UNITED STATES DEPARTMENT OF THE INTERIOR

U.S. GEOLOGICAL SURVEY

Coalbed Methane Study of the ' Anderson ' Coal Deposit Johnson County, Wyoming ---- A Preliminary Report

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature.

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INTRODUCTION

Historically, coalbed methane has been viewed as a hazard, particularly in relation to mining. Yet, in the late sixties and early seventies, researchers began to investigate the resource potential of coalbed methane. The majority of the attention has been focused on higher-rank coal as a source of methane gas. Presently, interest is also developing in lower-rank coal as a methane gas source.

A cooperative drilling program in 1983 between the Bureau of Land Management and the Geological Survey offered scientists from the Federal Government and academia the opportunity to investigate and study the hydrology, geochemistry, and geochemical properties of the Anderson coal deposit in the central Powder River Basin (Fig. 1). The authority for naming the coal in this report "Anderson" comes from the report by Pierce and Kent (1982) which states:

> " One or more of the upper beds forming the Wyodak merge westward with several overlying coalbeds to form the coal deposit described here. The deposit is defined as a single bed of coal, and the boundary of the subarea containing the deposit is placed at the approximate locations where the single bed splits. For convenience, the single bed is identified collectively as Anderson coal, because that name identifies one of the principle coalbeds included."

In this report, the single bed of coal is called Big George and it is the center core for the Anderson coal deposit (Fig. 2). The main purpose of drilling was to core the unusually thick coal for research purposes including proximate and ultimate analyses, heat-of-combustion, forms of sulfur and ash-fusion temperatures, as well as major and minor oxides, trace elements, petrography, mineralogy and methane content (Hobbs and Roberts, 1983). The methane study was divided into two parts:

1) evaluation of oil and gas geophysical logs and published material prior to drilling to determine the geologic potential of methane occurrence
2) actual determination of gas content and gas quality within the coal and its relationship to pre-drilling evaluation.

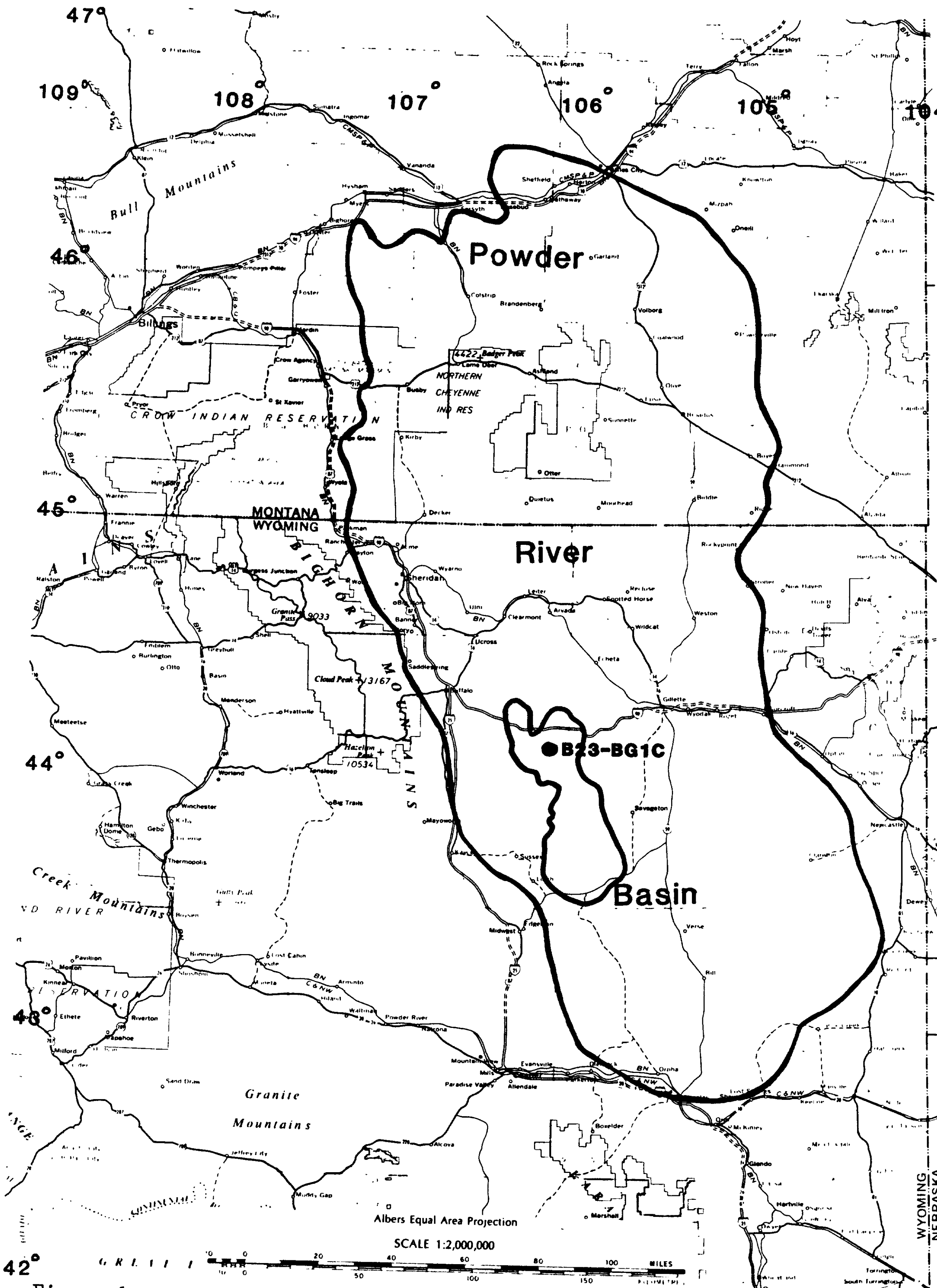

Figure 1. -- Index Map of the Powder River Basin, showing the outline of the Anderson Coal Deposit and the location of the methane test hole (B23-BG1C).

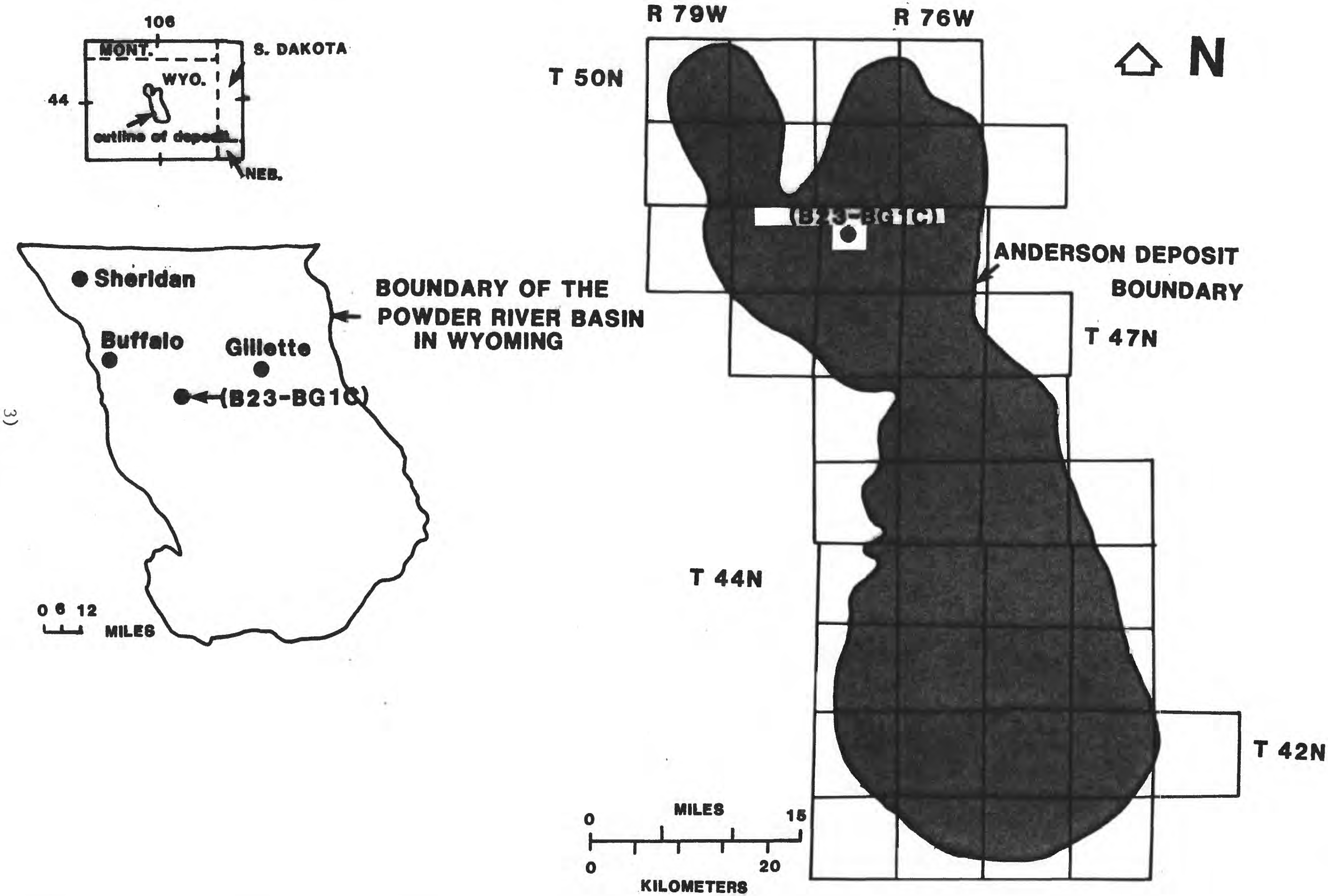

FIG. 2 LOCATION MAP (Modified from Pierce, 1982)

Previous Work

Olive (1957) reported the presence of natural gas in shallow wells throughout the Spotted Horse Field. The gas was presumed to have derived from the coal in the area. Olive noted one well in particular (SE 1/4, Sec. 30, T 58 N, R 75 W) that had produced gas since 1916. Three wells south of the Recluse area, near Horse Creek, produce from 500,000 to 1,000,000 cf/day from zones at depths of less than 50 feet. Whitcomb and others (1966), during discussions on groundwater resources, noted the presence of gas in water wells, its composition, and the effect of the gas on the water level. Lowry and Cummings (1966), expanded on the water resources, gas presence and aquifer characteristics of formations in Sheridan County. Hobbs (USGS, 1978) summarized encounters with methane during a Branch of Coal Resources drilling project in Campbell County, Wyoming. Gas analyses, gas quantity (ft /ton), porosity and permeability values for the coals and associated rocks, potential hazards, precautions and resources were calculated and included in his report. The drilling project was for coal exploratory investigation and it evaluated the Anderson and Canyon seams (splits of the Wyodak) as well as the Cook seam which underlies the Canyon. Methane was encountered in all of the 7 holes that were drilled. TRW (1981) shows hydrologic maps of the Powder River Basin with locations of at least 198 flowing artesian wells within the boundary of the Fort Union Formation. Methane is associated with many of these flowing wells.

Choate and Johnson (1980) presented a summary of the geology and methane resources of the Powder River Basin. Geologic factors controlling gas migration were pinpointed and potential target areas were delineated.

GEOLOGIC SETTING

The core hole site is located east of the Powder River axis, as evidenced by the structure contour of the base of the Anderson coal deposit (Fig. 3). The Anderson coal deposit lies within the Paleocene Fort Union Formation, which consists of three members, the upper most being the Tongue River. The Tongue River Member contains the major coalbeds of the upper Fort Union Formation within the Powder River Basin. The single, thick coalbed in B23-BG1C is subbituminous B (Hobbs, 1983). Geophysical logs of an oil and gas test hole, approximately one mile east of B23-BG1C core hole indicate that the Big George coalbed is 182 feet thick, whereas the Big George coalbed is 202 feet thick in the core hole. Regionally, the main deposit is from 50 feet to over 200 feet thick, with a rider coal that is from 11 feet to 58 feet thick. The rider splits from the main coal east of B23-BG1C with up to 140 feet of interburden separating the two beds west of the drill site.

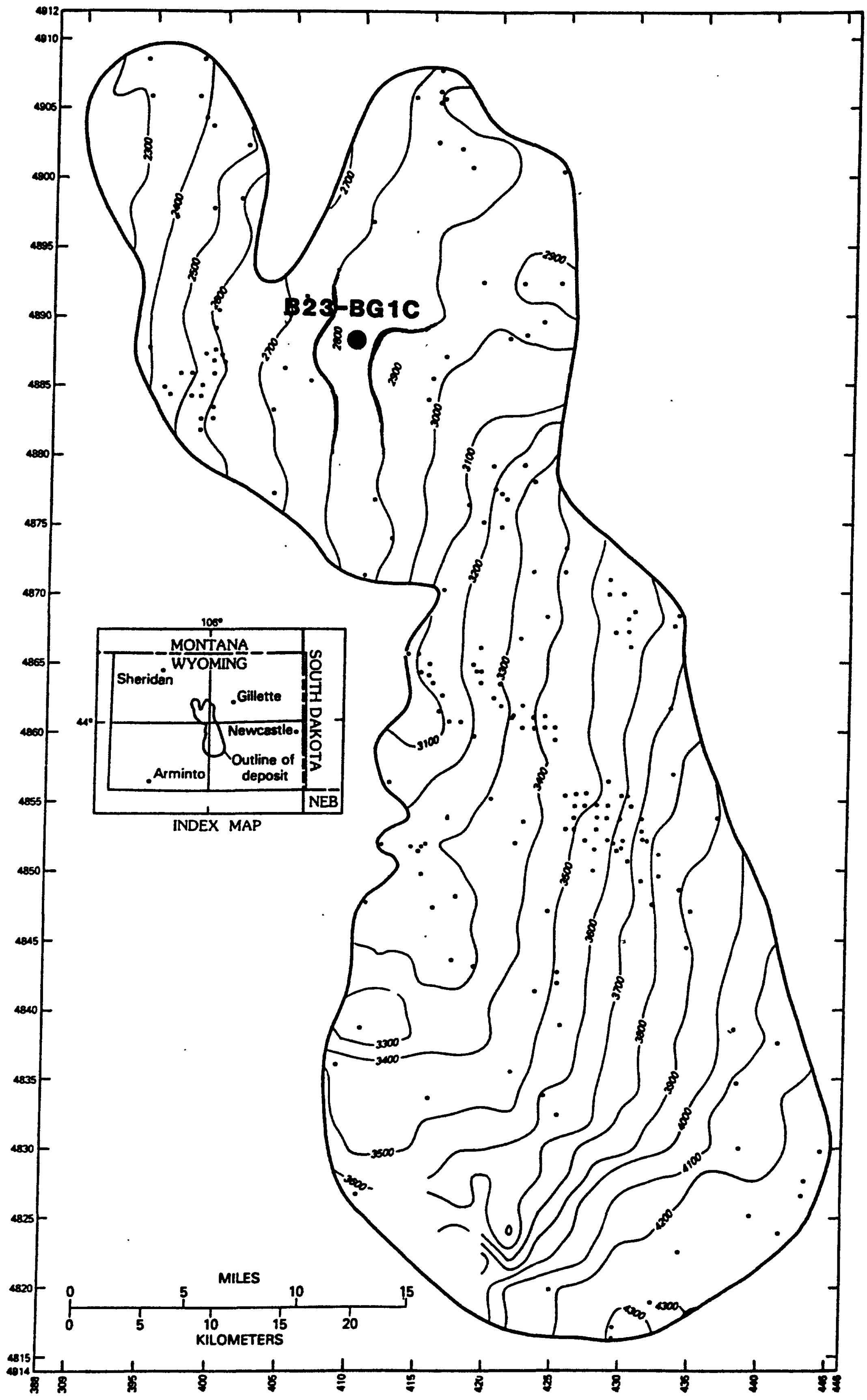

FIGURE 3 Structure Contour Map of the Anderson Coal Deposit (base) (Modified from Pierce, 1982)

RESULTS OF DRILLING

In June 1983, a rotary pilot hole (B23-BG1R) was drilled in SE SE Sec.7, T 48 N, R 77 W. The "twin" hole B23-BG1C (Hobbs, 1984) was drilled about 20 feet away (see Roberts, 1984 for full description of the drilling and coring details) and the coal interval was cored. Over 200 feet of coal and 34 feet of roof rock and floor rock were recovered. (Fig. 4).

METHANE EVALUATION -- PROCEDURES

Eight core samples were taken, one in roof rock and seven in the coal (Fig. 5) and desorbed using the standard Bureau of Mines desorption method (Diamond, 1982). Seven core samples were desorbed for one month. The sample of the roof rock (MRBGR) was taken in a carbonaceous shale above the coal and had terminated desorption within four days. The samples were sent to the Bureau of Mines Research Center in Bruceton, PA. for residual gas determinations. The data were corrected to standard temperature and pressure conditions of 60_oF temperature and 29.92 inches mercury. The results of the data are given in Table 1. The total gas content is shown graphically on Figure 5 (center). The gas was analyzed for volume percent of methane (C_1), ethane (C_2), propane (C_3), butanes and pentanes (C_4+), carbon dioxides (CO_2), and nitrogen and air (N_2). The stable carbon isotope ratios were measured on the methane constituents of all samples and are reported in the delta notations in parts per thousand (o/oo) deviations (relative to the Pedee belemnite (PDB) marine carbonate standard). The ratio of methane to the sum of C_1 through C_5 hydrocarbons was calculated for each sample. These analyses are shown on Table 2.

DATA EVALUATION

Coal has been assumed to be the source of gas found in shallow wells in the Powder River Basin in northern Wyoming. Canister samples taken from the core hole B23-BG1C emitted substantial, measurable quantities of methane. Values ranged from 56 to 74 standard cubic feet per ton (Table 1). Total gas content released during the first day of desorption ranged from 26 to 54 %. By the fifth day, 56 to 86 % had been desorbed.

GAS QUALITY

The gas derived from both the canisters and the well-head is made up predominantly of methane and carbon dioxide with minor amounts of heavier hydrocarbons (Table 2). Five canister gas samples, MRBG2 through MRBG6,

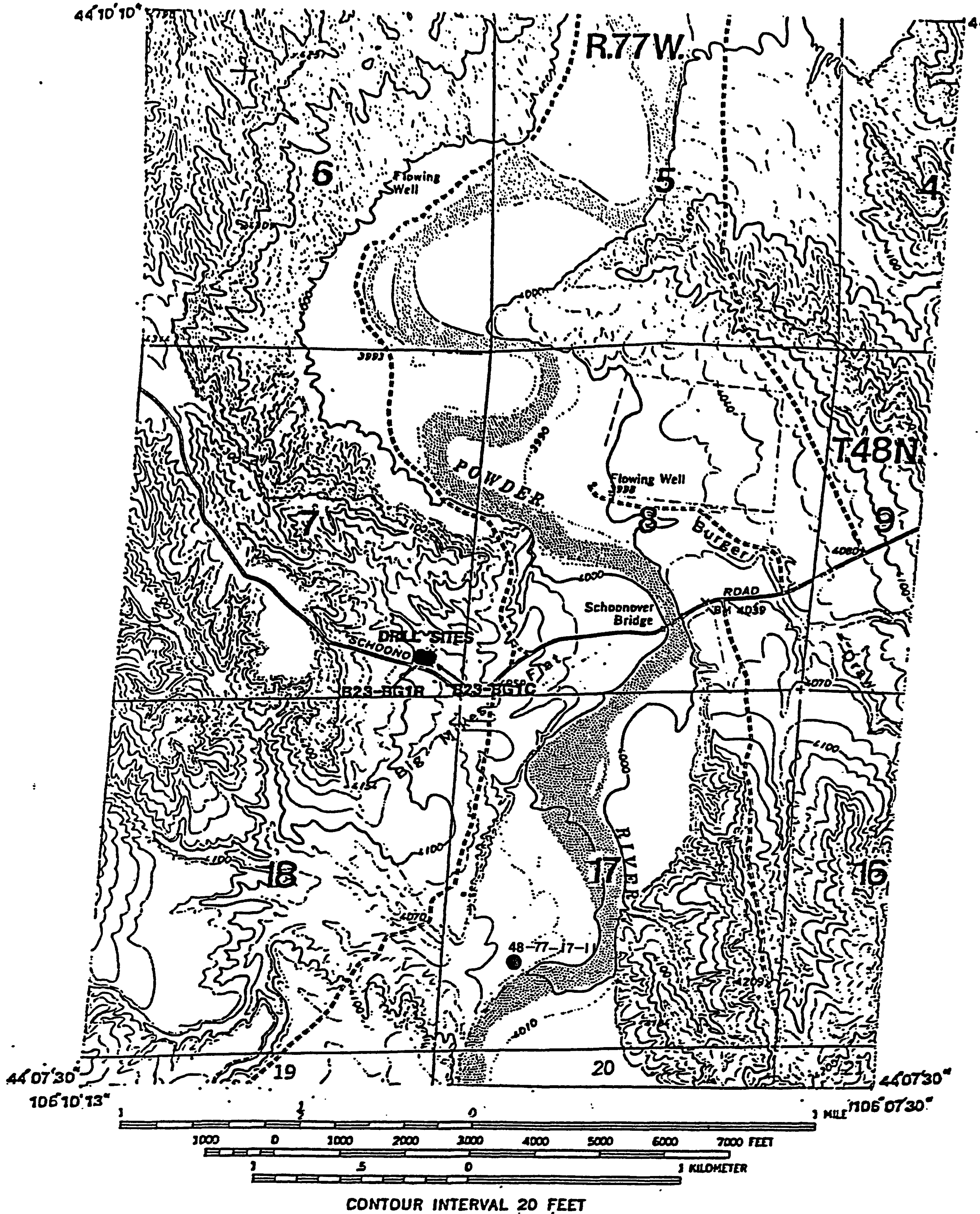

Figure 4 -- Location of drill holes in the Juniper Draw 7.5 minute quadrangle, Johnson County, Wyoming (Roberts, S. B., 1983)

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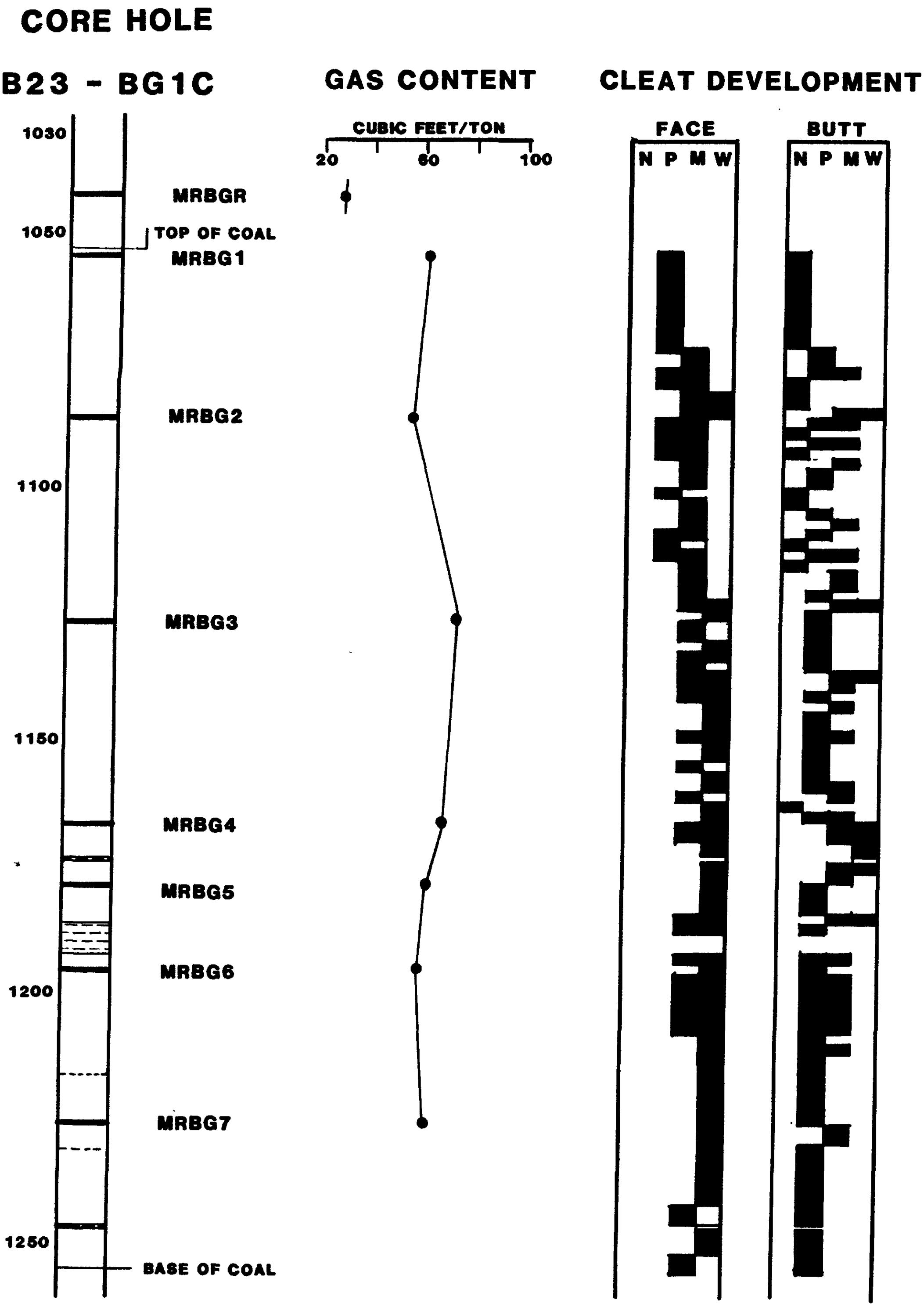


Figure 5 -- Generalized log of core hole B23-BG1C showing depth (in feet) of desorption samples, their gas contents (corrected to standard temperature and pressure), and the degree of cleat development through the core. Partings designated by dashes. Cleat development: N = none, P = poor, M = moderate, W = well.

Table 1. -- Desorption data from coal core samples in drill hole B23-BG1C
All data corrected to standard conditions of temperature and pressure.
($60^{\circ}F$ and 29.92 psi in mercury Hg)

Sample	Depth (ft)	Thickness (ft)	Weight (gm)	Lost Gas (cc)	Desorbed Gas (cc)	Residual Gas (cc/gm)	Total Gas (cc/gm)	Total Calculated Equivalents cu ft/ton
MRBG1	1052.25-1053.10	0.85	1220	340	2027	0	1.94	62
MRBG2	1085.20-1085.85	0.65	1563	460	2284	0	1.76	56
MRBG3	1124.35-1125.15	0.80	1458	776	2484	0.07	2.31	74
MRBG4	1166.15-1166.95	0.80	1300	358	2433	0	2.15	69
MRBG5	1178.40-1179.40	1.0	1196	438	1873	0.045	1.98	63
MRBG6	1195.26-1196.05	0.08	1516	334	2494	0	1.87	60
MRBG7	1225.25-1226.05	0.08	1362	375	2293	0	1.96	63

Table 2. -- Analyses of Gas Samples from Core Hole B23-BG1C and surrounding wells (upper row as received, lower row air free)

Sample	Type	N_2 nitrogen	CO_2 carbon dioxide	C_1 methane	C_2 ethane	C_3 propane	iC_4 isobutane	nC_4 normal butane	iC_5 isopentane	nC_5 normal pentane	dc^{13} 0/00	C_1/C_{1-5}
		%										
MRBG2	Canister	37.84	4.84	57.08	0.22	0.025	---	----	---	----	----	--
	air-free	-----	7.79	91.81	0.35	0.04	---	----	----	----	-58.64	0.9958
MRBG3	Canister	31.95	3.93	63.71	0.29	0.04	0.01	0.06	---	----	-------	------
	air-free	-----	5.78	93.63	0.43	0.06	0.02	0.08	---	----	-59.29	0.9936
MRBG4	Canister	34.23	6.17	59.08	0.30	0.10	0.03	0.02	0.06	0.005	----	-----
	air-free	----	9.38	89.83	0.45	0.15	0.05	0.03	0.10	0.01	-60.07	0.9913
MRBG5	Canister	44.42	3.90	51.45	0.14	0.09	---	---	----	---	----	-----
	air-free	---	7.01	92.57	0.26	0.16	---	---	----	---	-59.98	0.9955
MRBG6	Canister	43.43	6.07	50.03	0.33	0.13	0.01	---	----	---	----	-----
	air-free	-----	10.72	88.44	0.59	0.22	0.02	---	----	---	-60.85	0.9907
MRBG7	Canister	67.27	1.31	30.45	0.17	0.19	0.32	0.08	0.19	0.01	----	-----
	air-free	-----	4.00	93.04	0.53	0.58	0.97	0.24	0.59	0.04	-53.59	0.9691
B23-BG1R	Well head	11.37	10.49	78.01	0.13	---	---	---	---	---	---	-----
		----	11.84	88.02	0.14	---	---	---	---	---	-61.47	0.9983
B23-BG1C	Well head	19.07	9.79	71.02	0.11	---	---	---	---	---	---	----
		----	12.10	87.76	0.14	---	---	---	---	---	-61.48	0.9983
48771711	Well head	12.27	10.94	76.34	0.16	0.28	---	---	---	---	----	-------
		-----	12.47	87.02	0.18	0.32	---	---	---	---	-60.09	0.9941
Indian Creek No. 3	Well head	17.72	6.94	75.34	---	---	---	---	---	---	---	-------
		----	8.44	91.56	---	---	---	---	---	---	-62.45	0.9999

are similar, where as sample MRBG7 is substantially different in chemical and isotopic composition and will be discussed separately. Gas canister sample MRBGR was tested and the canister was reused due to low gas quantity.

The five gas canister samples vary from 84.4 to 93.63 % methane. Heavier hydrocarbons make up from 0.39 to 0.83 % of the sample. CO_2 is the principle non-hydrocarbon gas present in amounts ranging from 5.78 to 10.72 %. The stable carbon isotope ratios varied from -58.64 to -60.85 o/oo. Dryness (C_1/ C1+5) values ranged from 0.9907 to 0.9958 (Table 2). Rice and Claypool (1981) have shown that the isotopic composition of biogenic gas is lighter than -55 o/oo and is generally dryer (C/C1+5 > 0.98). Based on these data, the desorbed gas of the five canisters could be considered biogenic.

The gas recovered from sample MRBG7 was lower in CO_2 (4.00 %) and over three times as high as the other samples in heavier hydrocarbons (2.95 %). The carbon isotope value is heavier (-53.59 o/oo) and the dryness value falls below those of other samples (0.9691) as well as the limits of Rice and Claypool. This variation may be due to several factors: 1) a slight influx of hydrocarbons migrating from other sources, or 2) an increase of heavier hydrocarbons due to a change in source material. Due to problems with the canister, sample MRBG7 was not desorbed until 10 days after samples MRBG2 through MRBG6.

Analyses of samples taken at the well head (B23-BG1R and B23-BG1C, 48-7-17-11, Indian Creek) are not similar to the canister samples. In general, the gas has less methane, more carbon dioxide, and less heavier hydrocarbons. The source of the gas is probably biogenic (Table 2). The gas is isotopically lighter than the canister samples (from -60.06 to -62.45 o/oo), and the dryness value is higher.

Geologic Factors Affecting the Presence of Gas

The primary factors that may affect coalbed gas occurrence are:

1) regional tectonic structure and small-scale compaction structural features and,
2) internal structure of the coalbed:
   a) molecular
   b) cleat and other fracture development systems

Both molecular and regional tectonic structure are topics in themselves. Further detailed work needs to be conducted in order to accurately associate tectonics and internal structure of the coalbed.

The fracture system, primarily cleat development, are important controls in the retention and migration of gas within the coalbed. This does not mean that the cleats play any role in the formation of methane gas. The degree of cleat and other fracture development controls, in part the effective permeability of the coalbed. Based on the core diameter of 3 inches, the degree of cleat development is shown on Figure 5. The depth at which the cleats begin to show a better development is at approximately 1121 feet. This was determined through the examination of the core. The coal showed moderate-to-poor face cleat and poor-to-absent butt cleat development in the upper part (near 1121 foot marker) of the coalbed.

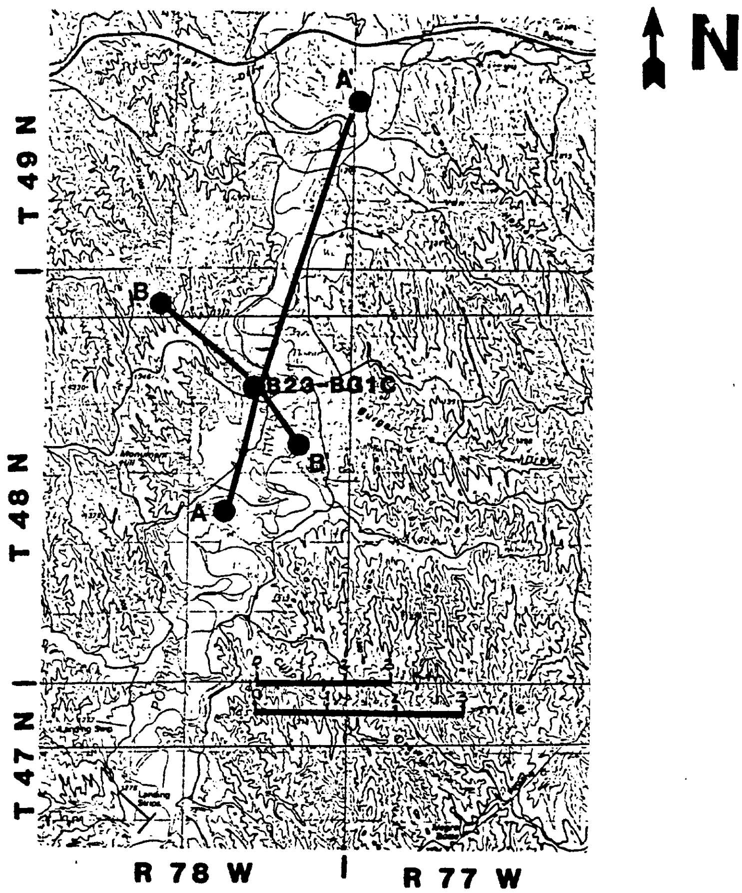
Figure 6 consists of a cross-section AA' and BB' showing the Big George coalbed with the rider seam above it. A location map shows the relationship of the two cross-sections to the core hole (B23-BG1C). Each point (B,B',A,A') represents a well. The arrows indicate a possible updip migration path for the methane gas. B23-BG1C is located in the middle of a structural "high". The structural "high" as well as other structural irregularities may affect a change in migration paths and also help to predict gas accumulations and production possibilities in specific areas. Partings may serve as impermeable seals and impede vertical as well as horizontal flow of the gas.

METHANE GAS DESORPTION PROCEDURES

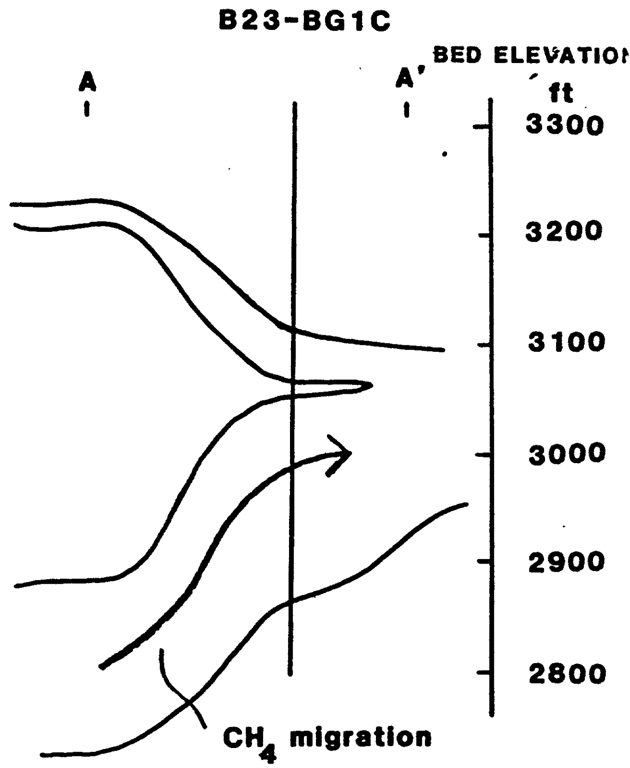
Although methane gas desorption methods do not yet have the precision of the majority of scientific instrumentation, it is felt that the difference in methane content are real based on the following data:

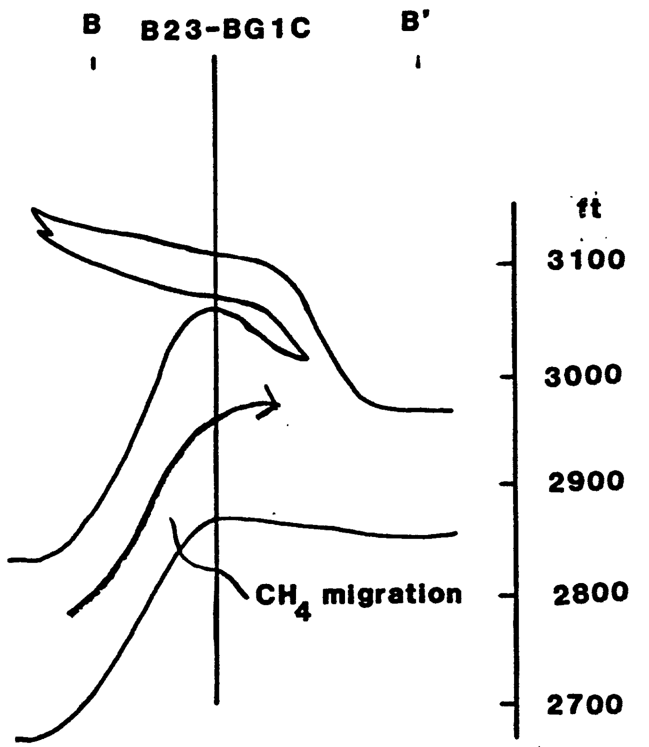
1) all samples were analyzed using the same air tight canisters. The gas emitted (desorbed) was measured by water displacement in an inverted graduated cylinder (Fig. 7). The coal sample was weighed so the gas content could be stated in cc/g (cubic centimeters/gram) or cf/t (cubic foot/ton). Gas lost by the sample before it was sealed in the canister was be estimated using a back calculation method. Gas remaining in the structure of the coal sample after natural desorption ceases was measured by crushing the sample in a sealed ball mill and determining volume, using water displacement. The desorbed, lost, and remaining gas valves were all added to give the total gas content (Boreck et al, 1981).

2) all samples were recorded in standard cubic feet and were evaluated as such. (Each individual sample was reorded individually).



AA' and BB' LOCATIONS





Drill Hole Locations

B : Sec. 1, T. 48 N., R.78 W.
B': Sec. 15, T.49 N.,R.77 W.
A : Sec. 19, T.48 N.,R.77 W
A': Sec. 20, T.49 N.,R.77 W.

FIGURE 6

Cross-sections AA' and BB' showing possible methane migration

(Bed elevations in feet above sea level)

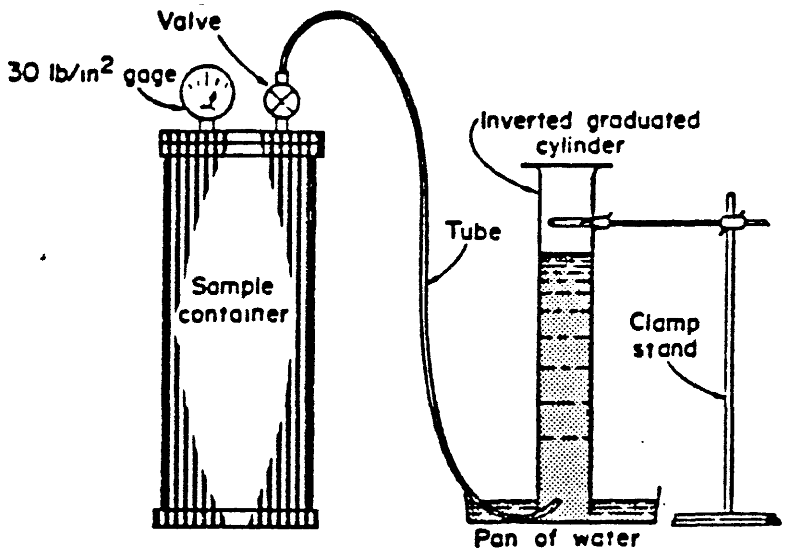


Figure 7. -- U.S.Bureau of Mines equipement for direct method desorption of coal samples (after Diamond and Levine, 1981)

SUMMARY AND DISCUSSION

The analyzed gas emitted from the cores does not have a defined source. The desorbed gas may have originated within the coal itself (biogenic). In contrast, the free-flowing gas of unknown origin, is associated with the samples from the well-heads of B23-BG1C through Indian Creek.

The Anderson coal is a thick deposit, providing a substantial source for gas formation and a good potential for gas storage. Coal and gas are two resources associated with the Anderson coal deposit. Methane gas (CH_4) as well as coal are valuable economic resources. More research is needed to understand and predict coal and gas occurrences and explain the association of coal with gas. This will aid in the delineation of a potentially valuable and substantial resource present throughout a major portion of the Powder River Basin.

ACKNOWLEDGEMENTS

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