GEOTHERMAL ENERGY POTENTIAL IN OKTIBBEHA COUNTY: IS MISSISSIPPI REALLY HOT?

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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 (USEIA, 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 (Google.org, 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 (US Census Bureau, 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. (USDOE, 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 (GEA, 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 (USDOE, 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 and Richards, 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 and Richards, 2004). The most recent example of this refinement is the Google Earth interactive map created by the team at Southern Methodist University (Google.org, 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).

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 (MSOGB, 2012). Information such as well location and temperature data is available through this resource. The Mississippi Department of Environmental Quality (MDEQ) offers maps such as structural and geologic maps of areas being assessed (MDEQ, 2012).

METHODS

Data Collection

Data were obtained directly from the Mississippi Oil and Gas Board website (MSOGB, 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 (Figure 1). Each well was then reviewed individually.

API #	Well Name	Field	Operator	County	BHT give	BHT (C°)	djustment	BHT (C°)	Lat	Long	Depth (m)
23105200020001	MS Fulgham	Maben	JAMES W. HARRIS	OKTIBBEHA	yes	147.220	19.090	166.310	33.46867	-89.04747	6519.57
23105200200000	WINTERS (FRMRLY ARCENEAUX #1) 1	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	138.880	19.090	157.970	33.45814	-88.99662	5072.48
23105200130000	GEORGIA PACIFIC 1	Maben S.	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	127.200	19.080	146.280	33.45834	-89.07116	4907.00
23105200250100	HAWKINS 20-3 # 1	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	128.000	19.080	147.080	33.50279	-89.06711	4677.46
23105200230100	J T Hamiton	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	116.100	19.080	135.180	33.48586	-89.04269	4587.00
23105200240100	SAUCIER 27-14 # 1	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	128.333	19.080	147.413	33.47599	-89.02995	4572.61
23105200020000	MISS. STATE UNIV. (frmly Ballard #1) 1	Wildcat	CLAYTON WILLIAMS ENERGY, INC.	OKTIBBEHA	yes	115.000	19.080	134.080	33.36245	-88.85657	4570.78
23105200220100	IRENE E BROWN ET AL 21-3 1	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	136.660	19.080	155.740	33.50162	-89.04731	4488.79
23105200190000	LOVE HEIRS 1	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	103.300	19.080	122.380	33.48999	-89.02967	4473.24
23105200120000	SANDERS 1	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	97.777	19.070	116.847	33.48130	-89.02230	4243.43
23105200010000	CLYDE Q SHEELY 1	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	no	91.111	19.060	110.171	33.48020	-89.04890	3854.20
23105200791000	Guitar 16-1H	Wildcat	ANADARKO PETROLEUM CORPORATION	OKTIBBEHA	yes	68.330	18.560	86.890	33.50940	-88.72863	3429.00
23105200260100	TORMIN 20-20 # 1	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	88.333	18.210	106.543	33.49164	-89.05855	3288.79
23105200370100	PEAY 1 (ST)	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	88.800	17.330	106.130	33.51239	-89.07660	3035.00
23105200170000	Richardson 2	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	88.880	14.700	103.580	33.47087	-89.01312	2529.84
23105200250100	HAWKINS 20-3 # 1	Maben	DEVON ENERGY PROD CO. L.P.	OKTIBBEHA	yes	128.333	7.040	135.373	33.50279	-89.06711	1630.68
23105000020000	W C HOWELL 1	Wildcat	JOHN ALLEN	OKTIBBEHA	yes	51.660	5.790	57.450	33.53996	-88.90866	1516.00
23105200710000	SIMMONS 22-16 1	Maben	D-S-B PROPERTIES, INC.	OKTIBBEHA	yes	60.000	5.320	65.320	33.49032	-89.02181	1473.71
23105200110001	WILLIAMS 9-6 1	Wildcat	GIBRALTAR ENERGY CO	OKTIBBEHA	yes	109.444	18.100	127.544	n/a	n/a	4538.47
23105200090000	TIMBER REX 1	Wildcat	AMOCO PRODUCTION CO.	OKTIBBEHA		73.333	16.800	90.133	n/a	n/a	2910.23
23105200060000	FULGHAM 22-6 1	Wildcat	AMOCO PRODUCTION CO.	OKTIBBEHA	yes	45.000	8.000	53.000	n/a	n/a	1722.12
23105200080000	FULGHAM 22-6 2	Wildcat	AMOCO PRODUCTION CO.	OKTIBBEHA	yes	67.778	15.230	83.008	n/a	n/a	2616.71
23105200030000	MISS UNIV UN 5-13 1	Wildcat	SHELL OIL CO. -NOLA	OKTIBBEHA	yes	81.100	18.330	99.430	n/a	n/a	3334.51
23105000040000	W P SUDDUTH A-1	Wildcat	CLEARY PETROLEUM CORPORATION	OKTIBBEHA	yes	62.778	14.860	77.638	n/a	n/a	2555.75
23105000090000	HARRY L COLE 1	Wildcat	McALESTER FUEL CO.	OKTIBBEHA	yes	64.400	16.520	80.920	n/a	n/a	2853.84
23105000080000	HARRION ESTATE 1	Wildcat	J.W. SPARKS, ET AL	OKTIBBEHA	NO	n/a					
23105200050000	BURGIN BROTHERS 1	Wildcat	AMOCO PRODUCTION CO.	OKTIBBEHA	NO	n/a			n/a	n/a	
23105000040000	W P SUDDUTH A-1	Wildcat	CLEARY PETROLEUM CORPORATION	OKTIBBEHA							
23105200110001	WILLIAMS 9-6 1	Wildcat	GIBRALTAR ENERGY CO	OKTIBBEHA							
23105000040000	W P SUDDUTH A-1	Wildcat	CLEARY PETROLEUM CORPORATION	OKTIBBEHA							

COMPLETED WELLS | NO TEMPERATURE | NO LAT/LONG | NO WELL LOG

Figure 1. Data Spreadsheet for Oktibbeha County

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 (Figure 2).

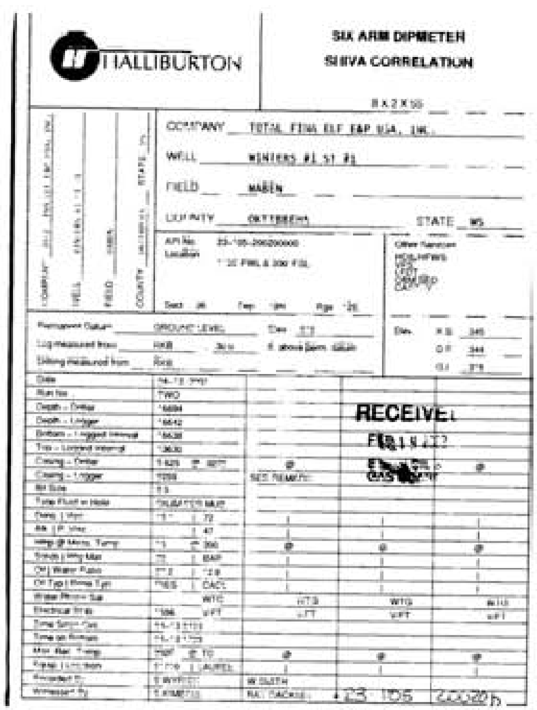

Figure 2. Sample Well Log Header

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.

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 and Richards, 2004):

$$°C = -16.51213476 + 0.01826842109z - 0.000002344936959z^2$$

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., 2012). 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 (MSOGB, 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 (Figure 3) and is classified as a plugged and abandoned dry hole (MSOGB, 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 (Figure 4).

Figure 3. MS Fulgham Well Location

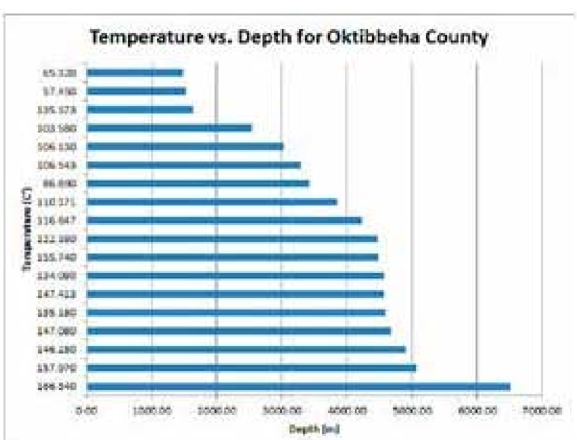

Figure 4. Temperature vs. Depth Trend

The data were also used to create a geothermal contour map of Oktibbeha County using R, a program used for statistical graphics (Figure 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.

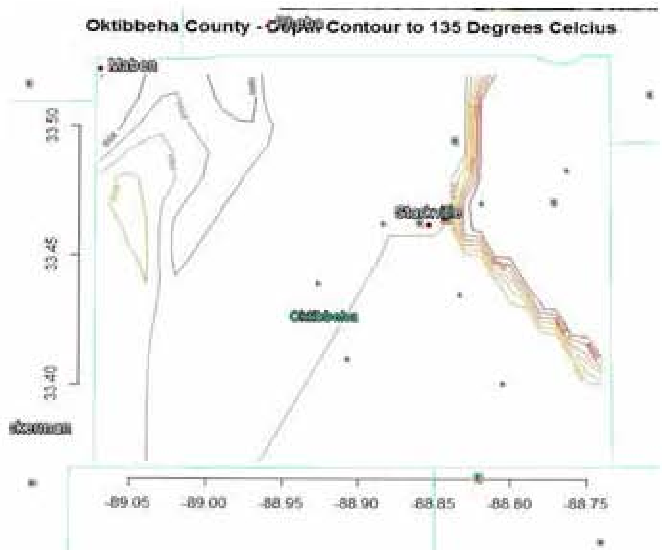

Figure 5. Geothermal Gradient Contour of Oktibbeha County

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, 2012), shows an average temperate 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 (MDEQ, 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, Undated). 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.

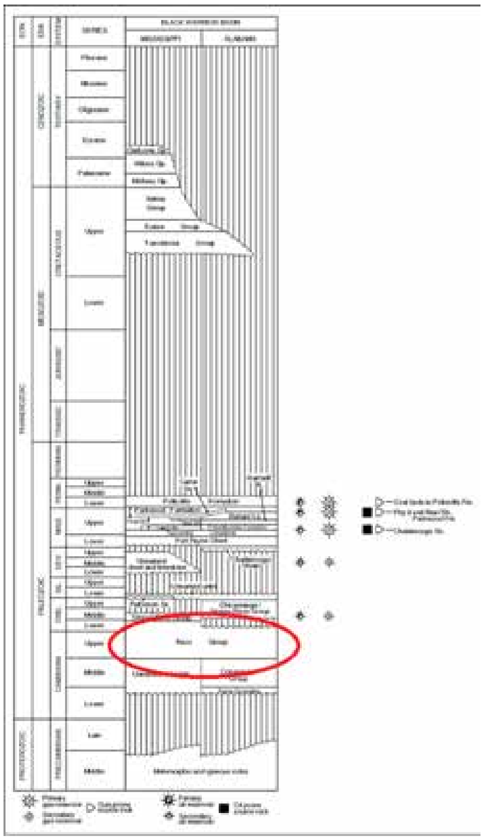

Figure 6. Stratigraphy of Black Warrior Basin

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.

EDITOR'S NOTE

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REFERENCES

Blackwell, D., M. Richards, 2004, "Calibration of the AAPG Geothermal Survey of North America BHT Data Base", AAPG Annual Meeting, Poster session, Paper 87616.

Blackwell, D., M. Richards, and Z. Frone, 2010a. "Elevated Crustal Temperatures in West Virginia: *Potential for Geothermal Power*. Web.

Blackwell, D., M. Richards, and P. Stepp. 2010b "Texas Geothermal Assessment for the I35 Corridor East For Texas State Energy Conservation Office Contract CM709", Southern Methodist University, p. 19-20.

Geothermal Energy Association, 2012. "Geothermal Energy Association", Webpage http://www.geo-energy.org downloaded April 02, 2012.

Google.org, 2012. "Google.org Enhanced Geothermal Systems." Webpage http://www.google.org/egs downloaded, April 02, 2012.

US Department of Energy, 2012b. "A History of Geothermal Energy in the United States." US Department of Energy, Energy Efficiency and Renewable Energy, Geothermal Technologies Program, Webpage http://www1.eere.energy.gov/geothermal/history.html, downloaded April 02, 2012.

Holm, A., 2011 "Geothermal Education and Training Guide." Geothermal Energy Association.

Jennejohn, J. 2010 "U.S. Geothermal Power Production and Development Update – Special NYC Forum Edition.", Geothermal Energy Association.

Mississippi State Oil and Gas Board, 2012. "Mississippi Oil and Gas Board", Webpage http://www.ogb.state.ms.us/ downloaded April 02, 2102.

US Census Bureau, 2012. "Mississippi QuickFacts from the US Census Bureau", Webpage http://quickfacts.census.gov/qfd/states/28000.html, downloaded April 02, 2012.

Pittenger, M., C. Feazel, G. J. Buijs, R. R. Reid and P.W. Johnson. 2009 "Evaluation of Knox Group Dolostones as a Target for CO2 Storage in Western Ketucky", AAPG Annual Meeting, Denver, CO, Poster session Paper 50212.

Richards, Maria. 2012. "Undergraduate Geothermal Research." Message to the author. E-mail.

Ryder, R. T., Undated. "Black Warrior Basin Province (065)", Webpage http://certmapper.cr.usgs.gov/data/noga95/prov65/text/prov65.pdf, downloaded April 02, 2012.

US Department of Energy, 2012a. "Energy Conversion: A History of Geothermal Energy Research and Development in the United States", US Department of Energy, Energy Efficiency and Renewable Energy, Geothermal Technologies Program, Webapge http://www1.eere.energy.gov/geothermal/pdfs/geothermal_hishist_4_conversion.pdf, downloaded April 02, 2012.

US Energy Information Administration, 2012. "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis," Webpage http://www.eia.gov/, downloaded April 02, 2012.