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Methane Content and Geology of the Hartshorne Coalbed in Haskell and Le Flore Counties, Okla.

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UNITED STATES DEPARTMENT OF THE INTERIOR

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METHANE CONTENT AND GEOLOGY OF THE HARTSHORNE COALBED IN HASKELL AND LE FLORE COUNTIES, OKLA.

by

Anthony T. Iannacchione[1] and Donald G. Puglio[2]

ABSTRACT

The Bureau of Mines developed data on the methane content of the Hartshorne coalbed, Haskell and Le Flore Counties, Okla. The methane content is calculated to be between 1.1 and 1.5 trillion cubic feet, based on an estimate of total coal in place of 2.4 to 3.2 billion short tons. Methane increases with depth, but the rate of increase decreases with greater depths. Degasification in advance of mining is recommended for all mines operating at depths greater than 500 feet to reduce hazards and methane explosions, decrease mine ventilation costs, and conserve the natural gas that would be otherwise wasted.

INTRODUCTION

As part of the Bureau of Mines methane control program, a study was conducted to determine the geology and methane content of the Hartshorne coalbed in an approximately 1,500-square-mile area in Le Flore and Haskell Counties, Okla. (fig. 1). Underground mines operating in the Hartshorne coalbed have had a long history of high methane emissions. Recently, two mines (Howe mine, Le Flore County, Okla., and Choctaw mine, Haskell County, Okla.) closed down completely or suspended mining owing to a combination of high methane emissions and roof control problems.

The purpose of this study is to establish a scientific basis for planning the degasification that will be essential for mining the coal safely. Approximately 900 data points were used to interpret the geology of the Hartshorne coalbed and to estimate the total coal in place. Gas resources estimated were calculated using direct-method analyses (9)[3] of 16 coal cores sampled between 1976 and 1978 from depths of 200 to 1,500 feet.

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[3]Underlined numbers in parentheses refer to items in the list of references at the end of this report.

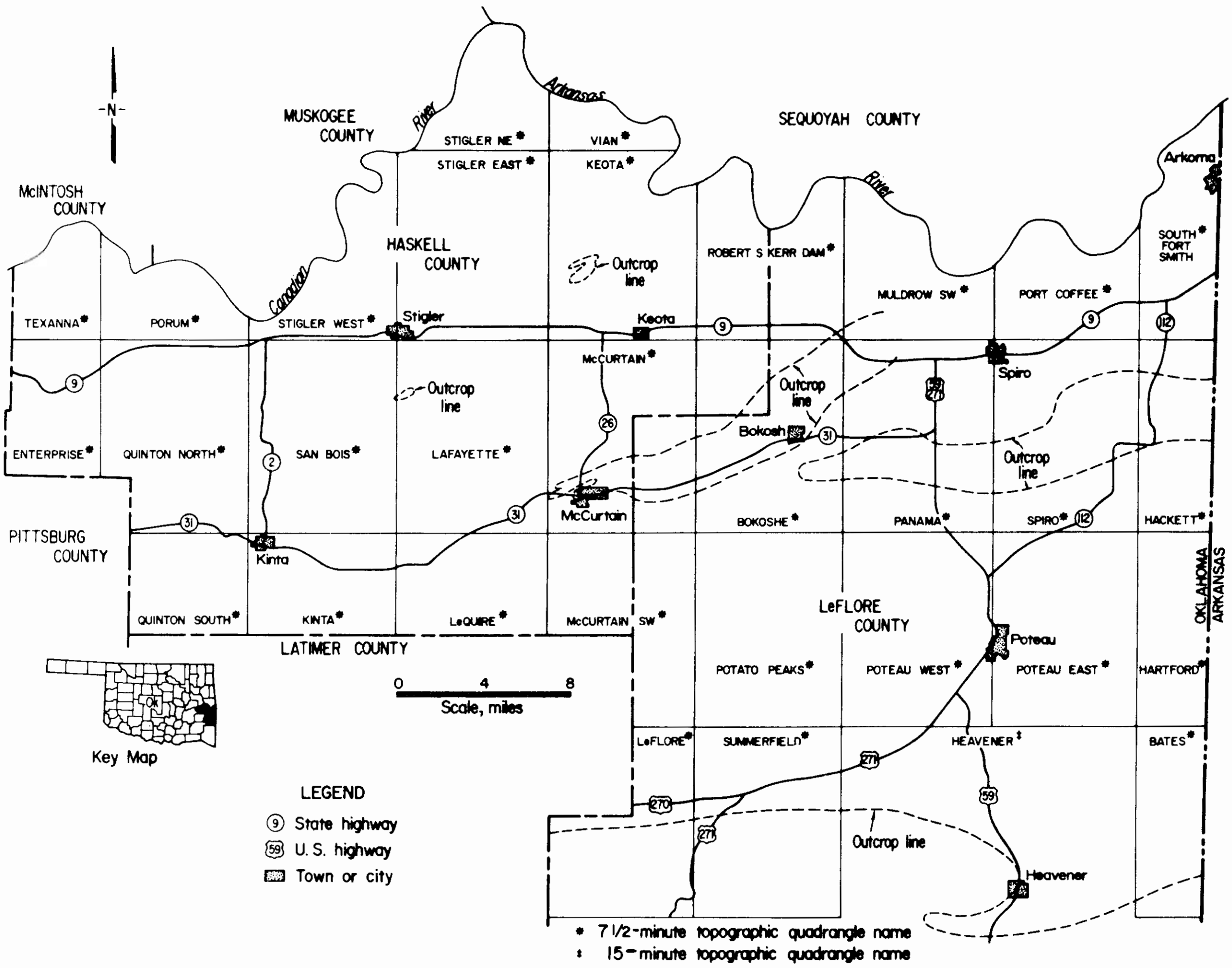

FIGURE 1. - Location map of study area showing topographic quadrangles, towns, and major roads.

The Hartshorne coalbed in the study area is a high-volatile A bituminous to semianthracite coal, which has been used for making coke in Indiana, Illinois, Texas, and Colorado. It is generally friable, has closely spaced cleat, and contains many inclined (shear) fractures that dip 45° to 55°. Individual coalbed thickness ranges from zero to approximately 6 feet, averaging 3 to 5 feet. Overburden ranges from zero at outcrop to almost 7,000 feet under Cavanal Mountain in Le Flore County.

In the past, the coal was mined close to the outcrop, as shown on the mined-out-area map (fig. 2). However, two newer operations (Kerr-McGee's Choctaw mine, 1,200 to 1,400 feet deep; and Armco's Experimental Mine No. 1, a drift mine that will eventually be under 1,500 feet of overburden) will be mining down to and at the bottom of major synclinal structures, where most of the leased remaining coal resources lie.

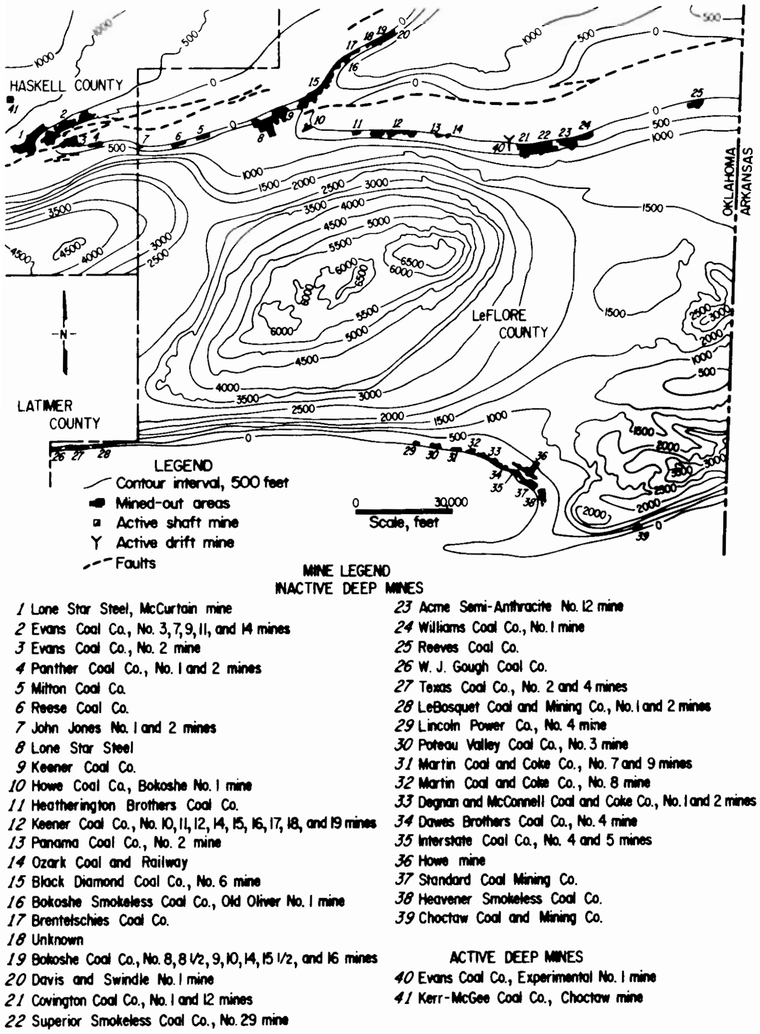

FIGURE 2. - Mined-out-area map and overburden map of the Hartshorne coalbed.

ACKNOWLEDGMENTS

The authors thank S. A. Friedman of the Oklahoma Geological Survey for providing core log data, mine maps, and review of the manuscript. Special cooperation was provided by personnel from Kerr-McGee Coal Corp. and Armco Inc. Preliminary investigations in this area (10) by former Bureau of Mines employee Gary W. Murrie were of considerable help in completing this study.

GEOLOGY

An examination of the geology of the Hartshorne coalbed was necessary because of high variability in the degrees of dip, areas of complex faulting, variation in thickness of overburden, and the regional splitting of the Hartshorne into an upper and lower coalbed. All of these geologic factors should be considered in the design of degasification programs in this area.

Stratigraphy

The Hartshorne coalbed is contained within the Hartshorne Formation (fig. 3) and is stratigraphically the lowest minable coalbed in the Arkoma basin. The coalbed is commonly overlain and/or underlain by the Hartshorne Sandstone (5, 8, 11).

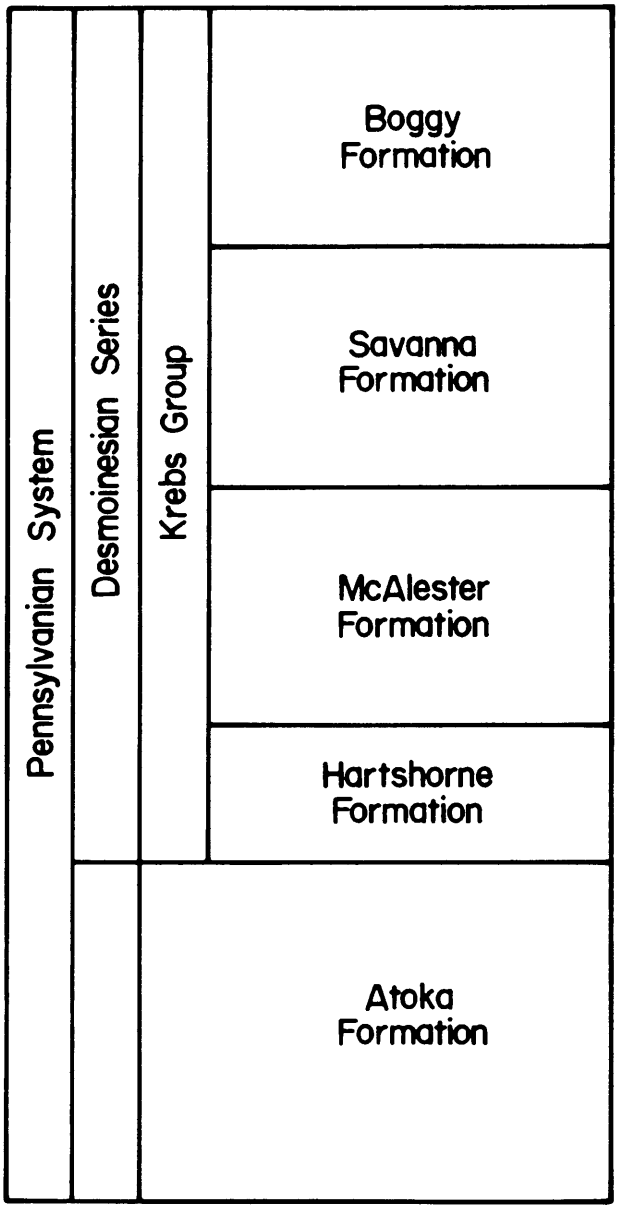

FIGURE 3. - Generalized stratigraphic column of exposed rocks in the study area.

In the eastern and southern portions of the study area, the Hartshorne coalbed is divided into two beds known as the Upper and Lower Hartshorne (8). The Hartshorne is considered divided wherever the parting within the coalbed exceeds 1 foot in thickness (4). Figure 4 shows the separation between these two important coal units. Areal distribution and coalbed thickness of the undivided Hartshorne, the Lower Hartshorne, and the Upper Hartshorne are shown in figures 5 and 6.

The coalbed splits along an irregular northeast-southwest "hinge" line, with the interval between the two benches thickening to the southwest (fig. 4). The maximum separation between the Lower and Upper Hartshorne coalbeds is approximately 115 feet within the Heavener 15-minute quadrangle, Le Flore County (figs. 1 and 4). Three coreholes in this same area indicate the presence of a 1-foot-thick, shaley "wild" coalbed approximately 70 to 90 feet above the Lower Hartshorne coalbed.

The Hartshorne Formation is comprised of complex layers of coal, shale, siltstone, and sandstone (fig. 7). We believe these sediments are part of a prograding deltaic complex that contains a distributary channel system, levee and overbank deposits, interdistributary bay sediments, crevasse splays, and peat swamps much like the environments found today on the Mississippi River Delta complex as described by Fisk (3).

The Hartshorne Formation is overlain by the McCurtain Shale Members of the McAlester Formation and is underlain by the shales, siltstone, and sandstones of the Atoka Formation. The Hartshorne Formation ranges in thickness from a minimum of 35 feet in the Lafayette 7-1/2-minute quadrangle to approximately 300 feet in portions of the northern Poteau East and southern Spiro 7-1/2-minute quadrangles (fig. 1). The base of the Hartshorne Sandstone defines the base of the formation, and the top of the undivided Hartshorne coalbed or of the Upper Hartshorne coalbed defines the top of the formation.

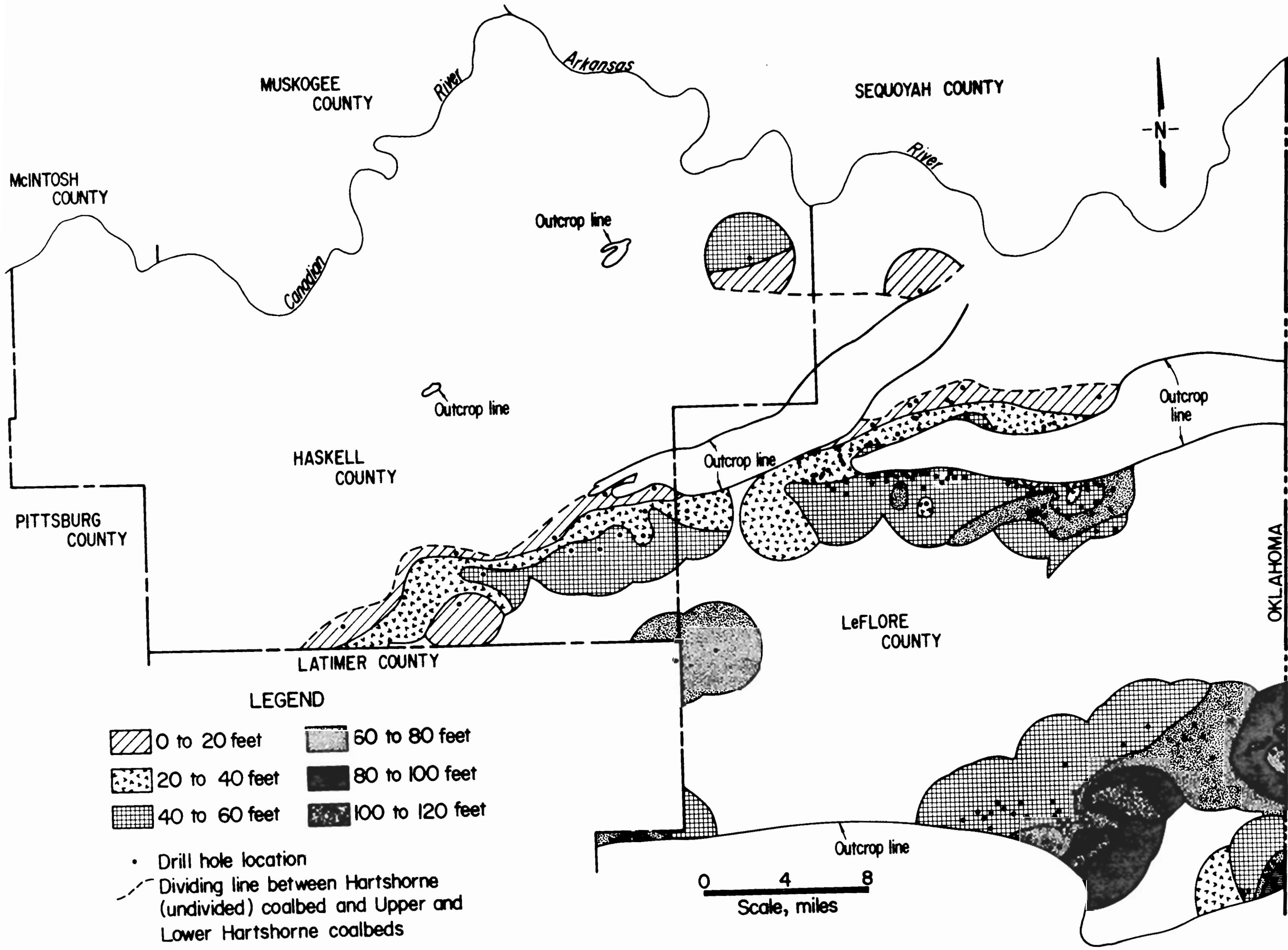

FIGURE 4. - Isopach map of interval between Lower and Upper Hartshorne coalbeds.

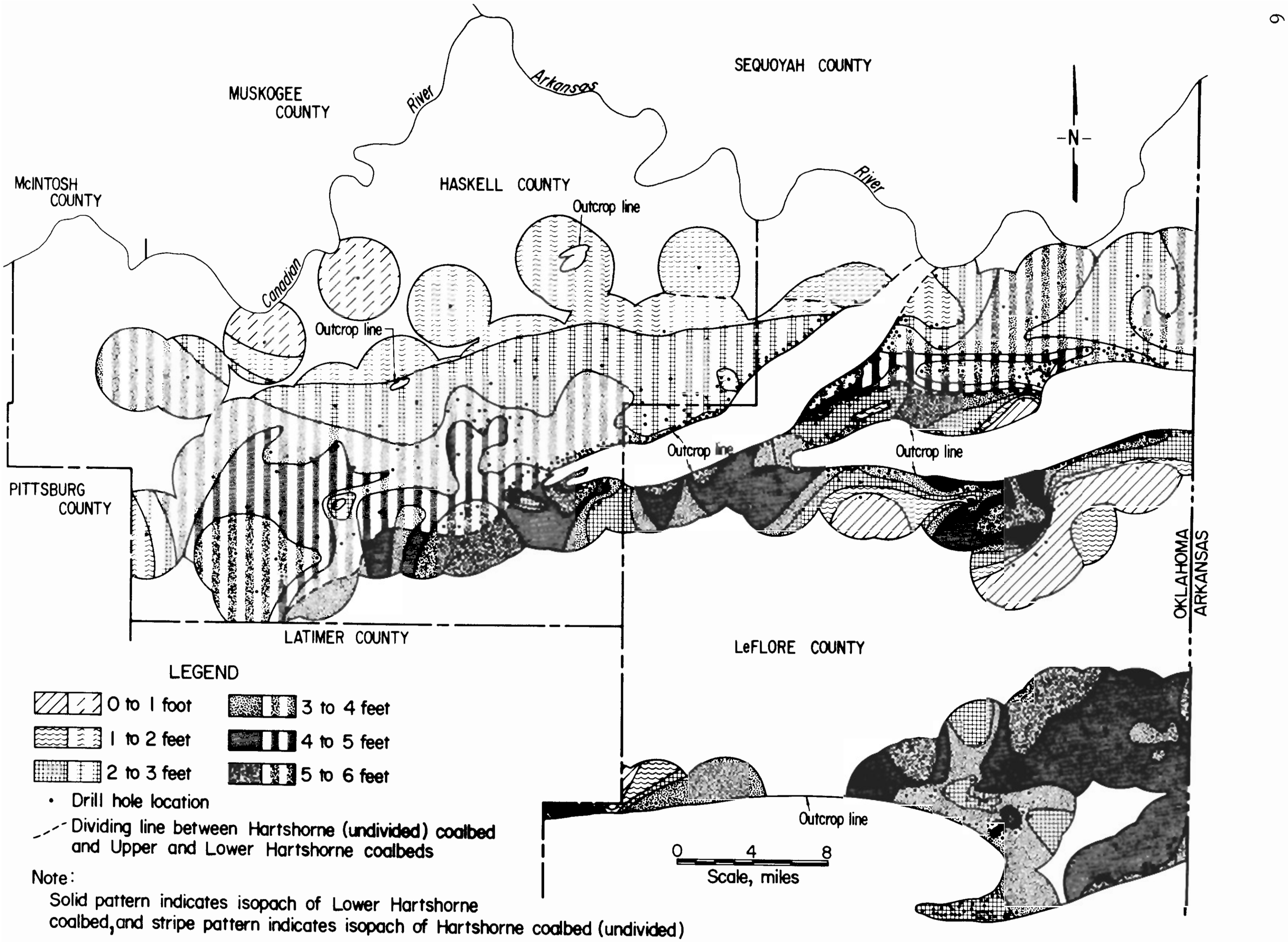

FIGURE 5. - Isopach map of the undivided Hartshorne and of the Lower Hartshorne coalbeds.

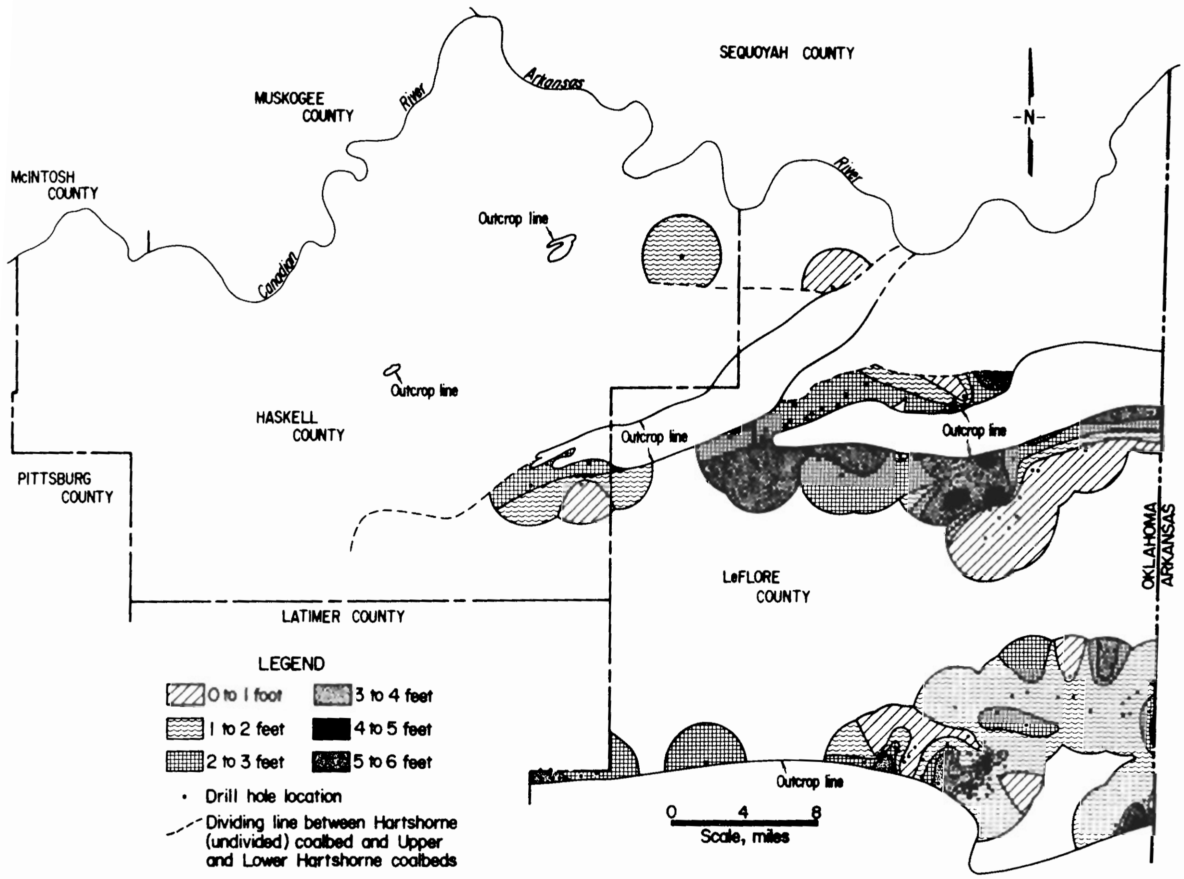

FIGURE 6. - Isopach map of the Upper Hartshorne coalbed.

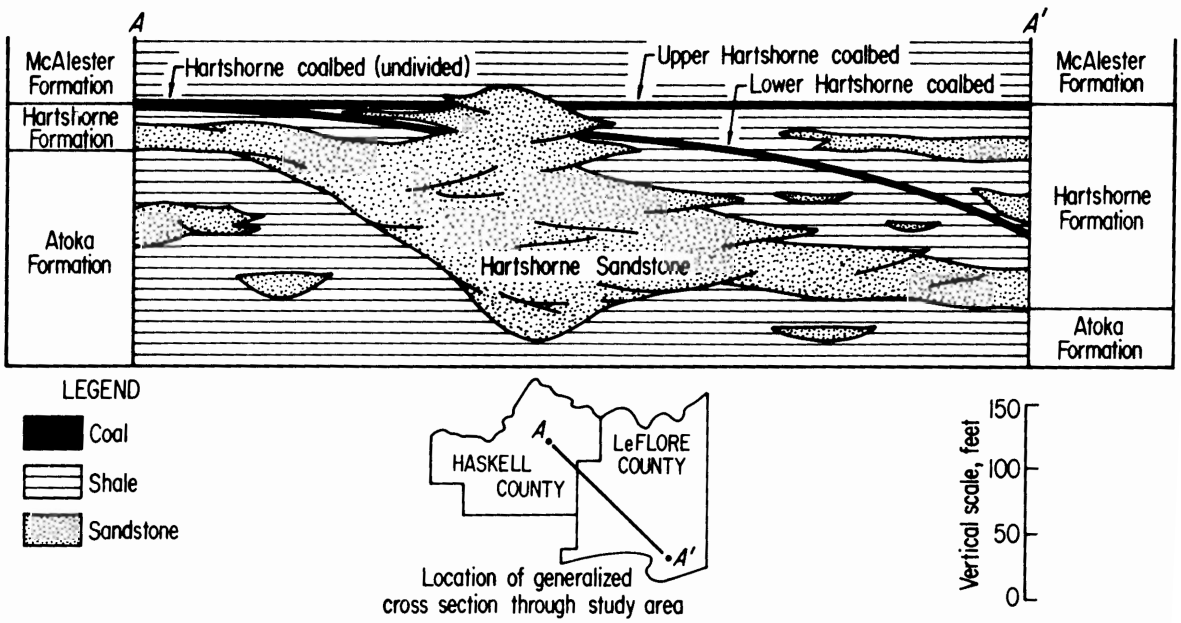

FIGURE 7. - Generalized cross section of the Hartshorne Formation through Haskell and Le Flore Counties.

Localized thickening of the Hartshorne Formation is generally associated with the thickening of the Hartshorne Sandstone. In the Poteau East and southern Spiro 7-1/2-minute quadrangles, this sandstone comprises the entire Hartshorne Formation, where ancient fluvial channels apparently eroded away the Hartshorne coalbed (figs. 5-6). Regional thickening of the Hartshorne Formation is generally associated with the thickening of the interval between the Lower and Upper Hartshorne coalbeds (fig. 4).

Structure

The study area is located within the Arkoma basin. This large synclinorium is comprised of synclines and faulted anticlines. The most prominent synclinal folds in the study area include the Cavanal, Panther Mountain, and Sans Bois (fig. 8), which form broad synclinal mountains. Dominant anticlinal axes folds are the Milton, Backbone, and Kinta (fig. 8). There are large-displacement faults paralleling the axes of these anticlines. The synclinal and anticlinal axes trend in easterly and northeasterly directions. Dips

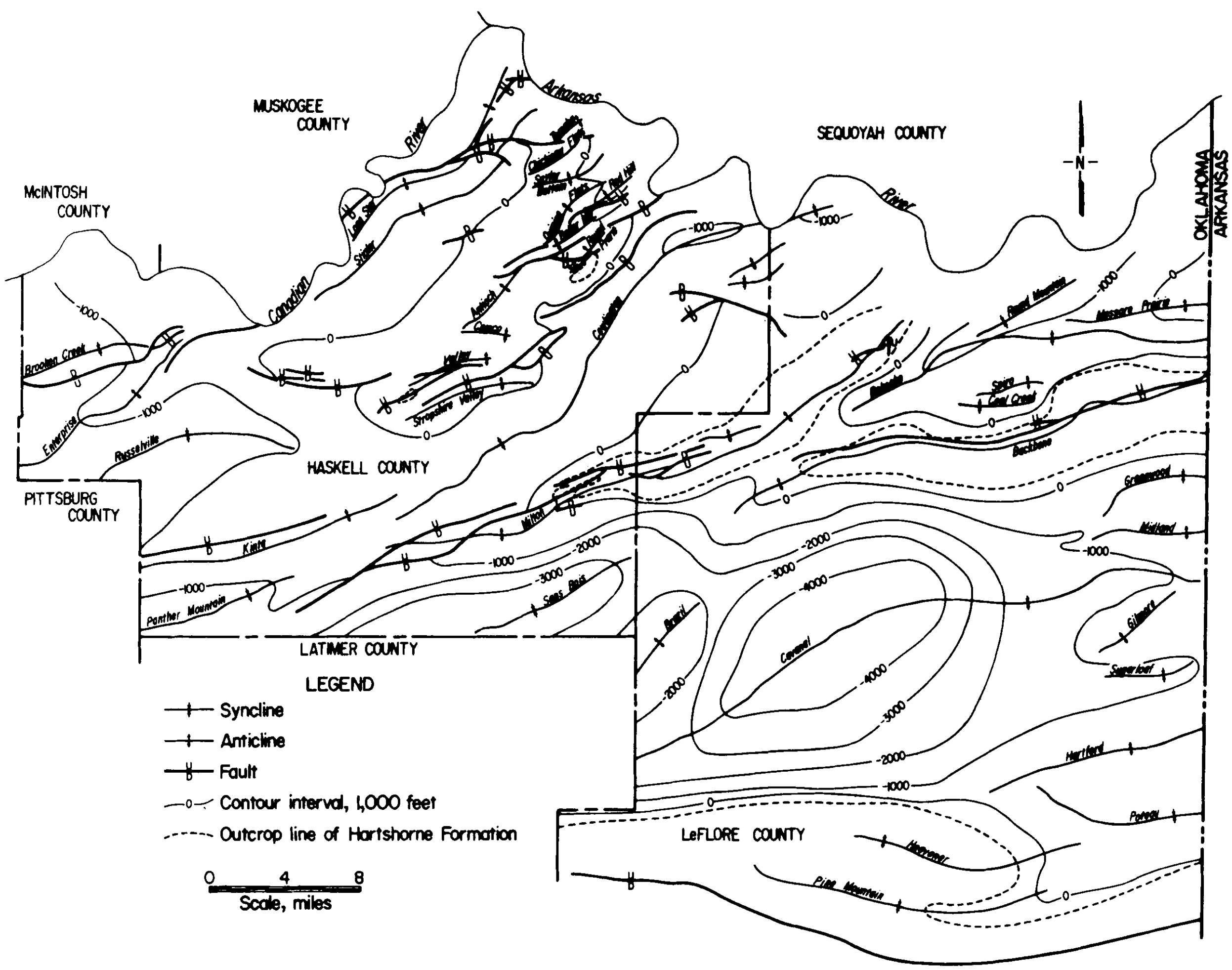

FIGURE 8. - Structure contours on the base of the Hartshorne coalbed in Haskell and Le Flore Counties.

range from nearly horizontal at the bottom of the Cowlington syncline at the site of the Choctaw mine, to steeply dipping beds that approach the vertical in places along the Milton anticline as observed at Great National's strip mine near McCurtain (fig. 1).

Intense faulting occurs along major anticlinal structures and within the complex Whitefield uplift (11) of north-central Haskell County (fig. 8). The Whitefield uplift, a broad anticlinorium, includes several small folds and faults. The oldest strata in the study area belong to the Atoka Formation and are exposed within the Whitefield uplift and along the axes of the Milton and Backbone anticlines.

Cleat

Cleat directions were measured at strip mines and surface exposures of coal (fig. 9). Cleat data were then analyzed using a method devised by Diamond (2). Results of these analyses show that the direction of face cleat ranges from N 32° W to N 17° W, which is perpendicular to structural trends in the area. The friability of the Hartshorne coalbed is due to close spacing of cleat and the frequent occurrence of shear fractures with dips of 45° to 55° within the coalbed. Directional permeability characteristics of coalbeds are generally dependent on the orientation of these cleat fractures (7).

METHANE CONTENT

Methane is always present in coal. Within the study area, methane gas constitutes a serious potential safety hazard for all future deep mining. Methane content of coalbeds is a function of depth and rank (6, 12). Methane emissions in coal mines are controlled by porosity, fracture permeability, and gas pressure.

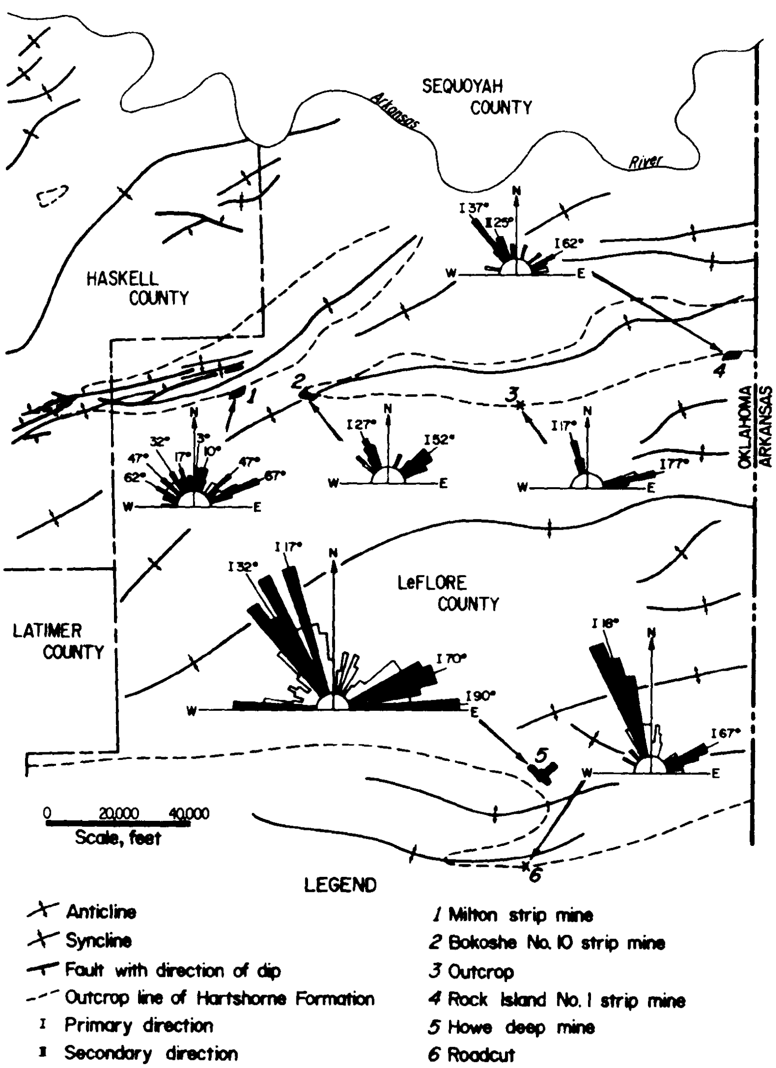

FIGURE 9. - Coal cleat orientations of the Hartshorne coalbed in Le Flore County.

Method of Calcualtions

Sixteen desorption samples from different coal cores collected within the study area were analyzed for methane content using the Bureau of Mines direct-method technique. This information was then used to construct the graph shown in figure 10. Equation 1 is the linear least-squares equation representing the changes in gas content with depth for this coalbed in the study area.

$$\hat{Y} = -27.88 + 6.25 (\ln X), \quad (1)$$

where X = overburden (feet)

and $\hat{Y}$ = expected methane content (cm^3/g).

This equation has a correlation coefficient of 0.908 with the data. The area between the dashed lines shown in figure 10 indicates the range of expected gas content, using the direct method, of coals collected at various depths at the 95-pct confidence level.

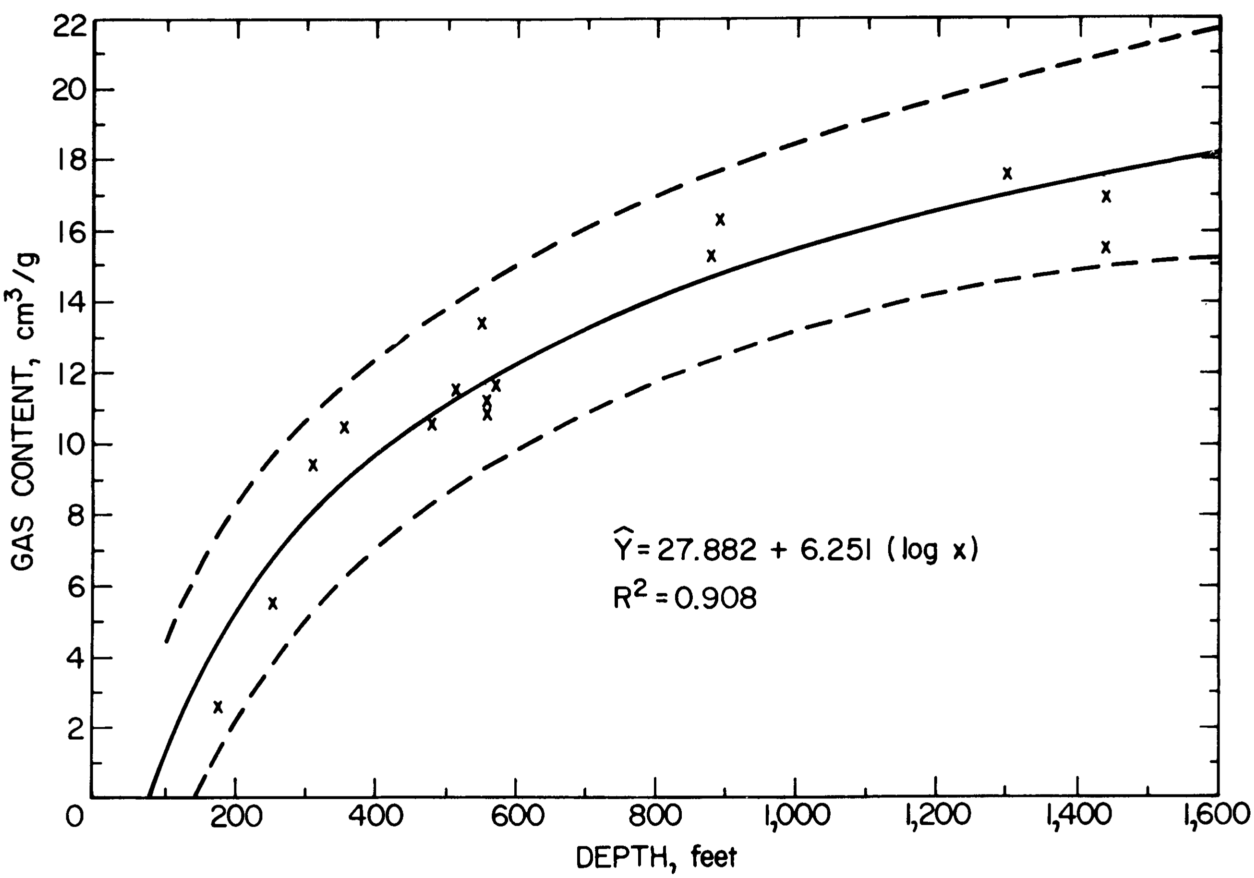

FIGURE 10. - Graph showing changes in gas content of the Hartshorne coalbed with changes in depth. R^2 = correlation coefficient.

To calculate the total volume of methane contained within the coalbed in the study area, it was necessary to estimate the amount of total coal in place within the various depth intervals indicated in table 1. This was accomplished by overlaying the overburden map (fig. 11) with the coal isopach maps of the Hartshorne coalbed (figs. 6-7).

TABLE 1. - Coal in place

Overburden, feet	Million short tons			Percent of total coal
	Hartshorne (undivided)	Upper Hartshorne	Lower Hartshorne	
0-500..............	Min 149 Max 221	Min 122 Max 178	Min 174 Max. 238	19
500-1,000..........	Min 368 Max 487	Min 108 Max 165	Min 228 Max 290	29
1,000-1,500........	Min 365 Max 475	Min 76 Max 120	Min 198 Max 252	27
1,500-2,000........	Min 158 Max 204	Min 37 Max 60	Min 160 Max 198	15
2,000-3,000........	Min 49 Max 61	Min 48 Max 75	Min 141 Max 176	10
Total.........	Min 1,089 Max 1,448	Min 391 Max 598	Min 901 Max 1,154	100

The different methane contents for the various depth intervals were calculated by plugging the median depth value for each overburden interval into the X variable of equation 1. The Y variable of this equation is the gas content of the coal in cubic centimeters of methane per gram of coal. The equivalent cubic feet of methane per ton of coal is obtained by multiplying the Y value by 32. Minimum and maximum methane contents were obtained by multiplying the minimum and maximum tonnages of coal times the methane content for each of the various overburden intervals (equations 2 and 3).

$$\text{Minimum methane content (ft}^3\text{) at Xx} = [\text{min coalbed thickness of Zx}] \times [\text{acreage within Xx}] \times [1{,}800\ \text{ft}^3/\text{ton}] \times [\text{Yx}]. \quad (2)$$

$$\text{Maximum methane content (ft}^3\text{) at Xx} = [\text{max coalbed thickness of Zx}] \times [\text{acreage within Xx}] \times [1{,}800\ \text{ft}^3/\text{ton}] \times [\text{Yx}]. \quad (3)$$

In these equations, Xx = overburden interval (0 to 500 = X_1, 500 to 1,000 = X_2, 1,000 to 1,500 = X_3, 1,500 to 2,000 = X_4, and 2,000 to 3,000 = X_5); Yx = average methane content of Xx; and Z = coalbed thickness in feet (1 to 2 feet = Z_1, 2 to 3 feet = Z_2, 3 to 4 feet = Z_3, 4 to 5 feet = Z_4, and 5 to 6 feet = Z_5).

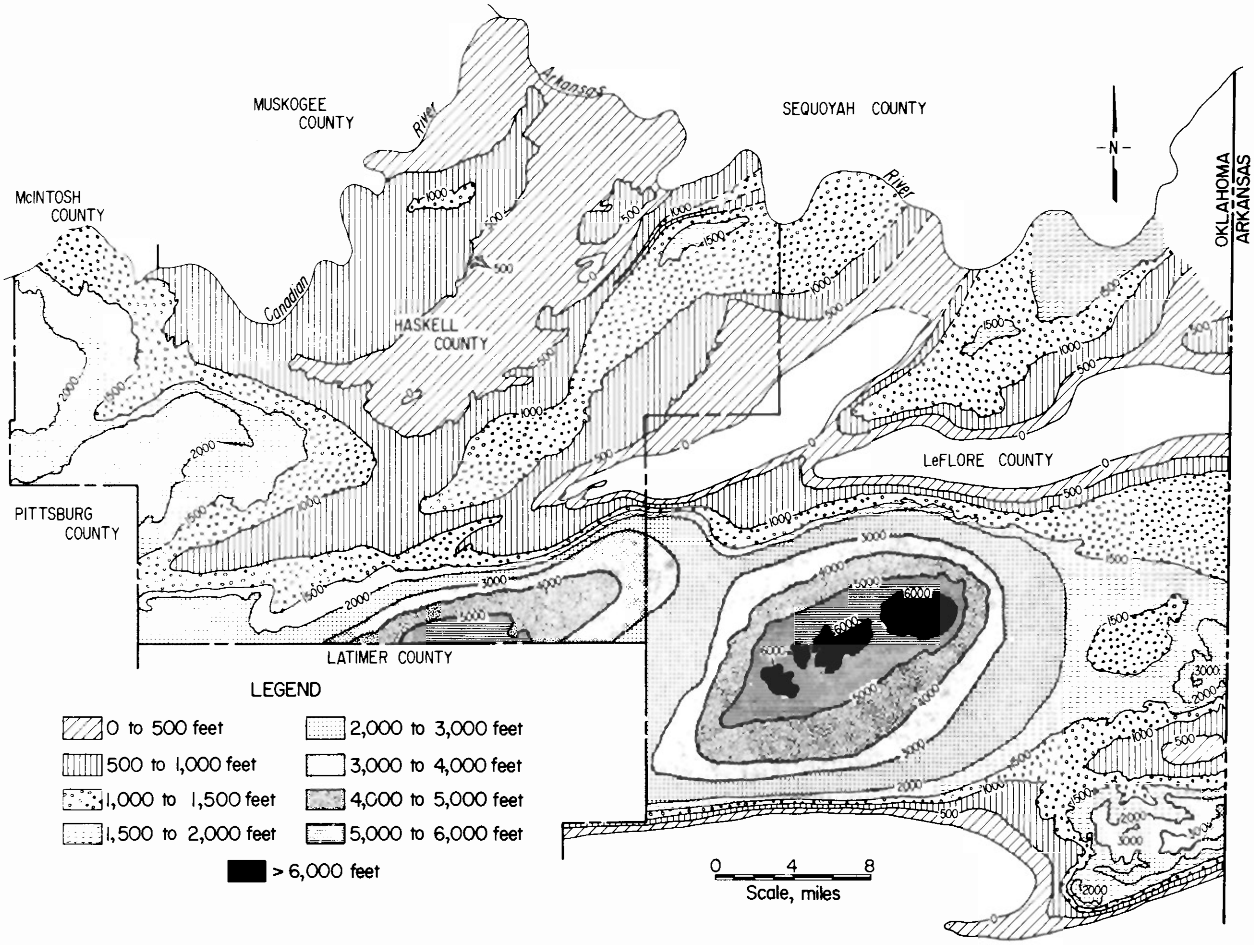

FIGURE 11. - Overburden above the Hartshorne coalbed.

Results

The Hartshorne coalbed in Haskell and Le Flore Counties is estimated to contain 1.1 to 1.5 trillion cubic feet of methane. Table 2 lists the gas potential for the Hartshorne coalbed at various overburden intervals within the study area. Methane distribution within each of the various overburden intervals (table 3) indicates that 58 pct of the total gas in the coalbed occurs at depths from 500 to 1,500 feet. This interval also contains approximately 56 pct of the total coal in place (table 1) and is the expected depth range of most future underground mining operations.

TABLE 2. - Methane content versus overburden

Overburden, feet	Average Methane content		Estimated methane content, billion cubic feet		
	Cm^3/g	Ft^3/ton	Undivided Hartshorne	Upper Hartshorne	Lower Hartshorne
0-500...........	6.6	211	Min 32 Max 47	Min 26 Max 37	Min 37 Max 50
500-1,000.......	13.5	432	Min 159 Max 210	Min 47 Max 71	Min 99 Max 125
1,000-1,500.....	16.7	534	Min 195 Max 253	Min 40 Max 64	Min 106 Max 135
1,500-2,000.....	18.8	602	Min 95 Max 123	Min 23 Max 36	Min 96 Max 119
2,000-3,000.....	21.0	672	Min 33 Max 41	Min 32 Max 51	Min 95 Max 119

TABLE 3. - Distribution of methane in the Hartshorne coalbed

Overburden, feet	Methane distribution, pct			
	Undivided Hartshorne	Upper Hartshorne	Lower Hartshorne	Total
0-500...........	6	15	9	9
500-1,000.......	31	28	23	27
1,000-1,500.....	38	24	24	31
1,500-2,000.....	18	14	22	19
2,000-3,000.....	6	19	22	4

SUMMARY AND CONCLUSIONS

Using data gathered from core logs, mine maps, outcrops, and desorbed coal core samples, the gas resources of the Hartshorne coalbed in Haskell and Le Flore Counties are calculated to be between 1.1 and 1.5 trillion cubic feet. These data were based on an estimated total coal in place of between 2.4 to 3.2 billion tons.

The Hartshorne coalbed has indicated dips ranging from horizontal to vertical and is intensely faulted. Overburden ranges from zero at the outcrop to nearly 7,000 feet. The coalbed is friable with principal cleat orientations developed parallel and perpendicular to regional structural trends, and it also contains a secondary shear cleat system. Stratigraphically, the Hartshorne coalbed splits into an upper and lower coalbed and ranges in thickness from zero to approximately 6 feet.

Methane content of the Hartshorne coalbed increases with depth, but at a decreasing logarithmic rate so that the maximum methane content will probably not exceed approximately 700 ft^3/ton at 3,000 feet of overburden. Degasification in advance of mining is recommended as part of a complete mine development plan for mines operating at depths greater than 500 feet to reduce methane emissions in mine workings. Also, there is the added possibility of commercial gas production from a degasification system (1), conserving this gas that would otherwise be vented into the atmosphere.

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