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CONTENT OF METHANE IN COAL FROM FOUR CORE HOLES IN THE RATON AND VERMEJO FORMATIONS, LAS ANIMAS COUNTY, COLORADO

by

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ABSTRACT

Gas desorption measurements were made on coal cores collected during the 1978 coal exploratory drilling program at four sites north of the Purgatoire River in the Trinidad coal field, Raton Mesa coal region, Las Animas County, Colorado. Cores of coal beds in the Paleocene and Upper Cretaceous Raton and Upper Cretaceous Vermejo Formations yielded from 23 to 492 cubic feet of gas per ton of coal (0.71-15.0 cc/g). The methane content of the gas ranged from 46 to 99 percent, and the heat of combustion of the gas ranged from 465 to 997 Btu/cf (17,000-37,000 kJ/m^3). Vermejo Formation coal beds ranging from three to seven feet and totalling as much as 10 feet (3 m) in thickness are believed present beneath an overburden of 1,200 to 2,200 ft (366-670 m) within a 25-square-mile area. Assuming that at least a seven-foot (2 m) thickness of coal extends throughout the area, the volume of gas in-place could be as much as 84 Bcf ($2.4 \times 10^9 m^3$).

INTRODUCTION

Mine emission data obtained from the Mine Safety and Health Administration, and information on mine gas explosions compiled by the Colorado Geological Survey (Fender and Murray, 1978) indicate that the southern half of the Raton Mesa region is one of the most promising areas in Colorado for new resources of methane. Coals in this area are known to be gassy, but quantitative data on their adsorbed methane contents are needed to establish whether these coal beds could become a source of pipeline-quality natural gas.

To furnish some data toward this objective, coal core desorption was done in conjunction with coal exploratory drilling by the U.S. Geological Survey (Danilchik, 1978). The gas desorption measurements were made by the Colorado

CONTENTS

ILLUSTRATIONS

TABLES

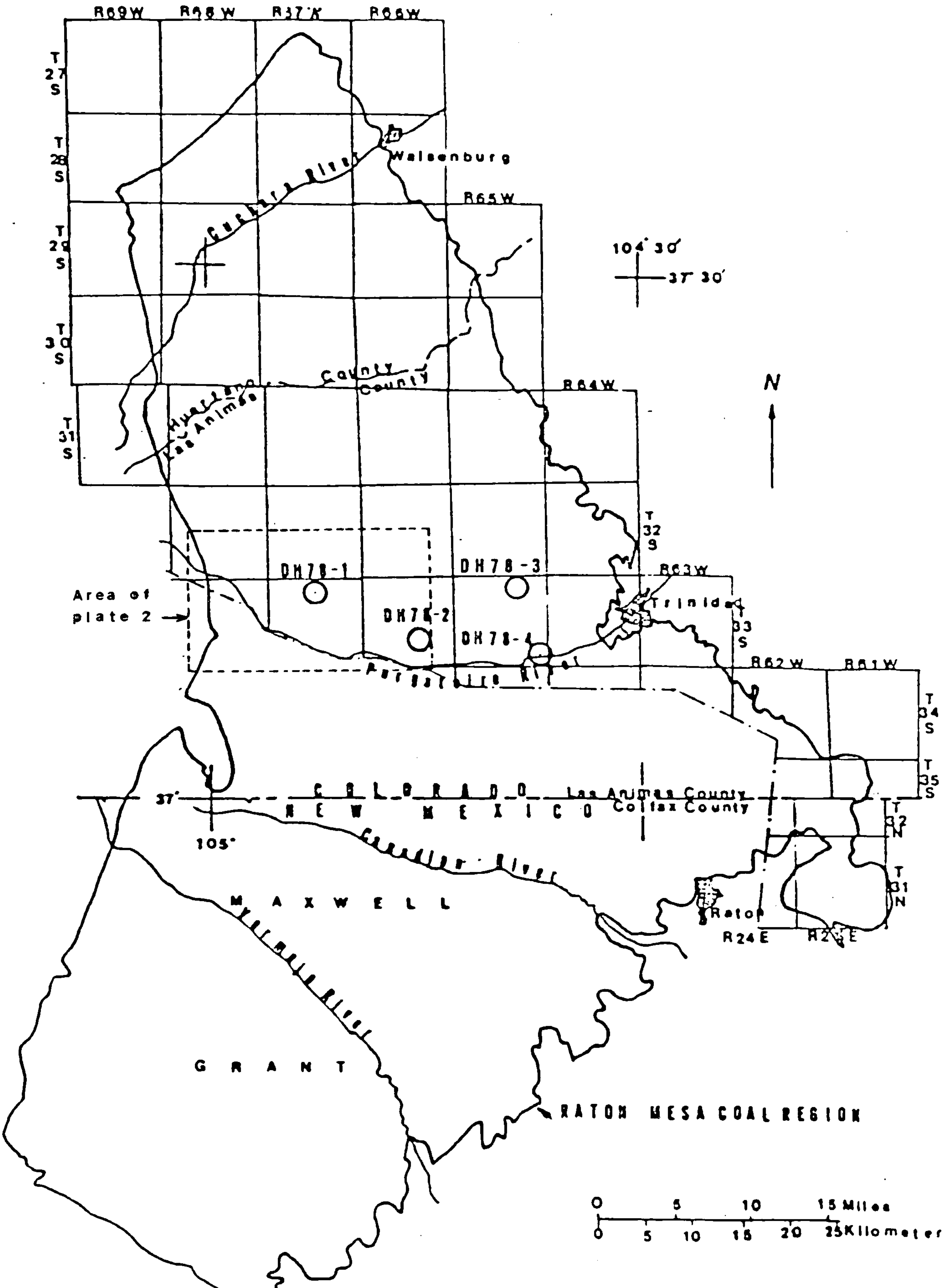

Figure 1.— The Raton Mesa coal region, Colorado and New Mexico, with 1978 coal exploratory drill sites

Geological Survey. This report presents the method and the results of the gas desorption measurements.

In the Appalachian region of the United States, techniques for draining methane from coal beds using drill holes have been successfully demonstrated (Deul, 1975). To apply these techniques to Colorado coal fields, it would be necessary to have one or more coal beds four feet or greater in thickness present at economically attainable depths in an area sufficiently large to constitute an appreciable resource. The drilling program, described by Danilchik (1978), provides some information (Plate 1), but failed to fulfill all the previously listed requisites because the holes were too few and too widely spaced to determine the continuity of the gas-bearing zones and were not deep enough to include all of the coal beds in the coal-bearing section. Outcrop and other data are presented, however, (Plate 2) to show that in the most promising area, the deepest coal beds are beneath an overburden less than 2,500 feet (760 m) thick, may reach a thickness of ten feet, and may be continuous over a wide area.

Description of drill sites and drilling operations

Four sites were drilled north of the Purgatoire River (fig. 1). The coal-bearing rocks that were drilled are the Vermejo Formation of Late Cretaceous age and the Raton Formation of Late Cretaceous and Paleocene ages. These formations consist of alternating beds of shale, sandstone, carbonaceous shale, and coal, and were deposited in a coastal-plain or deltaic environment. Intrusive igneous sills of Tertiary age were penetrated in at least two of the drill holes. Target (total depth) horizon of the the drilling program was the Trinidad Formation of Late Cretaceous age, which underlies the coal-bearing rocks; the Trinidad Formation was reached in DH-78-3 and 4 but not in DH-78-1 or 2.

At each of the sites, a pilot rotary hole was drilled to total depth. On completion of the pilot hole, geophysical logs were run. Interpretation of the logs provided depths and thickness of coal beds which was the basis for the selction of coring points. A twin hole was then drilled with a rock bit to the first selected coring point. The core interval was positioned to include the roof rock, coal bed, and floor rock. The hole was then deepened with a rock bit to the next core point. This procedure was repeated for each subsequent core interval. (Hereinafter, core holes will be designated by the letter "A" following the drill hole number, for example, DH 78-1A.)

Description of mud-logging operations

Drilling mud was used during the drilling of DH 78-1 and DH 78-1A; foam was used to drill the other pilot and core holes. A portable automatic gas detector monitored th return fluid during the drilling of DH-78-1. A gas trap was placed between the mud pit and flow line (approximately eight feet from the end of the flow line) in a narrow part of a trench dug approximately one foot deep and one foot wide. The gas trap was attached electrically to a portable automatic gas detector (recording device). The recording device was calibrated to the drilling rate recorder which was attached to the drill rig. The recording device was set to record dry gas given off by the drilling fluid only on a scale of 0 to 300; 300 represented 10 percent or more gas content in the drilling fluid. When the recording device reached 300, an alarm would sound and remain on until the amount of flammable gas in the fluid decreased to less than 10 percent, or until the alarm was turned off manually.

The function of the gas detector was to determine whether there is measurable gas in the coal beds and whether relative amounts of gas could be determined. For example, does the amount of gas detected increase with drilling depth? Or, do the depths of the gas shows correspond to the depths of the coal beds identified on the geophysical logs?

At a drilling depth of approximately 700 feet (213 m) in the pilot hole, the gas detector began to indicate an increasing amount of gas in the drilling mud during and after penetrating the coal beds and when some of the rocks adjacent to the coal beds were being drilled. At approximately 1,500 feet (457 m), gas began bubbling from the drilling mud immediately after the mud discharged from the flow line. A hand-held Auer Methanometer Model M502 detected over three percent methane in the air near the flow line and over five percent methane in the air directly at the end of the flow line. The gas detector had been recording greater than 10 percent gas in the mud.

The gas alarm continued to go off at irregular intervals while drilling the non-coal zones between the depths of approximately 1,400-1,700 feet. The alarm also sounded after drill pipe connections were made (indicating "trip gas") and when coal zones were drilled (as determined by drilling time and cuttings).

The gas detector was operated while drilling and coring the second hole, DH 78-1A, and it responded in the same manner as in the pilot hole, DH 78-1. The gas alarm buzzer went off with increasing frequency as the drilling depths increased. The portable automatic gas detector malfunctioned during the drilling of the remaining holes; gas content records were not obtained.

Description of desorption procedures

Gas desorption measurements were made on selected core samples; 11 of these are coal, one is natural coke, and one is a shale parting. For each interval that was desorbed, the time of initial penetration during coring was recorded, as well as the time elapsed during core retrieval. Upon reaching the surface, the core was removed from the core barrel and laid out on a collection trough, where it was measured. A segment of core approximately 1,000 gm (two lbs) in weight was selected, put into a canister, and sealed; the time of sealing was recorded. The amount of gas desorbing from the encapsulated core sample was then measured every 15 minutes for two hours after sealing, and once a day thereafter in accordance with techniques described by McCulloch and others, (1975). If the coal emitted a sufficient amount of gas (approximately 150 cc/day), a sample of gas was collected for analysis (table 2).

Measurement of the gas emitted by the encapsulated core sample was discontinued when the daily emmission rate decreased to approximately 0.05 cc/g. The core sample was then removed from the canister and sent to the U.S. Bureau of Mines in Pittsburgh for determination of the "residual" gas (McCulloch and others, 1975).

An estimate of the gas lost from the coal core between the time of penetration of the coal bed and the time of its sealing in the canister was calculated (using the recorded times and two hours of initial desorption measurements) according to the procedure developed by McCulloch and others (1975). The "lost," "desorbed," and "residual" gas were then added to give the total gas content of the coal in cubic centimeters per gram and cubic feet per ton. Table 1 lists the total gas content of the samples that were desorbed. Figure 2 is a graphic representation of the data listed on Table 1. Table 2 lists the composition, gravity, and heating value of the gas obtained from the gassier core samples. Appendix C shows the forms completed for each core sample.

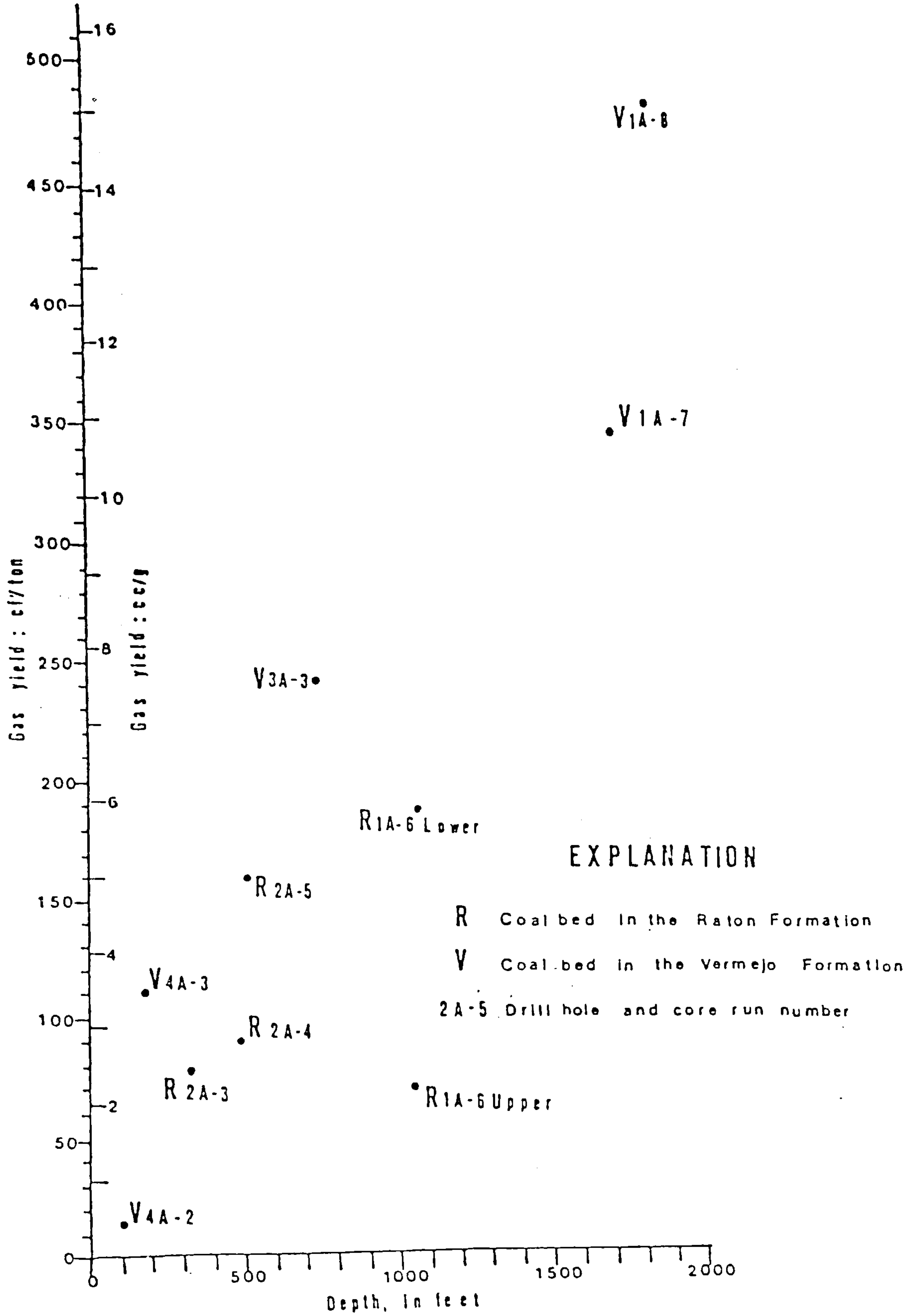

Figure 2.--Depth vs. gas-yield relationships of selected coal core samples from the Raton and Vermejo Formations, Las Animas County, Colorado.

Table 1.--Quantity of gas desorbed from coal, coke and shale, from four U.S. Geological Survey core holes. Raton Mesa coal region, Las Animas County, Colorado

Core hole number and location	Core run number	Description	Formation	Sample depth (ft)	Thickness (ft) bed	Thickness (ft) core	Sample weight (g)	Lost gas (cc)	Desorbed gas (cc)	Residual gas (cc/g)	Total gas[1] (cc/g)	Total gas[1] (cf/ton)
USGS DH 78-1 SE¼, SE¼ Sec. 4, T. 33 S., R. 67 W.	5 Upper bed	Coke	Raton	810-811	1.3	1.3	2,319	370	3,086	0.10	1.6	51
	5 Lower bed	Coaly shale	Raton	828.2-828.6	0.5	0.5	1,098	130	755	0.0	.81	26
	6 Upper bed	Coal, banded	Raton	1,053.5-1,053.9	0.4	0.4	2,308	480	4,731	0.0	2.3	74
	6 Lower bed	Coal, broken	Raton	1,063.1-1,064.1	2.1	1.3	1,710	850	9,448	0.01	6.0	190
	7	Coal, bright broken	Vermejo	1,691.2-1,692.2	5.6	4.2	1,600	3,400	14,255	0.04	11.0	350
	8	Coal, dull pyritic	Vermejo	1,792-1,793	3.0	1.8	1,724	8,300	18,098	0.06	15.37	492
USGS DH 78-2 NE¼, SW¼, SE¼ Sec. 27, T. 33 S. R. 66 W.	3	Coal, bright	Raton	308.3-310.5	2.2	2.2	1,461	170	3,390	0.16	2.6	83
	4	Coal, blocky	Raton	482.65-483.6	1.4	1.0	1,057	890	2,031	0.0	2.8	88
	5	Coal, blocky	Raton	499.7-501	2.4	2.0	767	1,110	2,719	0.0	5.0	160
USGS DH 78-3 NW¼, NW¼, SW¼ Sec. 2, T. 33 S., R. 65 W.	3	Coal, bright	Vermejo	729.4-732.5	3.2	3.1	1,768	3,300	10,176	0.33	7.9	250
USGS DH 78-4 C. Sec. 36, T. 33 S., R. 65 W.	2	Coal, blocky	Vermejo	100.5-101.05	2.1	2.1	808	170	158	0.3	.71	23
	3	Coal dull	Vermejo	167.9-168.45	1.9	0.55	553	800	1,057	0.2	3.6	115

[1]Total Gas Content = $\frac{\text{Lost Gas (cc) + Desorbed Gas (cc)}}{\text{sample weight}}$ + Residual Gas (cc/g)

Total Gas (cc/g) x 32 = Total Gas (cf/ton)

Table 2. Hydrocarbon (gas chromatographic) analysis, gravity, and heating value of gas desorbed from coal cores, Las Animas County, Colorado

Core hole and number	Core run number	Hydrocarbon Analysis (Mol percent, air-free)							Calculated[1] gas gravity	Heating value[2] Btu/cf dry gas
		H	H_2S	CO_2	N	Methane	Ethane	Propane plus		
USGS DH 78-1	5 Upper bed	7.76	0	Trace	25.45	66.78	0.01	0	0.621	693
	6 Upper bed	0.13	0	0.14	7.97	91.75	0.01	0	0.587	925
	6 Lower bed[3]	0.46	0	0.48	15.71	83.34	0.01	0	0.621	841
	6 Lower bed[4]	51.99	0	0.01	3.75	34.24	0.01	0	0.269	546
	7	0.04	0	0.0	53.80	46.14	0.02	0	0.776	465
	8 a	0.13	0	1.24	2.85	95.73	0.05	0	0.557	965
	8 b	0.14	0	1.11	0.10	98.59	0.06	0	0.564	994
USGS DH 78-3	3	0.0	0	0.62	0.37	98.98	0.03	0	0.561	997

[1] air = 1.000
[2] at 14.65 psia and 60°F
[3] sampled on June 13, 1978
[4] sampled on June 26, 1978

CONCLUSIONS

The Bureau of Mines "direct method" provides a means of measuring the "in-place" gas content of a coal bed if a coal core sample can be obtained immediately upon removal of the core from the core barrel. However, inherent factors such as coal composition, origin, and nature of the roof rock, as well as external factors such as igneous intrusions, faults, and possibly sampling procedures, could yield a wide range of gas content values for stratigraphically equivalent coal beds.

The gas detector detected methane originating from coal beds and also indicated that the relative amounts of gas in coal beds in a single drill hole increased with depth. From the total gas contents of the coals in these four core holes, it can be concluded that the gas content of the coals in a single core hole increased with depth and the gassiest coals were found in the Vermejo Formation.

RESOURCE ESTIMATES

The most prospective coal beds in this area (from the standpoint of methane resources) appear to be coals in the Vermejo Formation. Using the gas content and bed thickness figures from Table 1, the two deepest beds in the Vermejo Formation that were penetrated in the DH 78-1 contain an estimated 12.5 billion cubic feet (Bcf) of methane (350 x $10^9 m^3$) in-place within a one-mile (1.6 km) radius of the drill hole (See appendix A).

However, a much larger potential might be expected in the general area from coal beds in the basal part of the Vermejo Formation, which were not reached in either DH 78-1 or 78-2. These beds have a total thickness of as much as 10 feet (3 m), as indicated by outcrop measurements and available drill-hole logs (pl. 2). The areal extent of the basal Vermejo coals with overburden in the range of from 1,500 to 2,000 feet (457-610 m) is more than 25 mi^2 as shown on plate 2. The gas yield of these coals might be as much as 10-16 cc/g (320 to 512 cf/t) of coal. A mid-range value of 13 cc/g (416 cf/t) would indicate a potential of 750,000 cubic feet (21,000 m^3) of gas per acre-foot of coal at a depth of about 2,000 ft (610 m). Assuming that at least one of the basal Vermejo coal beds 7 ft (2 m) thick is present throughout an area of 25 mi (65 km^2), the volume of gas in-place could be as much as 84 Bcf ($2.4 \times 10^9 m^3$) (appendix A).

ACKNOWLEDGMENTS

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McCulloch, C. M., Levine, J. R., Kissel, F. N., and Duel, Maurice, 1975, Measuring the methane content of bituminous coal beds: U.S. Bureau of Mines Rept. Inv. 8043, 22 p.

APPENDIX A - Resource Calculations

Bituminous coal: 1,800 tons/acre-foot

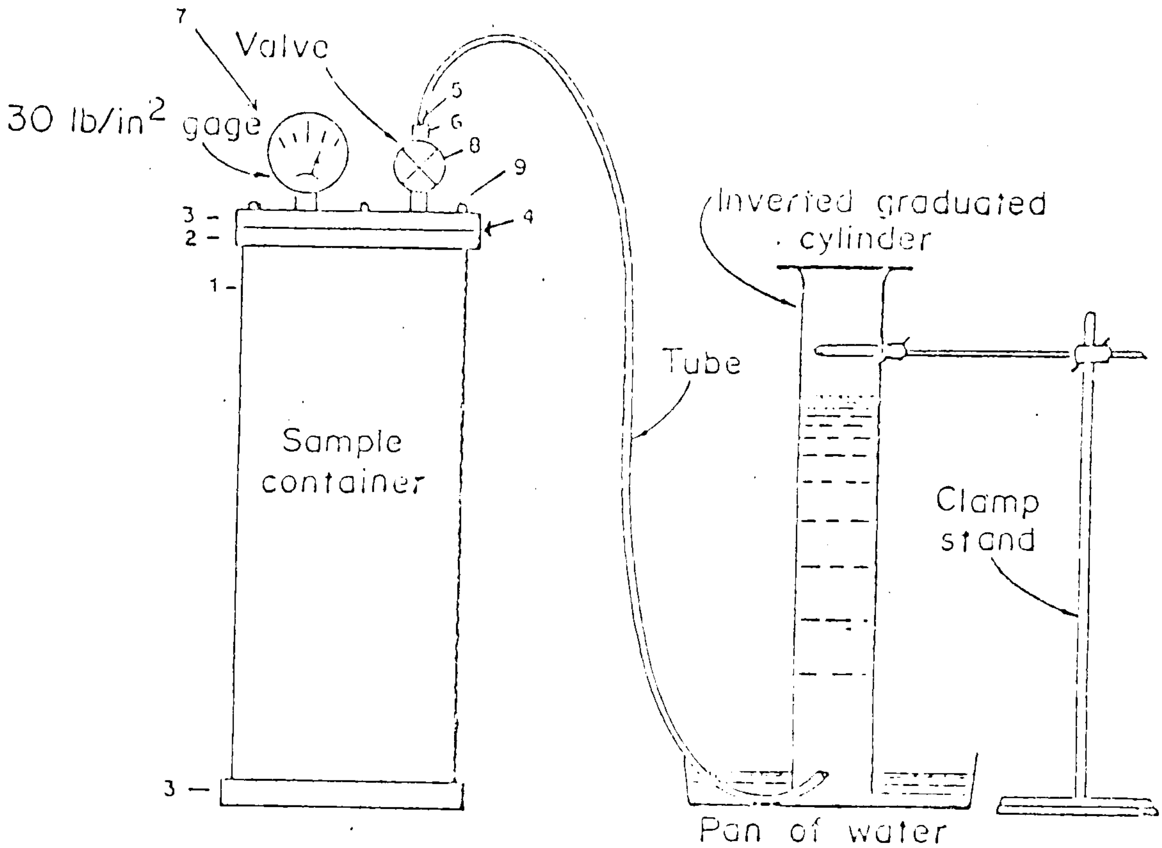
Gas content of two deepest beds of Vermejo Formation which were penetrated in DH-78-1 within 1 mile radious of drill hole =

(1,800 tons/acre-foot x 3.142 mi^2 x 640 acres/mi^2) (5.6 feet x 354 cubic feet/ton) + (3 feet x 492 cubic feet/ton) = $12.5 \times 10^9 ft^3$

Cubic feet of gas per acre-foot of coal at a depth of about 2,000 feet = 1,800 tons/acre-foot x 416 ft^3/ton = 750,000 ft^3/acre-foot

In-place gas in basal Vermejo Formation at depth of 2,000 feet and in a 25-square-mile area = 750,000 ft^3/acre-foot x 25 mi^2 x 640 acres/mi^2 x 7 feet = 8.4×10^{10} ft^3

Appendix B --Specifications for desorption equipment, courtesy of the U.S. Bureau of Mines



SUPPLIES NECESSARY TO CONSTRUCT DESORPTION CANISTERS

1. 12" - 6061-T6 aluminum tubing 4-1/2" od, 0.250 wall thickness.

2. 1" - 6061-T6 aluminum tubing 6" od, 1" wall thickness.

3. 6" (2 pcs) dia. - 6061-T6 aluminum sheet, 0.250 thickness.

4. 1 - O-ring type Buna-N No. 2-245.

5. 1 - Swagelok plug B-400-P.

6. 1 - male connector (Swagelok) B-400-1-4.

7. 1 - gage 0-30 psi (utility type).

8. 1 - Whitney shut-off valve B-16DKM4-F4-A.

9. 6 - bolts 5/16"-18-1" socket head.

Appendix C --forms completed for each core sample

CORE SAMPLE DATA SHEET

Company Drill Hole No. (Sample No.) ______________________ Date ________
(tape Company Name and Drill Hole No. on cylinder)
Company ______________________ Person Collecting Core ________

Drilling Company ______________________

Hole Location ______________________

County ______________________ State ________

Core Size ________ Barrel Length ________ Type of Core Retrieval ________

Drilling Media ________ Air Temperature ________ Surface Elevation ________

Coalbed ______________________ Coal Thickness ________

Depth to base of coalbed ________ Total Depth of Hole ________

Roof Rock ______________________

Floor Rock ______________________

Character and type of coal ______________________

Seam Description ______________________

Condition of Sample ______________________

Sampled Interval ________ Cored Interval ________

Cylinder Wt. ________ gm. Cylinder Wt. + Coal ________ gm. Coal Sample Wt. ________

Time Coring Started ________ Time Coring Completed ________

Time Coalbed Encountered (A) ________ Time Core Started Out of Hole(B) ________

Time Core Reached Surface (C) ________ Time Core Sealed in Cannister (D) ________

RESULTS

Lost Gas Time: (D-A) if air or mist is used ________

$(D-C) + (\frac{C-B}{2})$ if water is used ________

$\sqrt{\text{Lost Gas Time}}$ in minutes ________ Lost gas (cm^3) ________

Gas from Canister (cm^3) ________

Residual Gas from Crushing (cm^3/g) ________

GAS CONTENT CALCULATION ($\frac{cm^3}{g}$)

$$\text{Gas Content} = \frac{\text{Lost Gas } (cm^3) + \text{Gas from Canister } (cm^3)}{\text{Sample Weight (gm)}} + \text{Residual Gas from Crushing } \frac{(cm^3)}{gm}$$

Total $cm^3/g \times 32 = Ft^3/Ton$

State:	County:	Location	Hole No: P.

Time * Date	Time	Elapsed Min.	Ø T'	Cylinder Reading 1 ml 2	Cm³ Gas Released	Cm³ Total Gas Ø	DER Cm³/g †	Cylinder No. Sample Wt. Comments

* "Lost" gas time + desorption time in minutes

R = Reverse Flow

Ø Plot on Figure 4 graph

† Sample Weight/ Daily Emission = DER

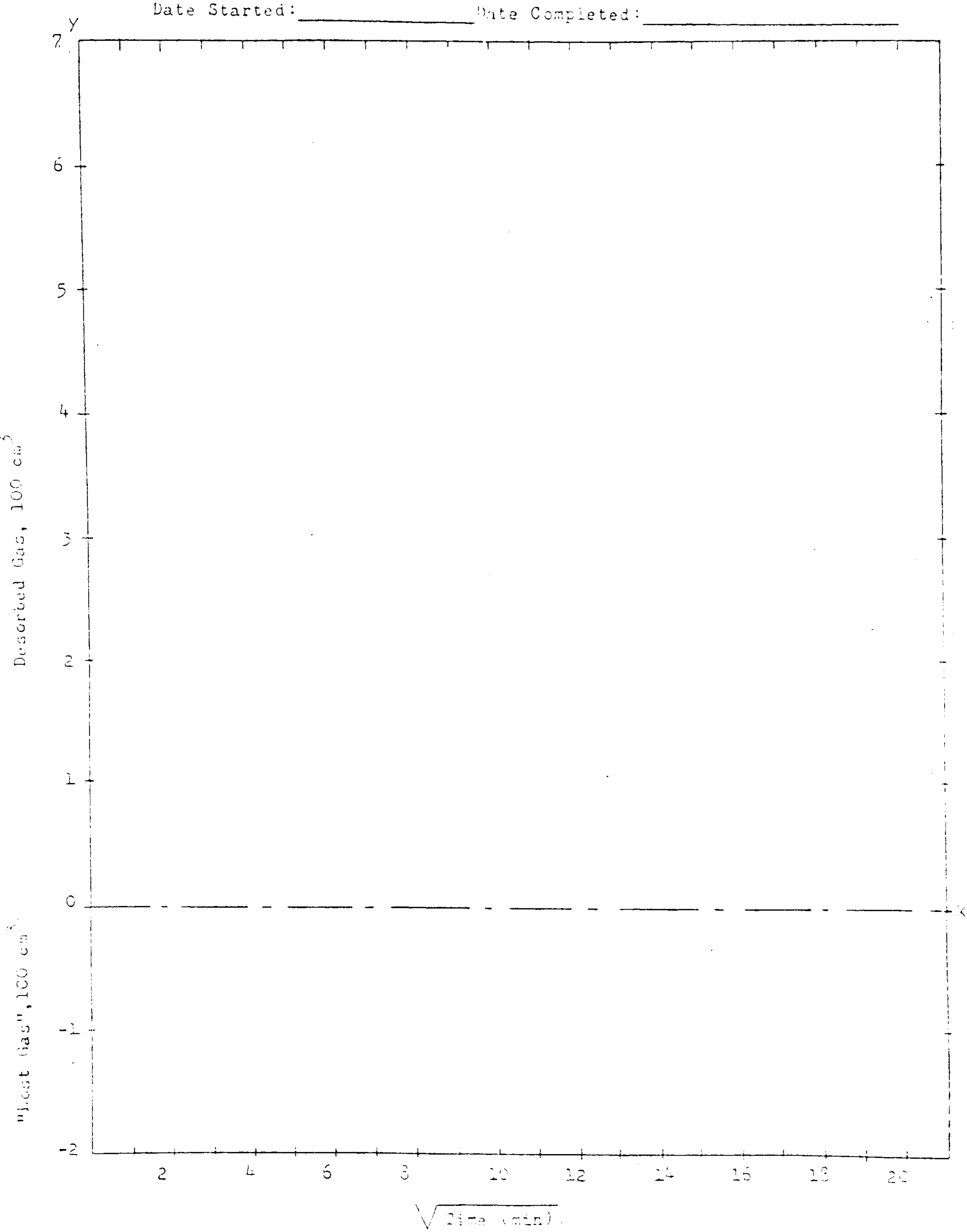
√"Lost" Gas Time =

Appendix C-3

State: ____________ County: ____________ Loc.: ____________

Co.: ____________ Hole No.: ____________ Cyl. No.: ____________

Date Started: ____________ Date Completed: ____________



CHECK LIST FOR PROCESSING METHANE DESORPTION AND COAL CORES

Region: Field: County:

Company Drill Hole No:
(Sample No. - tape number and company onto cylinder)

CGS No:

MC & V No:

Drill Hole Location:

USBM/USDOE No:

Company Name:

USGS No:

Address:

Telephone Number:

Contact Person:

"Memo of CGS Policy" sent: Date______________________

Company permission to use results: Yes__________ No__________

Comments:

Desorption Begins:______________________ Ends:__________ ______________

Core description taken: Yes:________ No:________

Weight of Cylinder: Empty:__________gm. Full:__________gm. Sample wt.________

COAL SAMPLES

Coal sent for residual gas tests: Date:______________ Coal sample returned________

Residual gas results received - Date:____________________

Sent to company: Date:______________________

Sample returned to company: Yes:________ Date:______________ No:__________

Comments:

Proximate and Ultimate Analyses received: Date: ____________________

Sent to company: Date:________________

Coal sample sent to USGS: Date:____________________

Geochemical Analyses returned to CGS: Date:__________________

Comments:

Sent to company: Date:________________

TOTAL ANALYSES SENT TO COMPANY: Yes____________ No___________

Comments:

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OPEN-FILE REPORT
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PLATE 1

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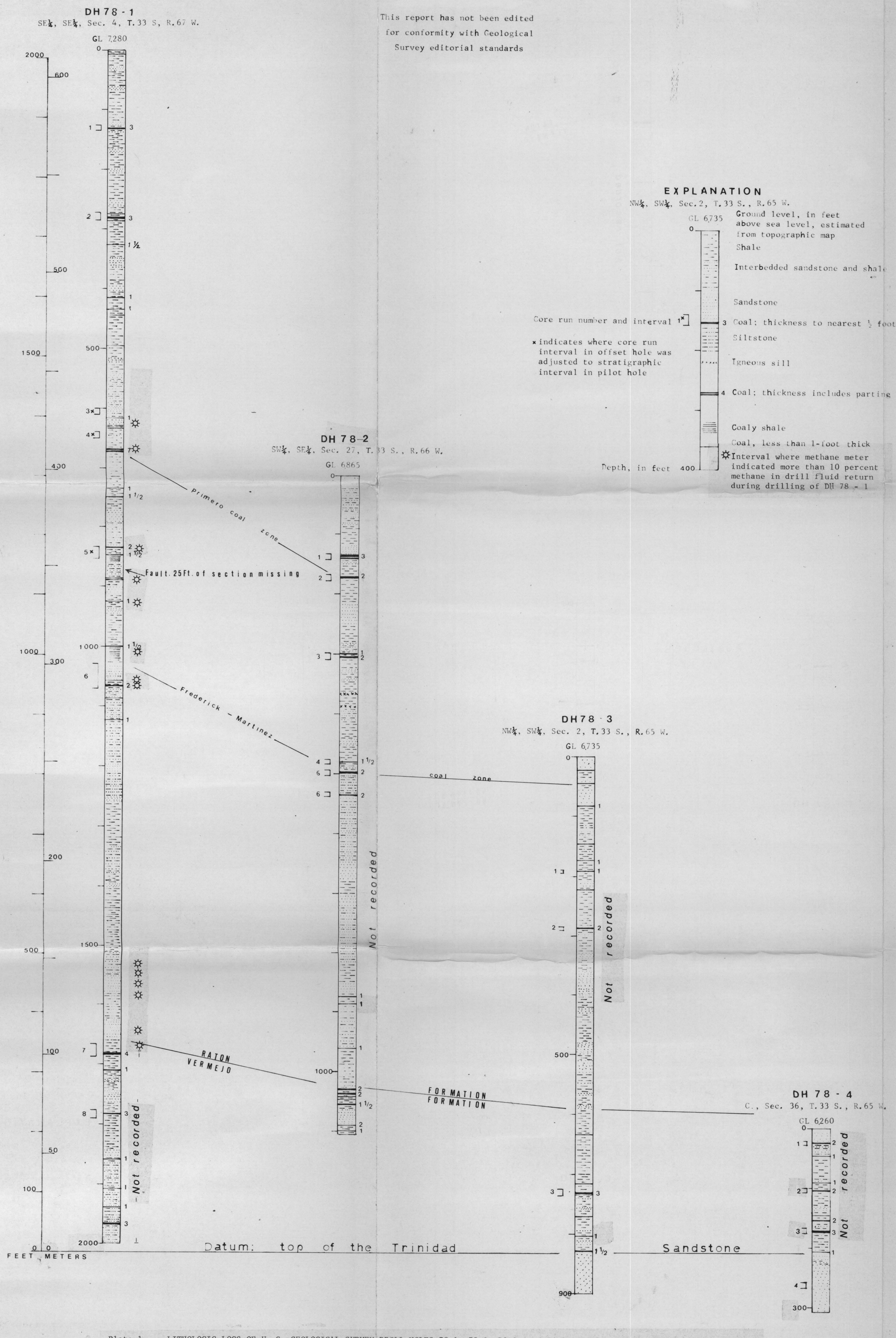

Plate 1. -- LITHOLOGIC LOGS OF U. S. GEOLOGICAL SURVEY DRILL HOLES 78-1, 78-2, 78-3, and 78-4 SHOWING METHANE SOURCES IN DRILL FLUID

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Plate 2

OF 79-3

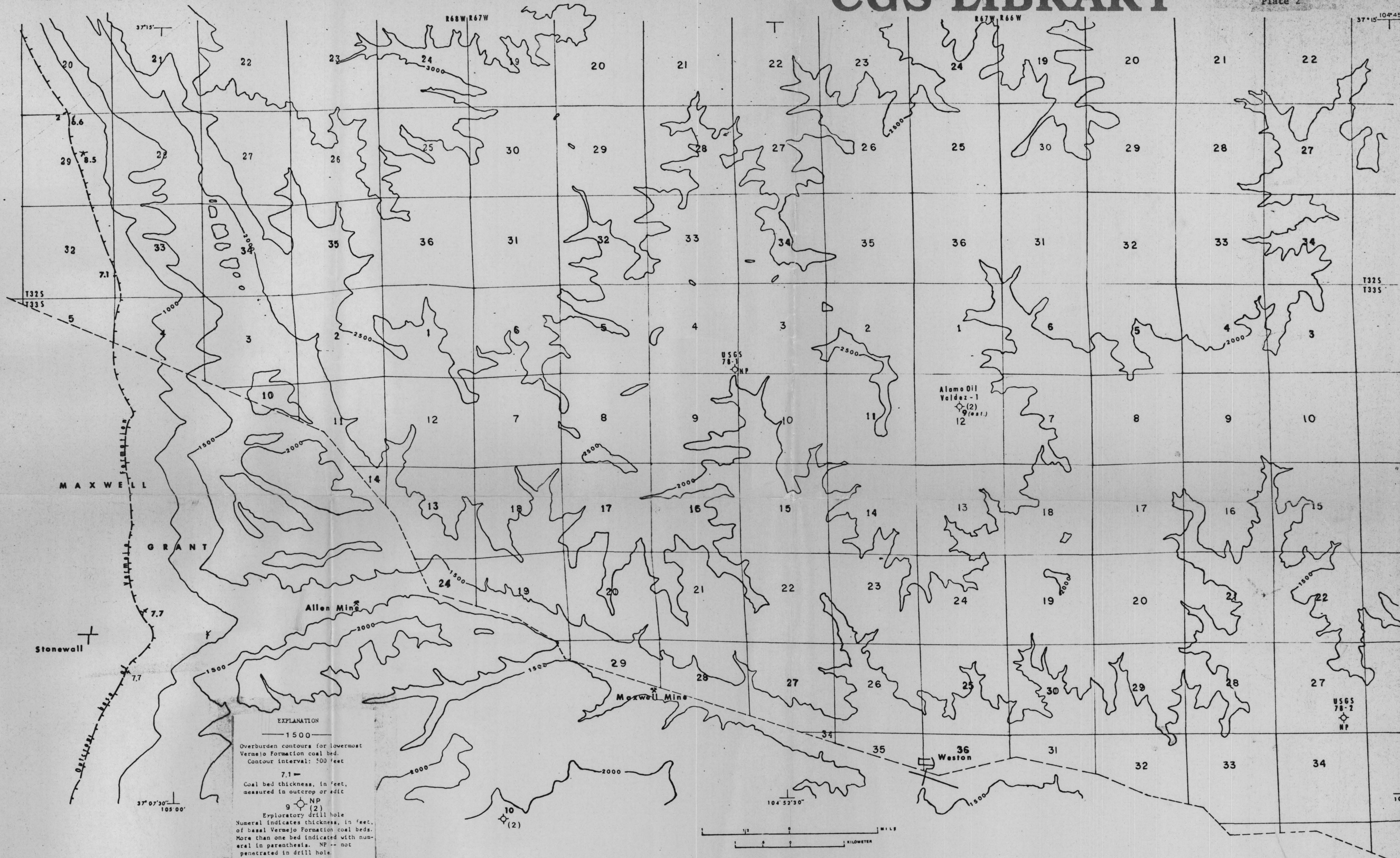

PLATE 2--OVERBURDEN ON BASAL VERMEJO FORMATION COAL BEDS AND COAL THICKNESS, THE STONEWALL-WESTON AREA, LAS ANIMAS COUNTY, COLORADO