DEVELOPMENT OF NEW GEOTHERMAL DATABASE FOR THE ILLINOIS BASIN

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ABSTRACT

The U.S. Department of Energy is currently funding a broad consortium of institutions to develop a new National Geothermal Data System (NGDS) for assessing the geothermal resources of the United States. During the 1970s, course maps of heat flow were produced. Numerous wells have since been drilled in the Illinois Basin region, of which bottom hole temperatures (BHTs) were recorded during the drilling process. Unfortunately, the bottom hole temperatures have never been viewed on high resolution maps. We compiled bottom hole temperature data from geophysical logs and created a detailed database that contains observations of temperature from more than 24,000 wells in Indiana, Illinois, and Kentucky, providing a substantial increase in information on the thermal state of the subsurface. Quality control of the data was based on reduction of duplication, correction of erroneous depths or temperature, and elimination of faulty data acquisitions. For Indiana and Illinois, many records with bottom hole temperature values of exactly 100ºF were removed from the database because they resulted from the field operator using depth charts to assign a BHT value, rather than an actual observation of temperature at depth. The BHT values at depths between 3,000 and 12,900 feet were corrected using the Harrison equation to account for error related to the circulation of drilling fluids and better represent an equilibrium, or in-situ, temperature. Geothermal gradients were calculated for each well by using a mean ambient surface temperature at the well location from values obtained from the PRISM Climate Group. Mean geothermal gradients were also calculated for specific geologic intervals. Updated maps of geothermal gradients and temperature anomalies throughout the Illinois Basin show a higher resolution of subsurface thermal conditions than earlier products. Preliminary results for this study suggest that higher gradient heat flows occurred at shallow depths whereas low gradient heat flows occurred at deeper depths.

PROBLEM

The bottom hole temperature datasets from Illinois, Indiana, and Kentucky were created by different people with different intentions for using the data and therefore had inconsistencies between them.

OBJECTIVES

- Provide a method to process data from three different states into a standardized, quality-controlled database for the Illinois Basin region
- Provide better understanding of heat flow in the subsurface

REFERENCES

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Sarekarimi, Abouzar and Muhammad, Kashif, 2009, Groundwater flow and salinity in the Illinois Basin: GeoHalifax 2009 Conference, 6 p.

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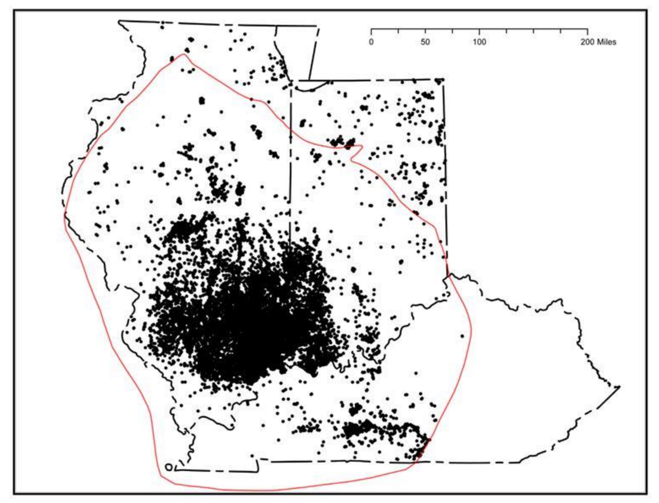
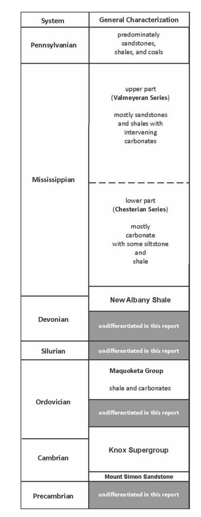
OVERVIEW OF STUDY AREA



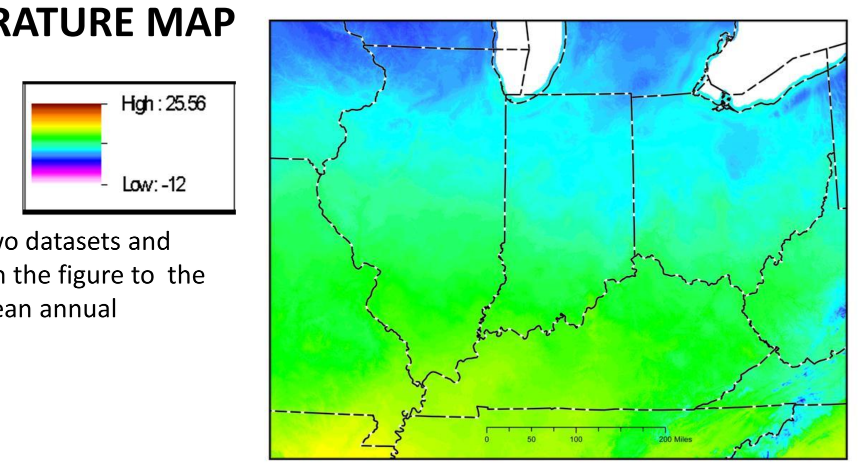
Locations of wells with BHT values used in this project. The outline of the Illinois Basin (red) is modified from Swezey (2007).



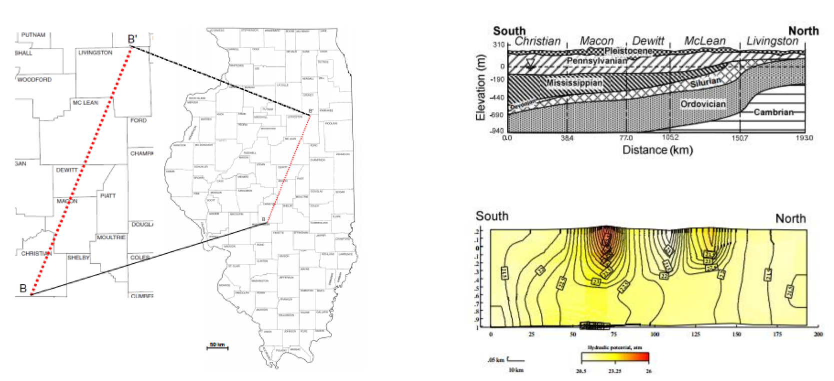
Generalized Stratigraphic Units of the Illinois Basin

SURFACE TEMPERATURE MAP

Maximum and minimum temperature data was downloaded from PRISM Climate Group. Rasters were created from the two datasets and averaged together to form the figure to the right which represents mean annual temperature.

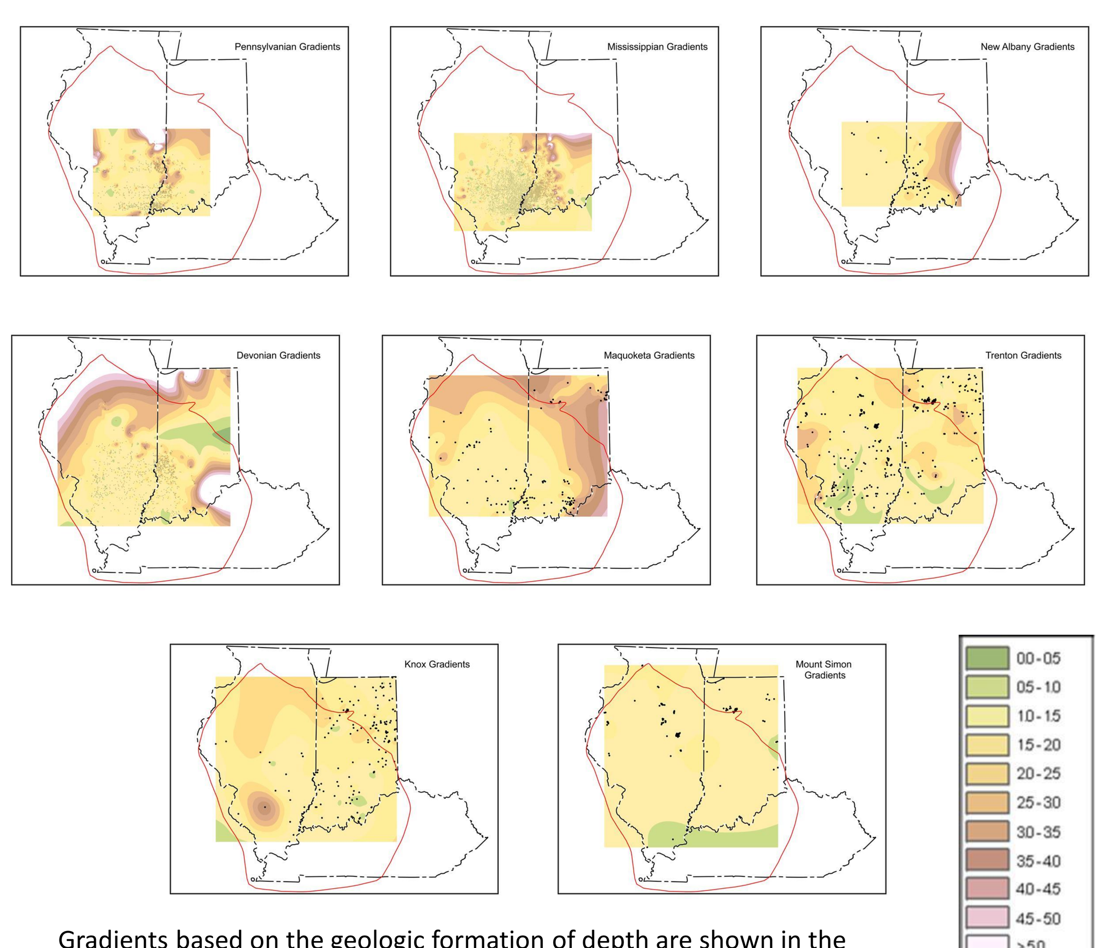


HYDRAULIC FLOW POTENTIAL



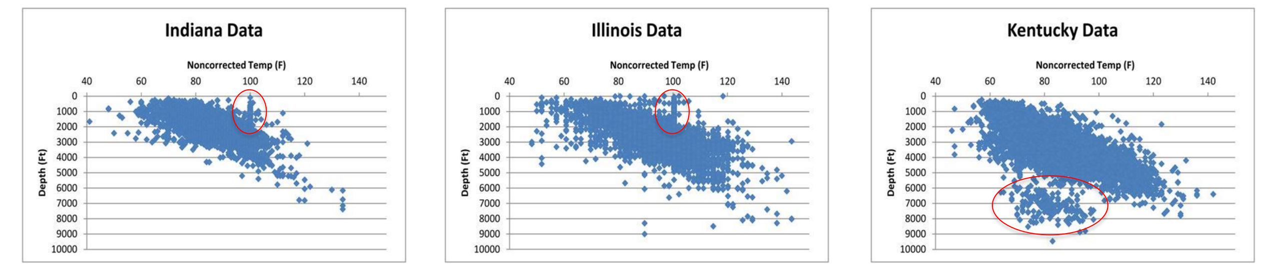
Hydraulic flow potential (bottom right) of the cross section at the indicated location shown in the left figure. The top right figure is a cross section view of the stratigraphic units.

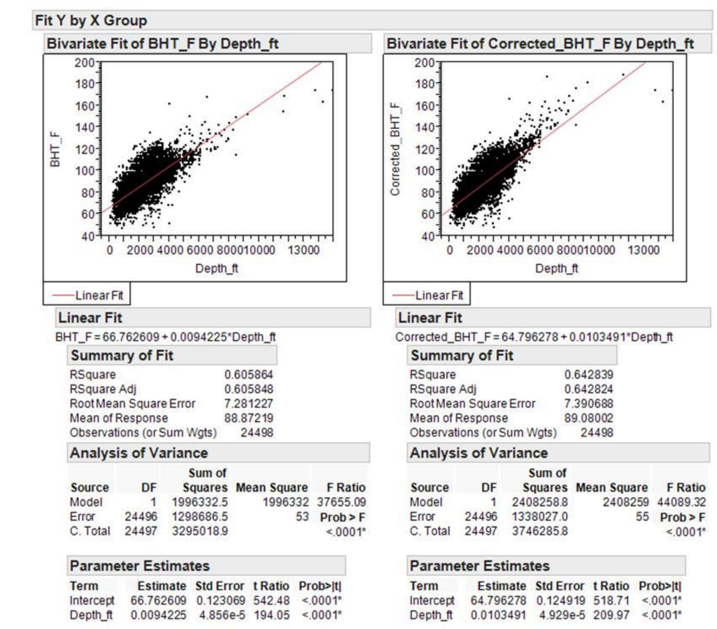
GEOLOGICALLY BASED GRADIENTS



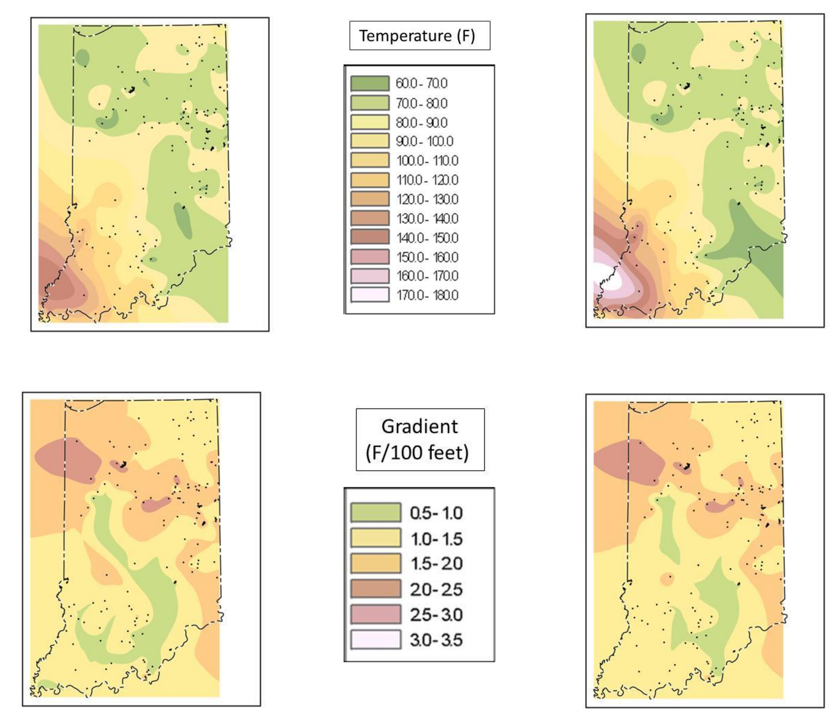
Gradients based on the geologic formation of depth are shown in the figure above. Again, the general trend of smaller gradients at deeper depths can be seen.

TEMPERATURE CORRECTIONS

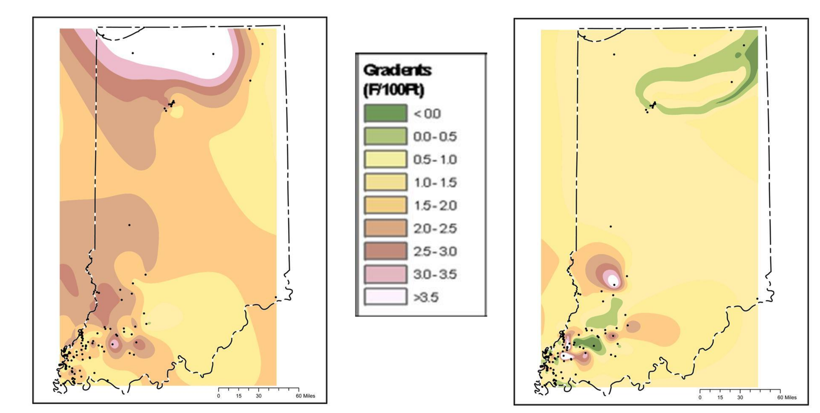




The datasets from Indiana, Illinois, and Kentucky as downloaded from the NGDS website (above). Circled in red are the 100-degree problem for Indiana and Illinois and the horizontal wells that had measured depth recorded in place of true vertical depth for the state of Kentucky. These records were removed from the final dataset for the Illinois Basin. The figure to the right is a statistical analysis of corrected versus uncorrected temperatures. The figures below are temperature and gradient maps for the Knox formation showing the effects of correcting temperatures.

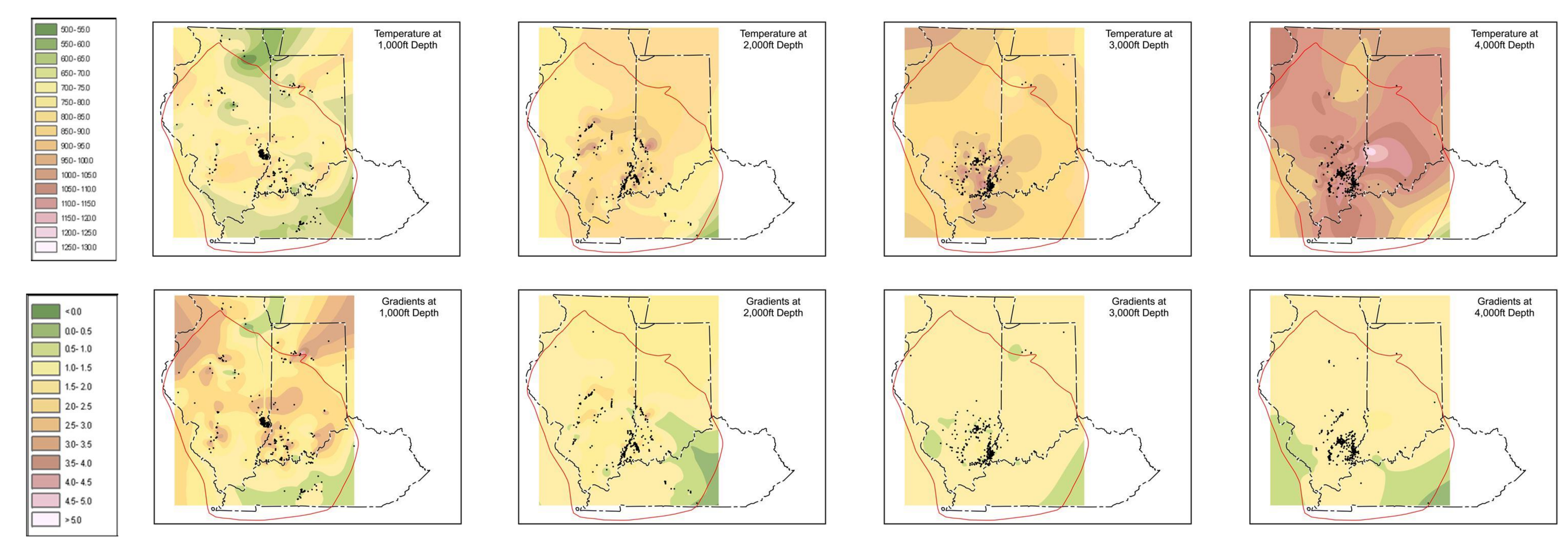


SHALLOW VERSUS DEEP GRADIENTS

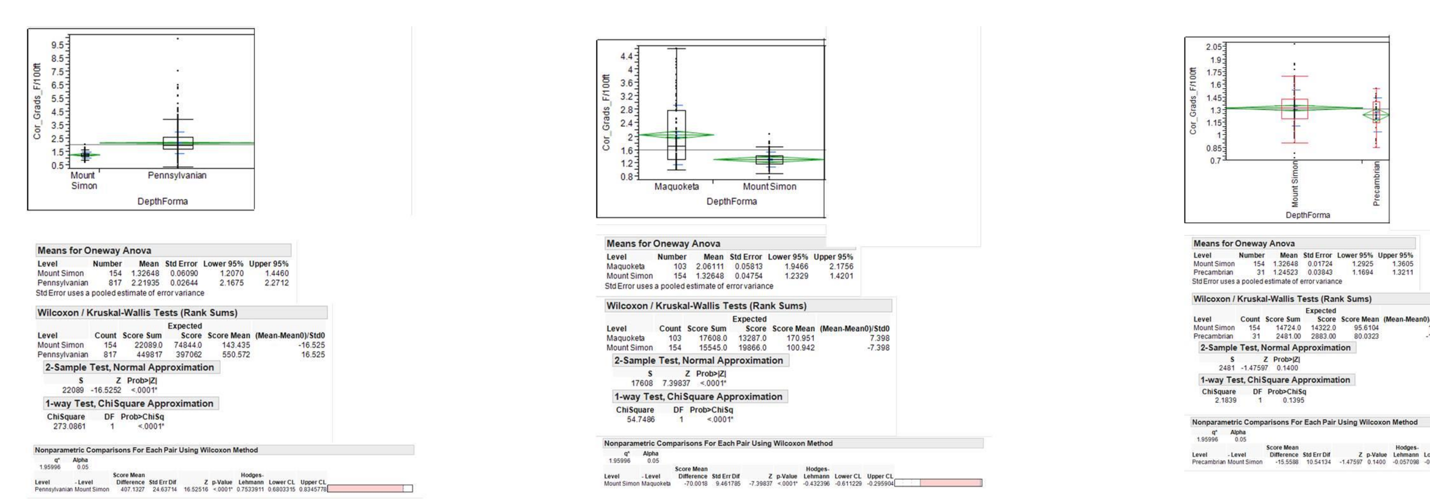


Wells that had two depths and temperatures recorded on geophysical logs. The figure on the left is an interpretation map of the geothermal gradients for the shallow portion of the wells while the figure on the right is the gradients for the deeper section of the well.

DEPTH SLICES



Temperatures and gradients for wells drilled to depths of 1,000 ft, 2,000 ft, 3,000 ft, and 4,000 ft were mapped. In order to ensure a suitable data size, a buffer of up to 75 feet was used for each depth range.



Statistical analysis of several select formations. As the hydraulic flow model shows, the Cambrian formation experiences less hydraulic potential. The Mount Simon formation at the base of the Cambrian was chosen for comparison with the Pennsylvanian, Maquoketa, and Precambrian. The geothermal gradient means for the three formations decreases with depth just as previous figures have indicated. No difference in the gradients can be determined between the Mount Simon and Precambrian basement as a p-value of 0.14 indicates.

METHODS

- Three datasets were reviewed for duplicate entries, missing data, and clearly erroneous data.
- Other records were considered to be obviously inaccurate and were removed from the datasets
- All well locations were projected to a consistent coordinate system, UTM X-Y, NAD83, Zone 16N.
- Applied temperature corrections using the equation of Harrison et al. (1982) to log header BHT values with an associated depth range of 3,000 to 12,900 ft to provide a more accurate in-situ well temperature
- Gridded data of annual maximum and minimum temperatures (1971-2000) from the PRISM Climate Group were used to create an average annual land surface temperature map
- Calculated a mean geothermal gradient for each well - the surface temperature was subtracted from the corrected BHT and divided by the depth
- A filter was used by mapping records with respect to depth formation. This minimized effects from lithology and depth when comparing the gradients
- The gradients were examined for values that deviated from the general trend in the region

RESULTS

- The R-squared value for corrected temperatures is almost 4% higher than non-corrected temperatures suggesting the Harrison equation provides a better fit to the data
- The commonly used estimate or 'national average' of 1 deg F/100 ft appears to be consistently low for the Illinois Basin region in which gradients greater than 4.0 deg F/100 ft were calculated during this study
- The new geothermal database of the Illinois Basin indicates that the mean geothermal gradient is 1.56 deg F/100 ft for the region
- Lower gradients appear at deeper depths with minimum gradients found at the heart of the basin, creating a bull's-eye effect of higher gradients in shallower wells around the basin margin
- Low thermal conductivity sediments may be enhancing temperature gradients due to a thermal blanket effect
- P-values indicate a difference in gradient means between deep geologic formations and shallow formations, which may be due to ground water flow patterns
- Shallower units such as the Pennsylvanian and Mississippian suggest advective heat transport may be significant from shallow groundwater flow systems, while the deeper units such as Knox and Mount Simon indicate that conduction is the most dominant process