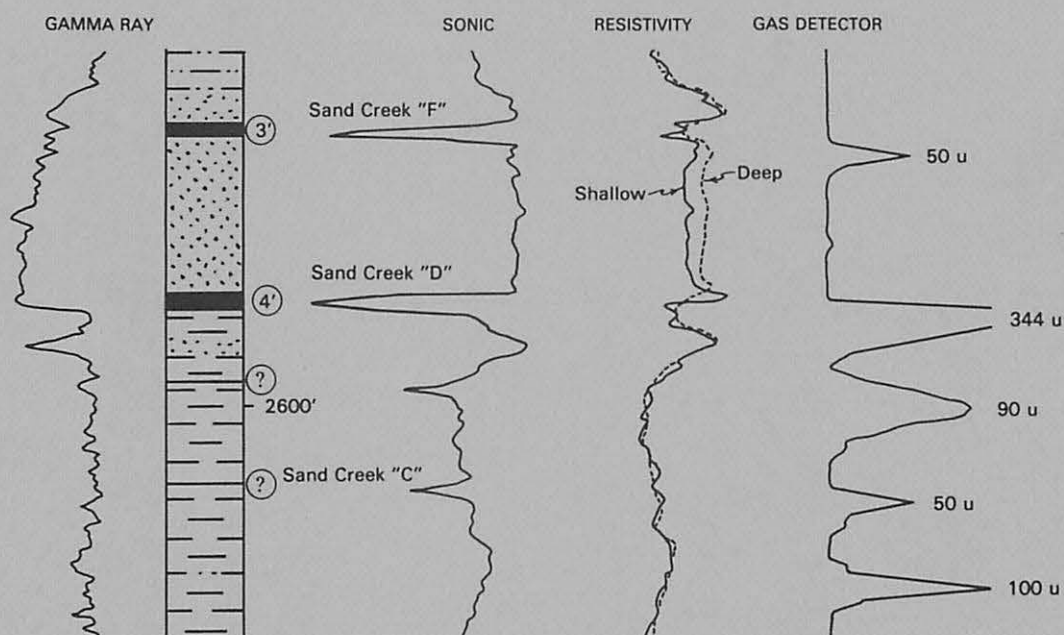


PRELIMINARY EVALUATION OF COAL AND COALBED GAS RESOURCE POTENTIAL OF WESTERN CLAY COUNTY, MISSISSIPPI

Kevin S. Henderson
Conrad A. Gazzier

UNION OIL COMPANY OF CALIFORNIA #1 E.D. PEARSON 21-7 (21-15S-4E)



REPORT OF INVESTIGATIONS 1

MISSISSIPPI DEPARTMENT OF NATURAL RESOURCES
BUREAU OF GEOLOGY

Conrad A. Gazzier
Bureau Director

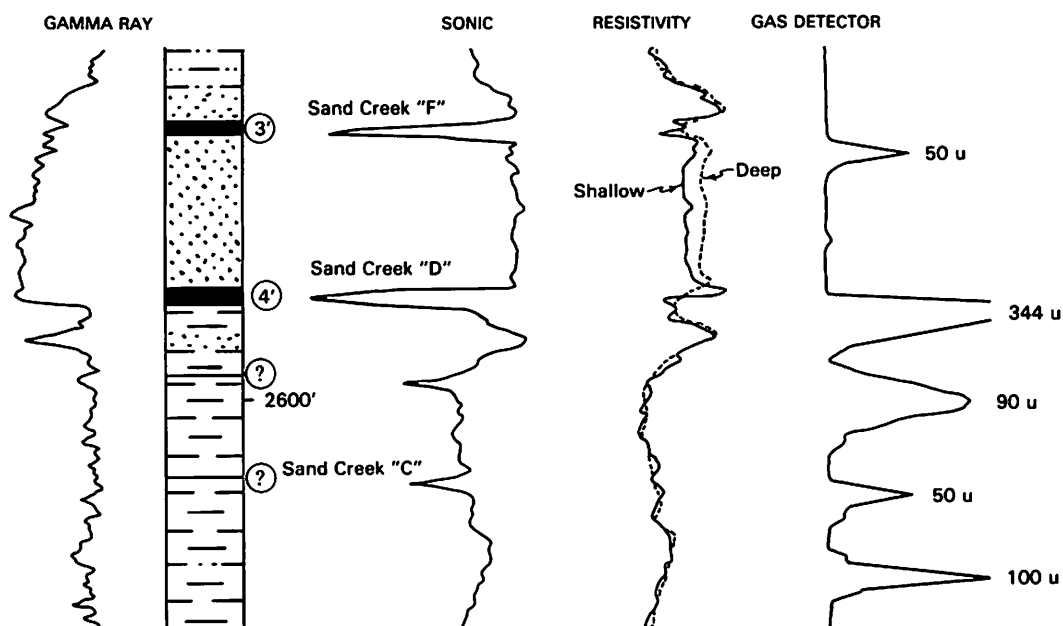
Jackson, Mississippi

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STATE OF MISSISSIPPI

RAY MABUS
GOVERNOR

I am pleased to transmit to the people of Mississippi a report entitled "Preliminary Evaluation of Coal and Coalbed Gas Resource Potential of Western Clay County, Mississippi" by Kevin S. Henderson and Conrad A. Gazzier.

This report was prepared for the public and for the coal and petroleum industries in the hope that these valuable natural resources might be developed for the benefit of Mississippi's citizens.

The authors and the Department of Natural Resources are to be commended for their efforts in developing such an outstanding scientific report.

Sincerely,

A handwritten signature in black ink, appearing to read "Ray Mabus", written over a horizontal line.

RAY MABUS
Governor

RM:MG:rc



MISSISSIPPI DEPARTMENT OF NATURAL RESOURCES

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LETTER OF TRANSMITTAL

Mississippi Department of Natural Resources

Bureau of Geology

Mr. Jolly McCarty, Chairman and
Members of The Commission
Department of Natural Resources

Commissioners:

The Bureau of Geology is pleased to transmit to you Report of Investigations 1, entitled "Preliminary Evaluation of Coal and Coal-bed Gas Resource Potential of Western Clay County, Mississippi" by Kevin S. Henderson and Conrad A. Gazzier.

Commercial coalbed methane production has been developed in other states under similar geologic conditions to those in Clay County, Mississippi. The resulting economic impact from coalbed methane gas development generated new jobs and increased tax revenues.

It is hoped that the oil and gas industry can utilize data from this report to assess the potential for development of Clay County's coal and gas resources to the benefit of its citizens.

Respectfully submitted,

A handwritten signature in black ink, appearing to read "Conrad A. Gazzier".

Conrad A. Gazzier
Director and State Geologist

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PRELIMINARY EVALUATION OF COAL AND COALBED GAS RESOURCE POTENTIAL OF WESTERN CLAY COUNTY, MISSISSIPPI

Kevin S. Henderson
Conrad A. Gazzier

INTRODUCTION

The development of deep underground coal mining and the subsequent production of coalbed gas from the Pottsville Formation of Alabama has increased the interest in these resources in Mississippi. The Mississippi Bureau of Geology initiated a preliminary evaluation of western Clay County in an effort to determine the economic potential for these resources (Figure 1). The top of the Pottsville Formation occurs in the subsurface of the study area at depths of approximately 1500 feet to 2500 feet. The total thickness of the unit varies from approximately 3000 feet north of the study area to more than 9000 feet in the central and southern portions of western Clay County. This study documented the presence of four coal groups within 3700 feet of the surface. These four groups consist of as many as 17 individual seams with thicknesses varying from two feet to six feet. Aggregate thicknesses of all coal seams in these four groups may exceed 25 feet, with 16 feet being the average.

The coal generally appears to be high volatile A bituminous in rank (see Table 1). This ranking is comparable with much of the identified coal resources of Alabama. It is estimated that the study area has coal resources in excess of 5.2 billion tons at depths shallower than 3700 feet. A significant portion of these coal resources may be economically attractive for underground mining. In addition to the mining potential of these coal seams, it is believed that a significant amount of coalbed gas is present. Coalbed gas is recoverable from coal seams by drilling wells in much the same manner as conventional oil and gas wells are drilled. Using the somewhat conservative estimate of 200 cubic feet of gas per ton of coal, the total coalbed gas reserves are estimated to exceed one trillion cubic feet of gas.

Previous Bureau of Geology studies have attempted to develop an understanding of the shallow Pennsylvanian stratigraphy of the Mississippi portion of the Black Warrior Basin (Bicker, 1979, and Tarbuton, 1980). These studies concentrated primarily on the shallow, updip section in order to develop a correlation scheme related to the well-known Pennsylvanian section in Alabama. These previous studies did not study the thicker sections of Pennsylvanian strata known to occur in Clay, Lowndes, Oktibbeha, and Noxubee counties.

A relatively unknown study by Cropp (1960) attempted to correlate the Pennsylvanian strata of a well drilled in Clay County with the well-known Alabama section in Walker County using Pennsylvanian fossil spores. The Clay County well, the

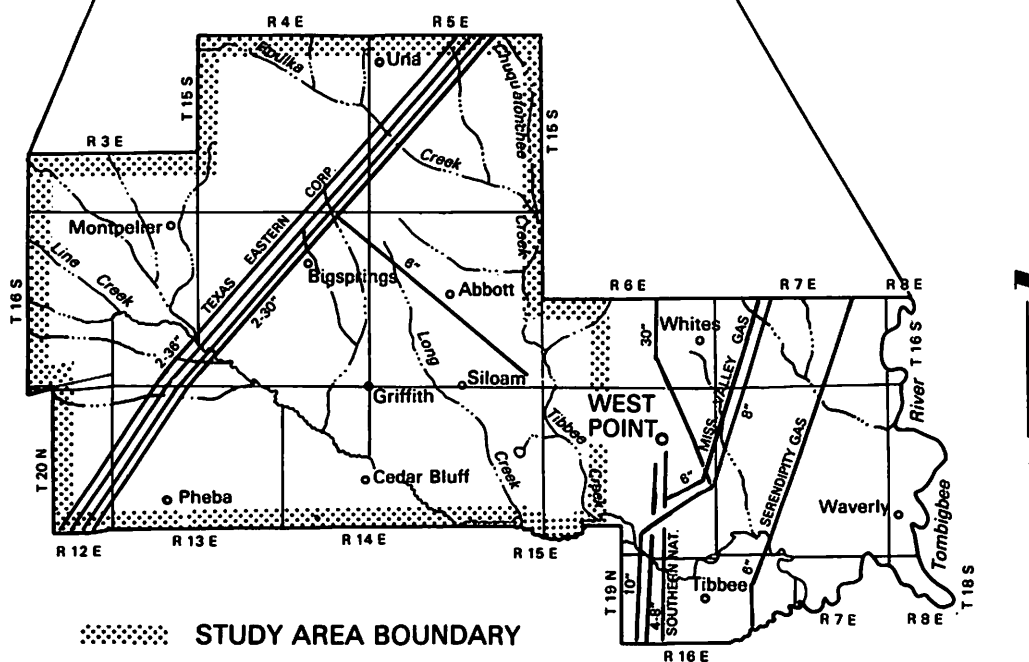
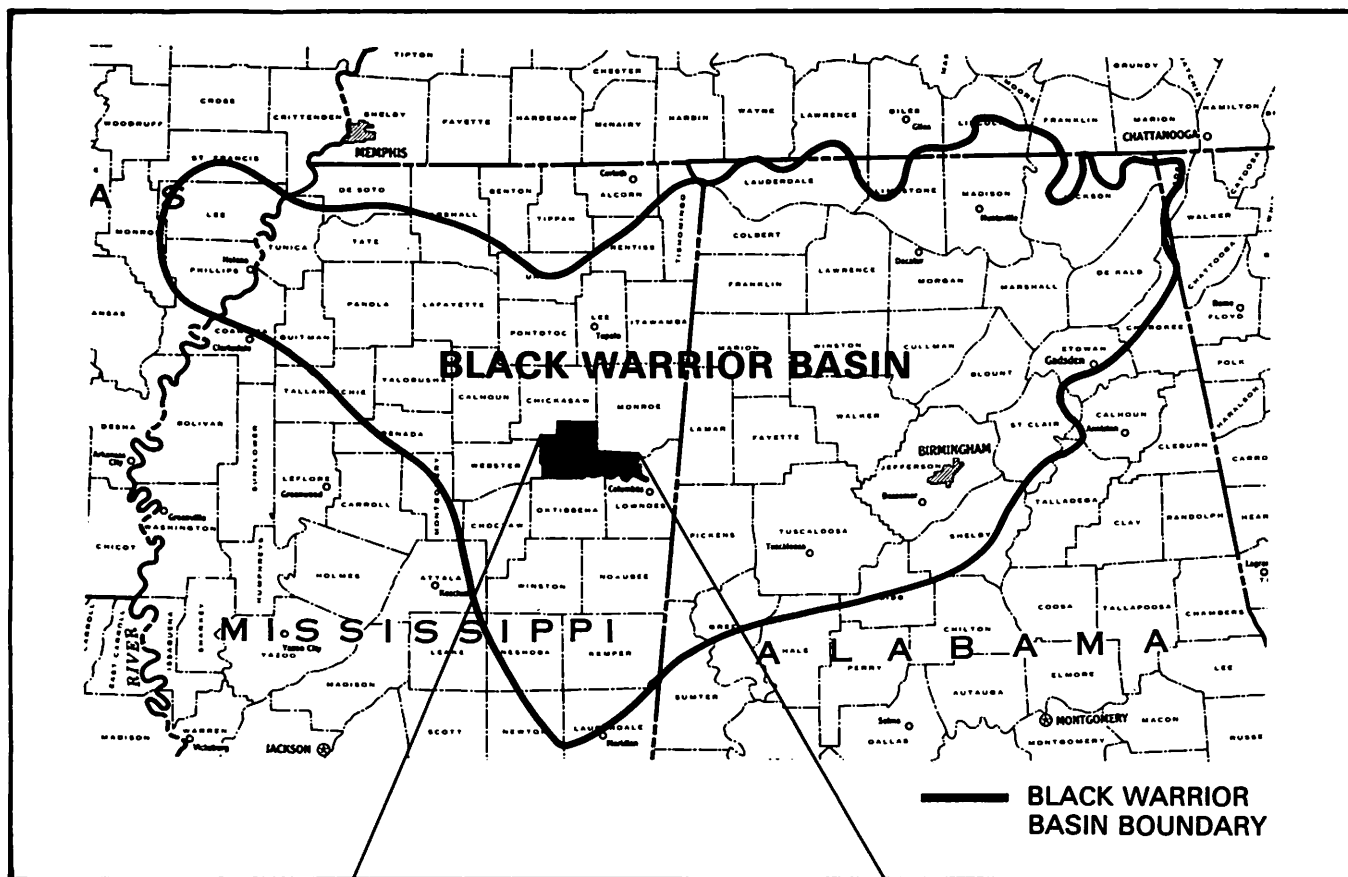


Figure 1. Black Warrior Basin Index Map showing location of Clay County, Mississippi, study area.

TABLE 1 Classification of Coals by Rank^A

| Class | Group | Fixed Carbon Limits, % (Dry, Mineral- Matter-Free Basis) | | Volatile Matter Limits, % (Dry, Mineral-Mat- ter-Free Basis) | | Gross Calorific Value Limits, Btu/lb (Moist, ^B Mineral-Mat- ter-Free Basis) | | Agglomerating Character |
|--------------------|------------------------------------|--|--------------|---|-----------------------|---|--------------------|---------------------------------------|
| | | Equal or Greater Than | Less Than | Greater Than | Equal or Less Than | Equal or Greater Than | Less Than | |
| I. Anthracitic | 1. Meta-anthracite | 98 | ... | ... | 2 | ... | ... | } nonagglomerating |
| | 2. Anthracite | 92 | 98 | 2 | 8 | ... | ... | |
| | 3. Semianthracite ^C | 86 | 92 | 8 | 14 | ... | ... | |
| II. Bituminous | 1. Low volatile bituminous coal | 78 | 86 | 14 | 22 | ... | ... | } commonly agglomerating ^E |
| | 2. Medium volatile bituminous coal | 69 | 78 | 22 | 31 | ... | ... | |
| | 3. High volatile A bituminous coal | ... | 69 | 31 | ... | 14 000 ^D | ... | |
| | 4. High volatile B bituminous coal | ... | ... | ... | ... | 13 000 ^D | 14 000 | |
| | 5. High volatile C bituminous coal | ... | ... | ... | ... | { 11 500 10 500 | { 13 000 11 500 | |
| III. Subbituminous | 1. Subbituminous A coal | ... | ... | ... | ... | 10 500 | 11 500 | } nonagglomerating |
| | 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 | } nonagglomerating |
| | 2. Lignite B | ... | ... | ... | ... | ... | 6 300 | |

^A This classification does not apply to certain coals.

^B Moist refers to coal containing its natural inherent moisture but not including visible water on the surface of the coal.

^C If agglomerating, classify in low-volatile group of the bituminous class.

^D Coals having 69 % or more fixed carbon on the dry, mineral-matter-free basis shall be classified according to fixed carbon, regardless of gross calorific value.

^E It is recognized that there may be nonagglomerating varieties in these groups of the bituminous class, and that there are notable exceptions in high volatile C bituminous group.

Modified from ASTM, 1988

Marshall R. Young #1 J. N. Henderson, reportedly contained an extraordinarily large number of coal seams (96). Cleaves (1981) attempted to develop a coal exploration model for the Mississippi portion of the Black Warrior Basin based upon a basin-wide analysis of the depositional environments of the Pottsville Formation. Cleaves (1981) recognized the presence of the major structural elements of the Black Warrior Basin but did not have the degree of well control and geophysical logs now currently available. As a result the great number of coal seams in Clay County were not initially identified.

PURPOSE OF THE STUDY

After reviewing all previously published data it appeared that if the Mississippi portion of the Black Warrior Basin contained potentially economic seams of coal the thicker downdip section was a more likely place to look. The generosity of several exploration companies in providing an extensive suite of logs that could be correlated with samples contained in the Bureau of Geology Sample Library allowed the authors to correlate and identify these upper Pottsville coal groups previously unknown in Mississippi.

The purpose of this study was to identify the potential for coal resources in western Clay County, Mississippi, and to correlate laterally any coal seams identified in order to develop a gross volumetric estimate of in-place resources. It became apparent that many of the shallow coal seams (1800 feet-3700 feet) had appreciable quantities of gas, for they exhibited excellent gas shows when drilled. Efforts to determine rank for these coals were made by vitrinite reflectance and thus a preliminary estimate was also made for the potential coalbed methane reserves (Eddy, Rightmire and Bryer, 1982).

STRUCTURAL SETTING

The presence of these coal groups is due primarily to a major fault system which has over 4500 feet of displacement. Aeromagnetic and gravity data suggest that this fault, hereafter named the West Point Fault (Stewart W. Welch, personal communication), is associated with the Muldon Uplift. The Muldon Uplift is a major Black Warrior Basin granitic basement structure of unknown origin.

The fortuitous position of these coal seams on the downthrown block allowed for their preservation during post-Pennsylvanian erosion. These coal seams, therefore, do not have equivalent updip units in the southern Appalachians and do not appear to be correlatable to any other known coal units at this time. The West Point Fault is the northern limit of the identified coal groups in western Clay County.

The available data from oil and gas test wells in Clay County are somewhat concentrated by location since most are field development wells. Thus the available data do not provide adequate coverage to limit the potential for additional coal resources not currently identified in this study. Nevertheless, these data do provide enough information to delineate the major structural elements responsible for the preservation of these identified coal resources.

The major structural elements of the Black Warrior Basin have been generally known since Welch (1978) provided an overview of the structure and Mississippian stratigraphy. The major fault (or group of associated faults) has an aggregate displacement of approximately 4500 feet. It is downthrown to the southwest and generally trends northwest-southeast. In northwest Clay County and southern Chickasaw County it appears to turn to a more east-west direction.

Southwest of this fault are several minor faults with displacements of 300 feet or less. These faults do not appear to have displacements significant enough to materially affect the occurrence or distribution of coal resources identified.

The major coal groups identified by this investigation appear to be concentrated in the area immediately south of the West Point Fault. The West Point Fault is a major fault, but its origin and time of development are unknown and it may have controlled the distribution of the mapped coal seams.

GEOLOGIC ANALYSIS

The economics of underground coal mining or coalbed methane development in the Black Warrior Basin has historically been limited to approximately 3700 feet. Therefore only those coals which are shallower than that depth were considered for this study. Within this interval as many as 17 individual coal seams have been identified. These seams have been assembled into four coal groups, which are, in descending stratigraphic order: West Point Group, Sand Creek Group, Houlka Creek Group, and Line Creek Group (Figure 2).

In order to identify these coals, all available density and sonic logs from wells drilled in the study area were obtained (Figure 3). Unfortunately, only 16 of the 31 wells within the primary coal study area had density or sonic logs for the Pennsylvanian interval of interest (Table 2). These density and sonic logs are conventional oil and gas industry logs and thus of limited bed resolution. The minimum bed thickness a conventional log requires to respond to is normally considered to be two feet. Thus, no coal seams less than two feet were considered discernible in this study. In those cases in which the coals are thick enough for the density or sonic logs to respond, the actual thicknesses of the coal seams are often a matter of interpretation. Indeed, just what is or is not a coal is frequently subject to some debate. In an effort to quantify identification of coal seams, drill cuttings were examined and used in conjunction with density and sonic logs. As density logs are very sensitive to changes in borehole diameter (wash-outs), sonic logs were considered preferable in determining coal lithology. For sonic logs, a bed was considered a coal if it showed an interval transit time (ΔT) of 100 microsec/ft or greater (Tixier and Alger, 1970). For density logs, samples were relied on to some degree along with a careful analysis of caliper and gamma ray log responses.

The actual thicknesses of individual coal seams were determined by the "mid-point method." This method is described in Reeves (1981). Basically, the footage measured at the point halfway between the point of inflection and the maximum deflection is taken to be the true thickness of the bed. In general, the authors have been conservative in measurements of bed thickness and specific identification of coal seams.

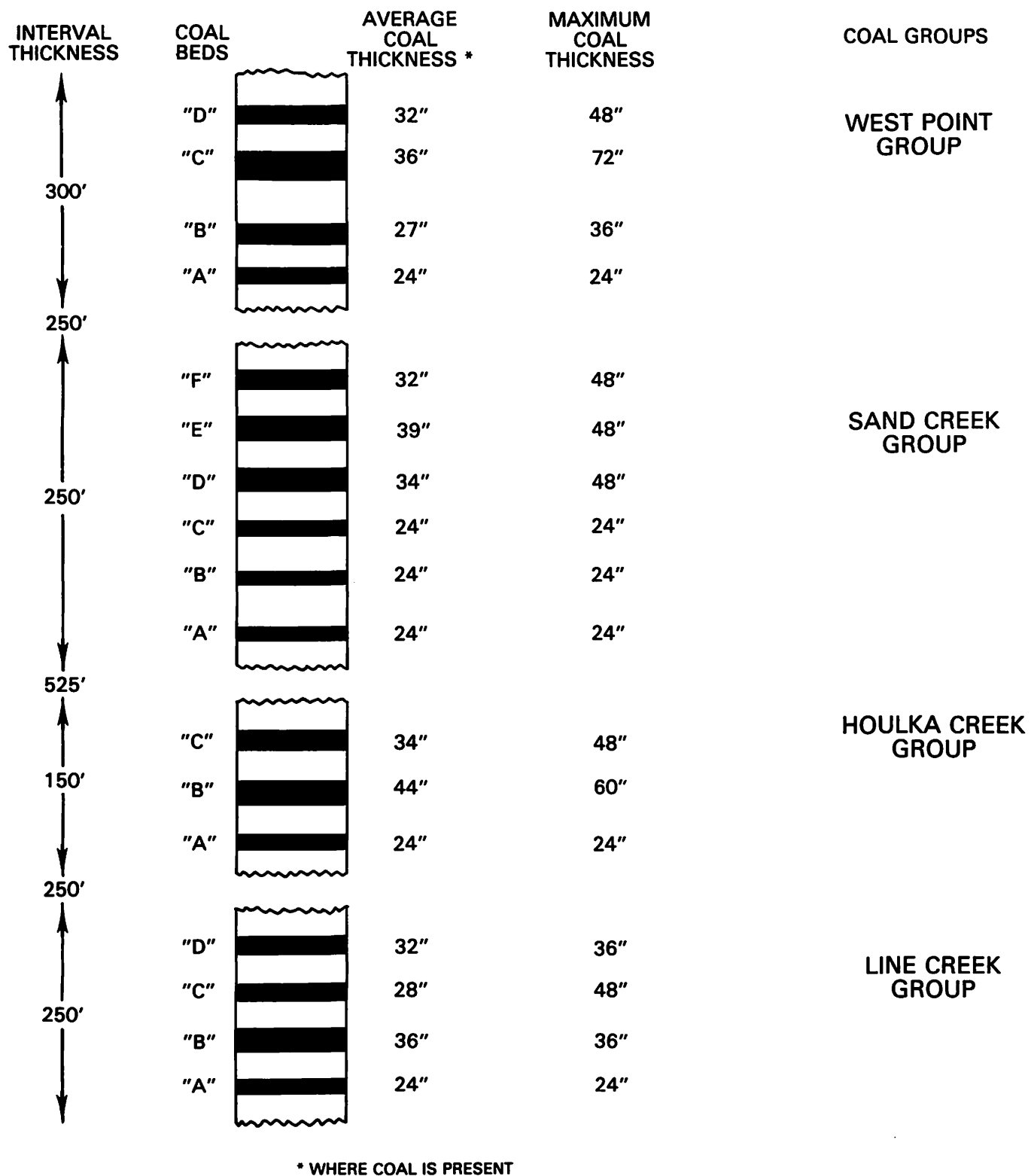


Figure 2. Generalized stratigraphic column of coal groups identified in western Clay County, Mississippi.

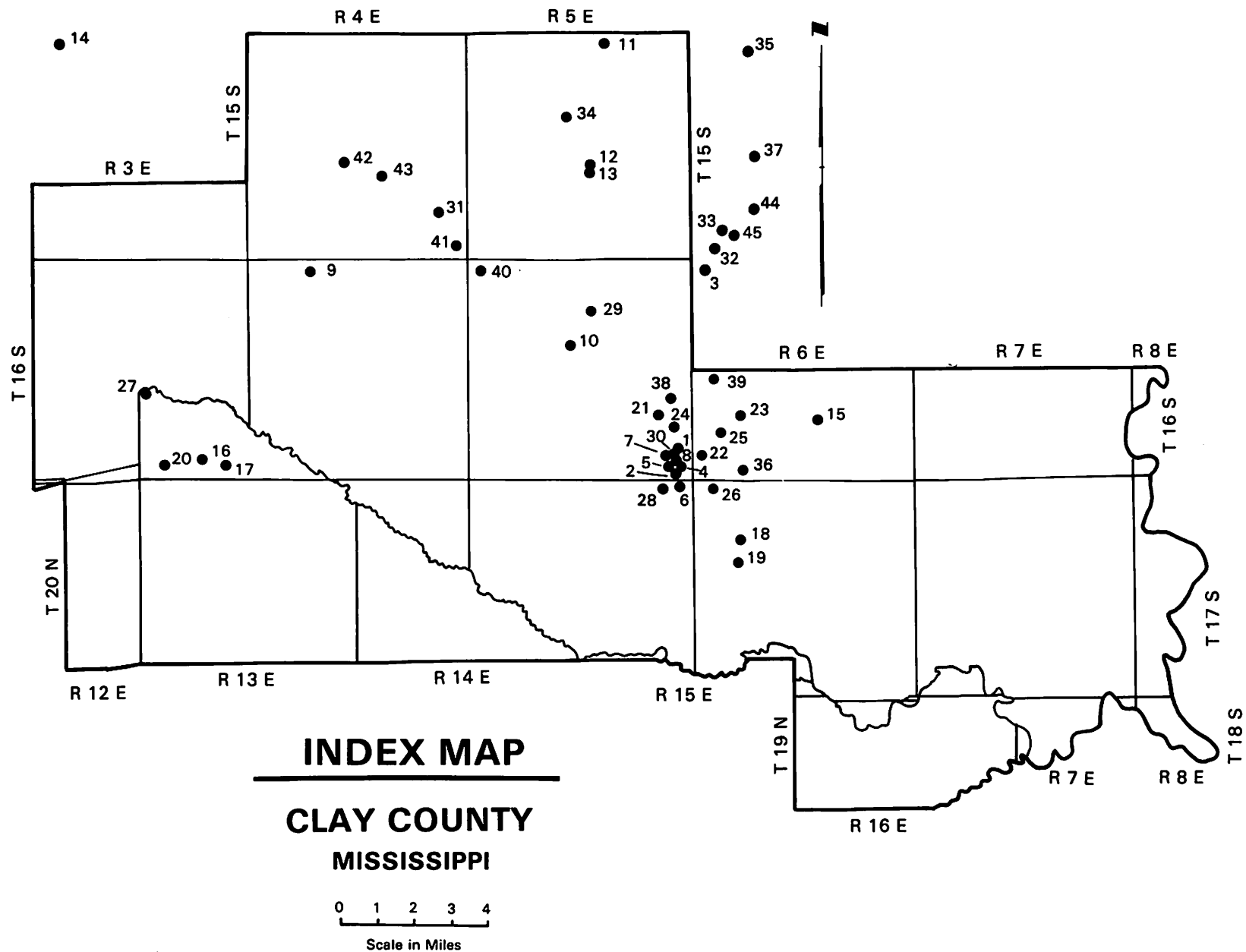


Figure 3. Index map of wells (well numbers refer to Table 2).

Table 2. List of Wells Used in This Report

| Well No. | Operator; Farm | Location | Den. Log | Smpl. |
|-----------------|---|-----------------|-----------------|--------------|
| 1 | American Exploration & Development Co.; McLemore #1 | 36-16S- 5E | No | No |
| 2 | Browning and Welch; Harkins et al. | 36-16S- 5E | Yes | No |
| 3 | Browning and Welch et al.; #1 Lilley 6-3 | 6-16S- 6E | No | No |
| 4 | Browning and Welch et al.; #1 McFadden | 36-16S- 5E | No | No |
| 5 | Browning and Welch et al.; #2 McFadden | 36-16S- 5E | No | No |
| 6 | Browning and Welch; Robinson #2 | 1-17S- 5E | No | Yes |
| 7 | Browning and Welch; #1 W. M. Simmons | 36-16S- 5E | No | No |
| 8 | Carter Oil Co.; #1 Mattie B. McFadden | 36-16S- 5E | No | Yes |
| 9 | Champlin Petroleum Co. et al.; #1 Kellogg 5-7 | 5-16S- 4E | Yes | Yes |
| 10 | Crump, Hadaway, Pepper Trust; Calvert #1 | 16-16S- 5E | No | No |
| 11 | Crystal Oil Co.; #1 Henley | 3-15S- 5E | No | No |
| 12 | W. R. Fairchild Constr. Co.; Bessie Brownlee #1 | 22-15S- 5E | No | Yes |
| 13 | W. R. Fairchild Constr. Co.; Bessie Brownlee #1-A | 22-15S- 5E | No | Yes |
| 14 | Getty Oil Co.; #1 Henry Beneka 6-1 | 6-15S- 3E | Yes | No |
| 15 | Grace Petroleum Corp.; #1 Allen 27-6 | 27-16S- 6E | Yes | No |
| 16 | Grace Petroleum Corp. & American Quasar #1 Davis 32-7 | 32-21N-13E | Yes | No |
| 17 | Grace Petroleum Corp.; #1 Davis Estate 33-11 | 33-21N-13E | Yes | Yes |
| 18 | Grace Petroleum Corp.; #1 Lone Oak Park Development 8-11 | 8-17S- 6E | Yes | No |
| 19 | Grace Petroleum Corp.; #1 Simmons 17-5 | 17-17S- 6E | Yes | Yes |
| 20 | Grace Petroleum Corp.; #1 Williamson 31-10 | 31-21N-13E | Yes | Yes |
| 21 | Hurst; Cottrell et al. Unit #1 | 25-16S- 5E | No | No |
| 22 | Hurst; Federal Land Bank et al. Unit #1 | 31-16S- 6E | No | No |
| 23 | Hurst; #1 James C. Foster et al. 29-3 | 29-16S- 6E | No | Yes |
| 24 | Hurst; Jarrett et al. #1 | 25-16S- 5E | No | Yes |
| 25 | Hurst; #1-A McClenton | 30-16S- 6E | No | Yes |
| 26 | Hurst; #1 Rogers et al. | 6-17S- 6E | No | No |
| 27 | Kirby Exploration Co.; #1 Clinton Pate | 19-21N-13E | Yes | No |
| 28 | Larco Drilling Co. et al.; #1 Robinson | 1-17S- 5E | Yes | Yes |
| 29 | L. O. McMillan; Frank Wilcox #1 | 10-16S- 5E | No | Yes |
| 30 | Meridian Oil, Inc.; #1 Simmons Unit 36-7 | 36-16S- 5E | Yes | Yes |
| 31 | Meridian Oil, Inc.; #1 David Waide 25-13 | 25-15S- 4E | Yes | Yes |
| 32 | Nason; #1 Lenior | 31-15S- 6E | No | No |
| 33 | Nason; #1 Wilson | 31-15S- 6E | No | No |
| 34 | Ohio Oil Co.; Cantrell #1 | 16-15S- 5E | No | Yes |
| 35 | Par Exploration Co.; #1 Evans | 5-15S- 6E | No | No |
| 36 | Neville G. Penrose; #1 J. H. Hawkins | 32-16S- 6E | No | Yes |
| 37 | Pruet Production Co.; #1 Metcalf 17-16 | 17-15S- 6E | No | No |
| 38 | Shell Oil Co.; #1 First Nat'l Bank of Birmingham et al. | 24-16S- 5E | No | Yes |
| 39 | Shell Oil Co.; #1 Grimes 19-7 | 19-16S- 6E | Yes | Yes |
| 40 | Southland Royalty Co.; #1 Scott 6-6 | 6-16S- 5E | Yes | No |
| 41 | Southland Royalty Co.; #1 Steele 36-10 | 36-15S- 4E | Yes | Yes |
| 42 | Union Oil Co. of California; #1 E. D. Pearson 21-7 | 21-15S- 4E | Yes | Yes |
| 43 | Union Producing Co.; #1 J. N. Henderson | 22-15S- 4E | No | Yes |
| 44 | Union Producing Co.; #1 Lenoir | 29-15S- 6E | No | No |
| 45 | Union Producing Co.; #1 Watson | 31-15S- 6E | No | No |

Two cross sections were constructed to show the relative positions of the coal seams present in the study area. Cross section A-A' (Plate 1) is a northeast-southwest dip section and indicates that the coal seams of the groups identified in this study thin and appear to pinch out to the southwest. Cross section B-B' (Plate 2) is a northwest-southeast strike section and illustrates the correlative scheme developed for this report.

In addition to the cross sections, a series of maps has been constructed. A top of Pennsylvanian map (Plate 3) illustrates the erosively smoothed nature of the Paleozoic subcrop and depicts a general deepening to the southwest. A structure map (Plate 4) has been constructed on the "x" marker, which is correlated to the Houlka Creek "C" seam. The Houlka Creek "C" horizon was chosen because it is recognizable on the more widely available induction geophysical logs. Total coal isopach maps were assembled for the Sand Creek (Plate 5) and Houlka Creek (Plate 6) groups. These two groups are the primary coal groups identified in this study. In addition to these maps, a total coal isopach map (Plate 7) was developed combining all four coal groups. This total coal isopach map serves as the basis for determining the estimated coal resources of the study area.

West Point Group

The West Point Group is the uppermost coal group present in the study area. While the greatest seam thickness observed in the present study area is only two feet, a seam of six feet in thickness is present in the Grace #1 Allen 27-6 (27-16S-6E). The Grace #1 Allen 27-6 is located approximately 3 miles east of the present study area (see Figure 3, well number 15). The greatest aggregate thickness for the group in the study area is four feet in the Union Producing Co. #1 E. D. Pearson 21-7 (21-15S-4E) and the Meridian Oil Co. #1 David Waide 25-13 (25-15S-4E).

In some locations the West Point Group is not present, apparently due to non-deposition. In the structurally higher areas, the West Point Group is not present due to post-Pennsylvanian erosion and truncation. This coal group interval was apparently faulted out in the Southland Royalty #1 Scott 6-6 (6-16S-5E).

Although the West Point Group is not important in the current area of study, it is well developed to the immediate east and southeast. For this reason, a well that is outside the study area was chosen as the "type log" for this group. The Grace Petroleum Corp. #1 Allen 27-6 (27-16S-6E) is the "type log" (Figure 4) of the West Point Group. This well lies approximately two miles east of West Point Field. Here, the West Point Group attains an aggregate thickness of 11 feet consisting of three seams ("A", "B", and "C"). The "C" seam is very well developed and is six feet thick at a depth of 2250 feet.

The strata associated with the West Point Group consist predominantly of silty shales and differ from the other coal groups of the study area in the relative sparsity of associated sandstones. These bounding strata are approximately 300 feet thick.

In the previously mentioned Grace #1 Allen 27-6 well a sustained gas reading of 40 units methane was recorded by a commercial mud logging company during drilling of the West Point "C" seam (Figure 4). A maximum of 120 units methane

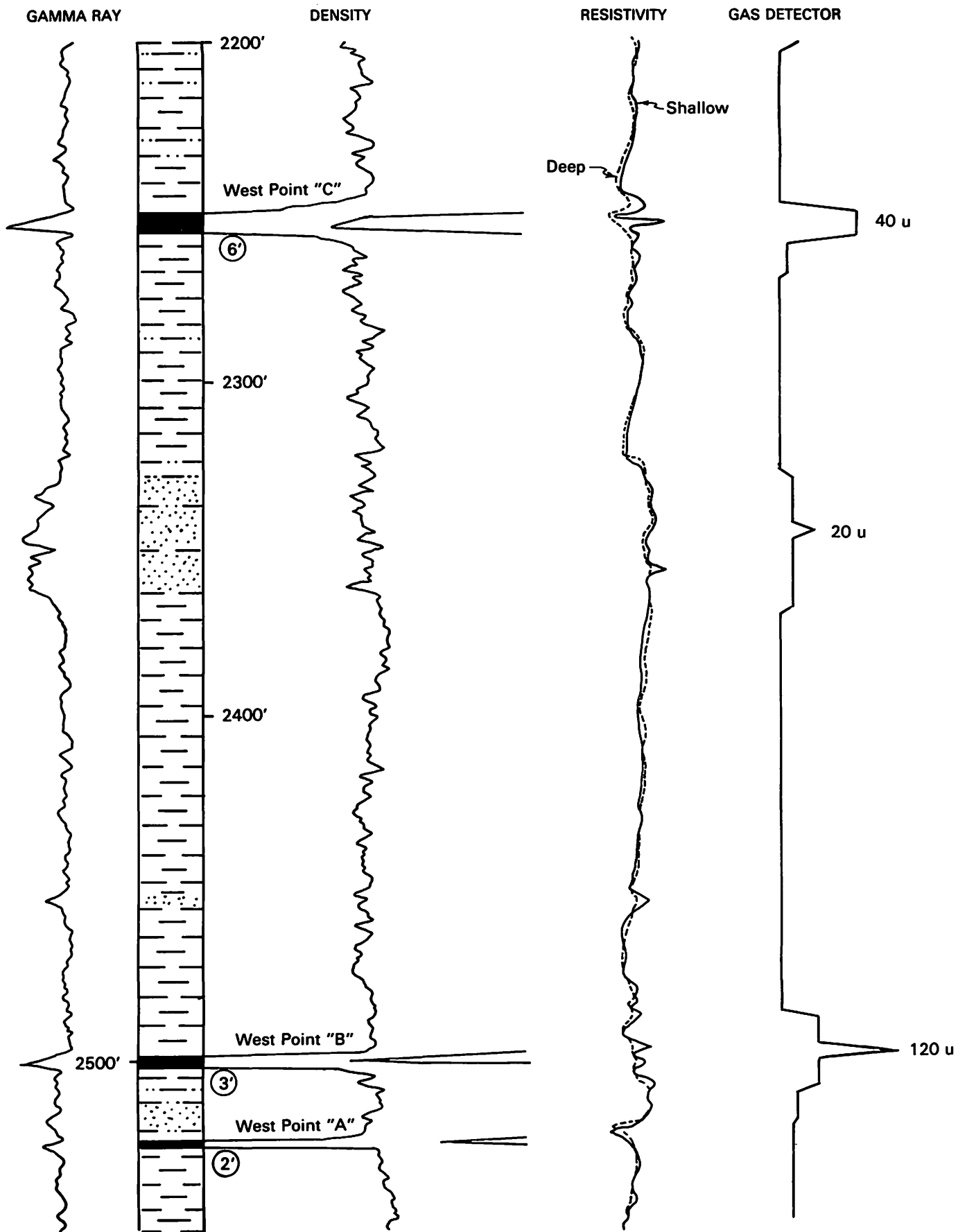


Figure 4. WEST POINT COAL GROUP "TYPE LOG"
 Grace Petroleum Corp. #1 Allen 27-6 (27-16S-6E)
 Scale: 2.5" = 100'

was recorded during drilling of the closely spaced West Point "B" and "A" seams. The correlation between observed gas readings recorded during drilling operations and actual gas content of the coal seam is not known. While this relationship is uncertain, the authors believe that the amount of gas recorded during drilling is a relative indicator of the gas content of coalbeds.

Sand Creek Group

The Sand Creek Group is the most extensively developed group both in terms of areal extent and aggregate thickness. As many as six individual seams comprise the Sand Creek Group, with the "D" seam being the most persistent. Individual seams vary from two feet to four feet in thickness. A maximum aggregate thickness of nine feet is recorded in three wells. The Sand Creek Group isopach map (Plate 5) shows the general trend of thickening to the northwest and southeast. The average aggregate thickness of the Sand Creek Group is 5.5 feet.

The Union Producing Co. #1 E. D. Pearson 21-7 (21-15S-4E) was chosen as the "type log" for the Sand Creek Group (Figure 5). In this well, the group consists of three seams which total nine feet in thickness. The "B", "C" and a "stray" seam occurring between the "C" and "D" seams were not considered coals in this well as they did not meet the criteria for a coal as defined in this report. In the Pearson well, the Sand Creek Group comprises a package of shales, silty shales, and fine-grained sandstones approximately 250 feet thick. For the most part, the Sand Creek Group coals appear to be associated with fining upward sandstones. Seams "D", "E", and "F" are the most laterally persistent and are associated with a thick (30 feet-60 feet), fine-grained, silty sandstone. In general, the bounding strata of the Sand Creek Group include more sandstones than do those of the other coal groups.

In an effort to determine the rank of the coal two samples of the Sand Creek Group coals were obtained from well cuttings stored at the Mississippi Bureau of Geology. These samples were sent to the School of Mines and Energy Development (SOMED) at the University of Alabama, Tuscaloosa, for vitrinite reflectance analysis. One of the samples was obtained from the Union Producing Co. #1 E. D. Pearson 21-7 (21-15S-4E) at a depth of 2570-2580 feet (Sand Creek "D"). This sample yielded a ranking of high volatile B bituminous. The other sample was obtained from the Meridian Oil Co. #1 Simmons 36-7 (36-16S-5E) at a depth of 1720-1750 feet (Sand Creek "F"). This sample was determined to rank high volatile A bituminous. While it is recognized that well cuttings may not be the best source for rank determination, they are the only presently available coal samples from the study area.

Whether or not sample age is a significant factor affecting the vitrinite reflectance values obtained from coal samples is not known. The coal sample from the Pearson 21-7 well yielding a high volatile B ranking was collected eight years prior to the time of analysis. The sample from the Simmons 36-7 which yielded a ranking of high volatile A was collected only six months before analysis (Table 3). The results of these two determinations suggest that sample age may be a factor. It is well known that postsampling conditions can have a degradational effect on coal samples. These include the environment in which they are stored and the preparation history of the samples. The coal samples used in this study were stored in an unheated and uncooled warehouse and, in addition, may have been subjected to multiple periods of intense heat from drying lamps prior to storage. Until core holes are drilled for the purpose

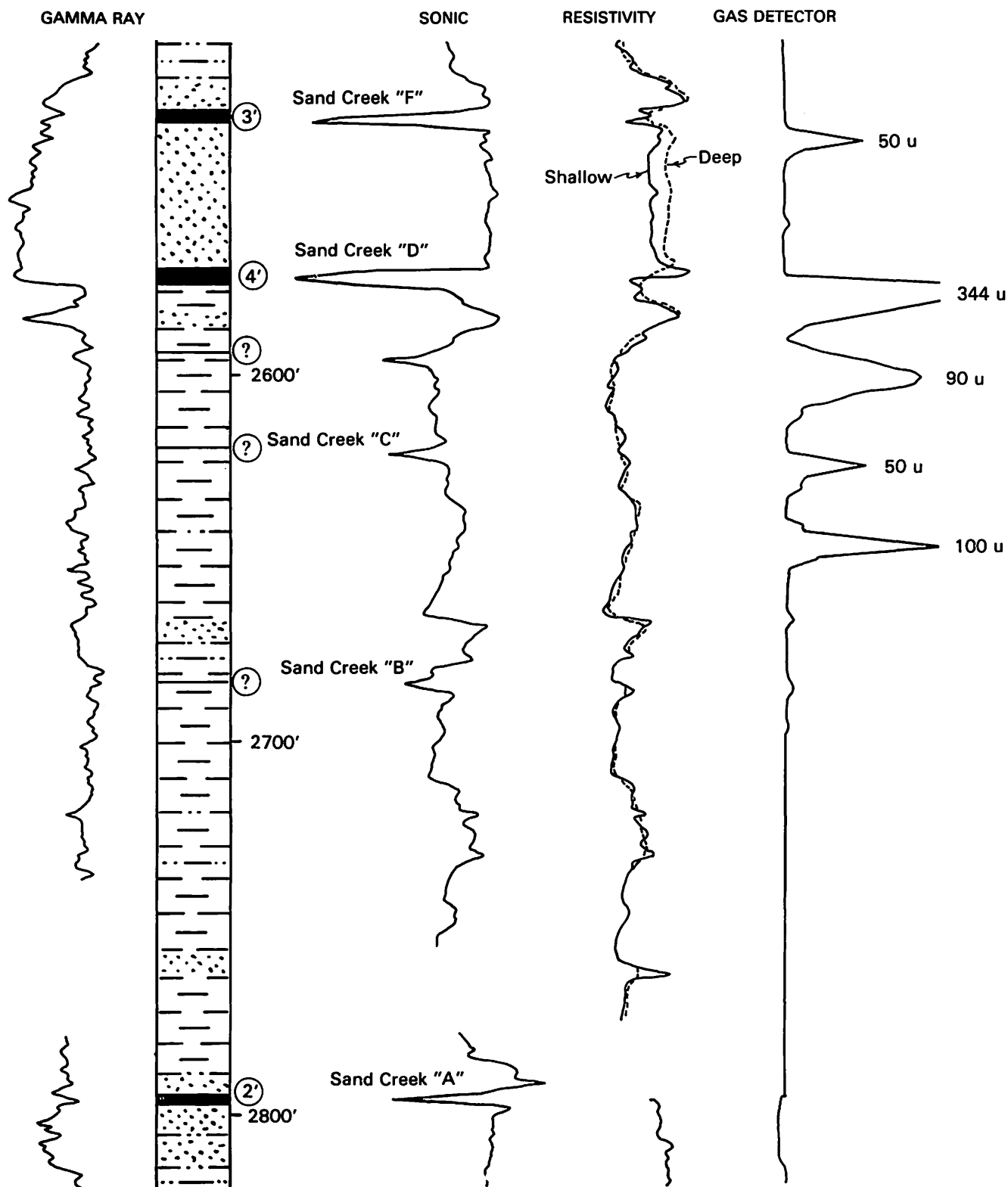


Figure 5. SAND CREEK COAL GROUP "TYPE LOG"
 Union Oil Co. of California #1 E.D. Pearson 21-7 (21-15S-4E)
 Scale: 2.5" = 100'

Table 3. Vitrinite Reflectance Analyses

| <u>Operator; Farm</u> | <u>Seam</u> | <u>Depth</u> | <u>Vitrinite Reflectance</u> | <u>Sample Age(years)</u> | <u>Rank</u> |
|-----------------------|------------------|--------------|----------------------------------|------------------------------|----------------------------|
| Union; Pearson | Sand Creek "D" | 2570-2580 | 0.65 | 8.0 | high volatile B bituminous |
| | Houlka Creek "B" | 3350-3360 | 0.79 | 8.0 | high volatile A bituminous |
| Champlin; Kellogg | Houlka Creek "B" | 3460-3480 | 0.74 | 8.5 | high volatile A bituminous |
| Southland; Steele | Houlka Creek "B" | 3190-3200 | 0.79 | 4.0 | high volatile A bituminous |
| Meridian; Simmons | Sand Creek "F" | 1720-1750 | 0.77 | 0.5 | high volatile A bituminous |

of obtaining more suitable coal samples, the accurate determination of rank and chemical properties of the coal seams identified will not be possible.

The "type log" (Figure 5) for the Sand Creek Group shows the gas detector readings for the coal beds. A reading of 50 gas units was recorded for the "F" seam. An impressive reading of 344 units methane gas was recorded for the "D" seam. An unnamed "stray" seam occurring below the "D" seam exhibited a maximum gas reading of 90 units. This "stray" seam was not named because it does not meet the previously discussed minimum criteria for a coal seam. The fact that a good gas reading was recorded for this "stray" seam would seem to indicate that the bed is in fact a coal seam. The same logic would apply to the Sand Creek "C" seam. This bed also recorded a gas show (50 units), but otherwise did not meet the minimum criteria for a coal seam. Another gas detector reading of 100 units occurring below the "C" seam is apparently not related to an individual coal seam but probably represents an accumulation of gas in the borehole during a drill string connection. The Sand Creek "B" seam is not developed in the "type log" well and no significant gas reading was recorded. Because surface casing was set a short distance from the top of the Sand Creek "A" seam, it is possible that this is the reason no gas show was recorded for this seam in the "type log" well.

The combination of multiple seams, favorable depth, and good gas shows make the Sand Creek Group the primary target for coalbed methane development in the study area.

Houlka Creek Group

The Houlka Creek Group is considered to be the most significant coal group other than the Sand Creek Group in the study area. The Houlka Creek Group consists of three coal seams, with the "B" seam the thickest and most persistent. Individual seams vary in thickness from two feet to five feet, with only the "B" seam attaining five feet. The "B" seam is probably the most important individual seam of the study area and averages 3.5 feet in thickness where it is present. The Houlka Creek Group isopach map (Plate 6) depicts the aggregate thickness of the group and indicates that it is best developed in the west-central portion of the study area.

The Union Producing Co. #1 E. D. Pearson 21-7 (21-15S-4E) was chosen as the "type log" for the Houlka Creek Group. In this well, the coal attains an aggregate thickness of seven feet. This aggregate thickness is representative of just two seams ("B" and "C"). The "type log" (Figure 6) shows the distinctive nature of the "x" marker (Houlka Creek "C") on induction type geophysical logs. This marker is characterized by a thin bed of very low resistance just below the "C" coal seam. In general, the Houlka Creek coals are associated with fine-grained silty sandstones. Bounding strata of the Houlka Creek Group consist of an approximately 150 foot thick sequence of silty shales and fine grained silty sandstones.

The rank of three samples of Houlka Creek coal was determined from well cuttings by vitrinite reflectance. All three samples were obtained from the Houlka Creek "B" seam. The age of the samples at the time of examination varied from four years to 8.5 years old. All three samples yielded a near uniform value for vitrinite reflectance (Table 3) and were determined to be of high volatile A bituminous rank. The reason for the uniformity of the vitrinite reflectance values obtained is not well

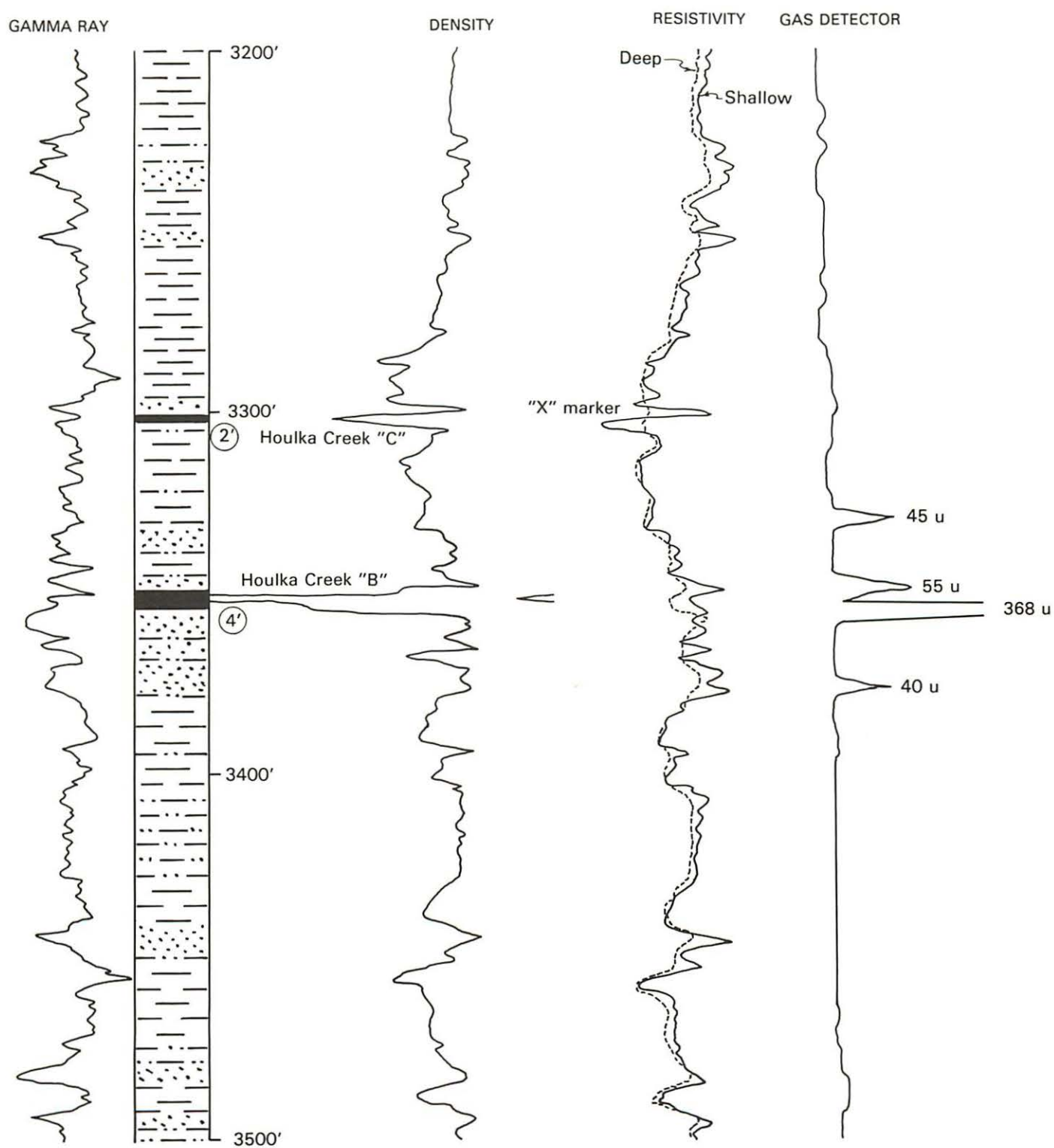


Figure 6. HOULKA CREEK COAL GROUP "TYPE LOG"
 Union Oil Co. of California #1 E.D. Pearson 21-7 (21-15S-4E)
 Scale: 2.5" = 100'

understood. Without additional study on the effects of sample age and other previously discussed factors affecting coal sample stability, it is not possible to conclusively determine coal rank.

In the Union Producing Co. #1 E. D. Pearson 21-7 (21-15S-4E) a gas detector reading of 368 units was recorded during drilling of the Houlka Creek "B" seam. This reading represents the highest coalbed gas value observed in the study area from the data available. The very high gas detector reading and the persistent lateral thickness of the Houlka Creek "B" seam make it the single most significant coal seam in the study area.

Line Creek Group

The Line Creek Group is the deepest of the studied coal groups, ranging from 2600 feet to 3700 feet deep. The group consists of four seams with thicknesses of individual seams varying from two feet to four feet. The maximum aggregate thickness of the Line Creek Group is seven feet and is attained in the Meridian Oil Co. #1 David Waide 25-13 (25-15S-4E). The Line Creek "C" is the most laterally persistent coal seam throughout the study area. The "C" seam averages 2.5 feet in thickness and is present in every well for which a density log was available.

The Meridian Oil Co. #1 David Waide 25-13 (25-15S-4E) was chosen as the "type log" for the Line Creek Group (Figure 7). The aggregate thickness of seven feet developed in this well is reflective of three of the four seams of this group. In this well the Line Creek Group coal seams are associated with thin, fine-grained sandstones. Bounding strata of the Line Creek Group consist of approximately 250 feet of predominantly silty shales with lesser amounts of silty sandstones. No samples of the Line Creek Group coals were examined for vitrinite reflectance values of rank. This is due in part to a lack of sufficient well cuttings for examination.

The Line Creek Group in the Waide 25-13 (Figure 7) includes three upper seams which occur within a 50-foot interval. Gas detector readings of 22, 78, and 80 units were recorded for the "D", "C", and "B" seams respectively.

Although the Line Creek Group does not appear to be as extensively developed as the Sand Creek and Houlka Creek groups, it is believed to be a potentially significant additional source of coalbed methane in localized areas.

RESOURCE POTENTIAL

Following the classification system of the United States Geological Survey, much of the coal resources of the study area must be classified as hypothetical. Hypothetical resources are defined as being more than three miles from a point of measurement (Wood et al., 1983). While some areas of western Clay County have good well control, there is an overall lack of sufficient data. For this reason, no attempt has been made to calculate demonstrated and inferred coal reserves as defined by Wood et al. (1983).

The gross volumetric tonnage of coal from the study area is based upon the net

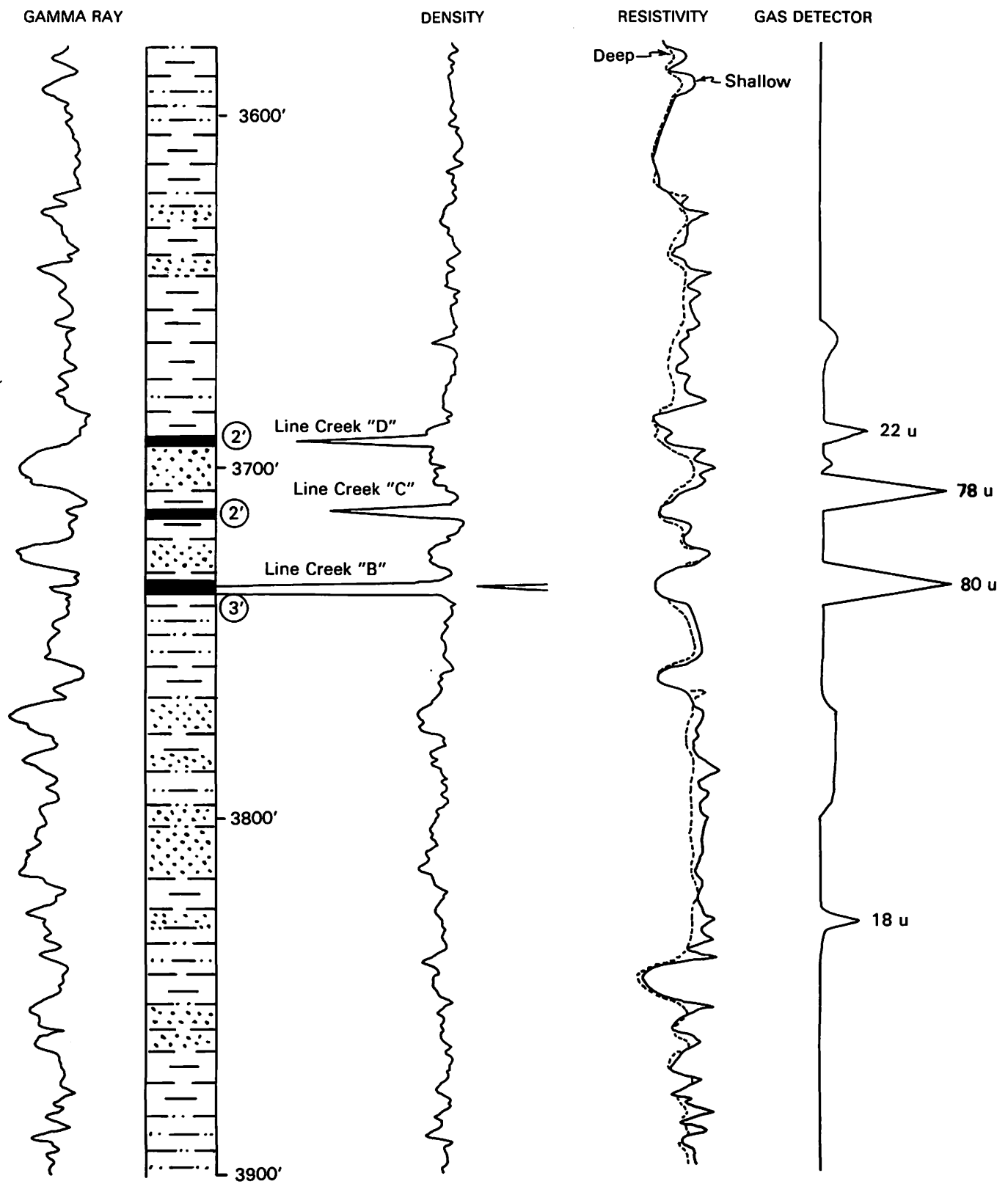


Figure 7. LINE CREEK COAL GROUP "TYPE LOG"
 Meridian Oil Company, Inc. #1 David Waide 25-13 (25-15S-4E)
 Scale: 2.5" = 100'

coal isopach map (Plate 7). Considerable latitude exists for interpreting the available well data and thus, also, for estimates of net coal tonnage. The tonnage for the four studied coal groups is estimated to be nearly 5.2 billion tons within the study area. This estimate of hypothetical coal resources was derived by direct measurement of net acreage multiplied by coal thicknesses derived from the net coal isopach map. Once the total acre-footage of coal was calculated, the net tonnage was obtained by multiplying this number by the generally accepted figure of 1800 tons/acre-foot for high volatile A bituminous coal (Averitt, 1975).

The coals identified in this report occur in discernible groups and were carefully correlated using key marker beds and stratigraphic relationships. While an attempt to correlate individual coal seams within these groups has been made, it is recognized that future data collection and well drilling could necessitate revision of these "seam to seam" correlations. The two cross sections (Plates 1 and 2) prepared for this study show the correlations and stratigraphic framework devised for the identified coal beds.

Although the gas content of the identified coal seams has never been directly measured, we believe significant coalbed methane reserves are present. This is based in part on significant gas shows (see "type log" illustrations) being recorded during drilling of some wells in the study area. Also, while several geologic and depositional factors influence methane content, coal rank and depth of burial are the two most important factors (McFall et al., 1986). The rank (high volatile A bituminous) and depth of burial (1800-3700 feet) of the coal seams identified in this report are favorable for the generation and retention of coalbed methane.

The gas content of the studied coal seams was estimated to average 200 cubic feet of gas per ton of coal. This estimate is derived from "Eddy" charts (Thompson and Telle, 1987) which relate methane content to coal rank and depth of burial (Figure 8). The maximum gas content for high volatile A bituminous coal is given as 480 cubic feet per ton and the minimum is given as 180 cubic feet per ton at a depth of 2500 feet.

While the maximum gas content is given as 480 cubic feet of gas for high volatile A bituminous coal at a depth of 2500 feet, this is not the highest value ever obtained. A gas content of 598 cubic feet per ton was measured for a Mary Lee coal group sample at a depth of 1504 feet in Tuscaloosa County, Alabama (Diamond et al., 1986).

Although no actual gas desorption studies have been initiated on the coals of western Clay County, the authors believe they have been conservative in arriving at a total estimated resource of slightly over one trillion cubic feet of gas (5.2 billion tons of coal multiplied by 200 cubic feet of gas per ton).

SUMMARY

One of the most accepted methods of geological investigation involves developing parallel comparisons ("look alike") between known geological phenomena or geographical areas and those subjects or areas being investigated. In an area such as Clay County with new coal groups, lack of definitive coal rank data, and no prior producing history, such comparisons are usually difficult. However, in view of the

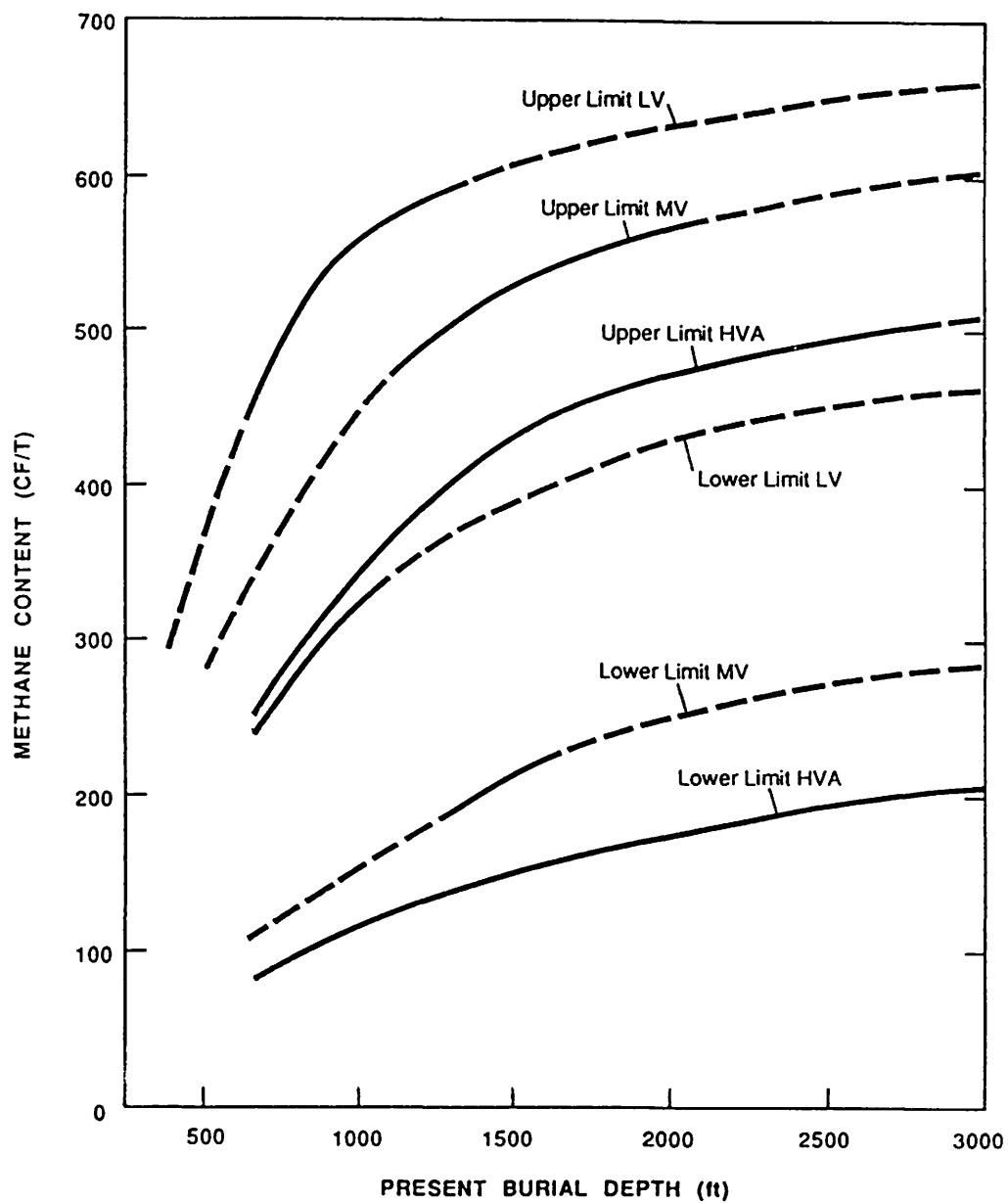


Figure 8. Graph showing observed gas content of bituminous coal versus present burial depth in the Black Warrior Basin of Alabama. (After Thompson and Telle, 1987)

recent success in Alabama of producing coalbed methane from the deeper seams of southeastern Tuscaloosa County, the potential for Mississippi must be considered as favorable. The rank of coal and depth of burial in western Clay County are analogous to much of Cedar Cove degasification field. Cedar Cove is located approximately ten miles east of the city of Tuscaloosa, Alabama.

The Alabama Methane Production Company (AMPCO) opened Cedar Cove Field in 1983. Production is from the Cobb through the Black Creek coal groups at depths ranging from approximately 1200 feet to 3150 feet. An aggregate coal thickness of 20 feet was recorded from 1193 feet to 3089 feet in the AMPCO well number 35-3/#6 (35-21S-8W). This well tested 263,000 cubic feet of gas per day with 37 barrels water per day (GRI, 1985).

Since gas sales began in July 1984, Cedar Cove Field has produced 2.4 billion cubic feet of gas through May 30, 1988 (GRI, 1988). In 1987, a total of 17 wells produced 724,721,000 cubic feet of gas (Tolson, 1988), making Cedar Cove the most successful coalbed degasification field in Alabama not associated with active coal mining operations.

An important factor related to the producibility of coalbed methane is the salinity of the produced water, because it has traditionally been disposed of by surface methods in Alabama. If the salinity of produced water were too great, it would have to be injected into disposal wells. This would probably make coalbed methane prohibitively expensive with today's economic climate.

Produced water in Cedar Cove Field averages 3900 mg/l chlorides and has a pH of 7.3 (O'Neil et al., 1987). The salinity of coalbed waters in Clay County, Mississippi, is not currently known; however, it seems reasonable to assume a water quality comparable with Cedar Cove Field. It is interesting to note that a thick sand occurring within the Sand Creek coal group in the Union Oil Company of California #1 E. D. Pearson 21-7 apparently contains "fresh" water. This is based on the observation that the induction log (Figure 5) shows a higher deep resistivity than it does shallow resistivity. The sodium chloride concentration of the formation water in this zone as calculated by the reverse Archie method (Schlumberger, 1987) is 2800 ppm. While log calculations permit estimates, without an actual water sample for analysis the salinity of the formation water cannot be accurately determined.

It must be understood that the authors have not developed speculative economic data that might be used in an attempt to commercialize the coal or coalbed methane resources of Clay County. Rather it was the specific purpose of this study to present all generally available data to both industry and the public so that any potential development can be made based upon facts, not speculation.

If the coalbed gas resources are economic, industry will develop them. If the coal seams contain economically recoverable coal reserves, industry will mine them. However, in order for any of this to take place the information concerning the presence of these resources must be made available.

It is the basic function of the Bureau of Geology to examine the geological resources of Mississippi and to publish reports useful to industry and the public. This investigation represents the first step in developing a better understanding of our bituminous coal resources. The potential for immediate development of these resources is unknown at this time, but the authors are confident that some future development of these resources will occur.

The future appears bright for the potential development of the coal resources of northeastern Mississippi. Additional coal and gas resources not yet investigated by the Bureau of Geology were noted during this study. These coal and coalbed methane resources are at depths deeper than those covered by this investigation. Some of the wells used for this study were noted to have significant deep coal potential; one well had over 70 feet of net coal measured in 31 different coal seams. At present the rank of these deeper coals is not known. If these coals are found to be medium or low volatile in rank and therefore contain more gas per ton (see Figure 8), these resources may potentially represent trillions of cubic feet of additional gas resources.

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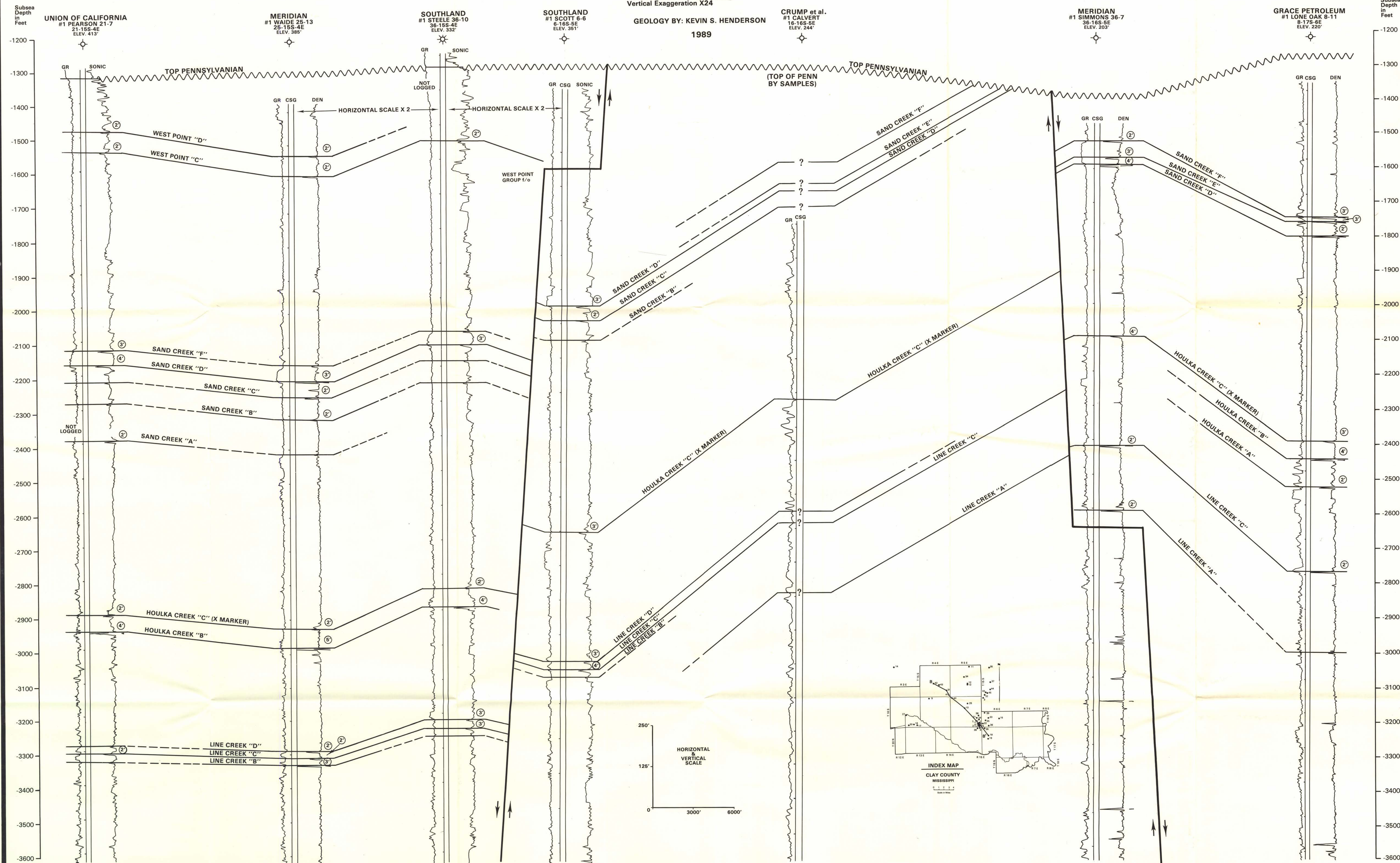
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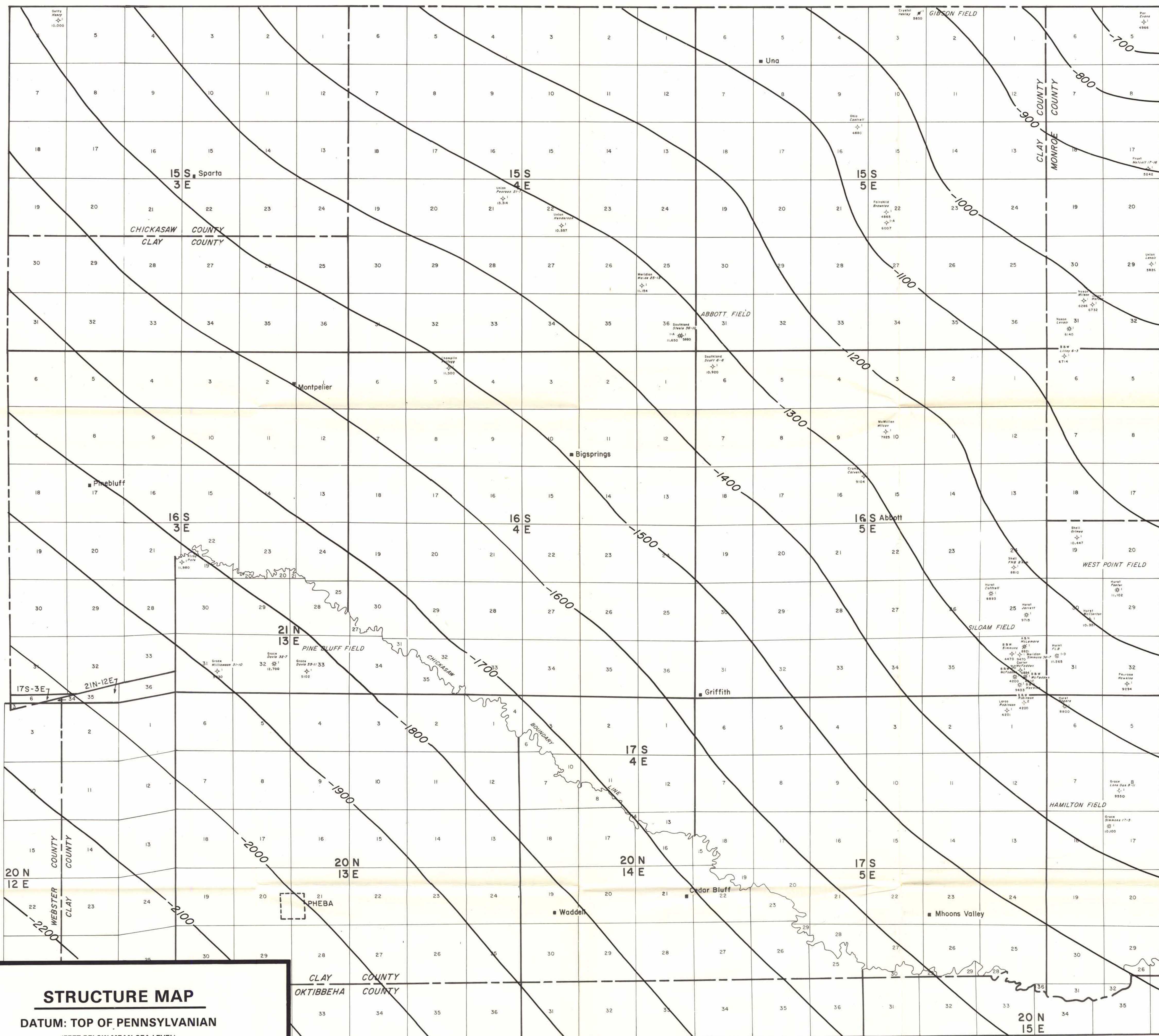
MISSISSIPPI BUREAU OF GEOLOGY
CONRAD A. GAZZIER, DIRECTOR

STRUCTURAL CROSS SECTION B-B'

REPORT OF INVESTIGATIONS 1
PLATE 2

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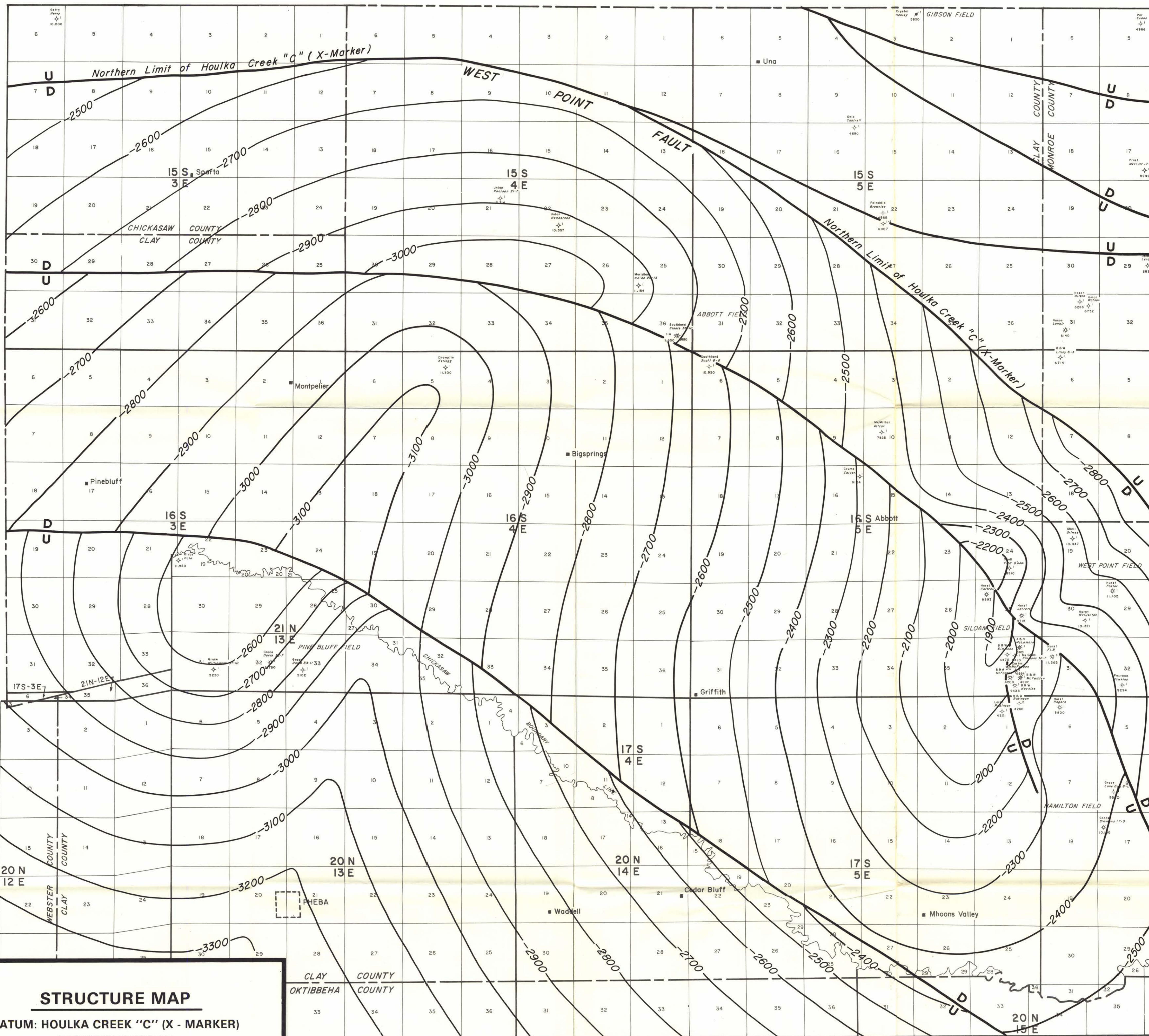
STRUCTURE MAP

DATUM: TOP OF PENNSYLVANIAN

(FEET BELOW MEAN SEA LEVEL)
CONTOUR INTERVAL - 100 FEET

4000 0 4000 8000 feet
SCALE

GEOLOGY BY: KEVIN S. HENDERSON



STRUCTURE MAP

DATUM: HOULKA CREEK "C" (X - MARKER)

(FEET BELOW MEAN SEA LEVEL)
CONTOUR INTERVAL - 100 FEET



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