2008 and 2009). Since Texas has extensive and diverse geothermal resources for electrical production it is helpful to divide them into three categories: 1) geopressured resources, 2) coproduced fluids, and 3) enhanced geothermal systems (EGS). The Gulf Coast geopressure resource is the main scenario for large-scale energy production in Texas because of the pressure and fluid flow. Most of East and North Texas oil and gas fields are more applicable to coproduced projects on a smaller basis or site specific projects tapping into the deeper formations. South Texas has the highest temperatures so it maybe ideal for EGS analysis. Drilling into the basement rocks of East Texas is the other potential focus area for EGS.

Many wells in Texas have temperatures less than 200°F with high water flow rates. In these situations the water production should be reviewed for economic applications. The warm water can be used for: absorption chillers, heavy oil extraction, heating/cooling buildings, sulfur extraction, coal desulfurization, chemical processing, water desalination, fish farming, greenhouse heating, cane sugar processing, and lumber drying (John et at., 1998). There are numerous ways to tap into the Texas geothermal resources.

References

AAPG, American Association of Petroleum Geologist, 1994. CSDE, COSUNA, and Geothermal Survey Data_Rom.

Blackwell, David and Maria Richards, 2004a. Geothermal Map of North America, AAPG Map, scale 1:6,500,000, Product Code 423.

Blackwell, D.D. and Maria Richards, 2004b. Calibration of the AAPG Geothermal Survey of North America BHT Data Base, AAPG Annual Meeting, Dallas, TX, Poster session, paper 87616.

Blackwell, David D., Petru T. Negraru and Maria C. Richards, 2006. Assessment of the Enhanced Geothermal System Resource Base of the United States, Natural Resources Research, Springer Netherlands, v 15/4, 283-308, DOI 10.1007/s11053-007-9028-7.

Burns, Steven W., 2004. Depositional environments and associated facies of the Late Jurassic Bossier Formation, Freestone County, East Texas Basin, SMU Master's Thesis.

DeFord, R.K., and R.O. Kehle, 1976. Geothermal gradient map of North America: AAPG and USGS, scale 1:5000000.

Erdlac, R.J., Jr., L. Armour, and R. Lee, 2006. A Resource Assessment of Geothermal Energy Resources for Converting Deep Gas Wells in Carbonate Strata into Geothermal Extraction Wells: A Permian Basin Evaluation: DOE Contract DE-FG36-05GO-85023.

Institute of Gas Technology, 1992. Testing of the Pleasant Bayou Well through October 1990. Eaton Operating Company USDOE Report for Contract DE-AC07-85ID12578. 218 p.

Harrison, W.E., and K.V. Luza, 1985. Monitoring temperature conditions in recently drilled nonproductive industry boreholes inn Oklahoma. DOE Technical Report 12172-T2.

Harrison, W.E., K.V. Luza, M.L. Prater and P.K. Cheung, 1983. Geothermal resource assessment in Oklahoma: Oklahoma Geological Survey Special Pub SP 83-1, 42 p.

Hunt Oil and Ramsey Kweik, 2009. Fairway Field oil and gas well data, SMU Geothermal Laboratory, Dallas Texas.

John, Chaco, Gina Maciasz, and Brian J. Harder, 1998. Gulf Coast Geopressed-Geothermal Program Summary Report Compilation for DOE contract DE-FG07-95ID 13366, Basin Research Institute at Louisiana State University, Vol 1 - 4.

Kehle, R.O., R.J. Schoeppel, and R.K. Deford, 1970. The AAPG Geothermal Survey of North America, Proceedings of the United Nations symposium on the development and utilization of geothermal resources, Geothermics, 1, pp. 358-367.

McKenna, Jason, D. Blackwell, C. Moyes, and P.D. Patterson, 2005. Geothermal Electric Power Supply Possible from Gulf Coast, Midcontinent Oil Field Waters: Oil & Gas J., p. 34-40.

Negraru, Petru, David D. Blackwell, and Kamil Erkan, 2008. Heat Flow and Geothermal Potential in the South-Central United States, Natural Resources Research, DOI: 10.1007/s11053-008-9081-x. http://www.springerlink.com/content/w8141135q47331q4.

Salvador, Amos, 1991. Origin and development of the Gulf of Mexico basin, in Salvador, A., ed. The Gulf of Mexico basin: Boulder, Colorado, Geological Society of America, The Geology of North America, v. J.

Richards, Maria, Richard Erdlac, and Janet Abbott, 2008. Texas Geothermal Energy, Chapter 7 in 2008, Texas Renewable Energy Resource Assessment http://www.seco.cpa.state.tx.us/publications/renewenergy/.

Richard, Maria, David Blackwell, Patrick Stepp, Ramsey Kweik, 2009. Texas Geothermal Assessment for the I35 Corridor East, Texas SECO Contract CM709.

SMU Geothermal Energy Utilization Conference, 2006. Abstracts and Presentations, http://smu.edu/geothermal/Oil&Gas/Oil&GasPresentations.htm.

Tester, Jefferson, Anderson, B., Batchelor, A., Blackwell, D., DiPippo, R., Drake, E., Garnish, J., Livesay, B., Moore, M. C., Nichols, K., Petty, S., Toksoz, N., Veatch, R., Augustine, C., Baria, R., Murphy, E., Negraru, P., Richards, M. 2006. The Future of Geothermal Energy: Impact of enhanced geothermal systems (EGS) on the United States in the 21st century. MIT, DOE Contract DE-AC07-05ID14517 Final Report, 374 p.

Wisian, K.W., D.D. Blackwell, S. Bellani, J.A. Henfling, R.A. Normann, P.C. Lysne, A. Förster, and J. Schrotter, 1996. How hot is it? A comparison of advanced temperature logging devices, Trans. Geothermal Resources Council, pp. 427-434.