MEMO: Heat Flow Calculations for the East Texas Deep Direct Use Study

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Surface heat flow is the first thermal reservoir assessment calculation made because surface heat flow is used to calculate temperature-at-depth for any given depth below the surface. There were 122 Bottom Hole Temperature (BHT) derived heat flow points within the 20 km radius area of interest already calculated as part of the SMU Geothermal Map of North America and the updated U.S. version (Blackwell and Richards, 2004; Blackwell et al., 2011). There were no equilibrium temperature log derived heat flow points. Additional available data were searched for on the National Geothermal Data System (Blackwell et al., 2014). BHT values collected for the NGDS project by the Texas Bureau of Economic Geology (BEG) were available, but still only covered a fraction of the study area (Figure 1). Additional BHT values were collected by SMU for this project to increase the resolution of the study area surface heat flow map. The data were collected first focused near the Eastman Chemical Company property, and then outward to fill in data gaps. Areas still with few points are generally related to human (cities) or geology (no oil/gas fields at depth.

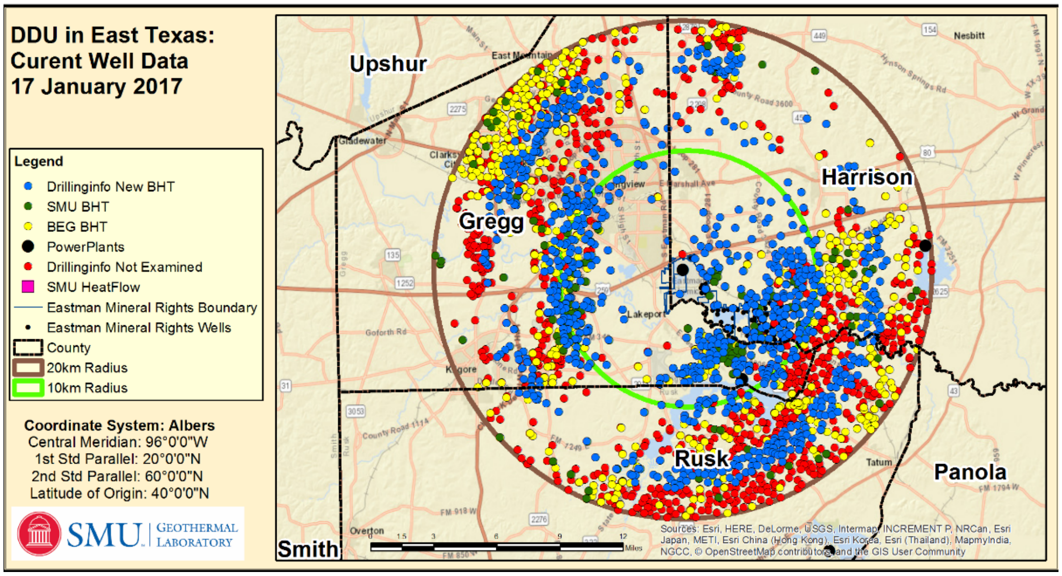

Figure 1. Data within the 20 km radius study area, color coded by data source and if temperature was collected.

Data quality control and quality assurance of all three data sets took place after new data collection. All BHT data were plotted to display temperature versus depth, and how all the various data sets compared to each other (Figure 2). The BEG BHT data are questionably high and also have several abnormally straight lines given the fact that these data are reported as uncorrected. Personal communication with the original authors confirmed that these were correctly reported values. Still, the BEG BHT values were treated here as corrected BHT values because the majority of the BEG reported measurements were closer to the corrected SMU BHT database than other uncorrected BHT values. It is still unclear where the linear patterns of BHT measurements came from, but these values have been incorporated into the surface heat flow mapping for this study.

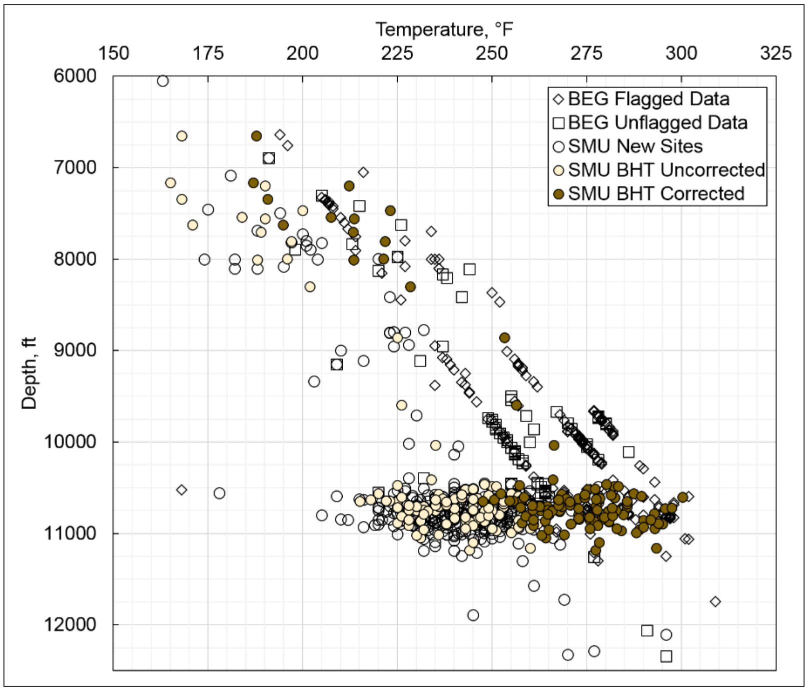

Figure 2. Temperature versus depth of BHT data points within the 20 km study area radius.

In addition to checking the BHT measurement quality, location of salt structures was examined because the study area is in close proximity to the East Texas Salt Basin, and because salt and evaporite deposits have a high thermal conductivity that can impact the local thermal regime if there is a large enough salt structure and within a close enough depth (Beardsmore and Cull, 2001). There are two salt pillows within the 20 km radius study area. The closer of the two is within the 10 km radius study area, west of Eastman Chemical Company property. This close proximity to the area of interest required more understanding of the salt pillow. The salt structures within the East Texas region all form from the Louann salt, a massive mid-Jurassic evaporite deposit that formed during the subsidence of the East Texas Basin (Jackson and Seni, 1983). The Tectonic Map of Texas (Ewing et al., 1991) calls the structures in the study area salt pillows, which are low to intermediate amplitude structures that do not pierce overlying sediment layers, rather instead are just thickened or thinned sections of the Louann Salt. This information leads to the hypothesis that the salt structures within the study area will have little impact on the thermal regime, which we examined by plotting the geothermal gradients on top of the location of the salt pillow structures (Figure 3). There is no definitive correlation between the salt pillows and a variation in geothermal gradient and the Tops of Formations above the pillows is not systematically different, therefore, the salt pillows are considered too deep and too small to impact the regional thermal regime greater than the surface heat flow measurement error.

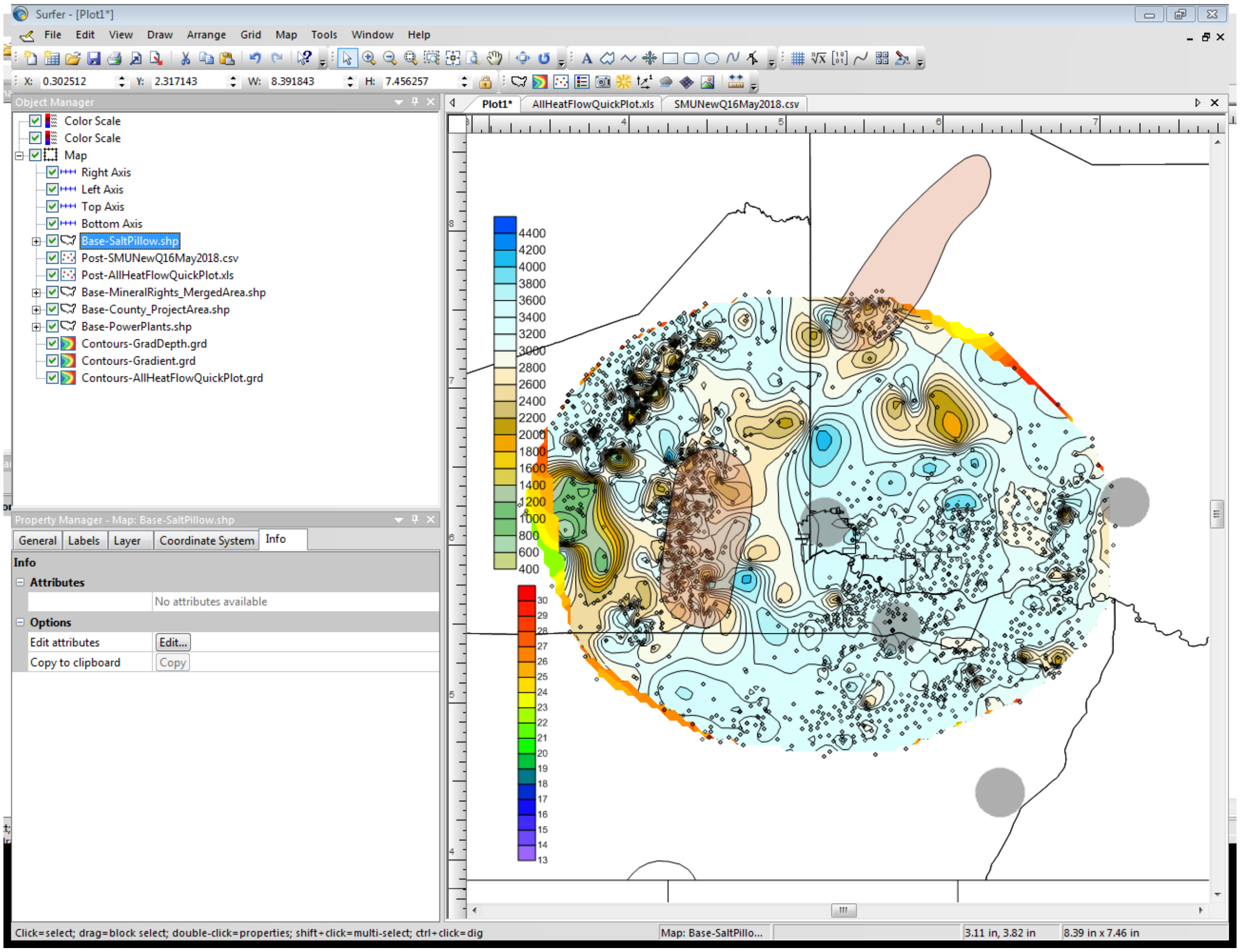

Figure 3. Placeholder. This will be the Salt Pillows plotted on top of a Geothermal Gradient plot.

Heat Flow Calculation

Heat flow is determined by site temperature gradient times thermal conductivity of the rocks. In working with large datasets, there are codes written in Excel (Stutz et al., 2012) and Python (Smith, 2016; Smith and Horowitz, 2016) based on the work by Batir during the Blackwell et al. (2011) Google Temperature-at-depth project.

Therefore, the heat flow calculations for this project followed the procedures and protocol previously implemented by the SMU Geothermal Laboratory and the Cornell University Geothermal team (Stutz et al., 2012; Smith and Horowitz, 2016). Heat flow calculations used the Cornell - Jared Smith (2016) written Python code (ver 2.7.14) as available through the computer link he provided. Batir used the ThermalModelStructure.py for calculating surface heat flow and temperature-at-depth for each well site. For this project, new stratigraphy sections compiled were based on COSUNA sections (Childs et al., 1988) for East Texas. Other changes included input and output files to include detailed project data. Here, we give general information on the sources for input data to the calculations.

Data Sources Needed To Calculate Heat Flow

1) Surface temperature – Surface temperature comes for the Gass (1982) surface ground water temperature map. Within the ArcGIS files, the raster layer is 96SRFTMPb.GRD. The annual air temperatures for Tyler, Longview, Jefferson, and Marshall were reviewed for consistency in the temperature trends of the contours in this map and they matched. Annual air temperatures are cooler than the surface groundwater of an area, and this is also consistent for these two sources.
2) Bottom Hole Temperature – Bottom Hole temperature is coming from two sources
    a. The BEG borehole Temperature data. These data are questionably high in temperature, therefore, the 'uncorrected temperature' will be used as the 'corrected temperature'
    b. Newly collected Bottom Hole Temperature from well log headers downloaded from the Texas Railroad Commission. These data are the recorded bottom-hole temperature on the publically available scanned well logs. These are uncorrected temperatures and are corrected using the Harrison Correction (Blackwell and Richards, 2004b). Depth is the Well header bottom logger depth, which assumes the bottom logger depth is the deepest point the logging tool sees and would therefore be the depth of the maximum recorded temperature reported on the well log.
3) Sediment Thickness / Basement depth – The sediment thickness is the same sediment thickness used for the 2011 Geothermal Map of North America. Within the ArcGIS files, the raster layer is SEDTHK2005.grd. This map was digitized from the AAPG Basement Map of North America, 1978.
4) Stratigraphy – Stratigraphy information used is the Correlation of Stratigraphic Units in North America (COSUNA), published by the AAPG (Childs et al., 1988).
5) Thermal Conductivity – No thermal conductivity values were measured for this study. There is one USGS Report with thermal conductivity values for the Louisiana – Texas Gulf Coast (Pitman and Rowan, 2012). Values from this USGS Report are used for overlapping formations. The measured values for the evaporites from the Anadarko Basin (Gallardo and Blackwell, 1999) were applied for formations that did not have a locally sourced published value. In the future it would be helpful to determine the thermal conductivity on cores using a divided bar method. This is the value of most potential error for heat flow in this project.

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