GEO 327G Semester Project

Comparison of Temperature Variation in Deep Sandstone Reservoirs of Coastal Onshore and Offshore Louisiana

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I. Problem

The goal of this study is to determine if temperature variation in deeply buried sandstones follows the same trend along the coast of Louisiana in onshore areas as it does in the near offshore. An offshore model for the northern continental shelf of the Gulf of Mexico was previously developed using ArcGIS (Nagihara, 2006). Using the 92^{0}W longitude as the approximate line of demarcation between western and eastern regions, this model (see **Figure 1.1**) predicts higher subsurface temperatures in western Louisiana and cooler temperatures in eastern Louisiana. This trend of decreasing temperature towards the east should be consistent onshore because variability in the reservoir properties of the two regions has been observed (Dutton, 2010). In order to test this hypothesis, attribute tables of point data from wells located in seven coastal, onshore parishes of Louisiana (See **Figure 1.2**) will be imported into ArcGIS and spatially interpolated into a raster map of thermal conditions at depths of 8,000ft (2.4km).

II. Data Collection

There are 114 wells for which well log header and scout report data were collected as part of a larger study for the Deep Shelf Gas research unit at the Bureau of Economic Geology. I created this set of onshore well data while I was employed at the Bureau of Economic Geology in the Deep Shelf Gas research unit during the summer of 2010. The methods applied to gather and process the data were developed by my superiors and are not the results of my own independent efforts (Dutton, 2010).

The information used to calculate subsurface temperature for each well was sourced from two online databases. The well logs were found on the Louisiana Department of Natural Resources website (SONRIS) and the scout reports came from IHS Worldwide's Enerdeq database. The latitude and longitude of the well locations listed in the IHS scout reports are in units of decimal degrees with North American Datum 1927 (NAD27) as the projection system.

There were three properties documented from well log headers in order to calculate temperature at the desired depths. The data recorded for each well were total depth (TD) as measured by the driller, bottom-hole temperature (BHT), and time since circulation. There is always a period of time between when a well is drilled and when the logging tool reaches the bottom of the wellbore where a BHT measurement can be taken. In order to achieve precise readings, a temperature correction must be used to account for this period of exposure.

Applying a correction method known as time since circulation yields a predicted value for the sediment temperature at the bottom of the wellbore before it was disturbed by the drilling process. The time since circulation and the BHT are the inputs required by the computer model used. Then, by dividing the corrected bottom-hole temperature by the TD (see ***Formula 2.1***), the geothermal gradient can be calculated (Dutton, 2010). Using the geothermal gradient, a close approximation of the temperature at any depth can then be found. This calculation was performed for each of the wells in the study.

Geothermal gradient (F^0/100ft) = (Corrected Bottom Hole Temperature/TD) x 100

(Formula 2.1)

Creating raster map involved making calculations of temperature conditions at a depth of 8,000ft for each well. Even though Nagihari's study was conducted at a depth of about 16,500ft, these data do not support extrapolation as deep because less than a third of the wells studied extend beyond 14,000ft, as seen in **Figure 2.1**. Furthermore, the purpose of the study is to compare temperature trends, not actual temperatures.

The area of interest contains the seven Louisiana parishes (east to west) of Cameron, Vermilion, Iberia, Saint Mary, Terrebonne, Lafourche, and Plaquemines. These areas were chosen because together they define most of the gulf coast of Louisiana and will be well-suited for comparison to offshore results. The maps onto which these data have been overlain came from two USGS resources. Onshore maps for the coastal parishes were created in a raster viewer and downloaded from the USGS Seamless Server. For coastline reference, a map of Federal Offshore OCS boundaries was downloaded from the USGS Coastal and Marine Geology Program Internet Map Server for the U.S. and Gulf of Mexico.

The metadata for the USGS Louisiana parish map show that the horizontal datum used is NAD83 and the latitude and longitude in decimal degrees are accurate to six decimal places. By rough calculation (110,600m/decimal degree), this means that the data are accurate to +/-11cm, which is a more than acceptable amount of error for these purposes. The Federal Offshore OCS boundaries metadata show that the shape file was created with data sourced from the Minerals Management Service in a 1997 survey whose horizontal datum is NAD27. There are no metadata for the wellbore point data because they are sourced in an attribute table created from scout reports rather than a downloaded GIS resource. However, finding the projection of the IHS longitude and latitude data (NAD27) was essential to producing proper maps. Since the study only concerns subsurface processes, no vertical geodetic datum reference was part of the metadata for the files used.

III. Data Processing

After all the well data for the BEG study were completed and the USGS maps were gathered, the well data tables needed to be reorganized and formatted so that data not pertaining to this project could be eliminated and the attribute tables could be imported. Although this was not a necessary step due to the ability of ArcGIS to join tables via a key field, such as well name in this case, doing so greatly simplified the process. The tables originally created for the BEG study were massive and contained much more information than required for this task. In addition to trimming the number of columns down to only those containing relevant variables, the text cells needed to be formatted as text and the number cells were formatted as numbers with the proper number of decimal places. The latitude and longitude from IHS scout reports contained nine decimal places, the geothermal gradient had eight decimal places, and the subsurface temperatures were rounded to whole integers for the purpose of creating a contoured raster much like Nagihara's. The calculated subsurface temperature at 8,000ft was found using the following formula:

Subsurface Temperature = [Geothermal Gradient (Fahrenheit degrees/100ft) x (Depth of Interest/100)] + 68.5^{0}F

(Formula 3.1)

The mean annual surface temperature for the state of Louisiana is 68.5^{0}F (Dutton, 2010), which is included in Formula 3.1 to account for the fact that the surface temperature of Louisiana is not zero. The gradient only describes the rate of change beneath the surface. Once the down-hole temperature at 8,000ft for all the wells was calculated, the attribute tables were complete. Then, the excel worksheet was saved in CSV (comma-delimited) format and imported into ArcMap.

IV. ArcGIS Processing

Preparing the data layers for display in ArcGIS involved a number of steps. The first required converting the projection of the USGS Louisiana parish maps from NAD83 to NAD27. This was accomplished in ArcCatalog using the Project Tool, which can be found under Data Management>Projections and Transformations> Feature>Project. The type of geographic transformation selected was NAD_1927_To_NAD_1983_NADCON (See **Figure 3.1**). The federal offshore lease block polygon was already projected in NAD27, so re-projecting it was not necessary. That layer was edited using the Create New Feature tool (with snapping set to vertices) and clipped to the area only on the Louisiana coast. It was then colored light blue and labeled with a plain text box as the Gulf of Mexico. This polygon is seen in Figure 1.2 and Figure 3.3. Advanced processing methods were not applied to this layer because it served only as reference.

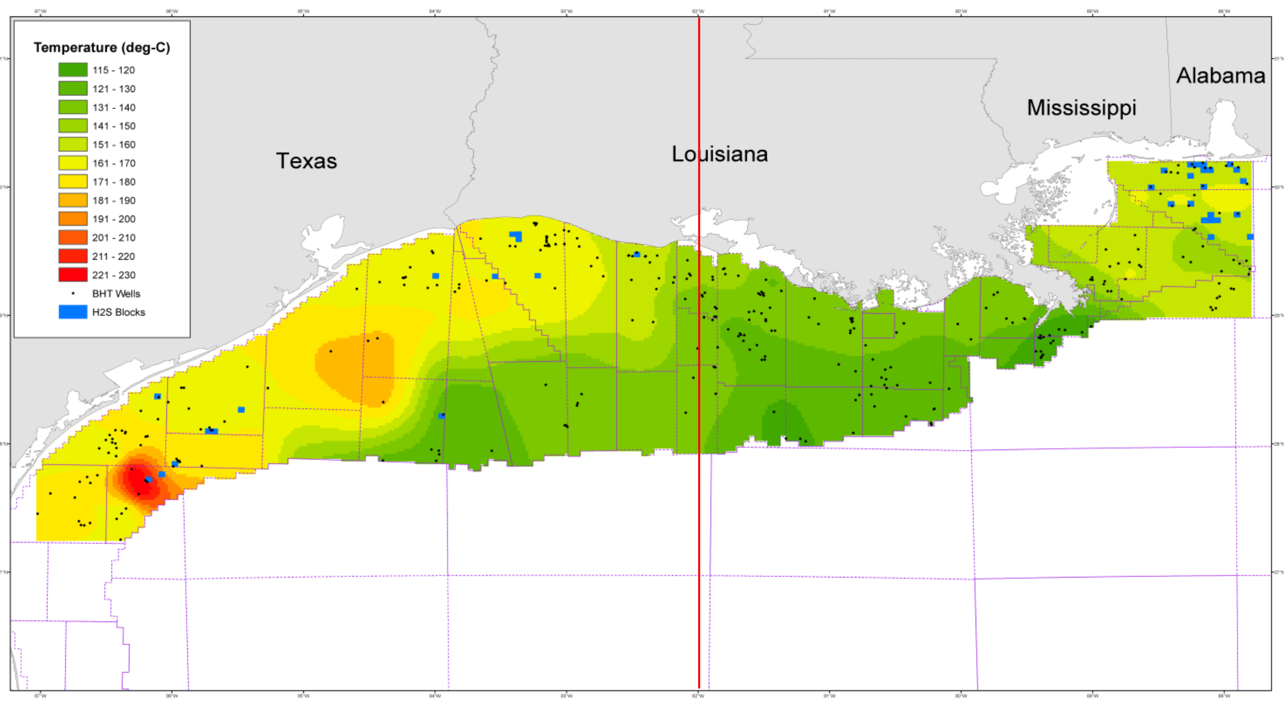
By using the Add XY data… function under Tools on the top toolbar of ArcMap, the well attribute table was imported and then converted to a shapefile. As shown, the fields for X and Y were Longitude and Latitude and the Geographic Coordinate System had to again be set to NAD27 (See **Figure 3.2**). In order to make these imported locations a point shape file, the data had to be exported and added to the map as a layer. After this step was accomplished, the well locations could now be displayed on the parish map in the proper projection (See **Figure 3.3**).

In order to later use only the area of the seven Louisiana parishes as a mask for the raster, a clipped shape file for the polygons of these parishes had to be created. This was accomplished by using Selection>Select by Attributes and querying the entire Louisiana county shapefile attribute table for those whose COUNTY attribute matched the seven chosen ones (See **Figure 3.4**). This step was necessary to create the map of the counties shown in **Figure 1.1**. The use of dynamic labeling was also applied to this new layer by turning on the label manager tool and clicking on the desired parishes in the area of interest to clearly label them (as seen in Figures 1.1 and 3.3).

The next step involved creating a raster image using the attribute field of temperature at a depth of 8,000ft. After turning on the Spatial Analyst extension under Tools>Extensions>Spatial Analyst, the options for creating the raster were set. At first, using the Spline technique appeared to be the most appealing because it created a smooth surface. However, it predicted maximum and minimum temperature values hundreds of degrees from the possible ranges. Instead the Inverse Distance Weighting technique was used since the data have less than 100^0F of variation. Specific options chosen for the layer's display included setting the clipped parish shape file as a mask and using a two standard deviation stretch on the color bar. This option allowed for maximum color variation over the desired range (See **Figure 4.1**).

V. Data and Figures

Sedimentary Temperature at 5 km Below Seafloor
Northern Continental Shelf, Gulf of Mexico



Geographically interpolated estimates of sedimentary temperature at 5 km sub-seafloor. Dots show the locations of the VRT-yielding wells. Blue squares show the locations of previously reported hydrogen sulfide occurrence deeper than 4 km.

Seiichi Nagihara, Texas Tech University, July 2006.

Figure 1.1-The results of Seiichi Nagihari's 2006 offshore study, with 92°W longitude marked in red.

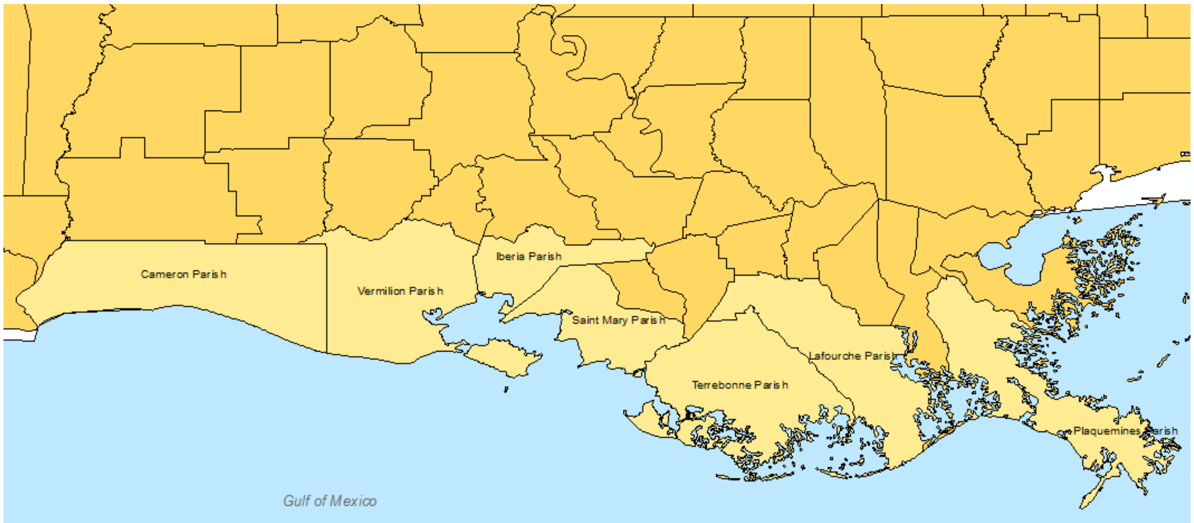


Figure 1.2-a map of coastal Louisiana with the seven parishes of interest highlighted

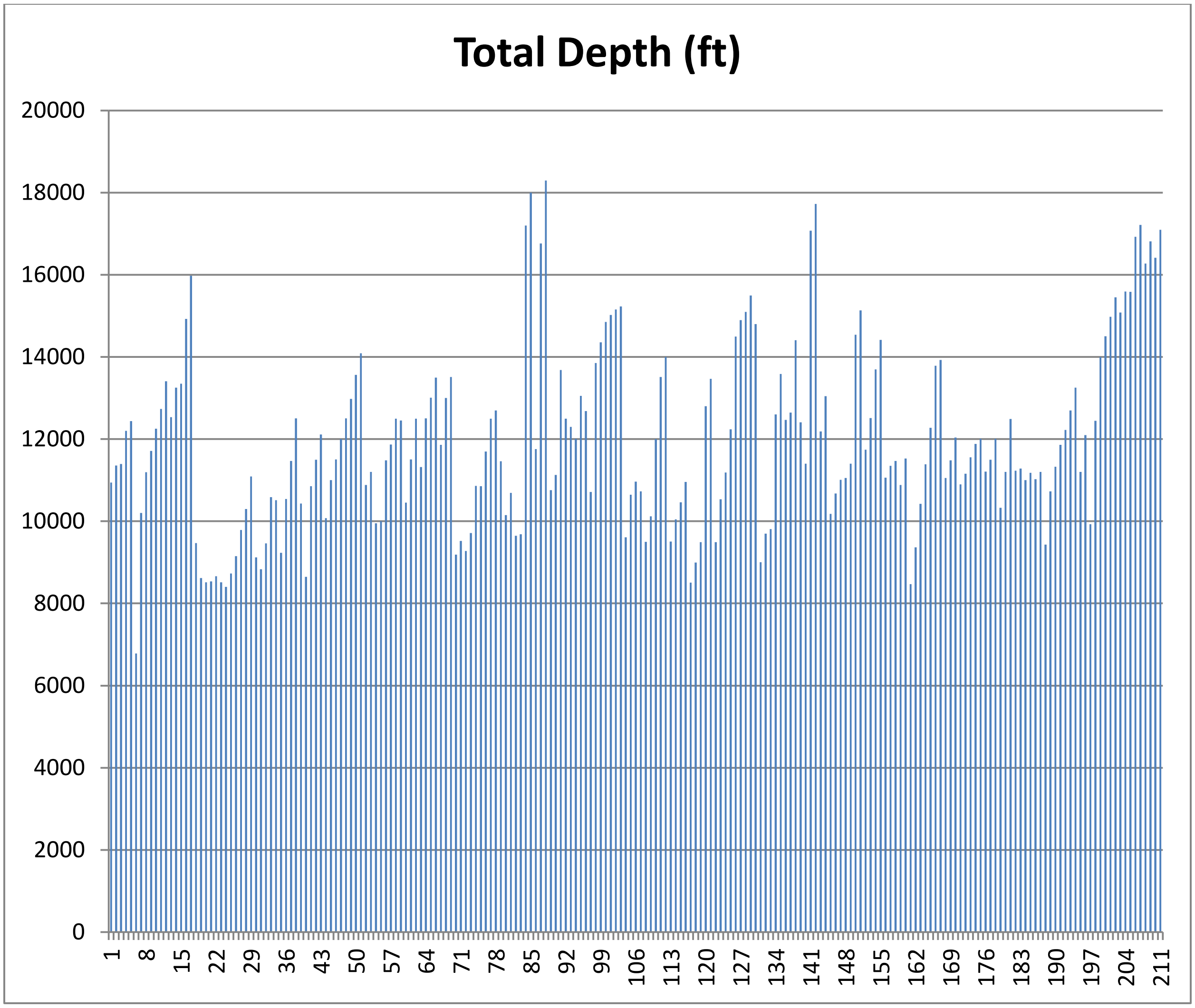


Figure 2.1-Plot of Well Depths

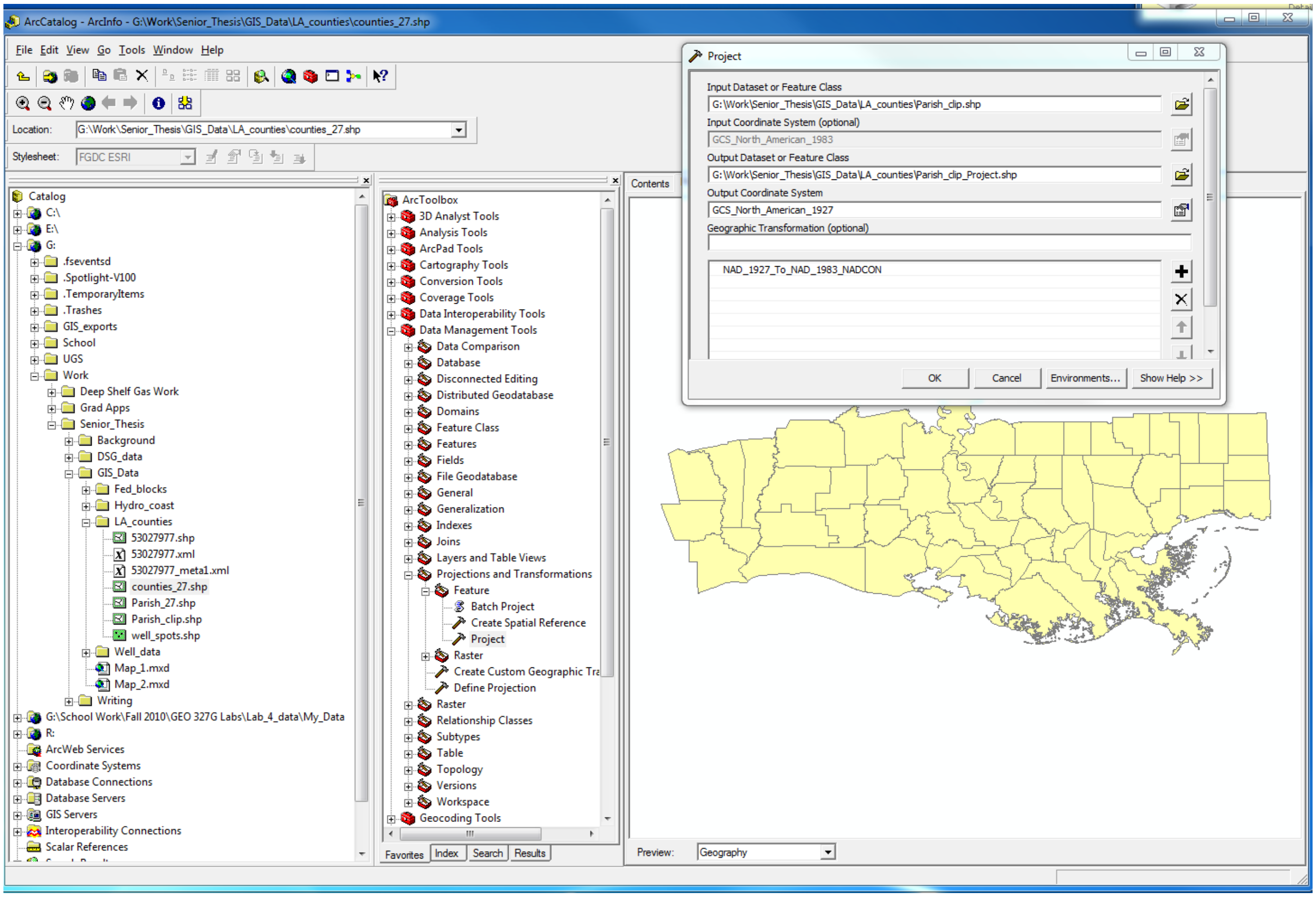


Figure 3.1-Reprojection of the Louisiana Parishes to NAD27 using the Project Tool

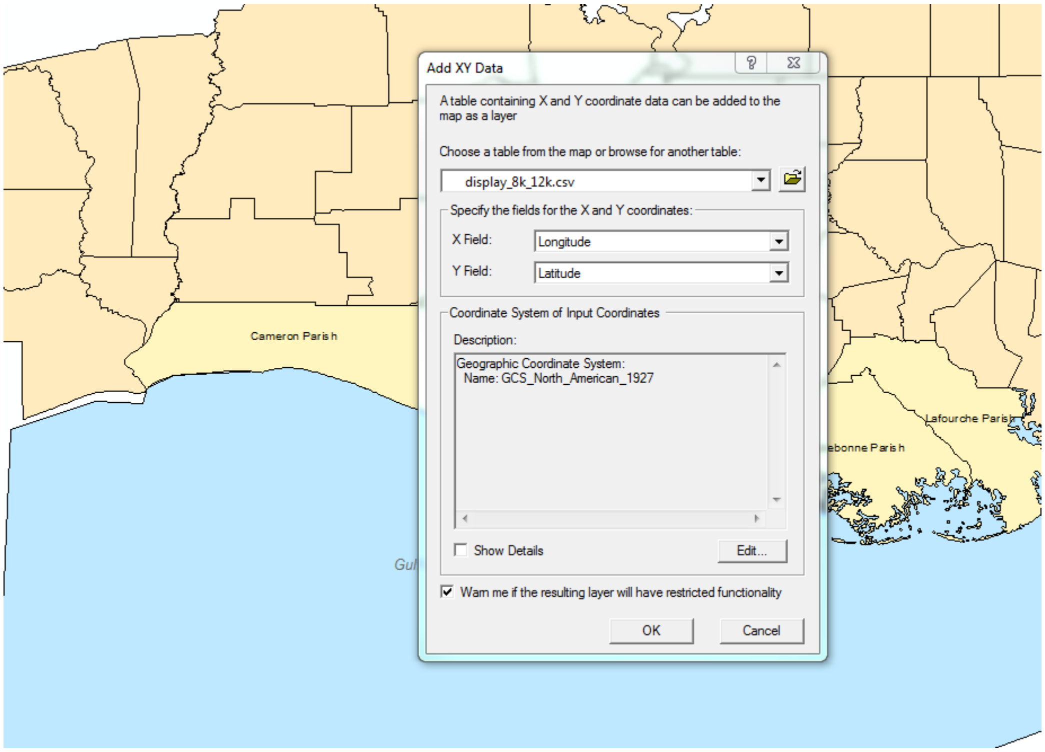


Figure 3.2-Importing the attribute table

Figure 3.3-Distribution of well locations over the area of interest

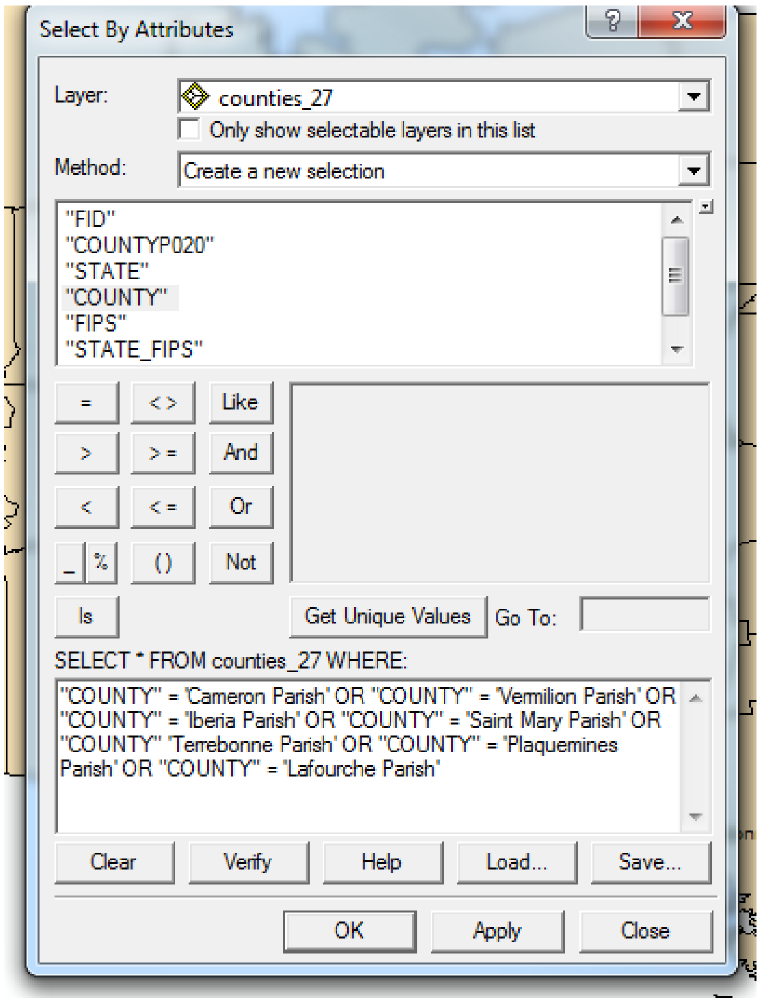


Figure 3.4-Selection query used to create a shape file of the area of interest

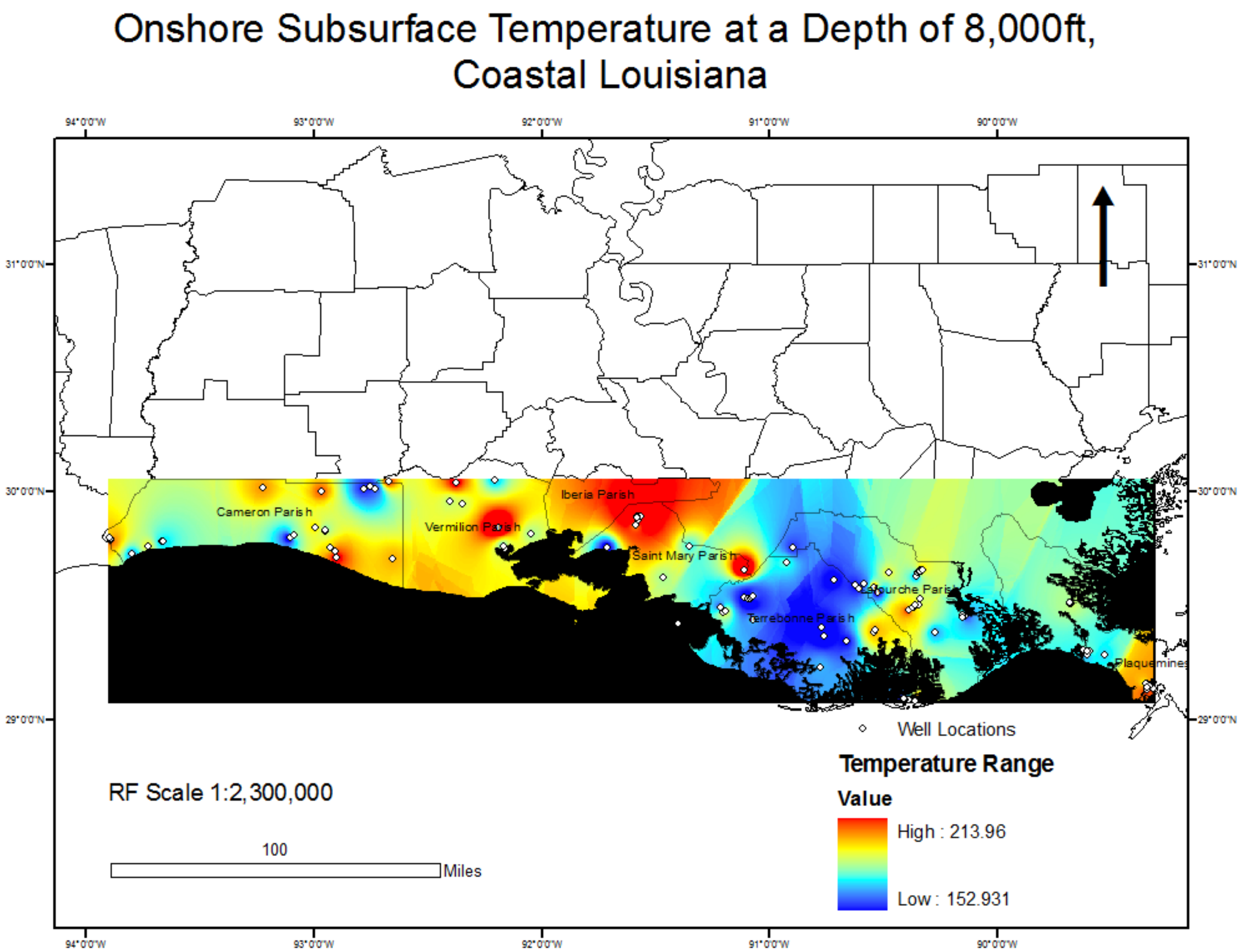


Figure 4.1-Interpolated raster map of thermal subsurface variation

VI. Conclusion

A clear trend in decreasing temperature from western to eastern Louisiana is observed in Figure 4.1, which agrees with the original hypothesis. However, the 92^0W longitude cannot be used as the separation line since temperatures there are shown to be relatively warm. This implies that subsurface thermal trends differ at varying depths. The offshore study differed from this one in many ways. The area of interest was much larger, the wells were consistently deeper, and the wells selected were subject to strict guidelines in order to create a smooth surface. Despite these differences, both studies provide evidence that supports similar trends in onshore and offshore areas. Further investigation to verify these results include increasing the density of data over the region by expanding the amount of well data. Using wells at greater depths in the area of interest would further augment this type of analysis. With more data raster creation could be improved and uncertainty decreased.

VII. Sources

Literature:

Bloch, S., R. H. Lander, L. Bonnell, L., 2000, Anonomously high porosity and permeability in deeply buried sandstone reservoirs: Origin and predictability: AAPG Bulletin, v.86, p302.

Nagihara, S., K. O. Jones, 2002, Geothermal heat flow in the northeast margin of the Gulf of Mexico: AAPG Bulletin, v.89, p824.

Nagihara, S., 2006, Deep Sedimentary Thermal Regime of the Texas-Louisiana Continental Shelf, Gulf of Mexico: Texas Tech University Department of Geosciences, p13.

Dutton, S., 2010, Stratigraphic Architecture and Sandstone Reservoir Quality in Deep Shelf Gas Plays: The Bureau of Economic Geology

Data:

Louisiana Department of Natural Resources (SONRIS)-well log header information

http://ucmwww.dnr.state.la.us/ucmsearch/busfunctions.aspx

IHS Worldwide Enerdeq Database-various scout reports

http://www.ihs.com/

Zetaware Time Since Circulation Correction

http://zetaware.com/utilities/bht/timesince.html

USGS Seamless Server-Louisiana parish GIS shapefile

http://seamless.usgs.gov/website/seamless/viewer.htm

USGS Coastal and Marine Geology Program-Federal offshore boundaries GIS shapefile

http://coastalmap.marine.usgs.gov/regional/contusa/gomex/gloria/data.html