Geothermal Energy Potential in Oktibbeha County: Is Mississippi Really Hot?

Cary Lindsey
Department of Geoscience, Mississippi State University
CI815@msstate.edu

Keywords
Mississippi, Oktibbeha, Geothermal Resource Assessment, Geology

ABSTRACT
Geothermal energy is a clean, renewable energy source. Previous geothermal energy assessments of Mississippi have focused on areas in southern Mississippi and the Mississippi River flood plain. The focus of the current project is Oktibbeha County in eastern North Central Mississippi, an area currently home to active lignite coal mining and exploration. Lignite is one of the least efficient forms of coal and it is being mined in an area that potentially has thousands of megawatts of clean geothermal energy potential. Well logs were reviewed to gather bottom-hole temperatures, mathematically normalized and used to create a thermal gradient map of the county. The map shows clear indication of above-normal temperatures in western Oktibbeha County beginning at depths of around four thousand meters.

Introduction
The United States Energy Information Administration estimates that the average American household uses 12,000 kWh of electricity per year (www.eia.gov, 2012). In 2011, Southern Methodist University researchers led by Dr. David Blackwell, in a project funded by Google, Inc., calculated that at 14% recovery, Mississippi had an estimated geothermal potential of over 60,000 megawatts (http://www.google.org/egs/, 2012), which is enough to supply electricity to over sixty million homes. As a point of comparison, according to 2010 United States Census Bureau data, Mississippi currently has less than 1.3 million homes (www.census.gov, 2012). Exploitation of this vast energy source could put Mississippi in the position of becoming an energy exporter.

It is likely actual temperatures found in some subsurface areas of Mississippi are higher than the estimates provide by Blackwell (2011). The numbers generated by Blackwell (2011) are based on data from only twenty-seven collection sites in Mississippi that were sampled in the 1970’s geothermal investigation by the Department of Energy, none of which were located in Oktibbeha County (Richards, 2012). The resolution of geothermal data, for Mississippi is, therefore, low. A new assessment of the thermal gradient is needed to verify the true geothermal potential in the state of Mississippi. The particular area of interest in this study is Oktibbeha County, since the county is the location of continued subsurface hydrocarbon exploration the Black Warrior Basin.

Literature Review
In the 1970’s several events led to increased interest in geothermal exploration in the United States, one of which was the formation of the Geothermal Energy Association. (http://www.eere.energy.gov/, 2012). The Geothermal Energy Association is a trade association focused on expanding research and development in the geothermal field to increase the use of geothermal energy production for electricity and promoting public policies that encourage this expansion (www.geo-energy.org, 2012). In 1974 the government enacted the Geothermal Energy Research, Development and Demonstration (RD&D) Act and following the creation of the Department of Energy in 1977, a nationwide assessment of geothermal potential began. As the Department of Energy campaign into geothermal assessment continued, a more cohesive network was formed and investments from both the public and private sectors increased (http://www.eere.energy.gov/, 2012).

In recent years researchers at Southern Methodist University have worked to refine the temperature data used to assess geothermal potential. An initial correction was made to the recorded bottom-hole temperatures using the Harrison et al. correction (Harrison et al. 1983 in Blackwell, 2004). A second correction was then added to account for the crossover point of the Harrison et al. correction. This crossover occurs at about 3900 meters and at this point the correction begins to become negative. The second correction was based on standard geothermal gradient and more accurately matches equilibrium well data for depths over three
thousand meters by increasing the temperature .01 degree C for every 500 additional meters (Blackwell, 2004). The most recent example of this refinement is the Google Earth interactive map created by the team at Southern Methodist University (http://www.google.org/egs/, 2012).

Mississippi currently has one geothermal project in development. The project is a hydrocarbon co-production system that utilizes geothermal fluids that are produced along with hydrocarbons to produce electricity. Gulf Coast Green Energy, in collaboration with Denbury Resources, will use the ElectraTherm mobile modular unit to produce as much as 50 kWh of electricity from hot water (Jennejohn, 2010). The project is a hydrocarbon co-production system that utilizes geothermal fluids that are produced along with hydrocarbons to produce electricity. The project is a hydrocarbon co-production system that utilizes geothermal fluids that are produced along with hydrocarbons to produce electricity. The project is a hydrocarbon co-production system that utilizes geothermal fluids that are produced along with hydrocarbons to produce electricity.

Mississippi government resources are also valuable for the assessment of geothermal potential. The Mississippi Oil and Gas Board website allows access to digital copies of oil and gas well logs (http://www.ogb.state.ms.us/, 2012). Information such as well location and temperature data is available through this resource. The Mississippi Department of Environmental Quality offers maps such as structural and geologic maps of areas being assessed (http://www.deq.state.ms.us/, 2012).

**Methods**

**Data Collection**

Data were obtained directly from the Mississippi Oil and Gas Board website (http://www.ogb.state.ms.us/, 2012). Well data for Oktibbeha County were exported from the website using the well information section of the data menu and selecting a filter to pull only Oktibbeha County. The complete report of all wells located within the county was exported to an excel file (Fig. 1). Each well was then reviewed individually. Latitude and longitude, if available, were given in the Oil and Gas Board report. For most of the wells the depth and temperature were available on the well log header (Fig. 2).

**Data Reduction**

Any well that did not include an image of the well log was not used. The criterion for a useful well was: bottom-hole temperature, latitude and longitude, and recorded depth. All well logs were entered on the data sheet but only those that met the needed criteria were used for creating the thermal gradient map of Oktibbeha County.

<table>
<thead>
<tr>
<th>API #</th>
<th>Well Name</th>
<th>Field</th>
<th>Operator</th>
<th>County</th>
<th>BHT given</th>
<th>BHT (°C)</th>
<th>Adjustment</th>
<th>Adjusted BHT (°C)</th>
<th>Lat</th>
<th>Long</th>
<th>Depth (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>23105200020001</td>
<td>MS Fulgham</td>
<td>Maben</td>
<td>James W. Harris</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>147.220</td>
<td>19.090</td>
<td>166.310</td>
<td>33.46867</td>
<td>-89.04747</td>
<td>6519.37</td>
</tr>
<tr>
<td>23105200200000</td>
<td>Winters (Mrly Arceneaux #1)</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>138.880</td>
<td>19.090</td>
<td>157.970</td>
<td>33.45814</td>
<td>-88.99662</td>
<td>5072.48</td>
</tr>
<tr>
<td>23105200130000</td>
<td>Georgia Pacific 1</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>127.200</td>
<td>19.080</td>
<td>146.280</td>
<td>33.45834</td>
<td>-89.07116</td>
<td>4907.00</td>
</tr>
<tr>
<td>23105200250100</td>
<td>Hawkins 20-3 # 1</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>128.000</td>
<td>19.080</td>
<td>147.080</td>
<td>33.50279</td>
<td>-89.06711</td>
<td>4677.46</td>
</tr>
<tr>
<td>23105200230100</td>
<td>J T Hamilton</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>116.100</td>
<td>19.080</td>
<td>135.180</td>
<td>33.48586</td>
<td>-89.04269</td>
<td>4587.00</td>
</tr>
<tr>
<td>23105200240100</td>
<td>Saucier 27-14 # 1</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>128.333</td>
<td>19.080</td>
<td>147.413</td>
<td>33.47599</td>
<td>-89.02995</td>
<td>4572.61</td>
</tr>
<tr>
<td>23105200620000</td>
<td>Miss. State Univ. (frmly Ballard #1)</td>
<td>Wildcat</td>
<td>Clayton Williams Energy, Inc.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>115.000</td>
<td>19.080</td>
<td>134.080</td>
<td>33.36245</td>
<td>-88.85657</td>
<td>4570.78</td>
</tr>
<tr>
<td>23105200220100</td>
<td>Irene E Brown et al. 21-3</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>136.660</td>
<td>19.080</td>
<td>155.740</td>
<td>33.50162</td>
<td>-89.04731</td>
<td>4488.79</td>
</tr>
<tr>
<td>23105200190000</td>
<td>Love Heirs 1</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>103.300</td>
<td>19.080</td>
<td>122.380</td>
<td>33.48999</td>
<td>-89.02967</td>
<td>4473.24</td>
</tr>
<tr>
<td>23105200120000</td>
<td>Sanders 1</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>97.777</td>
<td>19.070</td>
<td>116.847</td>
<td>33.48130</td>
<td>-89.02230</td>
<td>4243.43</td>
</tr>
<tr>
<td>23105200010000</td>
<td>Clyde Q Sheely 1</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>no</td>
<td>91.111</td>
<td>19.060</td>
<td>110.171</td>
<td>33.48020</td>
<td>-89.04890</td>
<td>3854.20</td>
</tr>
<tr>
<td>23105200791000</td>
<td>Guitar 16-1H</td>
<td>Wildcat</td>
<td>Anadarko Petroleum Corp.</td>
<td>Oktibbeha</td>
<td>no</td>
<td>68.330</td>
<td>18.560</td>
<td>86.890</td>
<td>33.59040</td>
<td>-88.72863</td>
<td>3429.00</td>
</tr>
<tr>
<td>23105200260100</td>
<td>Torrin 20-20 # 1</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>88.333</td>
<td>18.210</td>
<td>106.543</td>
<td>33.49164</td>
<td>-89.05855</td>
<td>3288.79</td>
</tr>
<tr>
<td>23105200370100</td>
<td>Peay 1 (ST)</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>88.800</td>
<td>17.330</td>
<td>106.130</td>
<td>33.51239</td>
<td>-89.07660</td>
<td>3035.00</td>
</tr>
<tr>
<td>23105200170000</td>
<td>Richardson 2</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>88.880</td>
<td>17.400</td>
<td>103.580</td>
<td>33.47087</td>
<td>-89.03132</td>
<td>2529.84</td>
</tr>
<tr>
<td>23105200250100</td>
<td>Hawkins 20-3 # 1</td>
<td>Maben</td>
<td>Devon Energy Prod Co. L.P.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>128.333</td>
<td>7.040</td>
<td>135.373</td>
<td>33.50279</td>
<td>-89.06711</td>
<td>1630.68</td>
</tr>
<tr>
<td>23105000200200</td>
<td>W C Howell</td>
<td>Wildcat</td>
<td>John Allen</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>51.660</td>
<td>5.790</td>
<td>57.450</td>
<td>33.53996</td>
<td>-88.90868</td>
<td>1516.00</td>
</tr>
<tr>
<td>23105200710000</td>
<td>Simmons 22-16</td>
<td>Maben</td>
<td>D-S-B Properties, Inc.</td>
<td>Oktibbeha</td>
<td>yes</td>
<td>60.000</td>
<td>5.320</td>
<td>65.320</td>
<td>33.49032</td>
<td>-89.02181</td>
<td>1473.71</td>
</tr>
</tbody>
</table>

**Figure 1.** Data Spreadsheet for Oktibbeha County.
Data Processing

The bottom-hole temperature data available on the site would not necessarily represent an equilibrium temperature. The skewed reading could be due to temperatures being logged immediately following drilling. In this case the well temperature would not be at equilibrium. Due to this, each bottom-hole temperature was mathematically recalculated based on the formula used by the geothermal research team at Southern Methodist University. The initial correction formula is the Harrison et al. correction (Harrison et al. 1983 in Blackwell, 2004):

\[ ^\circ C = -16.51213476 + 0.01826842109z - 0.000002344936959z^2 \]

where \( z \) = depth in meters.

Adjustments ranged from 5.32°C at just over 1400 meters to as much as 19.09°C at over 6500 meters. The recalculation formula was derived to adjust for climatic, geologic, or equipment interference with the actual temperature at depth. There is also a second correction that is applied for the deep wells, the SMU-Harrison correction, where the curve starts to overturn and decrease in correction values (at 3932 m the correction is about 19.07°C). Below this depth the highest correction value is taken and an additional .01°C is added for very additional 500 meter interval (Blackwell, et al., 2012b). Units were changed from feet to meters and from Fahrenheit to Celsius, as needed, for calculations. The calculation formula was not calibrated to Oktibbeha County but is a general form of the equation. To calibrate the equation more information...
is needed such as mean surface temperature and identification of subsurface formations being drilled. Once a well has been identified that can be used to log temperature in the area, a more exact equation will be formulated specific to Oktibbeha County.

## Results

The Mississippi Oil and Gas Board website (http://www.ogb.state.ms.us/, 2012) hosts records of thirty wells for Oktibbeha County. Of the thirty wells, three had no well log scanned, seven had no available latitude and longitude and two had no temperature data. The remaining eighteen wells were used to gather information regarding the availability of adequate heat energy for geothermal production.

The highest temperature located was calculated at 166.34°C (331.41°F) at a depth of about six and a half kilometers. The MS Fulgham well, API #23105200020001, is located in the Maben field of Oktibbeha County (Fig. 3) and is classified as a plugged and abandoned dry hole (http://www.ogb.state.ms.us/, 2012). The well was initially drilled for natural gas exploration. A total of nine other wells were identified as having temperatures exceeding 135°C, the minimum temperature required for the binary cycle geothermal energy facility. All nine wells with the minimum acceptable bottom-hole temperatures follow a general trend of increased temperature with increased depth (Fig. 4).

The data were also used to create a geothermal contour map of Oktibbeha County using R, a program used for statistical graphics (Fig. 5). A formula was written for R using recorded latitudes, longitudes, and adjusted bottom-hole temperatures. The formula was used to interpolate a depth for each site needed to reach 135°C. It is clear from this contour map that depths needed in the northwestern quadrant of Oktibbeha County are in fact much shallower than the rest of the county.

## Discussion

The temperatures found in Oktibbeha County exceed previous estimations on the most current geothermal maps of the United States. The latest, 2011 edition map created by the research team at Southern Methodist University, sponsored by Google Inc. (google.org/egs, 2012), shows an average temperature at six and a half kilometers depth to be around 100°C for Oktibbeha County. The presence of the higher temperatures found in this study is an indication that there is some geologic cause for this increased temperature reading that was not represented in previous assessments. Further evidence is needed to determine if this is, in fact, the case.

When compared to the 1969 geologic map of Mississippi (http://www.deq.state.ms.us/, 2012) the higher gradients found in this study appear to be clustered in eastern Oktibbeha County near an area where the Porters Creek, Wilcox and the Naheola Formation boundaries exist. Well records submitted to the Mississippi Oil and Gas Board indicate the formation at the depths drilled in Oktibbeha County, or at least those exceeding the normal temperature gradient, is the Knox Formation. The stratigraphy of the surrounding formations is presented in Figure 6 (Ryder, 2012)). The Knox formation is a Cambrian-Ordovician dolostone formation known to show evidence of karst porosity; and in some areas of Kentucky it shows evidence of porosity associated with dolomite crystal lined vugs, believed to have precipitated from hydrothermal fluids (Pittenger et al., 2009). The presence of either of these could be the cause for the increased temperature found in Oktibbeha County. Upon review of the structural map of Mississippi, also available on the MDEQ website, there is also evidence of two faults in this area. It is possible these faults allow for the upward movement of geothermal fluid in the crust, thus causing the increased temperatures (Blackwell, et al., 2012a). The horst area between these two faults could also have created traps for geothermal fluid. Further investigation is needed to determine if in fact these geologic occurrences are affecting the thermal gradient in Oktibbeha County.

The greatest significance of this study for Oktibbeha County and Mississippi is the opportunity for Oktibbeha County to become home to a clean energy-producing facility. Such a facility could provide an alternative to another lignite coal operation in Mississippi, increase economic stability in the area, as well as encourage further exploration of geothermal potential statewide. As geothermal production increases, Mississippi could
move from the top of the list of states that consume the most electricity per capita, to a state that actually exports electricity. Mississippi State University and the Department of Geosciences, in particular, also stand to gain from such an opportunity. Currently, the programs in the geosciences department are heavily geared towards petroleum exploration. Geothermal exploration would be an additional avenue of research for the department, adding Mississippi State to the small number of schools with geothermal programs (Holm, 2011). Research in geothermal could bring new funding, new staff, and an increased student body to the department.

Conclusions

Bottom-hole temperatures exceeding 135°C, a temperature sufficient for geothermal binary power production, were found to be present in Oktibbeha County. Mapping of the area suggests geologic causation, such as faulting or geothermal reservoirs to between stratigraphic layers, or increased temperature.

References


