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Development of 3-D Geological Model of Tuscarora Sandstone for Feasibility of Deep Direct-Use Geothermal at West Virginia University's Main Campus

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ABSTRACT

The Morgantown campus of West Virginia University (WVU) is uniquely positioned to host the first geothermal deep direct-use district heating system in the eastern United States. While much of the eastern United States is not blessed with extremely high heat flow and elevated temperatures, the northeastern part of West Virginia is unique in having a basin that is expected to support the achievable flowrate of geofluid through target formations, with sufficient temperatures at depth. These two factors were identified in the 2006 MIT Future of Geothermal Energy Report to be the two most critical factors in minimizing cost of geothermal energy. Our overall project objective is to determine the feasibility of designing a Geothermal District Heating and Cooling (GDHC) system for the West Virginia University campus utilizing Geothermal Deep Direct-Use (DDU) by 1) minimization of the uncertainty and risk associated with developing the geothermal resource for use on campus at WVU and 2) completion of an optimized design for the geothermal system, minimizing the delivered Levelized Cost of Heat (LCOH). Our first goal, to minimize the risk of project development, will be achieved by decreasing the uncertainty in both the subsurface geothermal system as well the surface distribution system.

The subsurface uncertainty is dominated by the uncertainty in the projections of geofluid flowrate in the target formation, the Tuscarora Sandstone. In this paper, three cores from the heterogeneous reservoir, available through West Virginia Geologic and Economic Survey, are analyzed by performing core analysis using CT scanning and permeability measurements via minipermeameter. Additional geological data are collected through cores, published literature, seismic data, and nearby, existing wells to estimate thickness, fracture network configuration and geothermal gradient to minimize the uncertainty of well deliverability. Using these estimated reservoir properties; a 3D conceptual model for the proposed geothermal site is developed.

1. Introduction

The Morgantown campus of West Virginia University (WVU), affords an optimal and unique combination of critical factors necessary to develop geothermal deep direct-use. In 2010, research at the Southern Methodist University (SMU) Geothermal Laboratory discovered that the temperatures beneath the state of West Virginia are significantly higher than those previously estimated (Blackwell et al., 2010). This high temperature region extends from north central West Virginia (Monongalia County), to southeastern West Virginia (Greenbrier County).

The Lower Silurian Tuscarora Sandstone (Figure 1), approximately 100 m-thick and encountered at a depth of 10,000 ft (~3000 m) in Monongalia County, is chosen as the preliminary target formation, as the geologic conditions of the reservoir indicate a fracture-dominated reservoir with significant potential porosity and permeability as shown in Table 1. The thermal resource at our chosen site has been informed by an ongoing project, led by West Virginia University and funded by the Office of Fossil Energy, called the Marcellus Shale Energy and Environment Laboratory (MSEEL). This innovative project has provided access to new geothermal gradient data for the proposed location, using a downhole fiber optic cable. The elevated temperatures and high flow conductivity makes the proposed site an ideal geothermal resource for direct use. These two factors were identified in the 2006 MIT Future of Geothermal Energy Report to be the two most critical factors in minimizing cost of geothermal energy. Deep direct-use geothermal development requires an additional critical factor for economic viability: available thermal demand and appropriate surface distribution infrastructure. The WVU campus site offers this surface demand coupled with potential subsurface viability.

Table 1. Characterization of the Tuscarora Sandstone in Morgantown, WV (Castle and Byrnes, 2005).

	Rock Type	Depth, m	Average Permeability, mD	Average Porosity, %
Morgantown, WV	Tuscarora Sandstone	3200 to 3350	0.0048 matrix ~20 mD fracture	6.8

The overall project objective is to determine the feasibility of designing a Geothermal District Heating and Cooling (GDHC) system for the West Virginia University campus utilizing Geothermal Deep Direct-Use (DDU) by 1) minimization of the uncertainty and risk associated with developing the geothermal resource for use on campus at WVU and 2) completion of an optimized design for the geothermal system, minimizing the delivered Levelized Cost of Heat (LCOH). Our first goal, to minimize the risk of project development, will be achieved by decreasing the uncertainty in both the subsurface geothermal system as well the surface distribution system. The subsurface uncertainty is dominated by the uncertainty in the projections of geofluid flowrate in the target formation, the Tuscarora Sandstone. The uncertainty in well deliverability is reduced by estimating reservoir properties through well log data, core analysis and permeability measurements.

In this paper, three cores from the heterogeneous reservoir, available through West Virginia Geologic and Economic Survey, are analyzed by performing core analysis using CT scanning and permeability measurements via minipermeameter. Additional geological data are collected through cores, published literature, seismic data, and nearby, existing wells to estimate thickness, fracture network configuration and geothermal gradient to minimize the uncertainty of well deliverability. Using these estimated reservoir properties; a 3D conceptual model for the proposed geothermal site is developed.

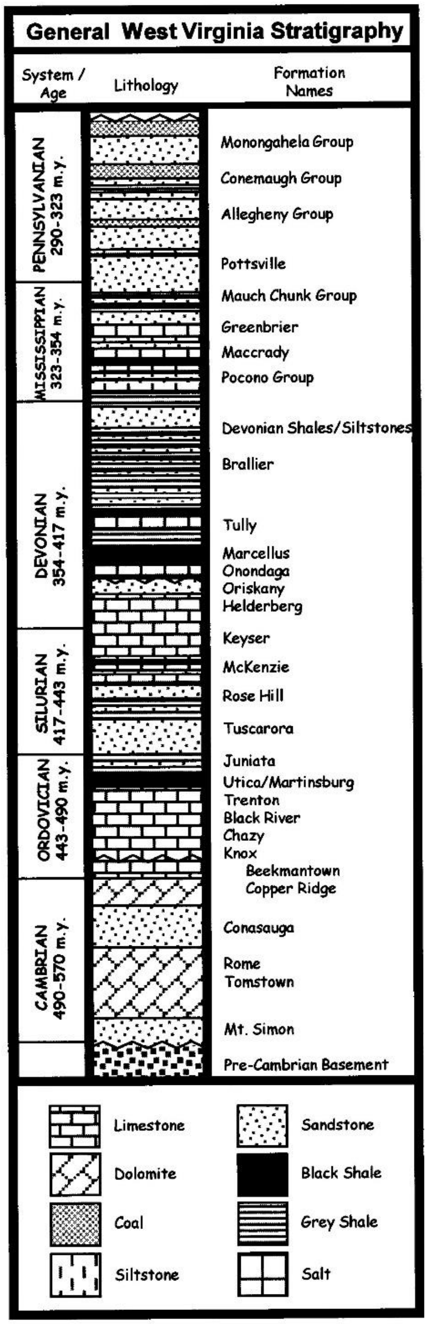

Figure 1: Generalized stratigraphic column of West Virginia.

2. Core Analysis and Permeability Measurements

The proposed geothermal site for DDU will be characterized based on the geological information available from the cores and well logs for nearby existing wells. The cores, and approximate distance from the proposed field site, are as follows: Harrison-79 (37 miles from site); Preston-119 (37.5 miles from site); and Clay 513 (105 miles from site).

The Preston-119 core, drilled by the Cities Service Oil Company in 1964, penetrates the Tuscarora Sandstone at 7,165 ft. (2184 m) below ground surface (elevation 2,172 ft. [662 m]). Gross reservoir thickness is 273 ft. (83 m). The American Petroleum Institute (API) number for this well is 4707700119.

The Harrison-79 core was drilled by the Hope Natural Gas Company in 1941. The well penetrates the Tuscarora Sandstone at 9,747 ft. (2971 m) below ground surface (elevation 1,113 ft.[339 m]). Gross reservoir thickness is 249 ft. (76 m). The API number for this well is 4703300079.

The Clay-513 core was drilled by the United Fuel Gas Company in 1953. The well penetrates the Tuscarora Sandstone at 7,420 ft. (2262 m) below ground surface (elevation 1,142 ft. [348 m]). Gross reservoir thickness is 80 ft. (24 m). The API number for this well is 4701500513.

Structural setting differs between the three core locations (Figure 2). The Harrison-79 and Clay-513 well locations are within the boundaries of the Rome Trough, an extensional graben of Early to Middle Cambrian age that extends from northern Tennessee through Kentucky, West Virginia, and western Pennsylvania (Harris and Baranoski, 1996). The Rome Trough is bounded by high angle normal faults that are rooted in Late Proterozoic basement rocks. Relief on the basement ranges from approximately 4,400 ft. (1341 m) in the Rome Trough's southern extent to over 20,000 ft. (6096 m) in southwestern West Virginia (Hickman, 2002).

The Preston-119 well is located to the east of the Rome Trough and west of the Allegheny Front, a prominent northeast-southwest trending geologic feature that separates relatively flat-lying strata of the Appalachian Plateau from the folded and faulted rocks of the Valley and Ridge province. The well is positioned on the western flank of the Deer Park Anticlinorium, which also trends northeast-southwest (Chapman, et al., in preparation).

In all three locations, the Tuscarora Sandstone is described as a white, fine- to very-coarse-grained, quartzose sandstone (orthoquartzite or quartz arenite), thin- to thick-bedded, with interbedded shale.

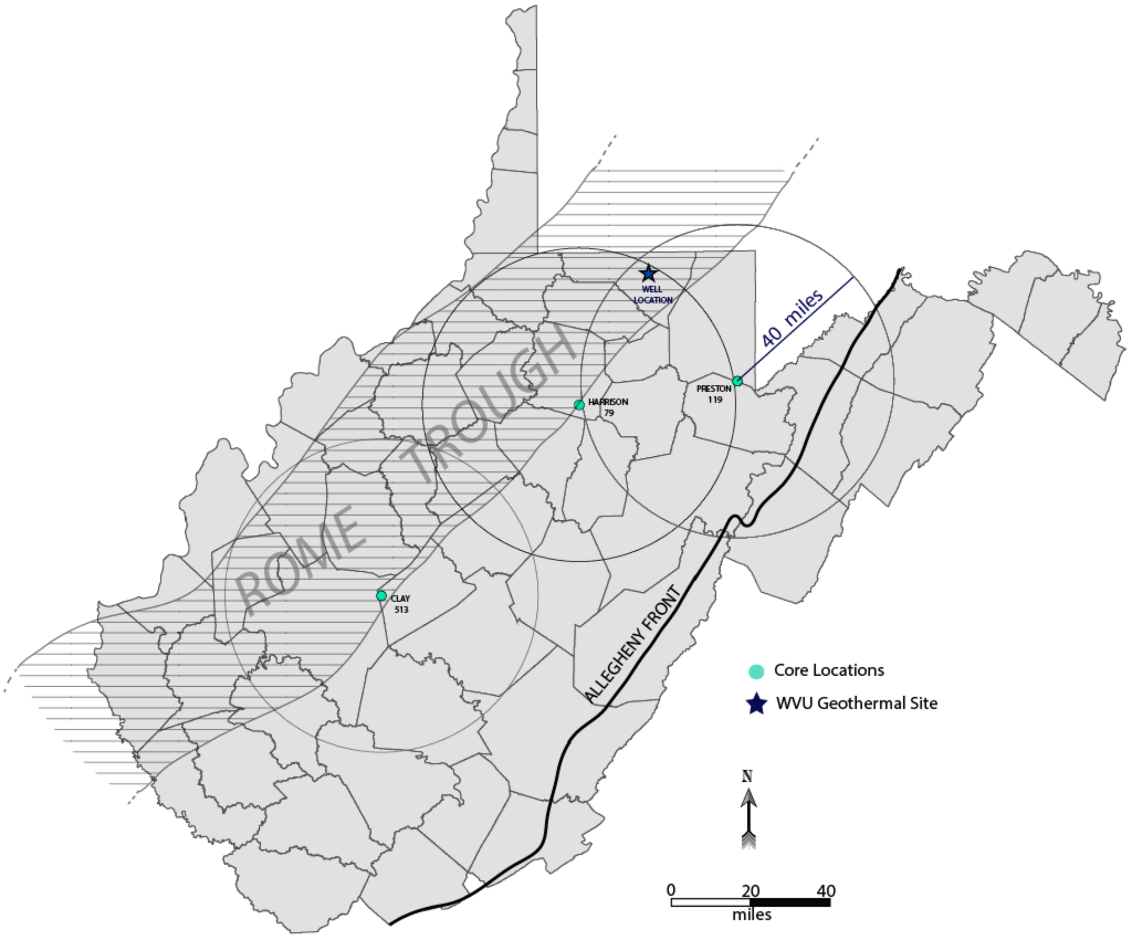

Figure 2: Location of cores in relation to West Virginia University's Evansdale campus. Circles surrounding core locations denote a 40-mile radius. The Harrison-119 and Clay-513 cores are located within the boundaries of the Rome Trough; the Preston-119 core is located east of the Trough.

2.1 Core Analysis

Cores are analyzed by performing core analysis using thin section analysis and computed tomography (CT) scanning. Computed tomography scanning is conducted by the U.S. Department of Energy National Energy Technology Laboratory (DOE-NETL), located in Morgantown, West Virginia.

2.1.1. Thin Section Analysis

Twenty-eight samples from the Clay-513 core are selected for thin-section analysis, the results of which are presented in Appendix A. Point counts and/or visual estimation of porosity, grain size, sorting, rounding, maturity, gross mineralogy, and cement type are noted. In this core, the Tuscarora Sandstone is a very fine- to very coarse-grained, poorly- to well-sorted, quartzose sandstone. Porosity, estimated visually from thin section examination, is generally low and what is present is often concentrated along small fractures, including stylolites (Figure 3), or within burrow-fills (Figure 4).

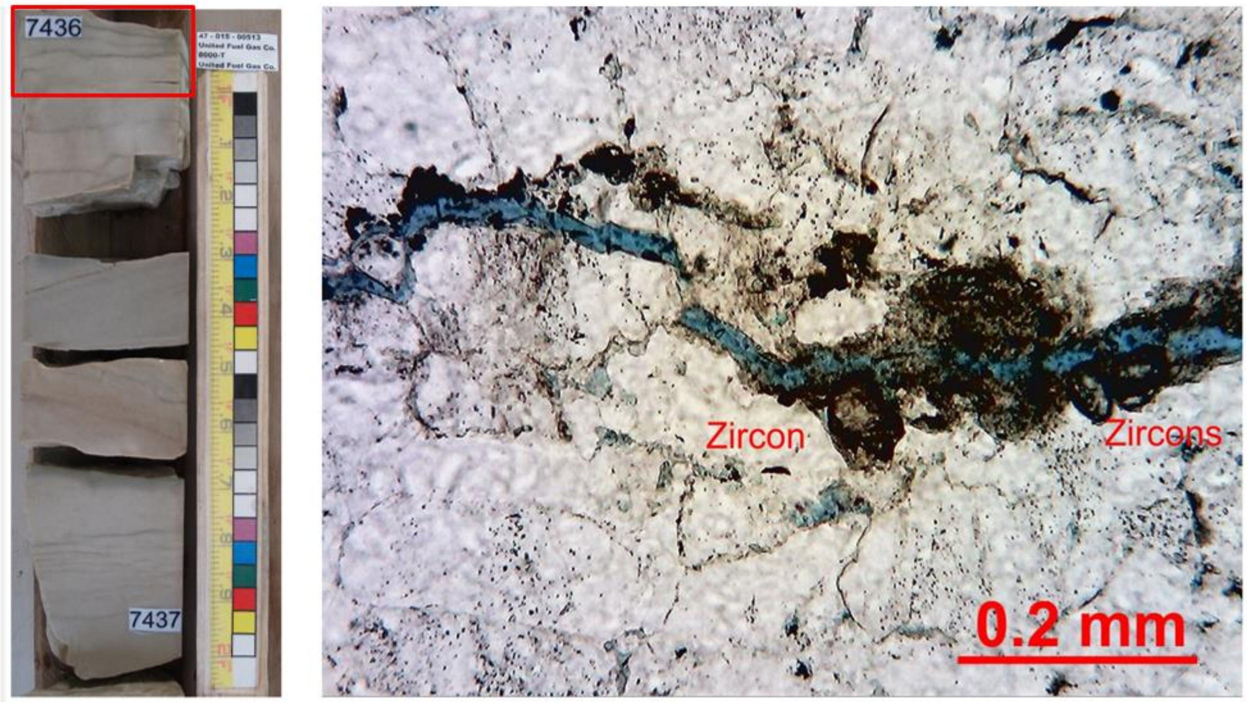

Figure 3: Thin-section photomicrograph from the Clay-513 core (Sample A; 7436 ft. [2266.5 m]). Heavy minerals are concentrated along a stylolite. Fracture with porosity (blue epoxy staining) follows the stylolite.

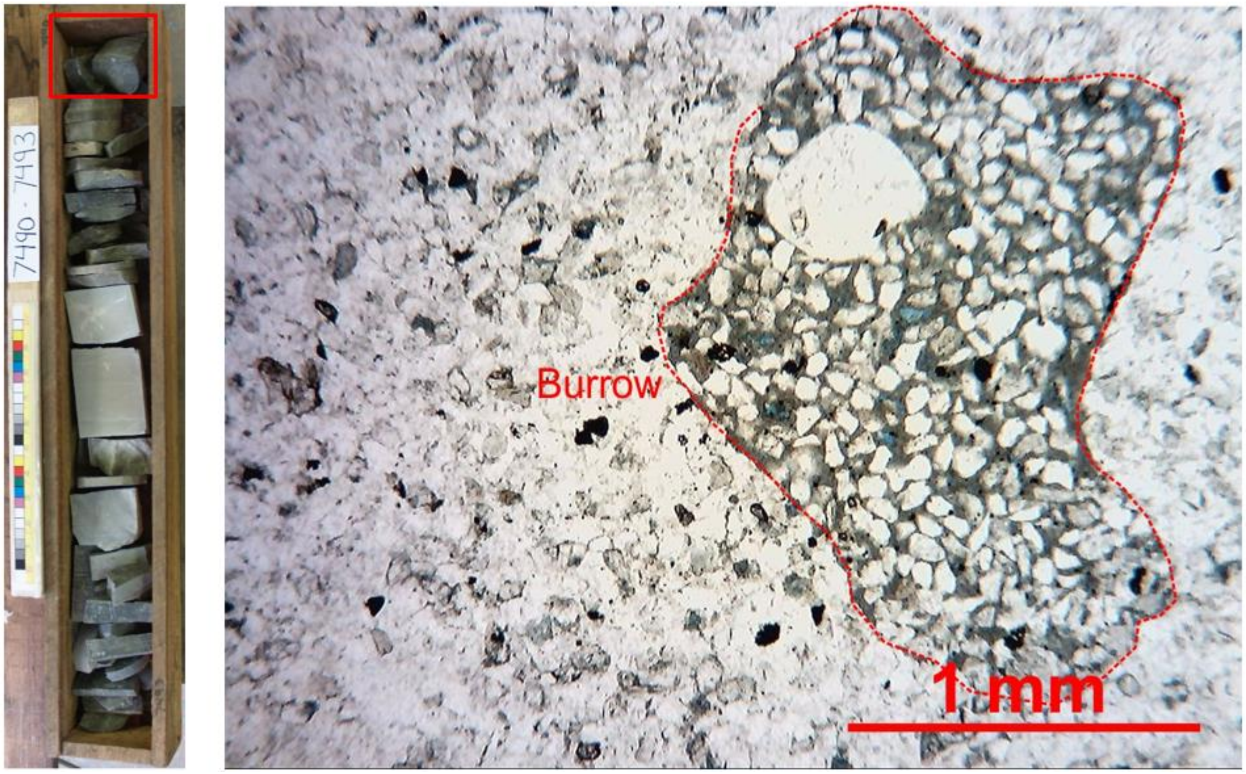

Figure 4: Thin-section photomicrograph from the Clay-513 core (Sample Y; 7490 ft. [2283 m]). Irregular burrow backfilled with very fine quartz sand. Blue epoxy indicates porosity within the burrow, as opposed to the matrix.

Porosity associated with the latter can be described as "patchy" or zonal distribution of porosity (based on epoxy staining). In several thin sections, impermeable layers were interrupted by irregular patches of grains associated with relatively high porosity. The localization of these higher porosity patches and the fact that they were often associated with a distinctly different grain size, suggests that these features might represent bioturbation in the form of actively or passively backfilled horizontal burrows. Other studies by WVGES, specifically of Devonian gas-bearing sandstone reservoirs (McDowell et al., 2001; Matchen et al., 2003), have noted heterogeneous distribution of porosity association with bioturbation – this may be the case for the Tuscarora, as well.

2.1.2. Computed Tomography Scans

Computed tomography (CT) images were collected by geoscientists at the U.S. Department of Energy National Energy Technology Laboratory (U.S. DOE-NETL) in Morgantown, West Virginia. The technique is non-destructive and enables characterization of bedding, fractures, and discontinuities without any damage to the core samples. A full report on the core scans (Moore et al., 2018) is available via NETL's EDX data exchange platform.

The scanning was performed with a medical Toshiba Aquilon TSX-101 A/R medical scanner. Resultant images have a millimeter-scale resolution (0.43 x 0.43 mm in the XY plane; 0.50 mm along core axis). Changes in the CT number obtained from the scans are visualized as grayscale values; the changes in CT number are directly proportional to attenuation and density of the scanned material. Light regions in the scan are more dense, and dark regions less dense.

The complete set of CT scans were then annotated in CorelDRAW to identify potential fracture networks and compile a preliminary list of permeability measurement sites. Figure 5 shows an example of original versus annotated CT scans for Preston 119 core. More than 800 discrete fracture traces were identified over the 267 ft. (81 m) interval.

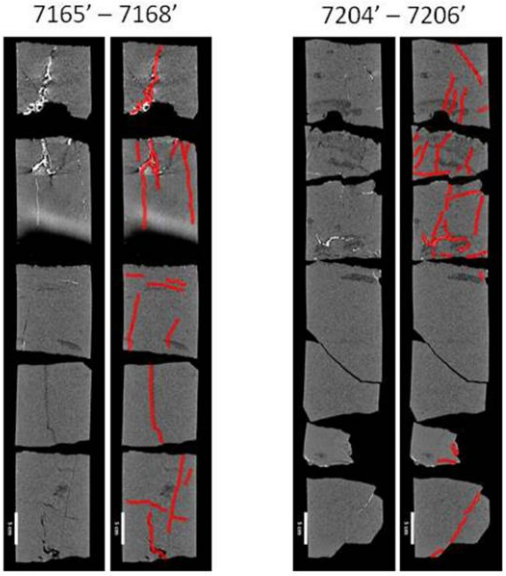

Figure 5: CT scan images of selected intervals from Preston 119. Fractures apparent (and not so apparent) in these images have been highlighted in red to assist in selecting core segments for direct permeability measurement.

Currently, the Harrison-79 core is in process at NETL for CT scanning, however due to its age the core is of questionable quality and may not be suitable for successful CT scanning. Therefore, this core will be used for destructive mechanical testing.

2.2 Permeability Measurements

In addition to examination of reports of permeability analyses performed previously on small diameter core plugs taken from Preston 119, direct permeability measurements are being taken on selected core segments from the entire length of the core. Measurements are made using the PPP-250 Minipermeameter purchased from Core Labs. This instrument injects air under pressure into the rock sample and computes permeability based on the rate of gas intake by the sample (see Figure 6). The focus of this part of the project is primarily the investigation of fracture permeability. Consequently, core segments are selected based primarily on the presence of visible fractures.

Figure 6: Core Labs PPP-250 Minipermeameter in operation. The instrument's probe is held tightly against the face of a core sample (on the right) while air is injected into the rock at approximately 26 psig. The instrument itself (on the right) measures the rate of gas uptake by the sample and computes the sample's permeability which is stored digitally on a small tablet computer (also on the right). The quantity being measured is k_{hAir} (horizontal permeability to air) in millidarcies (mD).

In addition to permeability, the fracture lengths, widths, and orientation with respect to core vertical and horizontal are measured, and other relevant lithologic features in the interval are noted before taking a digital photo of the core segment. For control purposes, matrix permeability for each segment is also measured. All measurements and observations, including a hyperlink to core photos, are presented in supplementary data. Investigation of the Preston 119 core is still in the preliminary stage. Thus far, we have measured fracture permeabilities ranging from less than 1 mDarcy to nearly 10 Darcies. However, a comparison of permeabilities taken from core plugs from Preston 119 to those taken from the core surface must be performed to confirm similarity. Until that is done, the new permeability measurements should be treated as "relative" values.

Examination of fractures encountered thus far suggests that there are several types of fractures present that can be generally characterized as tectonic – filled by mineralization or unfilled, stylolite-associated (Figure 7b & Figure 8a) – following or closely parallel to pressure-solution features, and lithology-associated – bordering contacts between different lithologies or grain sizes. Many, but not all, of these fractures are open (especially the last two fracture types), probably associated with the removal of the core from the stress regime at reservoir depth. However, the presence of relatively large, open voids (Figure 8b) suggests that some of the tectonic fractures may have been open, even at reservoir depth.

Figure 7: Core segments from Preston 119. 7a – 7203.0' depth – subvertical and subhorizontal fractures with widths ranging from "hairline" to greater and 3 mm. 7b – 7234.0' depth – open horizontal fracture, 1mm wide follows a horizontal stylolite (arrow).

Figure 8: Core segments from Preston 119. 8a – 7199.0' depth – vertical stylolite with an open fracture following across the length of the core segment. Coin is 3 cm in diameter. 8b – 7192.0' depth – relatively large, open vug lined with a coating of euhedral quartz crystals.

Because the core from Preston 119 was not drilled as a geographically oriented core, we refer to "vertical" as parallel to the length of the core and "horizontal" as 90° to the length of the core (NOTE: bedding observed in the core is often not "horizontal" because of the cross-bedded nature of the Tuscarora Sandstone). Generally, fractures must be greater than 1 cm in length to be recognize visibly. Maximum observed fracture lengths are greater than 12 cm – obviously, vertical fractures may potentially be as long as the length of individual core segments whereas horizontal fractures are constrained by the diameter of the slabbed drill core (approximately 9 cm). Both horizontal and vertical fractures may deviate from "true" horizontal or vertical by as much as 45°. In addition, vertical fractures may exhibit a "stairstep" effect where the fracture changes orientation drastically for a short distance before returning to its original vertical or subvertical orientation. Fracture widths are variable ranging from "hairline" width to less than 1 mm to as great as 3 mm. Furthermore, fracture width is frequently observed to taper from a readily observable and measureable width to nothing over the length of a few centimeters. In general, vertical or subvertical fractures have, thus far, exhibited the greatest widths but horizontal or subhorizontal fractures with widths of 1 mm or more have been observed, especially in association with stylolites (See Figure 7b).

3. Development of 3-D Geological Model

To develop the 3D geological model, structural surfaces were constructed from subsurface well picks. First, oil & gas wells around the proposed geothermal site were identified with available electric logs, so that correlations between the wells could be made, and tops picked. Figure 9 shows a map of all oil & gas wells around the project area that have publicly available logs. The large cluster of wells, southeast of Morgantown, were drilled in the South Burns Chapel Field, an Onondaga-Oriskany natural gas field.

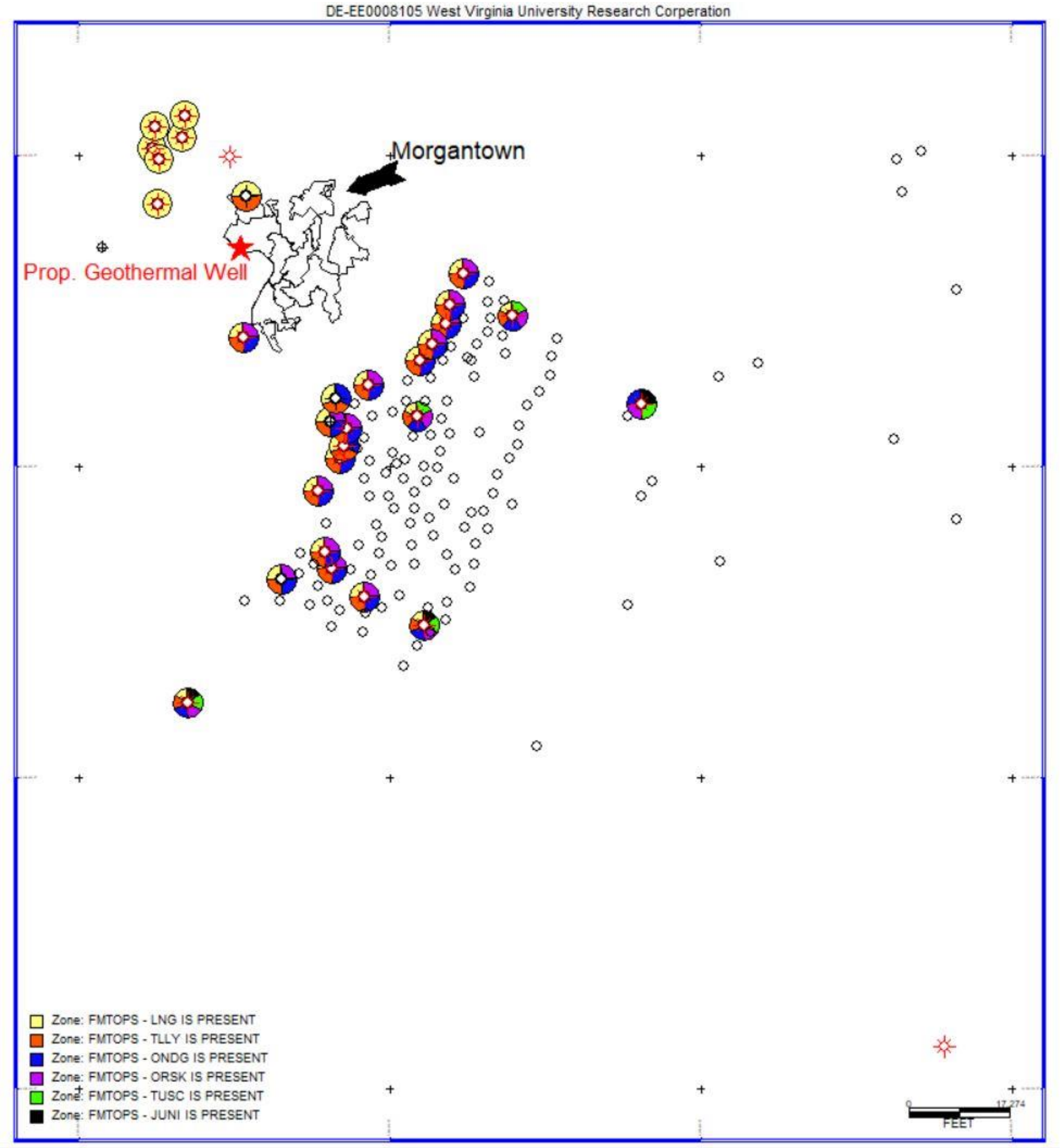

Figure 9: Map showing location of wells drilled around Morgantown, WV with available geophysical logs. Wells with tops picked are shown with color-filled doughnuts. Color-code for doughnut segments, located in the lower left-hand corner of the map, indicates tops available in each well. Stratigraphically, the shallowest top, LNG, is shown in yellow, and the deepest top, JUNI, is in black. Tuscarora (target) is represented by green. JUNI represents the base of Tuscarora pick. Tic marks on map are at 10-mile intervals.

There are several important aspects of the data availability shown in Figure 9:

1) in the 10 mi^2 (26 km^2) area surrounding the proposed geothermal wellsite, there are only 12 wells that have well logs,

2) most of the closest wells penetrate only the shallowest correlation top, indicated by the yellow circle segments,

3) only five wells in a 15 mi^2 (39 km^2) area around the proposed geothermal wellsite penetrate the target, Tuscarora Sandstone (TUSC, in Figure 9; wells with green segments), and

4) only three wells in the area penetrate the base of the TUSC.

These aspects create difficulty developing a structural model for the Tuscarora, in the area of the proposed geothermal well.

Thirty wells surrounding the proposed geothermal wellsite were correlated to generate structural surfaces. Six key tops were identified for mapping, based primarily on the ability to confidently correlate them between wells, but also to cover the depth range of the wells. The tops picked were LNG (unnamed marker-bed), TLLY (Tully Fm.), ONDG (Onondaga Fm.), ORISK (Oriskany Fm.), TUSC (Tuscarora Fm.), and JUNI (Juniata Fm.). The stratigraphic relationships between tops is displayed in Figure 1 (except the LNG marker, which is approximately basal Mississippian in age). Table 2. shows the number of tops picked for each surface. The depth difference between the LNG and the TUSC surfaces are approx. 7,500 - 8,000 ft (2,286 – 2,438 m).

Table 2. Number of tops available for each surface.

Surface	no of Tops
LNG	28
TLLY	22
ONDGs	22
ORSK	20
TUSC	5
JUNI	3

Figure 10 illustrates the structure and depth relationship of four of the six surfaces, the Tuscarora is the deepest surface. Apart from the shallowest surface, which had the most data, the five deeper surfaces were gridded using the trend of the surface above it, as a control. This conformable gridding methodology was important to developing a meaningful structural interpretation for the Tuscarora, because there are so few Tuscarora data points.

Figure 11 shows a 2D structure map of the Tuscarora surface. Figure 12. is a cross section through four wells, in a general NW-SE direction, including the proposed geothermal well and two Tuscarora penetrations. The cross section shows all six mapped surfaces. The location of the cross section is indicated by a green line on Figure 11. The cross section displays a gently southeast dipping Tuscarora surface, into a syncline separating the proposed geothermal site from the South Burns Chapel Field (a NE-SW trending anticline). The 2D-3D surface modeling was performed in GES modeling software, a product of GPT Reservoir Characterization Professionals (www.gptsoft.com).

Due to the lack of subsurface data available for this study, the results of the structural modeling have a significant amount of uncertainty. While the final structural interpretation of the Tuscarora is reasonable, in the context of regional structural trends, it lacks the data density to precisely constrain the structure under the site of the geothermal project. Regionally, the structural trends in the area are relatively tightly spaced, en echelon anticlinal and synclinal folds, orientated in a generally NE-SW direction (Figure 13). The structure map of the Tuscarora (Figure 11) exhibits the same generally NE-SW structural trend. The plan forward is to integrate available 2D seismic data to reduce the subsurface uncertainty of the model.

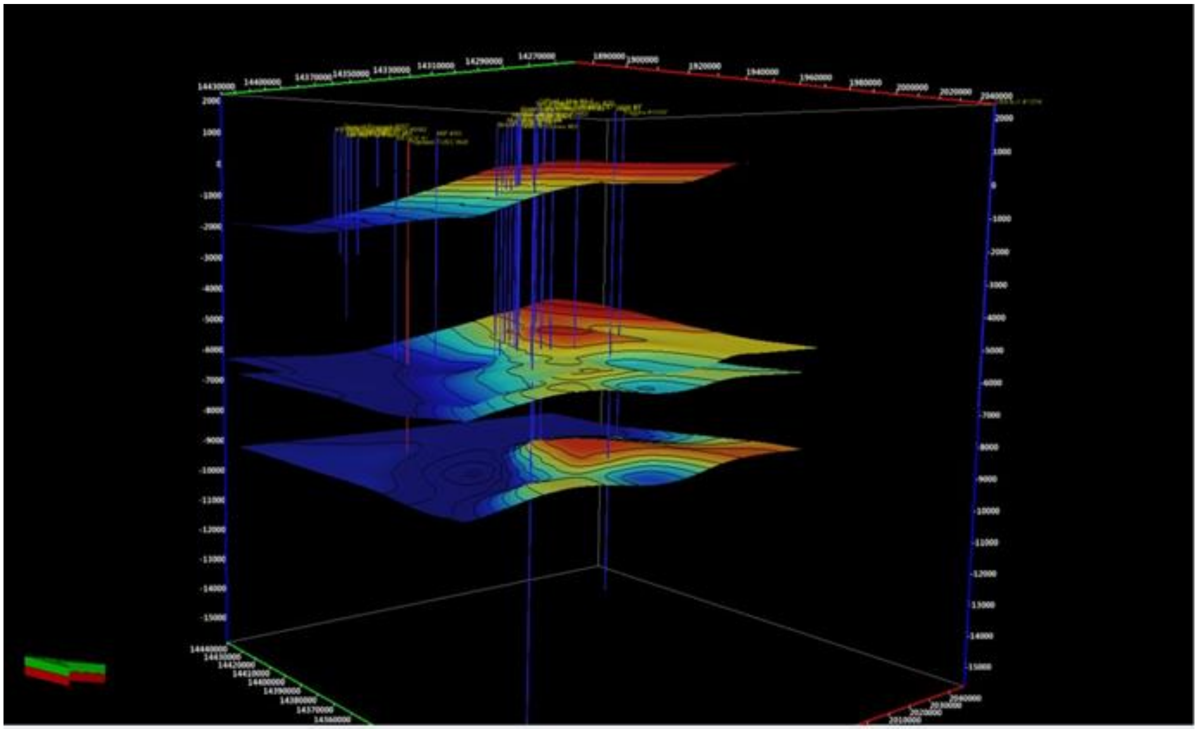

Figure 10: View of the 3D model, looking northeast. Four of the six surfaces are shown. From shallowest to deepest: LNG, TLLY (Tully Ls.), ORSK (Oriskany Ss.), and TUSC (Tuscarora Ss.). Wells with tops are drawn with blue lines, the proposed geothermal well is represented with the red line. Depth axis runs from +2,000 ft. SSSTVD to -15,000 ft. SSTVD, labels at 1,000 ft. intervals. Map extents are approximately 30 mi^2 (78 km^2).

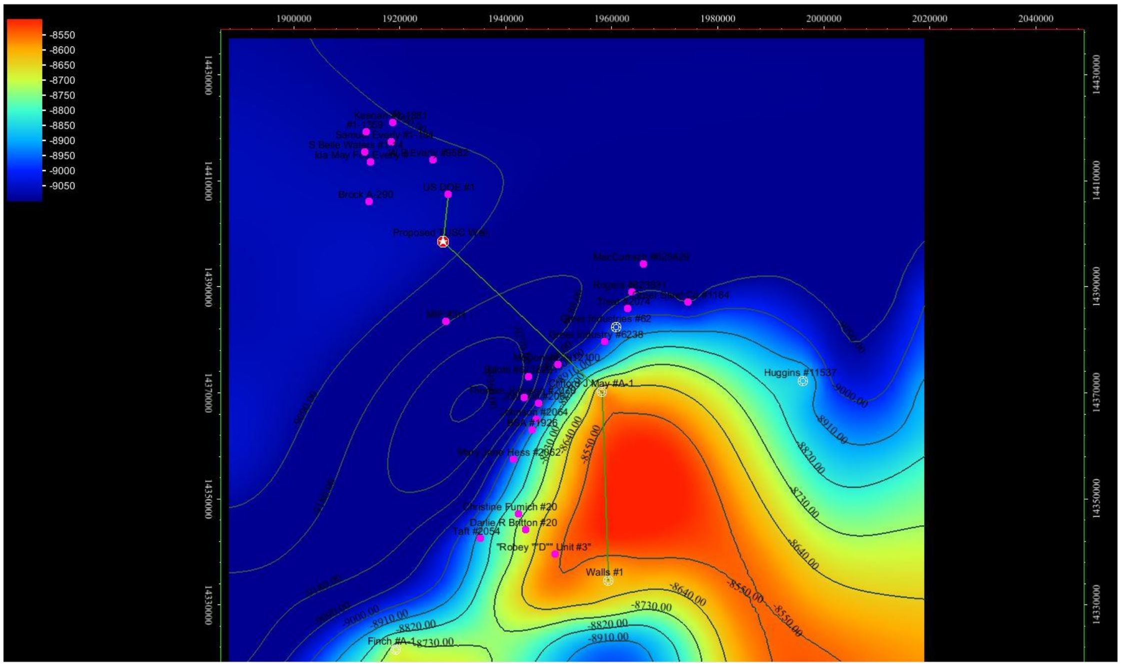

Figure 11: 2D structure map of the target Tuscarora Ss. Wells penetrating the Tuscarora are shown with white well symbols, the proposed geothermal well is shown with a white star on a red background. Contour interval is 90 ft. Axes are labeled every 20,000 ft (6.1 km). The top of the Tuscarora in the proposed geothermal well is at a depth of approximately -9,072 ft. SSTVD. Location of a line of cross section is shown with a green line.

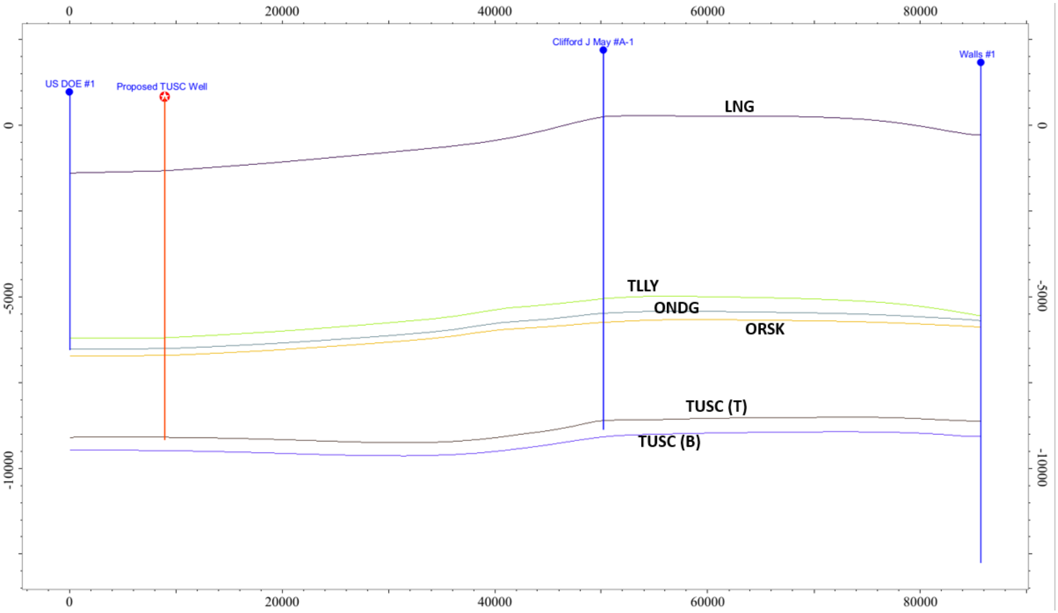

Figure 12: Line of cross section shown on Figure 11. Line of section runs generally NW-SE. The six mapped surfaces are labeled. The horizontal scale is 20,000 ft (6.1 km) between labeled tick marks. The vertical scale is 5,000 ft (1,524 m) between labeled tick marks.

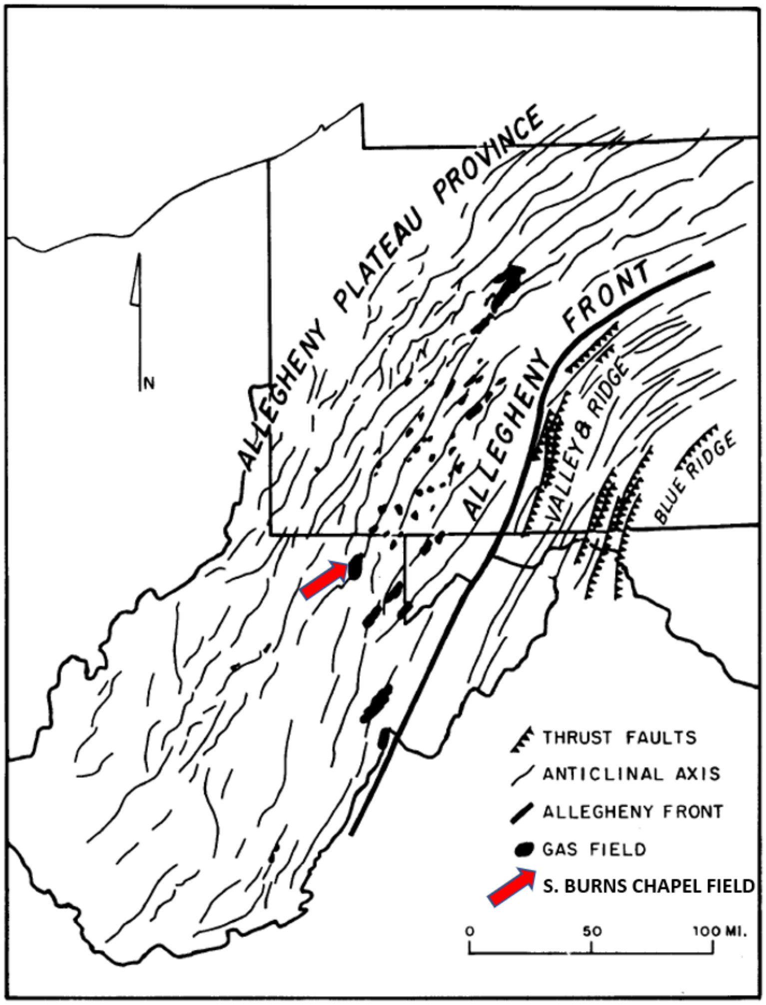

Figure 13: Structural provinces within the Appalachian basin region and location of Huntersville Chert and Oriskany gas fields. Red arrow points to South Burns Chapel Field and approximate location of the proposed geothermal site. (After Flaherty, 1996).

4. Conclusions

The Tuscarora Sandstone at a depth of 10,000 ft (~3000 m) in Monongalia County was chosen as the preliminary target formation due to its elevated temperatures and high flow conductivity. The proposed site is characterized based on the geological information available from the cores and well logs for nearby existing wells. The Tuscarora Sandstone is identified as a very fine- to very coarse-grained, poorly- to well-sorted, quartzose sandstone. Porosity appears to be generally low but what is present is often localized along small fractures. More than 800 discrete fracture traces over the 267 ft (81 m) interval are identified using CT scans on Preston-119 core. Direct permeability measurements are made using the PPP-250 Minipermeameter on selected core segments from the entire length of the core. Permeability, fracture lengths, widths, angle with respect to core vertical and horizontal are measured, and other relevant lithological features in the interval are also noted. The presence of relatively large, open voids suggests that some of the tectonic fractures may have been open, even at reservoir depth. A 3-D structural surface is generated by correlating thirty wells surrounding the proposed geothermal wellsite. The cross section displays a gently southeast dipping Tuscarora surface, into a syncline separating the proposed geothermal site from the South Burns Chapel Field (a NE-SW trending anticline). While the final structural interpretation of the Tuscarora is reasonable, in the context of regional structural trends, the structural model have a significant amount of uncertainty, due to the lack of subsurface data available for this study. The plan forward is to integrate available 2D seismic data to reduce the uncertainty of the subsurface model.

Acknowledgements

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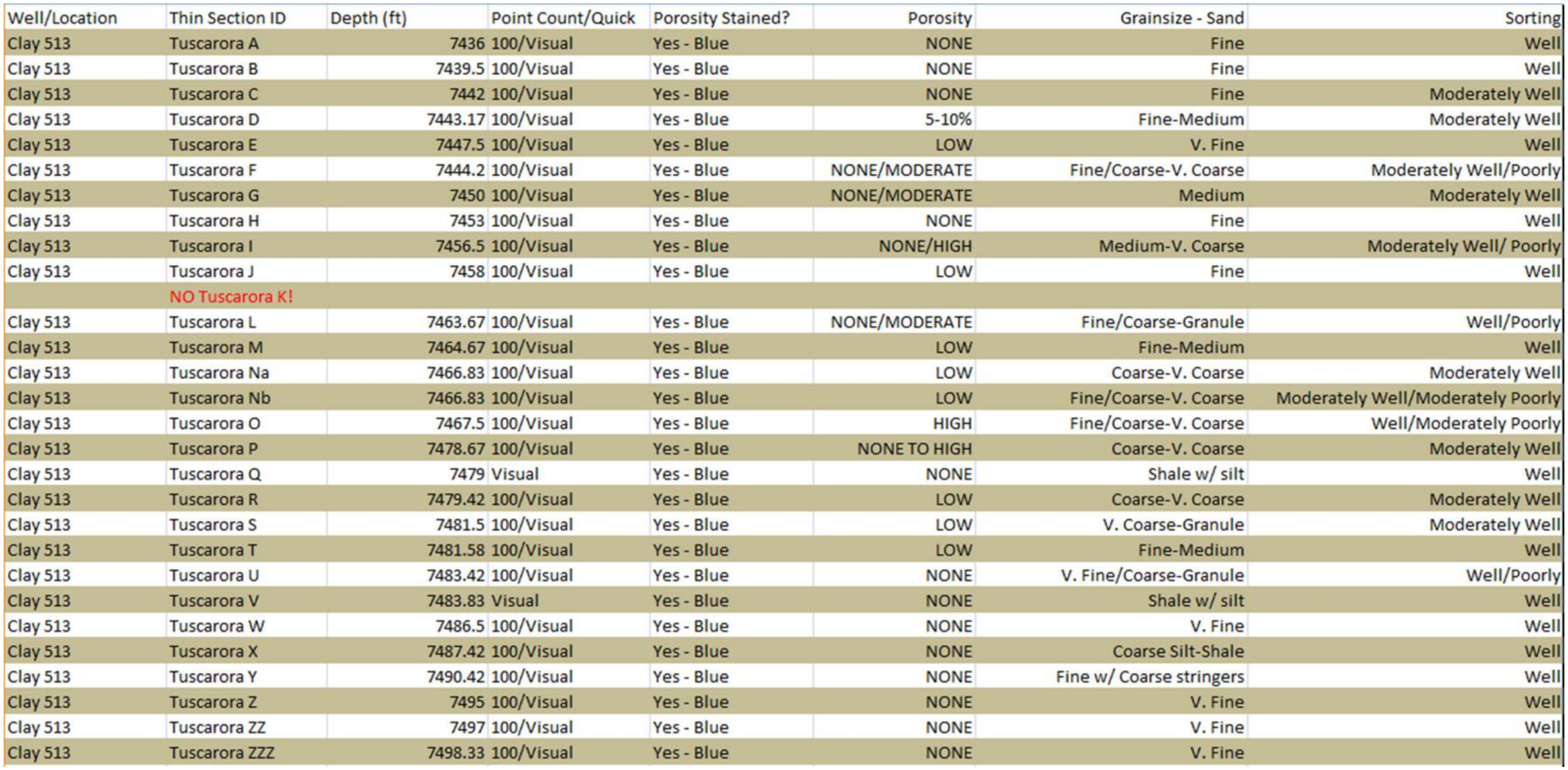
Appendix A: Thin section analysis of the Tuscarora Sandstone, Clay-513 well



Well/Location	Thin Section ID	Depth (ft)	Point Count/Quick	Porosity Stained?	Porosity	Grainsize - Sand	Sorting
Clay 513	Tuscarora A	7436	100/Visual	Yes - Blue	NONE	Fine	Well
Clay 513	Tuscarora B	7439.5	100/Visual	Yes - Blue	NONE	Fine	Well
Clay 513	Tuscarora C	7442	100/Visual	Yes - Blue	NONE	Fine	Moderately Well
Clay 513	Tuscarora D	7443.17	100/Visual	Yes - Blue	5-10%	Fine-Medium	Moderately Well
Clay 513	Tuscarora E	7447.5	100/Visual	Yes - Blue	LOW	V. Fine	Well
Clay 513	Tuscarora F	7444.2	100/Visual	Yes - Blue	NONE/MODERATE	Fine/Coarse-V. Coarse	Moderately Well/Poorly
Clay 513	Tuscarora G	7450	100/Visual	Yes - Blue	NONE/MODERATE	Medium	Moderately Well
Clay 513	Tuscarora H	7453	100/Visual	Yes - Blue	NONE	Fine	Well
Clay 513	Tuscarora I	7456.5	100/Visual	Yes - Blue	NONE/HIGH	Medium-V. Coarse	Moderately Well/ Poorly
Clay 513	Tuscarora J	7458	100/Visual	Yes - Blue	LOW	Fine	Well
	NO Tuscarora K!						
Clay 513	Tuscarora L	7463.67	100/Visual	Yes - Blue	NONE/MODERATE	Fine/Coarse-Granule	Well/Poorly
Clay 513	Tuscarora M	7464.67	100/Visual	Yes - Blue	LOW	Fine-Medium	Well
Clay 513	Tuscarora Na	7466.83	100/Visual	Yes - Blue	LOW	Coarse-V. Coarse	Moderately Well
Clay 513	Tuscarora Nb	7466.83	100/Visual	Yes - Blue	LOW	Fine/Coarse-V. Coarse	Moderately Well/Moderately Poorly
Clay 513	Tuscarora O	7467.5	100/Visual	Yes - Blue	HIGH	Fine/Coarse-V. Coarse	Well/Moderately Poorly
Clay 513	Tuscarora P	7478.67	100/Visual	Yes - Blue	NONE TO HIGH	Coarse-V. Coarse	Moderately Well
Clay 513	Tuscarora Q	7479	Visual	Yes - Blue	NONE	Shale w/ silt	Well
Clay 513	Tuscarora R	7479.42	100/Visual	Yes - Blue	LOW	Coarse-V. Coarse	Moderately Well
Clay 513	Tuscarora S	7481.5	100/Visual	Yes - Blue	LOW	V. Coarse-Granule	Moderately Well
Clay 513	Tuscarora T	7481.58	100/Visual	Yes - Blue	LOW	Fine-Medium	Well
Clay 513	Tuscarora U	7483.42	100/Visual	Yes - Blue	NONE	V. Fine/Coarse-Granule	Well/Poorly
Clay 513	Tuscarora V	7483.83	Visual	Yes - Blue	NONE	Shale w/ silt	Well
Clay 513	Tuscarora W	7486.5	100/Visual	Yes - Blue	NONE	V. Fine	Well
Clay 513	Tuscarora X	7487.42	100/Visual	Yes - Blue	NONE	Coarse Silt-Shale	Well
Clay 513	Tuscarora Y	7490.42	100/Visual	Yes - Blue	NONE	Fine w/ Coarse stringers	Well
Clay 513	Tuscarora Z	7495	100/Visual	Yes - Blue	NONE	V. Fine	Well
Clay 513	Tuscarora ZZ	7497	100/Visual	Yes - Blue	NONE	V. Fine	Well
Clay 513	Tuscarora ZZZ	7498.33	100/Visual	Yes - Blue	NONE	V. Fine	Well