

# Testing the Use of Gravity and Magnetic Methods for Broad Surveys in Energy Exploration

GEO386G: GIS & GPS APPLICATIONS IN EARTH SCIENCES

JONATHAN LY

## Introduction

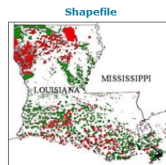
The dominant geophysical method used in the exploration and development of hydrocarbons is the analysis of seismic data. Though this technique is tried and true, as it has been responsible for nearly the entirety of discovered fields, seismic acquisition can be costly and its interpretation time-intensive. Potential geophysical alternatives to consider are offered by gravity and magnetic prospecting. These passive techniques of data acquisition require no initial energy input to acquire a reading. Because of this, they can be gathered at minimal cost and are an enticing option for their potential economic value. This study aims to analyze the question: *Can gravity and magnetic methods be used at a broad-scale to identify regions of hydrocarbon occurrence?*

The overall strategy used in this study to test the effectiveness of gravity and magnetic methods in the search for energy resources is to compare the raster data of known historical petroleum production to raster data of these geophysical methods. If a strong correlation can be shown to exist between these datasets, these geophysical methods can be said to be a predictor of hydrocarbon occurrence. A prime study location is offered by the state of Louisiana, which possesses about 4,500,000,000 barrels of oil equivalent in proven reserves. The majority of this energy is in the form of dry natural gas, which accounts for almost 90% of the total. A comprehensive dataset of historic production in the state provides the standard of comparison for use in this study.

## Data Collection and Preparation

- **Louisiana Gas and Oil Fields with Cumulative Production from 1977 -2014**
  - <http://certmapper.cr.usgs.gov/geoportal/catalog/search/resource/details.page?uuid=%7B4076D8D4-CEC8-4385-87C9-871F0C53CDF9%7D>

### Louisiana Gas and Oil Fields with Cumulative Production from 1977 - 2014



Tags

There are no tags for this item.

#### Summary

This dataset represents the producing, dry holes, wildcat wells and wells that have other well type categories other than the ones mentioned previously in Louisiana. These wells were used to create gas and oil field polygons. The field polygons include discovery data, number of producing wells in the field, average measured depth of those well, total gas and oil production from 1977-2014, gas oil ratio (GOR), and field type. Also, included is a table with historic gas and oil production from 1977-2014.

#### Description

The cumulative production files for gas and oil by field ranking by year (1977 - 2014) were copied from the Louisiana Sonris site and pasted into excel by year. These Excel files were imported into Access. The Oil and Gas wells database and field center points were downloaded from the Sonris GIS access site as geodatabases. These geodatabases were opened in ArcMap and there tables were exported as dbf files and imported into Access. In Access the field production numbers were summed. From the sums a gas/oil ration (GOR) was calculated to determine the field type i.e. gas field or oil field. The USGS standard is below 20,000 equal's an oil field and above 20,000 is a gas field. This table was linked (on field name) to the field center point table to pull in the discovery year. Using the wells file the measured depth was averaged on field name and this was added to the fields (cumulative production) file by linking on field name as was the field code ID. A well count (total of wells in a field) was also added by summing the field name column. The wells file was used to pull out dry holes (based on the legend description field) and wildcats based on the field name of wildcat. This file (wells file) was also used to create the field buffers in ArcMap based on buffering field name with an extent (buffer) of 2,000 feet and using dissolve all. The polygon buffering file that was created in ArcMap was joined to the cumulative production file based on field name. After the join the file was exported to a geodatabase. That geodatabase was brought into ArcMap and edits were done. Most of the edits were due to wells having the wrong field name assigned to them. If a polygon was far away from the main group it was deleted. An example is the Monroe Gas field in northern Louisiana. Many well are assigned to it and it creates a large polygon, but some of the well that were assigned to the Monroe field were all over the state. No guesses were made the extra polygons were deleted.

Field Name: name given to the field by the state. Field ID: numeric code assigned by the state to the field. Discovery year: the year the field was discovered. Well Count: the number of wells associated with a particular field. Casinghead Gas: the cumulative amount of casinghead gas (in Mcf) a field has produced from 1977 - 2014. Natural Gas: the cumulative amount of natural gas (in Mcf) a field has produced from 1977 - 2014. **Gas Total: the total amount of gas (casinghead gas plus natural gas in Mcf) the field has produced from 1977 - 2014.** Condensate: the cumulative amount of condensate (in barrels) a field has produced from 1977 - 2014. Crude Oil: the cumulative amount of crude oil (in barrels) a field has produced from 1977 - 2014. **Oil Total: the total amount (condensate plus crude) a field has produced from 1977 - 2014.** GOR: Gas Oil Ratio. This is a number for determining if a field is a gas field or an oil field. The gas is divided by the oil. The standard for the USGS is below 20,000 or equal to it is an oil field if the number is higher than 20,000 it is a gas field. Field Type: based on the GOR the field become "Gas" or "Oil". If the field has no reported production it is classed "Unknown". Average of Measured Depth: this is the average of the wells in a field measured depth.

#### Credits

There are no credits for this item.

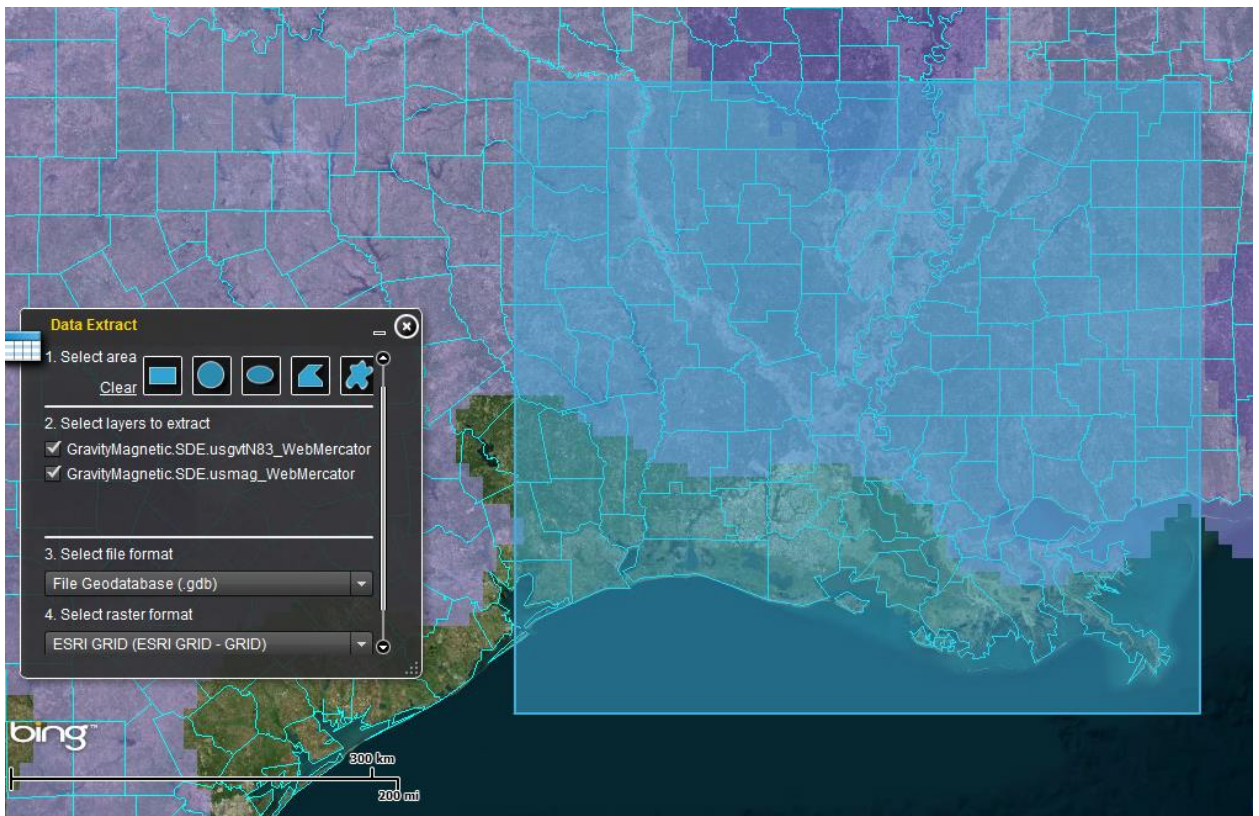
#### Use limitations

There are no access and use limitations for this item.

#### Extent

West: 90.000000 East: 92.000000

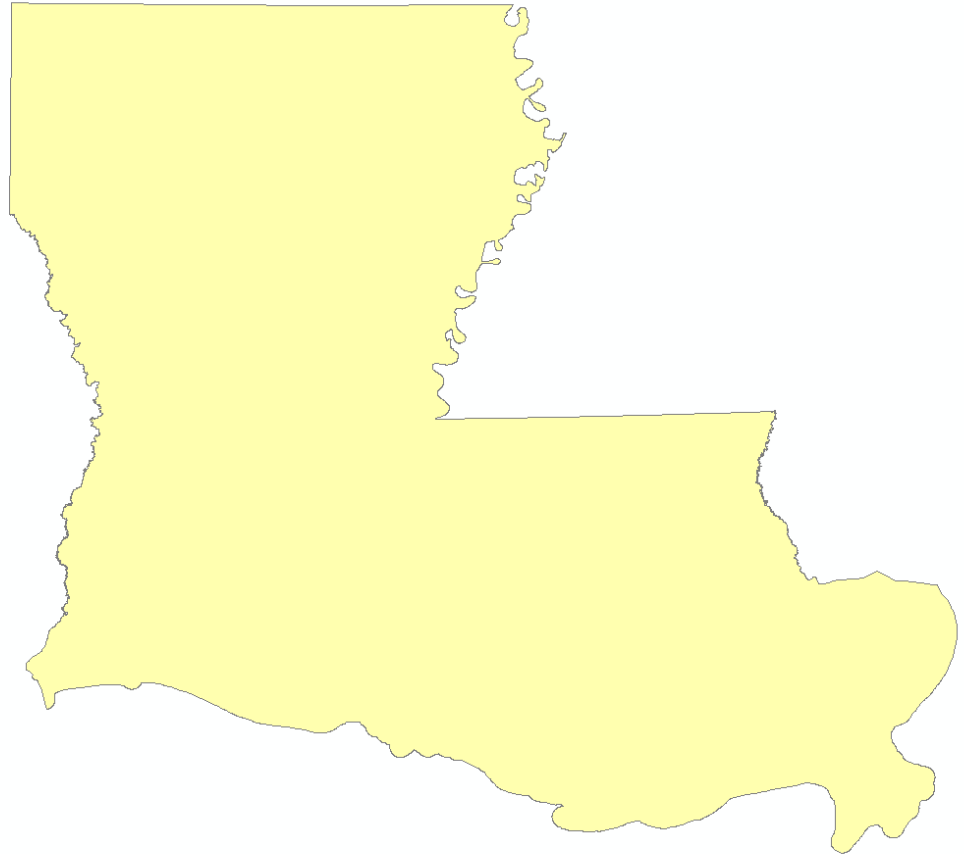
- This dataset was chosen because it provides a comprehensive review of oil and gas production spanning nearly four decades within the entire state of Louisiana. The Summary and Description were copied from the linked website and pasted into this file for easier reference. I chose to highlight the bold text because these two values, the Gas Total and the Oil total, will be normalized, combined, and used as the metric of hydrocarbon abundance. One caveat of this study is that production rates do not necessarily reflect actual reserve size. For example, a small field may be of a great reservoir quality, and so it is preferentially produced from. On the other hand, a large field may be of poor quality, and as a consequence, it may have been overlooked in the past. Nevertheless, these exceptions may be overlooked based on the assumption that fields with greater reserves will likely be the target for further exploration and development.
- The original geographic coordinate system for this file is NAD 1983.
- **Gravity and Magnetic Data for Louisiana**
  - <http://gis.utep.edu/data.html>



- These datasets were obtained through a web service offered by the University of Texas at El Paso through an effort to publish a database of gravity and magnetic information for the United States. The primary field of interest in the gravity data is titled “OBSGRV” which records readings of the gravimeter in units of Gals. Higher readings are indicative of denser bodies in the subsurface, and inversely, lower readings represent less dense bodies underground. The field of interest in the magnetic data attribute table is “MagI” which describes magnetic anomalies

across the region. This information is useful for defining basement blocks and their depths underlying the sedimentary basins.

- The original projected coordinate system for these files is WGS 1984 Web Mercator (auxiliary sphere).
- **State Boundary for Louisiana**
  - <http://louisianasiteselection.com/gis-data-download.aspx>



- This shapefile was included to delineate the resolvable boundaries of the rasters created from analyzing each of the previous files. This is necessary because the extent of the gravity and magnetic data were set such that their rectangular extent included portions of other states. The production data, however, were only known within the state of Louisiana, and so correlations within this area of known information are more reliable.
- The original projected coordinate system for this shapefile is NAD 1983 UTM Zone 15N.

## **Creating Rasters and Maps**

### **Creating a Raster of Known Production in Louisiana**

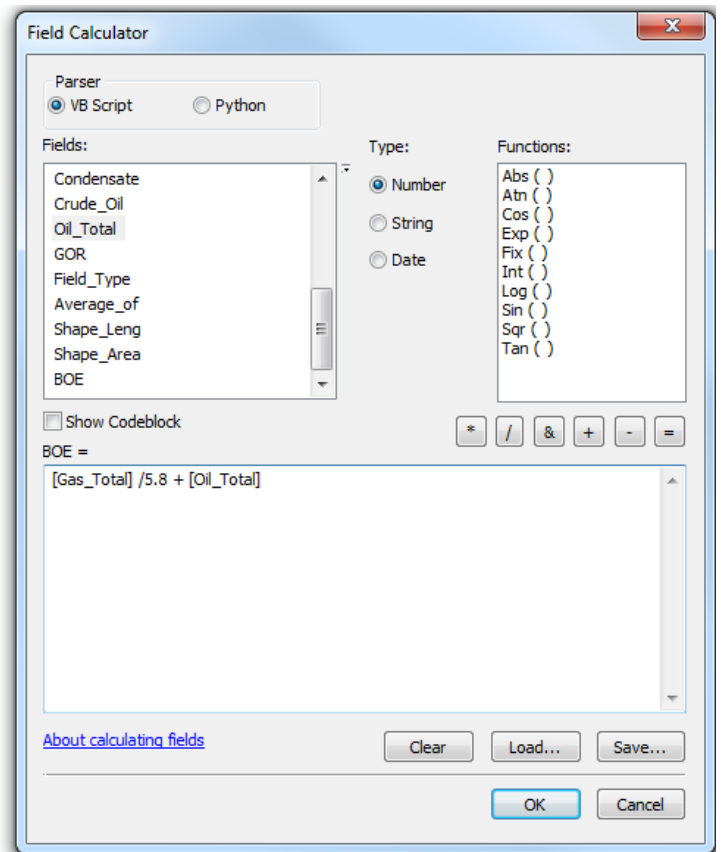
Petroleum can occur as either oil or gas depending upon the length of the carbon chains found in its chemical composition. Though these forms both have the potential to yield energy, their varying structure results in different energy yield, energy density, and economic value.

Consequently, a standard of comparison must be established in order to accurately assess the energy potential of multiple fields housing a complex mixture of these hydrocarbon forms. This standard is known as the barrel of oil equivalent (BOE), which is unit of energy released by burning one barrel of crude oil. In conventional terms, 5,800 cubic feet of natural gas is equal to one BOE. As previously mentioned, the majority of hydrocarbon fields in the state of Louisiana occurs in the form of dry natural gas which totals 90% of all hydrocarbons. As a result, the data being used in this project must be converted into BOE in order to simplify the analysis. This can be done by converting the gas total for each field from mcf (1,000 cubic feet of natural gas) to BOE through dimensional analysis.

$$\frac{x \text{ MCF}}{1} \times \frac{1,000 \text{ cubic feet}}{1 \text{ MCF}} \times \frac{1 \text{ BOE}}{5,800 \text{ cubic feet}} = y \text{ BOE}$$

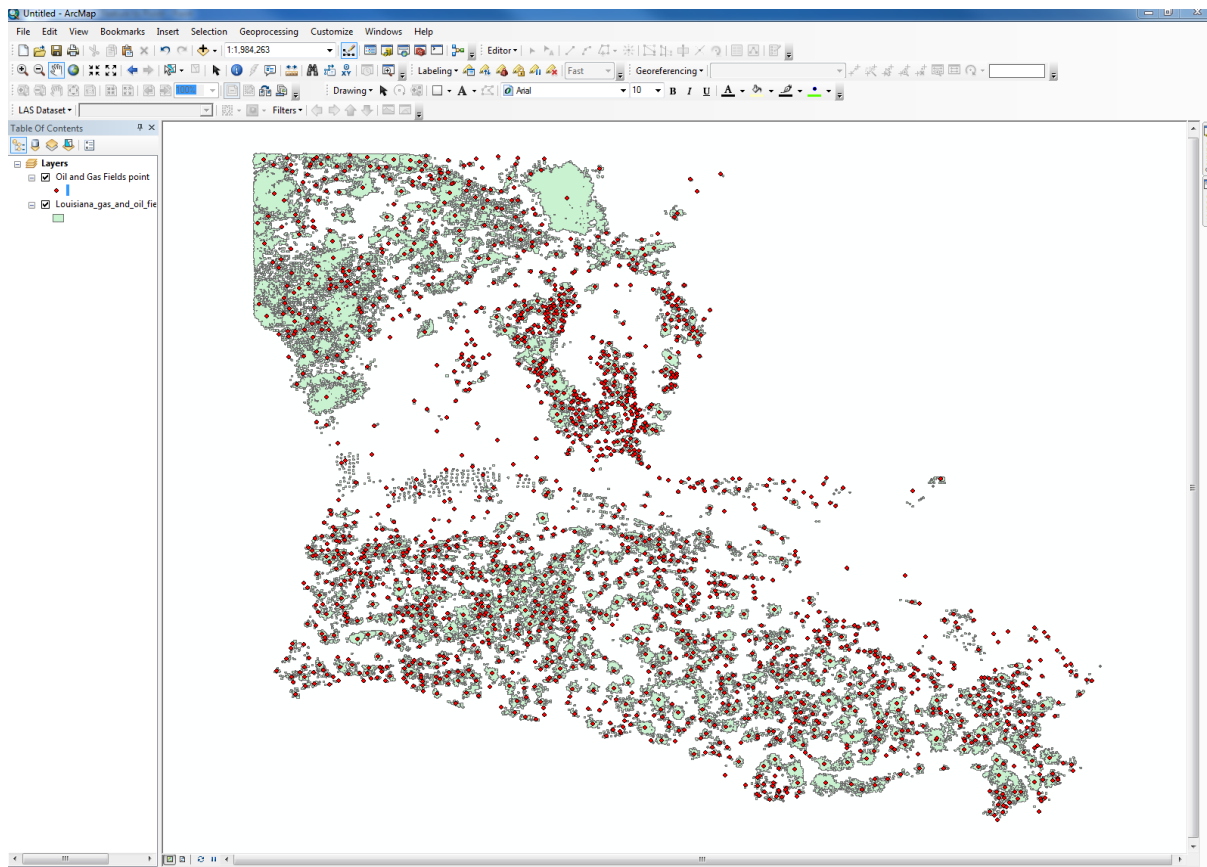
By simplifying this equation, MCF can be converted to BOE by essentially dividing by 5.8. The resulting value can then be added to the oil total for each field, which is already measured in barrels, to find the BOE of each field. This calculation is easily accomplished by creating a new field in the Louisiana Gas and Oil Fields attribute table by adding a new field, titled BOE, and using the Field Calculator on the newly created column. The result of these calculations are then added to the newly populated fields in the attribute table, as illustrated below.

Shape_Leng	Shape_Area	BOE
0.110718	0.000432	0
0.036874	0.000107	0
0.270241	0.001184	0
0.405582	0.00226	0
0.131672	0.000595	0
0.65959	0.003211	0
0.129114	0.000567	0
0.210596	0.001059	0
0.112252	0.000404	0

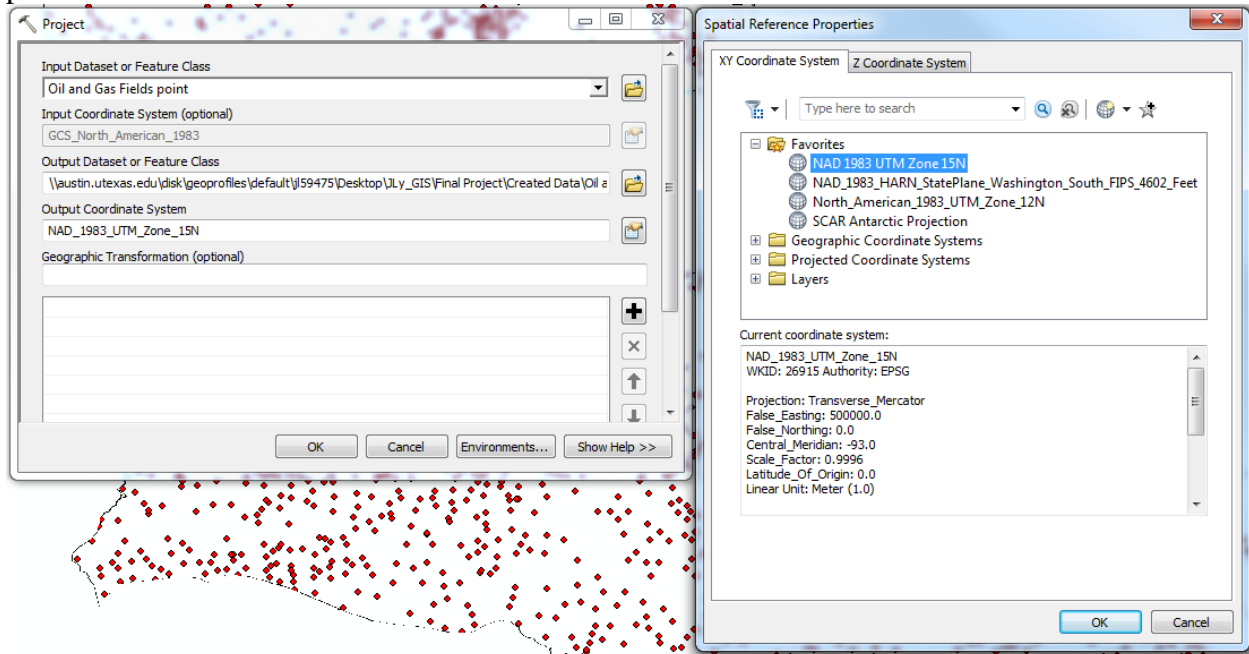


FID	Shape *	OBJECTID	Field_Name	Well_Count	Gas_Total	Oil_Total	Field_Type	Shape_Leng	Shape_Area	BOE
0	Polygon	1	ADAMS BAY	7	0	0	Unknown	0.110718	0.000432	0
1	Polygon	2	ADAMS BAY, SOUTH	1	0	0	Unknown	0.036874	0.000107	0
2	Polygon	3	ADDIS, WEST	26	1302292	176567	Oil	0.270241	0.001184	401100.103448
3	Polygon	4	AJAX	51	50046	3502	Oil	0.405582	0.00226	12130.62069
4	Polygon	5	ALABAMA BAYOU	9	0	0	Unknown	0.131672	0.000595	0
5	Polygon	6	ALABAMA BEND	96	87757628	27634	Gas	0.65959	0.003211	15158259.5172
6	Polygon	7	ALDEN BRIDGE	8	11783	3097	Oil	0.129114	0.000567	5125.103448
7	Polygon	8	ALLIANCE	27	2969995	187927	Oil	0.210596	0.001059	699995.103448
8	Polygon	9	ALLIGATOR LAKE	14	1135455	127923	Oil	0.112252	0.000494	323691.103448
9	Polygon	10	ALOHA	42	0	568310	Oil	0.150994	0.00087	568310
10	Polygon	11	ALPHA	2	702798	0	Gas	0.048751	0.000186	121172.068966
11	Polygon	12	ALSEN	21	98	21916	Oil	0.141828	0.0007	21932.896552
12	Polygon	13	AMELIA	22	0	0	Unknown	0.408754	0.001569	0
13	Polygon	14	AMERICAN ISLAND	17	0	0	Unknown	0.207194	0.00104	0
14	Polygon	15	AMERICAN ISLAND, NORTH	10	0	0	Unknown	0.1044	0.000535	0
15	Polygon	16	ANACOCO LAKE	1	0	0	Unknown	0.037241	0.000109	0
16	Polygon	17	ANDREPONT	11	4110729	475956	Oil	0.177218	0.000755	1184702.37931
17	Polygon	18	ANDREW	51	60882205	559366	Gas	0.316117	0.002099	11056297.8966

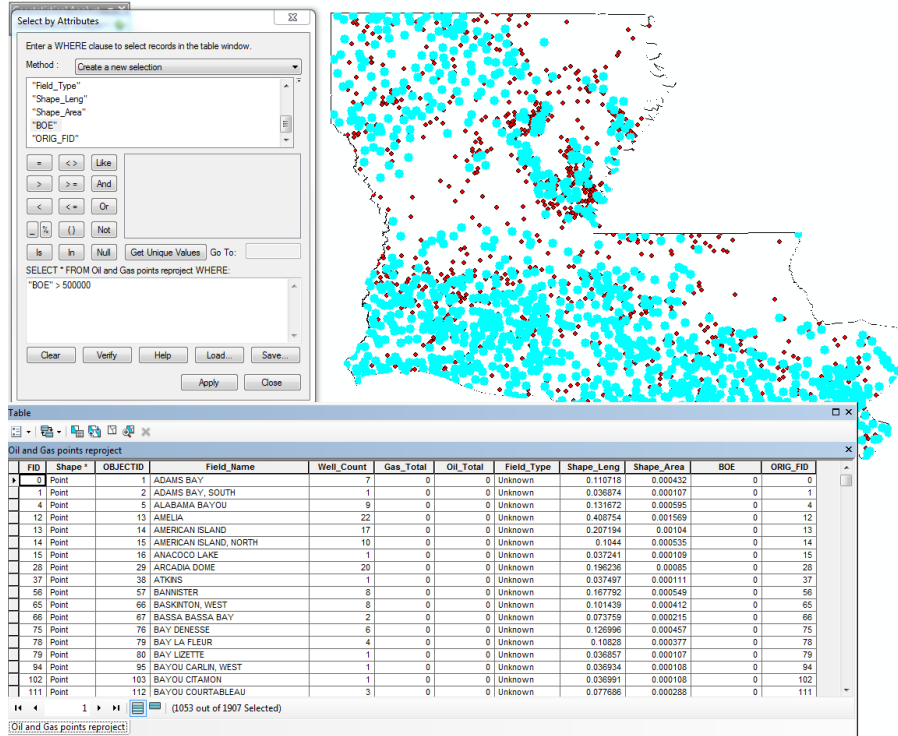
After creating this new field, the next step is to convert the features of the shapefile from polygons to points for later use in geostatistical analysis using the Feature to Point tool. Because the optional dialog box “Inside” was checked, this tool essentially condenses the areal extent of the polygon to a single point located at the centroid of each polygon while retaining all of the information in the attribute table. The result of this process is displayed below, which displays the newly created layer of red points overlying the pre-existing green polygons.



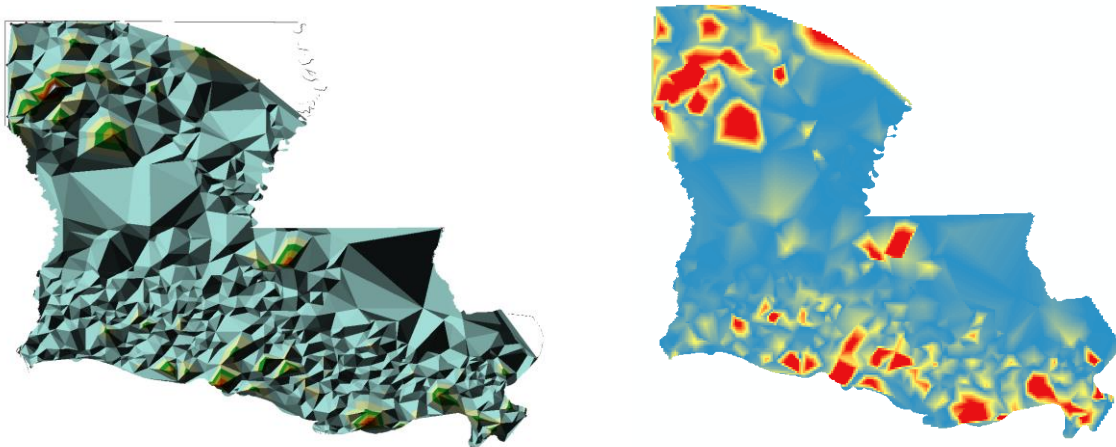
Before interpolating the points to produce a continuous raster, it is important to ensure that all of the data analyzed in this lab is in the same spatial reference. As outlined previously in the Data Collection section, all of the files used in this study are in different coordinate systems. The Louisiana state shapefile was selected as the standard, and so each other file must be converted to NAD 1983 UTM Zone 15N. This can be done using the Project tool on the Oil and Gas Fields points.



In its original state, there were 1907 points in the dataset, and this large amount of data was found to be a strain on the interpolation process. In addition, there was a large amount of skew towards low producing wells, which may have made the results less informative. As a result, a subset of this data was selected to include only fields which had produced more than 500,000 BOE over their lifetime. This was accomplished using a Select by Attributes query with the statement : "BOE" > 500000. The data was then exported from the options in the table of contents.



The subset of production data was then used to form a TIN using the Create TIN tool as a first pass for interpolating between the points' BOE values. However, as the goal is to depict a continuous surface for eventual comparison with other continuous fields, this data is better represented as a raster. A conversion between these data types was done using the TIN to Raster tool. The results of these two processes are illustrated for comparison below, and a completed raster map is included in the Final Products.

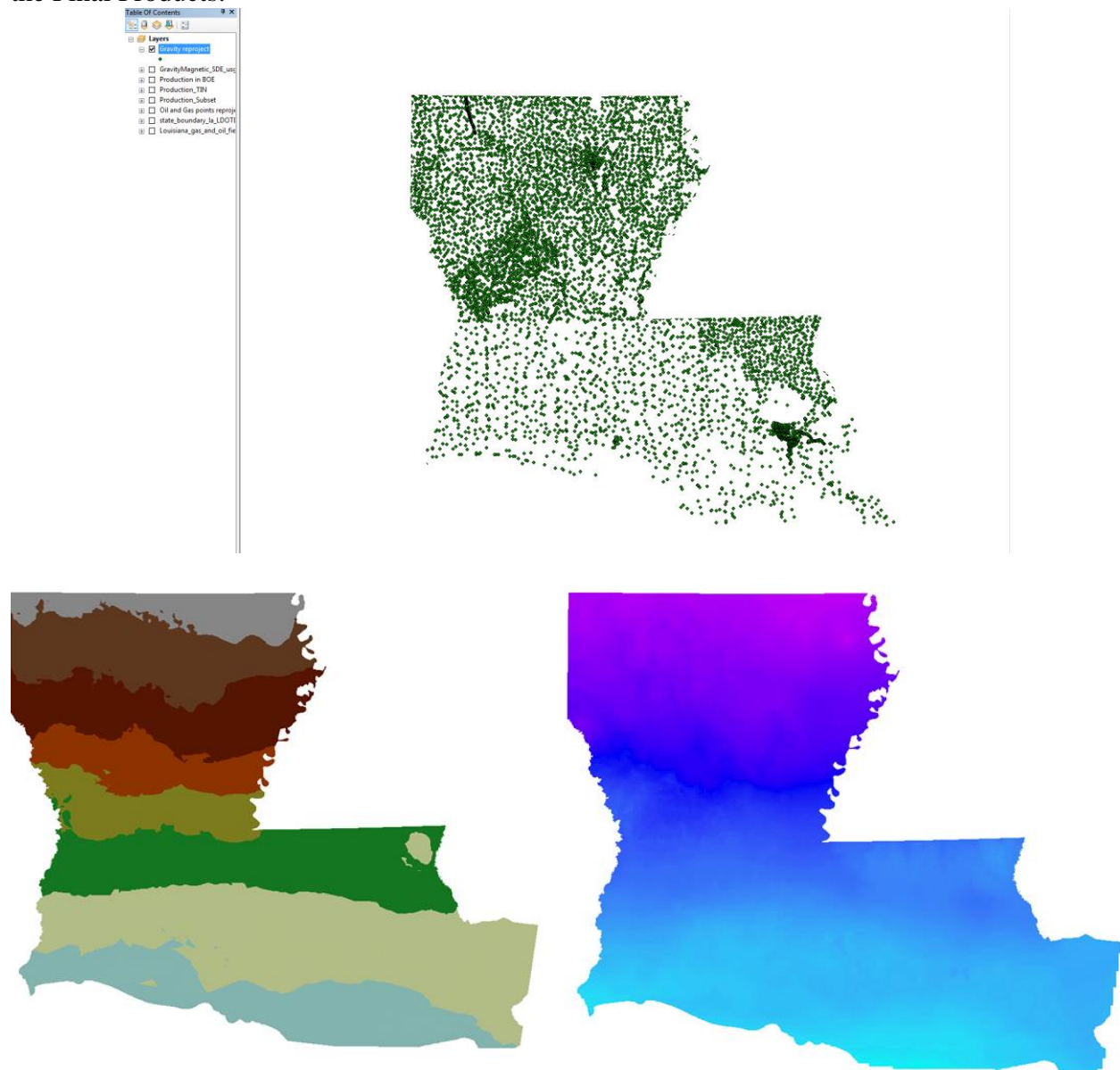


### Creating a Raster of Gravity and Magnetic Data

In comparison to the production data, which required quite a bit of preparation in order to create a continuous raster surface, the gravity and magnetic data sets were relatively straightforward to work with. As these data were both originally obtained as an array of points, the work flow for the two were the exact same. The original coordinate system for these files was WGS84, and so they were reprojected to NAD83 UTM Zone 15N using the Project tool. The



resulting reprojected layers were then used to create TINs using the eponymous Create TIN tool. Lastly, these TINs were converted into smooth raster using the TIN to Raster tool. This complete workflow is illustrated below for reference. In addition, the final maps of these processes are in the Final Products.



### Completed Maps

The completed maps for each of the above rasters are collected in the Final Products. Before moving on, however, it is worth discussing the patterns present in each raster. The production data show marked areas of high hydrocarbon occurrence in the north and south of the state. These highs, however, are not continuous features, as they occur in patches reflecting the disjunction between fields. The gravity data displays a smooth gradient that decreases from north to south. Lastly, the magnetic data shows a defined low running through the middle of the state. Moving northwards and southwards away from this median, however, there is a trend of increasing magnetic anomaly that eventually decreases and returns to lower values.

## Testing Correlations Between Datasets

A brief overview of the final maps is informative in illustrating some general trends in the data as previously discussed in the Completed Maps section. However, the aim of this study was to test whether or not gravity and magnetic data were adequate exploration tools in the search for hydrocarbons. A cursory graphic analysis reveals practically no connection between the production data and the gravity data, as their trends are visually dissimilar. However, the production data and magnetic data exhibit some similarities, and there may be some degree of correlation in these sets.

Fortunately, the use of GIS software enables a more rigorous analysis of these correlations that extends beyond this graphic analysis. In order to test this hypothesis, a random sample of points across the states will be taken, and values from each of the produced rasters will be incorporated. These points will then be analyzed in Excel to test for any potential correlations.

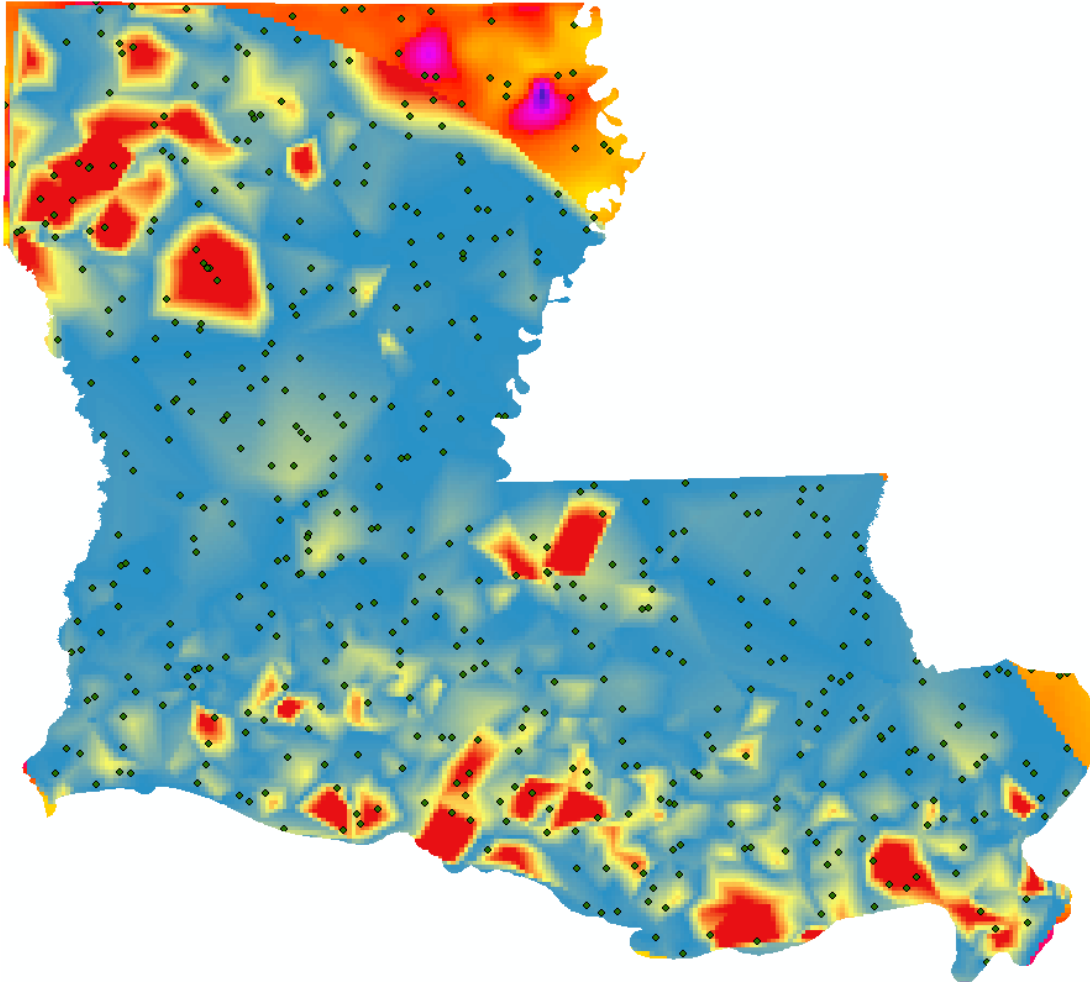
## Creating Random Points

The first step to testing correlations between these data sets is to create random points to serve as the random sampling for statistical analysis. These points can easily be created by using the Create Random Points tool.

The screenshot displays the 'Create Random Points' tool dialog box. The 'Output Location' is set to a path on the desktop. The 'Output Point Feature Class' is 'Sample Points'. The 'Constraining Feature Class' is 'state\_boundary\_la\_LDOTD\_2007'. The 'Constraining Extent' is defined by a bounding box with coordinates: Top (250.000000), Bottom (0.000000), Left (0.000000), and Right (250.000000). The 'Number of Points' is set to 500, with the 'Long' radio button selected. The 'Minimum Allowed Distance' is set to 0 meters, with the 'Linear unit' radio button selected. The 'Create Multipoint Output' checkbox is unchecked. The 'Maximum Number of Points per Multipoint' is set to 0. A help panel on the right explains the 'Number of Points' field, stating it can be a long integer or a field from the constraining features.

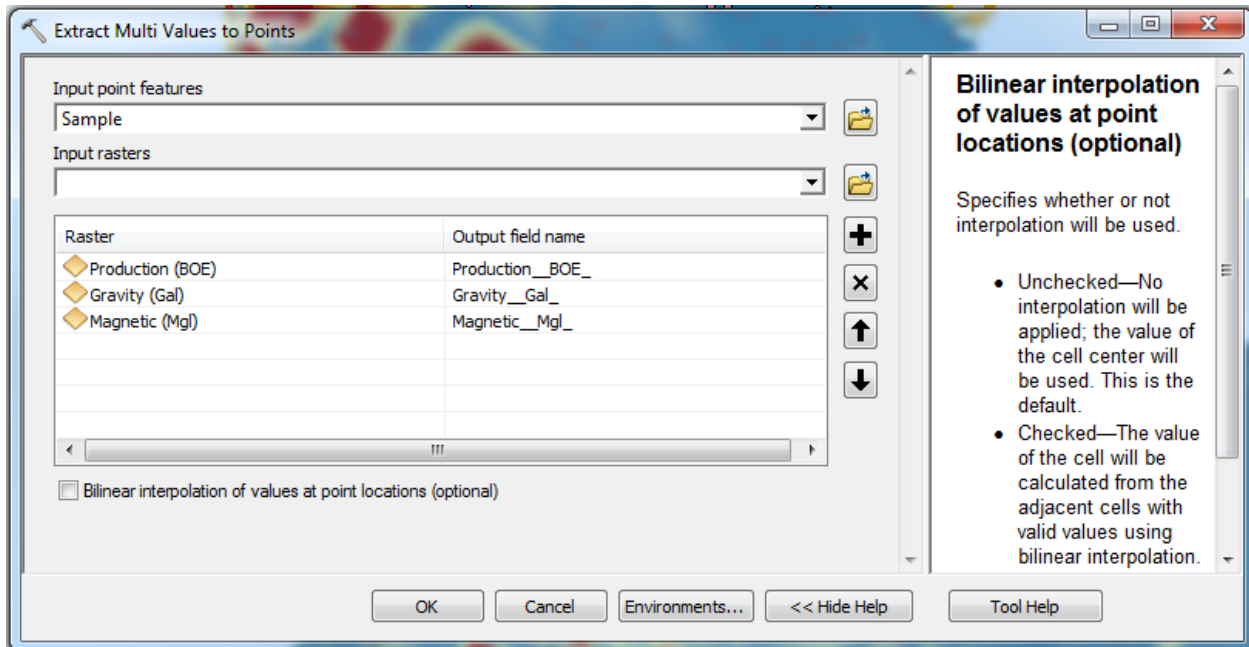
The tool and the input parameters are displayed in the image above. As indicated, the constraining feature class was chosen as the state boundaries of Louisiana, which was the extent previously set for our produced rasters. In addition, the Number of Points field is set to 500 to produce a number of points that will sufficiently sample across the extent of the state, but will not be excessively large such that processing takes an excessive amount of time. When the

process is complete, the newly created points are added to the map as a new layer, as represented by the green dots in the figure below. The rasters are included to show the extent and coverage of the points. As illustrated, these random locations appear to provide an adequate sample of the data below, with just a few points falling outside the range of the production data. These points will necessarily be excluded from the correlation as they will not be informative.



### **Adding Data to the Points**

The newly created points appear as if they will provide some appreciable spatial information for analysis, but they do not contain any other information just yet. In order to make these points useful, it is necessary to incorporate the values at each point from the underlying rasters. The Extract Multi Values to Points tool is perfectly suited for this job. This tool works by starting with an input point feature and a field for input rasters. The input feature in this case is the set of empty sample points, which will essentially provide the locations for which values will be determined. The input rasters are the sources from which these values will be extract and appended to the attribute table of the output points.



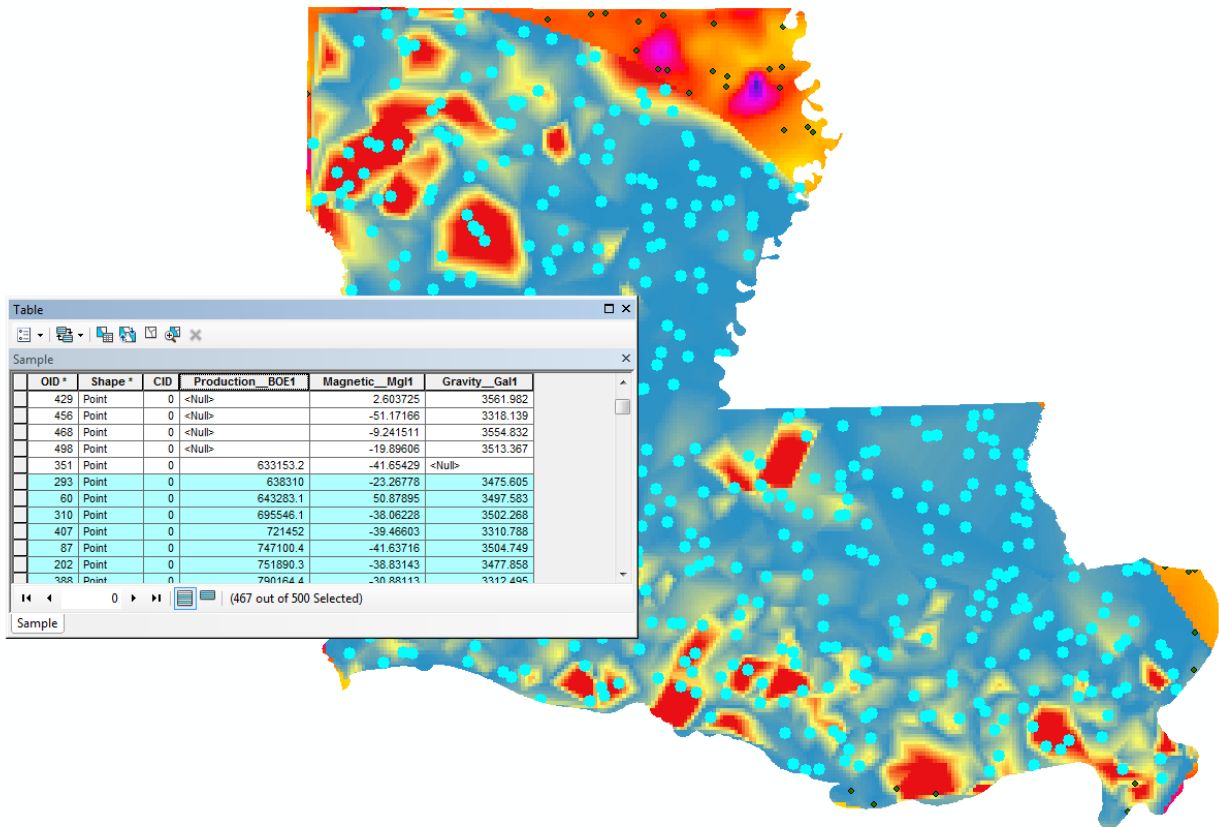
After running the tool, the results appear underwhelming as there is no new layer added to the map. However, opening the attribute table of the Sample points reveals an important difference. As indicated below, the attribute table now contains the values from each of the rasters at each point.

OID *	Shape *	CID	Production__BOE1	Magnetic__Mgl1	Gravity__Gal1
1	Point	0	8297460	-75.5501	3368.457
2	Point	0	9716503	-9.872293	3302.247
3	Point	0	7963606	-33.20445	3352.707
4	Point	0	14545900	69.01109	3305.146
5	Point	0	14272930	8.172727	3535.917
6	Point	0	20477320	-98.25897	3362.744
7	Point	0	8192229	34.22055	3308.082
8	Point	0	7689605	39.52308	3336.261
9	Point	0	32389130	-78.90321	3310.467
10	Point	0	<Null>	-36.29156	3503.062

With this attribute table, which combines data from three different data sets at specified points across the extent of the study, it is possible to export the data for analysis in Excel.

## Analyzing the Data

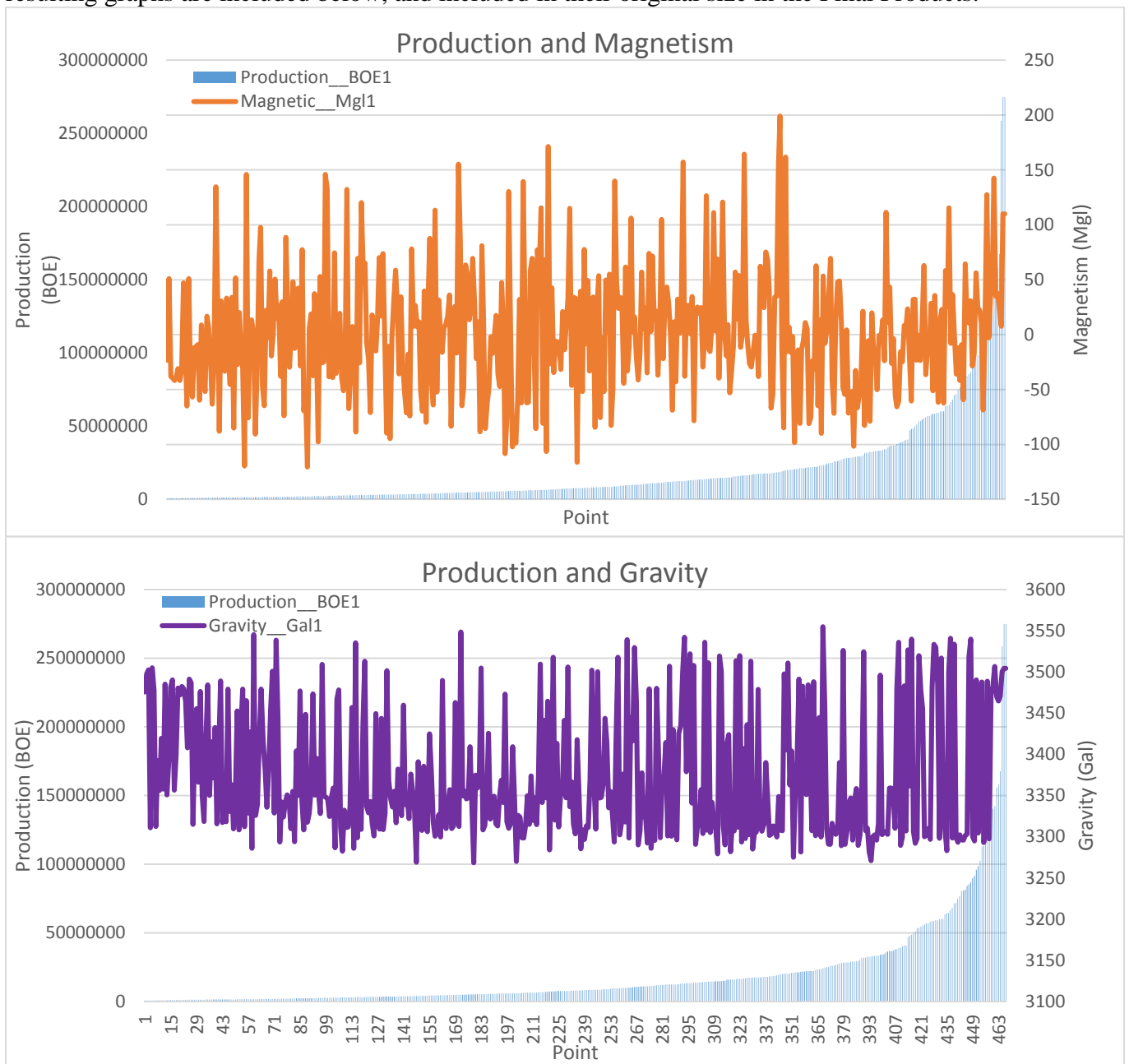
Before the data can be analyzed in Excel, points with null fields must be excluded because they will not be informative about potential correlations because of the lack of data. To begin, all of the points are selected from the previous table. With all of these points included in the current selection, the Select by Attributes option can then be used to pare down our selection more discriminately. This is done by using the statement “Production\_\_BOE1 IS NULL OR Magnetic\_\_Mg11 IS NULL OR Gravity\_\_Gal1 IS NULL” on the method “remove from current selection”. This will target and exclude all points for which any of the production, magnetic, or gravity fields contains a null field. As seen in the figure below, the entries with null fields are no longer selected in the attribute data or the map.



With only the informative points selected, exporting them to Excel is as simple as right-clicking on one of the selected entries, clicking “Copy Selected”, and pasting the fields into an Excel worksheet.

OID *	Shape *	CID	Production_BOE1	Magnetic_Mg11	Gravity_Gal1
293	Point	0	638310	-23.26778	3475.605
60	Point	0	643283.1	50.87895	3497.583
310	Point	0	695546.1	-38.06228	3502.268
407	Point	0	721452	-39.46603	3310.788
87	Point	0	747100.4	-41.63716	3504.749
202	Point	0	751890.3	-38.83143	3477.858
388	Point	0	790164.4	-30.88113	3312.495
184	Point	0	848036.1	-41.66844	3391.697

The data can be visualized by creating graphs to compare how the values for production in BOE, gravity in Gal, and magnetism in Mgl change from point to point. In order to cleanly display the data, it may be helpful to create a graph that juxtaposes a columnar graph and a line graph. The first step in doing so is to click on the Insert ribbon at the top of the screen and to click on the option for Clustered Column. This creates a blank graph, which serves as the canvas for visualization. Right-clicking on the chart brings up an option to Select Data Source, which allows for the values of interest to be specified. Once the two sets of values are plotted as columns, right clicking one brings up a dialog to change one of the displays to a line graph that can be plotted on a second axis. This procedure was performed twice in order to produce two graphs, each depicting the relationship between production and either gravity or magnetism. The resulting graphs are included below, and included in their original size in the Final Products.



Once again, the problem of visual approximation rears its head. Fortunately, Excel is well suited to the task of crunching numbers, and it possess the perfect function to calculate correlation coefficients. Correlation coefficients range between -1 and +1, and they describe how strongly two variables are related to each other. The magnitude of the number describes the strength of a correlation, with a magnitude of 1 describing a one-unit to one-unit correlation. The sign indicates whether the values are directly or inversely related. The CORREL function can be used to calculate these values. The general syntax of this function is “=CORREL(array1, array2)”, in which array1 and array 2 refer to the sets of values of interest.

	A	B	C	D	E	F
1	OID *	Shape *	CID	Production_BOE1	Magnetic_Mgl1	Gravity_Gal1
2	293	Point	0	638310	-23.26778	3475.605
3	60	Point	0	643283.1	50.87895	3497.583
4	310	Point	0	695546.1	-38.06228	3502.268
5	407	Point	0	721452	-39.46603	3310.788
6	87	Point	0	747100.4	-41.63716	3504.749
7	202	Point	0	751890.3	-38.83143	3477.858
8	388	Point	0	790164.4	-30.88113	3312.495
9	184	Point	0	848036.1	-41.66844	3391.697
10	408	Point	0	888130.3	-32.49466	3356.008

Using this function to compare production to magnetic and gravity data results in correlations of 0.118044 and 0.151972 respectively.

### Discussion and Conclusion

Unfortunately, an analysis of correlation between production information, gravity data, and magnetic data reveals very low correlation coefficients. Initial graphical analysis of the raster maps suggested that though there may have been absolutely no relationship between gravity and production, magnetism and production may have had shared a pattern since they displayed similar patterns of a central low flanked by high portions. More rigorous analysis performed by extracting raster values to points and working with the data in Excel, however, showed that neither of these field datasets could be correlated with production. Furthermore, gravity was unexpectedly demonstrated to have shown a stronger correlation with production than magnetism did, even in spite of the initial graphical analysis. Disappointingly, these results suggest that gravity and magnetic methods cannot be used to identify potential hydrocarbon fields on such a small scale.

However, not all is hope is lost for these survey methods in energy exploration. This study took an overly optimistic approach in that it stripped down the search for hydrocarbons to just two other variables. In reality, many more factors such as faulting, lithology, tectonics, and subsidence history determine the distribution of natural resources. Incorporating gravity and magnetic methods with these data has the potential to produce more accurate results than omitting them would. In addition, this study was performed on a small scale, such that the entire state of Louisiana was analyzed as whole. Magnetic and gravitational methods used on a larger

scale, perhaps within the scope of a single basin may provide more resolution and demonstrate the usefulness of these methods.

## **Final Products**

**Map 1: Production Data of Louisiana Hydrocarbon Fields**

**Map 2: Gravimetric Measurements in Louisiana**

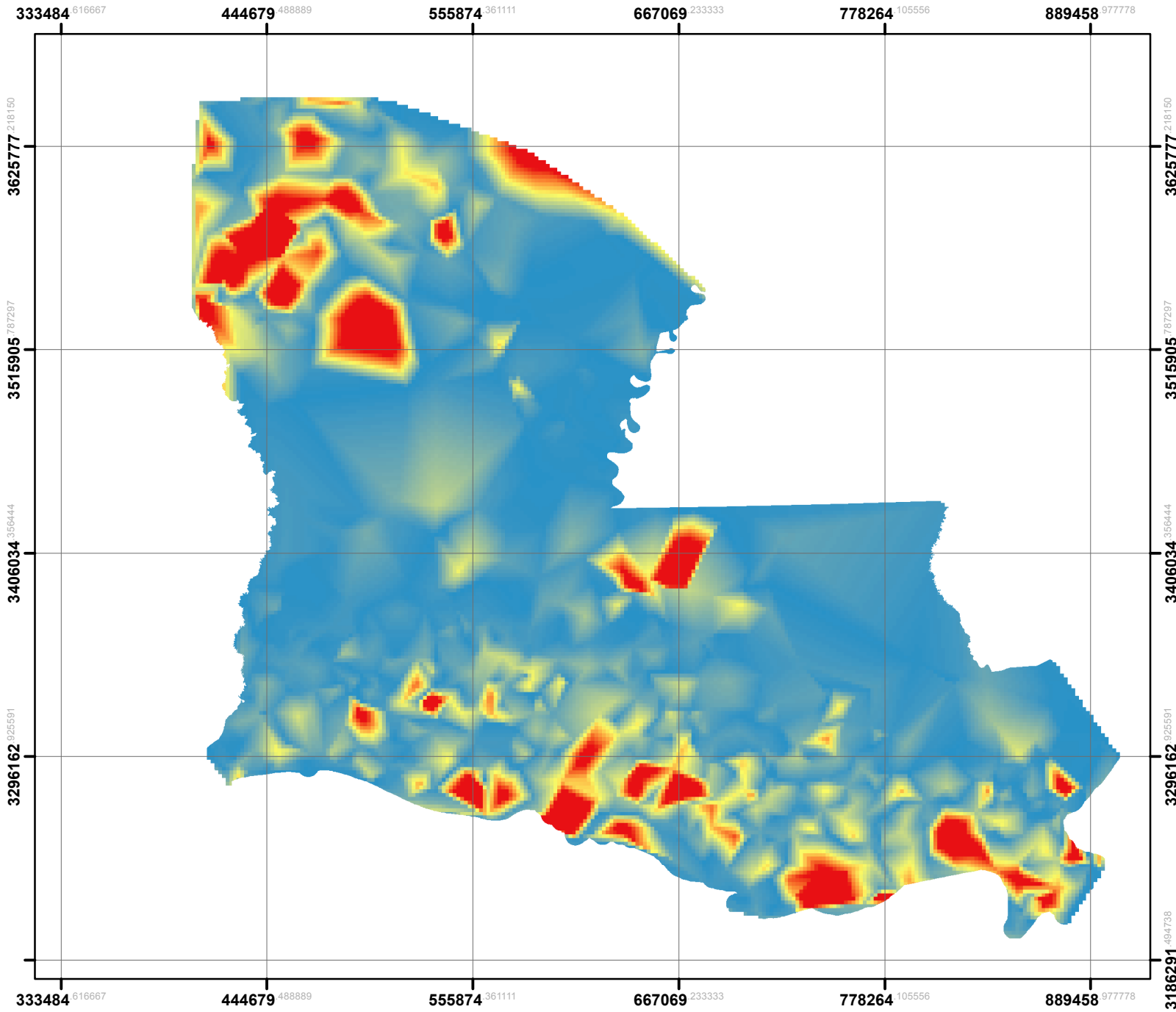
**Map 3: Magnetic Anomalies in Louisiana**

**Chart 1: Production and Gravity**

**Chart 2: Production and Magnetism**



# Production Data of Louisiana Hydrocarbon Fields

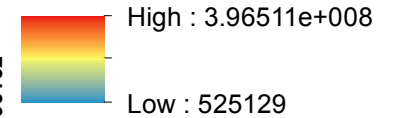


This map depicts an interpolation of hydrocarbon occurrence based upon cumulative production from wells from 1977-2014. The data standardizes natural gas and oil into BOE equivalents.

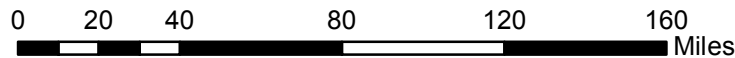
## Legend

**Production (BOE)**

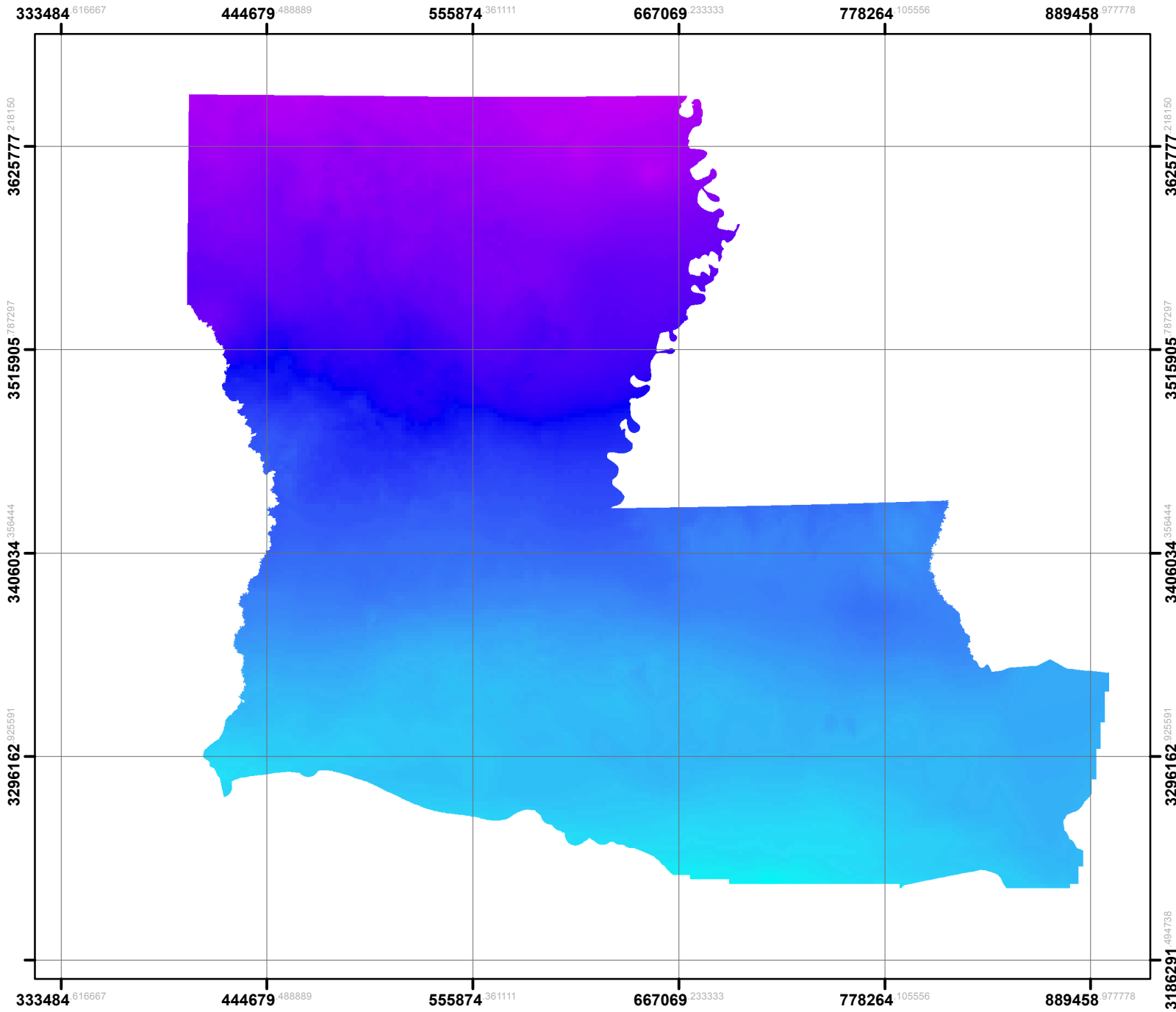
**Value**



NAD 1983 UTM Zone 15N  
Scale 1:3,000,000



# Gravimetric Measurements in Louisiana



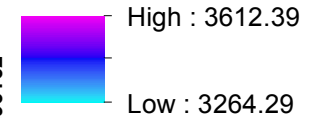
This map depicts an interpolation of gravity data in Louisiana based upon point data processed by the University of Texas at El Paso.

A smooth gradient of high to low values is seen going from north to south within the dataset.

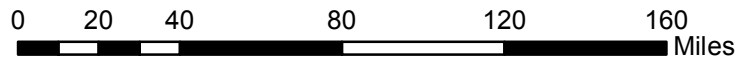
## Legend

### Gravity (Gal)

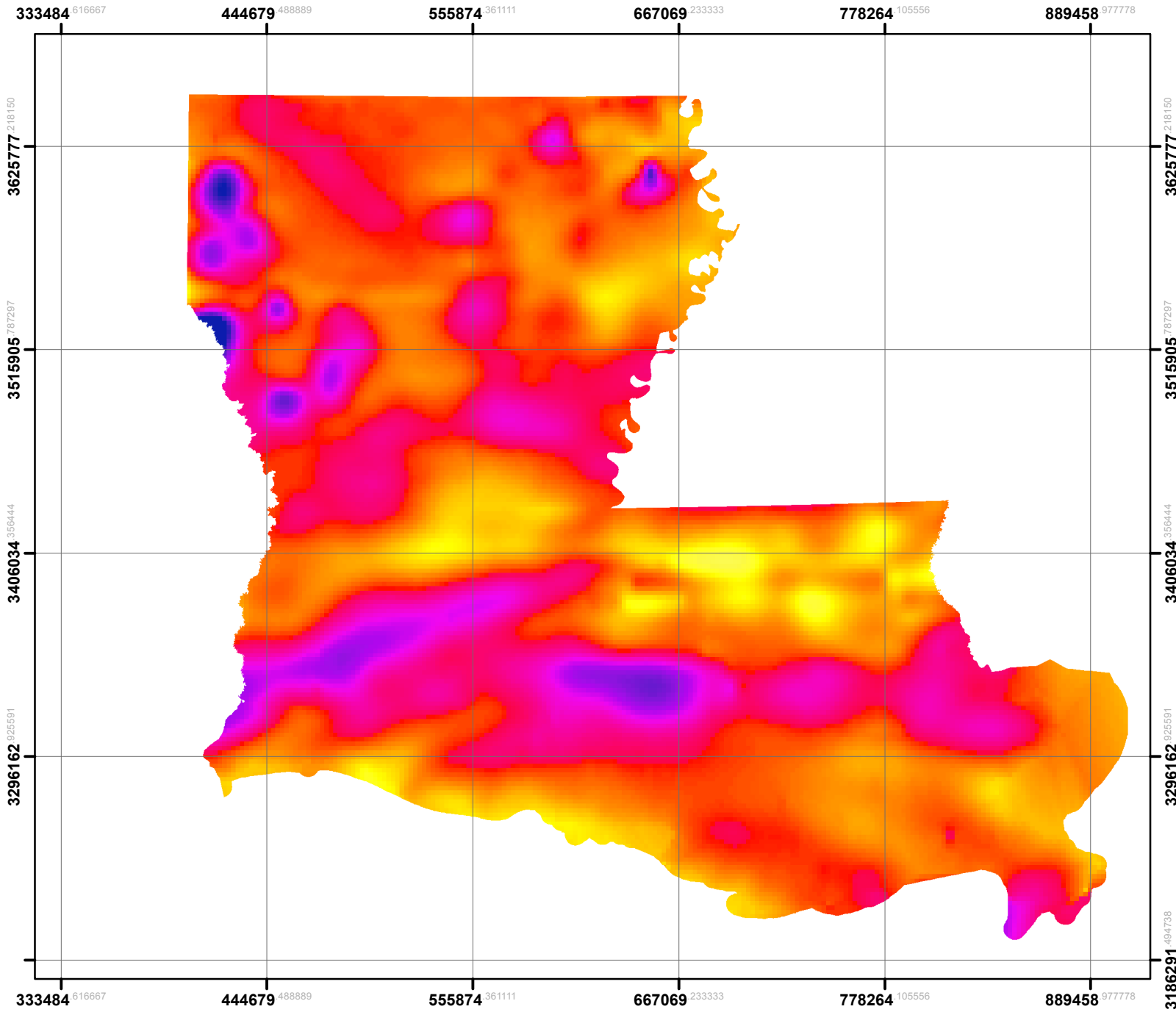
#### Value



NAD 1983 UTM Zone 15N  
Scale 1:3,000,000

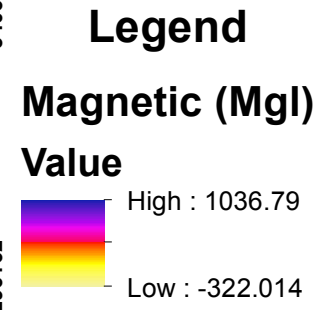


# Magnetic Anomalies in Louisiana

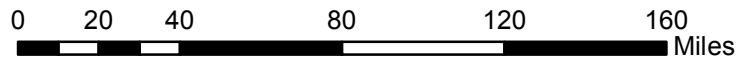


This map depicts an interpolation of magnetic anomalies in Louisiana based upon point data processed by the University of Texas at El Paso.

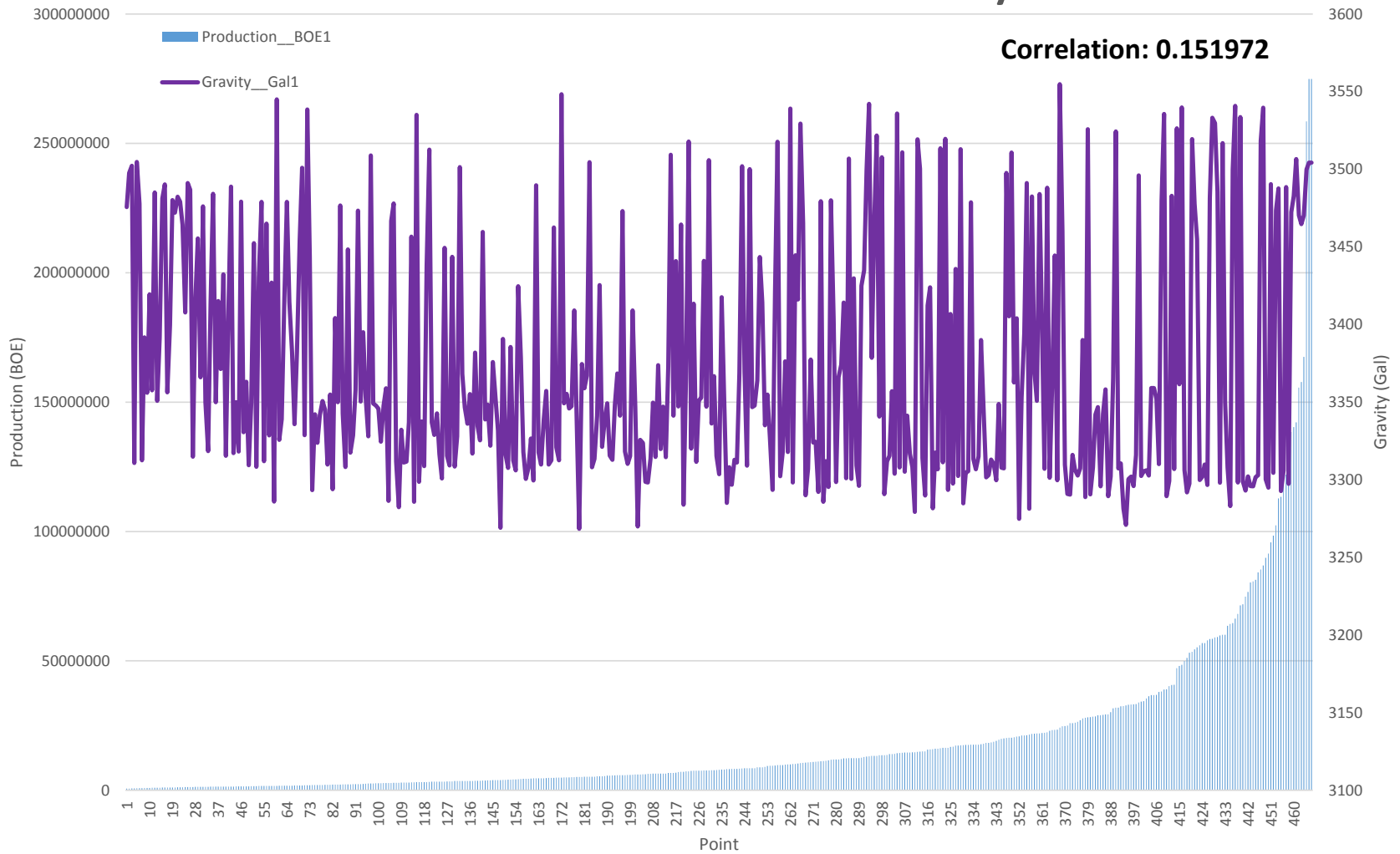
The lowest values are seen in the middle of the state, and the highest values are seen near the top and bottom.



NAD 1983 UTM Zone 15N  
Scale 1:3,000,000



# Production and Gravity



# Production and Magnetism

