UTILIZING THE UNCONVENTIONAL GAS RESOURCES OF THE POTTSVILLE FORMATION COALS IN TUSCALOOSA COUNTY, ALABAMA

Feasibility Study

prepared by
The University of Alabama
School of Mines and Energy Development

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EXECUTIVE SUMMARY

The University of Alabama, with a grant from the Department of Energy, has completed a feasibility study for coalbed methane development on campus.

A wireline corehole was drilled to a depth of 2965 feet and core was recovered continuously from the top of the Pottsville Formation. Over 33 lineal feet of coal was recovered of which 31 feet were subjected to desorption analysis.

Coal samples were desorbed of gas according to standard U.S. Bureau of Mines techniques for estimating gas content. Coal thickness and gas content data were used to calculate gas resources. The total resource present is nearly 10 billion cubic feet beneath the 760-acre campus. The Mary Lee coal group alone contains more than 3.4 billion cubic feet of gas at 75% recovery.

Within the context of the government and industrial experience and given the resource base, projected gas production rates, capital requirements and operating costs, standard techniques of economic analyses indicate that development of University property is feasible but requires careful planning and execution.

UTILIZING THE UNCONVENTIONAL GAS RESOURCES OF THE POTTSVILLE FORMATION COALS IN TUSCALOOSA COUNTY, ALABAMA

1.0 Project Description

The University of Alabama's unconventional gas project entitled "Utilizing the Unconventional Gas Resources of the Pottsville Formation Coals in Tuscaloosa County, Alabama," was funded in October, 1980. The project is part of the Department of Energy's Unconventional Gas Resources (UGR) program with general goals defined as exploratory drilling and evaluation to determine the amount of methane gas in various coalbeds, and as planning for efficient on-site or local utilization of the gas.

DOE's estimated average production costs for coalbed methane range from $1.25/MCF (optimistic) to $2.75/MCF (pessimistic). If these estimates prove to be realistic in a given area, coalbed methane can be competitive as a supplemental fuel even under the most pessimistic estimate of production cost and can represent an important energy source for community, institutional, and business development.

1.1 Background

Excerpts of the program plan for this project, as given in the original proposal, submitted to DOE in 1980, are paraphased below (with minor modifications).

The University of Alabama and the Bryce State Hospital, in Tuscaloosa, Alabama, are major consumers of energy, including natural gas. The two state institutions adjoin; and, through fee simple title, control the surface and mineral rights of about 1000 acres of land on which the facilities are located. The University and the Bryce State Hospital control 760 and 250 acres, respectively. The Partlow State School and Hospital, adjoining the University-Bryce operations, also controls a substantial acreage (see Figure 1); it is likely that they would participate in any expanded development program.

The Geological Survey of Alabama has identified 24 coal seams in the Pottsville Formation of Pennsylvanian Age which underlies the campus and surrounding area. Based on drill hole logs provided by Jim Walter Resources, Incorporated, from a borehole located about 10 miles north-northeast of Tuscaloosa, and on a neutron density log of a disposal well drilled on the property of the Reichhold Chemical Company about 4 miles northeast of Bryce Hospital, it was anticipated that perhaps 22 coal seams were present beneath the study area. Although most of the seams were considered to have potential for gas production, selected beds, because of their thicknesses and known gassiness in nearby areas, appeared to offer an excellent opportunity for producing substantial volumes of gas. The productivity level anticipated from one or more of the seams in combination with the large area controlled by the two institutions indicated that significant methane gas might be produced from a developed field over a long period of time.

The proposal committed The Unviersity of Alabama and the Bryce State Hospital to carry out a coordinated program embracing exploratory drilling

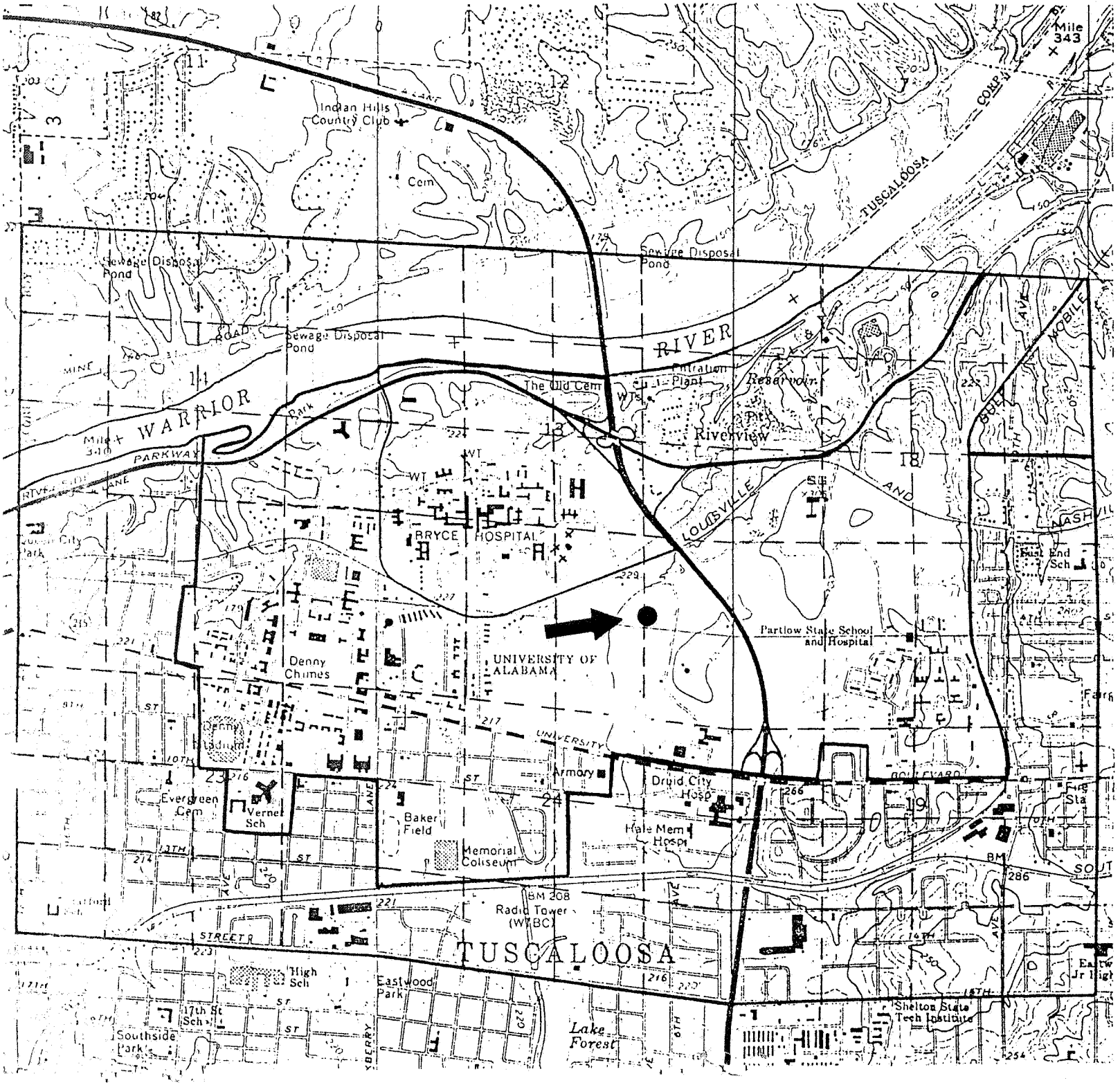


FIGURE. 1

THE UNIVERSITY OF ALABAMA
COALBED METHANE GAS DEVELOPMENT PROJECT

University of Alabama and Adjacent Properties

Location of Test Corehole ●

and coring to evaluate the gas production potential of the coalbeds underlying collective land and mineral holdings.

The report which follows is essentially a site-specific coalbed methane development feasibility evaluation (technical and economic) based on the project test data, together with information derived through numerous government and industry consultations.

2.0 Technical Data

The Coalbed methane test corehole was initiated on March 24, 1981, and was completed on April 16, 1981. The ground elevation of the site was surveyed at 262 feet above mean sea level. Surface casing was set to approximately 100 feet and size NX core was recovered continuously to the total depth of 2965 feet. Core recovery was about 99%.

Upon completion of the hole a suite of geophysical logs was run and printouts consisted of the following log combinations: gamma ray, long-spacing density, caliper; bed resolution (short-spacing) density, caliper; expanded scale gamma ray (reversed), expanded-scale long spacing density; single-point resistivity; and absolute temperature, differential temperature. Copies of all geophysical logs are on file with DOE's Region IV office in Atlanta and with the State of Alabama Oil and Gas Board in Tuscaloosa, Alabama.

The day-to-day operations of drilling, sampling and testing were supervised and/or carried out by personnel of the Mineral Resources Institute (MRI), a division of the School of Mines and Energy Development.

Over 33 lineal feet of coal was recovered from the hole, of which about 31 feet was subjected to testing for gas content. A schematic log of

the coal seams with tentative coal group correlations is provided as Figure 2. A detailed lithologic log of the entire core was prepared by personnel of the Geological Survey of Alabama, and is a appended to this report. The direct coal desorption method, standardized by the Bureau of Mines, was closely followed in the desorbed gas content determinations which were completed in the MRI laboratories. Lost gas and residual gas determinations were made by the U.S. Bureau of Mines Methane Control Group in Pittsburgh, Pennsylvania. An example of the computer-plotted lost gas graph is shown as Figure 3. All of the test procedures are well-established in the literature and will not be accorded a detailed discussion in this report. A summary of the data related to the gas content of the coal is given in Table 1. Gas chromatographic analyses (Table 2) indicate that the methane (CH_4) content generally averages about 95% with a heating value of 970 BTU or greater.

Measured coal thicknesses were used to estimate the volume of coal in place. The coal volumes and gas content data were then combined to calculate the total methane gas resource. Figure 4 provides an example of the coal and gas resource calculations and assumptions; Table 3 summarizes the findings.

2.1 Discussion

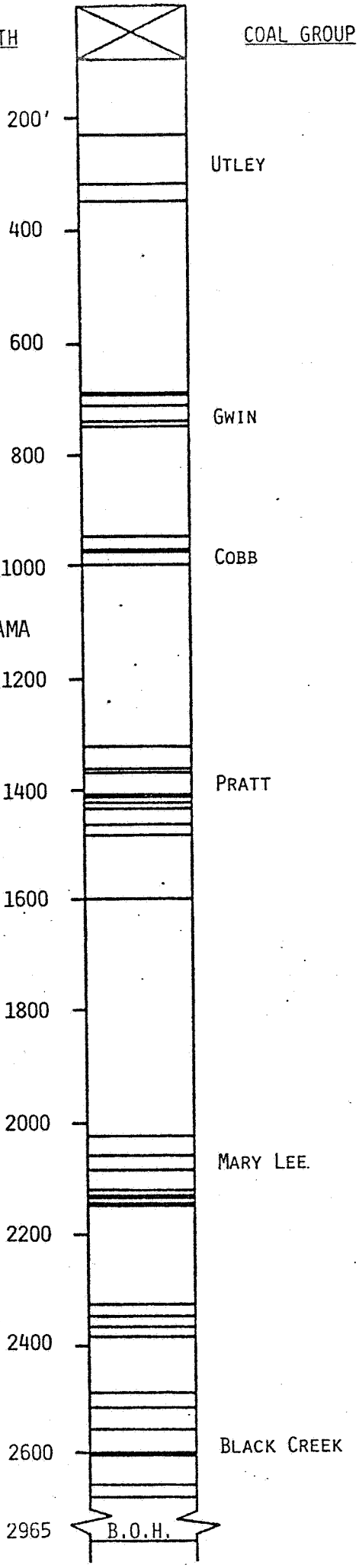
A total resource of nearly 10 billion cubic feet of coalbed methane is indicated beneath the 760 acre campus. As the data given in Tables 1 through 3 clearly illustrate, the coalbed methane, which is present beneath the University and Bryce Hospital, is a significant and potentially valuable resource not only in terms of market value but also assured gas

SURFACE ELEVATION:
262' MSL

FIGURE 2

UNIVERSITY OF ALABAMA
COALBED METHANE
GAS PROJECT

COAL LOG OF
TEST COREHOLE



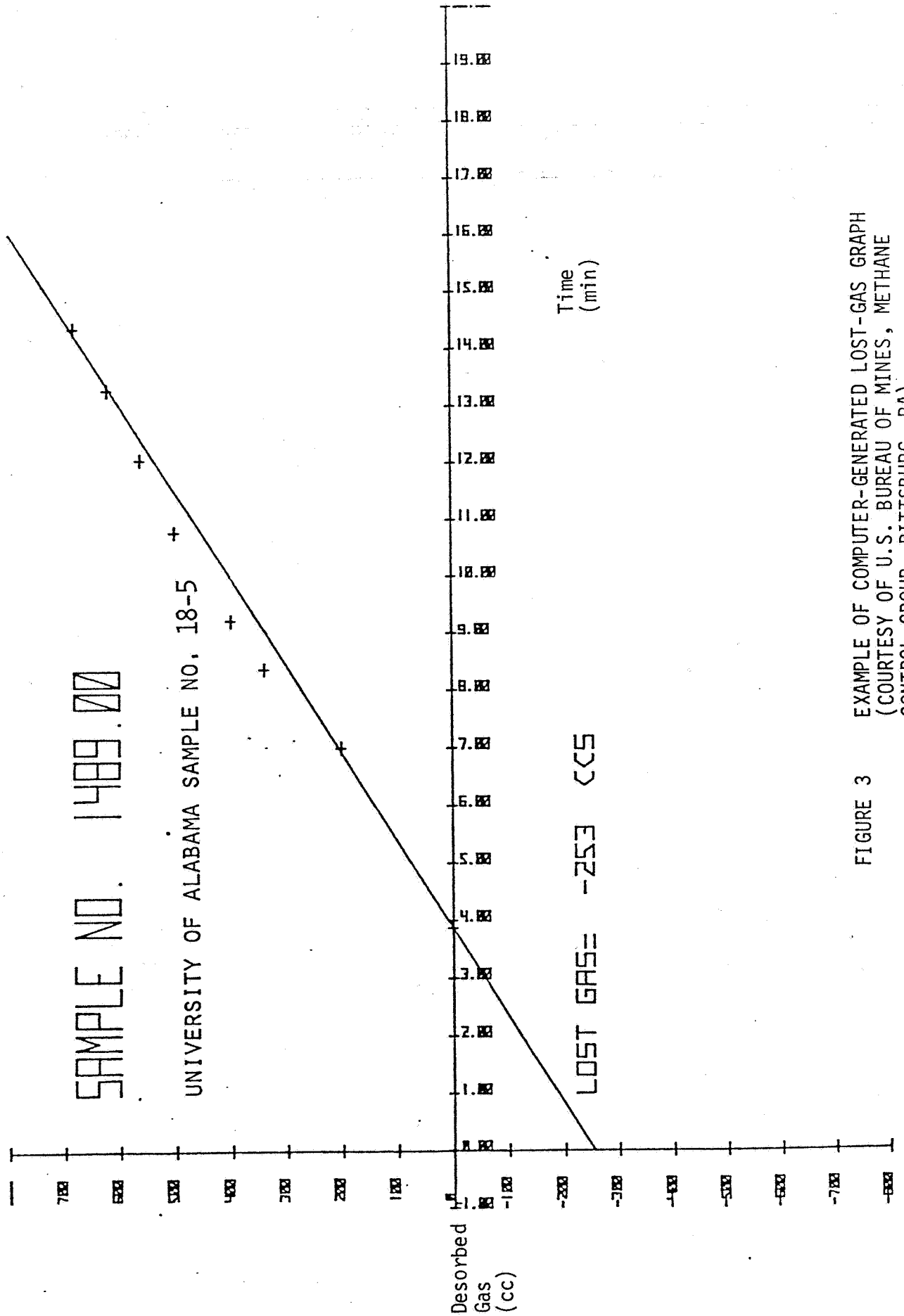


FIGURE 3 EXAMPLE OF COMPUTER-GENERATED LOST-GAS GRAPH (COURTESY OF U.S. BUREAU OF MINES, METHANE CONTROL GROUP, PITTSBURG, PA)

Table 1. Gas Content Data

Sample #	Depth To Top of Seam (ft.)	Sample Thickness (ft.)	Sample Weight (gms)	Extrapolated Lost Gas (cc)	Measured Desorbed Gas (cc)	Total Gas Desorbed (cc)	Residual gas (cc)	Gas Content (cc/g)	Gas Content (Cf/Ton)
AU-1-14A	226.9	1.30	712	2	139	141	0.4	0.2	6
AU-1-11A	318.4	1.65	1387	ND	180	180	0.4	0.1	4
AU-1-6A	689.5	2.00	1630	88	4,069	4,157		2.6	82
AU-1-3A	737.0	0.75	745	79	1,662	1,741	1.5	2.3	75
AU-1-4A	968.1	0.90	665	103	1,453	1,556	3.6	2.3	75
AU-1-24A	969.0	1.10	727	67	1,433	1,500	2.8	2.1	66
AU-1-20A	1315.3	0.45	334	26	805	831	1.3	2.5	80
AU-1-1A	1405.1	1.50	1179	74	7,321	7,395		6.3	201
AU-1-5A	1479.5	0.55	441	175	2,130	2,305		5.2	167
AU-1-21A	1596.7	0.67	550	36	3,909	3,945		7.2	230
AU-1-13A	2015.1	0.50	444	ND	4,048	4,048		9.1	292
AU-1-18A	2058.0	0.46	420	81	760	841	2.0	2.0	64
AU-1-12A	2077.5	0.60	479	137	3,575	3,712		7.7	248
AU-1-22A	2120.7	1.00	853	148	6,940	7,088		8.3	266
AU-18-3	2126.9	2.20	1928	299	20,443	20,742		10.8	344
AU-18-5	2129.1	1.60	1095	253	13,872	14,125		12.9	413
AU-18-1	2142.3	2.20	1915	484	20,035	20,519		10.7	343
AU-18-4	2146.7	2.70	2314	582	22,633	23,215		10.0	321
AU-1-2	2151.8	0.69	736	116	3,465	3,581		4.9	156
AU-1-7A	2321.6	0.45	306	71	1,550	1,621	1.2	5.3	170
AU-1-16A	2340.5	0.75	951	278	6,420	6,698		7.0	225
AU-1-25A	2356.7	0.33	369	95	3,770	3,865	0.9	10.5	335
AU-1-17A	2378.1	0.70	441	104	5,040	5,144		11.7	373
AU-1-8A	2469.7	0.60	490	131	3,110	3,241		6.6	212
AU-1-23A	2502.5	1.05	1117	407	5,410	5,817		5.2	167
AU-1-19A	2542.4	0.40	156	64	2,020	2,084		13.4	427
AU-1-9A	2594.4	1.20	1074	431	6,295	6,726		6.3	200
AU-18-6A	2595.6	1.80	1366	855	17,730	18,585		13.6	435
AU-1-15A	2648.2	0.25	182	95	2,215	2,310		12.7	406
AU-1-10A	2670.9	1.00	721	531	9,645	10,176		14.1	452

Table 2. Preliminary Gas Chromatographic Analyses of Mary Lee Group Coalbed Methane Samples

Sample No.	Mole Percent					Btu
	CH_4	C_2H_6	O_2	CO_2	N_2	
1-22*	76.1	0.207	4.33	0.55	18.8	775
18-3	95.9	0.037	0.41	0.62	3.0	972
18-5*	86.2	0.033	2.1	0.57	11.1	873
18-1	95.7	0.089	0.46	0.45	3.31	970
18-4	97.2	0.023	0.21	0.28	2.3	984

*Possible atmospheric contamination remaining with sample.

FIGURE 4

EXAMPLE OF GAS RESOURCE CALCULATIONS

A. Coal Tons in Place = Coal Thickness x 1750 Tons/Ac-Ft x Acres

= 10 Ft x 1750 Tons/Ac-Ft x 760 Ac

= 13.3 Million Tons

B. Gas Resource = Coal Tons x Gas Content

= 13.3 Million Tons x 340 Cf/Ton

= 4.5 Billion Cubic Feet

Table 3 The Gas Resource Base

Sample #	Depth to Top of Seam (Ft.)	Seam or Group	Sample Thickness (Ft.)	Gas Content Cf/Ton	Coal Base Per 40 Acres (Tons x 1000)	Total Gas Resources Per 40 Acres (MCF)	Gas Resources Per 40 Acres @ 50% Recovery (MCF)	Gas Resources Per 40 Acres @ 75% Recovery (MCF)
AU-1-14A	226.9		1.30	6	91	546	273	410
AU-1-11A	318.4		1.65	4	115	460	230	345
AU-1-6A	689.5		2.00	82	140	11480	5740	8610
AU-1-3A	737.0		0.75	75	52.5	393	1969	2953
AU-1-4A	968.1		0.90	75	63	4725	2363	3544
AU-1-24A	969.0		1.10	66	77	5082	2541	3812
AU-1-20A	1315.3		0.45	80	31.5	2520	1260	1890
AU-1-1A	1405.1		1.50	201	105	21525	10763	16144
AU-1-5A	1479.5		0.55	167	38.5	6430	3215	4822
AU-1-21A	1596.7		0.67	230	46.9	10787	5394	8090
AU-1-13A	2015.1		0.50	292	35	10220	5110	7665
AU-1-18A	2058.0		0.46	64	32.2	206	1030	1546
AU-1-12A	2077.5		0.60	248	42	10416	5208	7812
AU-1-22A	2120.7		1.00	266	70	18620	9310	13965
AU-18-3	2126.9		2.20	344	154	52976	26488	39732
AU-18-5	2129.1	Mary Lee	1.60	413	112	46256	23126	34692
AU-18-1	2142.3		2.20	343	154	52822	26411	39617
AU-18-4	2146.7		2.70	321	189	60669	30335	45502
AU-1-2	2151.8		0.69	156	48.3	7535	3767	5651

Table 3 Continued

Sample #	Depth to Top of Seam (Ft.)	Seam or Group	Sample Thickness (Ft.)	Gas Content Cf/Ton	Coal Base Per 40 Acres (Tons x 1000)	Total Gas Resources Per 40 Acres (MCF)	Gas Resources Per 40 Acres @ 50% Recovery (MCF)	Gas Resources Per 40 Acres @ 75% Recovery (MCF)
AU-1-7A	2321.6		0.45	170	31.5	5355	2678	4016
AU-1-16A	2340.5		0.75	225	52.5	11813	5906	8859
AU-1-25A	2356.7		0.33	335	23.1	7739	3869	5804
AU-1-17A	2378.1		0.70	373	49	18277	9139	13708
AU-1-8A	2469.7		0.60	212	42	8904	4452	6676
AU-1-23A	2502.5		1.05	167	73.5	12275	6137	9206
AU-1-19A	2542.4		0.40	427	28	11956	5978	8967
AU-1-9A	2594.4	Black Creek	1.20	200	84	16800	8400	12600
AU-18-6A	2595.6		1.80	435	126	54810	27405	41108
AU-1-15A	2648.2		0.25	406	17.5	7105	3553	5329
AU-1-10A	2670.9		1.00	452	70	31640	15820	23730
TOTAL			31.35		2,194	512,197	257,870	386,805
				GRAND TOTAL	41,686,000 Tons Per 760 Ac	9.7 BCF Per 760 Ac	4.9 BCF Per 760 Ac	7.3 BCF Per 760 Ac

supply. Even if only the Mary Lee coal at 50% recovery is considered, about 2.3 billion cubic feet of gas is available for development.

The quality of gas appears to be very good, and the quantity of methane gas indicated can supply the University's energy needs for many years provided that gas production is technically and economically feasible.

The technical aspect of coalbed methane production is an evolving science. In general, techniques developed by the petroleum industry (with modifications in some cases) are being applied to coalbed degasification with mixed results. The ultimate success of a degasification well is dependent on many site-specific factors (geological, hydrological, rock mechanical) being properly matched with well design and completion techniques. Standardization of techniques within a field does not insure production success -- each well is inherently different.

Despite the difficulty, enough success has been demonstrated that both government research and development programs, and industry commercialization projects are proceeding, if somewhat cautiously. The School of Mines and Energy Development's view is that technical problems, where they exist, will be resolved; and, that the feasibility of a coalbed gas field on campus is essentially contingent on the positive economic considerations which are discussed at length in Section 5.0.

The economic viability of coalbed methane production and utilization at The University of Alabama is based on the completed drilling testing and two development scenarios which have been subjected to economic analysis.

These include 1) a single well and 2) a three-well complex as an early phase of development of the entire University and Bryce Hospital properties. As previously mentioned, the adjoining Partlow State Hospital, and other entities, may also enter into the development of coalbed methane gas wells in this area.

Results of the economic study will be utilized by The University of Alabama's Board of Trustees in making a final decision regarding gas field development.

3.0 Development Planning

Multiple wells are planned on government quarter/quarter section (40-acre) spacings, but flexibility to change the spacing plan as technical and/or regulatory developments require is being retained in the field designs now under consideration. Close communication is being maintained with the Alabama State Oil and Gas Board regarding applicable regulatory constraints and rules changes which may be promulgated especially for coalbed gas well and field development.

The test corehole was left unplugged and, in cooperation with the U.S. Geological Survey, a continuous water level recorder has been installed. If a production well(s) is completed nearby, water level data may be useful in evaluating the effects of well stimulation, area of well influence, and drawdown, transmissivity and other hydrological parameters.

Long-range plans include a number of options for well completion and stimulation. The initial well(s), will probably be drilled to the bottom of the Black Creek coalbed but, for the purpose of economic studies, only two coal zones will be considered for stimulation -- the Mary Lee and the

Black Creek. Geophysical logs showing the seam spacings and other characteristics of the Mary Lee and Black Creek coals are given in Figures 5 and 6. Five to 6 additional zones contain sufficient gas to merit consideration for future development as dictated by changing technical, economic and gas supply conditions.

4.0 Energy Usage by The University of Alabama

Energy usage by The University of Alabama for the previous 4 years is given in Table 4.

Fluctuations are evident between usage of coal and natural gas and are dependent on coal pricing, environmental controls, and interruption of gas service. Natural gas provides heat for most essential hot water and cooking services for the campus and fills part of the need for steam heat. During winter months, coal is used extensively to generate steam heat. Thus, gas use fluctuates throughout the year based on ambient temperatures and use of coal as an alternate fuel. University consumption by month for the last full fiscal year is given in Table 5.

Gas costs are estimated for 1981-82 fiscal year at $3.48/MCF for interruptible gas (over 7800 MCF/month) and low sulphur coal at $57.50/ton. This approximates $2.40 per million BTU for coal compared to $3.48 per million BTU for gas.

Natural gas usage is expected to increase about 2% each year based on the projected increase of University physical plant facilities from 5.2 to 6 million square feet by 1990.

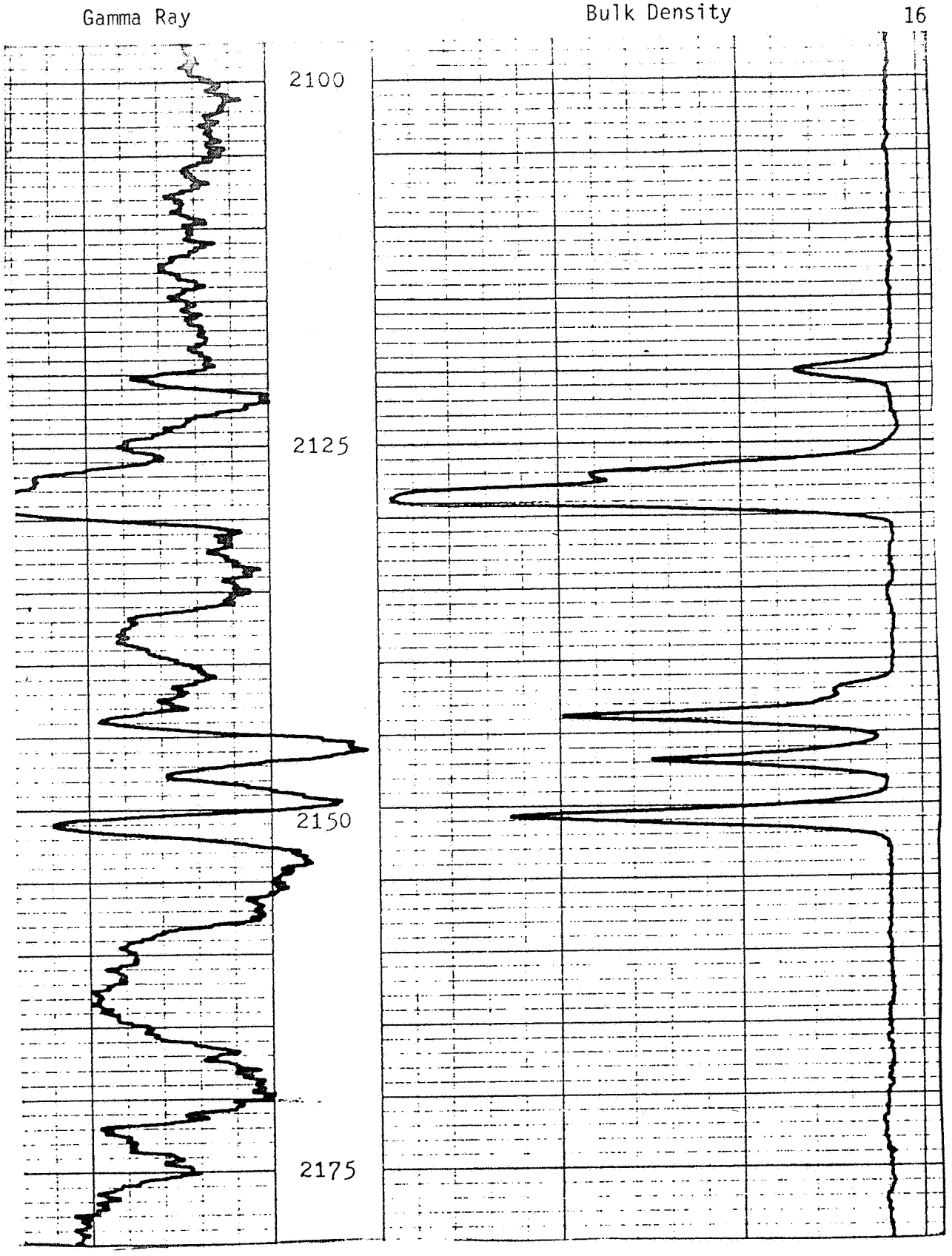


Figure 5. Geophysical Logs of a Portion of the Mary Lee Coal Group

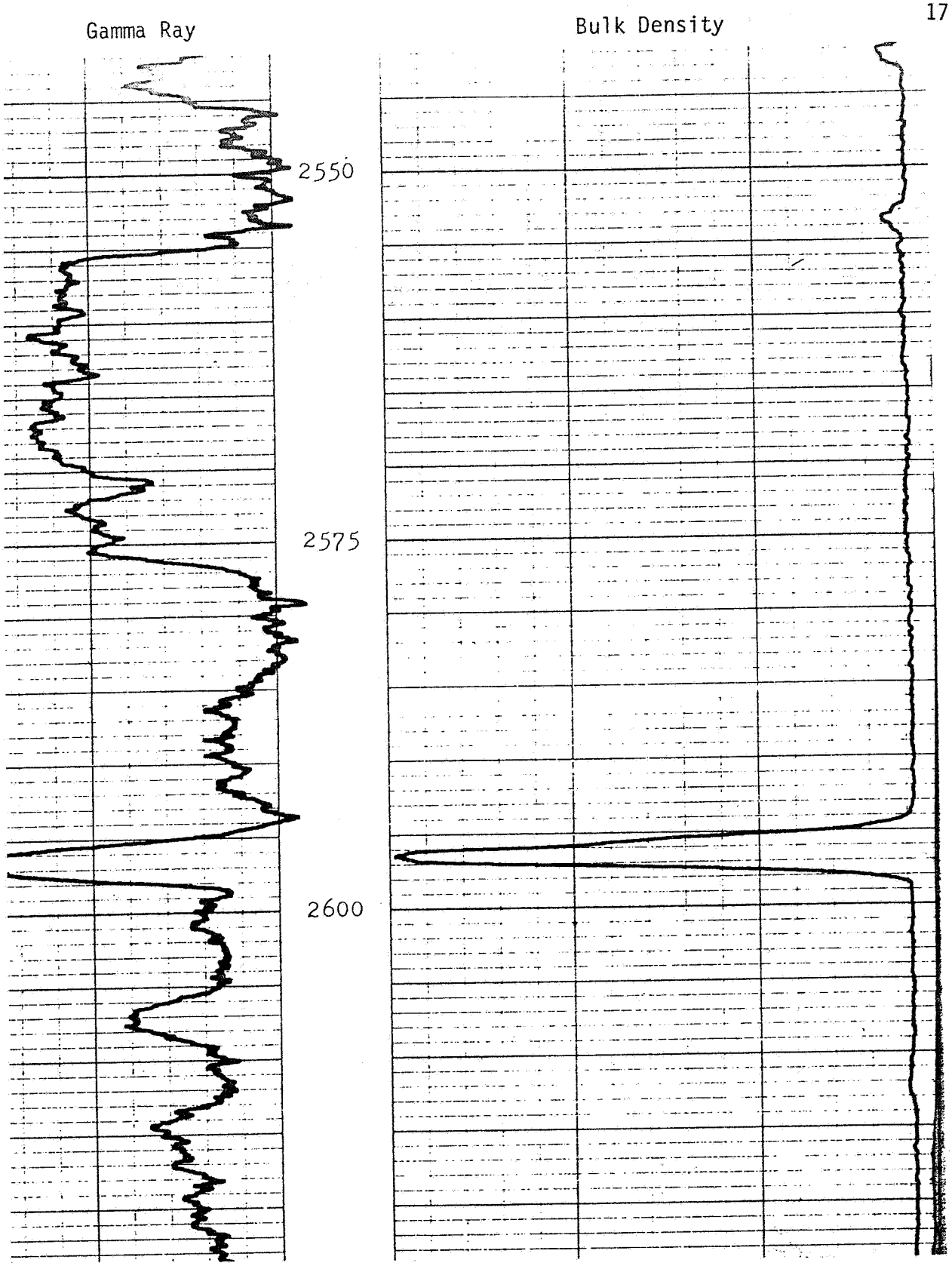


Figure 6. Geophysical Logs of a Portion of the Black Creek Coal Group

Table 4

Energy Usage - The University of Alabama
(Billion BTU's)*

Fiscal Year	Coal	Natural Gas	Electricity	Total
76-77	218.5	147.2	276.2	601.9
77-78	26.0	259.8	212.5	498.3
78-79	120.9	139.7	189.8	450.4
79-80	131.6	120.5	193.9	446.0

* One billion BTU's (1 x 10^9 BTU) is equivalent to 1,000 MCF of natural gas. Therefore, total campus energy usage of 446.0 x 10^9 BTU in 1979-80 is equivalent to 446,000 MCF of natural gas.

Table 5

Natural Gas Consumption - The University of Alabama

Fiscal Year 1979-80

	MCF	Dollars	Dollars/MCF
October 1979	12,654.1	$40,013	$3.16
November	29,271.9	83,073	2.84
December	12,961.1	39,282	3.03
January 1980	7,790.5	26,333	3.38
February	7,106.7	24,692	3.47
March	11,607.1	37,971	3.27
April	17,064.0	54,291	3.18
May	4,530.7	15,738	3.47
June	4,079.5	14,165	3.47
July	3,833.5	12,163	3.17
August	4,129.2	12,894	3.12
September	5,475.5	17,017	3.11
Average/Month	10,042.0	$31,469	$3.13
Maximum/Month	29,271.9		
Minimum/Month	3,833.5		

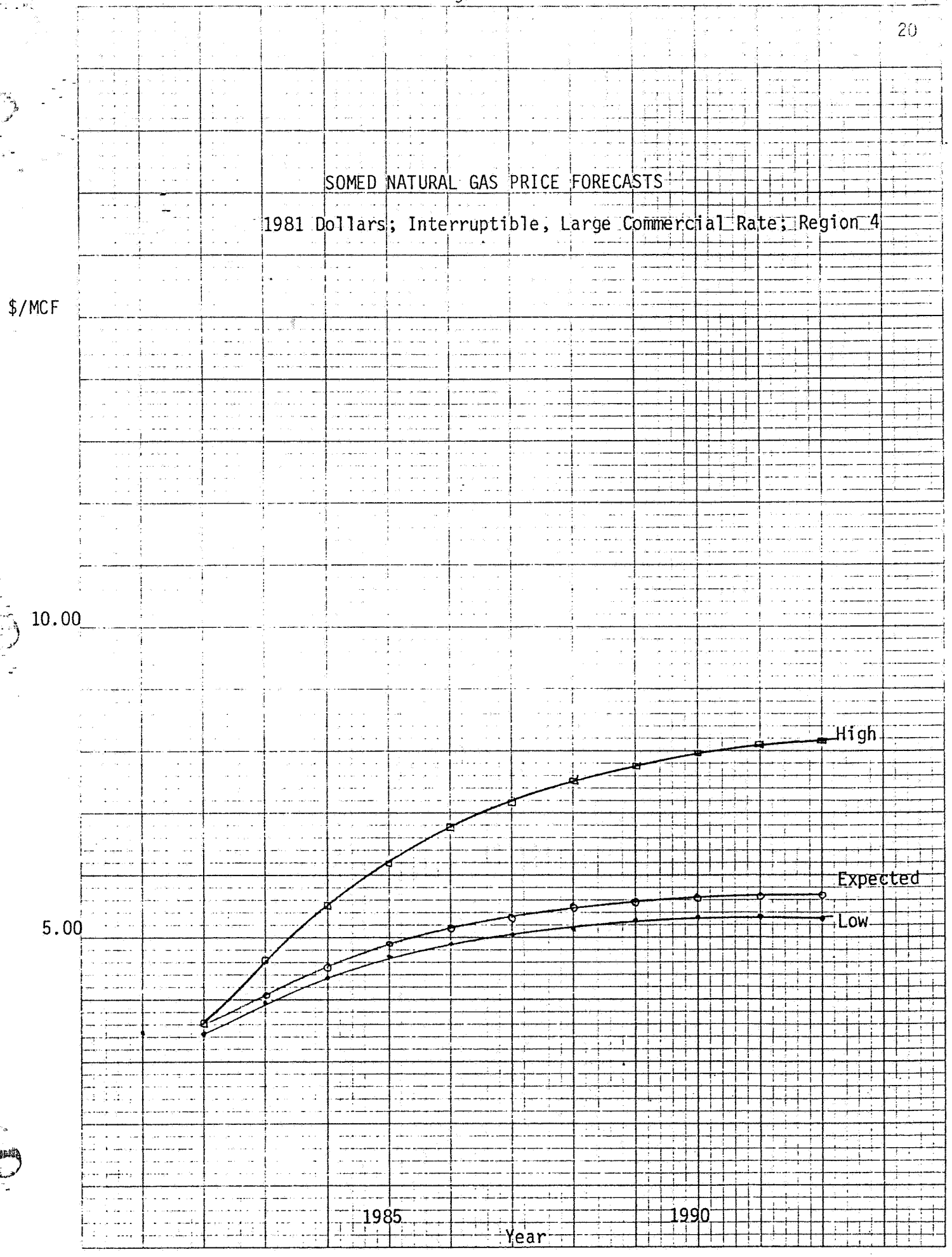
5.0 Economic Feasibility

The production gas could be dryed, purified if necessary, compressed to 31 psi, and pumped into the University gas system where it will replace interruptible natural gas. Excesses, if any, could be sold to surrounding institutions or to Alabama Gas Corporation, the local distributor. Prospects for using the gas for vehicle fuel (CNG) are currently being studied.

The analysis presented here is based on savings to the University by use of coalbed methane in lieu of commercial supplies of interruptible natural gas purchased from the local distributing utility. Key to this analysis is the expected cost of producing coalbed methane and the projected prices of natural gas available during the term of the project, which has been designed as 10 years for the base case.

Yields of gas per well have been estimated from the gas content of coal samples tested during core testing procedures. At the time the economics study was initiated, total Mary Lee/Black Creek reserves were estimated at 305 million cubic feet per 40 acres. Subsequent testing revised this figure to 310 million cubic feet. However, the base case utilizes the lower figure and assumes that 75% of the calculated in-place reserves (229 million cubic feet) will be recoverable during the estimated 10-year life of the field.

Figure 7.



10 Squares to the Inch

The gas from the well production is expected to decline in an exponential decay-curve of the type described by the general equation:

$$Q = Q_i \, e^{-kt}$$

Where:

Q = Expected production rate

Qi = Initial production

k = Exponential decline factor in this case 0.07 for 10 yr. well life

t = Year

Level production curves constructed with average values yield slightly lower internal rates of return, but do not induce significant changes in economics. For ease of calculation, the analysis which follows uses level production rates, which are given in Table 6.

5.1 Projected Natural Gas Costs

Data has been gathered on well-head, transmission, and distributor prices of natural gas from local, regional, and national sources. Prices developed are given in Figure 7. Base case calculations use the expected prices.

5.2 Cost of Coalbed Methane Production

Capital and operating costs estimates for 1 and 3 well developments are given in Tables 7 and 8.

5.3 Proforma Cash Flows in Constant 1981 Dollars

Proforma cash flows have been developed for the project. Depreciation entries have not been taken since the University is not a taxpaying entity. The finance charges assume 100% financing of the project at 11% -- a rate available to institutions such as The University of Alabama. This data was used to calculate payback and internal rate of return.

In this analysis Payback is a measure of risk and indicates the time required to recover capital investment. Internal Rate of Return (IRR) is the rate of discount that equals the present value of cash flows from the project with the present value of investments. A sample calculation for the Base Case -- 1 Well, is given in Table 9.

TABLE 6

BASE CASE PRODUCTION ESTIMATE

ONE WELL		THREE WELLS
22,876 MCF	per year	68,628 MCF
1,906	per month	5,719
78	per day	235

Table 7

Coalbed Methane Capital Cost Estimate (1981 Dollars)

		1 Well	3 Wells
Item 1	Pre Project Engineering		
	a. Topo and Location Survey		
	b. Site Preparation Engineering		
	c. Sedimentation Control, Water Disposal, etc.		
	Subtotal	$ 8,000	$ 20,000
Item 2	Site Preparation		
	a. Clearing and Grading		
	b. Coarse Stone Fill		
	c. Fencing		
	d. Concrete Pads		
	Subtotal	$10,000	$ 30,000
Item 3	Well Drilling (2700 ft.)		
	a. 1300 ft. Drilling casing and Cementing	35,700	106,800
	b. Drill Remaining 1400 ft.	19,600	58,750
	c. Logging	2,700	8,000
	Subtotal	$58,000	$173,550
Item 4	Well Stimulation		
	a. Fracturing Two Zones	47,000	135,000
	b. Equipment Rental and Workover Rig	11,500	33,000
	Subtotal	$58,500	$168,000
Item 5	Surface Equipment		
	a. Pump and Electric Motor	15,500	
	b. Separator	6,000	
	c. Well Head Equipment	2,000	
	d. Installation	6,000	
	Subtotal	$29,500	$ 88,500
Item 6	Subsurface Equipment		
	a. Down Hole Pump and Equipment	2,500	
	Tubing and Parts	12,000	
	Rods	3,000	
	Subtotal	$17,500	$ 52,500

Table 7 Continued

		1 Well	3 Wells
Item 7	Compressor System		
	a. 15 HP, 0-31 psi Compressor	15,000	
	b. Water Trap and After Cooler	2,000	
	c. Motor and Controls	1,000	
	Subtotal	$18,000	$ 18,000
Item 8	System Piping (6000 ft. @ $6.00/LF)		
	a. Gathering 4" Polyethylene		
	b. Distribution 2" Polyethylene		
	Subtotal	$36,000	$ 54,000
Item 9	Consulting Services		
	Subtotal	$ 8,000	$ 10,000
Item 10	Project Supervision and Monitoring		
	Subtotal	$10,000	$ 25,000
Item 11	Contingency		
	Subtotal	$18,500	$ 75,000
	GRAND TOTAL	$272,000	$715,000

Table 8

Coalbed Methane Annual Operating Cost Estimate (1981 Dollars)

		1 Well	3 Wells
Item 1	Electricity	$ 6,600	$12,000
Item 2	Maintenance		
	Repair, Workover	18,000	50,000
	Parts and Equipment	3,000	9,000
	Subtotal	$21,000	$59,000
Item 3	General Supplies	500	1,500
Item 4	Personnel		
	Field Supervisor	3,750	6,250
	Field Engineer/Technician	2,800	7,000
	Clerical	500	1,000
	Subtotal	$ 7,050	$14,250
	GRAND TOTAL	$35,150	$86,750

Table 9

Base Case -- 1 Well

Year	Commercial Price (Dollars/MCF)	Well Production (MCF)	Value	Operating Cost	Finance Cost	Savings	Outstanding Debt
1	$3.48	22,876	$ 79,608	35,200	$29,920	$ 14,488	257,512
2	4.05		92,648		28,326	29,122	228,390
3	4.52		103,400		25,123	43,077	185,313
4	4.86		111,177		20,384	55,593	129,720
5	5.12		117,125		14,269	67,656	62,065
6	5.29		121,014		6,827	78,987	-
7	5.46		124,903		-	89,703	-
8	5.57		127,419		-	92,219	-
9	5.63		128,792		-	93,592	-
10	5.65		129,249		-	104,049	-

Investment Cost $272,000
Working Capital -0-
Salvage Value $ 10,000

IRR = 15.49 percent
Payback = 5.79 years

Payback and internal rates of return for the base cases are as follows:

	Payback Years	Internal Rate of Return (IRR) Percentage
1 well	5.79	15.49
3 wells	4.59	22.46

5.4 Sensitivity

The sensitivity of payback and internal rate of return to possible variations from the base case were studied and the findings summarized below.

Price Variation -- Commercial natural gas price forecasts were developed for high and low range prices. The effect of these price variations on payback and internal rate of return is:

	Low		Expected		High	
	Payback Years	IRR Percentage	Payback Years	IRR Percentage	Payback Years	IRR Percentage
1 well	6.01	13.81	5.79	15.49	4.46	25.20
3 wells	4.78	20.90	4.59	22.46	3.73	31.92

Open vs. Cased Wells -- The effect of casing the wells gives better stability and could prevent future blockages, but could complicate well completions. Capital costs would increase to $287,000 (1 well) and $758,000 (3 wells). This reduces payback and IRR slightly as follows:

	Open		Cased	
	Payback Years	IRR Percentage	Payback Years	IRR Percentage
1 well	5.79	15.49	6.13	13.84
3 wells	4.59	22.46	4.88	20.55

Economics of Coal Stimulation Options -- A possible option is to drill to the Mary Lee Group and only stimulate that group. This reduces investment cost to $243,000 (1 well) and $641,000 (3 wells), but reduces production of gas and utilization of the resource available. The results calculated for this option are:

	Stimulate One Group		Stimulate Two Groups	
	Payback Years	IRR Percentage	Payback Years	IRR Percentage
1 well	8.22	5.89	5.79	15.49
3 wells	6.08	14.02	4.59	22.46

Length of Project -- The base case of 1 well for a period of 10 years was extended to 15 years, which in effect spreads the same amount of gas recovered over a longer time, and thus decreases annual production rates. Results are as follows:

	10 Years		15 Years	
	Payback Years	IRR Percentage	Payback Years	IRR Percentage
1 well	5.79	15.49	13.65	2.09
3 wells	4.59	22.46	9.06	9.74

Yield of Gas -- One of the more critical aspects of the project is the percentage recovery of the existing gas. The base case assumes 75% recovery. The effect of lesser rates of recovery are:

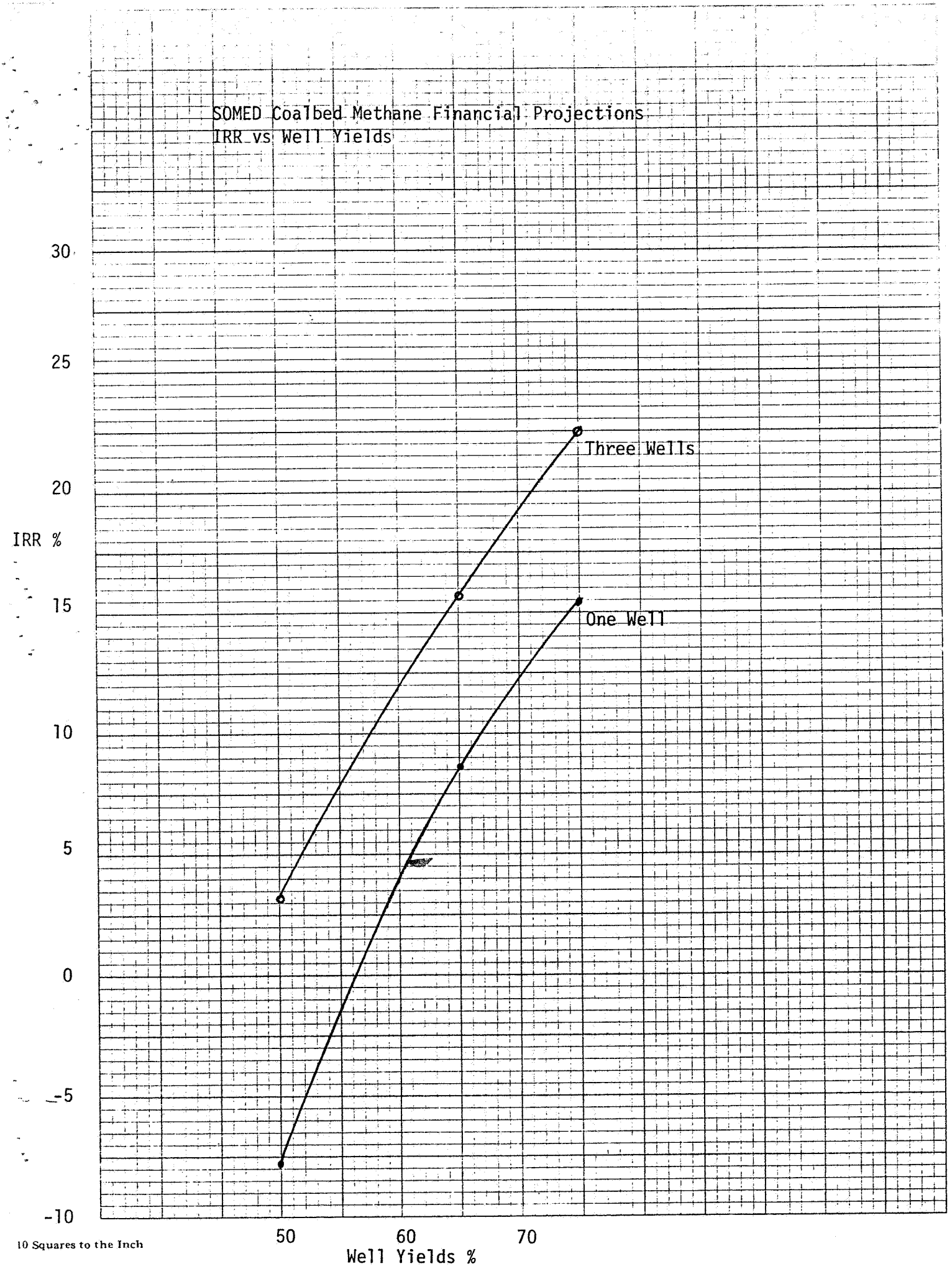
	75 Percent		65 Percent		50 Percent	
	Payback Years	IRR Percentage	Payback Years	IRR Percentage	Payback Years	IRR Percentage
1 well	5.79	15.49	7.38	8.71	>10.00	(7.78)
3 wells	4.59	22.46	5.68	15.93	9.05	3.20

The internal rate of return data provided above is also shown in graphic form in Figure 8.

Well Spacing -- The present economic assessments assumed a 40-acre well spacing. It is possible to reduce capital cost by moving to a larger well spacing, but questions remain as to the ability of one well to drain a larger area. To study the financial aspects the spacing was varied to 80 acres, and it was assumed that the total area would be drained in 20 years rather than 10. In this comparison three wells are placed in three 40-acre units and gas is drained for 10 years. The three 40-acre units are then abandoned and three new wells are placed in three new 40-acre units draining a total of 240 acres over 20 years on 40-acre spacing. At the same time three wells are placed in three 80-acre units (240 acres) and allowed to drain for 20 years without replacing the wells. All wells drain at the same rate producing the same amount of gas on both 40-acre and 80-acre spacings after a period of 20 years. Results for development of 240 acres are as follows:

	40-acre spacing		80-acre spacing
Number of Wells	6		3
Capital Investment	$715,000 in year one	$715,000 in year eleven	$715,000 in year one
Payback (Years)	4.59 for first investment	1.68 for second investment	4.74
IRR (Percentage)		23.68	25.35

Figure 8


SOMED Coalbed Methane Financial Projections
IRR vs Well Yields
30
25
20
IRR %
15
10
5
0
-5
-10
Three Wells
One Well
50
60
70
Well Yields %
10 Squares to the Inch

Of course, if the entire gas supply could be drained and used in only 10 years on 80-acre spacing, the IRR and Payback would be significantly improved over the 20-year case.

5.5 Financial Requirements

It is suggested that financial returns for investments be at least 15% for "low risk" projects and 20% for "medium risk" projects.

Obtaining 75% yields on coalbed methane wells could be considered a medium risk at this time. The 3-well case over a 10 year period consistently meets this 20% requirement. Therefore, from the standpoint of economics, planning for field development appears to be justifiable.

6.0 Environmental Factors

The potential environmental impacts of the test drilling project were identified in the Environmental Impact Analysis submitted to DOE in February 1981, as the following:

soil loss and habitat disruption
groundwater contamination
noise

The site conditions were field reviewed on August 13, 1981, 4 months after cessation of drilling. Despite the fact that those four months were relatively dry, the mud pit and the ground on which the drilling rig stood had revegetated almost completely with grasses and vines similar to those in the surrounding area. There were no areas which were obviously wetter than others, so it is assumed that the moisture content of the soil was

restored to its former state. It should be mentioned that construction of the University's new recreation center has begun approximately 100 yards from the site of the test drilling and any impact that the drilling project could have had on soils and habitat is insignificant when compared to that activity.

While there were no samples taken of the ground water, it was not expected that the drilling project would contaminate these waters because there were no drilling fluid additives used and the hole was cased into the Pottsville Formation. Noise levels were not measured during drilling, but there were no complaints from surrounding residential or commercial areas. The recreation facility construction activity will create noise levels which could be greater than those created by the drilling.

The location of the test drilling site, in a field which is well removed from populated areas and/or areas which experience heavy traffic, was a major reason for the minimal impact of the drilling.

Long-range planning for additional wells on the campus or in the surrounding community will consider this constraint. Efforts will be made to avoid pedestrian and vehicular traffic corridors, ecologically sensitive areas and areas (if any) in which there are deep wells which serve as drinking water sources. Based on regional coalbed gas well case histories, water production is expected to be site-specifically variable.

It is estimated that a production well will yield from 10-200 barrels per day of drainage water which may contain potentially deleterious quantities of chloride. Disposal of this water would appear to be the only major environmental impediment to gas production.

Current plans call for the water to be fed directly to the City of Tuscaloosa's sanitary sewer system through which it will discharge harmlessly diluted into the Black Warrior River. Contingency plans are being considered for other water disposal options which may be required during long term gas field development.

7.0 Human Resources

Gas field development activities such as drilling, fracturing, and laying pipe, would be accomplished by outside contractors under the supervision of the School of Mines and Energy Development and in close coordination with the University's Office of Physical Planning and Facilities. Day-to-day field maintenance and monitoring will be accomplished by personnel hired or reassigned as indicated in the operating budget detail in Table 8.

8.0 Options for Business Organization

The University will finance and manage the production and utilization of coalbed methane from this project within its existing entity structure. There appears to be no advantage in creating a separate entity.

9.0 Other Intangibles

Table 10 lists some of the intangible aspects of the project:

Table 10

Intangibles

PRO	CON
Achieves partial domestic energy self-sufficiency	Decreases academic atmosphere
Better utilization of resources	Possible negative environmmental aspects of noise, air, and water pollution (but only in the latter phase of development and only for a brief time).
Expanded employment opportunities	
Assurance of continuous fuel supply	
Assists Univiersity in achieving leadership in coalbed methane research and development	

10.0 Financing Options

The capital required for this project, ranging from $272,000 for 1 well to $715,000 for 3 wells, would be secured by loans from local banks. The anticipated interest rate is 11%.

11.0 References

McGuigan, J.R. and Moyer, R.C. Managerial Economics. West Publishing Company, St. Paul, Mn 1979.

TRW Energy Engineering Division. Economic Analysis of Vertical Wells for Coalbed Methane Recovery. McLean, Va. 1981.

DOE Region IV Unconventional Gas Program. Solicitation DE-PS44-80R410209 and associated notes.

National Petroleum Council. Unconventional Gas Sources - Coal Seams. Washington, D.C., 1980.

12.0 APPENDIX

UNIVERSITY OF ALABAMA
COALBED METHANE GAS PROJECT

Lithologic Log of Test Corehole

Nole No.: Alabama #1 Date Completed: April 16, 1981
Location: NW cor. NE¼NE¼ sec. 24, T.21S., R.10W. Drilled by: Joy Manufacturing Co.
Elevation: 262' MSL

Depth (feet)	Description
Cretaceous - Tuscaloosa Group	
0 - 85	Unconsolidated material, not described.
Pennsylvanian - Pottsville Formation	
85 - 100	Weathered zone, not cored.
100 - 101.9	Gray shale pebble conglomerate.
101.9 - 115	Sandstone, gray, medium to coarse-grained, massive; high-angle joints common, 15 - 20° to core axis.
115 - 116.2	Sandstone, gray, with shale streaks, rippled; sandstone, gray, medium-grained; shale, light gray.
116.2 - 118.7	Shale with sandstone streaks; shale, light gray; sandstone, fine-grained, rock is sheared at 45° angle to core axis from 118.5 - 118.7'.
118.7 - 144	Sandstone, light gray, medium-grained to 127.9', coarse-grained 127.9 - 1396, medium to coarse-grained 130.6 - 144; very few shale streaks; joints at 45° to core axis common.
144 - 144.6	Shale, gray, slickensides, fault gouge?.
144.6 - 149.6	(Core loss.)
149.6 - 150	Shale, dark gray, slickensides, fault gouge?.
150 - 156.7	Shale, medium-gray, sandy, brecciated, recemented.
156.7 - 181.7	Shale, medium-gray, sandy.
181.7 - 189.3	Sandstone and shale, interbedded; sandstone, medium-grained, in beds 0.2 - 0.8' thick alternating with gray, sandy, shale beds 0.05 - 1.2' thick.
189.3 - 226.5	Sandstone, gray, fine to medium-grained, massive, nearly vertical joint; 195 - 197'; gray shale pebble conglomerate, 210 - 210.8'; coal spars, 208.4 - 210' and 218 - 219'.

226.5 - 226.75	Shale, dark gray.
226.75 - 227.83	Coal sample.
227.83 - 228.66	Fireclay, dark gray, massive, fossil plants, coal spars to 227.9'.
228.66 - 229	Coal sample.
229 - 229.2	Sandstone, fine-grained, massive.
229.2 - 231.2	Fireclay, dark gray, sandy, rooted, fossil plants.
231.2 - 302.1	Sandstone, gray, massive, 231.2 - 253 fine to medium-grained, 253 - 274 medium to coarse-grained, 274 -292 coarse to very coarse-grained to conglomeratic, 292 - 302 fine to medium grained; coal spars 284 - 292'.
302.1 - 316.3	Sandstone with shale streaks, rippled; sandstone, gray, fine-grained, many thin coal spars and bands to 303', shale streaks diminish with depth.
316.3 - 317.38	Shale, dark gray to very dark gray.
317.38 - 318.38	Coal sample.
318.35 - 319.16	Shale and fireclay, dark gray, interbedded.
319.16 - 319.38	Coal sample.
319.38 - 320	Shale and fireclay, dark gray, interbedded.
320 - 320.34	Coal sample.
320.34 - 322	Fireclay, dark gray, sandy, massive, fossil plants.
322 - 331	Sandstone, light gray, finegrained, with shale streaks, flat.
331 - 332.5	Shale, dark gray, slightly sandy, massive.
332.5 - 349	Sandstone, gray, fine- to medium-grained, with shale streaks, flat.
349 - 351.75	Shale, very dark gray to black, with coal bands up to 1/4" thick.
351.75 - 351.92	Coal, banded bright and dull.
351.92 - 354	Sandstone, gray, fine-grained, churned.
354 - 358.5	Sandstone, gray, fine- to medium-grained, with shale streaks, rippled.

358.5 - 365	Shale, medium-gray, with sandstone streaks.
365 - 384.2	Sandstone, gray, massive, conglomeratic 374 - 378, scattered coal spars.
384.2 - 388	Shale, dark gray.
388 - 392.6	Sandstone and shale, interbedded, rippled, sandstone, fine-grained; shale, dark gray.
392.6 - 393.4	Shale, dark gray, massive.
393.4 - 393.66	Shale and coal interbedded; shale, very dark gray.
393.66 - 396.9	Fireclay, dark gray, sandy, scattered coal spars, fossil plants.
396.9 - 404.5	Shale, dark gray, with sandstone streaks.
404.5 - 435.2	Sandstone, gray, massive, with very few shale streaks and cross-bedding; blue-green, pea-size, shale conglomerate 425.2 - 426.2; gray-green, shale conglomerate 428.2 - 430; dark gray shale 430.5 - 430.9.
435.2 - 440	Shale, dark gray, with sandstone streaks.
440 - 442.2	Sandy shale mudflow, dark gray.
442.2 - 453.2	Shale, dark gray, sandy, massive; sandy shale mudflow 442.2 - 444.6, 449.8 - 451.6; partly burrowed.
453.2 - 476	Shale, dark gray, massive.
476 - 479	Shale, dark gray, sandy, massive, marine fossil bed.
479 - 485	Shale, dark gray, massive, few sandy shale beds.
485 - 500	Shale, dark gray, sandy, massive, scattered fossil plants.
500 - 523	Shale, dark gray, sandy, with sandstone streaks, churned in part.
523 - 540	Shale, dark gray, massive, few thin, sandstone beds.
540 - 553	Shale, dark gray, and sandy shale with sandstone streaks; sandy shale mudflow 550.9 - 551.3.
553 - 594	Shale, dark gray, massive, very few thin, fine-grained sandstone beds.

594 - 598.5	Shale, sandy, dark gray, massive, sandy shale mudflow 597 - 598.5.
598.5 - 600.8	Shale, dark gray, with sandstone streaks, sandstone, very fine-grained.
600.8 - 649	Shale, dark gray, widely scattered siderite nodules; scattered marine fossils 636 - 649; becomes churned and sandy 646 - 649.
649 - 663	Shale, dark gray, sandy, churned, carbonaceous in part.
663 - 670	Shale, dark gray, massive, scattered siderite nodules.
670 - 689.5	Shale, dark gray, with sandstone streaks, scattered siderite nodules.
689.5 - 691.6	Coal sample.
691.6 - 696.6	Fireclay, dark gray, sandy, massive, rooted, some waxy texture, scattered fossil plants.
696.6 - 702	Sandstone and shale, interbedded, rippled; sandstone, dark gray in part, fine to medium-grained.
702 - 717.5	Sandstone and gray shale, interbedded; sandstone, medium-grained, beds up to 0.6' thick, alternating with thin bedded, gray shale.
717.5 - 717.7	Coal; banded bright and dull.
717.7 - 718.3	Sandstone, gray, massive, several coal spars.
718.3 - 721.8	Fireclay, dark gray, rooted, scattered coal spars, waxy texture in part, few sandstone beds.
721.8 - 730.4	Sandstone, gray, very fine grained, with shale streaks, flat.
730.4 - 733.4	Shale, medium-gray, sandy shale mudflow in part.
733.4 - 737	Shale; dark gray, scattered fossil plants.
737 - 737.75	Coal sample.
737.75 - 783.4	Fireclay, dark gray, massive, waxy, fossil plants, rooted.
738.4 - 740.1	Fireclay, dark gray, sandy, massive, fossil plants.
740.1 - 742	Shale, dark gray, sandy, fossil plants, churned and rooted.

742 - 743	Sandstone, very fine grained, with shale streaks.
743 - 744.7	Fireclay, dark gray, sandy, waxy in part, rooted, fossil plants.
744.7 - 745.3	Shale, black, few coal bands.
745.3 - 745.55	Coal, banded bright and dull.
745.55 - 750.6	Fireclay, dark gray, sandy in part, fossil plants, waxy luster in part, rooted.
750.6 - 757.5	Fireclay, dark gray, sandy, massive, rooted, waxy in part, fossil plants.
757.5 - 797.5	Sandstone with shale streaks, rippled; sandstone, gray, very fine to fine-grained to 770', fine to medium-grained 770 - 797.5'; gray shale conglomerate 778.8 - 779.2'.
797.5 - 807.2	Shale, dark gray, with sandstone streaks, scattered small-scale mudflows and sandy shale.
807.2 - 829	Sandstone, gray, fine-grained, with shale streaks, rippled; shale in thin-bedded sections up to 0.8' thick; 817 - 818 coal spars; 812.5 - 814 churned sandstone; 819 - 825; vertical, calcite-lined joint; gradational lower contact.
829 - 832	Sandstone and shale, interbedded, flat; sandstone, fine-grained; shale, dark gray.
832 - 848	Shale, dark gray, sandy; scattered sandy shale mudflows; vertical joint 834 - 836.
848 - 855.5	Shale, dark gray, with sandstone streaks.
855.5 - 872	Shale, dark gray, sandy, massive, scattered fossil plants.
872 - 895	Shale and sandstone, interbedded, rippled; shale, dark gray, sandstone, very fine to fine-grained; scattered sandy shale beds up to 0.6' thick.
895 - 912	Shale, dark gray, scattered siderite bands and nodules; marine fossil throughout.
912 - 914	Shale, sandy, marine fossil bed.
914 - 917.5	Shale, dark gray, sandy, burrowed, carbonaceous.
917.5 - 919	Sandstone, gray, fine to medium-grained, burrowed.

919 - 924	Sandstone, gray, with shale streaks, rippled, small sand flows.
924 - 930	Sandstone and dark gray shale, interbedded, rippled and flat; shale, dark gray, usually sandy, few siderite lenses.
930 - 939.5	Sandstone, medium-gray, medium-grained, massive, minor cross-bedding.
939.5 - 939.7	Coal and bone, interlayered.
939.7 - 940.5	Fireclay, dark gray, waxy, massive, rooted, fossil plants.
940.5 - 942	Fireclay, dark gray, sandy, massive, rooted, fossil plants, some waxy.
942 - 942.1	Shale black, fossil plants.
942.1 - 942.2	Coal, banded bright and dull.
942.2 - 959	Sandstone, gray, medium-grained, massive, 942.2 - 943.5 many coal bands; 952 - 958 scattered coal bands; minor cross-bedding; vertical, calcite-filled joint 944 - 952.
959 - 963	Sandstone, gray, fine-grained, with shale streaks, flat.
963 - 967.5	Sandstone and shale, interbedded, flat, sandstone, very fine-grained; shale, dark gray, sandy.
967.5 - 968.25	Shale, dark gray to black, scattered coal bands.
968.25 - 970.25	Coal sample.
970.25 - 970.55	Fireclay, very dark gray, waxy, massive, fossil plants.
970.55 - 973.8	Sandstone, gray, rooted, massive, carbonaceous.
973.8 - 983.2	Sandstone, gray, fine to medium-grained, with shale streaks, rippled.
983.2 - 984.9	Shale, very dark gray, siderite nodules and fossil plants common.
984.9 - 985.2	Coal, banded, bright and dull.
958.2 - 986.15	Fireclay and black shale, with coal bands.
986.15 - 986.40	Interlayered bone and coal.

986.4 - 987.7	Fireclay, very dark gray, massive, waxy, rooted, fossil plants.
987.7 - 990	Fireclay, dark gray, sandy, rooted, massive, fossil plants.
990 - 993.8	Sandstone, gray, and shale, dark gray, interbedded, rippled, rooted in part.
993.8 - 995.8	Shale, dark gray, waxy fireclay in part, massive, rooted.
995.8 - 997.8	Shale, dark gray, sandy, churned, massive.
997.8 - 1000	Sandstone, gray, fine-grained, with shale streaks, rippled.
1000 - 1002.4	Shale, dark gray, sandy, with sandstone streaks fossil plants.
1002.4 - 1004	Sandstone, gray, fine-grained, with shale streaks, rippled and flat.
1004 - 1008.8	Sandstone, gray, fine-grained, with shale streaks, rippled.
1008.8 - 1015	Sandstone and shale, interbedded, rippled; sandstone, gray, fine-grained; shale, dark gray, sandy.
1015 - 1017	Shale, dark gray, with sandstone streaks; sandstone, fine-grained.
1017 - 1019	Shale, dark gray, sandy, massive.
1019 - 1021.4	Shale, dark gray, sandy, burrowed, fossil plants.
1021.4 - 1029	Sandstone, gray, with shale streaks, burrowed in part, fine-grained; sand flow 1027 - 1027.5.
1029 - 1061	Shale dark gray, sandy, alternating with gray shale, with sandstone streaks, sand flow 1037.5 - 1038'; 1052 - 1052.5', sandy shale, marine fossil bed 1050 - 1051.4'.
1061 - 1082.4	Shale, dark gray, sandy, burrowed, intensity decreasing with depth, marine fossil beds 1063.8 - 1064', 1079.8 - 1081.6' and 1082 - 1082.4'.
1082.4 - 1095.6	Shale, dark gray, sandy, massive; mudflow 1083 - 1084'; calcareous sandstone bed 1995.2 - 1095.6'.
1095.6 - 1098.6	Shale, dark gray, siderite bands and fossil plants.

1098.6 - 1127.9	Sandstone, gray, massive, fine to medium-grained, minor cross-bedding; coal spars and bands 1126 - 1227.9'.
1127.9 - 1156	Shale, dark gray, sandy, massive, few sandstone streaks, sandy shale mudflow 1127.9 - 1129.5'.
1156 - 1159	Shale, dark gray, sandy in part.
1159 - 1168.5	Shale, dark gray, sandy, burrowed, intensity diminishes with depth; scattered marine fossils.
1168.5 - 1216.9	Shale, dark gray, sandy, massive, few sandstone scattered burrowing and siderite nodules.
1216.9 - 1238	Sandstone and shale, interbedded, flat. Shale, dark gray, thin-bedded, alternates with sandstone beds up to 1 inch thick.
1238 - 1271	Shale, dark gray, sandy; sandy shale mudflow 1260.8 - 1261' and 1266 - 1267'; scattered siderite nodules.
1271 - 1284.4	Shale, dark gray, with scattered marine fossils throughout, some burrowing, many siderite nodules.
1284.4 - 1298.8	Shale, dark gray, sandy, burrowed, few scattered marine fossils.
1298.8 - 1301	Shale, very dark gray, fossil plant fragments, siderite nodules.
1301 - 1301.9	Sandstone and shale, calcareous, marine fossil bed.
1301.9 - 1307.6	Shale, dark gray, sandy, minor gray shale and siderite bands, burrowed.
1307.6 - 1314.3	Sandstone and shale, interbedded, rippled, shale, dark gray; sandstone, fine-grained; siderite nodules.
1314.3 - 1315.25	Shale, very dark gray, coal bands 1314.5 - 1314.55 and 1314.7 - 1317.77'.
1315.25 - 1315.6	Coal sample.
1315.6 - 1316	Fireclay, dark gray, waxy, rooted, fossil plants.
1316 - 1316.5	Fireclay, dark gray, sandy, massive, rooted, fossil plants.
1316.5 - 1320	Sandstone, gray, fine-grained, rooted.

1320 - 1323.3	Shale, dark gray, sandy, burrowed, minor rooting.
1323.3 - 1346	Shale and fireclay, interbedded; shale, gray; fireclay, dark gray; scattered sandstone beds. Waxy in part, fossil plants, rooted in part, siderite nodules.
1346 - 1347.6	Fireclay, dark gray, massive, rooted, fossil plants.
1347.6 - 1347.75	Coal and bone, banded, occasional fireclay.
1347.75 - 1352.5	Sandstone, fine-grained, gray, with shale streaks, rooted in part.
1352.5 - 1354.8	Fireclay, dark gray, massive, rooted, waxy, hard, fossil plants.
1354.8 - 1362.8	Sandstone, gray, fine-grained, with shale streaks, rippled.
1362.8 - 1363.1	Shale, dark gray.
1363.1 - 1363.35	Coal, banded, bright and dull.
1363.35 - 1365.6	Fireclay, dark gray, sandy, hard, massive, fossil plants.
1365.6 - 1366.25	Banded bone, coal, minor fireclay; 60% coal.
1366.25 - 1371.1	Fireclay, dark gray, sandy in part, waxy in part, massive, rooted, fossil plants.
1371.1 - 1394.6	Sandstone, gray, fine to medium-grained, some coarse-grained, massive, coal spars 1383 - 1388; vertical, calcite-filled, joint - entire section.
1394.6 - 1398.1	Shale, dark gray, sandy in part, with sandstone streaks, fossil plants; nearly vertical shear zone with slickensides 1397.1 - 1398.1'.
1398.1 - 1399.1	Bone (broken-up core).
1399.1 - 1399.2	Shale, dark gray.
1399.2 - 1399.5	Coal, banded bright and dull.
1399.5 - 1400.1	Fireclay, dark gray, massive, waxy, fossil plants.
1400.1 - 1401.5	Banded bone and coal.
1401.5 - 1405.75	Shale and fireclay, dark gray, interbedded, waxy in part, coal bands, fossil plants, siderite nodules.

1405.75 - 1407.4	Coal sample.
1407.4 - 1409.6	Fireclay, dark gray, soft in part, massive, waxy, fossil plants.
1409.6 - 1413.4	Shale, dark gray, sandy; sandy fireclay in part.
1413.4 - 1416	Sandstone, gray, very fine grained, with shale streaks, rippled.
1416 - 1417	Shale, medium-gray, sandy, massive.
1417 - 1418.2	Shale and fireclay, gray, interbedded, sandy in part, massive, partly waxy.
1418.2 - 1418.3	Coal, banded bright and dull.
1418.3 - 1421.2	Fireclay, dark gray, sandy, massive, rooted, fossil plants, waxy in part.
1421.2 - 1426.5	Sandstone, light gray, fine-grained, with shale streaks, rippled.
1426.5 - 1427.8	Shale, dark gray, sandy, massive.
1427.8 - 1428.7	Shale, dark gray to black, fossil plants.
1428.7 - 1430.4	Shale, dark gray, sandy, with sandstone streaks.
1430.4 - 1432.7	Shale, dark gray.
1432.7 - 1433.7	Shale, very dark gray to black, coal bands up to 0.09' thick.
1433.7 - 1436	Fireclay, dark gray, sandy, massive, rooted, fossil plants.
1436 - 1440	Shale, dark gray, sandy, massive.
1440 - 1442	Sandstone, gray, fine-grained, with shale streaks, rippled.
1442 - 1442.6	Dark gray to black shale.
1442.6 - 1442.9	Coal and bone, interlayered.
1442.9 - 1448	Fireclay, dark gray, sandy in part, massive, rooted, waxy in part, fossil plants.
1448 - 1449.8	Sandstone, gray, very fine grained, with shale streaks, rippled.
1449.8 - 1463.2	Shale, dark gray, sandy, churned in part, very dark shale 1451.4 - 1451.7, siderite bands.

1463.2 - 1463.9	Shale, dark gray, siderite bands.
1463.9 - 1464.25	Coal and bone, banded, bright and dull coal.
1464.25 - 1466	Fireclay, dark gray, massive, waxy, fossil plants, siderite nodules.
1466 - 1470.6	Shale, very dark gray, massive, fossil plants.
1470.6 - 1474.5	Fireclay, dark gray, sandy, massive, rooted, waxy in part, fossil plants.
1474.5 - 1479.5	Shale, dark gray, partly rooted, grades downward to black shale, siderite nodules.
1479.5 - 1479.8	Coal sample.
1479.8 - 1480.25	Shale, black bone and coal, interlayered, mainly bone.
1480.25 - 1480.5	Coal sample.
1480.5 - 1485.5	Fireclay, dark gray, sandy in part, massive, waxy, rooted.
1485.5 - 1488.2	Sandstone, gray, very fine grained, with shale streaks, rippled.
1488.2 - 1493.5	Shale, dark gray, siderite nodules.
1493.5 - 1495.8	Fireclay, dark gray, massive, waxy, rooted, fossil plants.
1495.8 - 1496.9	Shale, dark gray, fossil plants.
1496.9 - 1497.05	Coal, banded bright and dull.
1497.05 - 1497.9	Fireclay, dark gray, sandy, massive, fossil plants.
1497.9 - 1501.4	Sandstone, gray, fine grained, with shale streaks, rippled.
1501.4 - 1503.7	Sandstone, gray, fine-grained, with shale streaks, rippled.
1503.7 - 1525	Sandstone and shale, interbedded; sandstone, gray, fine-grained, burrowed 1503.7 - 1506'; massive, medium-grained sandstone 1513 - 1513.6'; fossil plants.
1525 - 1533.7	Sandstone, gray, fine to medium grained, with shale streaks, rippled.
1533.7 - 1545.6	Sandstone, gray, fine to medium-grained, minor cross-bedding.

1545.6 - 1568.9	Shale, dark gray, sandy, massive; mudflow 1547.6 - 1548' and 1549 - 1549.6', other small-scale mud/sand flows.
1568.9 - 1569.2	Limestone, marine fossil bed with siderite nodules.
1569.2 - 1579.5	Shale, dark gray, sandy, with sandstone streaks, burrowed 1577 - 1579.1'.
1579.5 - 1591.6	Sandstone, gray, fine to medium-grained, massive, gray shale sandstone conglomerate 1589 - 1589.6'.
1591.6 - 1595.7	Shale, dark gray, with sandstone streaks, fossil plants.
1596.7 - 1596.25	Shale, dark gray, fossil plants.
1596.25 - 1597.15	Coal sample.
1597.15 - 1597.9	Fireclay, dark gray, sandy, partly waxy, rooted, fossil plants.
1597.9 - 1599.5	Sandstone, gray, argillaceous, rooted, massive.
1599.5 - 1626	Sandstone, gray, fine-grained, with shale streaks, flat. Coal bands 1608 - 1609.2; vertical calcite vein, 1/8" thick 1618 - 1622'.
1626 - 1649	Shale, dark gray, sandy in part, with sandstone streaks, plant fossils.
1649 - 1656.5	Shale, dark gray, marine fossils 1655 - 1656.5'; siderite nodules.
1656.5 - 1660	Sandstone, gray, fine grained, rooted, argillaceous; fossil plants.
1660 - 1662.7	Sandstone, gray, medium-grained, with shale streaks, rippled.
1662.7 - 1744.5	Sandstone, gray, medium-grained to 1668'; medium to coarse-grained 1668 - 1699', fine to medium grained 1699 - 1744.5; scattered coal bands 1676.5 - 1685; slumped sandstone and shale 1700 to 1704; coal spars 1725 - 1731'.
1744.5 - 1748.2	Shale, dark gray, sandy, massive; sand flow 1745.2 - 1745.6' and 1746.6 - 1747'.
1748.2 - 1753.7	Sandstone, gray, fine-grained, cross-bedded, scattered coal spars 1752 - 1753.7.
1753.7 - 1763.4	Sandstone, gray, fine-grained, with shale streaks, flat; scattered thin coal spars.

1763.4 - 1769.2	Sandy shale mudflow, dark gray.
1769.2 - 1780.8	Sandstone, gray, fine-grained, and shale, dark gray, interbedded, flat.
1780.8 - 1784.6	Shale, dark gray, sandy, scattered marine fossils, churned.
1784.6 - 1786.5	Shale, dark gray, with sandstone streaks, carbonaceous.
1786.5 - 1795.3	Sandstone, gray, with shale streaks, flat; rooted 1786.5 - 1786.9'; sand flow 1792 - 1792.6'.
1795.3 - 1802	Sandstone, gray, fine-grained, with shale streaks, rippled.
1802 - 1806.7	Sandstone, fine-grained, and shale, flat, interbedded.
1806.7 - 1812	Sandstone, gray, fine-grained, with shale streaks, rippled; few siderite bands.
1812 - 1873	Sandstone, fine-grained, and shale, flat, shale, dark gray, sandy in part.
1873 - 1874.3	Sandstone, gray, fine- to medium-grained, with shale streaks, flat.
1874.3 - 1888.6	Shale, dark gray, sandy, massive; scattered small scale mudflows and thin sandstone beds.
1888.6 - 1894.1	Shale, dark gray, with sandstone streaks, scattered siderite bands.
1894.1 - 1902.7	Shale, dark gray, scattered siderite bands.
1902.7 - 1917.6	Shale, sandy in part; scattered thin, sandstone beds, small-scale mudflows and siderite bands.
1917.6 - 1927.7	Shale, dark gray, sandy, massive, carbonaceous, few siderite nodules and bands.
1927.7 - 1955	Sandstone, gray, fine-grained, with shale streaks, flat; massive sandstone beds up to 5' thick, alternate with thin-bedded, dark gray shale beds in sections up to 1' thick. Scattered siderite bands in shale.
1955 - 1963.6	Shale, dark gray, sandy in part, scattered sandy shale mudflows; widely scattered, thin sandstone beds; few siderite bands.
1963.6 - 1973.8	Shale, dark gray, with sandstone streaks, few sandstone beds from 0.1' to 0.3' thick, scattered siderite bands.

1973.8 - 1984.3	Shale, dark gray, scattered fossil plants.
1984.3 - 1987.8	Sandstone, gray, fine-grained, burrowed, carbonaceous; marine fossils 1984.3 - 1985.2'.
1987.8 - 1991.8	Sandstone, gray, fine-grained, with shale streaks, rippled; burrowed in part.
1991.8 - 2001.4	Shale, dark gray, sandy burrowing common but diminishing with depth.
2001.4 - 2015	Sandstone, fine-grained, and shale, rippled, interbedded; burrowed in part, few siderite nodules; thin, bone/coal bands at 2014.8 and 2015'.
2015 - 2015.5	Coal sample.
2015.5 - 2016.7	Fireclay, dark gray, hard, waxy in part, fossil plants.
2016.7 - 2035	Sandstone, very fine grained, and shale, rippled, interbedded; burrowed in part, dark gray shale.
2035 - 2042	Shale, dark gray, sandy, burrowed. (Core is largely broken-up because of vertical joints.)
2042 - 2058	Sandstone and shale, interbedded, rippled; burrowed in part, scattered siderite nodules.
2058 - 2058.6	Coal sample.
2058.6 - 2064.8	Fireclay, very dark gray, massive, few coal bands, fossil plants, rooted, siderite nodules, grades into very dark shale.
2064.8 - 2067.4	Shale, very dark gray, siderite nodules, fossil plants.
2067.4 - 2076.6	Sandstone, very fine grained, and shale, very dark gray, interbedded, rippled; burrowed in part, siderite nodules.
2076.6 - 2077.5	Shale, very dark gray, soft, fossil plants.
2077.5 - 2077.7	Coal sample.
2077.7 - 2077.78	Coal, banded, bright and dull.
2077.78 - 2078.32	Fireclay, very dark gray, sandy, massive, fossil plants.
2078.32 - 2078.66	Coal sample.
2078.66 - 2079	Fireclay, dark gray, coal bands, fossil plants.

2079 - 2079.1	Coal rubble.
2079.1 - 2081.7	Fireclay, dark gray, sandy, waxy in part, rooted, fossil plants.
2081.7 - 2101.6	Sandstone, very fine grained, and shale, dark gray, interbedded, rippled; burrowed in part, scattered fossil plants, and siderite nodules.
2101.6 - 2103.8	Shale, very dark gray, fossil plants, siderite nodules.
2103.8 - 2107.6	Fireclay, very dark gray, hard, waxy, fossil plants, rooted.
2107.6 - 2117.7	Shale, very dark gray, with sandstone streaks, fossil plants, siderite nodules.
2117.7 - 2120.75	Shale, very dark gray, fossil plants, siderite nodules; hard fireclay bottom 0.4'.
2120.75 - 2121.75	Coal sample.
2121.75 - 2123.4	Fireclay, very dark gray, waxy, massive, rooted, fossil plants.
2123.4 - 2125.2	Fireclay, dark gray, sandy, massive, rooted, fossil plants.
2125.2 - 2126.72	Fireclay, dark gray, massive, rooted, waxy, fossil plants.
2126.72 - 2126.92	Shale, black fossil plants.
2126.92 - 2130.57	Coal sample.
2130.57 - 2136.6	Fireclay, very dark gray, sandy in part, waxy, fossil plants; 2136 - 2136.05' coal.
2136.6 - 2140.7	Sandstone, gray, very fine grained, with shale streaks, rippled.
2140.7 - 2142.15	Shale, dark gray, with sandstone streaks.
2142.15 - 2142.35	Banded bone, coal and black shale.
2142.35 - 2142.9	Coal sample.
2142.9 - 2143.55	Fireclay, dark gray, massive, rooted, fossil plants.
2143.55 - 2146.2	Coal sample.
2146.2 - 2147.9	Fireclay, very dark gray, hard and soft, waxy, fossil plants.

2147.9 - 2149.15	Coal sample.
2149.15 - 2151.45	Fireclay, very dark gray, hard, waxy, rooted, fossil plants.
2151.45 - 2153.55	Coal sample.
2153.55 - 2154.2	Fireclay, dark gray, sandy, hard, rooted, fossil plants.
2154.2 - 2157.6	Shale, dark gray, sandy, with thin sandstone beds.
2157.6 - 2165.6	Sandstone, gray, fine-grained, cross-bedded.
2165.6 - 2171.9	Shale, dark gray, sandy, scattered mudflows.
2171.9 - 2183	Sandstone, gray, massive, cross-bedded in part.
2183 - 2190	Shale, dark gray, with sandstone streaks.
2190 - 2204.2	Sandstone, very fine grained, and shale, dark gray, interbedded, rippled; burrowed in part, scattered siderite nodules; 0.5' sand flow at 2126'.
2204.2 - 2219	Sandstone, gray, fine-grained, with shale streaks, rippled; nearly vertical calcite-lined joint 2218 - 2219'.
2219 - 2223.2	Sandstone, fine-grained, and shale, interbedded, rippled; burrowed in part.
2223.2 - 2235	Sandstone, gray, with shale streaks, rippled; burrowed sandy shale 2229 - 2229.8'; marine fossils 2229.8 - 2230.1'; sand flow 2231.4 - 2231.7'.
2235 - 2239.8	Sandstone, gray, fine to medium-grained, massive, cross-bedded in part.
2239.8 - 2246.5	Sandstone, very fine grained, and shale, dark gray, interbedded, flat.
2246.5 - 2247.5	Sandy shale mudflow, dark gray.
2247.5 - 2249	Sandstone, very fine grained, and shale, dark gray, interbedded, flat.
2249 - 2258	Shale, dark gray, sandy, massive, few, thin sandstone beds and siderite bands.
2258 - 2280	Shale, dark gray, sandy, churned, massive.

2280 - 2290	Shale, dark gray, sandy, churned in part, few siderite nodules and sandstone beds.
2290 - 2306.5	Shale, very dark gray, scattered, marine fossils; marine fossil bed 2304.5 - 2305'.
2306.5 - 2314	Sandstone, gray, fine to medium-grained, with shale streaks, rippled; burrowed in part.
2314 - 2315	Shale, dark gray, sandy, burrowed.
2315 - 2316.6	Sandstone, fine-grained, and shale, interbedded, rippled; burrowed in part,
2316.6 - 2320	Shale, dark gray, sandy, burrowed, vertical, calcite-lined joint 2319.5 - 2320.5'.
2320 - 2324.67	Sandstone, fine-grained, and shale, interbedded, rippled; burrowed in part.
2324.67 - 2325.02	Coal sample.
2325.02 - 2325.6	Fireclay, dark gray, sandy, waxy in part, fossil plants.
2325.6 - 2333.4	Sandstone, fine-grained, with shale streaks, rippled; argillaceous sandstone.
2333.4 - 2336	Shale, dark gray, sandy, massive.
2336 - 2337.8	Shale, dark gray, fossil plants.
2337.8 - 2340.5	Fireclay, very dark gray, rooted, waxy in part, fossil plants.
2340.5 - 2341.3	Coal sample.
2341.3 - 2353.6	Fireclay, very dark gray, hard, massive, waxy in part, fossil plants.
2353.6 - 2359.75	Shale, dark gray, few thin sandstone beds.
2359.75 - 2360.05	Coal sample.
2360.05 - 2364	Fireclay, very dark gray, hard, rooted, waxy in part, fossil plants.
2364 - 2378.16	Shale, very dark gray, fossil plants, siderite nodules.
2378.16 - 2378.87	Coal sample.

2378.87 - 2384.7	Fireclay, dark gray, sandy in part, rooted, hard, fossil plants.
2384.7 - 2429	Sandstone, gray, fine to medium-grained, massive, minor cross-bedding; vertical joint 2399 - 2402'; gray shale 2406 - 2406.6; thin coal spars 2413 - 2415.
2429 - 2431.8	Sandstone mudflow, light to dark gray.
2431.8 - 2435	Sandstone, gray, fine-grained, with shale streaks, rippled.
2435 - 2435.8	Sandy shale mudflow, dark gray.
2435.8 - 2439.1	Shale, dark gray, sandy, massive, few, thin sandstone beds.
2439.1 - 2445.5	Shale, dark gray, sandy, siderite bands, burrowed.
2445.5 - 2461	Shale, very dark gray, siderite nodules.
2461 - 2462	Shale, sandy, marine fossil bed.
2462 - 2469	Shale, very dark gray, sandy, scattered burrowing and fossil plants.
2469 - 2469.66	Coal sample.
2469.66 - 2470.66	Fireclay, very dark gray, waxy in part, massive, rooted, fossil plants, coal bands.
2470.66 - 2481.33	Sandstone and shale, interbedded, rippled; grading downward to very dark gray shale with sandstone streaks; fossil plants, siderite nodules.
2481.33 - 2481.78	Coal sample.
2481.78 - 2487.5	Fireclay, dark gray, waxy, rooted, fossil plants.
2487.5 - 2489.3	Sandstone, gray, fine grained, massive.
2489.3 - 2490.3	Shale and fireclay, dark gray, interbedded, waxy in part, fossil plants.
2490.3 - 2494.2	Sandstone, gray, fine-grained, with shale streaks, rippled.
2494.2 - 2497.8	Shale, dark gray, sandy, with sandstone streaks, siderite bands.
2497.8 - 2499.6	Shale, dark gray, sandy, massive, siderite bands.

2499.6 - 2502.5	Shale, very dark gray, siderite nodules.
2502.5 - 2503.34	Coal sample.
2503.34 - 2509.53	Shale, dark gray, sandy, waxy, rooted, fossil plants.
2509.53 - 2509.84	Coal sample.
2509.84 - 2510.4	Shale, dark gray, sandy, waxy, rooted, fossil plants.
2510.4 - 2516.5	Sandstone, gray, fine-grained, with shale streaks, rippled; rooted and burrowed in part, siderite lenses and nodules.
2516.5 - 1541.9	Shale, very dark gray, siderite nodules and bands, fossil plants.
2541.9 - 2542.12	Shale, very dark gray fossil plants.
2542.12 - 2542.45	Coal sample.
2542.45 - 2543.4	Fireclay, dark gray, sandy, massive, rooted, fossil plants.
2543.4 - 2545.4	Sandstone, gray, fine-grained, with shale streaks; argillaceous, fossil plants, rooted.
2545.4 - 2552.9	Shale, very dark gray, fossil plants, siderite bands.
2552.9 - 2554.0	Banded coal, bone and black shale.
2554.0 - 2554.6	Fireclay, very dark gray,waxy, fossil plants.
2554.6 - 2576	Sandstone, gray, fine to medium grained, massive, cross-bedded in part, few siderite and shale pebbles, few coal spars and bands.
2576 - 2594	Shale, very dark gray,fossil plants, siderite bands.
2594 - 2594.42	Shale, dark gray to black, with coal bands.
2594.42 - 2597.42	Coal sample.
2597.42 - 2598.5	Fireclay, very dark gray, and black shale interbedded, waxy in part, fossil plants, coal bands.
2598.5 - 2599.8	Fireclay, dark gray, sandy, rooted, waxy, fossil plants.

2599.8 - 2605.9	Sandstone, fine-grained, and shale, interbedded, rippled; burrowed in part, siderite nodules.
2605.9 - 2608.5	Sandstone, gray, with shale streaks, rippled, partly rooted, coal spars.
2608.5 - 2624.2	Sandstone and shale, interbedded, rippled; burrowed and rooted in part, fossil plants, siderite nodules and bands.
2624.2 - 2637.2	Shale, dark gray, with sandstone streaks, siderite nodules and bands.
2637.2 - 2637.4	Shale, black, fossil plants.
2637.4 - 2637.55	Coal and bone.
2637.55 - 2638.8	Fireclay, dark gray, sandy and waxy in part, massive, rooted, fossil plants.
2638.8 - 2647.8	Sandstone, gray, fine-grained, with shale streaks, rippled; rooted and burrowed in part to 2642'.
2647.8 - 2648.4	Black shale, coal bands.
2648.4 - 2648.65	Coal sample.
2648.65 - 2649.1	Dark gray sandy fireclay, massive, rooted, fossil plants.
2649.1 - 2668.6	Massive, gray sandstone, fine to medium-grained, rooted in part to 2655.
2668.6 - 2670.75	Black shale, thin coal bands, fossil plants, siderite bands.
2670.75 - 2671.08	Coal sample.
2671.08 - 2672	Dark gray fireclay, waxy, fossil plants, coal band 2671.2 - 2671.24.
2672 - 2672.66	Coal sample.
2672.66 - 2675.5	Fireclay, medium gray, sandy, waxy in part, rooted, fossil plants.
2675.5 - 2680	Sandstone, gray, fine-grained, with shale streaks, rippled.
2680 - 2686.8	Shale, dark gray, sandy, with sandstone streaks.
2686.8 - 2689.3	Fireclay, dark gray, sandy, massive, rooted, waxy in part, fossil plants.

2689.3 - 2689.4	Nodular ironstone, and shale, gray-green, sandy, rounded siderite pebbles.
2689.4 - 2696	Shale, black, fossil plants, siderite nodules.
2696 - 2696.5	Shale, black, with coal bands.
2696.5 - 2703.2	Fireclay, dark gray, massive, waxy, rooted, fossil plants, sandy 2702 - 2703.2.
2703.2 - 2706.8	Shale, dark gray, sandy, massive, burrowed in part.
2706.8 - 2709.4	Sandstone, gray, fine-garined, with shale steaks, rippled.
2709.4 - 2711.6	Sandstone, gray, fine-grained, with shale streaks, flat.
2711.6 - 2728	Shale, dark gray, sandy, massive, small-scale sandy shale mudflows, fossil plants.
2728 - 2787	Sandstone, gray, fine-grained, with shale streaks, flat; vertical, calcite-lined, joint 2750 - 2778'; shale streaks contain coalified plants and become common 2771 - 2787'.
2787 - 2886.5	Sandstone, fine-grained, and shale, dark gray, interbedded, flat; some rippled bedding to 2822', burrowed sandstone 2803 - 2803.8', vertical calcite-lined, joint 2796 - 2797' and 2807 - 2805'.
2886.5 - 2929	Shale, dark gray, sandy, massive, scattered thin sandstone beds and sandy shale mudflows.
2929 - 2947	Shale, dark gray, with sandstone streaks, sandstone beds up to 0.5' thick 2947 - 2949.2'.
2947 - 2965	Shale, dark gray,very few thin sandstone beds, one pyrite lens.

Bottom of drill hole AL #1 - 2965'

Lithologic Description by the Geological Survey of Alabama