1984

# Investigation of Wilcox (Lower Eocene) Lignites in Choctow and Winston Counties, Mississippi

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## Recommended Citation

Dueitt, Darren and Froelicher, Franz, "Investigation of Wilcox (Lower Eocene) Lignites in Choctow and Winston Counties, Mississippi" (1984). *Open-File Reports*. 69.
https://egrove.olemiss.edu/mmri_ofr/69

Open-File Report 84-2F

# Investigation of Wilcox (Lower Eocene) Lignites in Choctaw and Winston Counties, Mississippi

Darren Simison Dueitt and Franz Froelicher

1984

The Mississippi Mineral Resources Institute
University, Mississippi 38677

University of Southern Mississippi

# INVESTIGATION OF WILCOX (LOWER EOCENE) LIGNITES IN CHOCTAW AND WINSTON COUNTIES, MISSISSIPPI

by

Darren Simison Dueitt

Final Copy

Wilcox Lignites and Analogs

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M.M.R.I. Grant # 84-F2

(Bureau of Mines Grant# G 1134128)

University of Southern Mississippi

# INVESTIGATION OF WILCOX (LOWER EOCENE) LIGNITES IN CHOCTAW AND WINSTON COUNTIES, MISSISSIPPI

by

Darren Simison Dueitt

A Thesis
Submitted to the Graduate School
of the University of Southern Mississippi
in Partial Fulfillment of the Requirements
for the Degree of Master of Science

Approved:

Director

Dean of the Graduate School

May 1985

# ACKNOWLEDGEMENTS

The writer wishes to express his sincere appreciation to the members of his committee, Dr. Franz Froelicher, Dr. Dean A. Dunn, and Dr. Sam W. Rosso, for their assistance and guidance during the preparation of this report.

A special thanks is expressed to the Mississippi Mineral Resources Institute for funding this research report (grant 84-2F). A special thanks is also reserved for Dr. dames Hower and the University of Kentucky Institute for Mining and Minerals Research at the Kentucky Center for Energy Research Laboratory in Lexington, Kentucky for the use of their microscope equipment.

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# PART ONE. INTRODUCTION

# I. INTRODUCTION

Coal has had a long history of being a primary energy source, and world reserves of coal are, and estimated coal resources continue to be, extremely larger than either oil or natural gas (Figure 1). Based on present estimates, the known world reserves of coal could probably meet energy requirements for the next two hundred years (Ross and Ross, 1984).

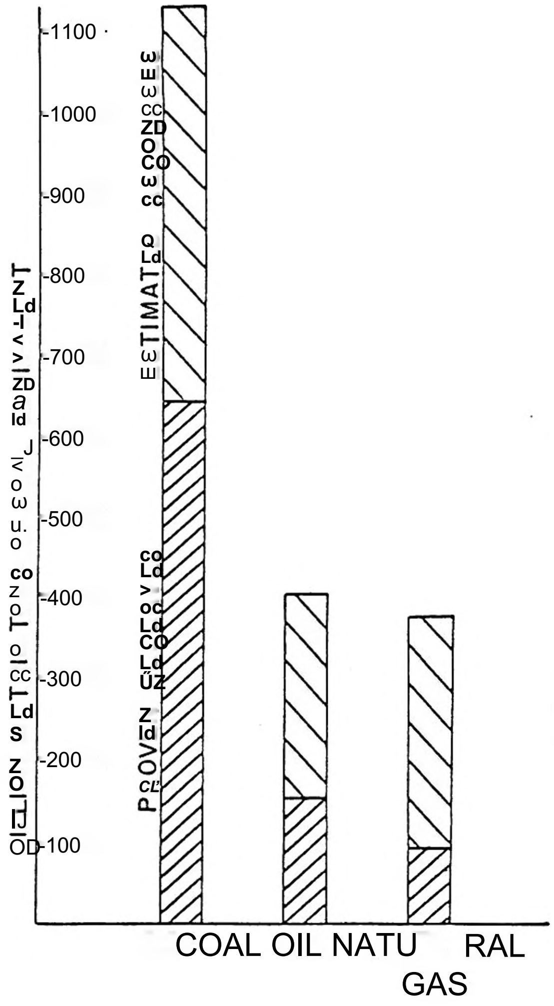


Figure 1. Estimated World Reserves and Resources of Coal, Oil, and Natural Gas (from Ross and Ross, 1984).

Coal, unlike oil or natural gas, occurs in sedimentary layers or seams as a solid material and, once formed (a process involving burial and compaction referred to as coalification), it is not able to "migrate" to become trapped in "pools". Therefore, coal is relatively easier to find because its location is fixed by depositional events and burial history, whereas oil and natural gas generally accumulate by a complicated series of post-depositional steps involving the primary migration from a source rock into a porous and permeable reservoir rock until the petroleum accumulates as a pool in a suitable trap.

Currently, the study of the geology of coals centers around two aspects: First, the depositional setting of the original marsh or swamp environment in which the organic material accumulated, and second, the changes in that organic material as it became buried - i.e., its coalification history. These two geological aspects of coal have many important applications in the mechanics of actually mining the coal and in making the best economical use of the rank, grade, and type of coal in a seam (Ross and Ross, 1984).

The terms "lignite" and "brown coal" have been the most widely used for designating the lowest-rank coals. The name "lignite" is of French origin and first came into use in that country for referring to deposits of dark-brown, firmly consolidated, banded, low rank coals of the type common in early Tertiary sedimentary strata. In the United States, virtually all the early Tertiary low-rank coals are referred to as lignite, and in most occurrences the coal closely resembles French lignite (Parks, 1951).

Lignite is the third largest coal resource of the United States behind bituminous and subbituminous coals. The remaining identifiable lignite resources are estimated to total 478 billion short tons, equivalent on a tonnage basis to nearly 30 percent of the estimated total identifiable coal resources of all ranks. On the basis of equivalent heating values, lignite resources represent approximately 20 percent of the total coal resources of the United States (Scollen and Sheridan, 1978).

In spite of the many economic, environmental, and political uncertainties, the low rank coals are becoming increasingly important as an energy source. The proximity of the Gulf Coast Tertiary lignite deposits to major population centers, and also the increasing costs of transporting massive quantities of higher rank coals into these regions assures the Gulf Coast lignite deposits an important part in meeting the area's future energy demands (Gutzler, 1979).

## A. Objectives

Most of the available information on the depositional environments of the Mississippi lignites is very general in nature. Although there have been some rather detailed studies concerning the lignite deposits of Texas and Alabama, the petrographic and depositional environment studies of the Mississippi lignites are virtually non-existent or are in progress.

This report is an investigation of the Wilcox Group (early Eocene) lignite outcrops in Choctaw and Winston Counties in the state of Mississippi (Figure 2). This report goes beyond the large scale geologic features of the Mississippi lignite deposits toward a more detailed consideration of the petrography, economic value, and the paleoenvironmental details of the origin and development of the lignite coals of Winston and Choctaw Counties in Mississippi.

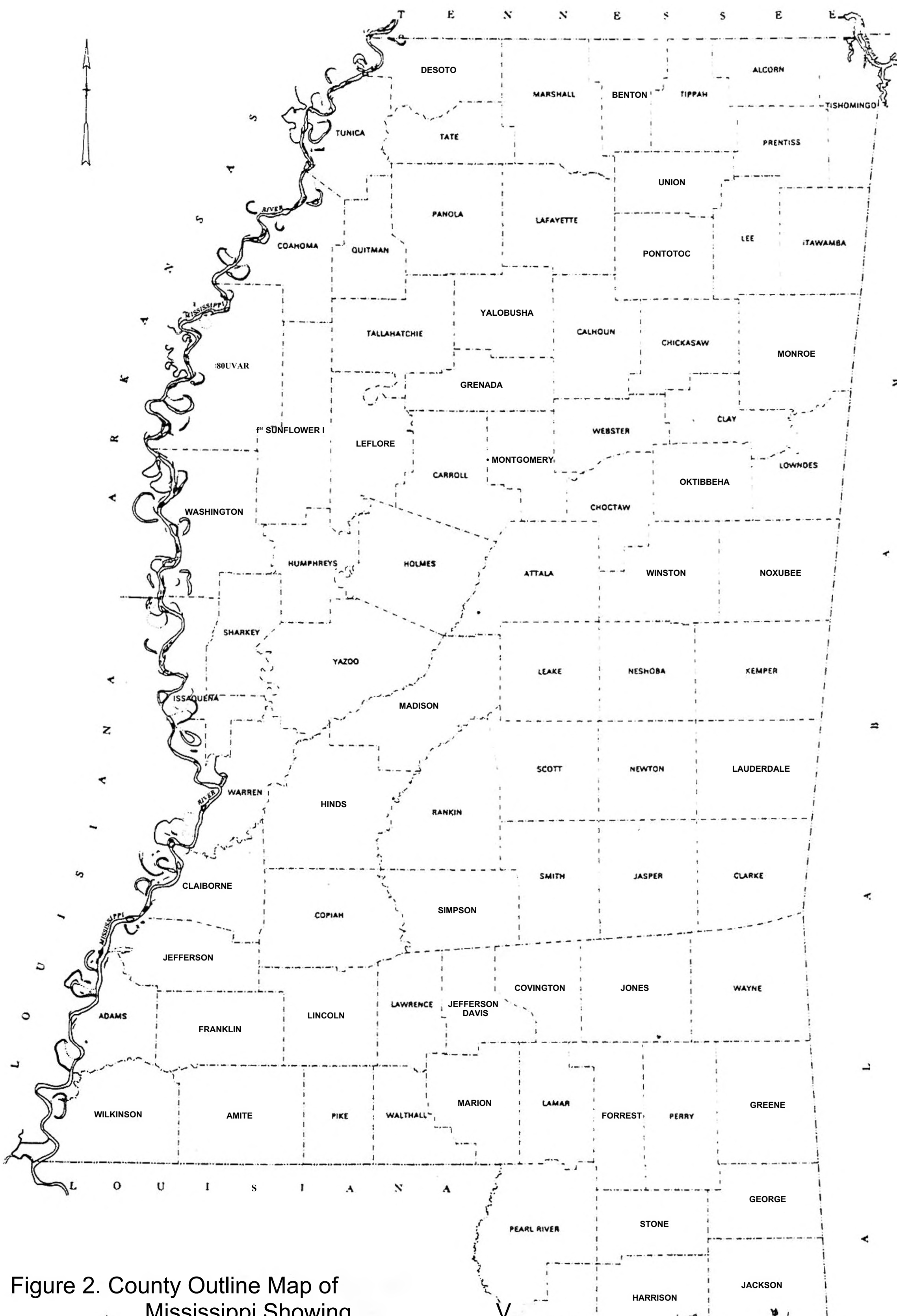


Figure 2. County Outline Map of Mississippi Showing location of Study Area (Choctaw and Winston Counties) in Red (modified from Mississippi Highway Department Transportation and Planning Division

## B. Gulf Coast Lignite

### 1. Coal Rank

The accepted system for classification of United States coal by rank is that defined by the American Society for Testing Materials (ASTM). In accordance with this system, low-rank coals are those having a higher heating value of less than 11,500 Btu/lb on a moist, mineral-matter-free (MMMF) basis, where moist means containing bed moisture (Table 1). This definition separates lower-rank from higher rank coals at a slightly higher level than that which is designated by the International Coal Classification System (ICCS). The ICCS identifies brown coals and lignites as those coals having a gross heating value less than 10,260 Btu/lb on a moist, ash-free basis (Nowacki, 1980).

Table 1. Classification of Coals by Rank
(from ASTM, 1958)

| | | Fixed carbon limits (%) (dry, mineral-matter-free basis) | | Volatile matter limits (%) (dry, mineral-matter-free basis) | | Calorific value limits (Btu/lb) (moist mineral-matter-free basis) | |
|---|---|---|---|---|---|---|---|
| Class | Group | 5s | < | > | 5s | ≥ | < |
| I. | Anthracitic | | | | | | |
| | 1. Meta-anthracite | 98 | — | _ | 2 | _ | _ |
| | 2. Anthracite | 92 | 98 | 2 | 8 | — | — |
| | 3. Semianthracite | 86 | 92 | 8 | 14 | — | — |
| II. | Bituminous | | | | | | |
| | 1. Low volatile bituminous coal | 78 | 86 | 14 | 22 | — | _ |
| | 2. .Medium volatile bituminous coal | 69 | 78 | 22 | 31 | — | — |
| | 3. High volatile A bituminous coal | — | 69 | 31 | — | 14,000 | — |
| | 4. High volatile B bituminous coal | — | — | — | — | 13,000 | 14,000 |
| | 5. High volatile C bituminous coal | — | — | — | — | 11,500 | 13,000 |
| | | | | | | 10,500 | 11,500 |
| in. | Subbituminous | | | | | | |
| | 1. Subbituminous A coal | _ i | — | — | — | 10,500 | 11,500 |
| | 2. Subbituminous B coal | — | — | — | — | 9,500 | 10,500 |
| | 3. Subbituminous C coal | — | — | — | — | 8,300 | 9,500 |
| IV. | Lignitic | | | | | | |
| | 1. Lignite A | — | — | — | _ | 6,300 | 8,300 |
| | 2. Lignite B | — | — | — | — | — | 6,300 |

## 2. Characteristics of Lignite

Lignite is brown to black in color. Its luster is commonly dull, but may be brighter. Its coherence may be strong, causing the material to be hard, compact, and firm, or may be weak, leaving the mass soft and unconsolidated (Vestal, 1943). The texture of lignite is based on the petrographic composition of the lignite. Lignites are usually divided into attrital and xyloid types based on petrographic composition. Attrital lignite is composed predominantly of the residual remains of vegetal matter that was macerated and decomposed by bacterial and chemical processes. Most of the attritus, which consists of fibrous plant tissue, has been reduced by mechanical and biological action to a microscopic state and retains little evidence of original cellular structure. Attrital lignites are non-banded, relatively soft, and possess a uniform fine-grained texture (Williamson, 1976).

Xyloid lignites are characterized by a woody texture and generally are prominently banded. They usually exhibit well preserved relict structures of the original plant material. The term anthraxylon was devised by Reinhardt Thiessen for the transluscent, vitreous, banded components of coal. Anthraxylon is derived from the trunks, barks, stems, roots, leaf tissues, and tissues of certain fruiting organs of herbs, shrubs, and trees. Xyloid lignites tend to be hard,.compact, and firm (Parks and O'Donnei, 1956).

Lignite is lighter than coal but heavier than wood having a specific gravity of 1.2 to 1.5; its hardness is between 1 and 1.5 according to Mohs[1] scale of hardness. The fuel value, expressed in British thermal units (Btu), is greater than that of wood and peat but less than that of bituminous coal.

Commonly, lignite burns with a yellow flame and gives off much smoke and a disagreeable odor. In only few instances does lignite fuse or cake on burning; hence, it usually can not be used for making coke.

In the bed or seam, lignite may be blocked by vertical joints and by planes of cleavage parallel to the stratification planes. Lignite exhibits a conchoidal or irregular fracture, depending on whether the material is harder or softer. The quality of lignite may vary from a pure wood residue to a mixture of plant material with abundant sediment (Vestal, 1943).

### 3. Geologic Distribution of Gulf Coast Lignite

The most extensive Gulf Coast lignite deposits occur in non-marine strata of the Wilcox Group (Upper Paleocene to Lower Eocene) and the Claiborne Group (Middle Eocene). Much smaller deposits are found in the Jackson Group (Upper Eocene) in Texas. The lignite-bearing Paleocene and Eocene strata outcrop in a narrow band extending across the Gulf Coastal Plain from eastern Alabama to northern Mexico. Lignite outcrops have been reported from Paleocene and Eocene rocks in Alabama, Mississippi, Louisiana, Arkansas, and Texas. These Tertiary lignite-bearing rock units extend far gulfward into the subsurface.

Along the eastern edge of the Gulf Coastal Plain, the most important lignite deposits are in the Naheola Formation (Midway Group) of Mississippi, and western Alabama, and the Nanafalia Formation (Wilcox Group) of eastern Alabama. The Claiborne and Jackson groups are predominantly marine in Alabama and contain little or no lignite, but significant coal deposits are found in the Claiborne Group in Mississippi (Williamson, 1976).

important lignite-bearing formations in the Wilcox Group of the central and western Gulf Coast are the Nanafalia, Tuscahoma and Hatchetigbee Formations of Mississippi, the Marthaville and Pendleton Formations of Louisiana, and the Indio (Sabinetown)/Calvert Bluff, and Rockdale Formations in Texas.

Separated from the Wilcox Group by a major marine transgression, the continental rocks of the Claiborne Group contain a few important lignite deposits. Major lignite-bearing formations of the Claiborne Group include the Sparta Formation of Texas and Louisiana, the Cockfield Formation of Louisiana and Mississippi, and the Yegua Formation of Texas. Table 2 shows the Paleocene-Eocene formations and the stratigraphic nomenclature used by the various states of the Gulf Coastal Plain.

Table 2. Paleocene-Eocene formations of the Gulf Coastal Plain. Modified from American Association of Petroleum Geologists (1973, 1975) (from Gutzler, 1979).

| | | TEXAS | LOUISIANA | MISSISSIPPI | ALABAMA | GEORGIA |
|---|---|---|---|---|---|---|
| EOCENE | JACKSON GROUP | WHIISEIT<br>MANNING<br>McELROY<br>WELLBORN<br>CADDEu · MOODYS BRANCH | DANVILLE LANDING<br>YAZOO<br>MOODYS BRANCH | YAZOO<br>MOODYS BRANCH | YAZOO · OCALA<br>MOODYS BRANCH | OCAIA |
| | CLAIBORNE GROUP | YEGUA · COCKFIELD<br>COOK MOUNTAIN<br>STONE CITY<br>SPARTA<br>WECHES<br>QUEEN CITY<br>REXtAW | COCKFIELD<br>COOK MOUNTAIN<br>SPARTA<br>CAHE RIVER | COCKFIELD<br>COOK MOUNTAIN<br>KOSCIUSKO<br>ZILPHA<br>WINONA<br>TALLAHAITA | GOSPORT<br>LISBON<br>TALLAHATTA | LISBON<br>TALLAHATTA |
| PALEOCENE | WILCOX GROUP | CARRIZO<br>CALVERT BLUFF · SABINETOWN<br>SIMSBORO · ROCKDALE · PENDLETON<br>HOOPER · SEGUIN | CARRIZO<br>SABINETOWN<br>PENDLETON<br>MARTHAVILLE<br>HALL SUMMIT<br>LOGANSPORT<br>MABORTON | HATCHETIGBE<br>TUSCAHOMA<br>NANAFALIA | HATCHETIGBEE<br>TUSCAHOMA<br>NANAFALIA | TUSCAHOMA<br>NANAFALIA |
| | MIDWAY GROUP | WILLS POINT<br>KINCAID | PORTERS CREEK<br>KINCAID · CLAYTON | NAHEOIA<br>PORTERS CREEK<br>CLAYTON | NAHEOIA<br>PORTERS CREEK<br>CLAYTON | PORTERS CREEK<br>CLAYTON |

Discovery of additional lignite deposits in unexplored and deep subsurface areas can be expected to add appreciably to the energy reserves of the Gulf Coast States.

Lignite comprises the total coal resources of Louisiana and Mississippi, the major portion of Texas coal, and a relatively small part of Alabama and Arkansas coal. A few very small deposits of lignite are found in Kentucky and Tennessee (Gutzler, 1979).

### 4. Previous Investigations of Gulf Coast Lignites

Several of the early geologists working in the Gulf Coastal Plain noted the presence and general characteristics of the Tertiary lignites (Hilgard, I860; Tuomey, 1858; and Conrad, 1865). Many of the reports of the early geological surveys of the Gulf Coast states provide brief descriptions of lignite, but relatively few of the early investigators have dealt specifically with the coal deposits.

Detailed study of Gulf Coast lignite began with the report by Dumble (1892), in which he described the distribution, formation, properties, and utilization of Texas lignite. Phillips, et al. (1902) and Phillips (1914) described the lignite deposits in reports on the fuel and mineral resources of Texas.

Fisher (1963) and Fisher and McGowen (1967) began a new approach to lignite research in Texas with their work on the relationship of the distribution and properties of the Tertiary coal to its depositional environments. They distinguished between lignites formed in fluvial, deltaic, and lagoonal settings. This information was used as a basis for palynological and petrological study of the Texas Wilcox Group lignites by Nichols and Traverse (1971). The work of Kaiser (1974) has filled in many of the details regarding the occurrence and depositional enviornments of the Texas lignite deposits.

Information on the Arkansas lignite consists mainly of an old report on the Camden Coal Field (Taff, 1900) and brief descriptions of the deposits by Haley (I960) and Selvig, et al. (1950). Lignite interbedded with Arkansas bauxite deposits has been described by Gordon, Tracey, and Ellis (1958).

Louisiana lignite is found in the area surrounding the Sabine uplift in the northwest corner of the state. Gi enk (1921) summarized the available information on Louisiana coal and Meagher and Aycock (1942) made a reconnaissance survey of all known outcrops of Wilcox Group lignite in the state. Galloway (1968) reports on numerous lignite beds encountered in subsurface wells as do Roland, et al. (1976).

The first published information concerning the location and properties of Alabama lignite consisted of a short report by Barksdale (1929). Beginning in the mid 1960's, the Alabama Geological Survey conducted extensive lignite exploration programs in the southern part of the state, culminating in the reports of Daniel (1973) and Self, et al. (1976). Self and Williamson (1977) provided a general description of the geology and characteristics of the Lower Tertiary lignite of Mississippi and Alabama. Gutzler (1979) has done some valuable work on the petrology and depositional environments of some Alabama Tertiary lignites, based on lignite cores from the Midway and Wilcox Groups in southwestern and southeastern Alabama, respectively.

Calvin Smith Brown, Jr., in his 1907 reported entitled “The Lignite of Mississippi", presented the first detailed listing of lignite exposures, analyses, and a discussion of geologic conditions as related to lignite in Mississippi. Various Mississippi Geological Survey bulletins have described lignite occurrences within the state. Several doctoral dissertations have been completed which mention the presence of lignite in Mississippi, such as the work of Roux (1958), Wärter (1966), and Stewart (1971). The most extensive work done to date on Mississippi lignite is that by Williamson (1976), which presented the results of lignite investigations sponsored by the Mississippi Geological, Economic, and Topographic Survey. In his work, Williamson used existing data to map locations of lignite both in outcrop and in the subsurface, but did not perform or include any petrographic analyses of Mississippi lignites. Cleaves (1980) has presented a report on the depositional systems and lignite prospecting models with respect to the Wilcox Group and the Meridian Sandstone of Northern Mississippi. The only detailed petrographic work on Mississippi lignites is that by Froelicher and Pescatore (1981), and Wright (unpublished thesis, 1984).

# II. GEOLOGIC SETTING

## A. Wilcox Outcrop of the Gulf Coastal Province

The Wilcox Group of the Gulf Coastal Province crops out in a narrow belt through the states of the lower Mississippi Valley region. This belt, which extends as far north as the southern tip of Illinois, almost continuously outlines the margin of the Mississippi Embayment (Figure 3). The Tertiary sediments of the Mississippi Embayment were deposited in a structural basin associated with the Mississippi River. Slow subsidence during the Cretaceous and Tertiary Periods has caused the sediments to be downwarped along the southward plunging axis of the basin. The lignite-bearing strata have been exposed on the surface by erosion of the overlying Quaternary sediments and by the structural dip associated with the embayed area (Williamson, 1976).

## B. Tertiary Climate

Inspection of the fossil floras of the Gulf Coast Tertiary coal swamps indicates ample or moderate rainfall and relative mildness of climate (White, 1925).

Most palynologists working with the Tertiary rocks of the Gulf Coastal Plain have noted a mixture of palynomorphs from tropical, subtropical, and temperate plants. This pattern appears to be characteristic of the floras of the Midway, Wilcox, and Caliborne Groups (Potter, 1976). Englehardt (1964) discovered similar features in his study of the Middle Eocene palynoflora of the Cockfield Formation of Mississippi. He identified palynomorphs from a "tropical" flora of ferns, taxodiaceous trees, palms, and tropical angiosperms mixed with those of a "temperate" flora consisting of oaks, pines, chestnut, birch, elm and alder.

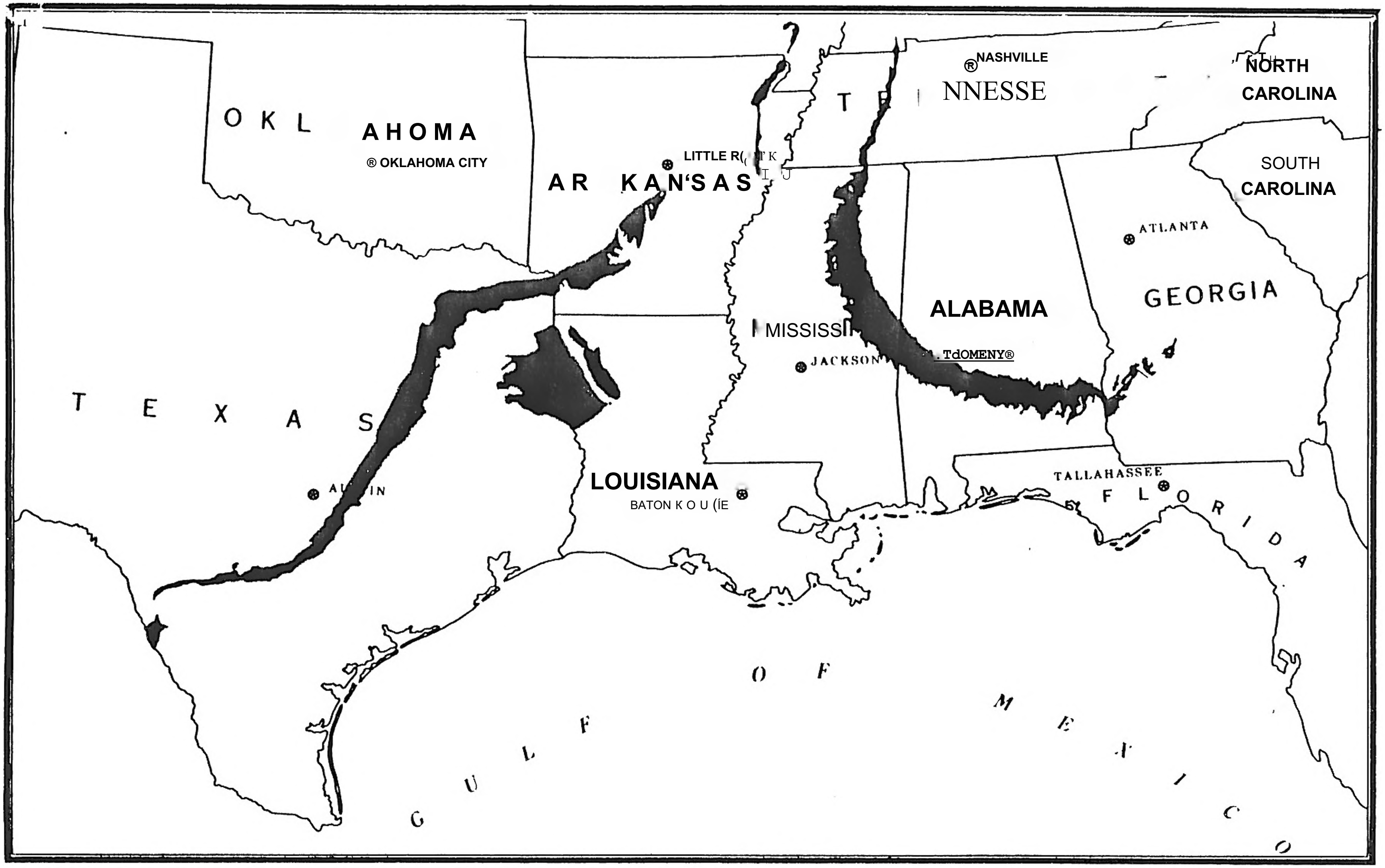


Figure 3. The Wilcox Sediments of the Mississippi Embayment (Williamson, 1976).

The temperate palynomorphs are scarce in the flora and, according to Engelhardt, were apparently transported long distances before their deposition in the Coastal Plain sediments of the Cockfield Formation.

Convincing evidence of long distance transport of palynomorphs in the Coastal Plain of the Early Tertiary was provided by McClean (1968). He found that the Oak Hill member of the Naheola Formation (Midway Group) in Alabama contained abundant reworked palynomorphs ranging in age from Devonian to Lower Cretaceous.

Other evidence of a warm and humid climate in the Gulf Coast region during the Tertiary is provided by the extensive bauxite deposits in Alabama, Mississippi, and Arkansas associated with the lower part of the Wilcox Group (Gordon, Tracey, and Ellis, 1958). Figure 4 shows the global climate over the last 65 million years, with the earth being much cooler now than during the Eocene.

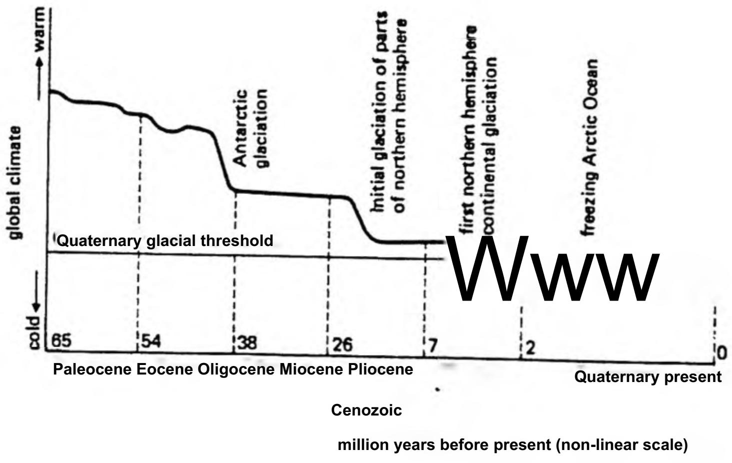


Figure 4. The Global Climate Over the Last 65 Million Years. The Earth Has Cooled Gradually. (After J. Andrews in B. S. John (ed. ), Winters of the World, David and Charles, 1979.)

## C. Wilcox Group Stratigraphy

More than 100 stratigraphic terms have been applied to the Lower Tertiary rocks of the Gulf Coastal Plain and their inadvertent misuse has caused much confusion in the literature. The stratigraphy of the Gulf Coast Tertiary is inherently difficult because of the highly variable lithology and the close lithologic similarity of rock of different ages (Fisher, 1961).

' In Mississippi, the Wilcox Group crops out in an arcuate belt which extends from the north-central to the east-central parts of the state (Figure 5).

The Wilcox Group in Mississippi is composed almost entirely of non-marine beds devoid of stratigraphically valuable fossils. Traditionally, relationships are present in Kemper and Lauderdale Counties, Mississippi, where non-marine strata of the Wilcox Group interfinger and interbed with the marine facies of the Wilcox formations of Alabama.

The outcropping Wilcox Group in Mississippi is composed predominantly of non-marine sediments deposited on a broad flat coastal plain. These sediments are about 700 feet thick in Lauderdale County but thin in north-central and northern Mississippi to less than 100 feet at the Tennessee line (Williamson, 1976).

According to Rainwater (1964) "The Wilcox can be subdivided as follows in Lauderdale and Kemper Counties where the marine Nanafalia (lower Wilcox) and the Bashi beds (upper Wilcox) crop out:

Hatchetigbee Formation - about 200 feet thick, non-marine.
Bashi 'marl' - about 20 feet thick, shallow marine.
Tuscahoma Formation - about 400 feet thick, non-marine.
Nonafalia Formation - about 100 feet thick, shallow marine.

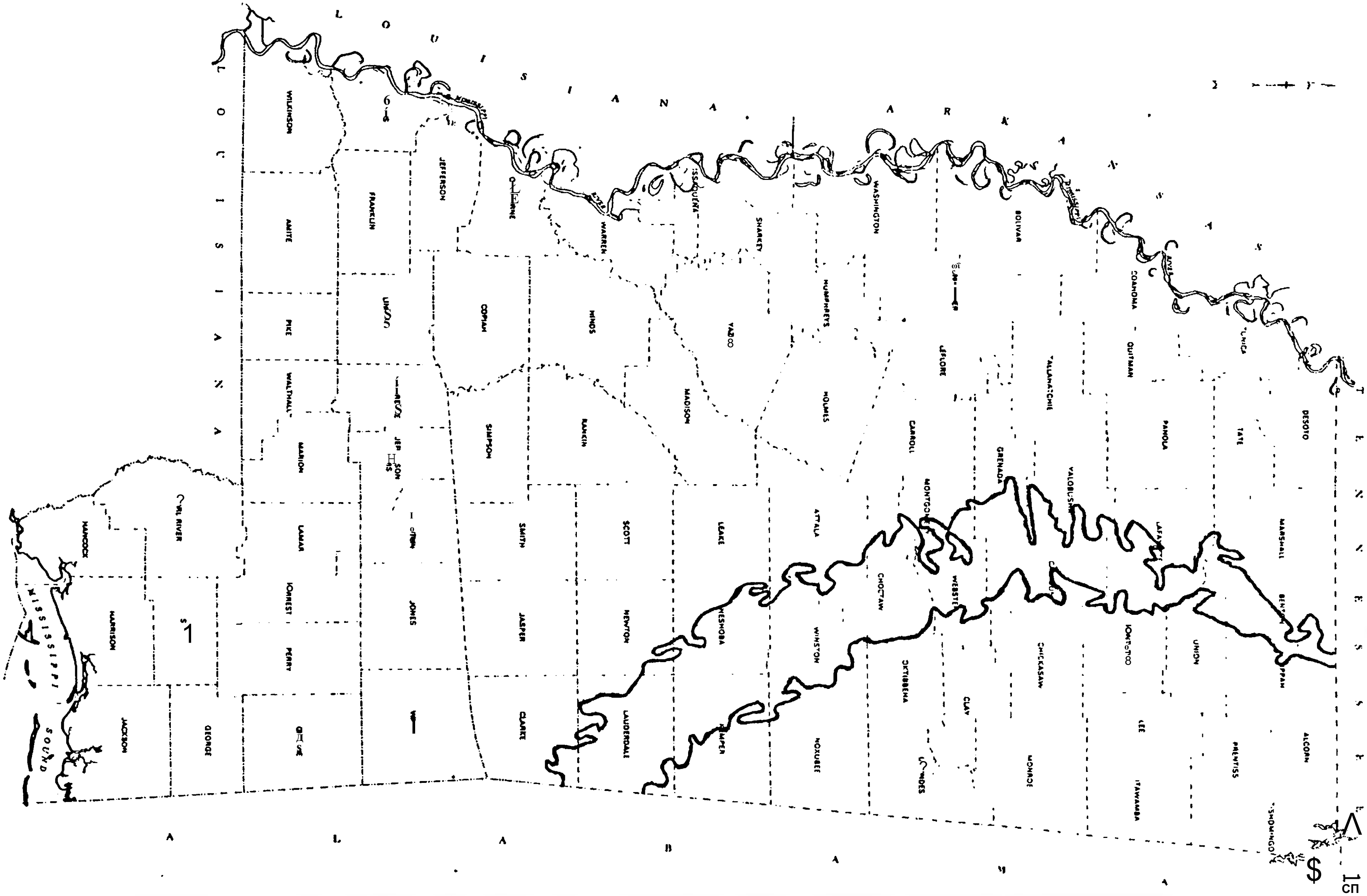


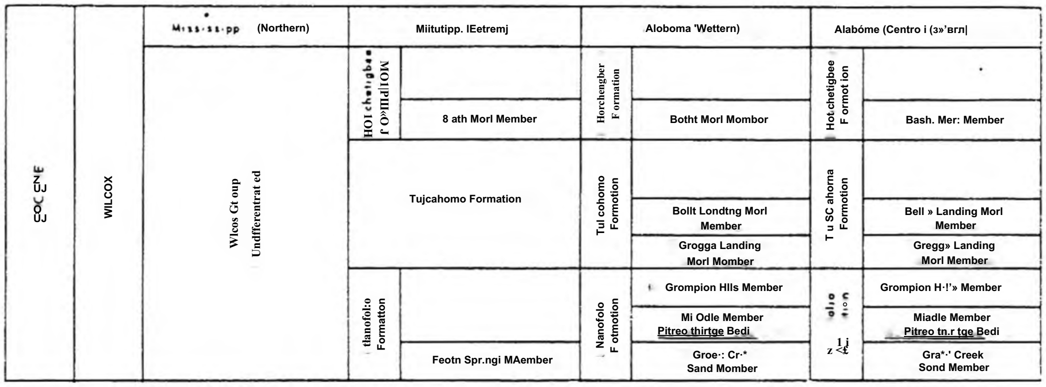
Figure 5. County Outline Map Showing Outcrop Location of Wilcox Group in Mississippi.

In this report, all the lignite outcrops investigated in both Winston and Choctaw Counties were found to be in the Wilcox Group Undifferentiated or Eastern Mississippi equivalent Nanfalia Formation.

In north-central (Winston and Choctaw Counties, inclusive) and northern Mississippi, the Wilcox Group consists primarily of continental sediments. No reliable correlation markers have been found in the Wilcox Group of central and northern Mississippi. Rapid changes in the lithology, thickness, and lateral continuity of individual beds due to the complexity of the fluvial and transitional sedimentary sequences makes it impractical to attempt to divide the Wilcox of central and northern Mississippi into formational units. These strata, therefore, are termed "Wilcox Group Undifferentiated". These strata, which overlie the Naheola Formation (Midway) and underlie the Claiborne Group, consist of complex deltaic, fluvial, and paludal sedimentary sequences (Self and Williamson, 1977). Figure 6 shows a general correlation chart of the Wilcox Group in Mississippi and Alabama and Figure 7 shows the lower Wilcox sediment dispersal system.

### D. Coal-Forming Sedimentary Environments

Modern coastal plain and deltaic environments are condusive to the accumulation of organic material, such as peat, in a wide variety of climatic settings. Upon burial, diagenesis, and passage of time, these peat deposits are converted to various coals, including lignite (Wielchowsky, et al., 1977). Kaiser (1974) has applied modern depositional analogues of peat accumulation to the ancient records, and has divided lignite occurences in Texas into component facies of Tertiary fluvial, deltaic, and lagoonal depositional environments.



| | | M·ss·ss·pp (Northern) | Miitutipp. lEetremj | | Aloboma 'Wettern) | | Alabóme (Centro i (з»'вгл\| | |
|---|---|---|---|---|---|---|---|---|
| EOC ENE | WILCOX | Wlcos Gt oup Undfferentrat ed | HOI chetigbee F O»IIdIOW | | Horchengber F ormation | | Hot chetigbee F ormot ion | |
| | | | | 8 ath Morl Member | | Botht Morl Mombor | | Bash. Mer: Member |
| | | | Tujcahomo Formation | | Tul cohomo Formotion | | T u SC ahorna Formotion | |
| | | | | | | Bollt Londtng Morl Member | | Bell » Landing Morl Member |
| | | | | | | Grogga Landing Morl Momber | | Gregg» Landing Morl Member |
| | | | tlanofol:o Formatton | | Nanofolo F otmotion | Grompion Hlls Member | olıo ‡ıon | Grompion H·!'» Member |
| | | | | | | Mi Odle Member<br>Pitreo thirtge Bedi | | Miadle Member<br>Pitreo tn.r tge Bedi |
| | | | | Feotn Spr.ngi MAember | | Groe·: Cr·* Sand Momber | z <£ 1 j | Gra*·' Creek Sond Member |

Figure 6. A General Correlation of the Wilcox Group in Mississippi and Alabama (Self and Williamson, 1977).

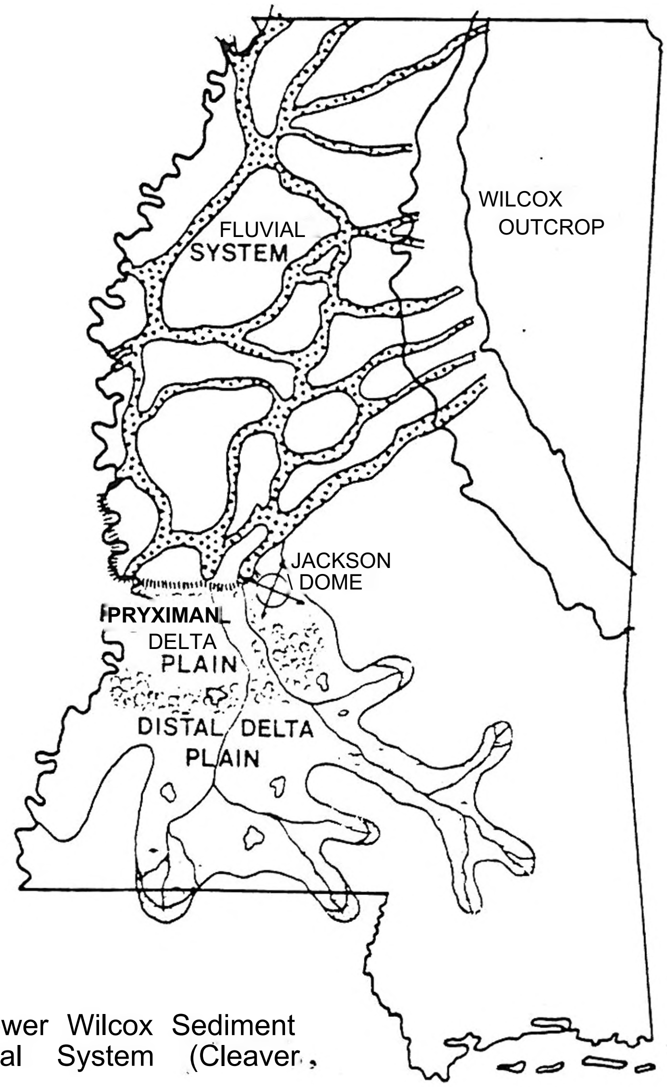


Figure 7. The Lower Wilcox Sediment Dispersal System (Cleaver, 1980).

### 1. Fluvial Environments

According to Kaiser (1974), lignites that accumulated in fluvial environments should have a high percentage of woody material, low to moderate Btu values, a high volatile-matter and moderate fixed-carbon content, a low specific gravity, a low sulfur content, a moderately low ash content, a palynoflora that is consistent with fresh water swamps, and should be associated with a fining upward, cyclic sedimentary sequence typical of fluvial cycles. These backswamps persist because peat accumulation can keep pace with subsidence and are far enough from active channels so that sediment influx does not inhibit growth of vegetation (Figure 8).

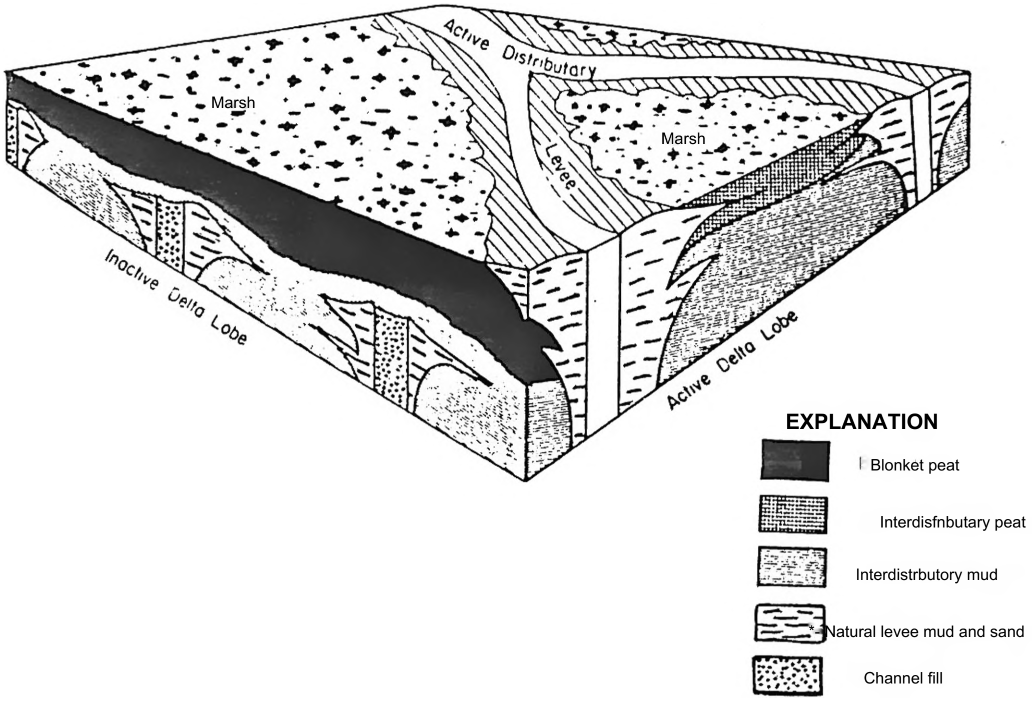


Figure 8. Schematic Drawing of Blanket and Interdistributory Peat Development in a Modern Fluvial Environment (from Wielchowsky and others, 1977).

### 2. Deltaic Environment

The accumulation of organic debris in a deltaic system is dependent on the variety and fluctuation of many factors such as sediment input, stream discharge, basin structure and size, size of drainage area, rate of subsidence, etc., and on the cyclic phase of the delta. For example, in a constructive, progradational , fluvially dominated delta system (Figure 9), plant debris has time to accumulate in topographic lows and backswamp areas. The initial geometry of the peat deposit will depend on the rate of basin subsidence and the general dynamics of the delta system. In a rapidly subsiding basin, the peat deposits are characteristically thicker with a different floral pattern and a limited areal extent, as opposed to a slowly subsiding basin where the peat is thinner with a larger areal extent. According to Kaiser (1974), lignites that accumulated in deltaic environments are characterized by low ash content, moderate sulfur content, high Btu values, moderate volatile-matter content, high fixed-carbon content, high specific gravity, a tabular shape and wide extent, and a non-woody composition.

### 3. Lagoonal Environment

The organic deposits associated with lagoonal sedimentation are generally thin and occupy a small area. They are high in sulfur and ash content; low to moderate in heating value, volatile-matter content, and specific gravity; low in fixed-carbon content, and poorest in quality (Kaiser, 1974)

Table 3 allows comparison of the characteri sties of lignites formed in the different coal-forming sedimentary environments identified by Kaiser (1974).

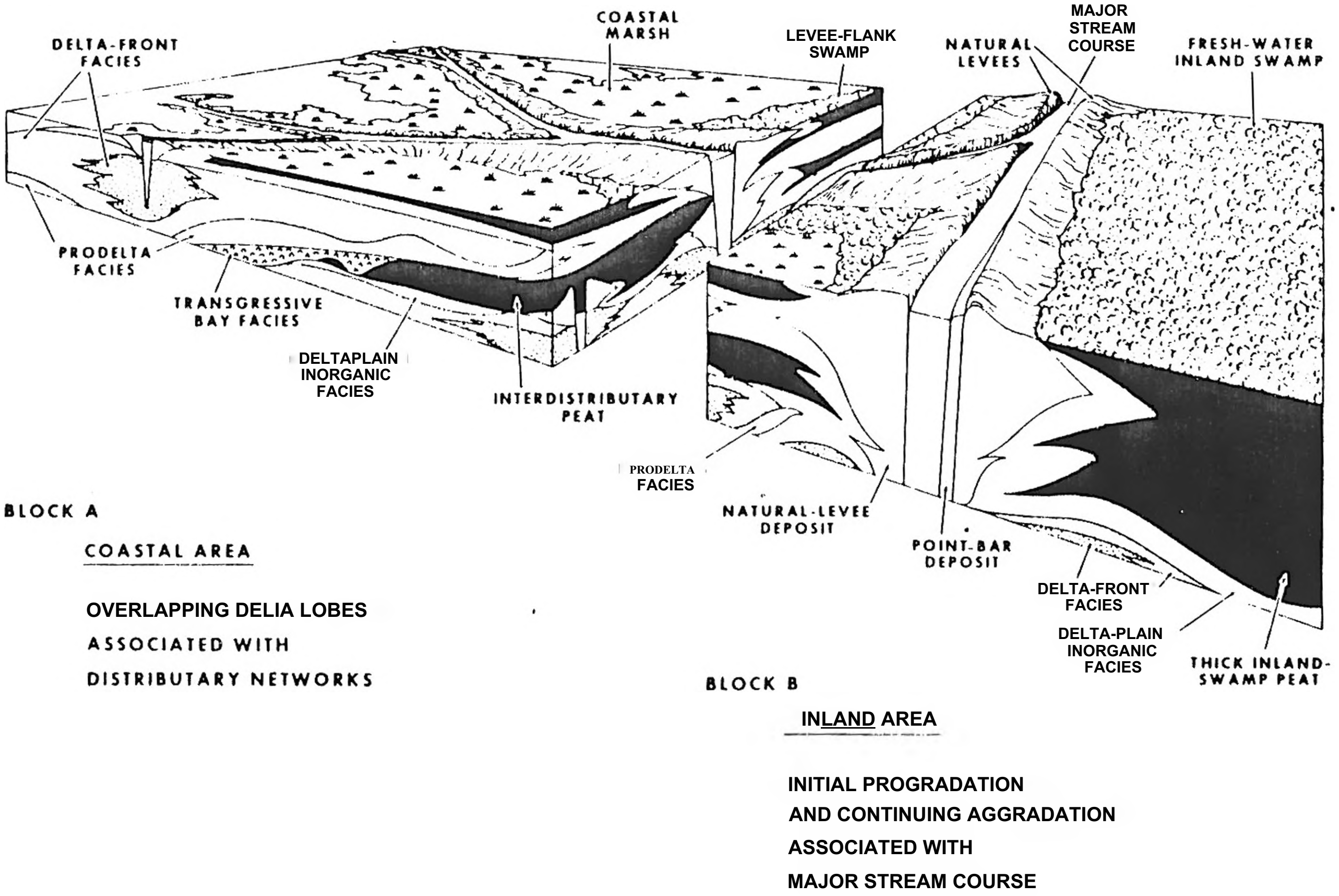


Figure 9. A Constructive, Progradational , Fluvially Dominated Delta System (from Kaiser, 1974).

## TABLE 3

## CHARACTERISTICS OF LIGNITE DEPOSITS

| | DELTAIC | FLUVIAL | LAGOONAL |
|---|---|---|---|
| Sulfur | M | L | H |
| Ash | L | M | H |
| Btu | H | L-M | L-M |
| Volatile Matter | M | H | L-M |
| Fixed Carbon | H | M | L |
| Specific Gravity | H | L | L-M |

L- Low; M- Medium; H- High
(After: Kaiser, 1974, pp. 5-12)

# III. LIGNITE UTILIZATION

## A. Lignite Mining

The primary and currently the most promising use of lignite is as a boiler fuel for steam electric plants (Haynes and Cornell, 1981).

In 1954, the first large lignite surface mine was opened in Texas to supply energy for an aluminum plant. The lignite is crushed, sized, then pulverized to less than 0.074 mm and air-fired as dust. At the present, lignite mining on a large scale has been limited to Texas.

Surface mining for lignite can be expected to increase in number of mines and production throughout the Gulf Coast region. In the near future, economics of mining low Btu coal (lignite) favors large surface mines that attain a maximum depth of about 200 feet and a stripping ratio of no more than 11:1. The maximum depth of surface mining may be limited locally by ground water, but maximum depth is more likely to be limited by a maximum allowable stripping ratio, which is determined by economics and marketability of the lignite (Hirsch, 1977).

## B. Lignite Gasification

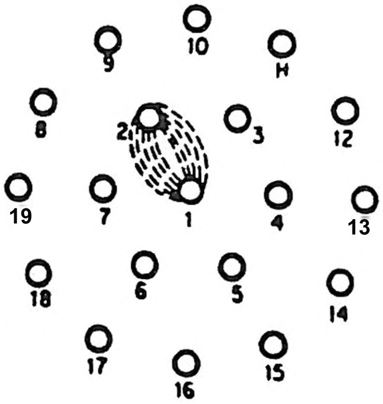
The second most promising use of lignite is power generation using underground coal gasification in a combined cycle of gas turbines and boilers (Haynes and Cornell, 1981).

Underground coal gasification (UCG) has as its objective the recovery of the energetic and chemical content of coal without mining. A gaseous mixture composed of nitrogen, oxygen, steam, and carbon dioxide in variable proportions is introduced into a coal seam prepared for gasification; combustion and gasification reactions occur in-si tu. The products, carbon monoxide, carbon dioxide, hydrogen, water vapor, methane, nitrogen, and other hydrocarbons are obtained in a readily usable form for the production of electric power or the manufacture of chemicals. The successful application of lignite gasification would provide a low Btu gas (100 - 300 Btu/SCF) which is relatively clean (for sulfur compounds) and at the same time eliminate many of the health, safety, and environmental problems associated with conventional shaft mining of coal. The in-situ method also has the potential to recover the energy from deep coal deposits which are not economically feasible to mine by conventional schemes (Edgar and Kaiser, 1977).

The in-situ gasification method currently being tested on Texas lignites is the so-called percolation or filtration method (Figure 10), in which numerous variations involve different borehole sizes, number of boreholes, locational patterns, methods of linking, and gasification procedures. The coal seam is penetrated by vertical boreholes spaced 50 to 100 feet apart and located in various geometric patterns or by long horizontal boreholes. Gasification takes place between different pairs of linked boreholes, with off-take and in-take holes depending on the locational pattern and gasification procedure (Edgar and Kaiser, 1977).

## C. Other Uses

Lignites have also been used in making barbeque briquettes, montan wax, and activated char. Although not economically feasible at this time, processes have been developed in which lignite can also be used for the production of chemicals, high Btu gases, liquid fuels, fertilizers, specialty carbons, and as a reductant for preparation of taconite pellets (Scoi len and Sheridan, 1978).



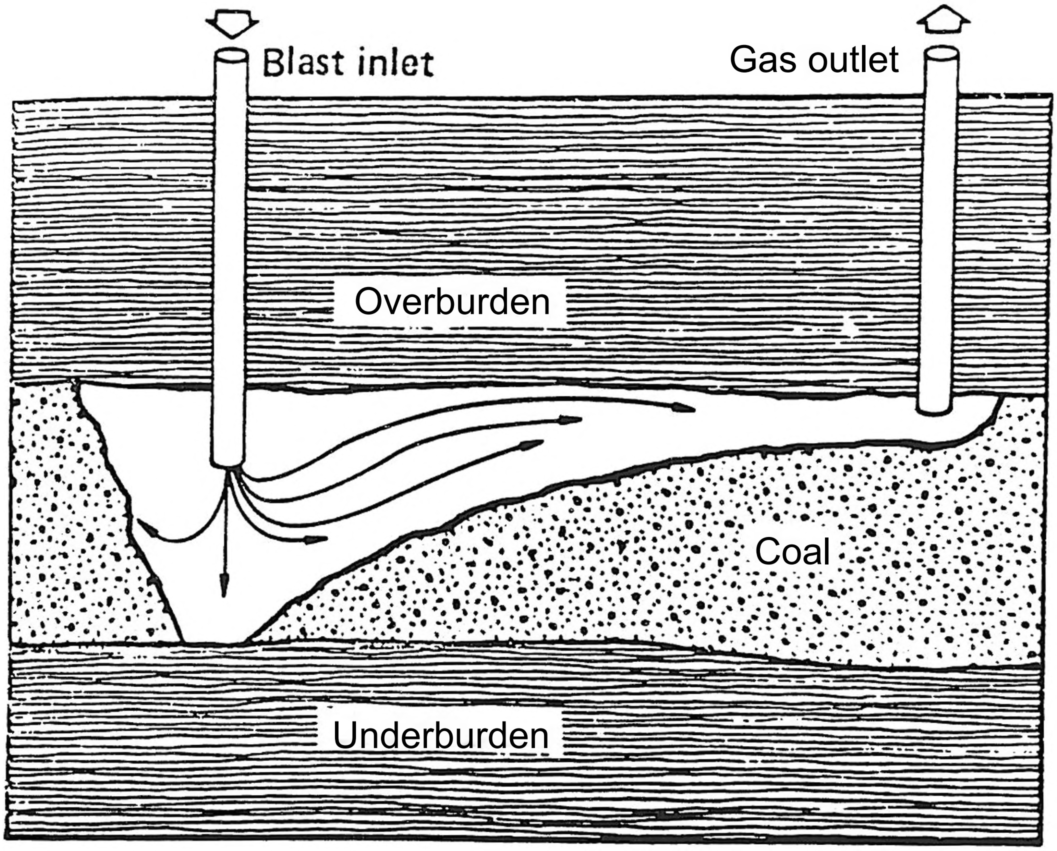


Figure 10. The In-situ Gasification Method
(Edgar and Kaiser, 1977).

# PART TWO. LIGNITE PETROLOGY

## A. Proximate Analysis

### 1. Sample Collection

Upon locating the lignite outcrop, a channel was cut a minimum of 45 cm into the seam in order to obtain fresh lignite samples that have been exposed to a minimum amount of oxidation and weathering (Figures 11 and 12).

The channel cut was made as near as vertical as possible to the dip of the seam in order to aid in the sampling process and to insure correct measurements of the seam thickness and sample intervals. Each sample interval represented approximately 15 cm of the lignite seam. For example, if a lignite seam was 45 cm thick, 3 samples would be taken with each sample interval representing 15 cm (Figure 13). The lignite samples were immediately placed into Ziploc freezer bags labelled with the appropriate sample letter, number, and interval. The sample letter represented the county from which the sample came, the number represented the seam from which the sample came, and the interval represented the thickness interval sampled in the seam. The Ziploc (air tight) bag was then stored in an ice chest in order to keep the sample out of direct sunlight until it was taken to the laboratory for analyses. This procedure helped to minimize moisture loss from the samples.

### 2. Sample Preparation

To insure accuracy, three proximate analyses were conducted for each sample interval. These three proximate analyses were then averaged so that each sample interval had an averaged proximate analysis value. Then, the sample intervals were averaged so that each seam had an averaged proximate analysis value. Figure 14 summarizes how the average proximate analysis was obtained for each lignite seam.

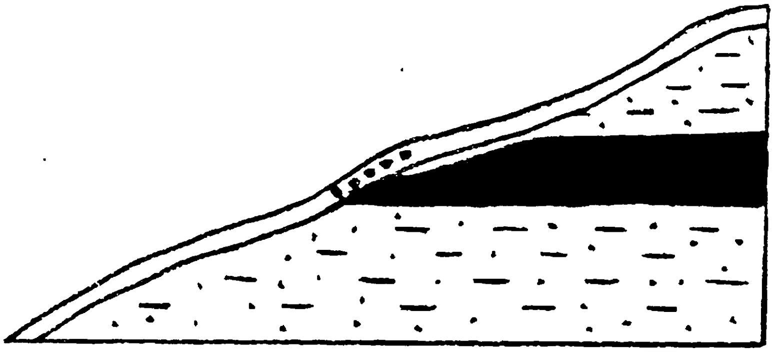


Figure 11. Generalized Cross-section Showing the Weathering of a Lignite Outcrop.

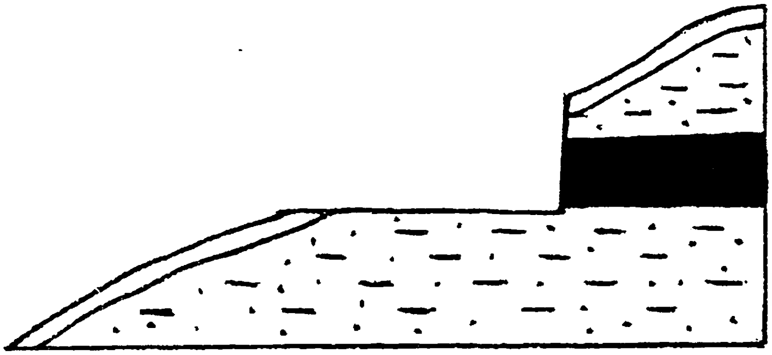


Figure 12. Generalized Cross-section showing the Technique of Digging Back Into the Lignite Seam in Order to Obtain a Fresh Sample.

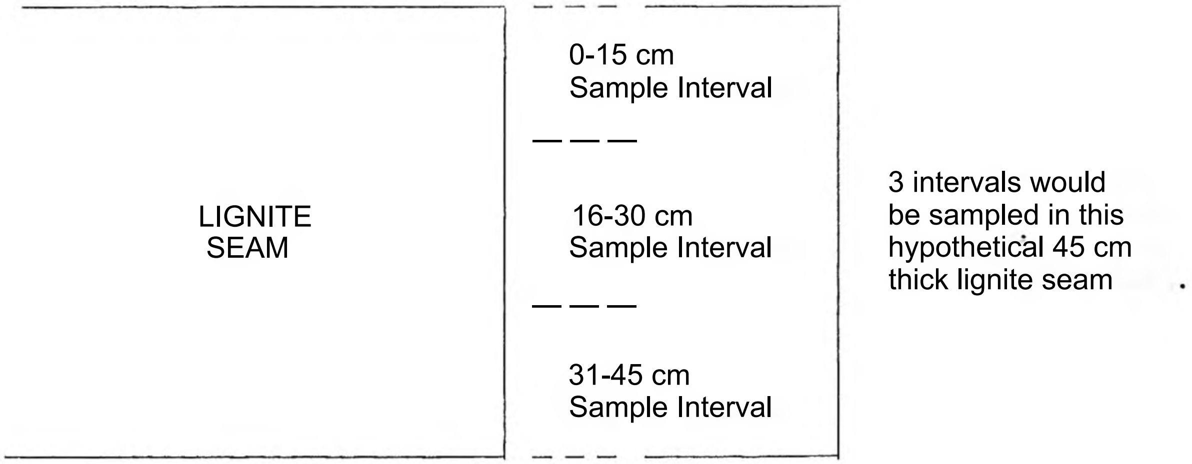


Figure 13. Diagram Showing How Lignite Seam is Broken Up Into Sample Intervals.

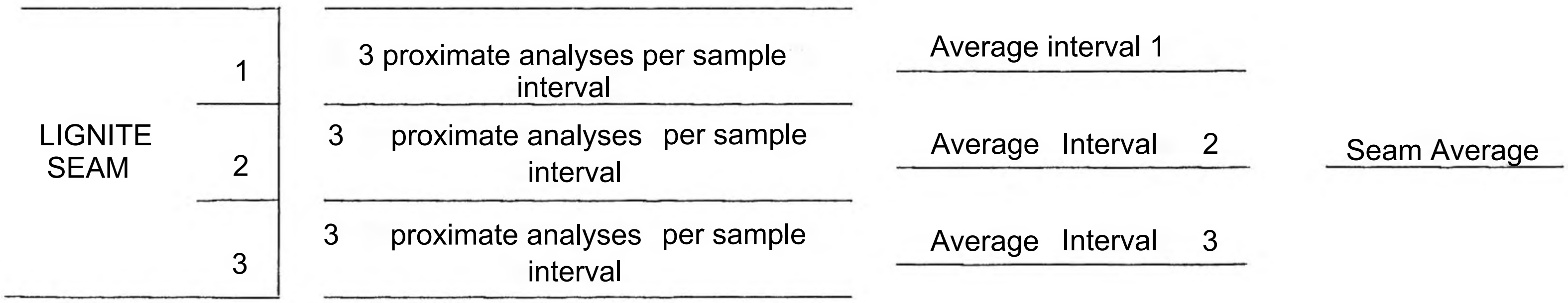


Figure 14. Diagram Showing How Seam Average of Proximate Analysis was Derived,

### 3. Method of Analysis

Proximate analyses involves the determination of the three constituents which make up coal and the moisture content. Those three constituents (volatile matter, ash, and fixed carbon) are calculated on a percentage basis with all three adding up to 100 percent.

Two sets of proximate analyses were run on each sample interval. Proximate analysis was performed on each lignite sample "as is" (AI), meaning with the moisture content as near as possible to the moisture content when the sample was removed from the seam. Proximate analysis was also performed on the sample after the sample had been crushed and allowed to air dry (AD) at room temperature for 24 hours. This gives some idea as to how much of the original moisture is lost by evaporation. A high seam moisture content has a negative effect on the Btu value of the coal. The comparison of the moisture content of the two proximate anlayses (i.e., (1) with original seam moisture content and (2) the moisture content after crushing and 24 hours of air drying at room temperature) shows how much seam moisture can be lost by simple evaporation in only 24 hours. This may be important to industry because a lower moisture content increases the Btu value, and thus the amount of taxes and fees paid would tend to increase because the "worth" of the coal has increased. If the Btu value is determined on an "as is" lignite sample, the company should have to pay less taxes and may even receive a tax credit because the added moisture content decreases the Btu value*

The proximate analysis was conducted using a Fisher Coal Analyzer 490. The Fisher Coal Analyzer 490 uses a combination of time and temperature to drive off the particular constituents of coal and the moisture content. The steps employed by the proximate analysis procedure allow for the individual determination of the percentages of the three constituents (i.e., volatile matter, ash, and fixed carbon) which make up coal as well as the moisture content. Figure 15 summarizes, in general, the procedure employed by the analyzer.

The procedure used in performing the proximate analyses of the lignites in this report meets with those standards set up by the American Society for Testing and Measurements (ASTM). It should be noted that Figure 15 is only a general guideline on the procedure of conducting proximate analyses. A more detailed study of the use of the Fisher Coal Analyzer 490 would be required before proximate analyses could actually be conducted.

## B. Petrographic Analysis

### 1. Particulate Pellet Preparation

For the particulate pellets, a representative sample of each sample interval was crushed with a mortar and pestle until all of the sample passed through a series of sieves (4, 8, 16, and 20 mesh). After each lignite sample interval of each lignite seam was crushed, approximately 40 grams from each lignite interval was mixed thoroughly to create a mixture which would be representative of the lignite seam as a whole. Once a representative sample of the seam was acquired, the crushed sample was placed in an oven for 24 hours at $34^0$C. This process removed the seam moisture which is necessary to make the particulate pellets. (It was found that not removing the moisture from the crushed lignite sample or trying to make particulate pellets on rainy days produced a situation in which the catalyst and resin would not react properly with each other in order to obtain a hard pellet).

Once the crushed lignite sample has been dried, approximately 50% crushed lignite and 50% resin with catalyst is combined and mixed thoroughly. A soupy mixture of appxoimately 120 milliliters is required to make 3 pellets of each seam 3-4 cm in diameter and 2 cm thick. The pellets are allowed to harden for 48 to 72 hours before they are expelled from their molds. When the pellets become hard, polishing may commence. Figure 16 summarizes the procedure for pellet preparation and pellet polishing. It should be noted that pellet polishing and storage of the polished pellet for a long period of time, (i.e., one month or longer) before petrographic analysis is performed is not recommended because desiccation cracks may result which can ruin the polished surface.

### 2. The Coal Petrography Microscope

The petrographic analyses were performed on polished particulate pellets with the use of a Leitz MPV 77 reflectance and fluorescence microscope. The analyses were conducted in oil immersion with a 50X oil immersion objective in combination with a 1.25X 'spacer' and a 10X ocular, for a total magnification of 625X. The microscope was equipped with a prism polarizer set at the 45° position. The polarizer was removed when the fluorescence unit was engaged. This allowed more light to reach the objective and prevented damage to the prism.

The fluorescence unit employed a 100 watt mercury arc lamp. It was used in combination with a BG 12 excitation filter, a BG 23 heat absorbing filter, a dicromatic beam-splitting mirror, and a 510 mm barrier filter.

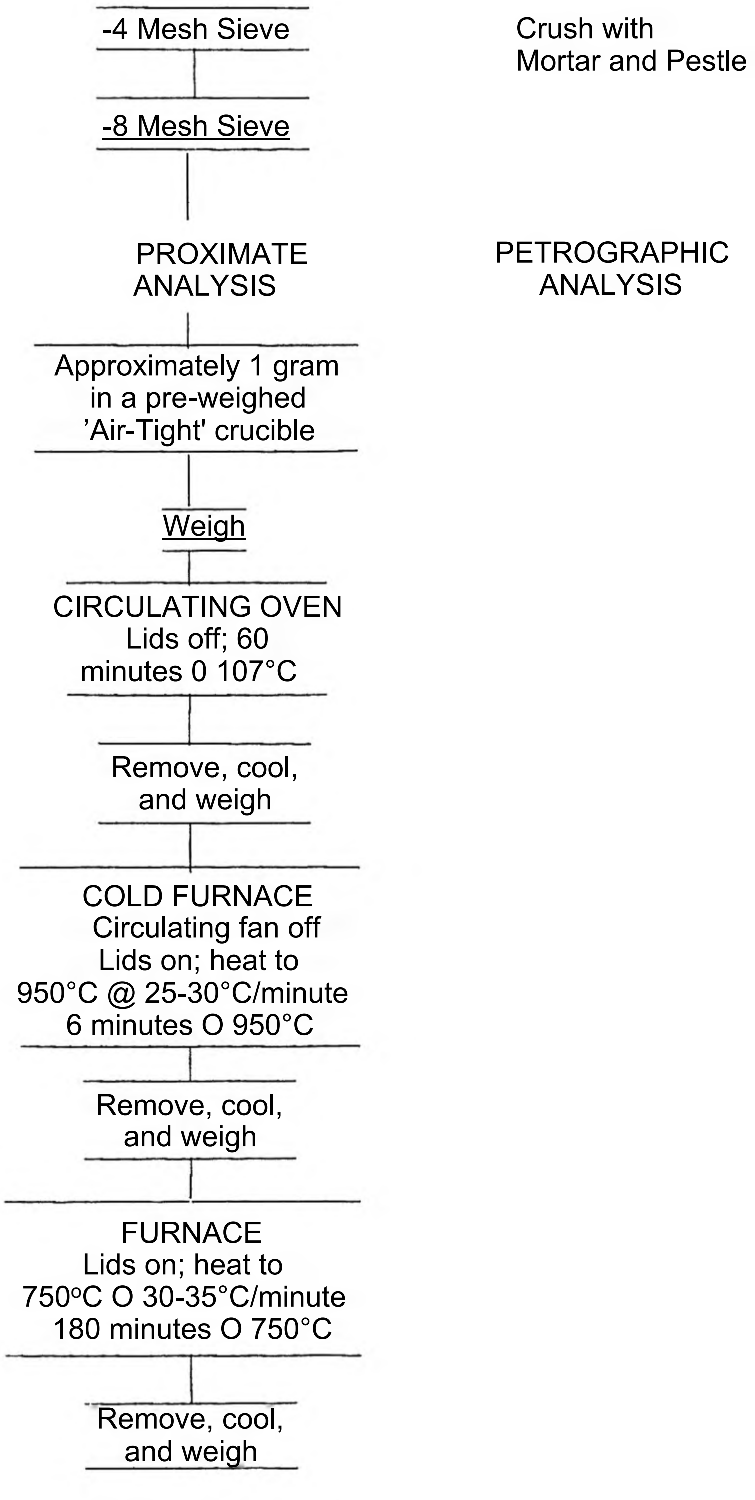
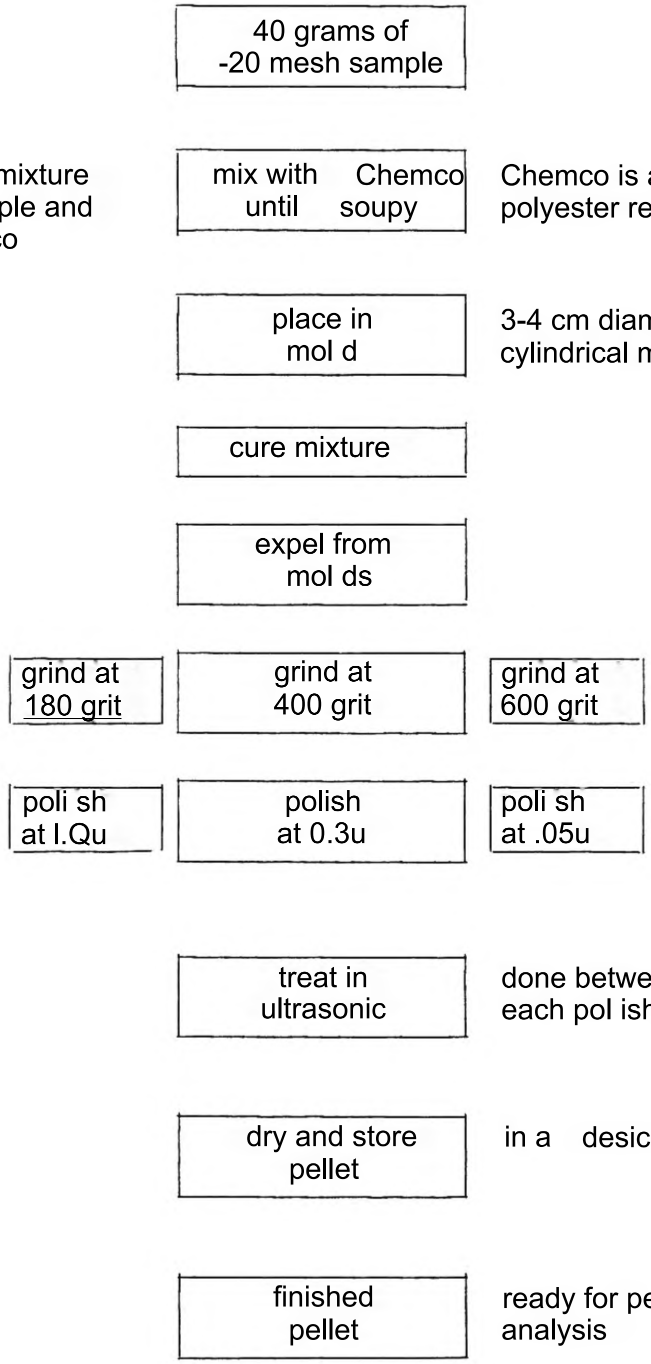


Figure 15. Sample Preparation and Proximate Analysis Method.



50-50 mixture of sample and Chemco

Chemco is a clear, cold setting polyester resin

3-4 cm diameter, 2 cm thick cylindrical molds

Hand grind on sandpaper

Hand polish on aluminum blocks using alumina Silica polish

done between each polishing step

in a desiccation cabinet

ready for petrographic analysis

Figure 16. Pellet Preparation for Petrographic Analysis.

### 3. Method of Analyses

Three representative particulate pellets were made for each lignite seam. A 500 point maceral count was performed on two of the three pellets of each seam. If the maceral point count of the two pellets agreed within a 5% mean variation, then the two 500 maceral point counts were added together and calculated as a percent of the total from 1,000 points. If the maceral point counts on the two pellets did not agree within the 5% mean variation, then the third pellet was counted and the three counts were averaged. The point counts represent the volumetric percentages of each maceral per lignite seam. The accuracy of analysis for 1,000 measuring points is approximately ±2 percent, irrespective of whether macerals, maceral groups, microlithotypes or the composition of the microlithotypes are determined (ICCP, 1971).

The pellets were transversed using a mechanical stage with 0.4 mm advancements. Points were counted on a 0.4 by 0.4 mm grid system when possible. However, since the counts were done on a mineral matter free basis and most lignites contain a fair amount of mineral matter, the grid was often altered slightly so that a humic maceral could be counted.

### 4. Reflectance

Reflectance measurements were taken on polished particulate pellets. Reflectance was measured on unscratched sections of the maceral gel inite (brown coal equivalent of the hard coal maceral vitrinite) using a photomultiplier with a circular aperture (set at a minimum opening) and a 50X objective with oil immersion. With the photomultiplier on, the stage was rotated 360° and the maximum reflectance reading was recorded. A minimum of 30 measurements were taken per pellet for a minimum of 60 per seam. Several of the pellets contained very small amounts of gel inite, therefore, making it impossible to take 60 measurements.

According to Stach, et al. (1975), reflectance measurements done on brown coals for the purpose of determining coal rank are unreliable. With that in mind, no attempt was made to determine the exact rank of the individual coal seams investigated in this report. Seam average reflectance values have been included in this report for the purpose of giving at least an approximate figure for the coal rank and/or for the purpose of having the data available in case a system is adopted for brown coals which will make these reflectance measurements reliable for determining the rank of the coal in the future.

### C. Fossil Wood Identification

The on-site field studies of the Wilcox lignite outcrops in Winston and Choctaw counties revealed several horizontally-positioned, intact tree trunks. The trunk specimens collected from the Choctaw site exhibited both bark and wood tissues whereas the specimen,from the Winston site consisted solely of wood tissues. The presence of intact bark and wood in the Choctaw specimen and the general textures of all specimens suggest that these trunks were buried by organic debris within a relatively short time following submersion in anoxic waters.

Wood samples from both localities were processed for historical examination according to procedures described in Johansen (1940) and Foster (1949). The basic steps in these procedures required (1) dehydration in a graded series of ethanol (70%, 95%, absolute), (2) clearing in xylol, and (3) embedment in paraffin. The paraffin-embedded specimens were then sectioned at varying thicknesses ranging from 10 to 30/jm, after which the sections were mounted on glass slides, deparaffinized, and mounted in Permount or Canada balsam.

Microscopic examination of the cross-sections of the Choctaw wood showed that severe compression of the thinner-walled spring wood tracheids had occurred and that cell walls of both the spring and summer wood cells had undergone extensive delignification (See Plate 1). This latter feature was confirmed by negative tests of unembedded specimens with phloroglucinol, which normally yields a red color upon reaction with lignin substance. The cross-sectional views did show, however, the presence of scattered axial parenchyma cells filled with a dark resinous substance (herein called resin cells) and a predominance of tracheids within each growth ring. An absence of resin ducts and vessel elements was noted in cross-sectional and radial views. Radial sections also confirmed the chain-like, vertical arrangement of the resin cells (See Plate 2), the presence of large bordered pits arranged in single rows on the axial tracheids, and the taxodioid and cupressoid bordered pit-types of the vascular ray crossfield areas.

The crossfield pitting of the vascular rays, pitting characteristics of the axial tracheids, ray widths, predominance of tracheids, lack of vessel elements and resin canals, and presence of scattered axial parenchyma cells indicate that the Choctaw woods are comparable to woods described for both modern and extinct species of the family Taxodiacease (Rosso, personal communication, 1984).

Considering the moist environment in which most lignite-producing species were living, it is not surprising to find a taxodiaceous species in the particular sites. It is well documented (Arnold and Lowther, 1955) that the Late Cretaceous and early Tertiary were periods in which several taxodiaceous groups, including Sequoia, Taxodium, and Metasequoia were evolving. Also, several extinct genera have been described from early Tertiary foliage and compression specimens, and it is possible that the Choctaw County species might well represent the woody stems of these as well as of extinct species of the bald cypress genus, Taxodium, which has been mentioned above. An identification on the generic and/or specific level would be speculative at best and will not be attempted until further anatomical analyses are completed.

The Winston County wood specimens are probably from a woody dicotyledonous species. The tentative results of the current anatomical analysis indicate that the wood has undergone less deterioration than the Choctaw woods. The wood anatomy is markedly different from previously described silicified woods from Tertiary and Pleistocene sites in Mississippi. The discovery of this relatively unaltered early Tertiary wood may prove to be a significant contribution to our knowledge of the Tertiary floras of the southeastern United States (Rosso, personal communication, 1984).

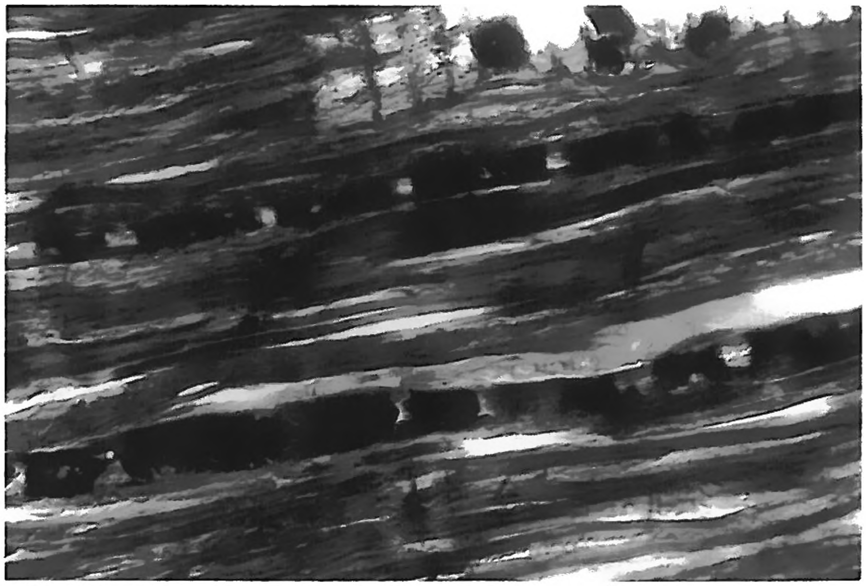


Plate 1: Cross-section of Choctaw wood (C-5) showing severe compression of the thinner-walled spring wood tracheids and axial parenchyma cells filled with a dark resinous substance.

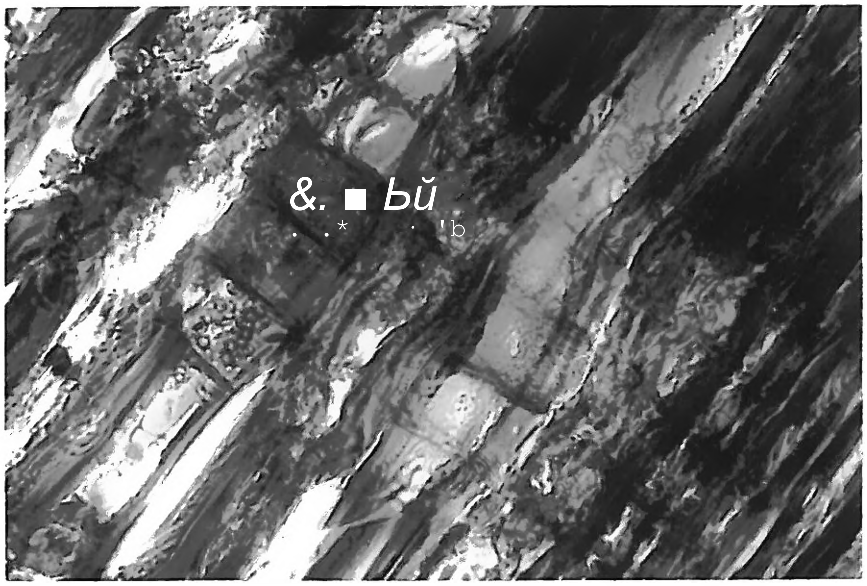


Plate 2: Radial section confirming the chain-like, vertical arrangement of the resin cells.

# II. THE LIGNITE MACERALS

## A. Definition of a Maceral

Coal macerals evolve from the different organs or tissues of the initial coal-forming plant materials during the source of the first stage of carbonification. However, because of the variable and often severe alteration, it is not always possible to recognize the starting materials. Macerals are the microscopically recognizable individual constituents of coal and depending on their associations, they control the chemical, physical and technological properties of a coal of given rank. In a sense, the macerals of coals are analogous to the minerals of rocks.

Reflectivity, shape, structure, fragmentation, fluorescence, and the degree of gélification are the prime criteria used to identify brown-coal macerals. A summary of the macerals discussed in this section can be seen on Table 4 (ICCP, 1971).

## B. The Huminite Group

The maceral group huminite in Tertiary brown coals is predominant and is technologically the most important. It is essentially composed of the plant substances cellulose and lignin and it is subdivided on the basis of the morphological state of preservation of these substances into three maceral subgroups: humodetrinite, humocollinite, and humotelinite. These three maceral subgroups of brown coals correspond morphographically (not always genetically) to the hard-coal macerals vitrodetrinite, collinite, and telinite. Because of the greater heterogeneity of brown coals, each of these three subgroups comprises different macerals, which are distinguished from one another primarily on their state of gélification. The degree of gélification of a huminite maceral is not only genetically important, but it is also an essential factor in determining the technological suitability of a brown coal. The gélification influences the crushing behavior, the briquetting capacity and also the suitability for the preparation of high-temperature coke. With maceral analyses of huminite, it is also possible to make additional comments on the crushing behavior, which is influenced strongly by the amount of humotelinite, and on the combustion behavior of a brown coal (ICCP, 1971).

### 1. Humotelinite Subgroup

Humotelinite is a maceral subgroup of huminite which consists of intact cell walls of tissues or isolated single cells in a humic state of preservation. Depending on its degree of gélification, it is subdivided into the macerals textinite and ulminite (ICCP, 1971).

#### a. Textinite Maceral

Textinite consists of plant-cell walls, both isolated occurences of intact individual cells and also cell tissues, which are ungelified. Size and form of the cells may vary and the cell lumens are mainly open (See Plate 3). Textinite occurs in large quantities in many brown coals, and is particularly abundant in xylite-rich (tree) brown coals or coal layers of coniferous forest-swamp type (ICCP, 1971).

#### b. Ulminite Maceral

Ulminite denotes the partly or totally gelified plant-cell walls in isolated occurrences of individual cells and cell tissues. Size and shape of the cells can vary. The cell lumens are partly or wholly closed. In tissues, the cell walls are often packed together, so that individual cells in sections perpendicular to the bedding appear elongated (See Plate4 ).

Ulminite occurs particularly in subaquatic deposits and facies very much similar to those which produce forest-swamp type coal deposits (ICCP, 1971).

3. Humodetrinite Subgroup

Humodetrinite is a maceral subgroup of huminite which consists of the finest humic fragments (mostly <10 microns) with a finely distributed humic gel between them. Depending upon its degree of gélification, it may be subdivided into the macerals attrinite and densinite. Since the degree of gélification is often difficult to determine in the fine grained humic "groundmass", no attempt was made to identify attrinite from densinite. For this reason, all fine grained humic "groundmass[11] was classified in the maceral subgroup humodetrinite (See Plate 5). The occurrence of humodetrinite is facies-dependent, being especially abundant (up to 90%) in coals which form from herbaceous plants (reeds) and from fragments of angiosperm (flowering) trees (ICCP, 1971).

3. Humocol i inite Subgroup

Humocollinite is a maceral subgroup of huminite which consists of an amorphous humic gel or of intensely gelified plant tissues and humic detritus. It is subdivided into the macerals corpohuminite and gelinite (ICCP, 1971).

a. Gelinite Maceral

Gel inites are predominantly precipitated humic gels without any definite form. Under the term gelinite, only huminites, which are homogeneous without etching, are recorded. Characteristic features of gelinite are a tendency of fissuring (shrinkage cracks due to desiccation) as well as distinct, smooth grain boundaries and fissures in fragments (See Plate 6 ). Concentrations of gel inites are facies-dependent. They occur particularly in brown coals deposited under limnotelmatic (freshwater, especially ponds and lakes) conditions and in combination with layers of stumps (ICCP, 1971).

b. Corpohuminite Maceral

Corpohuminites are in-situ or isolated phlobaphenitic cell excretions and secondary huminitic cell infillings, provided that the latter cannot be classified with certainty as gelinite. Essentially, a cell infilling, corpohuminite has an approximate spherical, elliptical, rod or plate-like form (See Plate 7 ). Corpohuminite is found in most brown coals and peats. It occurs in larger quantities in xylites from conifers (often more than 10%), and it is especially abundant as cell infillings in cork and bark tissues (ICCP, 1971).

## C. The Liptinite Group

The term liptinite was originally applied to the material composing the plant cuticles and the walls (exines) of pollen and spores found in coal (Stopes, 1935). The term has been broadened to designate a maceral group consisting of the macerals sporinite, cutinite, resinite, alginite, bituminite, exsudatinite, along with several other less common macerals which will not be discussed in this report.

The liptinite macerals originate from a wide variety of plant source materials. Most of the macerals of the liptinite group can be considered primary macerals representing slightly altered resin bodies, and pollen and spore exines. The liptinite macerals are most abundant in cannel or boghead coal types. Concentrations of liptinite macerals, for example, sporinite, may be caused by their resistance to many of the processes of mechanical and microbiological degradation of the plant remains (Gutzler, 1979).

Most of the liptinite macerals were uncommon, and often completely absent, in the brown coal studies of this report. Only the maceral sporinite was found to be even remotely common in the lignite seams investigated. Due to the rarity of the liptinite macerals, identification of the individual liptinite macerals was not attempted. All liptinite macerals observed, chiefly sporinite, were identified under the liptinite group. It should be noted that petrographic analysis with reflected white light methods is not sufficient for the identification of liptinite macerals. Most of these macerals can only be confidently identified by their fluorescence behavior (See Plates 8 & 9).

## D. The Inertini'te Group

Inertinite plays a secondary role in the brown coals of the great Teritiary deposits, and consists of oxidized or fusinitized huminite or liptinite macerals. The macerals are considered inert because of their high carbon, low hydrogen contents.

The macerals which make up the inertinite group are fusinite, semi-fusinite, sclerotinite, macrinite, and inertodetrinite. Although all the macerals of the inertinite groups are discussed, the rarity of the maceral occurrences of sclerotinite, macrinite, and inertodetrinite and also the similarity of their reflecting capacity to the fusinite maceral made it necessary for them to be added to the maceral percentage of fusinite. The semifusinite maceral retained its own grouping due to its individual reflecting capacity (ICCP, 1971).

### 1. Fusinite Maceral

Fusinite consists of intact fusinitized cell walls (See Plate 10). It is characteristically identified by its high reflectivity. Fusinite occurs in small amounts in brown coals, generally dispersed with humodetrinite. It occurs most abundantly in finely divided form in subaquatic facies types and in massive form in laterally extensive "fusinite horizons" where it is found as fusain lenses. A large portion of the fusinite in brown coals, particularly the fusinite composing laterally extensive fusain horizons, is derived from forest and peat fires (fossil charcoal). Fusinite can also be created by decarboxylation with the aid of fungi and bacteria, but such "decomposition fusinites" are relatively rare in brown coals (ICCP, 1971).

2. Semifusinite Maceral

Semifusinite consists of relatively well-preserved cellular structure and cell walls whose reflecting capacity lies between that of the huminite and fusinite of the same coal (See Plate 11). Semifusinite has its origin in the cellulose and lignin of plant cell walls. The formation of semifusinite may be caused by fire (incomplete carbonification), by the effects of bacteria and fungi (decomposition fusinite), or due to other unknown cause (ICCP, 1971).

3. Sclerotinite Maceral

Sclerotinite originates as fungal spores and sclerotia. It is typically identified by its characteristic oval shape and highly reflective boundary (See Plate 12). So far as is known at present, fungal remains represented by the maceral sclerotinite are derived from primary dark colored organs (hyphae, spores, sclerotia, and plectenchyme) of different fungal species. It generally only occurs in small amounts and can be associated with all other brown coal macerals (ICCP, 1971).

4. Macrinite Maceral

Macrinite originates from decomposed and gelified peat particles that have been secondarily fusinitized and deposited. It occurs in the inertinite-bearing microlithotypes and often forms only a few percent of the total inertinite group (ICCP, 1971).

5. Inertodetrinite Maceral

Inertodetrinite is a collective term for constituents of the inertinite group, which, on account of their finely detrital condition and/or small particle size, can no longer be assigned with certainty to one or other macerals of the inertinite group (fusinite, semifusinite, sclerotinite, or macrinite). Inertodetrinite originates from different plant materials by different processes before and during peat accumulation. For example, inertodetrinite may be formed through carbonization by the burning of wood or peat, by fungal attack, and/or by strong oxidation and decomposition of humic material (ICCP, 1971).

Table 4. Summary of the Macerals of Brown Coals as Determined by the International Committee for Coal Petrology (1971) and the Corresponding Macerals Used In This Report,When Performing the Petrographic Analysis

| MARCERAL GROUP | MACERAL SUBGROUP | MACERAL | THIS REPORT |
|---|---|---|---|
| Huminite | Humotelinite | Textinite<br>Ulminite | Textinite<br>Ulminite |
| | Humodetrinite | Attrinite<br>Densinite | Humodetrinite |
| | Humocollinite | Gelinite<br>Corpohuminite | Gelinite<br>Corpohuminite |
| Liptinite | | Sporinite<br>Cutinite<br>Resinite<br>Suberinite<br>Alginite<br>Liptodetrinite<br>Chiorophylinite | Liptinite |
| Inertinite | | Fusinite<br>Semifusinite<br>Sclerotinite<br>Macrinite<br>Inertodetrinite | Fusinite<br>Semifusinite |

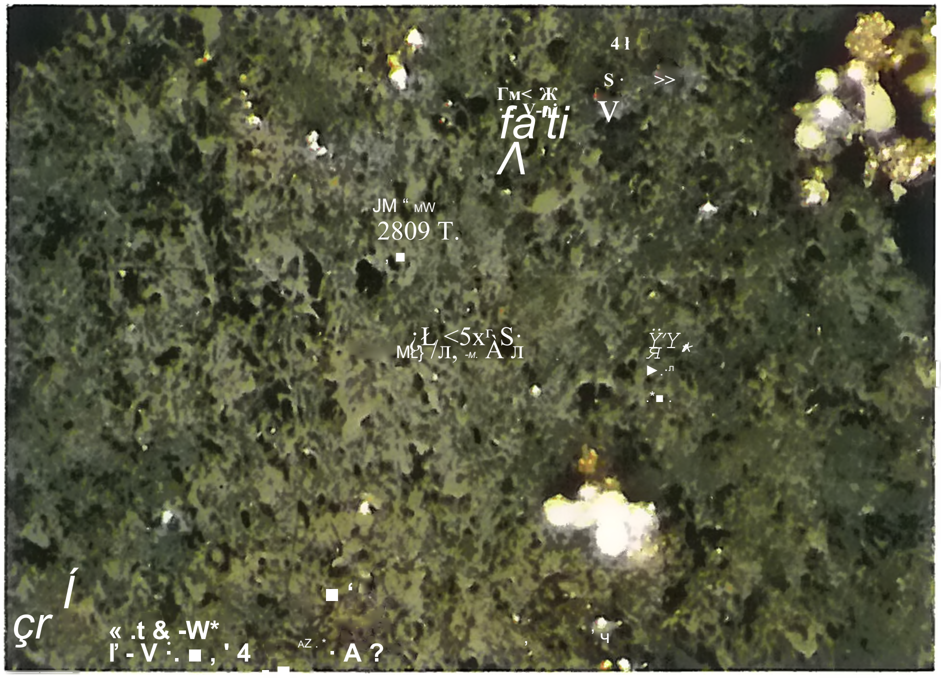


Plate 3: Textinite - ungelified cell tissue. (Photo from seam W-3, magnified 350x.)

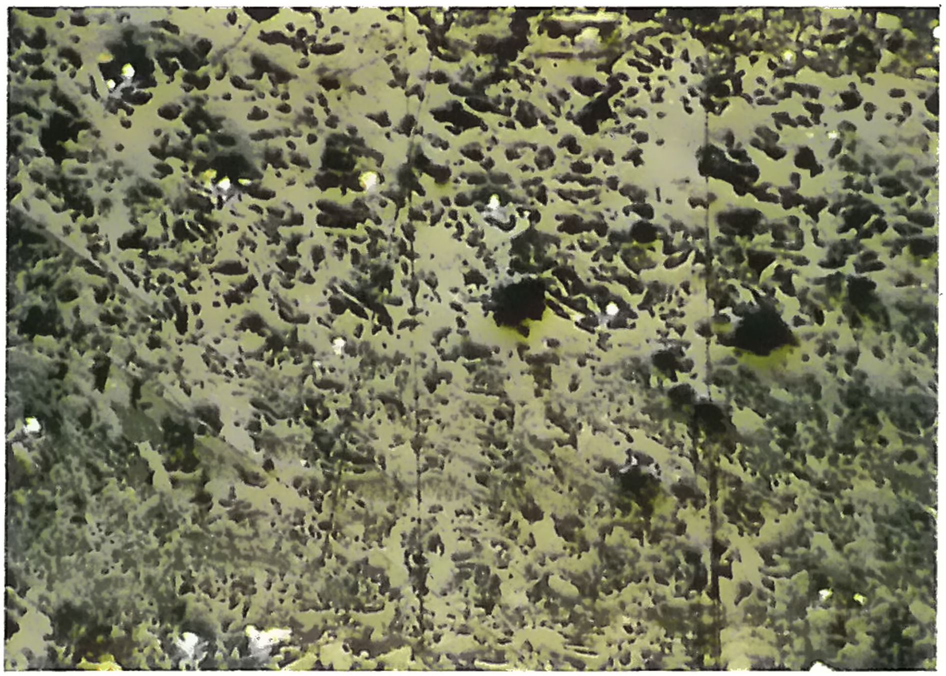


Plate 4: Ulminite - partially or totally gelified cell walls and tissues. (Photo from seam W-2, magnified 350x.)

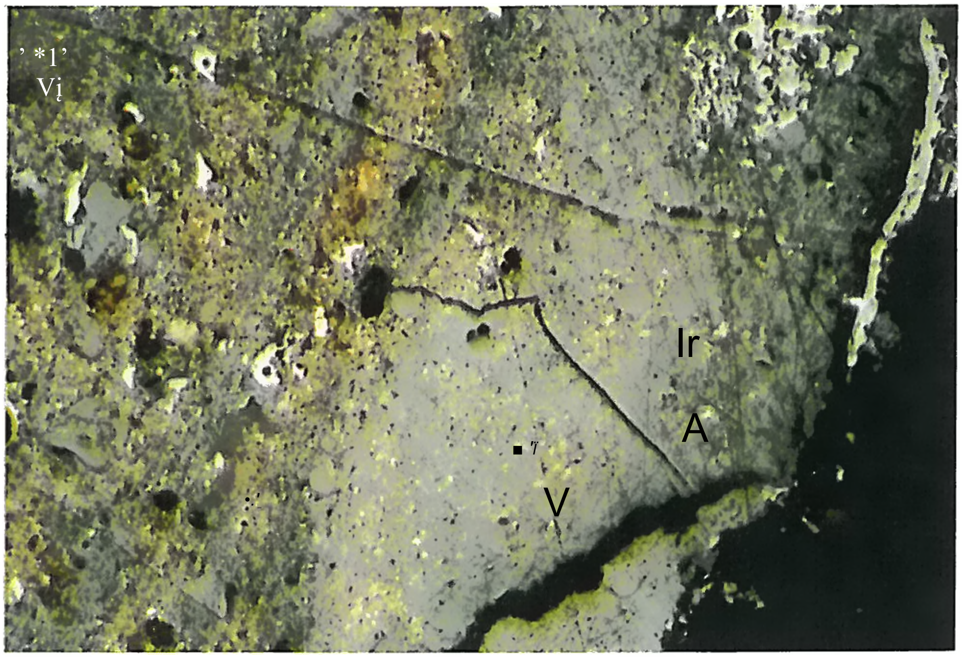


Plate 5: Humodetrinite - fine grained humic groundmass ( <10 microns). (Photo from seam W-3, magnified 350x.)

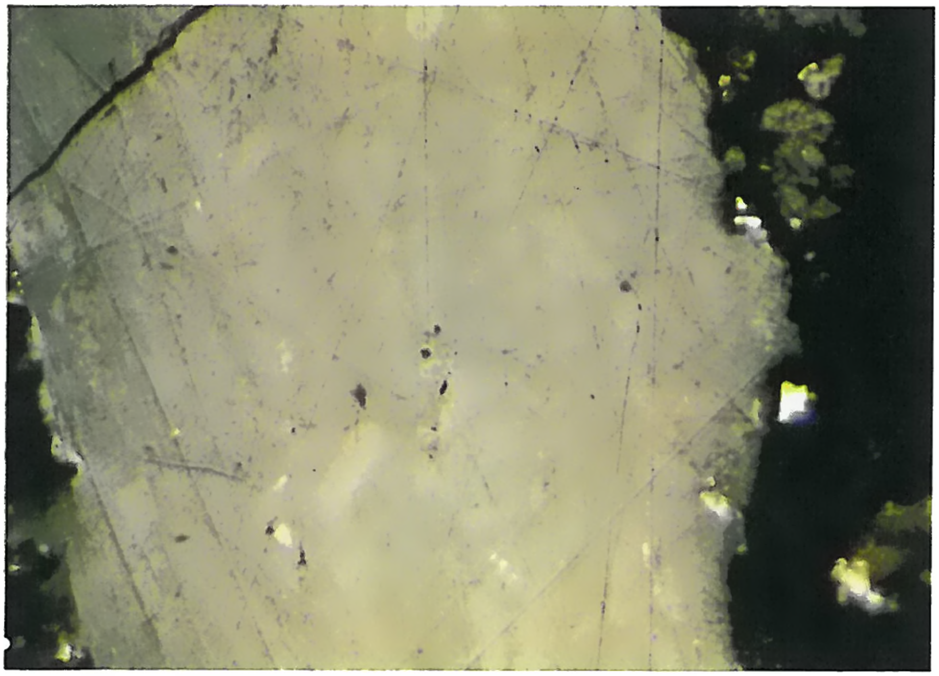


Plate 6: Gelinite - homogenous humic gels without any definite form. (Photo from seam W-8, magnified 350x.)

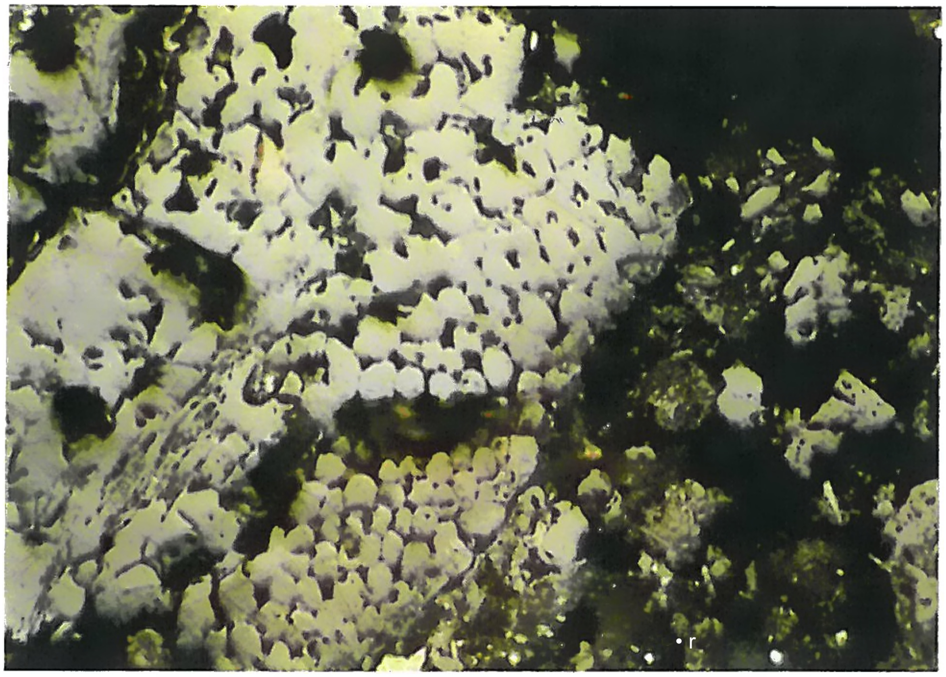


Plate 7: Corpohuminite - approximately spherical secondary cell infillings. (Photo from seam W-2, magnified 350x.)

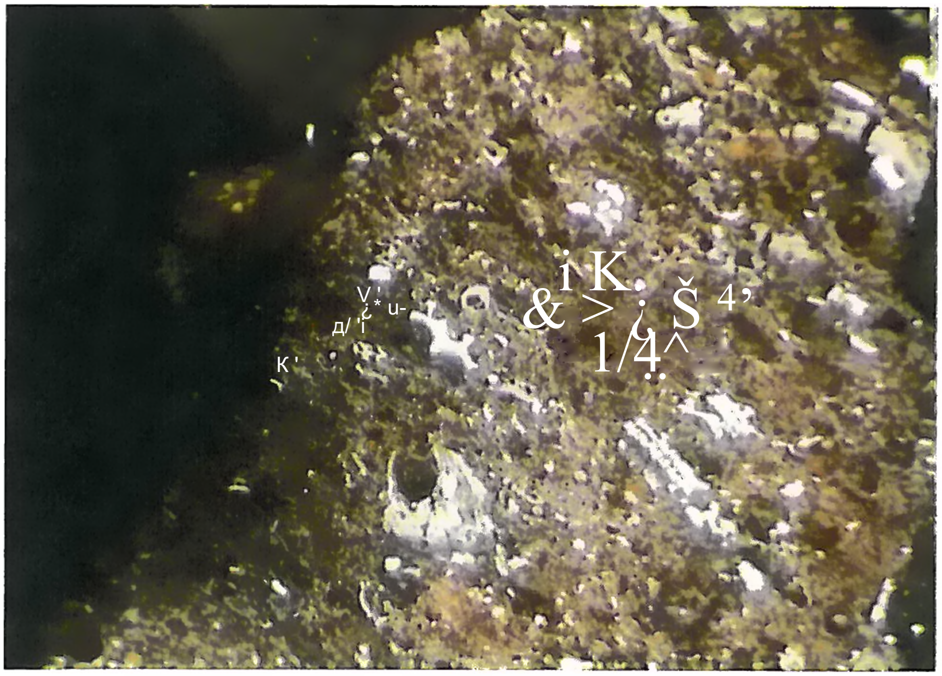


Plate 8: Liptinite (Sporinite) - pollen and/or spore exines as seen under reflected white light. (Photo from seam W-8, magnified 350x.)

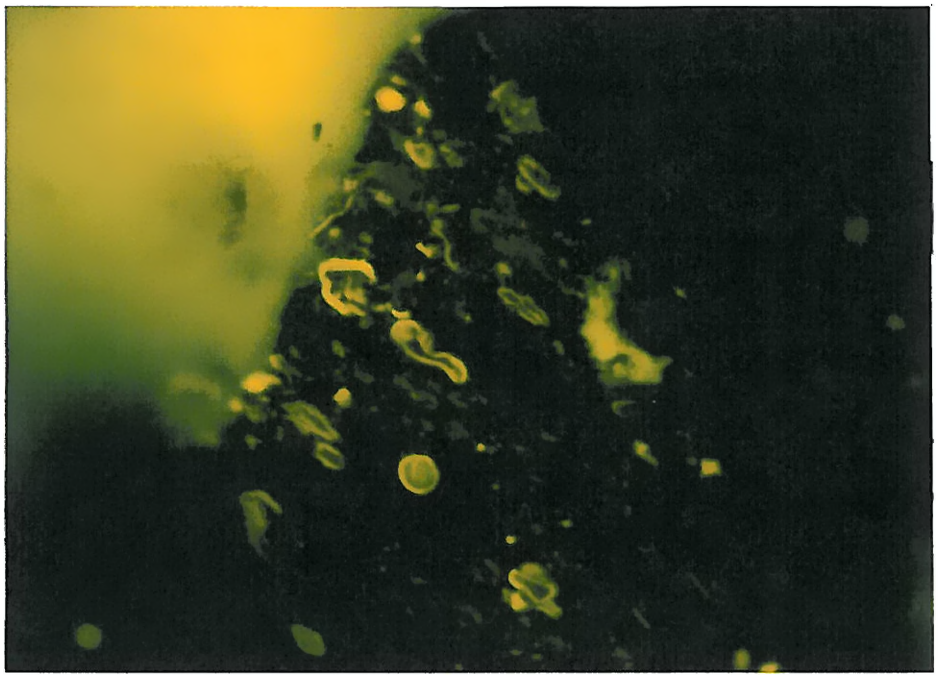


Plate 9: Liptinite (Sporinite) - pollen and/or spore exines as seen under fluorescent light (same picture as plate 8). (Photo from seam W-8, magnified 350x.)

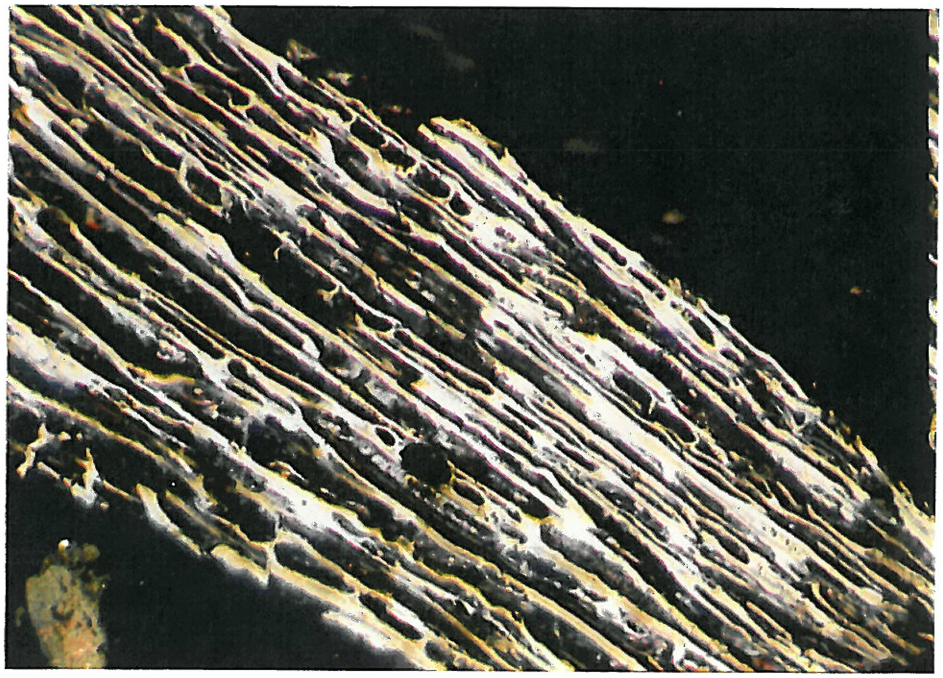


Plate 10: Fusinite - intact fusinitized cell walls. (Photo from seam W-3, magnified 350x.)

Plate 11: Semifusinite - relatively well-preserved cellular structure and cell walls whose reflecting capacity lies between that of huminite and fusinite. (Photo from seam W-3, magnified 350x.)

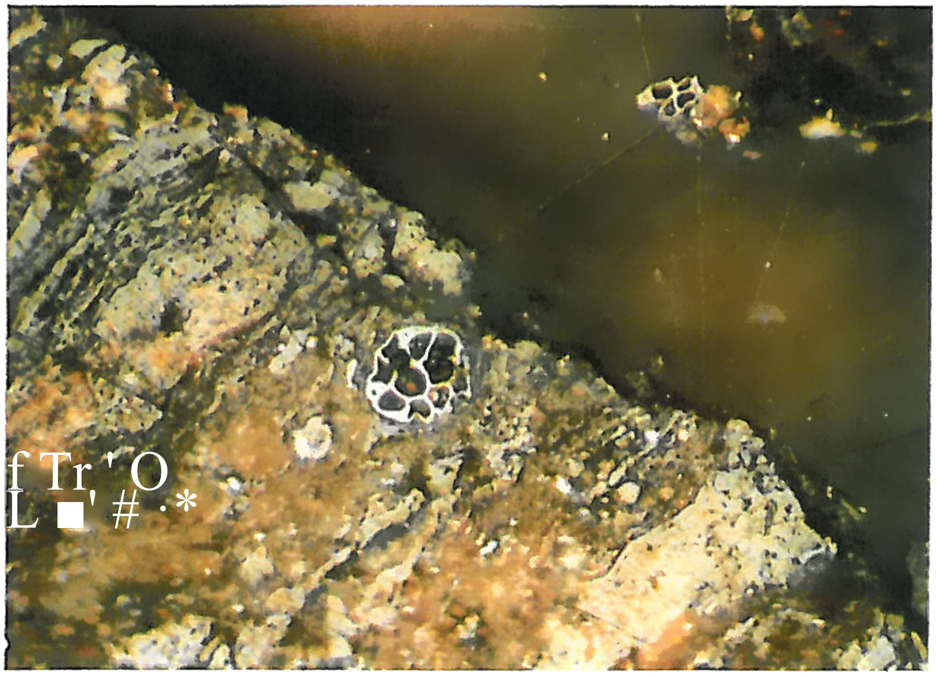
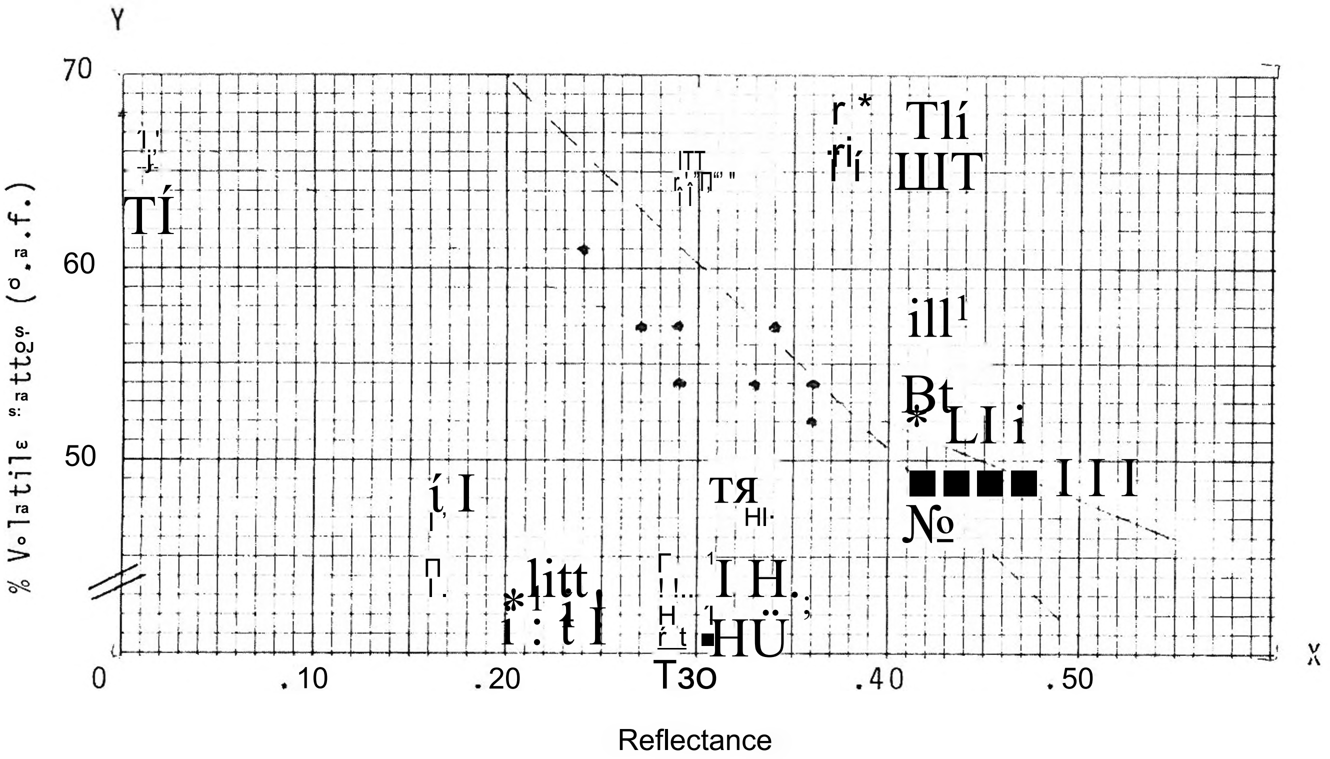


Plate 12: Sclerotinite - characteristic oval shape and highly reflective boundary. (Photo from seam W-5, magnified 350x.)

According to Stach et al. (1981), reflectance measurements done on brown coals are not sufficiently reliable to determine the rank of the coal. However, while reflectance measurements on brown coals may not be as accurate a rank indicator as those for hard coals, reflectance measurements on brown coals provide an estimate of the calorific yield (Btu) and thus the potential value of these coals. Figure 17 shows the results of reflectance measurements plotted against the volatile matter content on nine of the fourteen lignite seams examined in this report. (The reason five of the fourteen seams did not have reflectance measurements performed on them is because either 1) the seam thickness was so small that no petrographic analysis was performed on the seam or, 2) there was an insufficient amount of gel inite (the maceral from which reflectance measurements are taken) in the sample.) When reflectance increases, rank increases which in turn means that the calorific value (Btu) of the coal increases. Therefore, reflectance measurements done on brown coal show which seams should give a higher calorific (Btu) yield.

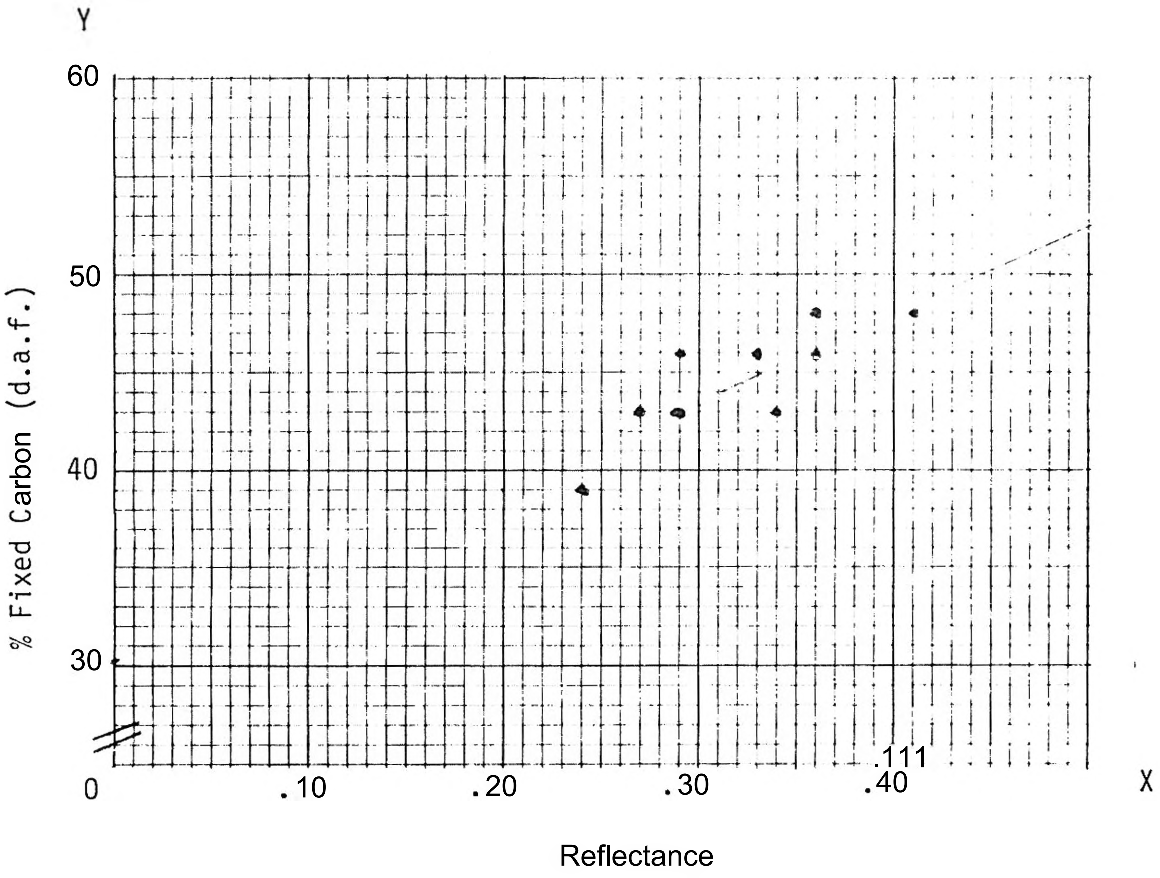
Figure 18 shows the results of reflectance measurements plotted against the fixed carbon content of the same nine lignite seams used in figure 17. The graph shows that as the reflectance increases, the fixed carbon content increases. When the fixed carbon content increases, the calorific value (Btu) increases and therefore the potential value of the coal increases.



| SEAM | X | Y |
|---|---|---|
| W-2 | 36 | 54 |
| W-3 | 36 | 52 |
| W-3A | 34 | 57 |
| W-4 | 41 | 52 |
| W-5 | 24 | 61 |
| W-7 | 29 | 57 |
| W-8 | 33 | 54 |
| C-4 | 27 | 57 |
| C-5 | 29 | 54 |

slope = -OΛO
intercept = 68.24
corr. = -0.75

Figure 17. Reflectance increases as the volatile matter content (d.a.f.) decreases. According to Stach, et al., (1982, p. 45), the volatile matter content decreases as reflectance increases at a much more rapid rate (broken line) than is actually observed (solid line) in the lignites investigated from Choctaw and Winston counties in this report. A flatter line results because of the lack of exines in the lignites investigated from Choctaw and Winston counties.



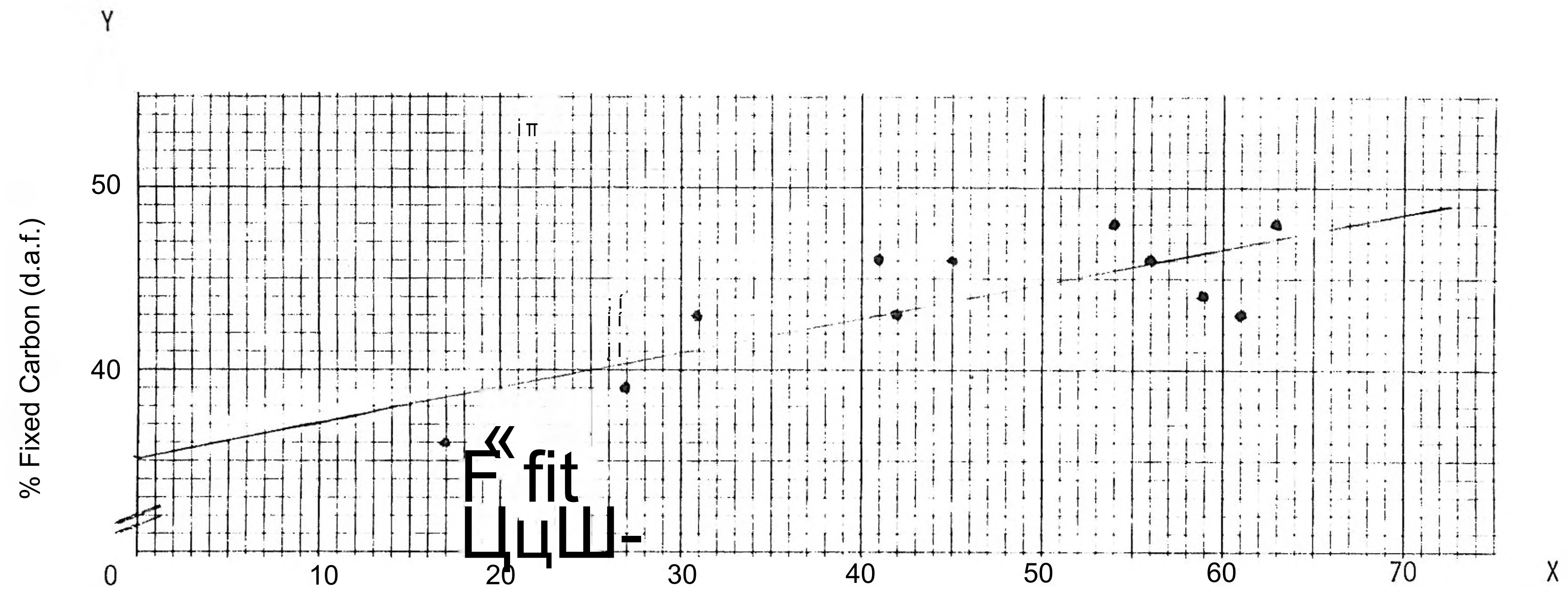
| SEAM | X | Y |
|---|---|---|
| W-2 | 36 | 46 |
| W-3 | 36 | 48 |
| W-3A | 34 | 43 |
| W-4 | 41 | 48 |
| W-5 | 24 | 39 |
| W-7 | 29 | 43 |
| W-8 | 33 | 46 |
| C-4 | 27 | 43 |
| C-5 | 29 | 46 |

slope = 0.82
intercept = 30.20
corr. = 0.82

Figure 18. Fixed carbon content (d.a.f.) increases as the reflectance increases. As reflectance increases so does the rank, and as rank increases the calorific yield (Btu) increases.

Comparisons of the proximate analysis data to the petrographic data were made in an attempt to determine if any relationship existed between the fixed carbon content (proximate analysis data) and the maceral percentages (petrographic analysis data). By comparing the fixed carbon content to the various macerals and combinations of macerals, the only consistent relationship appeared to be that between the fixed carbon content (on a dry, ash-free basis) and the subgroup combination of humotelinite and humodetrinite (Figure 19), showing that the fixed carbon content of the lignite increases as the combined percentages of the subgroups humotelinite and humodetrinite increase. Apparently, the subgroups humotelinite and humodetrinite are in some way responsible for the fixed carbon contents in these lignites.

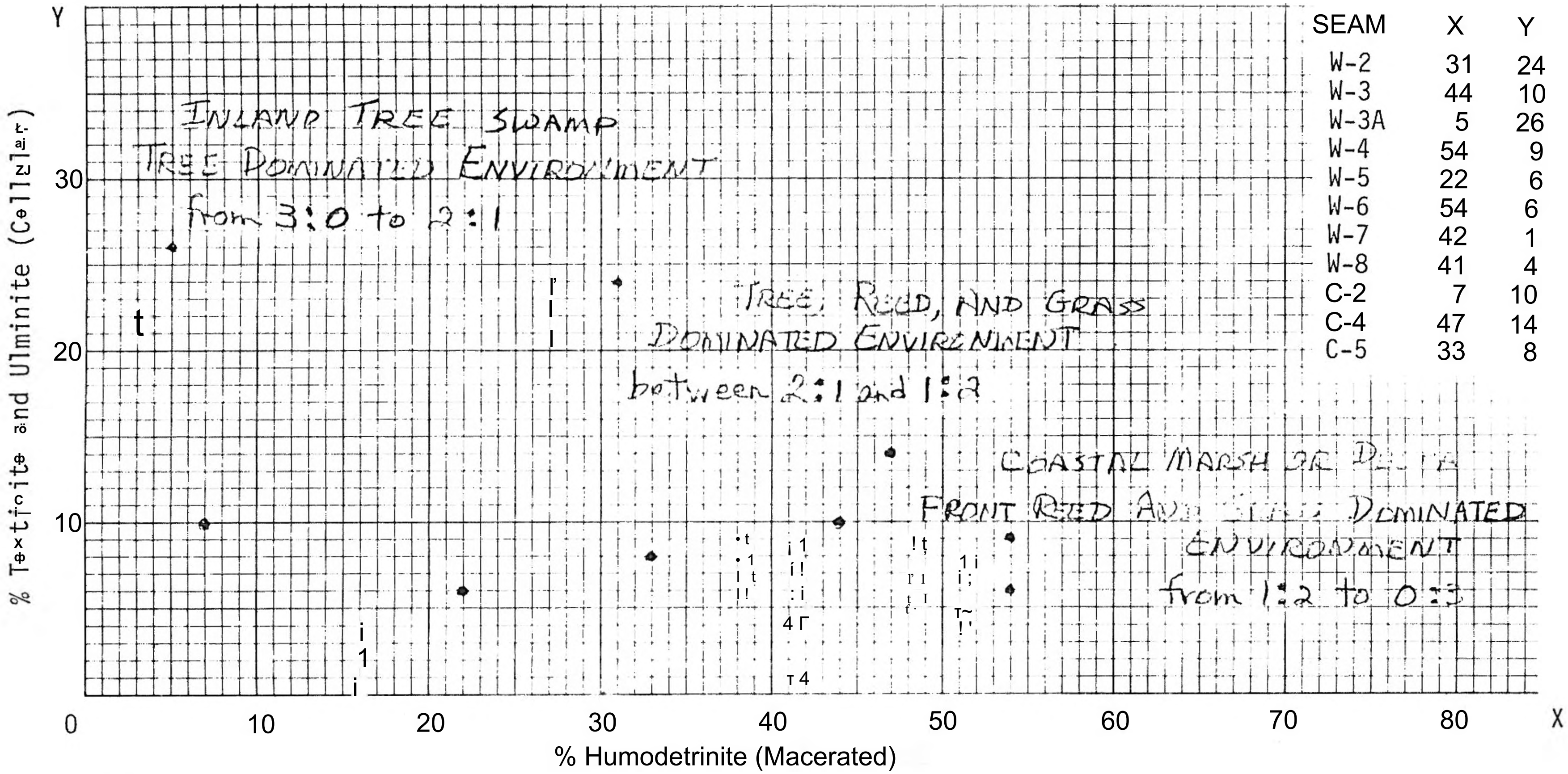
Comparison of the cellular humic material (textinite and ulminite) versus the macerated humic material (humodetrinite) possibly gives an indication to the physical and botanical environment present during the period of humic accumulation. The data identifies three types of plant communities and the corresponding physical environment which might enhance humic accumulation as a result of the particular plant community. The three types of swamp plant communities are 1) tree dominated plant community, 2) reed and grass dominated plant community, and 3) a marginal plant community composed of trees, reeds, and grasses (Figure 20).



| SEAM | X | Y |
|---|---|---|
| [illegible] | [illegible] | 46 |
| W-3 | [illegible] | [illegible] |
| W-3A | 31 | [illegible] |
| [illegible] | [illegible] | [illegible] |
| W-5 | 27 | [illegible] |
| W-6 | [illegible] | 44 |
| W-7 | 42 | 43 |
| W-8 | 45 | 46 |
| C-2 | 17 | 36 |
| C-4 | 61 | 43 |
| C-5 | 41 | 46 |

slope = 0.19
intercept = 35.27
corr. = 0.78

Figure 19. Fixed carbon content (d.a.f.) increases as the humotelinite and humodetrinite contents increase. Since there is a lack of large quantities of inertinites (the maceral group richest in carbon) in brown coals, the huminite subgroups humotelinite and humodetrinite must be primarily responsible for the fixed carbon content in these lignites.



| SEAM | X | Y |
|---|---|---|
| W-2 | 31 | 24 |
| W-3 | 44 | 10 |
| W-3A | 5 | 26 |
| W-4 | 54 | 9 |
| W-5 | 22 | 6 |
| W-6 | 54 | 6 |
| W-7 | 42 | 1 |
| W-8 | 41 | 4 |
| C-2 | 7 | 10 |
| C-4 | 47 | 14 |
| C-5 | 33 | 8 |

Figure 20. Comparision of the cellular humic material (textinite and ulminite) content versus the macerated humic material (humodetrinite) content identifies three types of plant communities and the corresponding physical environment which might enhance humic accumulation as a result of a dominant plant community. A lignite seam containing a cellular humic material ratio to macerated humic material from 3:0 to 2:1 respectively, would indicate a tree dominated environment such as an upland tree swamp. A lignite seam containing a cellular humic material ratio to macerated humic material from 1:2 to 0:3 respectively, would indicate a reed and grass dominated plant community such as a coastal marsh or delta front environment. A lignite seam containing a cellular humic material ratio to macerated humic material between 2:1 and 1:2 respectively, would indicate a marginal plant community containing trees, reeds, and grasses and found in an area somewhere between the tree community and the reed and grass community.

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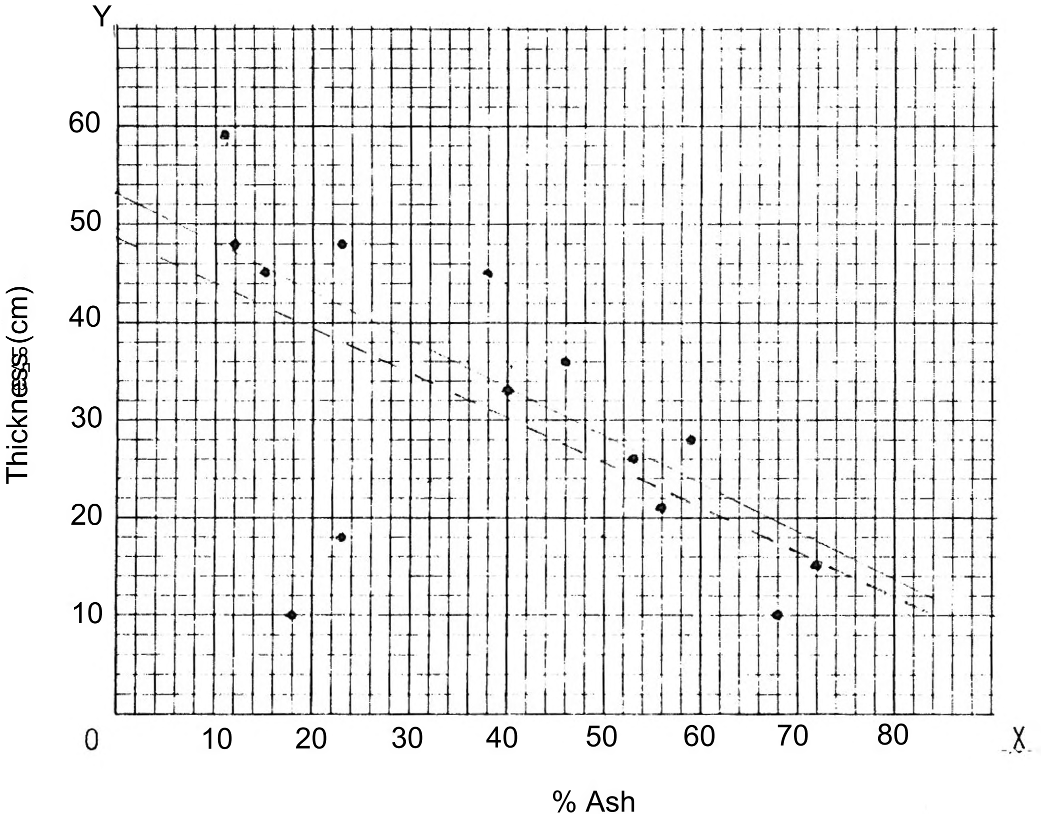
Figure 21 shows that the ash content decreases as the seam thickness increases. A low ash content associated with a high seam thickness might indicate a slowly subsiding, highly vegetated environment far enough removed from any fluvial system so that humic debris could accumulate uninhibited by sediment influx. A high ash content associated with a low seam thickness might indicate a rapidly subsiding environment in which vegetation growth could not keep pace with subsidence, or an environment in which the vegetation was not particularly thick, or (and probably most likely) an environment in which the accumulation of humic debris was inhibited by sediment influx from a nearby fluvial system. (Seams W-1 and W-7 probably represent isolated, shallow, stable basins initially removed from any appreciable sediment influx but whose humic accumulation was interrupted by rapid sediment influx, or a sudden rise or fall in the water table.)

Of the lignite seams investigated in this report, 12 out of 14 seams showed that the ash content decreases as the seam thickness increases (Figure 21). This should be beneficial to any industry contemplating lignite research or mining in Winston and/or Choctaw counties because it shows that the thicker the seam, the more likely that the lignite is of good quality. This will aid industry in determining which seams have the best economic potential based on the seam thickness and thus eliminate wasted time and money researching lignite seams of less thickness and apparently poorer quality.



| SEAM | X | Y |
|---|---|---|
| W-1* | 18 | 10 |
| W-2 | 40 | 33 |
| W-3 | 38 | 45 |
| W-3A | 56 | 21 |
| W-4 | 15 | 45 |
| W-5 | 59 | 28 |
| W-6 | 53 | 26 |
| W-7* | 23 | 18 |
| W-8 | 12 | 48 |
| C-1 | 68 | 10 |
| C-2 | 23 | 48 |
| C-3 | 72 | 15 |
| C-4 | 46 | 36 |
| C-5 | 11 | 59 |

Broken Line

slope = -0.44
intercept = 48.45
corr. = -0.60

Solid Line (* seams omitted from calculations)

slope = -0.49
intercept = 53.02
corr. = -0.81

Figure 21. In 12 out of 14 seams investigated, the ash content decreases as the seam thickness increases. A low ash content associated with a high seam thickness might indicate a slowly subsiding, highly vegetated environment far enough removed from any fluvial system so that humic debris could accumulate uninhibited by sediment influx. A high ash content associated with a low seam thickness might indicate an environment in which the accumulation of humic debris was inhibited by sediment influx from a nearby fluvial system. Seams W-1 and W-7 probably represent isolated, shallow, stable basins initially far removed from any appreciable sediment influx but whose humic accumulation was interrupted by rapid sediment influx, or a sudden rise or fall in the water table.

Entire lignite seams investigated in this report may be thicker or thinner, better or worse in quality (ASTM) than reported since this report is limited to outcrop analysis. Of the seams investigated in this report, seams W-4, W-8, C-2, and C-5 show the best economic potential. Other lignite seams in the subsurface may be thick, numerous, and of good quality which would enhance the economic potential of Mississippi lignites.

No attempt was made to calculate the reserve tonnage of the lignite seams investigated in this report. This would require extensive drilling which is beyond the scope of this report. This report only shows that there are some outcrop seams which have economic potential and it is only reasonable to assume that many more minable seams are buried in the subsurface.

Other lignite outcrops were reported in the literature but were not investigated. An attempt was made to locate all lignite outcrops reported in the literature. Some seam locations were inaccessible or vegetation growth made it impossible to locate and collect samples for this report. Some "lignite" seams reported in the literature by Williamson (1976) were actually lignitic clays.

IDENTIFICATION NUMBER: W-I
LOCATION: T15N R12E Sec 14

SEAM THICKNESS: 8 cm.

Average Proximate Analysis

| Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 50.7 | 42.6 | 18.4 | 39.0 | AD | 39.7 | 39.4 | 14.7 | 45.9 |

Average Petrographic Analysis

| Textinite | Ulminite | Humo-Detrinite | Gelinite | Corpo-Huminite | Fusinite | Semi-Fusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| - | - | - | - | - | - | - | - | - |

Discussion:

Since this seam was only 8 cm thick, petrographic analysis was not performed. The proximate analysis data shows a high volatile matter content. This indicates a fluvially controlled depositional environment.

IDENTIFICATION NUMBER: W-2
LOCATION: T14N R11E Sec 33

SEAM THICKNESS: 33 cm

Average Proximate Analysis

| Condition | Moisture | Volatile | Ash | Fixed Carbon | Condition | Moisture | Volatile | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 42.9 | 32.8 | 40.5 | 26.7 | AD | 21.8 | 36.3 | 32.4 | 31.3 |

Average Petrographic Analysis

| Textinite | Ulminite | [illegible] | Densinite | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|---|
| 7.4 | 17.0 | 31.3 | 38.9 | 1.9 | 1.2 | 1.5 | 0.8 | .36 |

Discussion:

Examination of the proximate analysis data shows a moderate fixed carbon and ash content. This indicates a fluvial environment. The petrographic data shows a high textinite, ulminite, and gel inite, along with a moderate humodetrinite content. This indicates a fluvially controlled, back swamp type deposit containing both trees and grasses.

IDENTIFICATION NUMBER: W-3
LOCATION: T14N R12E Sec 6

SEAM THICKNESS: 45 cm.

Average Proximate Analysis

| Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 42.2 | 32.3 | 38.5 | 28.8 | AD | 6.6 | 32.4 | 38.2 | 29.4 |

Average Petrographic Analysis

| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|---|
| 1.5 | 8.8 | 43.5 | 35.1 | 1.9 | 6.1 | 2.3 | 0.4 | .36 |

Discussion:

Examination of the proximate analysis data shows moderate ash and fixed carbon contents. This indicates a fluvial environment. The petrographic data shows a relatively high ulminite, gel inite, and humodetrinite content. This indicates a fluvially controlled, back swamp type environment containing both trees and grasses.

IDENTIFICATION NUMBER: W-3A
LOCATION: T14N R12E Sec 6

SEAM THICKNESS: 21 cm.

Average Proximate Analysis

| Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 38.6 | 25.3 | 56.2 | 18.5 | AD | 27.2 | 25.1 | 56.2 | 18.7 |

Average Petrographic Analysis

| Textinite | Ulminite | Humo-Detrinite | Gelinite | Corpo-Huminite | Fusinite | Semi-Fusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| 2.4 | 23.8 | 4.8 | 65.6 | 1.4 | 1.8 | 0.2 | 0.2 | .34 |

Discussion:

Examination of the proximate analysis of this seam might cause one to identify this depositional environment as lagoonal. However, the petrographic analysis indicates this is not the case. The high textinite, ulminite, and gelinite contents, along with the low humodetrinite content indicates that this is a fluvial, back swamp type deposit dominated by trees.

IDENTIFICATION NUMBER: W-4
LOCATION: T15N R12E Sec 32

SEAM THICKNESS: 45 cm.

Average Proximate Analysis

| Condition | Moisture | Volatile | Ash | Fixed Carbon | Condition | Moisture | Volatile | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 44.8 | 46.6 | 14.8 | 38.6 | AD | 9.8 | 44.4 | 14.8 | 40.7 |

Average Petrographic Analysis

| Textinite | Ulminite | Humo-Detrinite | Gelinite | Corpo-Huminite | Fusinite | Semi-Fusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| 5.4 | 3.7 | 53.8 | 23.7 | 1.8 | 8.3 | 3.2 | 0.3 | .41 |

Discussion:

The proximate analysis data of this seam shows a low ash content and a high fixed carbon content indicative of a deltaic deposit. The petrographic analysis data shows a relatively high humodetrinite content with a moderate amount of gel inite and fusinite, which indicates a grass dominated environment with some trees much like that of a deltaic environment.

IDENTIFICATION NUMBER: W-5
LOCATION: T15N R12E Sec 9

SEAM THICKNESS: 28 cm.

Average Proximate Analysis

| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
|---|---|---|---|---|---|---|---|---|---|
| AI | 35.4 | 25.5 | 58.7 | 15.8 | AD | 9.4 | 25.1 | 59.0 | 15.9 |

Average Petrographic Analysis

| Textinite | Ulminite | Humo-Detrinite | Gelinite | Corpo-Huminite | Fusinite | Semi-fusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| 1.4 | 4.1 | 21.6 | 62.6 | 5.7 | 2.5 | 2.0 | 0.3 | .24 |

Discussion:

The proximate analysis data of this seam showa a relatively high ash content and a high volatile matter content when compared to the fixed carbon content. The petrographic analysis shows a high amount of gel inite with some ulminite and corpohuminite and a relatively low humodetrinite content, which indicates a fluvially controlled depositional basis. The humic material was deposited in an area not far removed from the fluvial system and represents a tree dominated environment with some grasses present.

IDENTIFICATION NUMBER: W-6
LOCATION: T15N R12E Sec 22

SEAM THICKNESS: 26 cm.

Average Proximate Analysis

| Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 37.6 | 26.3 | 53.4 | 20.3 | AD | 20.9 | 27.4 | 51.2 | 21.4 |

Average Petrographic Analysis

| Textinite | Ulminite | Humodetrinite | Gelinite | Corpo-Huminite | Fusinite | Semi-Fusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| 4.4 | 1.2 | 53.9 | 13.7 | 0.1 | 22.0 | 4.4 | 0.3 | - |

Discussion:

The proximate analysis data of this seam shows a relatively high ash content and a moderately high volatile matter content compared to the fixed carbon content. This indicates a fluvially controlled basin where the humic material was deposited not far removed from the fluvial system. The petrographic data shows a relatively high humodetrinite and fusinite content, which indicates a fluvial environment in which the humic material was composed of both trees and grasses.

IDENTIFICATION NUMBER: W-7
LOCATION: T15N R12E Sec 32

SEAM THICKNESS: 18 cm.

Average Proximate Analysis

| Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 42.1 | 43.7 | 23.4 | 32.8 | AD | 26.8 | 43.8 | 23.7 | 32.5 |

Average Petrographic Analysis

| Textinite | Ulminite | Humodetrinite | Gelinite | Corpohuminite | Fusinite | Semifusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 0.4 | 41.8 | 15.4 | 1.8 | 37.2 | 3.4 | 0.2 | .29 |

Discussion:

The proximate analysis data of this seam shows a moderate ash content and a high volatile matter content, which indicates a fluvially controlled back swamp type deposit. The petrographic data shows a relatively high humodetrinite and fusinite content, which indicates a fluvial environment in which the humic material was composed of both trees and grasses.

IDENTIFICATION NUMBER: W-8
LOCATION: T15N R12E Sec 32

SEAM THICKNESS: 48 cm.

Average Proximate Analysis

| Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 46.4 | 47.4 | 11.7 | 40.9 | AD | 25.2 | 47.0 | 12.2 | 40.8 |

Average Petrographic Analysis

| Textinite | Ulminite | Humodetrinite | Gelinite | Corpohuminite | Fusinite | Semifusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| 0.0 | 4.3 | 40.9 | 41.3 | 1.5 | 5.0 | 2.3 | 4.8 | .33 |

Discussion:

The proximate analysis data of this seam shows a low ash content, a high fixed carbon content, and a moderately high volatile matter content, which indicates a deltaic environment. The petrographic data shows a high humodetrinite and gel inite content, which indicates an environment containing both trees and grasses much like that associated with an upland swamp of a delta.

IDENTIFICATION NUMBER: C-1
LOCATION: T17N RUE Sec 2

SEAM THICKNESS: 10 cm.

## Average Proximate Analysis

| Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 29.7 | 23.0 | 67.8 | 9.2 | AD | 12.3 | 23.5 | 67.9 | 8.6 |

## Average Petrographic Analysis

| Textinite | Ulminite | Humo-Detrinite | Gelinite | Corpo-Huminite | Fusinite | Semi-Fusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| - | - | - | - | - | - | - | - | - |

## Discussion:

Since this seam was only 10 cm thick, petrographic analysis was not performed. The high ash content and the high volatile matter content compared to the fixed carbon content indicates a fluvially controlled dispositional basin not far removed from the fluvial system.

IDENTIFICATION NUMBER: C-2
LOCATION: T18N RUE Sec 34

SEAM THICKNESS; 48 cm.

## Average Proximate Analysis

| Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 54.4 | 48.8 | 23.3 | 27.9 | AD | 16.2 | 48.8 | 23.6 | 27.6 |

## Average Petrographic Analysis

| Textinite | Ulminite | Humo-Detrinite | Gelinite | Corpo-Huminite | Fusinite | Semi-Fusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| 3.7 | 5.9 | 7.2 | 2.8 | 1.0 | 3.0 | 76.3 | 0.1 | - |

## Discussion:

The proximate analysis data of this seam shows a moderate ash content and a high volatile matter content, indicating a fluvial environment. The petrographic data shows that the seam is predominantly composed of semifusinite and very little humodetrinite, which indicates a fluvial environment in which the humic material was composed almost entirely of trees.

IDENTIFICATION NUMBER: C-3
LOCATION: T18N RUE Sect 35

SEAM THICKNESS: 15 cm.

Average Proximate Analysis

| Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 20.9 | 21.5 | 72.0 | 6.5 | AD | 13.1 | 21.1 | 72.0 | 6.9 |

Average Petrographic Analysis

| Textinite | Ulminite | Humo-Detrinite | Gelinite | Corpo-Huminite | Fusinite | Semi-Fusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| - | - | - | - | - | - | - | - | - |

Discussion :

Since this seam was only 15 cm thick and the ash content was so high, petrographic analysis was not performed. The high ash content and the high volatile matter content compared to the fixed carbon content indicates a fluvially controlled environment in which the depositional basin was not far removed from the fluvial system.

IDENTIFICATION NUMBER: C-4
LOCATION: T17N RIOE Sec 4

SEAM THICKNESS: 36 cm.

Average Proximate Analysis

| Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 36.8 | 30.4 | 46.3 | 23.3 | AD | 13.0 | 30.2 | 46.7 | 23.1 |

Average Petrographic Analysis

| Textinite | Ulminite | Humo-Detrinite | Gelinite | Corpo-Huminite | Fusinite | Semi-Fusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| 5.7 | 8.5 | 46.5 | 31.7 | 1.9 | 3.1 | 2.6 | 0.1 | .27 |

Discussion:

The proximate analysis data shows a moderate ash content and a moderate fixed carbon content, which indicates a fluvial environment. The petrographic data shows a relatively high amount of textinite, ulminite, humodetrinite, and gel inite, which indicates an environment containing both trees and grasses.

IDENTIFICATION NUMBER: C-5
LOCATION: T19N RIOE Sec 15

SEAM THICKNESS: 59 cm.

Average Proximate Analysis

| Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|
| AI | 44.0 | 47.8 | 10.6 | 41.6 | AD | 23.5 | 48.1 | 10.4 | 41.5 |

Average Petrographic Analysis

| Textinite | Ulminite | Humo-Detrinite | Gelinite | Corpo-Huminite | Fusinite | Semi-Fusinite | Liptinite | Reflectance Rm |
|---|---|---|---|---|---|---|---|---|
| 1.0 | 6.9 | 33.1 | 26.9 | 1.4 | 26.3 | 2.6 | 2.6 | .29 |

Discussion:

The proximate analysis data shows a very low ash content and an extremely high fixed carbon content, which indicates a deltaic environment.
The petrographic data shows moderate amounts of humodetrinite, gel inite, and fusinite, which indicates an environment containing both trees and grasses much like that associated with an upland swamp of a delta.

# PART FOUR. CONCLUSIONS

1) Based on the seam thickness and the proximate analysis data, lignite seams are present in Winston and Choctaw counties in potentially economical quantity and quality. The seams which show the best economic potential are W-4, W-8, C-2, and C-5.

2) Reflectance measurements on lignites are useful because they aid in determining the expected calorific yield (Btu) and thus the potential value of these coals. This is possible because as reflectance increases so does the rank, and as the rank increases so does the fixed carbon content, and as the fixed carbon content increases the calorific yield (Btu) increases.

3) The volatile matter content (d.a.f.) in lignites decrease as the reflectance increases. This is because of the increase in the aromaticity of the humic molecule (conversion of open carbon atom chains to closed or ringed carbon atom chains) and the subsequent increase in fixed carbon content.

4) There is a relationship between the ash content and the seam thickness showing that in 12 of the 14 lignite seams investigated in this report, the ash content decreases as the seam thickness increases. This is because a low ash content associated with a high seam thickness indicates a slowly subsiding, highly vegetated environment far enough

removed from any fluvial systen so that humic debris could accumulate uninhibited by any sediment influx. A high ash content associated with a low seam thickness indicates a vegetated environment that has sediment influx from a nearby fluvial system.

5) Historical examination of several wood samples obtained from two lignite seams (W-3 and C-5) investigated in this report have identified the wood as belonging to the family Taxodiacease. This may prove to be a significant contribution to our knowledge of the Tertiary floras and depositional environments associated with the Tertiary lignite deposits in Choctaw and Winston counties.

6) The fixed carbon content increases as the humotelinite and humodetrinite contents increase. This results because more cellular humic material (intact and broken up) has survived in its original state than has been altered by decomposition and/or gélification.

7) The petrographic and proximate analysis data suggests that the lignite deposits of Choctaw and Winston counties are derived from a fluvially controlled environment containing trees, reeds, and grasses. Field observations (as well as Cleaves (1980)) indicate that the Choctaw and Winston county lignite deposits were separated by a relatively large fluvial system trending NE to SW with a stream size on the order of

that like the Biloxi/Pascagoula River rather than that of a larger river such as the Mississippi. The presence and identification of woody parts in several of the lignite seams represent a taxodium (upland swamp) freshwater environment. The lignite seams investigated in this report rarely represent a single time horizon. Thus, a meandering stream system during a time span of 10,000 years or so could appreciaby influence the basin where humic accumulation is occurring and cause somewhat erratic ash contents in seams located very close to each other laterally but not necessarily time stratigraphically.

8) The lignite deposits in Winston and Choctaw counties were formed in a fluvially controlled taxodium (upland swamp) environment containing trees, reeds, and grasses. These deposits differ from those identified by Wright and Froelicher (in press) in Lauderdale county which indicate a back-barrier or back-shore environment to 10 km behind a barrier. Additional evidence of a freshwater upland environment associated with the lignite deposits in Winston and Choctaw counties are the low ash contents in some seams (i.e. W-1, W-4, W-8, C-2, C-5). In an ongoing project, G. Bonn has found that ash content is high in strongly marine and tidaly influenced freshwater paralic Bayou type areas associated with organic accumulations.

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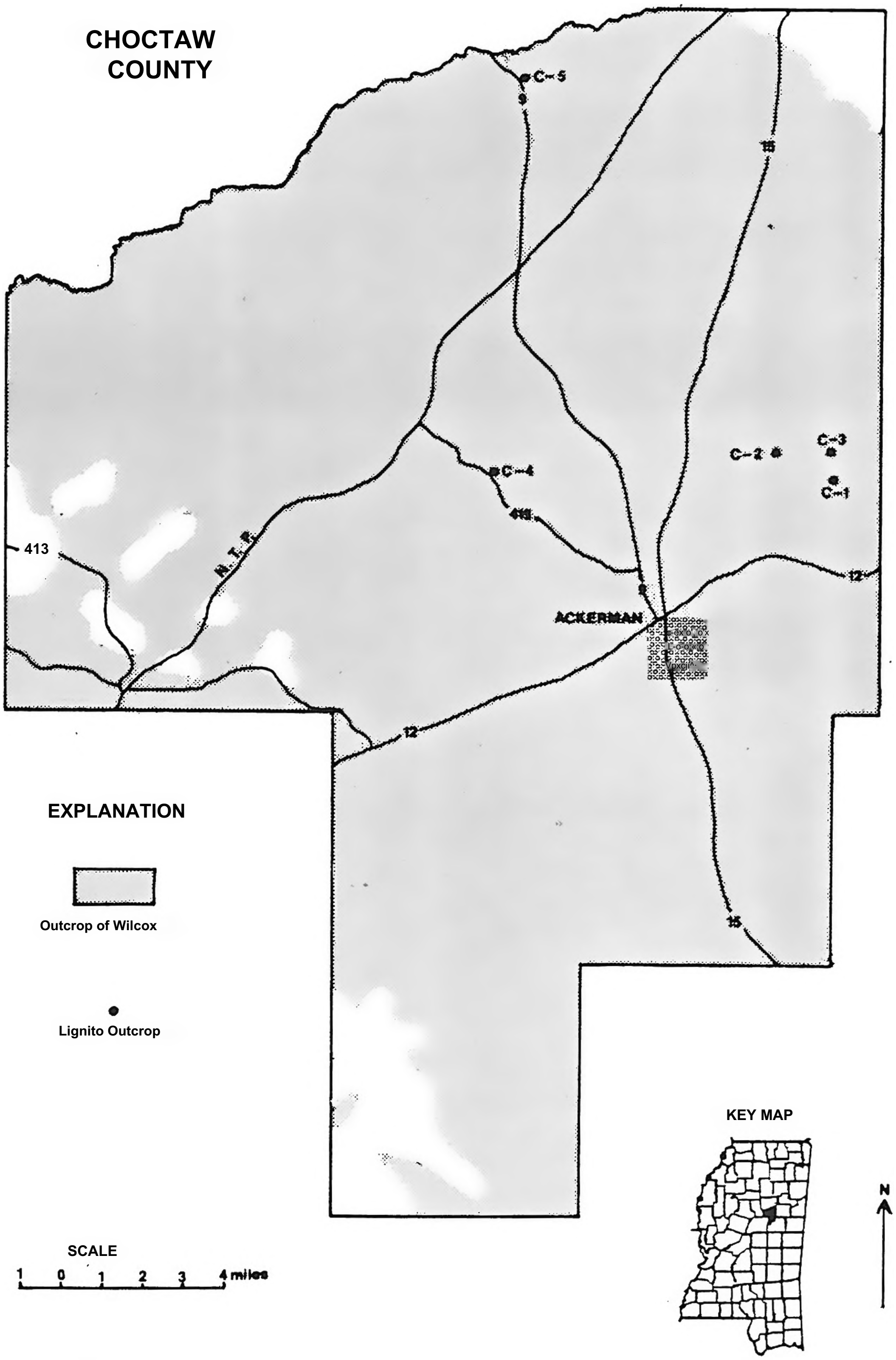
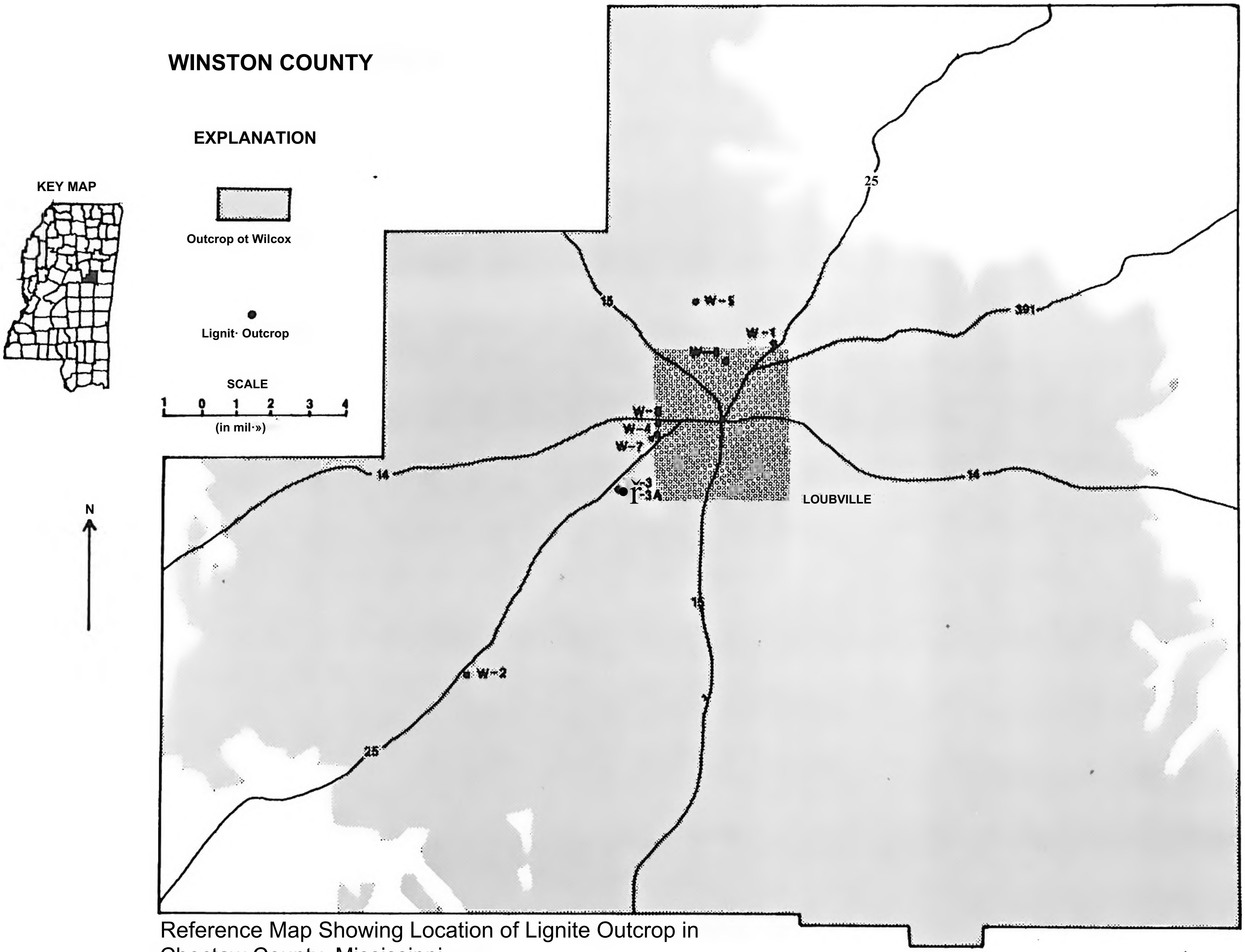
# APPENDIX



Reference Map Showing Location of Lignite Outcrops in Choctaw County, Mississippi.



Reference Map Showing Location of Lignite Outcrop in Choctaw County, Mississippi.

Proximate Analysis Data (in percent)

| Seam | Seam Thickness | Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| W-1 | 8 cm | AI | 50.65 | 42.58 | 18.37 | 39.04 | AD | 39.72 | 39.35 | 14.72 | 45.92 |
| W-2 | 33 cm | AI | 42.90 | 32.82 | 40.47 | 26.71 | AD | 21.82 | 36.31 | 32.39 | 31.30 |
| W-3 | 45 cm | AI | 42.17 | 32.32 | 38.50 | 28.84 | AD | 6.60 | 32.36 | 38.20 | 29.44 |
| W-3A | 21 cm | AI | 38.56 | 25.28 | 56.18 | 18.54 | AD | 27.23 | 25.12 | 56.16 | 18.72 |
| W-4 | 45 cm | AI | 44.76 | 46.60 | 14.79 | 38.61 | AD | 9.79 | 44.44 | 14.83 | 40.72 |
| W-5 | 28 cm | AI | 35.38 | 25.52 | 58.66 | 15.82 | AD | 9.44 | 25.11 | 59.03 | 15.87 |
| W-6 | 26 cm | 'AI | 37.56 | 26.32 | 53.43 | 20.25 | AD | 20.85 | 27.45 | 51.17 | 21.41 |
| W-7 | 18 cm | AI | 42.11 | 43.73 | 23.43 | 32.84 | AD | 26.80 | 43.84 | 23.70 | 32.46 |
| W-8 | 48 cm | AI | 46.40 | 47.40 | 11.74 | 40.85 | AD | 25.18 | 46.98 | 12.21 | 40.82 |
| C-1 | 10 cm | AI | 29.67 | 22.99 | 67.84 | 9.16 | AD | 12.25 | 23.51 | 67.85 | 8.64 |
| C-2 | 48 cm | AI | 54.42 | 48.82 | 23.26 | 27.92 | AD | 16.17 | 48.85 | 23.59 | 27.56 |
| C-3 | 15 cm | AI | 20.92 | 21.47 | 71.99 | 6.54 | AD | 13.07 | 21.10 | 71.99 | 6.90 |
| C-4 | 36 cm | AI | 36.83 | 30.42 | 46.34 | 23.24 | AD | 12.98 | 30.23 | 46.68 | 23.09 |
| C-5 | 59 cm | AI | 44.02 | 47.84 | 10.57 | 41.59 | AD | 23.46 | 48.13 | 10.42 | 41.45 |

<u>Explanation</u>:

"W" denotes Winston County.
"C" denotes Choctaw County.

AI represents "as is".
AD represents "air dried".

## Petrographic Analysis Data (in percent)

| Sample | Thickness | Textinite | Ulminite | Humodetrinite | Gelinite | Corpohuminite | Fusinite | Semifusinite | Liptinite | Reflectance |
|---|---|---|---|---|---|---|---|---|---|---|
| W-2 | 33 cm | 7.4 | 17.0 | 31.3 | 38.9 | 1.9 | 1.2 | 1.5 | 0.8 | .36 |
| W-3 | 45 cm | 1.5 | 8.8 | 43.5 | 35.1 | 1.9 | 6.1 | 2.3 | 0.4 | .36 |
| W-3A | 21 cm | 2.4 | 23.8 | 4.8 | 65.6 | 1.4 | 1.8 | 0.2 | 0.2 | .34 |
| W-4 | 45 cm | 5.4 | 3.7 | 53.8 | 23.7 | 1.8 | 8.3 | 3.2 | 0.3 | .41 |
| W-5 | 28 cm | 1.4 | 4.1 | 21.6 | 62.6 | 5.7 | 2.5 | 2.0 | 0.3 | .24 |
| W-6 | 26 cm | 4.4 | 1.2 | 53.9 | 13.7 | 0.1 | 22.0 | 4.4 | 0.3 | -- |
| W-7 | 18 cm | 0.0 | 0.4 | 41.8 | 15.4 | 1.8 | 27.2 | 3.4 | 0.2 | .29 |
| W-8 | 48 cm | 0.0 | 4.3 | 40.9 | 41.3 | 1.5 | 5.0 | 2.3 | 4.8 | .33 |
| C-2 | 48 cm | 3.7 | 5.9 | 7.2 | 2.8 | 1.0 | 3.0 | 76.3 | 0.1 | —— |
| C-4 | 36 cm | 5.7 | 8.5 | 46.5 | 31.7 | 1.9 | 3.1 | 2.6 | 0.1 | .27 |
| C-5 | 59 cm | 1.0 | 6.9 | 33.1 | 26.9 | 1.4 | 26.3 | 2.6 | 2.6 | .29 |

# DEPOSITIONAL ENVIRONMENTS OF WILCOX LIGNITES IN CHOCTAW AND WINSTON COUNTIES, MISSISSIPPI

Darren S. Dueitt[1], Franz Froelicher[1], and Samuel W. Rosso[2]

## ABSTRACT

Proximate analyses and petrographic measurements were made on fourteen lignite outcrops from Lower Eocene Wilcox Group sediments in Choctaw and Winston counties in central Mississippi. The lignite exposures appear to be irregular in shape, limited in areal extent, and variable in seam thickness. Locations of lignite deposits appear to be related to ancient fluvial systems, and the shapes and areal extent of the lignite deposits appear to have been determined by the configuration of the ancient basins in which the coal-forming vegetal matter accumulated.

Twelve of the lignite seams showed a negative correlation between ash content and seam thickness. Most of the lignite seams investigated petrographically show a dominance of humodetrinite, indicating that the lignites were formed from herbaceous, cellulose-rich/lignin-poor marsh plants. Several well preserved tree trunks obtained from two lignite seams have been identified as being taxodiaceous and dicotyledonous which indicates a fresh water marsh/swamp environment associated with the lignite deposits.

*Gulf Coast Association of Geological Societies Transactions, v. 35, pp. 347-352.*

## INTRODUCTION

The study of the geology of coals centers around two aspects: first, the depositional setting of the original marsh or swamp environment in which the organic material accumulated and, second, the changes in that organic material as it was buried (i.e., its coalification history) (Ross and Ross, 1984).

Lignites provide an intermediate stage in the coalification series ranging from modern peats to ancient bituminous coals. Lignite is intermediate in properties between peat and bituminous coal and is typically soft, friable, and dark brown to black in color, with a dull luster. Lignite has a heating value of less than 8300 Btu/lb (4607 kcal/kg) on a moist, mineral-matter-free basis (ASTM, 1976).

The most extensive lignite deposits in Mississippi occur in the Upper Paleocene to Lower Eocene non-marine strata of the Wilcox Group (Williamson, 1976). Less extensive deposits are found in the Claiborne Group (Middle Eocene) and the Midway Group (Paleocene). The lignite deposits of Mississippi were first studied by Brown (1907), who described the known occurrences of coal in the state and provided some general information on the properties of the coals. Several doctoral dissertations concerning palynology of some Mississippi lignites have been completed (Roux, 1958; Wärter, 1965; and Stewart, 1971). Many of the state geological survey reports (Mellen, 1939; Foster, 1940; Vestal, 1943; Hughes, 1958; and Parks, 1961 ) provide brief descriptions of lignite, but relatively few of the investigators have dealt specifically with lignite deposits. The most extensive work done to date on Mississippi lignite is that of Williamson (1976). His report served as a preliminary guide to potential lignite outcrops in the two counties investigated in this study. To date, no petrographic studies of Mississippi lignites have been published.

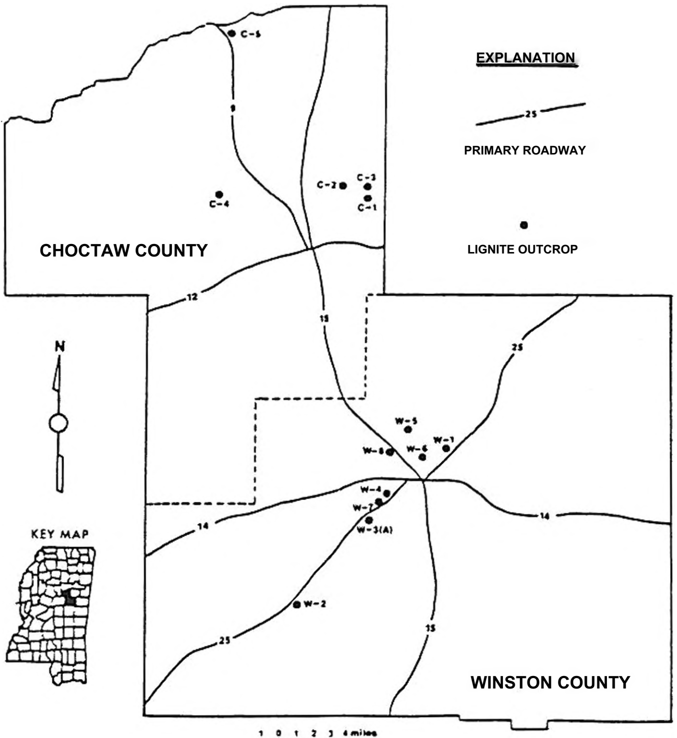


**Figure 1. Reference map showing the location of lignite outcrops in Choctaw and Winston counties with respect to primary roadways.**

## STRATIGRAPHY

In Mississippi, the Wilcox Group is exposed in an arcuate belt which extends from the north-central to the east-central parts of the state. The outcropping Wilcox Group in Mississippi is composed predominantly of non-marine sediments deposited on a broad flat coastal plain. These sediments are about 215 meters thick in Lauderdale County and thin in north-central and northern Mississippi to less than 30 meters at the Tennessee line. The complexity of the Wilcox is made difficult and confusing by problems concerning stratigraphic nomenclature and attempts at subdivision by various geologists during the past 125 years (Williamson, 1976).

In Choctaw and Winston counties, the Wilcox Group consists primarily of continental sediments devoid of

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stratigraphically valuable marker beds. Rapid changes in the lithology, thickness, and lateral continuity of individual beds caused by the complexity of the fluvial and transitional sedimentary sequences have caused many writers to conclude that it is impractical to divide the Wilcox sediments of central and northern Mississippi into formational units. The Wilcox sediments, termed 'Wilcox Group Undifferentiated," overlie the Upper Paleocene Naheola Formation (Midway Group) and underlie the Middle Eocene Tallahatta Formation (Claiborne Group) (McGlothlin, 1944). Included in the Wilcox Undifferentiated sequence are complex deltaic, fluvial, and paludal sedimentary sequences (Self and Williamson, 1977).

## METHODOLOGY

### Sample Collection

At each lignite outcrop, a channel was cut a minimum of 45 cm horizontally into the lignite seam in order to obtain fresh samples exposed to a minimum amount of oxidation and weathering.

Lignite samples were taken perpendicular to the dip of the lignite exposure in order to aid in the sampling process and to insure correct measurements of the seam thickness and sample intervals. Each sample interval represented approximately 15 cm of the lignite seam.

The lignite samples were immediately placed into Ziploc® freezer bags labelled with the appropriate sample letter, number, and interval and then stored in an ice chest in order to keep the sample out of direct sunlight until it was taken to the laboratory, where proximate analysis was performed according to standard techniques prescribed by ASTM (1958).

### Maceral Counts

Three representative particulate pellets were made for each lignite seam. A 500-point maceral count was performed on two of the three pellets of each seam with a Leitz MPV 77 reflectance and fluorescence microscope. The two counts were summed and calculated as a percent of the total of 1000 points. The point counts represent volumetric percentages of each maceral per lignite seam. Maceral counts and reflectance measurements were not made on 3 seams (W-1, C-1, and C-3) of the 14 examined because the seam thickness was less than 15 cm, so it was felt that these analyses would not be significant.

The accuracy of analysis for 1000 measuring points is approximately ±2 percent, irrespective of whether macerals, maceral groups, microlithotypes, or the composition of the microlithotypes are determined (ICCP, 1971). Points were counted on a 0.4 by 0.4 mm grid system when possible. However, because the counts were done on a mineral-matter-free basis, and most lignites contain a fair amount of mineral matter, the grid was often altered slightly so that a humic maceral could be counted.

### Reflectance Measurements

Reflectance measurements were taken on the maceral gelinite (brown coal equivalent of the hard coal maceral vitrinite) because of its homogeneity. A maximum of 25 measurements were taken per pellet for a maximum of 50 per seam. In addition to the three seams previously discussed (i.e., W-1, C-1, and C-3) for which no reflectance measurements were made, two other lignite seams (W-6 and C-2) were not analyzed for their reflectance characteristics. Seams W-6 and C-2 had insufficient amounts of homogenous gelinite to make a significant number of reflectance measurements.

### Data Analysis

The Pearson Product Moment correlation coefficients were computed to determine the relationship between ash content and seam thickness. Slope and y-intercept were calculated to illustrate the correlations graphically.

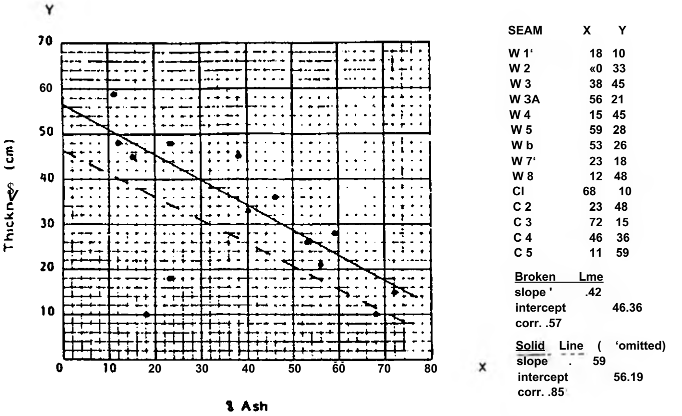

**Figure 2. In 12 out of 14 seams investigated, the ash content decreases as the seam thickness increases. (Seams W-1 and W-7 probably represent isolated, shallow depressions.)**

## RESULTS AND DISCUSSION

### Nature And Location Of Lignite Seams

The outcropping lignite deposits investigated in Choctaw and Winston counties appear to be irregular in shape, limited in areal extent, and variable in seam thickness. These lignite seams range from a few centimeters to approximately 60 centimeters in thickness. Other lignite seams encountered in drill holes in Choctaw and Winston counties are reported to reach a maximum thickness of 2.5 and 3.5 meters respectively (Williamson, 1976). The shapes and areal extent of the investigated lignite deposits appear to have been determined by the configuration of the ancient basins (swamps, bogs, bayous, marshes, and abandoned stream channels) in which the coal-forming vegetal matter accumulated.

Locations of the studied lignite outcrops in Choctaw and Winston counties are shown in figure 1. Fourteen lignite outcrops were found and examined in this study; detailed locations of the lignite exposures are listed in Dueitt (1985). Five seams in Choctaw County and nine seams in Winston County were subjected to proximate and petrographic analysis.

### Laboratory Analyses Results

A total of 14 lignite exposures were investigated and proximate analyses performed on each. Petrographic analyses were made on 11 of these 14 exposures and reflectance measurements were conducted on 9 of the 11 exposures investigated petrographically. The individual seam averages of the proximate and petrographic analyses are listed in Tables 1 and 2, respectively. Complete data from

**Table 1. Average proximale analysis results of the lignite deposits investigated in Choctaw and Winston counties, Mississippi.**

| Seam | Seam Thickness | Condition | Moisture | Volatiles | Ash | Fixed Carbon | Condition | Moisture | Volatiles | Ash | Fixed Carbon |
|---|---|---|---|---|---|---|---|---|---|---|---|
| W-1 | 8 cm | Al | 50.65 | 42.58 | 18.37 | 39.04 | AD | 39.72 | 39.35 | 14.72 | 45.92 |
| W-2 | 33 cm | AI | 42.90 | 32.82 | 40.47 | 26.71 | AD | 21.82 | 36.31 | 32.29 | 31.30 |
| W-3 | 45 cm | Al | 42.17 | 32.32 | 38.50 | 28.84 | AD | 6.60 | 32.36 | 38.20 | 29.44 |
| W-3A | 21 cm | Al | 38..56 | 25.28 | 56.18 | 18.54 | AD | 27.23 | 25.12 | 56.16 | 18.72 |
| W-4 | 45 cm | AI | 44.76 | 46.60 | 14.79 | 38.61 | AD | 9.79 | 44.44 | 14.83 | 40.72 |
| W-5 | 28 cm | AI | 35.38 | 25.52 | 58.66 | 15.82 | AD | 9.44 | 25.11 | 59.03 | 15.87 |
| W-6 | 26 cm | AI | 37.56 | 26.32 | 53.43 | 20.25 | AD | 20.85 | 27.45 | 51.17 | 21.41 |
| W-7 | 18 cm | Al | 42.11 | 43.73 | 23.43 | 32.84 | AD | 26.80 | 43.84 | 23.70 | 32.46 |
| W-8 | 48 cm | AI | 46.40 | 47.40 | 11.74 | 40.85 | AD | 25.18 | 46.98 | 12.21 | 40.82 |
| C-1 | 10 cm | AI | 29.67 | 22.99 | 67.84 | 9.16 | AD | 12.25 | 23.51 | 67.85 | 8.64 |
| C-2 | 48 cm | AI | 54.42 | 48.82 | 23.26 | 27.92 | AD | 16.17 | 48.85 | 23.59 | 27.56 |
| C-3 | 15 cm | Al | 20.92 | 21.47 | 71.99 | 6.54 | AD | 13.07 | 21.10 | 71.99 | 6.90 |
| C-4 | 36 cm | AI | 36.83 | 30.42 | 46.34 | 23.24 | AD | 12.98 | 30.23 | 46.68 | 23.09 |
| C-5 | 59 cm | AI | 44.02 | 47.84 | 10.57 | 41.59 | AD | 23.46 | 48.13 | 10.42 | 41.45 |

Explanation: V denotes Winston County. "C" denotes Choctaw County. AI represents "as is."AD represents "air dried."

Table 2. **Average petrographic analysis results of the lignite deposits investigated in Choctaw and Winston counties, Mississippi.**

| Seam | Seam Thickness | Textinite | Ulminite | Humo-detrinite | Gelinite | Corpo-huminite | Fusinite | Semi-fusinite | Liptinite | Reflectance |
|---|---|---|---|---|---|---|---|---|---|---|
| W-2 | 33 cm | 7.4 | 17.0 | 31.3 | 38.9 | 1.9 | 1.2 | 1.5 | 0.8 | .36 |
| W-3 | 45 cm | 1.5 | 8.8 | 43.5 | 35.1 | 1.9 | 6.1 | 2.3 | 0.4 | .36 |
| W-3A | 21 cm | 2.4 | 23.8 | 4.8 | 65.6 | 1.4 | 1.8 | 0.2 | 0.2 | .34 |
| W-4 | 45 cm | 5.4 | 3.7 | 53.8 | 23.7 | 1.8 | 8.3 | 3.2 | 0.3 | .41 |
| W-5 | 28 cm | 1.4 | 4.1 | 21.6 | 62.6 | 5.7 | 2.5 | 2.0 | 0.3 | .24 |
| W-6 | 26 cm | 4.4 | 1.2 | 53.9 | 13.7 | 0.1 | 22.0 | 4.4 | 0.3 | — |
| W-7 | 18 cm | 0.0 | 0.4 | 41.8 | 15.4 | 1.8 | 36.8 | 3.4 | 0.2 | .29 |
| W-8 | 48 cm | 0.0 | 4.3 | 40.9 | 41.3 | 1.5 | 5.0 | 2.3 | 4.8 | .33 |
| C-2 | 48 cm | 3.7 | 5.9 | 7.2 | 2.8 | 1.0 | 3.0 | 76.3 | 0.1 | — |
| C-4 | 36 cm | 5.7 | 8.5 | 46.5 | 31.7 | 1.9 | 3.1 | 2.6 | 0.1 | .27 |
| C-5 | 59 cm | 1.0 | 6.9 | 33.1 | 26.9 | 1.4 | 26.3 | 2.6 | 2.6 | .29 |

which the individual seam averages were derived are listed in Dueitt ( 1985). The proximate analysis was conducted using a Fisher 490 Coal Analyzer, which enables the determination of the three coal constituents as well as the initial moisture content.

The moisture content is determined by the amount of weight lost from a lignite sample that has been placed in an oven for 60 minutes at 107° C. Once the moisture is removed from the sample, the three constituents which make up coal (i.e., volatile matter, ash, and fixed carbon) can be determined by the proximate analysis procedure established by ASTM and employed by the Coal Analyzer. Those three constituents (volatile matter, ash, and fixed carbon) are calculated on a dry percentage basis with all three adding up to 100 percent (Table 1).

An interesting relationship was found between seam thickness and ash content. In 12 out of 14 seams investigated, the ash content decreased as the seam thickness increased (fig. 2). The ash content represents the non-combustible material in coals and is composed of various amounts of clay, silica, sulfide, and carbonate minerals. A low ash content associated with a high seam thickness might indicate a slowly subsiding, highly vegetated environment far enough removed from fluvial influences so that humic debris could accumulate uninhibited by sediment influx. A high ash content associated with a low seam thickness might indicate a rapidly subsiding environment in which vegetation growth could not keep pace with subsidence; an environment in which the vegetation growth was not particularly dense; or an environment in which the accumulation of humic debris was inhibited by sediment influx from a nearby fluvial system. We presume that the latter case is the most likely, that lignites deposited in Choctaw and Winston counties were deposited in an environment in which the accumulation of humic debris was inhibited by sediment influx from a nearby fluvial system.

Seams W-1 and W-7 differ from the general negative correlation between ash content and seam thickness (fig. 2). They probably represent isolated, shallow depressions initially removed from any appreciable sediment influx, but whose humic accumulation was interrupted by rapid sediment influx or a sudden rise or fall in the water table.

Field observations as well as previous studies by Galloway (1968) and Cleaves (1980) indicate that the Wilcox sediments of Choctaw and Winston counties were deposited in association with active fluvial systems trending northeast to southwest (fig. 3). Lignite outcrops were found between massive sand bodies observed in the field, apparently representing the fluvial systems described by Cleaves (1980). This pattern indicates that the lignite deposits are associated with these fluvial systems and represented swamp environments found between or on the flanks of active stream channels.

On-site field studies of the Wilcox lignite outcrops in Winston County seam W-3A and Choctaw County seam C-5 revealed several horizontally-positioned, intact tree trunks. The trunk specimens collected from the Choctaw site (C-5) exhibited both bark and wood tissues whereas the specimens from the Winston site (W-3A) consisted solely of wood tissues. The presence of intact bark and wood in the Choctaw specimen and the general textures of all specimens suggest that these trunks were buried by organic debris within a relatively short time following submersion in anoxic waters.

Wood samples from both localities were processed for histological examination according to procedures described in Johansen (1940) and Foster (1949). Microscopic examination of the cross-sections of the Choctaw wood showed that severe compression of the th inner-walled springwood tracheids had occurred and that cell walls of both the spring and summer wood cells had undergone extensive delignification.

The crossfield pitting of the vascular rays, pitting characteristics of the axial tracheids, ray widths, predominance of tracheids, lack of vessel elements and resin canals, and presence of scattered axial parenchyma cells indicate that the Choctaw woods are comparable to woods described for both modern and extinct species of the family Taxodiaceae (Ramanujam and Stewart, 1968).

Considering the moist environment in which most lignite-producing species were living, it is not surprising to find taxodiaceous specimens in the sites. It is well documented (Arnold and Lowther, 1955) that the late Cretaceous and early Tertiary were periods in which several taxodiaceous groups, including Seęwña, *Taxodium,* and *Metasequoia,* were evolving. Also, fossil woods and foliage of several extinct taxodiaceous genera are common in certain early Tertiary strata (Ramanujam and Stewart, 1968). The Choctaw specimens show affinities with the extinct taxodiaceous genera as well as with the modern *Taxodium* that was mentioned above.

The presence of vessel elements, wide rays, and the lack of resin cells and/or resin canals indicate that the Winston County wood specimens are remains of a medium to large-sized angiosperm tree. Although positive identification to family level has not been made, comparative analyses show that the wood anatomy is markedly different from silicified angiosperm woods described by Blackwell et al. (1980) from Tertiary sites in Mississippi.

The petrographic analysis data show that the lignite seams investigated in Choctaw and Winston counties contain a dominant amount of the maceral humodetrinite (see Table 2). According to Stach et al. (1982), large amounts of humodetrinite represent reed-dominated brown coal deposits consisting of poorly lignified and correspondingly relatively cellulose-rich plants. In contrast, large amounts of the macerals textinite and ulminite would represent *Taxodium*-like woody swamp plants whose cells are lignified and are very resistant to material, structural, and biochemical decomposition.

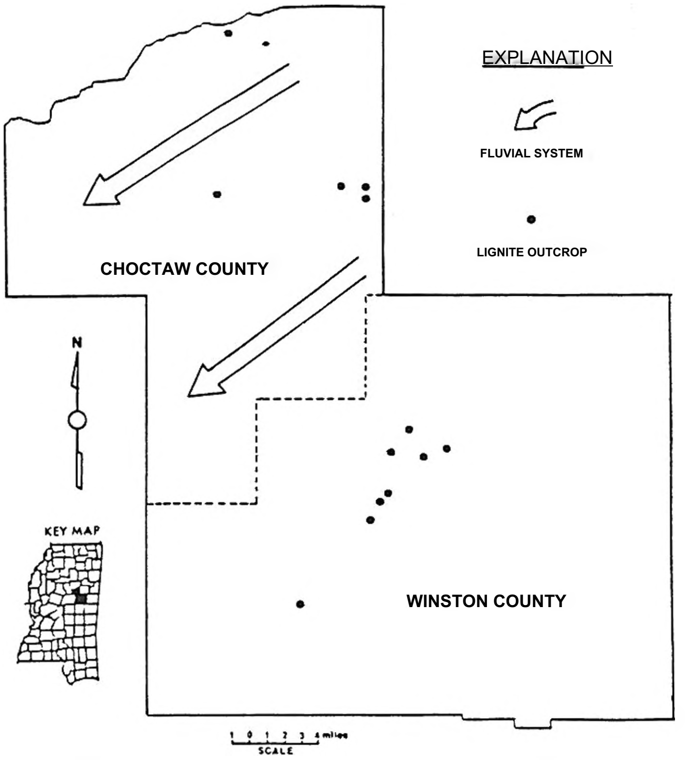

**Figure 3. Major fluvial systems identified by Cleaves (1980) and the locations of lignite exposures investigated in this study.**

Comparison of the cellular humic material content (textinite and ulminite) with the macerated humic material content (humodetrinite) in the lignite seams examined in this study can give an indication to the physical and botanical environment present during the period of humic accumulation. The data show a clear division into seams dominated by the macerated humic material maceral humodetrinite (Area A), and seams dominated by the cellular humic material macerals textinite and ulminite (Area B) (fig. 4). According to the paleoecological model presented in Stach et al. (1982), most of the lignite deposits examined in this study were formed from herbaceous, cellulose-rich/lignin-poor marsh plants.

## CONCLUSIONS

1. In 12 of the 14 lignite seams investigated in this study, the ash content decreased as the seam thickness increased. This is believed to be related to terrigenous sediment influences from nearby fluvial systems.

2. Histological examination of several wood samples obtained from two lignite seams (W-3A and C-5) investigated in this study has tentatively identified the wood as being taxodiaceous (C-5) and dicotyledonous ( W-3A). This supports the conclusion of a fresh water environment associated with the lignite deposits.

3. Most of the lignite seams investigated petrographically show a dominance of humodetrinite. This indicates a paleoenvironment dominated by herbaceous, cellulose-rich/lignin-poor marsh plants.

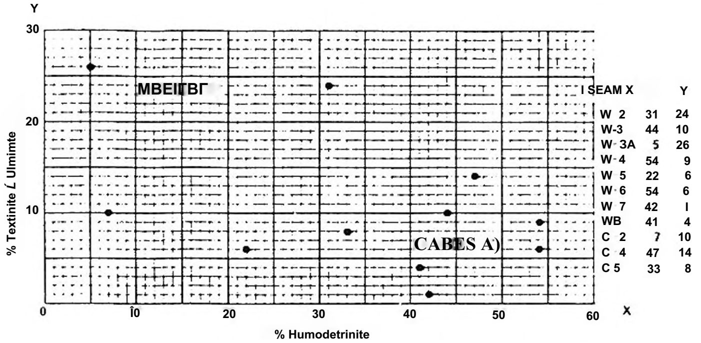

**Figure 4. Cellular humic maceral (textinite and ulminite) content versus the macerated humic maceral (humodetrinite) content. Most of the seams show a dominance of humodetrinite, indicating the lignite deposits were formed primarily from herbaceous, cellulose-rich/lignin-poor marsh plants (Area A).**

## ACKNOWLEDGMENTS

We thank the Mississippi Mineral Resources Institute for funding this investigation (grant 84-2F), and Dr. James Hower and his staff at the University of Kentucky Institute for Mining and Minerals Research at the Kentucky Center for Energy Research Laboratory in Lexington, Kentucky, for the use of their microscope equipment and other courtesies. Special thanks is also reserved for Laurie Dueitt for her clerical assistance in preparing the manuscript.

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# CHARACTERISTICS OF ORGANIC-RICH DEPOSITS OF COASTAL HANCOCK COUNTY, MISSISSIPPI

Gregory N. Bonn[1] and Franz Froelicher[2]

## ABSTRACT

The brackish marshes of coastal south Hancock County, Mississippi, consist largely of organic sediments that range in ash content from 27 to 92 percent (dry basis) and average around 55 percent. Results from 11 piston cores and 382 Macaulay cores taken along five traverses, coupled with proximate analyses, have established the most organic-rich sites in the marginal deltaic study area. These sites, which consist of very peaty sediment up to 1.5 meters thick, occur as channel-fill deposits near the Pleistocene mainland and blanket deposits between the levees of some of the larger tidal creeks meandering through the central portion of the study area.

Factors influencing the development of the organic-rich deposits are: 1) presence of channel-like depressions in the underlying topography, which initially were favorable accumulation sites; 2) location distal to estuarine-lagoonal and deltaic environments, which are sources for silts and clays deposited within the organic material; 3) protection by nearby or adjacent higher topography during periodic inundation; 4) in some cases, ability of marsh vegetation to accrete upward while keeping pace with sea level in response to locally subsiding older beach deposits; and 5) effectiveness of plant baffling relative to the previously mentioned factors.

Despite the high organic content of these deposits, good quality coals would not be expected to form upon coalification due to the high silt and clay content and absence of thick accummulations. Coals resulting from the channel-fill deposits would tend to occur as thin stringers less than 1 meter thick, while blanket deposits would produce even thinner coals interbedded with carbonaceous shales.

## INTRODUCTION

The study of organic-rich deposits (peats) is of interest because: 1) it helps to understand some of the depositional and chemical processes that occur prior to the formation of coal; and 2) may add to the understanding of the quality and distribution of coals within ancient environments.

The coastal marshland along southern Hancock County, Mississippi, represents an area where merging deltaic and estuarine-lagoonal processes have influenced the quality and distribution of *in situ* organic deposits. Consequently, the study area is best described as a marginal deltaic plain characterized by laterally continuous organic deposits, locally variable in ash content and thickness. Organic-rich deposits occurring in a similar Holocene depositional setting in central coastal Louisiana have been studied by Coleman and Smith (1964), Coleman (1966), Kosters (1983), and Kosters and Bailey (1983).

Early investigations by Brown and others (1944), Treadwell (1955), and Kolb and Van Lopick (1958) briefly addressed abandoned beaches in the south Hancock marshland. More recent investigations by Otvos (1973,1978,1981,1982), Otvos and Price (1979), and Pellegrin (1981) focused on the Late Pleistocene-Holocene geomorphology, depositional framework, and evolution of the coastal Hancock study area. Neither of these researchers addressed the near-surface organic deposits in detail or as coal precursors. The objective of this study is to document the quality and distribution of the organic-rich deposits, the factors influencing the development of these deposits, and their potential as coal precursors.

## DESCRIPTION OF STUDY AREA

The south Hancock marshland occupies approximately 30 square kilometers (19 square miles) along the extreme southwest portion of coastal Mississippi (fig. 1). The study area is bound to the west by the East Pearl River and Mulatto Bayou, and along the eastern margin by Mississippi Sound. The Late Pleistocene Port Facility Ridge (Pellegrin, 1981) and Magnolia Ridge, a Holocene barrier trend (Otvos, 1978), comprise the northern limit, while Lake Borgne and Grand Island Pass from the southern boundary. Within these limits meandering tidal creeks are markedly abundant, slowly draining and flooding the marsh during extremes of the normally occurring diurnal microtidal regime. Salinities are typically brackish due to Pearl River discharge mixing with waters of Lake Borgne and Mississippi Sound. The vegetation within the study area is dominated by *Juncus roemerianus* (Scheele). The moderate to low salinity, poor drainage, and subtropical climate provide a thriving environment for this member of marsh plant community. Species of lesser occurence include *Spartina patens* (A.T.) (Muhi), *Spartina cynosuroides* (L.) (Roth) and *Scirpus olneyi* Gray. Stranded beach deposits (Campbell Island, Point Clear Island and Magnolia Ridge), shell middens, tidal creek levees, and spoil deposits represent the topographic highs within the marsh. These features are vegetated with deciduous trees, evergreens and scrub brush, highlighting their presence.

The blocking effect created by the prograding St. Bernard subdeltas of the Mississippi River occurred around 2900-2600 years ago (Frazier, 1967), converting the once open nearshore marine study area into a marginal deltaic plain. Although the St. Bernard Subdeltas are no longer active, their remnants and the present-day Pearl River Delta help to reduce erosion and maintain the marginal deltaic environment. Nearshore processes are influenced by remnant St. Bernard delta morphology and Pearl River deltaic processes interacting with the estuarine-lagoonal regime of Mississippi Sound and Lake Borgne.

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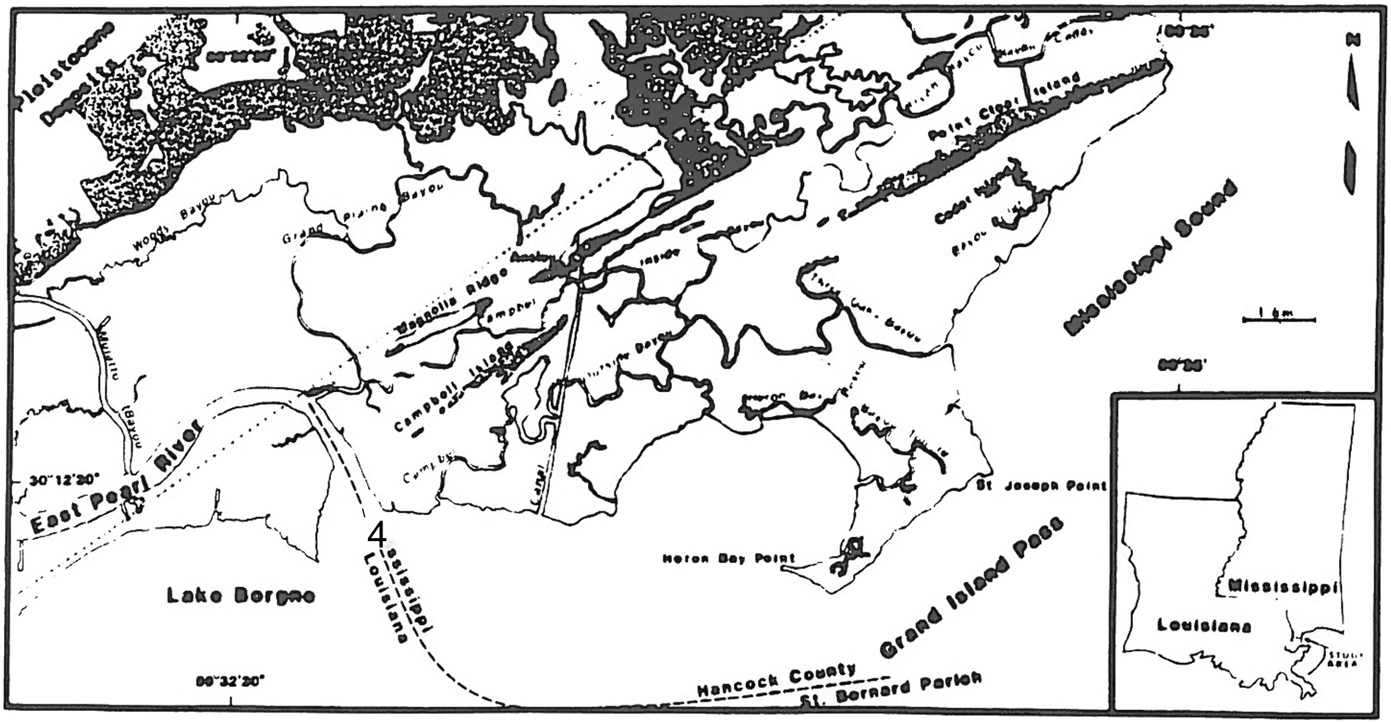

Figure 1. Index map of study area.

**Stratigraphy and Sedimentology**

Holocene near-surface sediments in the (Coastal Hancock) study area represent a regional transgressive and localized regressive-transgressive sequence of initial estuarine, beach, nearshore, lagoon-bay, brackish marsh, natural levee and active shoreline sedimentary environments (fig. 2). Initial estuarine and stranded beach deposits represent regional transgressive and laterally migrating coastal sedimentary environments prior to St. Bernard Delta development. Nearshore, lagoon-bay, brackish marsh, natural levee and active shoreline deposits represent the more recent regressive-transgressive phase reflecting the proximity (development and abandonment) of the St. Bernard Delta over the past 2900 years.

These sedimentary deposits are best recognized by their variation in sediment type (fig. 2). Stranded beach deposits consist of moderately to well-sorted fine sand; nearshore and estuarine deposits are made up of muddy sand-sandy mud; and lagoon-bay deposits are composed of silty clay. For the purpose of this study these deposits represent the lower clastic sequence (fig.2).

Marsh deposits consist of three organic sediment subfacies; slightly organic mud, peaty mud and very peaty mud. These terms are based on the dry weight percentage of inorganic material (ash). The classification of organic sediments applied to this study has been adopted from the work of Ingram (pers, comm., 1984) and Otte (1984) from their investigations of North Carolina peat resources (fig. 3). Marsh deposits together with natural levee, spoil and active shoreline deposits compose the upper sequence.

## FIELD SAMPLING

Two devices were employed to collect sediment samples. The first was the piston core (method) descrived by Cohen and Spackman (1972). This device was used to take eleven 7.6 centimeter (3 inch) diameter cores up to 3.9 meters (12.8 feet) below the marsh surface at suspected peat localities (fig. 4). The cores were taken back to the laboratory where they were cut open and described in detail for their sedimentological content. The second method utilized the Macaulay soil auger. Five traverses were sampled in a northwest to southeast direction across the study area (fig. 4). Thirty-five centimeter (14 inch) continuous core segments were described in the field at 50 meter spacings along each traverse until sand or clay was encountered. At approximately 250 meter spacings, organic-rich samples were collected at 0.5 meter (1.6 feet) or 1 meter (3.28 feet) depth intervals. These samples were taken back to the laboratory and analyzed for organic content by proximate analysis. Cores were also taken intermittently between traverses along two northeast to southwest trends. Because the Macaulay sampler was lightweight and easy to use, it provided the majority of information obtained through field mapping. However, it was inferior to the piston coring method when analyzing detailed sedimentological and stratigraphic characteristics.

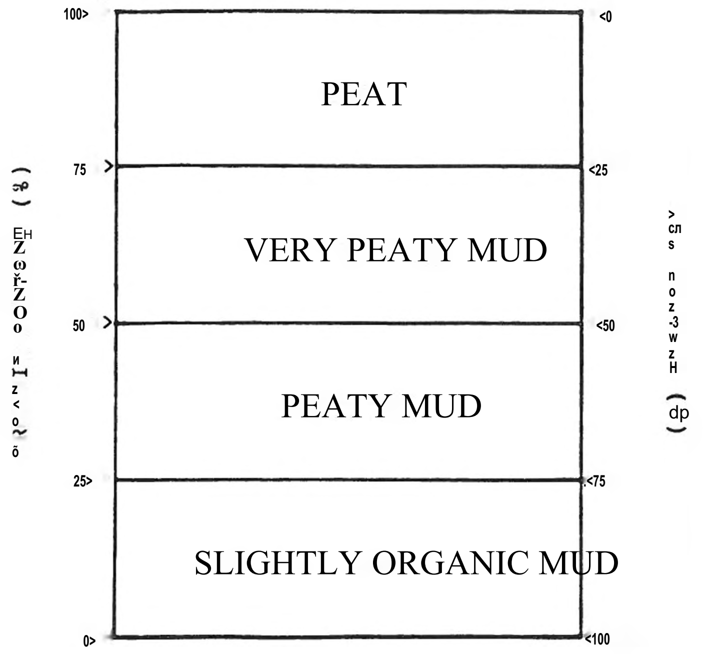

**Figure 3. Classification system for organic sediments used in this study; modified from Ingram (pers, comm., 1984) and Otte (1984). Sediments with more than 25 percent organic matter are considered to be "organic-rich" in this paper.**

## LABORATORY METHODS

Organic samples collected by Macaulay and piston core methods were analyzed first for moisture content. Moisture analysis was performed by both air and oven dry methods. The first method involved air drying 100-300 gram bulk samples at 35°C according to the University of North Dakota Energy Research Center (UNDERC) procedure (Schelkoph and others, 1983). The purpose of this procedure was to minimize the effects of ashing. The second method involved oven drying a 10-12 gram test specimen at 105°C for 16 hours as prescribed by the American Society for Testing and Materials (ASTM) procedure D 2974-71. Moisture data obtained by the ASTM method were usually only a few percent higher than the air dry method.

Air dried samples were prepared and analyzed according to the UNDERC procedure for proximate analysis of peats (Schelkoph and others, 1983). The percentages of volatile matter, ash, and fixed carbon were calculated on a moisture-free basis. Volatile matter was determined at 950°C for 3 minutes while the percent ash was determined at 750°C for 3½ hours. Ten samples were analyzed twice according to this procedure and each produced a difference of less than 1 percent. Hence, it seemed unnecessary to analyze sampled more than once in order to obtain average values. A total of 283 samples were analyzed by proximate analysis. These data are listed in Bonn (1986).

## RESULTS AND DISCUSSION

### Proximate Analysis

Analyses of the organic sediments indicates much variation in moisture content and the dry weight percentages of volatile matter, ash, and fixed carbon. Moisture content varies betwen 80-90 percent in the most organic-rich samples, while the organic-poor samples often contain less than 70 percent moisture. The amount of mineral sediment (ash) appears to be the primary factor controlling the moisture content in the organic sediments. A high percentage of mineral matter results in less pore space available for water content upon saturation. In most of the study are, below the top meter, ash content generally increases with depth and reflects this decrease in moisture. The effects of compaction are considered to be slight in the near-surface organic sediments and probably do not influence the moisture content noticeably.

Dry weight percentages of volatile matter, ash, and fixed carbon have been determined at each sample collection site along the 5 traverses. Considering all sites, the ash content varies between 27-92 percent and averages around 55 percent. Volatile matter ranges between 10-45 percent and averages about 25 percent. The fixed carbon content is least variable ranging between less than 1-25 percent and averaging roughly 15 percent. ASTM (1969) defines peat as organic mat of plant origin with less than 25 percent ash on a moisture-free basis. According to this definition, peat is not present. Within these ranges the dry weight percentages of volatile matter, ash and fixed carbon vary from site to site. Except for several organic-rich deposits, most of the organic material in the study area contains more ash than total organic matter (volatile matter and fixed carbon). Considering only the organic fraction, volatile matter is 2-3 times greater than the amount of fixed carbon. These characteristics are not unusual considering the highly decomposed texture of the organic-rich sediment and depositional setting of the study area.

Proximate analyses of the organic sediments in piston cores 1-11 (Sites 1-11) reveal vertical variation in their constituents. Near the surface, the dry weight percentages of volatiles, ash, and fixed carbon range around 20-45 percent, 40-75 percent and 5-15 percent, respectively. At depths exceeding 1 meter, the volatile matter, ash, and fixed carbon values vary between 5-20 percent, 65-90 percent and 0-10 percent, respectively. Although these percentages vary with increasing depth, the general trend is that ash increases while volatile matter and fixed carbon decrease with depth. The ratio of volatile matter to fixed carbon averages about 2.5 to 1 and does not appear to change significantly with increasing depth.

### Quality and Distribution of Organic-rich Deposits

Deposits of very peaty mud range up to 1.5 meters thick and occur in four main areas. Deposit I (fig. 5) is looted directly seaward of central Magnolia Ridge. Deposit II occurs above the submerged southwest end of Point Clear Island. Deposit III is located behind Magnolia Ridge and Deposit IV is found directly seaward of the Pleistocene mainland (fig. 5). Deposits of very peaty mud probably formed in these select areas due to: 1) the presence of channel-like depressions in the underlying topography which initially were favorable accumulation sites; 2) the location distal to Lake Borgne, Mississippi Sound, and the Pearl River Delta where suspened sediment is most

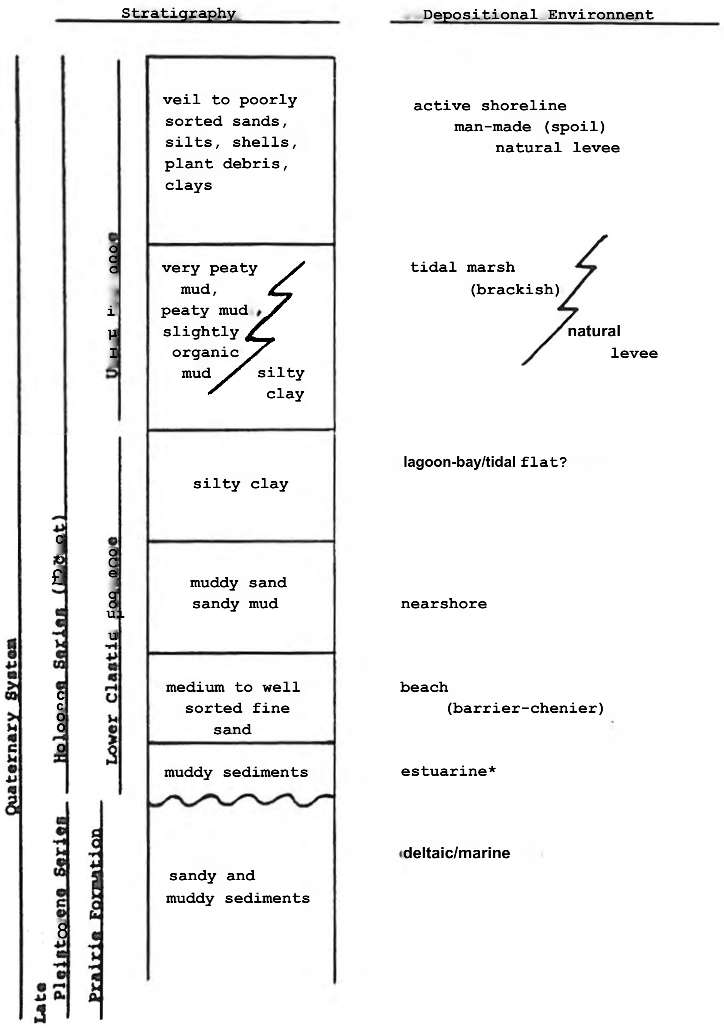

**Figure 2. Stratigraphy and depositional environment of Holocene sediments in the south Hancock study area. Asterisk indicates unsampled deposits previously described by Otvos (1978); from Bonn (1986).**

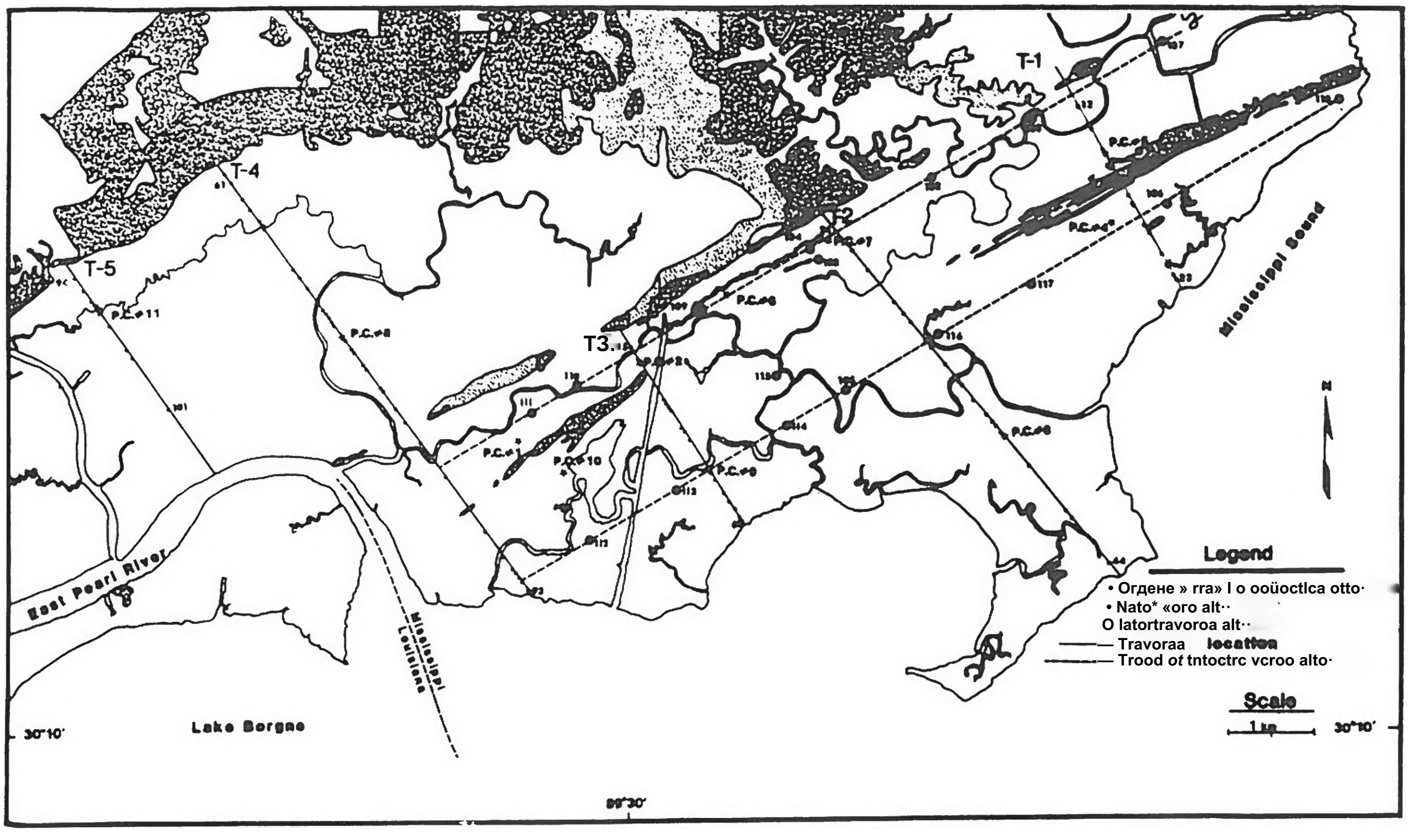

Figure 4. Traverse location map with sample collection sites.

abundant; 3) greater protection by nearby or adjacent higher topography during periodic inundation; 4) in some situations, ability of marsh vegetation to accrete upward while keeping pace with sea level in response to locally subsiding older beach deposits; and 5) effectiveness of plant baffling relative to the previously mentioned factors.

Deposits directly seaward of central Magnolia Ridge and the Pleistocene mainland (Deposits I and III) partially formed as channel-fills. Coupled with the previously mentioned factors, the vegetaion probably flourished in these channel-like depressions and the very peaty mud accreted upward at a greater rate compared to the more seaward regions of the marsh. In addition, fresh water runoff from the adjacent mainland may have enhanced the growth of vegetation as well as inhibited the process of decompositioin by lowering the pH. Ash content is the lowest in these two deposits, ranging from 27-35 percent (moisture-free).

Deposit II, which is centrally located in the study area, probably formed as an interlevee blanket. Plant baffling probably played a significant role during the development of this deposit. The baffling action by marsh vegetation is a major factor in reducing the flood energy behind tidal creek levees where silts and clays settle out. While the marsh environment close to tidal creeks commonly experiences higher energy flooding (and has surface accumulations of slightly organic mud), portions of the marsh further inland, or centrally located between tidal creeks (such as Deposit II), are subject to greater protection during flooding and plant baffling is more efficient. Hence, the centers of interlevee deposits are exposed to less sediment in suspension and tend to accumulate cleaner organic deposits. Otte (1984) made similar observations regarding plant baffling during his studies about the quality and distribution of mineral sediment in North Carolina peat deposits.

Another interesting observation regarding the development of Deposit II is that it overlies the buried southwest end of Point Clear Island (fig. 5). Otvos (1982) suggested that this portion of Point Clear Island subsided due to compaction. Evidence of subsurface continuation of Point Clear Island is present in the form of linear marsh creek orientation. This localized subsidence probably occurred sometime during the development of the surrounding marsh. At that time the vegetation flourished as it accreted upward, while keeping pace with subsidence. In this way thicker accumulations of very peaty mud resulted. Ash values average around 38 percent (moisture-free) in this deposit, which grades laterally into peaty mud. This relationship suggests that plant growth was slower where detrital influx was greater adjacent to the subsiding area, and indicates why very peaty mud is not found there. These two organic-rich sediment types, however, are both part of the same large interlevee deposit. This small-

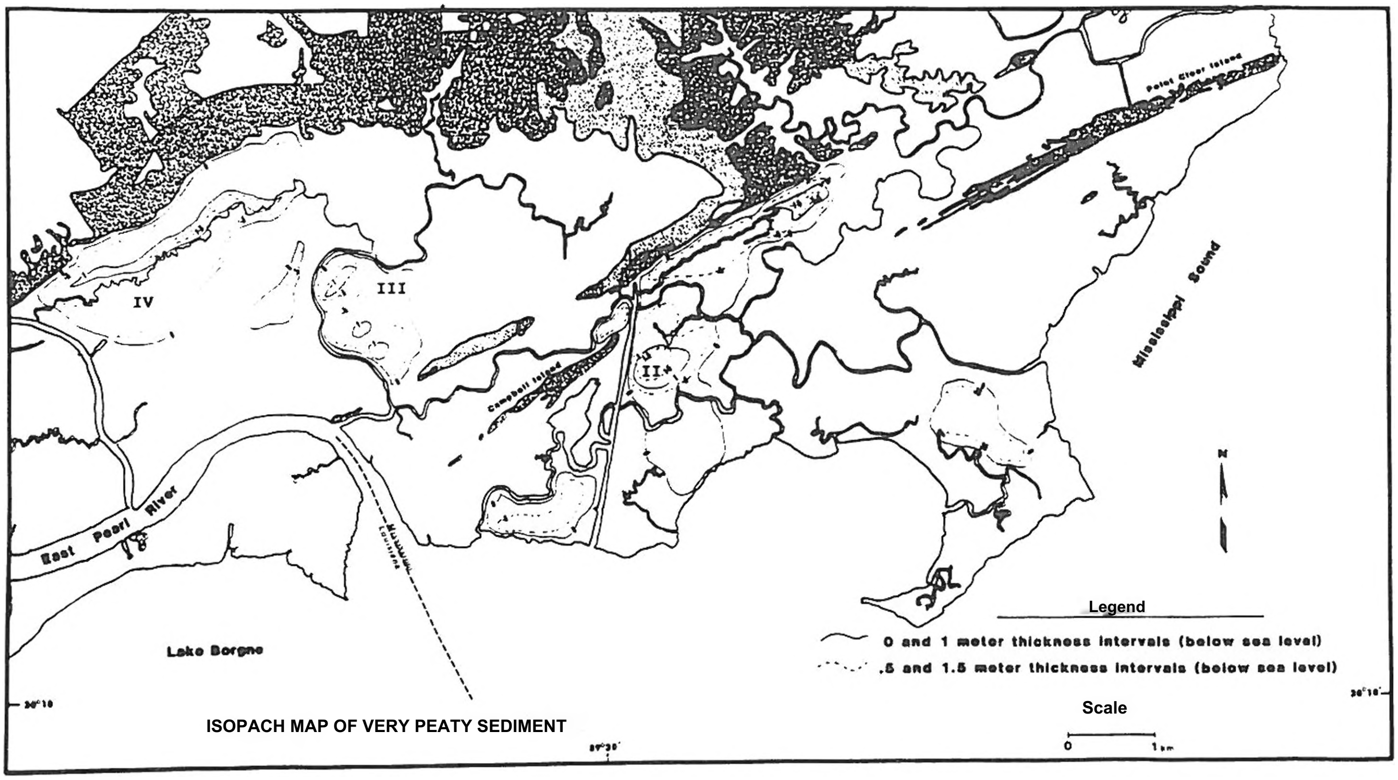

**Figure 5. Isopach map of very peaty sediment. Deposit numbers are shown as roman numerals.**

scale subsidence related to the accumulation of very peaty mud is comparable to similar occurrences in Louisiana (Kosters, 1983) where peats form in interdistributary basins over slowly subsiding abandoned delta lobes of the Mississippi River.

The remaining thick accumulation of very peaty mud is Deposit III, which also formed as an interlevee deposit (fig. 5). It is the smallest of the four deposits and contains more mineral matter than the others. The ash content ranges between 32-45 percent (moisture-free). This deposit is situated between Magnolia Ridge and the well developed natural levee along Grand Plains Bayou. Plant baffling during overbank flooding was probably most important during the development of this deposit. At this location the very peaty mud is covered by almost 1 meter of peaty mud indicating that plant growth has slowed down and the present marsh is being blanketed by detrital influx.

Seaward of Campbell and Point Clear islands, a thin blanket of very peaty mud (20-25 centimeters) occurs around 2 meters below the marsh surface (fig. 5). This deposit is also covered with peaty mud and slightly organic mud indicating that more recently detrital influx has been greater than vegetation growth. Due to the proximity of Lake Borgne and Mississippi Sound, flood conditions are more dynamic there than in the more interior regions of the marsh and account for the Present increase in inorganic sedimentation. One interesting observation is that in some places this veneer of very peaty mud is continuous beneath the active shoreline along the southern limits of the study area. This observation provides possible evidence that at one time the marsh extended beyond the present shoreline and has slowly eroded back to its present position in response to wave action.

The volume of very peaty mud in the study area has been roughly estimated from the approximate dimensions of each deposit (table 1). Deposits I, II, III, and IV contain roughly $3.0 \times 10^5 m^3$, $1.35 \times 10^5 m^3$, $2.0 \times 10^5 m^3$, and $6.0 \times 10^5 m^3$, respectively. Actual weights have not been calculated due to the unknown bulk density of the very peaty mud necessary for such calculations. The bulk density is probably highly variable due to differences in the moisture, ash, and fixed carbon content. If, however, a bulk density of 0.12 g/cm3 is assumed, which is the average of Louisiana high ash peats (Kosters, 1983), then the total amount of very peaty mud can be roughly estimated. Under these circumstances there is roughly $1.48 \times 10^5$ metric tons of very peaty mud (dry) in the study area. Although the very peaty mud forming these deposits probably has no potential as a fuel source because of the high ash content, it would be suitable for agricultural purposes such as a soil conditioner.

**Table 1. Rough Estimate of the Total Volume and Weight of Very Peaty Mud in Study Area**

| Deposit | Volume (Length x Width x Thickness = m$^3$) | Weighty (Metric Tons) |
|---|---|---|
| I | 2000m x 300m x 0.5m =<br>3.0 x $10^5$ | 3.6 x $10^4$ |
| II | 900m x 300m x 0.5m =<br>1.35 x $10^5$ | 1.62 x $10^4$ |
| III | 1000m x 400m x 0.5m =<br>2.0 x $10^5$ | 2.4 x $10^4$ |
| IV | 2000m x 600m x 0.5m =<br>6.0 x $10^5$ | 7.2 x $10^4$ |
| Total | 1.24 x $10^6$<br>12.35 x $10^5$ | 1.48 x $10^5$<br>14.82 x $10^4$ |

*Assumed bulk density of very peaty mud = 0.12g/cm$^3$

tWeight of Im$^3$ of very peaty mud (dry) = x $\frac{0.12\text{g}}{1\text{cm}^3}$ 1 x $10^6$cm$^3$ = 1.2 x $10^5$g = 0.12 metric tons

**Table 1. Rough estimate of the total volume and weight of very peaty mud in study area.**

## PREDICTIONS REGARDING COAL FORMATION AND RELATED CHARACTERISTICS

Considering a 6:3:1 compaction ration from peat to brown coal to bituminous coal (Stach and others, 1975), those coals forming in the south Hancock marginal deltaic setting would have a high ash content and occur mostly as thin stringers, less than 1 meter thick. The thickest coals would be found overlying or associated with ancestral channels and older beach deposits. Also, they would be restricted to around 100 meters wide, yet continuous parallel to these sandy trends for at least 1 kilometer. Perpendicular to these trends, the coals originating from blanket deposits would be much thinner, interbedded with silty shales and carbonaceous shales, and highly discontinuous.

Regardless of thickness and lateral extent, the data obtained from proximate analyses indicate that these coals would be low in fixed carbon, but high in ash and volatile matter. The high ash content results primarily from the abundance of silt and clay deposited with the plant remains during frequent tidal and river inundation. Cecil and others (1980) described other possible sources for ash such as: 1) mineral matter in plants (that become peat, or in the case of this study become very peaty mud); 2) chemical precipitates such as sulfides and carbonates; and 3) ionic exchange with pore water which incorporates elements with the peat; in addition to 4) sponge spicules and similar biogenic material (Cohen, 1973; Andrejko & Cohen, 1984, Yeakel and Spackman, 1984). It is possible, however, that some of this inorganic material could be leached prior to or during early stages of coalification which would increase the quality and volume of the coal (Kosters and Bailey), 1986. The high volatile and low fixed carbon content reflects the high rate of cellular decomposition of the rush, grass, and sedge constituents due to substantial bacterial activity occurring in the brackish environment prior to coalification. In addition, the sulfur content would be high as well due to the brackish origin of these coals. Recently, Cohen (1984) found that peats forming in a brackish environment generally contain a higher pyrite and sulfur content compared to freshwater and marine peats. In this environment, sulfate ions are available in greater quantities due to the saltwater influence. In addition, the decompositional activity of anaerobic bacteria is enhanced by the marine influence which can add to the sulfur content as well as enrich peaty sediments with nitrogen (Stach and others, 1975). Decomposition by anaerobic bacteria may also result in a low framework to matrix ratio of these coals. This coincides with the observation that organic particle size generally decreases with depth in the organic-rich deposits common to the study area. All of the above characteristics are similar to those of marine-influenced coals described by Teichmueller (cited in Stach and others, 1975). Stach and others (1975) suggested their origin to be similar to the Mississippi delta swamps that are frequently inundated by the sea.

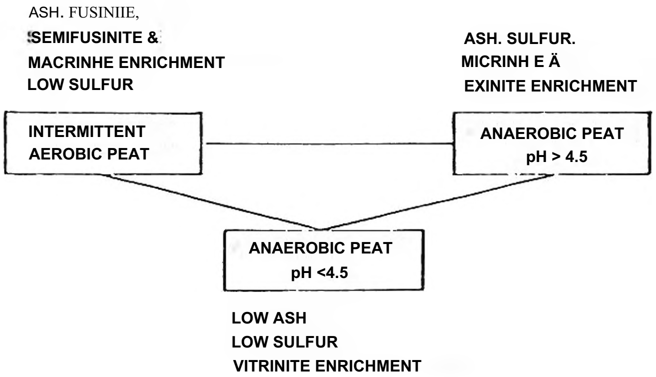

**Figure 6. Hypothetical model indicating some controls on mineral and maceral variation in coal; from Cecil and others (1980).**

in view of the above characteristics, the petrography of these peats when they have attained the rank of mature coals would reveal large quantities of mineral matter, pyrite, exinite, and inertinite and lesser amounts of vitrinite. The vitrinite content would probably be low due to the decomposition of cell walls and other cellular material from bacterial action. Inertinites would probably consist of fusinite (pyrofusinite), semifusinite and micrinite. The presence of these macerals probably is due to the preservation of charred plant remains resulting from winter fires, in addition to degradation of some organic particles prior to coalification. The abundance of exinite which is illustrated by the high volatile content probably would consist mostly of cutinite. This maceral is derived from the highly resistant outer layers of leaves, shoots, stalks, and thin stems which appear to be the most abundant plant parts of the organic-rich sediments in the study area. Cecil and others (1980) suggested a hypothetical model indicating some controls on mineral and maceral variation in coal (fig. 6). Their observations are similar to those in this study expected from the coalification of very peaty sediments, with the exception of fusinite and semifusinite macerals. Because of these characteristics, the type of bituminous coal that would result from deposition in this brackish setting, although high in ash, would be similar to the durain lithotype of humic coal. The potential for the formation of this type of coal, however, is highly restricted to the thickest deposits of very peaty sediment where ash values are around 30 percent (dry basis) such as the channel-fill deposits. Otherwise, bone coal and carbonaceous shale would result after coalification of these deposits. In any event, these coals would be of poor quality and probably not economic due to the high ash and sulfur content, and because of poor seam characteristics such as thin laterally discontinuous seams.

## CONCLUSIONS

1) Proximate analyses of the organic sediments reveal much variation throughout the study area in the dry weight percentages of volatile matter, ash, and fixed carbon. By ASTM definition, no *in situ* peat is present. Four deposits of very peaty mud contain the lowest amounts of ash, averaging around 30-40 percent. These occur as channel-fill deposits along the northern limit of the study area and blanket deposits between the levees of some of the larger tidal creeks meandering through the central portion of the study area. In the four deposits, there is a combined total of roughly $1.48 \times 10^5$ metric tons of very peaty mud.

2) Factors influencing the development of the most organic-rich deposits are: 1) presence of channel-like depressions in the underlying topography which initially were favorable accumulation sites; 2) location distal to estuarine-lagoonal and deltaic environments which are sources for silts and clays deposited in with the organic material; 3) protection by nearby or adjacent higher topography during periodic inundation; 4) in some cases, ability of marsh vegetation to accrete upward keeping pace with sea level in response to locally subsiding older beach deposits; and 5) effectiveness of plant baffling relative to the previously mentioned factors.

3) High quality coals would not be expected as a result of coalification due to the high silt and clay content and absence of thick accumulations. Channel-fill coals would tend to occur as thin stringers less than 1 meter thick, while blanket deposits would produce even thinner coals interbedded with carbonaceous shales.

## ACKNOWLEDGMENTS

This research project was funded in part by the Mississippi Mineral Resources Institute (grant number MMRI-84-2F) and in part by the Gulf Coast Association of Geological Societies, Committee for Financial Aid to Students. Special thanks are extended to Mary Kate Gammel for her clerical assistance in preparing the manuscript.

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