Comparison and Analysis of a Lignite Seam in the Wilcox Group, Choctaw and Kemper County, Mississippi

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COMPARISON AND ANALYSIS OF A LIGNITE SEAM IN THE WILCOX GROUP, CHOCTAW AND KEMPER COUNTY, MISSISSIPPI

By

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The Wilcox Group includes the most abundant lignite bearing strata in Mississippi. Currently, the only lignite mine in Mississippi is located in Choctaw County with a proposed mine in Kemper County. Six lignite seams are currently mined in Choctaw County. One of those seams is believed to be continuous, from SE Choctaw County through central Winston County, NE Neshoba County into SW Kemper County (roughly 50 miles). Establishing a cross section from Choctaw to Kemper County verifying a continuous lignite seam would provide a stratigraphic marker horizon in correlation along strike, which is uncommon in the Wilcox Group sediments. Through observation of over 60 geophysical logs from test wells along strike, SEM and petrographic microscopy, the lignite seam was verified as being continuous from the mine in Choctaw County to the new proposed site in Kemper County and should be used as stratigraphic marker horizon for correlation along strike.
DEDICATION

To my family and friends for all the support and especially Bear, I would have
never made it through the summer of 2008 without you buddy!
ACKNOWLEDGEMENTS

I would like to express my utmost gratitude for the Department of Geosciences. You all have truly taken care of me during my career here as a student. I would like to especially thank my committee members for all I have learned in geology and life. As head professor of my thesis, I would like to thank Dr. Darrel Schmitz for all your guidance and knowledge, and the opportunity to accomplish and obtain a masters of science degree. I would also like to thank Dr. Christopher Dewey and Dr. Brenda Kirkland for all the encouragement and always being there anytime I needed advice or valuable input during my entire career at Mississippi State University. Furthermore, I would like to thank Dr. John Rodgers for your expertise in plant biology and Dr. James May for your valued input and friendship. I would also like to thank Bill Monroe and Amanda Lawrence at the EMC for their help and patience in the microscopy lab. I would like to personally thank Mary Courtney Black, Cale Sellers, Kevin Moore, Will McBryde, Brittany Weeks, and Inoka Peiris for all your help in research, advice and your friendship. I would like to thank North American Coal Corporation, especially Benson Chow and Rebecca Buell, for funding, data and the will to help whenever it was needed. I would finally like to thank all those who I”m sure I neglected to mention for your assistance on completion of this project. THANK YOU.
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CHAPTER I
INTRODUCTION

The following research compares and analyzes what is believed to be a continuous lignite seam in the Wilcox Group from Choctaw County, where it is currently mined by North American Coal Corporation, to Kemper County, where a proposed mine site is located. The Wilcox Group occurs in most of east-central, eastern and northeastern Mississippi and is the only active lignite-producing strata in the state. North American Coal Corporation currently mines six lignite seams in its only mine in Mississippi. The “G” seam is supposedly continuous and is a possibility to be mined in the proposed mine.

Through geophysical logs, SEM, and chemical analysis, the “G” seam in Choctaw and its potential lateral continuation in Kemper County were compared and a cross section was created. Geophysical logs produced a cross section extending roughly 50 miles. Samples were taken from each county; Choctaw County samples were provided by the Red Hills Mine, and Kemper County samples were taken from cores located within the proposed mine site. SEM analysis compared samples from both counties in an attempt to prove a continuous seam by identifying similar characteristics. Chemical analysis, as well as geophysical and SEM analysis were used collectively to create a depositional environment along the section. The Wilcox Group is made up complex fluvial and coastal sediments and contains little, if any marker horizons for correlation purposes along strike.
If continuous, the “G” seam would provide a Stratigraphic marker horizon in the Wilcox Group.
CHAPTER II

SETTING

Location

The Wilcox Group outcrops in 21 counties in the state of Mississippi, from Tippah County at the Tennessee border down to Lauderdale County at the Alabama border. Occurring mainly in the East/Northeast portion of the state, the Wilcox occurs as a bow-shaped formation and follows the main depositional trends for sediments of the Eastern Mississippi Embayment (Figure 2.1).

Lignite samples were obtained for analysis from two counties within the Wilcox outcrop: Choctaw and Kemper. Choctaw County lies in the northern half of the state and is covered almost entirely by the Wilcox Group. Samples were collected from the Red Hills Lignite Mine near Ackerman which is in the center of the county. Kemper County is located in the Eastern region of the state, and the Wilcox only outcrops in the western half of the county. Core samples were collected from the southwest portion of the county, about 10 miles north of Collinsville.

The line of section (Figure 2.2, 2.3) created begins in Choctaw County near Ackerman and continues south through central Winston and extreme northeast Neshoba Counties terminating in Kemper County at the proposed mine site (roughly 50 miles).
Figure 2.1  Geologic map of Mississippi.
Figure 2.2 Geologic map of Mississippi with highlighted Wilcox Group and area of study.
Figure 2.3  Line of section marked by the black line. Actual drill hole locations are proprietary and will not be shown. Wilcox Group highlighted (tan color).
Geology

The sediments of the Wilcox Group overlie the Upper Paleocene Naheola Formation of the Midway Group and underlie the Middle Eocene Tallahatta Formation of the Claiborne Group (Figure 2.4). The Wilcox Group (Eocene Epoch) in Mississippi is the most abundant lignite-bearing stratum in the State (Hawkey, 2005). It is composed of mostly non-marine sediments that were deposited on a coastal plain. In Lauderdale County, sediments can be more than 700 feet thick and thin continually through north central and northern Mississippi (Williamson, 1976). The Wilcox is a complex sequence of fluvial and coastal sediments exhibiting multiple changes in lithology, unit thickness and lateral continuity. As a direct result of the vertical and horizontal facies complexities and transitions, the Wilcox contains very few, if any, marker horizons that can serve as tools for stratigraphic correlation purposes, especially along strike.

Traditionally, the Wilcox has been divided into the Nanafalia Formation, Tuscahoma Formation and the Hatchetigbee Formation (Toulmin, 1977). The Nanafalia Formation lies on the top of the Naheola Formation of the Midway Group. It is comprised of mostly clayey sand, silty clays and shales with numerous lignite beds. The Lower Fearn Springs Member of the Nanafalia consists of laminated silty, micaceous clay and fine sand with thin lignites and reworked bauxite material (Williamson, 1976). The Tuscahoma Formation consists of sands with laminated clays and shales. Lignites beds are common (Williamson, 1976). It’s thin-bedded and laminated character distinguishes itself from the Nanafalia and Hatchetigbee and can be traced from eastern Mississippi into western Georgia (Toulmin, 1977). The Hatchetigbee Formation is similar to the Tuscahoma and consists of interbedded sands, clays, carbonaceous clays and lignites
(Williamson, 1976). The basal Bashi Marl Member consists of glauconitic, fossiliferous sandy marl and can be traced from eastern Mississippi into western Georgia (Williamson, 1976; Toulmin, 1977). Lignite seams are common throughout the entire Wilcox Group. Beds generally dip to the west-southwest and strike northwest to southeast (Figure 2.5).

![Stratigraphic column.](image)

Figure 2.4 Stratigraphic column.
Figure 2.5  Cross section just north of area in study but displays beds dipping west-southwesterly (adapted from Newcome and Bettandorf, 1973 and TVA, 1998).
Mining History

Lignite was first mined in Mississippi as early as the 1920’s by an unknown company and evidence of the mining activity could once be found in Choctaw and Winston County (Bicker, 1970). Currently, there is only one active lignite mine in the State. Red Hills Lignite Mine owned by North American Coal Corporation is a strip mine that began production in 2000. It is located seven miles northwest of Ackerman, Mississippi in Choctaw County and lies within the Wilcox Group. Each year, the mine produces approximately 3.5 million tons of coal per year (NACC, 2006). The Red Hills power plant supplies electricity to the Tennessee Valley Authority. Mineable reserves of lignite at the Red Hills Mine site are estimated at more than 200 million tons, in a total of 5,809 acres of permitted area. Only six seams are mined and are located primarily within the Tuscahoma Formation and the Upper Nanafalia Formation. Average lignite quality: 5120 BTU/lb, 43.09% moisture, 14.40% ash (NACC, 2006).
CHAPTER III
REVIEW OF LITERATURE

The majority of analysis studied on lignite from the Wilcox Group was generated in the 70’s and 80’s prior to mining. James A. Luppens (1978) provides quality data for lignite found in various areas of Mississippi. Ash content is typical of the Gulf Coast lignite trend and the moisture content is higher than found in Louisiana and Texas. He also found a small increase in sulfur content from north to south as deposition becomes more of a marine type environment (Table 3.1). Sulfur content is lower in Mississippi than in many eastern U.S. coals (Luppens, 1978).

Table 3.1
Typical Quality Analysis of Mississippi Lignite (Luppens, 1978; Phillips Coal Company)

<table>
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<tr>
<th></th>
<th>North Wilcox</th>
<th>Central Wilcox</th>
<th>South Wilcox</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture</td>
<td>43.51</td>
<td>42.08</td>
<td>43.19</td>
</tr>
<tr>
<td>Ash</td>
<td>12.08</td>
<td>12.05</td>
<td>11.84</td>
</tr>
<tr>
<td>Volatile Matter</td>
<td>25.26</td>
<td>24.59</td>
<td>24.33</td>
</tr>
<tr>
<td>Fixed Carbon</td>
<td>19.15</td>
<td>21.28</td>
<td>20.64</td>
</tr>
<tr>
<td>Sulfur</td>
<td>0.54</td>
<td>0.55</td>
<td>1.17</td>
</tr>
<tr>
<td>Btu/lb</td>
<td>5396</td>
<td>5534</td>
<td>5509</td>
</tr>
</tbody>
</table>
Known as the “Lignitic Formation” in the late 1890’s (Harris, 1894) and “Sabine Formation” in the early 1900’s, the USGS permanently provided the name Wilcox to the group of beds between the Midway Group and the Claiborne Group in 1910 (Williamson, 1976). By the time that Williamson (1976) published an information pamphlet for the Mississippi Geological Survey, the inherent complexity of the Wilcox had been made more difficult due to the various attempts to name and subdivide the group by many geologists.

Although Williamson (1976) indicates that the Wilcox in Mississippi is composed of almost entirely non-marine beds, most of the Wilcox in Alabama contains marine marker beds (Toulmin, 1977). It is in Kemper and Lauderdale Counties in Mississippi, therefore, that the non-marine beds begin to interdigitate with marine facies of the Wilcox in Alabama. While Wilcox beds in Kemper and Lauderdale Counties may be subdivided into four formations (Hatchetigbee-non-marine, Bashi Marl-shallow marine, Tuscahoma-non-marine and Nanafalia-shallow marine), Williamson (1976) explains that the Wilcox Group in north-central and northern counties of Mississippi are generally referred as „Wilcox undifferentiated” due to the complex fluvial and sedimentary sequences.

Lignite beds found in the Mississippi Wilcox tend to occur as irregular units, extending for varying distances and thicknesses. Seams that range from four to seven feet thick are common while some are more than ten feet thick. Lignite seams are often interrupted, subdivided and truncated by ancient fluvial channels (Williamson, 1976).

Sulfur content within the seams was found to increase from north to south. Sulfur found in coal samples can be attributed to three forms: sulfate, pyritic and organic. Mississippi lignite sulfur content can be typically attributed to organic origins. The
increase in sulfur from north to south supports the theory that Mississippi lignites are fluvial for the majority of the state and become marginally deltaic in Kemper and Lauderdale counties (Williamson, 1976). In Alabama, lignite continually grades into more marine, deltaic environments (Williamson, 1976). Kaiser (1974) states that low sulfur content can be attributed to fluvial lignites, moderate sulfur content may be associated with deltaic lignites and high sulfur content can be associated with lagoonal lignites. Ash content found in lignite samples was moderate to high and BTU were found to be low (Williamson, 1976).

Dueitt (1985) studied lignite found specifically in Choctaw and Winston counties. A total of 14 lignite samples (nine from Winston and five from Choctaw) were obtained from outcrops where they were taken from at least 45 cm into the lignite seam to avoid any weathering or oxidation. Each sample collected represented approximately 15 cm of lignite. In 12 of 14 samples, the ash content decreased as the seam thickness increased (Table 3.2).
Wood samples were also collected from two lignite seams and are believed to belong to Taxodiaceous and Dicotyledonous genera which support the theory of fresh water swamp environments. Petrographic analysis indicated the lignite contained a large amount of the maceral humodetrinite (Dueitt, 1985). Dominant portions of humodetrinite represent reed-dominated coal deposits, usually consisting of plants that are poorly lignified and retain some of their original cellulose. When compared to similar data of coal containing cellular humic material content (textinite and ulminite), there was a distinct division between the two. While some samples were found to contain textinite and ulminite (representing a woody swamp type environment with plants whose cells are lignified and resistant to material, structural and biochemical decomposition), the majority of the samples were dominated by the macerated humic material indicating swampy, marshy lignin-poor plants (Stach, 1982).
CHAPTER IV
PURPOSE OF STUDY

The “G” seam, currently mined in Ackerman and will be mined at the proposed mine site, is believed to be a continuous lignite seam within the Wilcox Group with an increase in sulfur content from north to south. The increase in sulfur is thought to be the effect of a more marine environment. Little research has included the lignites of the Wilcox Group in Mississippi. Palynological and mineralogical studies in this area are scarce, especially within the last 20 years and are important in developing a stratigraphic marker horizon for correlation along strike.

Hypothesis

1. The “G” seam is a continuous lignite seam in the Wilcox Group.

2. The “G” seam extends over a strike distance of at least 30 miles, extending from Choctaw to Kemper County.

3. The lateral extent of the “G” seam permits its use as a stratigraphic marker horizon in correlation along strike.
Objectives

The objectives of this study were to prove a continuous coal seam through verification of geophysical logs, as well as microscopic evidence. Chemical analyses, both old and new, are also important aspects of the study in determining depositional setting along the lignite seam. Specific objectives include:

- Verify the presence of a continuous seam by developing a cross section from geophysical logs from Choctaw to Kemper County.
- Compare similarities and identify minerals and plant material found in lignite samples taken from both counties through FESEM, ESEM and petrographic microscopy.
- Compare chemical analysis, especially sulfur content, in both locations.
- Develop a facies model for deposition along the lignite seam.
CHAPTER V
METHODOLOGY

Cross Section

The cross section provided was formed by observation of over 4800 drill holes. A total of 37 drill holes define the line of section with over 60 used for verification. The geophysical logs used were provided by North American Coal Corporation. Each geophysical log was used to determine the “G” seam, a supposedly continuous lignite seam. All “G” seams were determined by spreading each log out on a table and carefully matching each seam to the other, beginning in Choctaw County. Typically at least five logs were on the table at any given time. Only geophysical logs with core data were used for the cross section. The line of section was primarily kept in the middle of the Wilcox except in northwest Winston County where the line moves up-dip due to a massive sand body that has washed out a section of the lignite seam. Geophysical logs without core data were used to verify the “G” seam up-dip until a log with core data was found.
Coal Samples

Lignite samples were taken in Choctaw and Kemper County in the summer of 2009. Three samples of the “G” seam were obtained from Choctaw County at the Red Hills Lignite Mine. The samples were taken from the same general area due to access difficulties and mine regulations. Choctaw County samples were taken from an outcrop along one of the access ramps in the mine. Holes were dug into the seam two to three feet deep to obtain samples devoid of weathering and oxidation (Figure 5.1).

Kemper County samples were taken at seven various locations within the proposed mine site. A mobile cable tool drill rig (Figure 5.2) was used to core several seams including the “G” seam for lignite quality data. Core samples were brought up and logged, cleaned and sent off for analysis (Figure 5.3). Small lignite samples were taken

Figure 5.1 Collecting samples at the Red Hills Lignite Mine outcrop.
from these seven cores and were brought back to Mississippi State University. Each sample taken from Choctaw and Kemper were left to dry for up to two weeks.

Figure 5.2 Cable tool drilling rig used to collect core samples.
Figure 5.3  Core samples measured and logged.
**Scanning Electron Microscopy**

A piece of each lignite sample was taken to the Electron Microscope Center (EMC) on the campus of Mississippi State University. Samples were viewed using a Field Emission Scanning Electron Microscope (FESEM) and an Environmental Scanning Electron Microscope (ESEM) to distinguish plant components/parts. To prepare samples, small pieces of lignite, four to six mm in diameter, were mounted on aluminum stubs with hot glue. The samples were then coated, using the Polaron SEM Coating System (Figure 5.4), at a thickness of around 40 nm using the Polaron SEM Coating System set at 20 mA at 2.4 kV for a maximum of 30 seconds (Folk and Lynch, 2001).

![Samples being coated with Gold-Palladium.](image)

Figure 5.4  Samples being coated with Gold-Palladium.
Thin Section Petrography

Small pieces of five samples taken from Kemper and Choctaw County were sent to Spectrum Petrographics, Inc. Thin sections were vacuum-embedded with epoxy resin, 25 mm. Confocal laser scanning microscopy was performed with an Axiovert 200 M Inverted Research microscope with three confocal detection channels. Images were created with AimImageBrowser software. Petrographic analysis was completed with a standard research grade petrographic microscope (Olympus BX50) structured for photography. Photos were captured with a Nikon Coolpix 990, 3.34 megapixel camera.
CHAPTER VI
RESULTS

Chemical Analysis

Core data, initially collected by Phillips Coal Company in the 1970’s, illustrated fluctuations of data for Sulfur content (Chart 6.1). Choctaw County data fluctuated the most with Sulfur content as low as 0.26 and as high as 1.71. Winston County contained the highest Sulfur content at 1.78. Neshoba County contained a high of 0.96 and a low of 0.36. Kemper County contained a high of 1.07 and a low of 0.46.

BTU content also fluctuates with this data (Chart 6.2). Choctaw County contains a high of 6272 BTU/lb and a low of 4306 BTU/lb. Winston County contains a high of 5759 BTU/lb and a low of 3534 BTU/lb. Neshoba County contains a high of 5205 BTU/lb and a low of 4399 BTU/lb. Kemper County contains a high of 5583 BTU/lb and a low of 4119 BTU/lb.

Other analysis revealed moisture content from Choctaw to Kemper County averaged 42.21% while ash content averaged 14.56%. Further analysis is proprietary and will not be included in this document.
Cross Section

Data compiled using geophysical logs provided a cross section of the “G” seam from Choctaw County to Kemper County. The lignite seam is continuous along this line and maintains an average thickness of about 5.27 feet (Chart 6.3). Due to a confidentiality agreement with North American Coal Corporation, geophysical logs actually used are not presented herein but an example of a typical log for representation purposes is given (Appendix A.)

Chart 6.1   Sulfur content of all drill holes used for cross section.
Chart 6.2  
BTU content of all drill holes used for cross section.
Chart 6.3  Cross section of coal seam from 37 drill holes from Choctaw County to Kemper County, Mississippi. Blue line marks ground level and red lines mark “G” seam.
Scanning Electron Microscopy

Samples A, B-1, B-2, C-1, C-2, D and E were taken from Kemper County.

Sample A was taken the “G” seam. It contains sclerotinite (Stach, 1982) (Figure 6.1) originating from a form of fungal mycelia. Mostly organic material can be found in SEM pictures taken from sample A (Figure 6.2).

Figure 6.1 Sclerotinite (fungal remains) found in Kemper County.
Figure 6.2  Organic material commonly found in Kemper County. Generally what was seen throughout samples.
Sample B-1 was taken from a piece of woody material found within the core while coring the “G” seam. Woody tissue can be easily seen in SEM photos (Figure 6.3, 6.4).

Figure 6.3 View of woody material found within the core.
Figure 6.4   Woody tissue from sample found within the core.
Sample B-2 was taken from “G” seam near where parent material was found. Sample is mostly dominated by woody tissue (Figure 6.5) with some pyrite framboids (Stach, 1982) (Figure 6.6) found along with sporinite (Stach, 1982) and quartz crystals (Figure 6.7). The skins of spores and pollens found in lignite and bituminous coals are referred to as sporinite. Specific spore types found in coal seams are occasionally used for seam identification (Stach, 1982) in which this study attempts to do.

Figure 6.5 Woody tissue protruding from organic material. Horizontal lines represent charging on the sample
Figure 6.6 Framboidal pyrite.
Figure 6.7 Large deflated sporinite (A) with pyrite crystal (B) and quartz grains (C).
Sample C-1 was taken from the upper “G” seam. Pyrite was visible in the core but none was found in the SEM. The sample contains mostly organic material with feldspar (Weeks, 2009) (Figure 6.8).

Figure 6.8  Feldspar.
Sample C-2 was taken at the same location as C-1, as a part of the upper “G” seam. It contains shell fragments (Figure 6.9) verified using EDX (Energy Dispersive X-ray) with Inca software (Figure 6.10). CaCO3 was indicated by the software verifying a shell fragment. Sporinite was also found (Figure 6.11).

Figure 6.9 Shell fragment.
Figure 6.10  EDX analysis showing percentages of elements found in fragment analyzed. Sufficient amounts of CaCo$_3$ were found to support identification of shell fragment.
Figure 6.11 Sporinite found in Kemper County.
Sample D was taken in the same location as sample C and comes from the lower “G” seam. It contains well preserved plant material in the form of vascular tissue (Figure 6.12, 6.13).

Figure 6.12  Well preserved plant material.
Figure 6.13  Plant material and vascular tissue.
Sample E was taken from the “G” seam. It contains well preserved plant materials (Figure 6.14, 6.15) along with some sporinite (Figure 6.16) and possibly sclerotinite (Figure 6.17).

![Plant tissue. No other similar tissue found throughout study.](image)

Figure 6.14  Plant tissue. No other similar tissue found throughout study.
Figure 6.15  Woody tissue which was not found anywhere else throughout the study area.
Figure 6.16  Sporinite similar to what is displayed in Fig. 6.11. Both display “bumps” on outer shell. Two spores presented in this particular photo.
Figure 6.17  Sclerotinite (fungal remains). Similar to what was found in Fig. 6.1 with the spherical body missing.
Samples F, G and H were taken from Choctaw County in an outcrop of the “G” seam located in the open pit of the mine. The only difference in location is laterally with 20 foot spacing between samples.

Sample F revealed impressive framboidal pyrite (20µm) (Figure 6.18, 6.19) and dolomite (possibly gypsum) (Stach, 1982; Gournay, 1999) (Figure 6.20), in addition to well preserved plant material (Figure 6.21).

Figure 6.18  Large framboidal pyrite. One of the larger framboids found in Choctaw County.
Figure 6.19 Clusters of frambooidal pyrite often seen throughout this particular sample.
Figure 6.20  Euhedral dolomite (possibly gypsum) with associated organic matter.
Figure 6.21  Plant material. Probably fragments of vascular tissue.
Sample G contains well preserved plant material (Figure 6.22) and dolomite (Figure 6.23).

Figure 6.22  More well preserved vascular tissue. Notice scale for size of tissue.
Figure 6.23  Dolomite (possibly gypsum) (A) with fragments of plant tissue and associated organic matter (B).
Sample H contains well preserved plant material (Figure 6.24) with what is interpreted as dolomite (Figure 6.25) and sporinite (Figure 6.26).

Figure 6.24 Well preserved plant material.
Figure 6.25  Plant material (A) with euhedral dolomite rhombs (possibly gypsum) (B) growing out of plant remains.
Figure 6.26  Sporinite and fragments of plant tissue and organic debris.
Petrographic Microscopy

The thin section made from sample A from Kemper County contained a visible circular piece of a plant fragment. The parent material shown with the Olympus microscope (Figure 6.27) and the Axiovert confocal microscope (Figure 6.28) can easily be seen. When the image was enlarged using the confocal software, the sample appeared to display what looked to be fossil pollen. (Figure 6.29).

![Figure 6.27 Parent material found in thin section sample A from Kemper County, 10x.](image)
Figure 6.28  Confocal imagery: parent material from thin section sample A from Kemper County. Top left displaying green channel, top right displaying red channel, bottom right displaying UV channel, and bottom left displaying transmitted light.
Figure 6.29  Confocal imagery: top left displaying green channel, top right displaying red channel, bottom right displaying UV channel and bottom left displaying transmitted light. Red channel displays fossil pollen.
CHAPTER VII
DISCUSSION

The “G” seam is a continuous lignite seam, extending more than 50 miles from Choctaw to Kemper County. The continuity of the seam proves it should be used as a stratigraphic marker horizon in the Wilcox Group.

The continuous “G” seam shares some characteristics from Choctaw to Kemper County but also displays some differences. The geophysical logs verify a continuous seam with data from samples taken from both counties. Other SEM photos taken from both counties not mentioned are located in Appendix B.

Cross Section

The cross section from Choctaw to Kemper County is continuous and relatively follows the topography. Thickness remains similar (average of around 5 feet thick) except for Winston County where the seam decreases to as thin as two feet. As the cross section enters Winston County, it takes an abrupt turn up-dip due to a large sand body (Figure 2.3). Most likely a fluvial system cut through the seam but the seam was traced from Choctaw up-strike into Winston County with other geophysical logs. The reason for thinning of the seam is probably due to the seam pinching out up-dip. There are also indications of one or more faults located in Winston County (around W107 and N178)
The “G” seam nearly outcrops between drill holes W39 and W107. Fluvial systems often follow old faults and could explain the fluctuations in seam thickness and change in topography, although this could not be verified with geophysical logs. It is possible faults may have formed due to sedimentation loading, however, further research is needed to confirm this possibility. The fluctuations in topography and the “G” seam (Figure 7.1), however, extend into Neshoba County before becoming more stable in Kemper County. The “G” seam appears to become shallower in depth from north to south (Chart 7.1) but this is mainly due to a slight move up-dip in Kemper County and a decrease in elevation of ground level. The coal seam stays at relatively the same depth throughout the cross section.

Figure 7.1 Lignite seam on the far wall rolling along with the topography.
Chart 7.1  Difference in ground level to the top of the lignite seam. Notice the seam becoming closer to ground level from north to south.
**Sulfur Content**

Sulfur content appears to fluctuate throughout the cross section but remains close to 0.6-1.0 in both Choctaw and Kemper. Highest concentrations of sulfur occur in southern Choctaw and northern Winston County.

Sulfur bacteria in peats and organic muds reduce sulfates to sulfur, which allow the formation of pyrite and marcasite. Neavel (1966) suggested that FeS$_2$ in peat may only form by bacterial activity because of a lack of energy for a pure chemical reduction of sulfates to disulfides. Sufficient amounts of sulfur and iron are required for pyrite formation. Sulfur originates from bacterial protein, plant and animal protein or it may be carried in by streams or sea water as sulfate ions. Iron can be found wherever silicate minerals weather or groundwater carries Fe-ions. Pyrite in coal can usually be found concentrated in the lower or upper portion of the seam or near old washouts (Stach, 1982).

Casagrande (1971) investigated amino acids in Florida peats and found that microorganisms contribute at least 5-10% of organic matter in peat. He later compared marine and fresh-water peats studying the origin of sulfur content. Marine peats were found to have a higher sulfur content. The sulfur content increases with depth because of pyrite formation through the sequence of H$_2$S→S→FeS$_2$. Hydrogen sulfide is formed from sulfate-reducing bacteria that favor high pH values. With sea water providing most of the sulfate, pyrite becomes prolific in marine peats (Casagrande, 1977). It is concluded by both Casagrande (1977) and Staub & Cohen (1979) that “environmental conditions, especially pH, appear to have a dramatic effect on pyrite content,” (Stach, 1982).
BTU

BTU fluctuates also within the cross section but like sulfur content, remains relatively similar in both Choctaw and Kemper County. As the section extends south toward Winston County, the highest BTU readings are found in southern Choctaw County.

Sporinite

Fossil spores found in Choctaw and Kemper show resemblance in shape but have differences. It should be reiterated that Choctaw County samples were taken from one particular area due to the Red Hills Mine safety and regulations. Although the same spore assemblages may not be identified in these particular samples from Choctaw County does not mean it does not exist.

Choctaw County sporinite appears smooth and often times appears macerated (Figure 6.26, 7.2). Kemper County sporinite varies in size from 10 to 20μm and contains „bumps” on their outer shell (Figure 6.11, 6.16, 7.3). In figure 6.11, to the left of the sporinite sample common to Kemper County appears to be a spore similar to those found in Choctaw but there is not enough evidence to prove this suggestion. As these spores or pollen are ruptured or crushed, their outer cuticle is left torn and can be seen in both locations (Figure 7.2, 7.4, 7.5).
Figure 7.2  Macerated sporinite from Choctaw County.
Figure 7.3  Common sporinite found in Kemper County.
Figure 7.4  Macerated sporinite from Kemper County.
Figure 7.5  Macerated sporinite from Kemper County.
Fossil spores are divided into megaspores and microspores. Megaspores of up to 3mm in size have been found belonging to lepidodendrons (Stack, 1982). One particular spore found in Kemper County exhibits the megaspore characteristics (Figure 6.7). Microspores are much smaller and are extremely difficult to discriminate from pollen grains (Stach, 1982). Guennel (1952) introduced the term „miospore“ to describe mega- and microspores for botanical accuracy and the term is used by coal petrologists. In coal, these spores often appear flattened or deflated such as found in Kemper County (Figure 6.7) (Stach, 1982).
Pyrite

Pyrite, along with marcasite and melnikovite-pyrite are some of the most common sulfides found in coal. It can usually be seen in the form of fine grains or fine concretions in coals containing high percentages of vitrinite and also in sapropelic coals (Stach, 1982). Pyrite concentration was much higher in Choctaw County than Kemper County. Framboidal pyrite was found in numerous places on sample F from Choctaw County (Figure 6.18, 6.19, 7.6, 7.7). The only sample from Kemper County to contain pyrite was B-2 (Figure 6.6, 6.7, 7.8).

Figure 7.6  Small pyrite octahedral crystals scattered amongst organic material. Smallest octahedral pyrite found in the study area.
Figure 7.7 Framboidal pyrite (A) and dolomite (possibly gypsum) (B).
Figure 7.8    Kemper County euhedral pyrite.
Coals rich in pyrite are usually deposited in paralic (near marine) basins, whereas coals deposited in limnic (freshwater) basins contain less pyrite. In paralic basins, coal seams that have been affected by marine transgressions contain a relatively high content of pyrite and occasionally organic sulfur (Stach, 1982) which applies to lignite in Choctaw and Kemper County. The occurrence of synsedimentary or early-diagenetic pyrite in a coal seam can be used for seam identification (Stach, 1982).

It is interesting to note that although more pyrite was found while coring in Kemper County samples than Choctaw County, pyrite appeared much more frequently in Choctaw County. Framboidal pyrite appears throughout sample F from Choctaw County, appearing as clusters. Kemper County displays octahedral pyrite crystals that are only found in sample B-2 and mostly as isolated crystals. It is also important to remember that only seven samples were taken in Kemper County and three were taken in Choctaw County all of which were in the same general location. A much more accurate assessment of the pyrite and sulfur content could be obtained with a more robust and distributed sample base, however the confidentiality agreement with North American Coal Corporation limited sample collection. Pyrite was expected to be found in both locations, however more had been expected to be found in Kemper County.
Dolomite

The appearance of dolomite in all Choctaw County samples is not uncommon, especially due to the proximity of the samples. Dolomite is not an uncommon mineral found in coal. It is typically found in seams exposed to marine conditions, usually occurring in the form of idiomorphic or euhedral crystals (Figure 6.20, 7.9) or infused in plant material (Figure 6.25, 7.10). Dolomite may form in the early or late stages of the coalification process (Stach, 1982). It appears as though the dolomite found in Choctaw County samples formed in the latter stages of the coalification process as they appear to be growing out of the plant material and display no compressional features (Stach, 1982). Dolomite is not used for identification purposes and therefore, should not be expected in Kemper County samples, although it most likely exists. It should be noted the possibility of gypsum interpreted as dolomite.
Figure 7.9  Euhedral dolomite (possibly gypsum) from Choctaw County.
Figure 7.10  Dolomite (possibly gypsum) crystals imbedded in plant material from Choctaw County, shown at lower magnification than Figure 7.9.
Quartz

Quartz crystals and detrital grains are commonly found in coal although only a small amount was found in the samples collected. The occurrence of quartz in coal is almost always a product of the first stage of the coalification process. Quartz grains can either be brought in by water or air, in which grains are rounded, or can form from solution (Stach, 1982). It is believed that all quartz grains found in this study were most likely formed authigenically as a result from weathering of feldspar or mica, and are usually angular to subangular (Figure 6.7, 7.11). The occurrence of quartz grains in sedimentary and metamorphic rocks are often flattened due to directional pressure. In certain cases, the occurrence of quartz in coal has been used as a means of seam identification but is generally not applicable (Stach, 1982). Samples B-2 and C-2 from Kemper County were the only samples to contain quartz grains.
Figure 7.11  Quartz grain found in sample C-2 from Kemper County.
**Feldspar**

Feldspars are most likely represented in coal by potassium-feldspar and plagioclase feldspar. The plagioclase feldspars are most likely what appears in C-1 (Figure 6.8) and C-2 (Figure 7.12) due to their ability to endure weathering and the harsh coal swamp environment. They are often angular to semi-rounded grains or prismatic crystals that display weathering (Stack, 1982). Most feldspars are detrital in origin (Vassilev, 1996), deposited most likely by a fluvial system. No other areas in the study contained evidence of feldspar.

Figure 7.12  
Feldspar in dissolution from sample C-2, Kemper County.
Sclerotinite

Sclerotinite was found in Kemper County sample A and possibly in E and Choctaw County sample G (Figure 6.1, 6.17, 7.13). In Tertiary coals, sclerotinite consists of mostly fungal remains and can be used to describe hyphae, mycelia, plectenchyme, spores and sclerotia. Fungal remains in Tertiary coals can almost always be recognized by their morphology. “They occur in the form tubular, cellular or non-cellular hyphae which have grown together in various irregular forms (mycelia, plectenchyme),” (Stach, 1982). To protect themselves from moisture and cold, they developed sclerotia (resistant bodies) which formed multicelled rounded to elliptical shapes. These are known as *Sclerotites brandonianus*. Cavities in the *Sclerotites* can be in the shape of irregular rounded contours, which are similar to bubbles found in resinite bodies. It should be noted that sclerotinite found in bituminous coals is not limited to fungal remains. „Sclerotinite” only indicates that the bodies are extremely hard and have high reflectance. Tertiary brown coals are typically poor in inertinite macerals but fungi-sclerotinite is a common characteristic of coals of that particular time period (Stach, 1982).
Figure 7.13  Sclerotinite from Choctaw County.
**Possible *Wetherellia***

One of the samples (Figure 7.14), D from Kemper County, contains what appears to be a pollen or spore that has been torn open or damaged and exposed. This particular specimen looks very similar to one found in Lauderdale County in Meridian, MS.

Victor B. Call (1993) and others studied plant fossils found in the upper Paleocene and lower Eocene sediments of the Tuscahoma, Bashi and Hatchetigbee formations. An extinct genus known as *Wetherellia* (Figure 7.15) was found and is only believed to occur in lower to middle Eocene marginal marine sediments of eastern North America and Western Europe. The samples of *Wetherellia* found in Meridian are the westernmost occurrence of the fossil fruit and was believed to have been scattered by marine currents along the Tethyan seaway.

*Wetherellia* fruits were produced from plants believed to have thrived in mangrove or coastal wetland habitats. These fruits are comparable to the extant genus *Hippomane* which grows in coastal thickets in the Caribbean and off the coasts of Central and South America. The *Hippomane* fruit could maintain buoyancy for up to two years and usually are recovered as drift fruits along beaches. “Biogeographically, it is interesting to note that *Wetherellia* fruits from Virginia, Maryland, Great Britain, and Germany, and *Palaeowetherellia* fruits from Egypt and Virginia occur in nearshore marine environments of the greater Tethyan Ocean,” (Mazer and Tiffney, 1982; Collison and Hooker, 1987).

The specimens of *Wetherellia* fruits were found in the Tuscahoma Formation which is the same formation that extends north where coal samples A-E were taken. It is
not certain that Figure 7.14 in fact is an example of *Wetherellia* mesocarp cells, but it is a possibility that deserves further expert scrutiny.

Figure 7.14 Possible mesocarp cells of *Wetherellia*. 
Figure 7.15  Mesocarp cells of *Wetherellia* with pyrite framboids and octahedral found by Call et al. (1993) in Meridian, MS, 300x.
Depositional Setting

The Gulf Coast during the Paleocene-Eocene Epoch was a warm, humid environment, sustaining a vegetation-rich community, recovering from the K-T extinction. The region experienced mean annual temperatures of around 27°C (Wolfe and Dilcher, 2000). The lignites mined at the Red Hills Mine in Choctaw County are believed to have originated in paratropical forested coastal swamps (Jardine, 2008) extending down through Kemper County. A high amount of Betulaceae (birch family) and Myricaceae (shrubs) pollen were found in lignites samples collected by Jardine and were believed to be wind-deposited but at a proximity to the swamps. Taxodiaceae (bald cypress) were also found and may have been wind-blown as well. Schizaeaceae (ferns), Sparganiaceae (bur reeds), Sphagnaceae (sphagnum moss) all can be found in the lignite (Jardine, 2008). Harrington (2008) suggests the vegetation in these swamps was” heterogeneous and patchy” and also credits animal pollination factors into the diversity of pollen found. Flora found in Late Paleocene deposits of Texas provide evidence that regions of the Gulf Coast are more diverse than originally thought (Jardine, 2008) and could be used to explain the differences and similarities found in fossil spores and pollen from Choctaw and Kemper County. A much more intense study into the palynological assemblages of the continuous lignite seam is encouraged for correlative purposes.

Temporary sea level rises may have occurred and flooded the swamps, which is reflected in the extensive clay layers separating the lignite seams. As sea levels rose, swamp waters became brackish although for relatively short periods. Pyrite is expected throughout the seam and is not believed to occur more often in Choctaw County than Kemper County. Although sulfur content fluctuates throughout the seam, it remains
relatively even with a slight increase from north to south, which would be expected from a continuous seam. Kemper County pyrite seemed to occur as single crystals rather than large framboidal groups found in Choctaw County and are most likely a result of the diversity of the swamp systems. The idea of an increase in sulfur content due to an increase in marine conditions is possible but sulfur content data in this study does not suggest this scenario.

The lignites probably formed as a result of a highstand systems tract after the K-T extinction followed by a series of local regressions associated with delta progradation, forming large, laterally extensive swamps. These communities were mainly angiosperm-dominated forested coastal ecosystems (Jardine, 2008).
The “G” seam was found to be continuous in the Wilcox for at least 50 miles along strike from Choctaw to Kemper County. Sulfur content and BTU fluctuate throughout the seam but remain relatively similar near the Red Hills Mine and near the proposed mine site in Kemper County. SEM photos capture the heterogeneity of the coal and provide an idea of the minerals that can be found in lignite, especially pyrite. Pyrite is found in both locations in the form of frambooidal pyrite and octahedral crystals. Marine influence, vegetation and groundwater all contributed to proper sulfur and iron contents for pyrite. Although sulfur content fluctuates throughout the seam, it remains relatively even with a slight increase from north to south, which would be expected from a continuous seam.

The continuous “G” seam should be used as a stratigraphic marker horizon for correlation along strike. A much more intense study of palynological assemblages throughout the seam is suggested for use as a much more accurate marker horizon, however the “G” seam was verified as continuous and is the only known marker of its length in the Wilcox Group.
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APPENDIX A

GEOPHYSICAL LOG
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APPENDIX B

SCANNING ELECTRON MICROSCOPY