Exploring the Marcellus Shale using ArcGIS 3D Analyst

Advanced GIS

GEOG/ES 490

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Project Background

The Marcellus Shale is a subsurface rock formation that has recently created quite a buzz in the natural gas industry. It is a Devonian age black shale that is predominately found in the subsurface beneath Ohio, West Virginia, Pennsylvania, and New York. The Marcellus Shale is an unconventional shale, meaning it is both the source of the natural gas as well as the reservoir, and it could be the largest unconventional shale in the country with at least 50 trillion cubic feet of recoverable natural gas. What sets the shale apart from other formations is the method in which the formation is drilled. Until the Marcellus Shale, natural gas wells in Pennsylvania were drilled vertically through sandstone reservoirs and if chosen so fractured with water and sand to break the rock apart and allow the natural gas to easily flow through the rock and into the well bore. This reflects the property of sandstone as it is a porous rock in which the natural gas can flow through easily. When drilling a Marcellus well, the well is drilled vertically until the formation is reached. Then, the drill is turned and drilling continues horizontally to break open as much of the rock as possible and to intersect a maximum number of natural vertical fractures (Fig.1). This method reflects the characteristic of shale, which is not porous and does not allow natural gas to flow through easily. Advanced drilling methods have had an enormous effect on the production from unconventional shales.

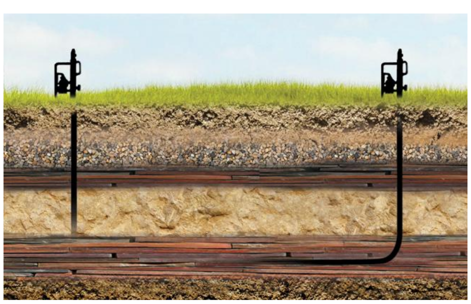

Figure 1: Diagram depicting the horizontal drilling of the Marcellus Shale from Pennsylvania General Energy (PGE), located in Warren, Pennsylvania.

For my final project I created a layer using the 3D Analyst tool in ArcGIS Desktop software that shows a depiction of Marcellus Shale in the subsurface. This project would be useful to any natural gas company that is interested in obtaining production from the Marcellus. The cost to drill a Marcellus well range from $800,000 for a vertical well to as much as $3.5-4.0 million to drill a horizontal well. With the high investment that is put into drilling a Marcellus well, companies would gladly accept any information that they can get.

To get to the point of being able to create a 3D layer, layers such as wells, wells with geophysical logs, and wells with logs that penetrate the Marcellus Shale were included. Attributes within these layers containing the information about a particular well are extremely beneficial to any natural gas company in their own right, and these layers are the other major part of the project.

Project Objectives

A. The general project objective was to create a layer to be used in ArcGIS Desktop software that mimics the Marcellus Shale formation through available statewide well data. Although current isopach maps generalize the thickness of the shale across the state (Fig. 2), a particular area could be mapped in detail depending on the availability of data. Layers were created that provide information about the top and bottom of the shale as well as the thickness. The other general objective was to spatially recognize gas wells in an area and be able to easily locate, interpret, and update the information that pertains to these wells.

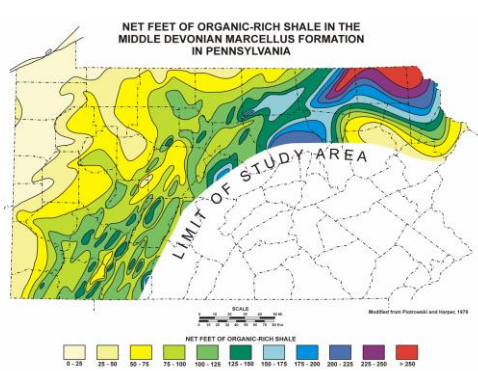

Figure 2: Image showing the net feet of the Marcellus Shale in Pennsylvania from Susquehanna Wayne Oil & Gas Group (SWOGG).

B. Specific project objectives included revealing patterns about the formation that can be analyzed to define or recommend good locations to place a gas well along with places to avoid. In the case of the Marcellus Shale, most gas is locked up in the thickest sections with the most organic material. Overlaying created layers such as depth to the top of the formation and thickness of the formation would result in a good well location that is cheaper to drill because of a shallower depth.

Methods

To begin the project I retrieved well data for Pennsylvania counties where the Marcellus Shale is found. I then analyzed this well data to locate gas wells that have corresponding geophysical logs and located wells in which the geophysical logs penetrated the Marcellus Shale. From there I planned to interpret the logs for information such as depth and thickness of the shale and use this data in 3D analyst to create a 3D model of the formation. Important gas well information such as permit number, county, farm name, farm number, elevation, total depth, formation thickness and others were included as attributes that provide a wide range of insight into an area of interest for any company.

Many steps were taken in order to reach the final result, first of which was to create my geodatabase. I included shapefiles of Pennsylvania county boundaries obtained from the Pennsylvania Spatial Data Access (PASDA) website to be used as a base layer. I then added data pertaining to the shale itself, an isopach map that showed the general thickness of the formation across the state. Then I explored gas well data by county and selected Greene County, Pennsylvania as the location of the project. To get this information I used the Pennsylvania Internet Record Imaging System (PA IRIS) account of G&G Gas (with permission) to obtain the location of wells within the state and import this data into ArcMap through an excel spreadsheet using the 'add XY' data capabilities of the software. I then used the same PA IRIS website to locate the wells that had corresponding geophysical logs to present the number of well in which subsurface data was available and that could be used to mimic the project. To further separate the data to find a good location to perform the project, I created another layer pertaining to the wells with geophysical logs that have been drilled deep enough to show the location of the shale. Although I could have simply created one wells layer and selected by attribute the wells with geophysical logs and/or wells that penetrate the shale, I found it easier to take the time and create a layer for each. Not only is this data beneficial in its own right, but this sequence within the project helped convey to the audience the way that the data was analyzed.

Once the data was collected I began to analyze the geophysical logs for the Marcellus Shale data that they contained. It is here that a major problem occurred. When analyzing the geophysical logs it became apparent that although the wells were drilled deep enough to penetrate the formation and had associated geophysical logs, most logs were of poor quality and did not provide the expected information. Instead of looking through all the well logs when I knew that data would have to be made up, I decided to randomize all the data based on Marcellus Shale figures. I randomized the thickness to be between 0 and 250 feet and the top of the formation to be between 5000 and 8000 feet below the surface. I added this data to the attribute tables using the 'Start Editing' tool so I could begin working with the data.

The focus of my project switched to ArcScene where I could create my 3D model. To start, I added the Greene County wells layer to the display. From here I used raster interpolation along with the elevation data that was associated with each well to create an interpolation of the surface. I then added the other well layers, wells with logs and wells with Marcellus logs. I extruded the Marcellus logs to a negative Total Depth to show visually that these wells penetrated the formation. I then created three more raster interpolations: the top of the formation, bottom of formation, and thickness of formation using the randomized data that I added earlier. This created my visual model with an elevation surface, top and bottom of the Marcellus Shale, and wells that penetrate through the shale.

After these steps, I added the interpolated raster images to ArcMap. These interpolations became the heart of the project as they allow the user to quickly determine depth to top and thickness of the formation at any location.

The database created can be extremely flexible. New wells could easily be added that fit the criteria, and any area in the state that had geophysical information pertaining to the Marcellus Shale, or any rock formation for that matter, could be transformed into a 3D layer.

Data

Layer Name	Alias	Feature Type	Attributes	Alias	Example
Counties	Counties Boundaries	Polygon			
Marc_Thick	Isopach	Raster Image			
Wells	Wells	Point	Perm_Num	Permit Number	003-00020
			Field	Field Name	GLENSHAW
			Operator	Operator	X Company
			Name	Farm Name	JOHN DOE
			Number	Farm Number	1
			County	County Code	3
			Elevation	Elevation	1472
			TD	Total Depth	3825
			TD_Form	Total Depth Formation	VENANGO

			Quad	Quadrangle	GLENSHAW
			Type	Well Type	DRY
			Comp_Date	Completion Date	04/20/1956
			Municipality	Municipality	OHARA
			Latitude	Decimal Latitude	40.53178494
			Longitude	Decimal Longitude	-79.92224250
Wells with Logs	Logs	Point	Same as Wells		
Marc_Logs	Marcellus Logs	Point	Same as Wells		
			Top	Marcellus Top	7400
			Bottom	Marcellus Bottom	7414
			Thickness	Net Thickness	14
Elevation	Elevation	Raster Interpolation			
Thickness	Marcellus Thickness	Raster Interpolation			
Marc_Top	Top of Marcellus	Raster Interpolation			
Marc_Bot	Bottom of Marcellus	Raster Interpolation			

Table 1: Project Data

Output

One output of the project is a 3D model (Fig. 3) depicting the Marcellus Shale that provides a visual aid to any natural gas company that is considering drilling a horizontal well. Tables of data are included that could easily be found using the 'select by attributes' tool in ArcMap (Table 2). The raster interpolation of the thickness of the shale is also included (Fig. 4). This allows an analyst quick interpretation of the area. Using my randomized numbers, it is obvious that the shale is thicker to the eastern side of the county. Using this information along with depth to the top of the shale, a quick determination could be made to locate a potentially successful gas well.

Other than the created 3D layer, the other layers pertaining to the wells themselves could be printed as maps and used for informational purposes. For example, a gas company may be curious to know if any rival companies are intruding on their leases. A map printout with gas wells and the operator attribute could be used to provide this information.

Permit Number	Log?	Operator	Farm No.	Elevation	Total Depth	Completion Date	Decimal Latitude	Decimal Longitude
059-24220	Yes	X Company	1	1138	5594	06/21/2007	39.77865443	-80.04627500
059-24221	Yes	X Company	2	1375	5662	07/23/2007	39.77217576	-80.05056310
059-24222	Yes	X Company	1	1138	5575	06/12/2007	39.78043881	-80.04917520
059-24223	Yes	X Company	1	1140	5467	05/26/2007	39.78112511	-80.05810720
059-24255	No	X Company	1	1076	5498	06/28/2007	39.77590923	-80.04085220
059-24256	Yes	X Company	Jan-00	1395	5867	08/04/2007	39.77073453	-80.04344590
059-24268	Yes	X Company	1	1144	5691	08/15/2007	39.79141960	-80.06145220
059-24305	No	X Company	1	1137	5316	08/26/2007	39.76901878	-79.99089410
059-24306	No	X Company	1	1137	5317	09/12/2007	39.76723440	-79.98580540
059-24375	No	X Company	Jan-00	1170	5756	09/27/2007	39.78279968	-80.06114970

Table 2: An example of information available on a specific company's gas wells in the county.

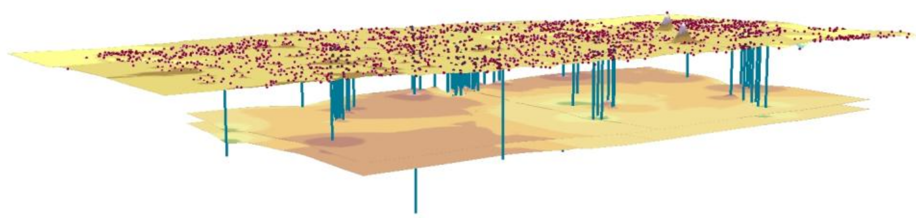

Figure 3: 3D depiction of the Marcellus Shale showing all Greene County wells and interpolated surface, extruded wells with geophysical logs that penetrate the shale, and top and bottom of the formation.

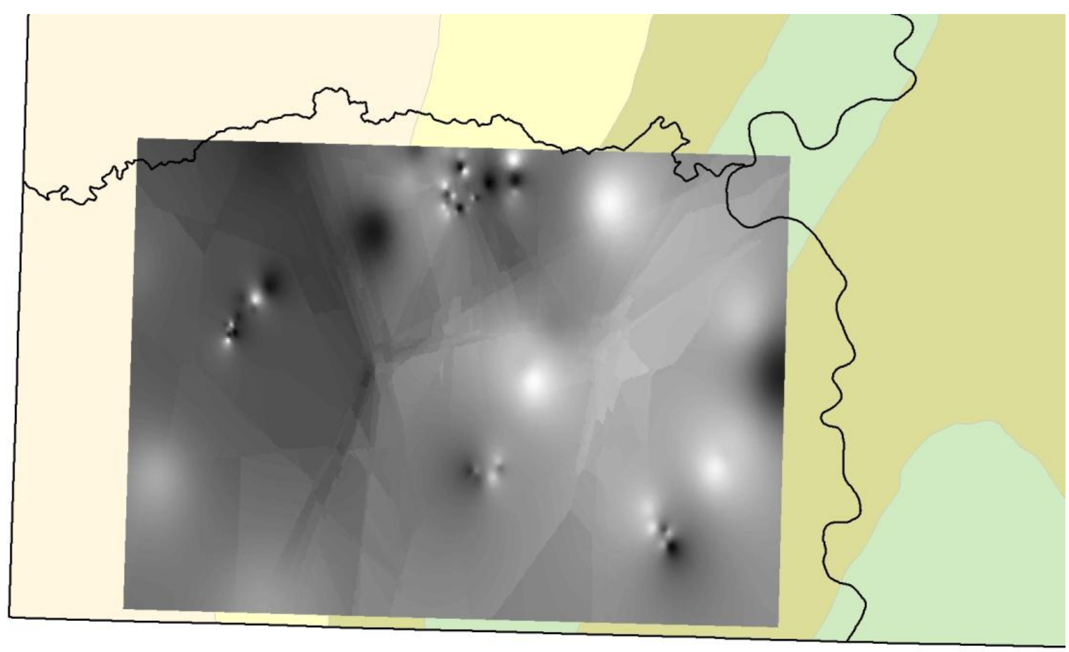

Figure 4: Interpoloated raster image created in ArcScene and imported into ArcMap. Light areas represent a greater thickness, so based on the randomized information it is clear that the formation is thicker in the eastern part of the county.

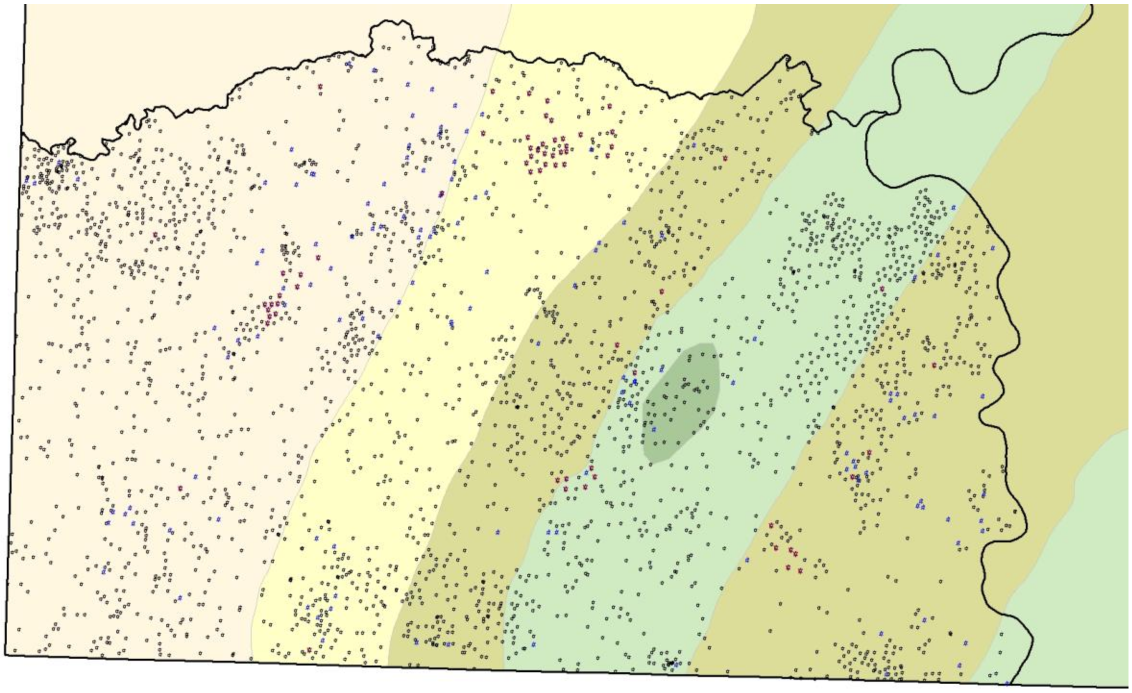

Figure 5: Greene County wells showing the sequence from all wells in the county (black) to wells with geophysical logs (blue) to wells with geophysical logs that penetrate the Marcellus Shale (red).

Outcomes and Benefits

I believe the outcome of this project would be very beneficial to any natural gas company (with real information) regardless of how many wells they drill or what formation they plan to produce from. The flexibility of the project allows any formation to be transformed into a 3D layer, and most natural gas companies with a full time geologist likely already have all of the information required.

Without even creating a 3D layer of the formation, the general well information imported through the excel spreadsheet would be useful for numerous purposes, and any information about the wells could be included as attributes. Another example of the usefulness of a general well layer is to locate a site for a new well and obey drilling regulations such as distance from other wells by easily measuring using the interactive capabilities of the software.

A layer that represents gas wells that have corresponding well logs would also be very beneficial to anyone within a company that is not interested in the well production itself, but the geology that affects the production. The amount of wells that have well logs available online are not staggering, so quickly being able to identify an area that can be analyzed geologically would be much more efficient than going back and forth between permit numbers and well logs by county.

Timeline Budget

Week	Activity
1	Brainstorm project ideas
2	Explore information pertaining to project
3	Work on project proposal
4	Complete project proposal
5	Turn in project proposal and begin data collection
6	Continue data collection
7	Complete data collection
8	No continuation of project
9	Proceed with data enhancement and prepare for rehearsal presentation
10	Conduct rehearsal presentation and proceed with project
11	Work on project
12	Work on project
13	Work on project
14	Complete project and work on final presentation
15	Conduct final presentation and complete final project document
16	Turn in final project document

References

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