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Methane Occurrences, Hazards, and Potential Resources, Recluse Geologic Analysis Area, Northern Campbell County, Wyoming

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards.

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Introduction

The Geological Survey conducted a seven-hole core-drilling program in the Recluse Geologic Analysis Area, northern Campbell County, Wyoming, in 1975. The purpose was to acquire rock and coal samples to further evaluate the surface-minable coals of this area. In 1976 the Bureau of Land Management defined a portion of this area as an Energy Mineral Resource Inventory and Analysis Program reclamation study area and drilled an additional eight core holes.

During the course of the 1975 drilling methane (CH_4) emissions were detected in all holes. The quantities ranged from very small amounts of methane ($\pm$0.1 percent) in the return drilling air to major flows estimated to be as much as 1,000,000 cubic feet per day.

Methane in the return drilling air or fluid is a serious safety hazard to personnel and equipment. On the other hand, the methane might have economic value.

Acknowledgments

Acknowledgments with sincere appreciation are expressed to the drilling contractor, Mr. William Lake, owner and operator, B&B Drilling Co., Libby, Montana; Mr. and Mrs. James Oedekoven, Mr. and Mrs. Leon Oedekoven, and the people of Recluse, Wyoming; Ms. Ann G. Kim and Mr. David Dufresne, chemists, both of the U.S. Bureau of Mines, Pittsburgh, Pennsylvania; Richard Klein and Patrick Roche, Technical Support Center, Mining Enforcement and Safety Administration, Denver, Colorado; Mr. D. G. Malotte, Independent, Denver,Colorado; and J. D. Sanchez and J. F. Windolph Jr., U.S. Geological Survey Denver, Cololorado and Reston, Virginia, for their contributions and assistance throughout the project.

General

Location

The Recluse Geologic Analysis Area is in the northeast part of the Powder River Basin, about 35 miles north-northwest of the town of Gillette in Campbell County, Wyoming; it encompasses four U.S. Geological Survey topographic quadrangles--Homestead Draw Southwest, Pitch Draw, Recluse, and White Tail Butte (figs. 1 and 2).

Drilling

The drilling was done by a private drilling company under contract with the U.S. Geological Survey. Seven holes, titled RM-1 through RM-7, were drilled at the locations shown on figure 2. A total of 3,110 feet were drilled: 1,807 feet NX wireline core and 1,303 feet non-core. For details of the lithology and hole completion, see Hobbs and others, (1977).

Geology

The surface rocks in the Recluse Geologic Analysis Area are the uppermost part of the Tongue River Member of the Paleocene Fort Union Formation, and the Eocene Wasatch Formation (See Hayes, 1973; Kent, 1976; Landis and Hayes, 1973; and McLaughlin and McKay, 1973). The Tongue River Member in the subject area contains eight persistent coal beds as listed below in descending order:

Smith - Anderson rider

Anderson

Canyon-

Canyon "A"
Canyon "B" - where split (The Canyon A has also been mapped as the Dietz coal bed)

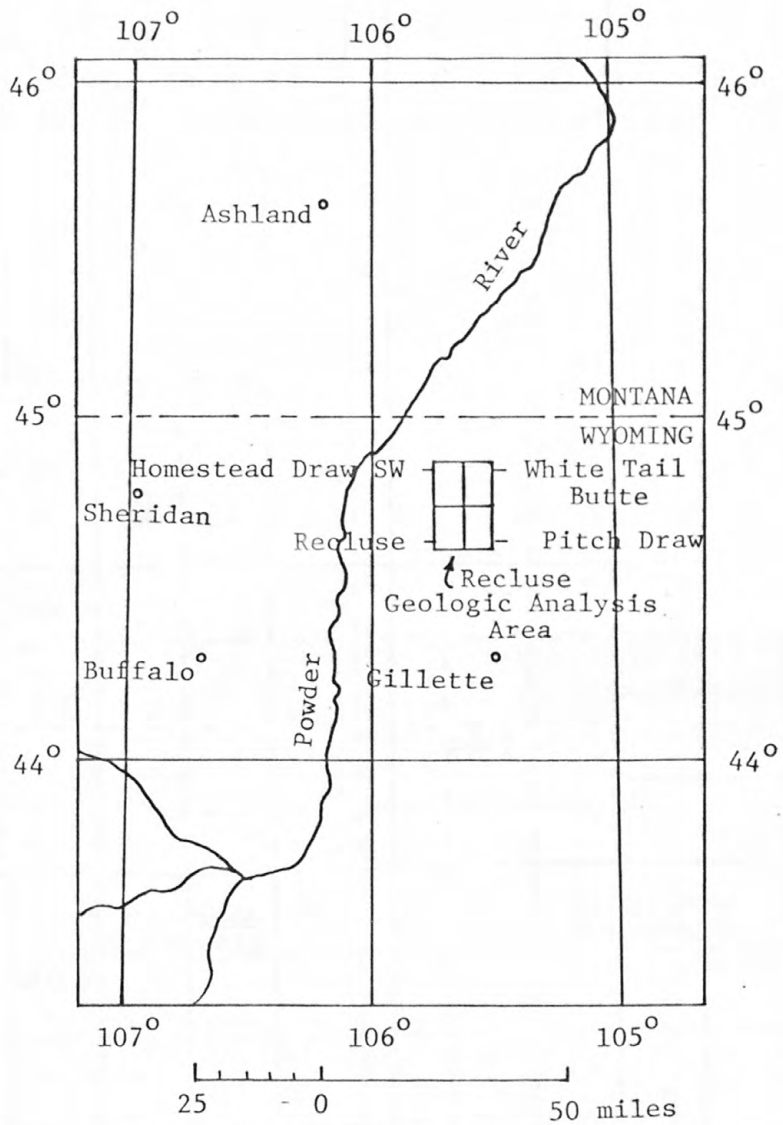

Figure 1.--Index map showing location of Recluse Geologic Analysis Area and U.S. Geological Survey topographic quadrangle maps of area.

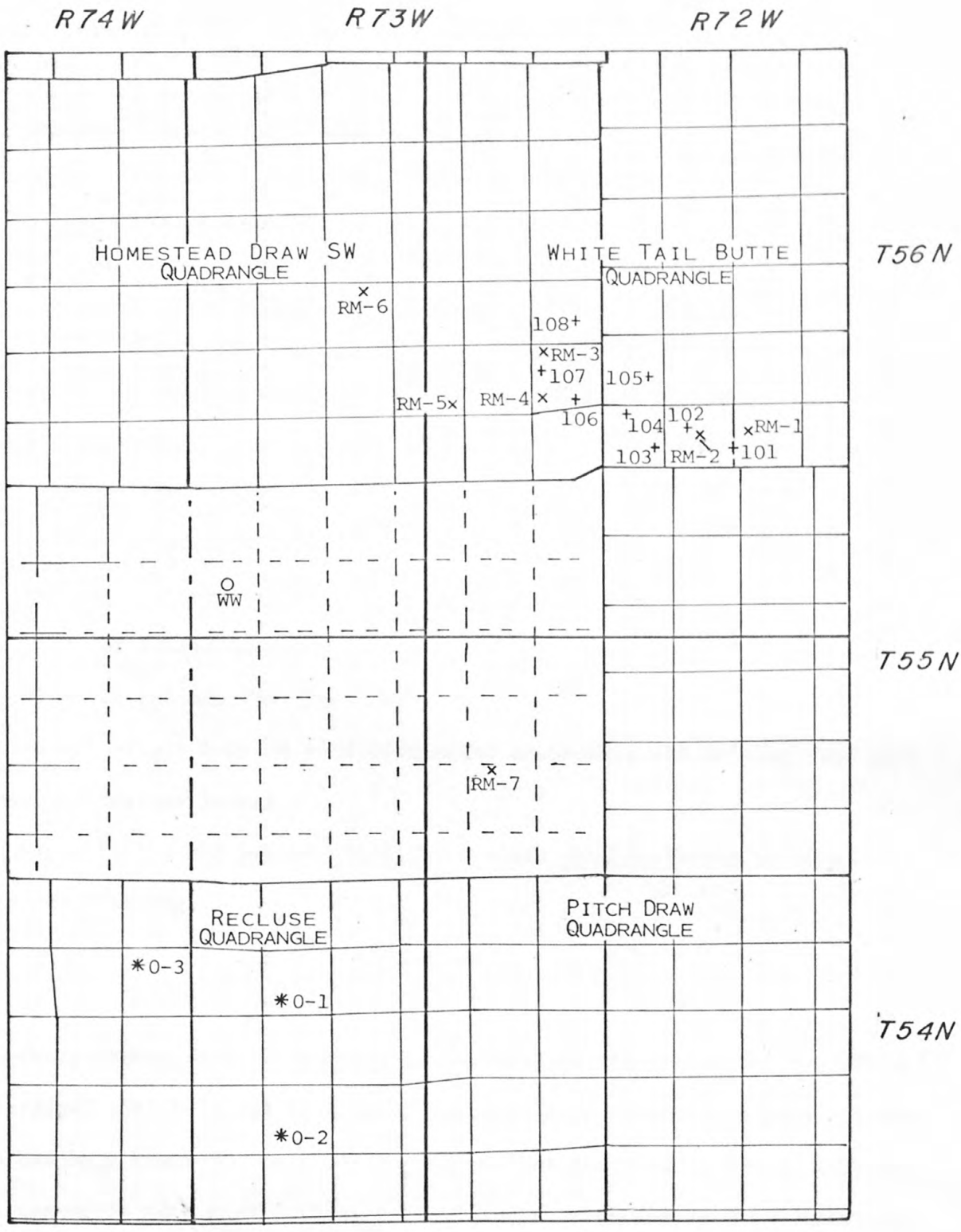

Figure 2.--Drill hole locations in the Recluse Geologic Analysis Area, Campbell County, Wyoming.

Cook

Unnamed (Blue Marker - informal name)

Wall

Pawnee

Cache

The overlying and intervening rocks of the Tongue River Member are principally interbedded massive mudstones and sandstones; shales are minor, usually roof and/or floor rock. Sandstone beds become thicker and more numerous below the Anderson bed. The sequence including the Anderson and Cook beds was penetrated in all drill holes. The position and correlation of coal beds in this sequence are shown in figure 3.

Study of subsurface structure at the base and top of major coal beds shows minor anticlines and synclines. These are considered to be of depositional origin induced by differential compaction and draping over more competent sandstone lenses.

Minor faults are present locally, but are not considered to be a hindrance to mining.

Methane

General

The presence of methane (CH_4) in the shallow (less than 500 feet from the surface) coal beds and associated rocks of this part of the Powder River Basin has been known for many years, and the gas has been utilized locally. Three gas wells with high initial potential were reported by Olive (1957, p. 23):

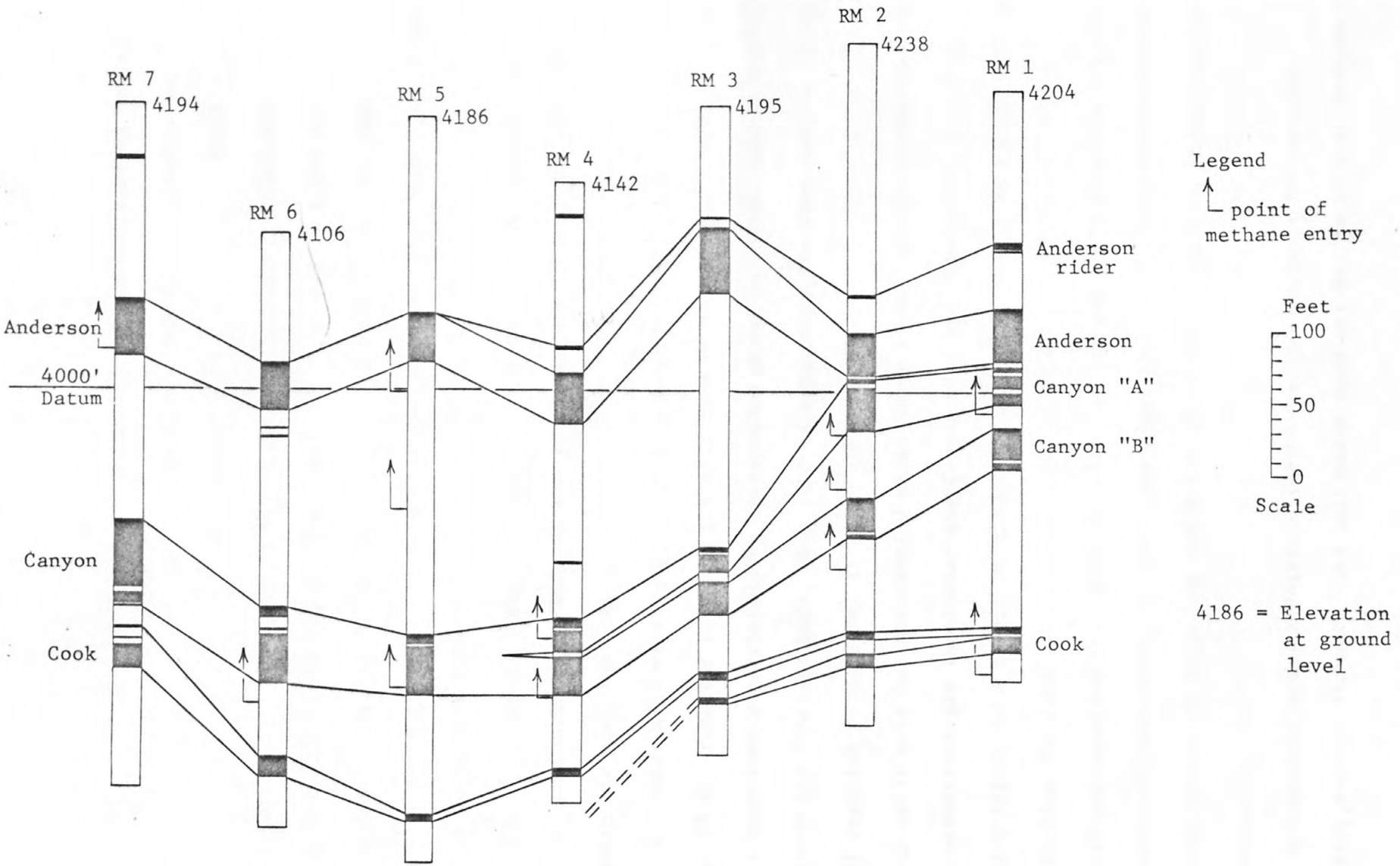

Figure 3.--Generalized drill hole sections showing coal bed correlations and major points of methane entry.

	Total depth (feet)	Gas zone (feet)	Initial daily production (ft^3)
1. Sec. 8, T. 54 N., R. 73 W.	245	223-229	1,000,000
2. Sec. 20, T. 54 N., R. 73 W.	415	395-415	1,000,000
3. Sec. 12, T. 54 N., R. 74 W.	(?)	263- ?	500,000

Olive also reported other wells in this general area that have yielded gas used for domestic purposes.

The gas in wells 1 and 2 is apparently from the zone between the Anderson and Canyon beds, whereas the gas in well 3 is from the zone between the Smith and Anderson coal beds.

The owner of a water well drilled in August 1976, in section 7, T. 55 N., R. 73 W., reported a strong gas flow from 88 to 101 feet. This flow is from a sandstone zone containing interbedded minor coal beds that is between the Smith and Anderson beds. This zone is apparently the same zone as Olive (1957) reported in hole No. 3.

A drill hole located about 7 miles NW of RM-6 (fig. 2) is reported to have encountered gas in or near the Canyon coal bed. The ensuing blowout formed a crater 6 to 8 feet in diameter, and cement had to be pumped into the hole to stop the flow.

It was expected that some emissions of methane would occur during the course of the 1975 drilling, and appropriate precautions were taken. However, the large number of emissions and the high volumes of methane encountered were not expected.

A hand-held methane detector (methanometer) was used for methane detection and measurement. The instrument read-out was in percent methane of

the sample measured and is reported as such. Containers for laboratory sample analysis and methane desorption canisters for determining the quantity of methane in a given sample of coal were acquired later in the project.

The generalized drill hole sections are shown on figure 3, which also shows the points at which methane emissions were encountered during drilling. A summary of these methane emissions for each well is given below:

RM-1

1. After the inner core barrel was pulled, 0.5 percent CH_4 was measured at the wire-line drill-rod collar--there was not a perceptible flow. The depth was 222 feet in a thin sandstone bed between the Canyon A and B coal beds.
2. Erratic, very low (0.1-0.2 percent) CH_4 readings were obtained from the 222-foot depth to the total well depth of 402 feet.
3. During geophysical logging of the open hole, a very low flow, measuring greater than 60 percent CH_4, was detected. (Note: The upper limit on the methanometer read-out was 60 percent or greater and, therefore, any sample containing from 60 to 100 percent CH_4 could only be reported as having greater than 60 percent CH_4.)

RM-2

1. The first significant CH_4 emission was detected at 269 feet in a sandstone bed 5 feet below the Canyon A coal bed--correlative with the gas-bearing sandstone of RM-1. This emission continued to 308 feet, where the CH_4 increased: the flow increased again at 365 feet and persisted to the total well depth of 465 feet. The CH_4 percentages (records for which were inadvertently destroyed) ranged from $\pm$0.5 percent to $\pm$1.0 percent at the total depth.

RM-3

1. Positive identification of CH_4 could not be made during the drilling of RM-3 because of instrument failure.

RM-4

1. The first significant CH_4 emission (0.2 percent) occurred at 312 feet at the position of the Canyon coal bed; the emission of 0.2 percent continued, though at times erratically, to the total well depth of 422 feet. One exception occurred at 349-350 feet while coring a black carbonaceous shale at the base of Canyon coal bed. At this point methane increased to 8.0 percent, but dropped back to 0.2 percent after the shale was penetrated.

RM-5

1. This hole blew out while it was being cored at 193 feet, or about 24 feet below the Anderson coal bed, and continued to blow strongly for about 30 minutes. The hydrostatic pressure created by water flowing into the hole from the Anderson coal bed reduced and then stopped the gas flow. The gas flow was estimated to be about 600 cfm (cubic feet per minute) or about 850,000 cfd (cubic feet per day).
2. At 273 feet drilling was suspended for conversion from coring to conventional drilling; during this time the CH_4 concentration at the hole collar increased to 2 percent until drilling was resumed.
3. A second CH_4 blowout occurred at 391 feet, during drilling near the base of the Canyon coal bed. This emission measured 60 percent or greater CH_4. The blow subsided after a short time because of an inflow of water, probably from the Canyon coal bed.
4. From 0.1 to 0.5 percent CH_4 was detected in the return drilling air from 193 feet to the 509 feet total well depth.

RM-6

1. Surges in the return foam were common when drilling through the Canyon coal bed (272 to 306 feet) to a depth of 323 feet. At the 323-foot depth, the CH_4 emission from a fine-grained, friable sandstone zone measured 1 to 2 percent. The hole blew out when the inner core barrel was retreived. The gas flow was estimated at 900,000 to 1,000,000 cfd and continued for 30 to 45 minutes until stopped by an inflow of water. An analysis of gas from this hole is shown on table 1.
2. After drilling was completed and the surface cap was being installed 24 hours after the casing had been set, a perceptible flow of gas was observed. This was lighted and burned with a 3- to 5-foot flame from the 4 inch I.D. casing.
3. Several months later, a pull down test of this well was made using a submersible pump. The recovered water contained a large amount of gas and resembled "soda pop."

RM-7

1. Methane was detected occasionally and in small quantities ranging from 0.1 to 0.2 percent from the Anderson and Canyon coal beds to the total depth of 465 feet.

Sample analyses

After the holes were completed and capped, samples were taken from the more important holes for laboratory analysis. The results are summarized in table 1.

These subsequent analyses are significant because they show some gas emission after the water level stabilized above perforations in the water and gas zone. Of special importance are:

[All values in percent except where noted (ppm). Analysis, moisture-free basis, by David Dufresne, chemist, U.S. Bureau of Mines, Analytical Research Group, Gas Laboratory, Pittsburgh, Pa. All samples taken at casing collar. WLS = water level stablized; N.D. = not detected]

Hole No.	Sampling conditions	Sample No. and date	O_2	N_2 + A	CO	CO_2	Hydrocarbons: CH_4 (Methane)	Hydrocarbons: Other	H_2
RM-1	WLS, well shut in since 7/3/75	N7419 8/22/75	20.58	Rem	0.0025	0.18	0.0005	C_2H_6 & C_2H_2, <1 ppm	0.0025 H_2
RM-2	WLS, well shut in since 8/9/75	N7424 8/22/75	17.59	72.33	N.D.	.95	9.1	0.005 C_2H_6, 1 ppm C_3H_8 & C_4H_{10}, <1 ppm	.02 H_2
RM-3	WLS, well shut in since 7/14/75	N1336 7/14/75	17.76	81.40	.0036	.69	.15	N.D.	-----
RM-3	10 minutes after test above	N1322 7/14/75	20.93	79.58	.0001	.05	.0003	N.D.	-----
RM-3	WLS, well shut in since 7/14/75	N7411 8/22/75	16.82	81.80	.0015	1.30	.06	.0001 C_2H_6 & C_3H_8 <1 ppm	.0080 H_2
RM-4	WLS, well shut in since 7/25/75	N7412 8/22/75	20.78	79.13	N.D.	.07	.014	.0001 C_2H_6, C_3H_8 <1 ppm	.0020 H_2
RM-6	During blowout from sandstone below Canyon coal bed, while coring at 323 ft.	0530 8/16/75	5.5	22.5	N.D.	9.0	63.0	.02 C_2H_6	--------
RM-6	WLS, well shut in since 8/18/75	N7399 8/22/75	17.91	70.59	.0005	.80	10.7	.0008 C_2H_6, C_3H_8, C_3H_6, C_5H_{12} <1 ppm	.0035 H_2

RM-2 - a CH_4 buildup

RM-3 - a CH_4 buildup, a bleed off, and a subsequent slow buildup

RM-6 - a CH_4 buildup

During the summer of 1976, all seven holes were rechecked at the casing collar. All seven showed CH_4 in small quantities not exceeding 0.5 percent, indicating that the CH_4 was still bleeding off through the water.

Desorption Tests

Two samples of coal were taken for gas desorption tests using the method described by by McCullough and others, 1975. One was from the Canyon coal bed in RM-5: the other was from the Cook coal bed, hole RM-7. These were forwarded to the U.S. Bureau of Mines, Pittsburgh, Pennsylvania, for analysis.

The results indicated that these samples contained 8 to 9 cubic feet of recoverable methane per ton of coal.

Reservoirs

The methane reservoirs are, in apparent order of importance, the sequence of sandstones between the Anderson and Canyon coal beds, the Canyon coal bed, the sandstone unit below the Canyon coal bed, the sandstone units between the Canyon "A" and "B" coal beds in the eastern part of area, and the Anderson coal bed.

The concentrations of gas are apparently in sandstone lenses and coal beds enclosed in shale, with some possible localization on depositional structural highs.

Available core samples of coal from holes 76-103 and 76-108 from the Bureau of Land Management 1976 EMRIA drilling, and rock samples from holes 76-101, 76-107, and 76-108 were analyzed for porosity and horizontal and vertical permeability. The results are summarized in table 2.

The low porosity and permeability values shown for the coal beds

Table 2.--Permeability and porosity values of the Anderson and Canyon coal beds and selected rock samples.

[Analyses by Core Lab, Inc., Casper, Wyoming. Samples furnished by the U.S. Geological Survey]

Hole No.	Depth (ft)	Lithology or coal bed name	Permeability (millidarcy) Vertical	Permeability (millidarcy) Horizontal	Porosity (percent)
76-103	53.0 - 53.2	Anderson coal	.72	.11	5.0
	63.2 - 63.4	Anderson coal	.19	.12	2.7
	79.5 - 79.7	Anderson coal	3.10	.06	N.A.[4]
	155.5 - 155.6	Canyon "A" coal	.21	.03	3.8
	183.3 - 183.5	Canyon "B" coal	3.1	.06	5.1
	193.0 - 193.3	Canyon "B" coal	.12	.05	N.A.
76-108	83.8 - 84.0	Anderson coal	.05	.02	5.6
	93.2 - 93.4	Anderson coal	2.0	.03	N.A.
	96.2 - 96.4	Anderson coal	2.1	.06	4.9
	270.6 - 270.8	Canyon "A" coal	.60	.35	N.A.
	272.6 - 272.8	Canyon "A" coal	.05	.01	3.8
	274.7 - 274.9	Canyon "A" coal	3.7	.22	N.A.
	314.1 - 314.2	Canyon "B" coal	.02	1.22[1]	N.A.
	314.3 - 314.5	Canyon "B" coal	.06	.02	3.5
	318.1 - 318.3	Canyon "B" coal	.28	.03	3.0
	323.0 - 323.3	Canyon "B" coal	2.0	.05	N.A.
	326.1 - 326.2	Canyon "B" coal	.92	.35	3.0
76-101	331.5 - 331.8	Silty sandstone[2]	1.8	1.0	30.1
76-107	239.0 - 239.3	Silty sandstone[3]	.03	.01	11.6
76-108	450.7 - 459.0	Mudstone	.49	.20	15.3

[1] Permeability may be erroneously high due to fracturing of sample.

[2] Below Canyon coal bed.

[3] Between Anderson and Canyon coal beds.

[4] Not analyzed

Average values of each hole:

76-103	Anderson coal	1.37	0.1	3.8
	Canyon "A" coal	.21	.03	3.8
	Canyon "B" coal	1.61	.05	5.1
76-108	Anderson coal	1.38	.04	5.2
	Canyon "A" coal	1.43	.19	3.8
	Canyon "B" coal	.66	.33	3.2

Average values by coal beds:

Anderson coal	1.37	.07	4.5
Canyon "A" coal	.82	.11	3.8
Canyon "B" coal	1.13	.19	4.2

indicate that undisturbed, unfractured solid coal is not a reservoir capable of producing significant quantities of methane. However, inherent in most coal is a cleat and (or) induced fracture system that increases permeability. These were observed in the cores at various intervals in all of the coal cored during 1975 and 1976. It is the fracture cleat and (or) induced systems of fractures and the resultant fracture permeability that will determine a coal bed's productivity of methane and (or) water.

The sandstone sequences that showed significant methane emissions were fine grained, very friable, and loosely cemented. Core recovery from these intervals was very low and samples were not available for analysis. However, gas and water inflow from these sandstones indicates that the porosity and permeability are good to very good. The rock sequences shown in table 2 are not truly representative of the sandstone from which the more significant CH_4 emissions occurred. The samples in table 2 do show, however, what the lower permeability values of the silty sandstones may be.

Preliminary mapping of the shallow, potentially surface-minable coals and the intervening rocks in this area shows the Anderson and Canyon coals to be persistent and reasonably thick throughout the area. Probably more important, the thickness of rock between the Anderson and Canyon coal beds ranges from 5 feet to about 300 feet, and the thickness changes are caused by concentrations of sandstone (potential methane reservoirs) in former stream channels.

The Anderson and Canyon coals in this area are also the major shallow-water aquifers in this area. The water produced while drilling the coals ranged from 2 to 15 gpm (gallons per minute). The sandstone sequences, especially those with CH_4 emissions, were also good to very good aquifers, producing up to 20 gpm (gallons per minute) in RM-5 and RM-6.

Potential Hazards

The explosive limits of methane in air (average) are between approximately 5 and 15 percent. However, the potential of a fire fueled by methane is always present, regardless of the methane quantity (percent) present in a CH_4/air mixture.

The probability of encountering methane while drilling sedimentary rocks is high, and the probability increases when fractured coals and sandstones enclosed by impermeable mudstones are present.

The occurrence and possible emission of CH_4 from a drilled hole poses a definite safety hazard to the personnel and equipment in the area surrounding the hole. This applies to drilling personnel and equipment, and continues through all phases of geophysical logging, water-well testing, or well-equipment installation.

The potential hazards are usually greatest during drilling when using air or air/foam as the circulating medium. Another hazardous period is when the water level in the well is reduced by pumping (during use or during pull-down tests).

Precautions

The hazards of methane are greatly reduced when it is recognized that concentrations do occur and standard precautionary measures can be taken to remove or reduce the potential methane entrapment areas and ignition sources. These measures include the following:

1. Ventilating all areas where CH_4 could accumulate, such as the hoods of engines working at the drill site. This is especially important for gasoline engines. It is also very important to maintain good ventilation, especially near the roof, in the equipment trailers, in logging trucks, etc.

2. Keeping unnecessary vehicular traffic away from the drilling area.
3. Limiting smoking to designated areas.
4. Using caution when operating any spark-producing equipment (hammers, electric grinders, drills, and any welding or cutting tools) at or near the well site, and operating this equipment only when appropriate methane tests are made before and during the operation.
5. Using and placing heating units with caution.

A small hand-held methane-detecting device (methanometer) is recommended for permanent use at the drill site. Appropriate actions should be taken when the CH_4/air mixture reaches various levels. For example, if CH_4 has been detected but mixtures are below 1.0 percent, operations can be allowed to continue, but with frequent CH_4 monitoring. At mixture levels from 1.0 to 3.0 percent, continuous CH_4 monitoring is necessary, accompanied by a switch from air-drilling to mud-drilling medium. At CH_4 concentrations over 3.0 percent, all operations should be shut down until the level is reduced below 1.0 percent.

The best precaution that can be taken is using common sense by responding to a situation in a manner consistent with the hazards and/or problems presented.

Potential resources

The data are not sufficient to estimate the methane resources of the Recluse Geologic Analysis Area and surrounding areas. These data show, however, that the total amount of methane could be significant and that recovery might be economically feasible.

Further investigation is warranted and should include the following:

1. Completion methods for drilling shallow gas wells.
2. Temporary above-ground pipelines for gas transportation.

3. Portable compression plants for the temporary transportation system.
4. Markets for the gas.
5. Possible legal problems such as conflicts with existing oil and gas leases for the deeper hydrocarbon reservoirs and coal leases.

Developers of coal leases might be able to reduce mining costs by using available methane to heat shops and offices or to partially dry the coal. This would utilize a valuable source of energy, which is usually lost once coal mining begins, and the safety hazards from methane emission into the mining area would be reduced.

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