OPEN-FILE REPORT 81-06

THE COAL BED METHANE POTENTIAL OF THE SAND WASH BASIN, GREEN RIVER COAL REGION, COLORADO

by

Donna L. Boreck, Carol M. Tremain,
Linda Sitowitz, and Thomas D. Lorenson

DOI: https://doi.org/10.58783/cgs.of8106.ywfz6710

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO 80203

1981

REPORT DOCUMENTATION

TITLE: The Coal Bed Methane Potential of the Sand Wash Basin, Green River Coal Region, Colorado

AUTHORS: Donna L. Boreck, Carol M. Tremain, Linda Sitowitz, and Thomas D. Lorenson

PERFORMING ORGANIZATION: Colorado Geological Survey
Room 715, 1313 Sherman Street
Denver, Colorado 80203

SPONSORING ORGANIZATIONS: Colorado Oil and Gas Conservation Commission,
U.S. Department of Energy
(Grant No. DE-FG21-80MC14256)

REPORT DATE: August 7, 1981

REPORT NUMBER: Final

ORIGINATOR KEY WORDS: Methane, Green River region, Sand Wash Basin, coal mine data, oil and gas production

NUMBER OF PAGES: 26, including 10 figures, 1 table, 3 appendices, 4 plates.

ACKNOWLEDGEMENTS

The authors wish to particularly thank the Colorado Oil and Gas Conservation Commission and the U.S. Department of Energy for funding this project. In addition, the Oil and Gas Commission provided the well files and logs used in this study and the Dept. of Energy lab provided the coal analyses.

The U.S. Bureau of Mines ran our residual gas analyses and provided expert advice. The Colorado Division of Mines and the Colorado State Archives graciously permitted us to use their files. The U.S. Geological Survey and numerous coal mine and oil and gas operators allowed us to sample their coal. Our thanks go to all these agencies and individuals.

Finally, special thanks are due to the supervisors and staff of the Colorado Geological Survey for their assistance in preparing this report.

CONTENTS

FIGURES

TABLE

PLATES

APPENDICES

ABSTRACT

The Sand Wash Basin covers most of the Colorado portion of the Green River coal region. Significant coal beds are found in four Cretaceous formations in the basin: the Iles and Williams Fork Formations of the Mesaverde Group, the Lance Formation, and the Fort Union Formation. Individual coal beds can reach thicknesses of 36 ft in the Mesaverde, 13 ft in the Lance, and 50 ft in the Fort Union. Net coal isopach maps of these formations indicate coal resources of: 128 billion short tons in the Mesaverde Group, 16 billion short tons in the Lance Formation, and 52 billion short tons in the Fort Union Formation.

Several lines of evidence indicate coal bed methane is present in some of the coals in the basin: 1) gas emissions from coal mines (up to 11,400 cubic feet of gas per ton (cf/t) of coal mined per day), 2) 23 desorbed coal samples with gas contents ranging from 0 to 376 cf/t, 3) mud log reports of gas coming from coals in all four formations, and 4) successful drill stem tests and production tests from mixed sandstone and coal zones. A 414 sq mi area of Mesaverde coals (5,000± ft deep) may contain nearly 14 trillion cubic feet of gas in place.

INTRODUCTION

The Green River coal region is the vast coal bearing area in northwestern Colorado and southwestern Wyoming shown in Figure 1. Coal is present here from the surface to depths of greater than 10,000 ft. Oil and gas drill hole and coal mine reports give evidence of coal bed methane in the deeper coals. Analyses of coal gas from other coal regions in Colorado indicate the gas is often pipeline quality methane. Hence, this coal bed methane could be an addition to Colorado's natural gas resources.

The Colorado Geological Survey, funded by the Colorado Oil and Gas Conservation Commission and the U.S. Department of Energy, has attempted to locate and estimate the amount of coal bed methane in the Green River coal region of Colorado. The following geologic report, including coal isopach maps and desorption data, was written to this end.

GEOLOGY

The geologic boundary of the Green River coal region is drawn on the base of the coal bearing Mesaverde Group. As shown in Figure 1 the Mesaverde occurs throughout a large area which is marked by broad uplifts and deep basins (see McCord, 1980, p 1).

Coal bed methane is most likely to be present in recoverable amounts in the basins of this region due to: 1) increased generation of gas as rank and depth increase, and 2) increased retention of gas as depth increases.

The only basin in the Colorado portion of the Green River coal region is the Sand Wash Basin. Structural boundaries of the Sand Wash Basin are: the Uinta Uplift to the west, the Park Range Uplift to the east, the Cherokee Ridge to the north, and the Axial Basin Anticline to the south. The basin's axis trends west-northwest across the basin's center (Figure 2). There is a structural

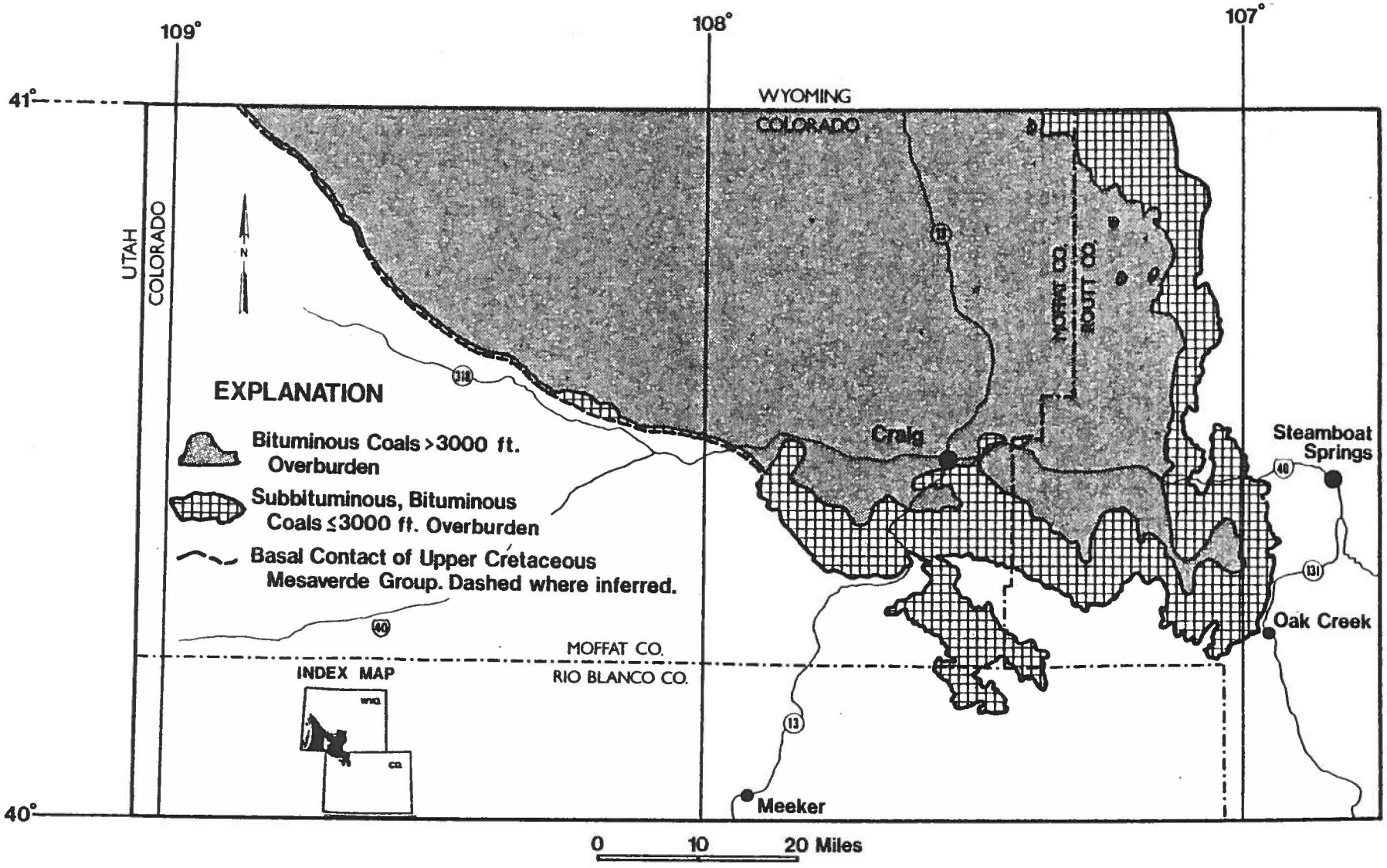


Figure 1. The Green River coal region, Colorado.

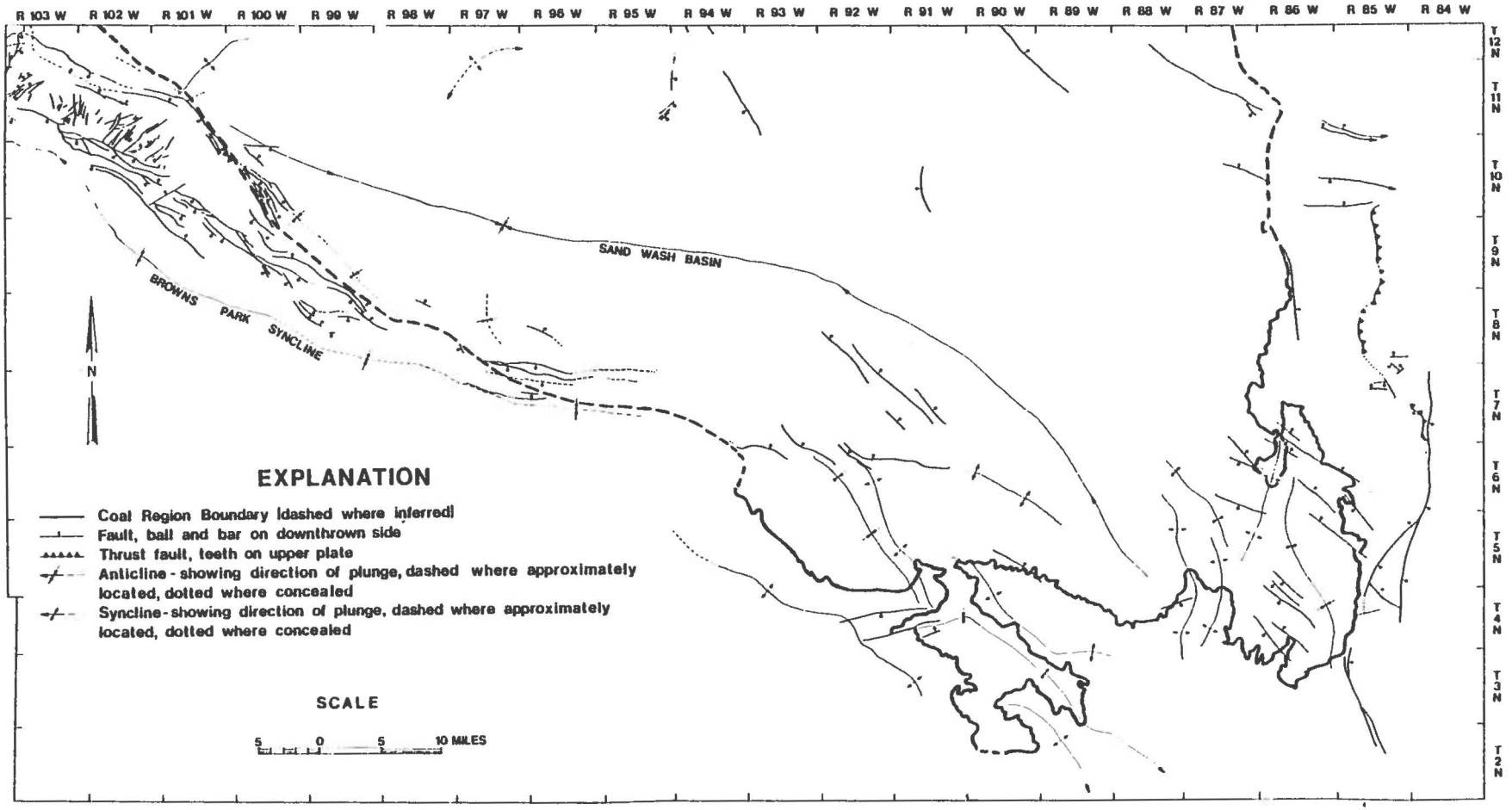


Figure 2. Tectonic map of the Green River coal region, Colorado.

structural relief of ± 29,440 ft between the Precambrian basement at the deepest point in the basin (-17,500 ft) and Mount Ethel (11,940 ft) in the Park Range (Haun, 1962, p. 11).

Both folding and faulting are extensive around the periphery of the basin. Although fold axes extend in all directions, a northwesterly trend dominates. Faults are especially prominent along the southern edge of the basin. These faults show the same northwest trend as the folds.

Every geologic period is represented in the basin except for the Silurian. Figure 3, a stratigraphic chart, briefly describes the formations deposited during these periods. Plate 1, Map A, a geologic map, shows the present surface distribution of these rocks. However, most of the oil and gas and all of the coal and coal bed methane in the region are found in the Cretaceous and younger rocks.

Coal Bearing Formations

The coal bearing formations of the Sand Wash Basin are: the Upper Cretaceous Iles and Williams Fork of the Mesaverde Group, the Upper Cretaceous Lance, the Cretaceous-Paleocene Fort Union, and the Paleocene-Eocene Wasatch (Figure 4). Survey personnel checked approximately 150 wells in the basin (see Plate 1, Map B) to determine the coal distribution in these formations.

The Iles and Williams Fork Formations are ± 2000 ft and ± 1600 ft thick (respectively) and are composed of white, gray, and brown sandstones; gray shales; and coals all deposited in a marginal marine environment. Surface coal samples and subsurface coal cores rank from high volatile C bituminous to high volatile A bituminous. Most individual coal beds are less than 10 ft thick with the thickest bed measuring 36 ft (see Plate 2, Map A). Net thicknesses of these Mesaverde coals vary from 18-136 ft (see Plate 2, Map B). Planimetering the 1638 sq. mi. mapped area of Map 2 yields 128 billion tons of coal in place.

The Lance Formation is 0-2000 ft thick and is composed of gray carbonaceous shale, gray to white fine-grained sandstones, and coal. The Lance was deposited in a marginal marine and fluvial environment not unlike the present day Atlantic coastal plain (Earl Kauffman, personal communication). Coal formed in swamps adjacent to meandering rivers and in interdeltaic areas where peat accumulated. Lance coal beds are often found immediately above the Fox Hills Sandstone and rank subituminous B and C where mined (Murray, 1980, p. 16). The thickest individual bed attains 13 ft (see Plate 3, Map A). Net thicknesses of Lance coals reach 29 ft (see Plate 3, Map B). Planimetering the 1186 sq. mi. area of Map 2 which contains 5 or more feet of coal yields 16 billion tons of coal in place.

Lying unconformably above the Lance is the fluvial Fort Union Formation. This formation is 0-2500 ft thick and is composed predominantly of drab brown and gray sandstones and gray shale with some coal. Fort Union coals were deposited in swampy areas adjacent to meandering rivers; the thickest coal beds flank the north trending river sandstone belt of the Fort Union (Beaumont, 1979, p. 203). Individual beds reach up to 50 ft in thickness (see Plate 4, Map A). Net coal thicknesses range from 0 to 114 ft (see Plate 4, Map B).

PERIOD	FORMATION	THICKNESS	LITHOLOGY	OIL, GAS & COAL
MIOCENE	Browns Park Fm	0-2000'	ss & sltst	
	Bishop Cgl	0-300'?	pebbles & boulders of ss quartzite, & schists	
EOCENE	Bridger Fm	+800'	claystone & mudstone	
	Green River Fm	±1200'	claystone, sh, oil shale, ss, & marlstone	
PALEOCENE	Wasatch Fm	±6000'	claystone, sh, & ss, minor coal	● ☼ C
	Fort Union Fm	0-2500'?	gray ss, gray sh, & coal	● ☼ C
	Lance Fm	0-2000'	gray to white ss, gray sh , coal	● ☼ C
UPPER CRETACEOUS	Fox Hills Ss	0-100'	gray ss & sandy sh	
	Lewis Shale	1500-2100'	gray marine sh, some gray ss	● ☼
	Mesaverde Gp: Williams Fork Fm.	1100-2000'	ss, gray sh, & coal	● ☼ C
	Mesaverde Gp: Iles Fm	1300-1550'	ss, gray sh, & coal	● ☼ C
	Mancos Sh	±5000'	gray marine sh	● ☼
	Niobrara Ls	±900'	calcareous sh	● ☼
	Frontier Ss	±600'	calcareous ss	● ☼
	Mowry Sh	100-200'	gray to black marine sh	●
LOWER CRETACEOUS	Dakota Gp	100-250'	ss, shale, & shaly ss	●
JURASSIC	Morrison Fm	300-800'	claystone, sltst, ss, sh, & ls	● ☼
	Curtis Fm	0-100'	glauconitic & oolitic ss, calcareous sh, & oolitic ls	●
	Entrada Ss	75-175'	pink & gray siliceous ss	☼
	Carmel Fm	0-600'	red sltst, ss, & calcareous sh	
TRIASSIC	Navajo Fm	0-800'	fine-grained, ss	
	Chinle Fm	0-450'	red & orange calcareous sltst, ss, sh, red claystone	
	Shinarump Fm	±30'	red sh, ss, & quartz pebble cgl	● ☼
	Moenkopi Fm	0-850'	red sltst, green & gray sh, ss, & anhydrite	
PERMIAN	Park City Fm (Phosphoria Fm) (State Bridge Fm)	0-300'	orange sltst, orange & red sh, oolitic dolomite & anhydrite	
PENNSYLVANIAN	Weber Ss	±100-200'	light gray to white, siliceous ss	● ☼
	Maroon Fm	0-2000'	red ss, sltst, & cgl, rare ls or dolomite	
	Morgan Fm	500-1400'	tan bioclastic ls, calcareous & siliceous ss, & calcareous sh	
	Minturn Fm	0-1000'	arkosic ss, cgl, & sh, with carbonate & anhydrite stringers	●
	Belden Sh	0-100'	gray to black sh, & black ls, with some ss stringers	
	Molas Fm	±30'	variegated sh, occasional ls & ss stringers	
MISSISSIPPIAN	Madison Fm (Leadville Ls)	0-700'	light & dark gray, cherty crystalline ls; dolomite	
DEVONIAN	Chaffee Gp: Dyer Fm: Coffee Pot Mbr	>±190'	stromatolitic dolomite	
	Chaffee Gp: Dyer Fm: Broken Rib Mbr		dolomitic ls	
	Chaffee Gp: Parting Ss	±80'	siliceous and dolomitic ss with sh & dolomite streaks	
CAMBRIAN	Lodore Ss	0-300'	siliceous & glauconitic ss	
PRECAMBRIAN	Uinta Mtn Group	undetermined	quartzite & conglomeratic ss	
	Metamorphic and Igneous Rocks			

Figure 3. Stratigraphic chart of the Green River coal region, Colorado.

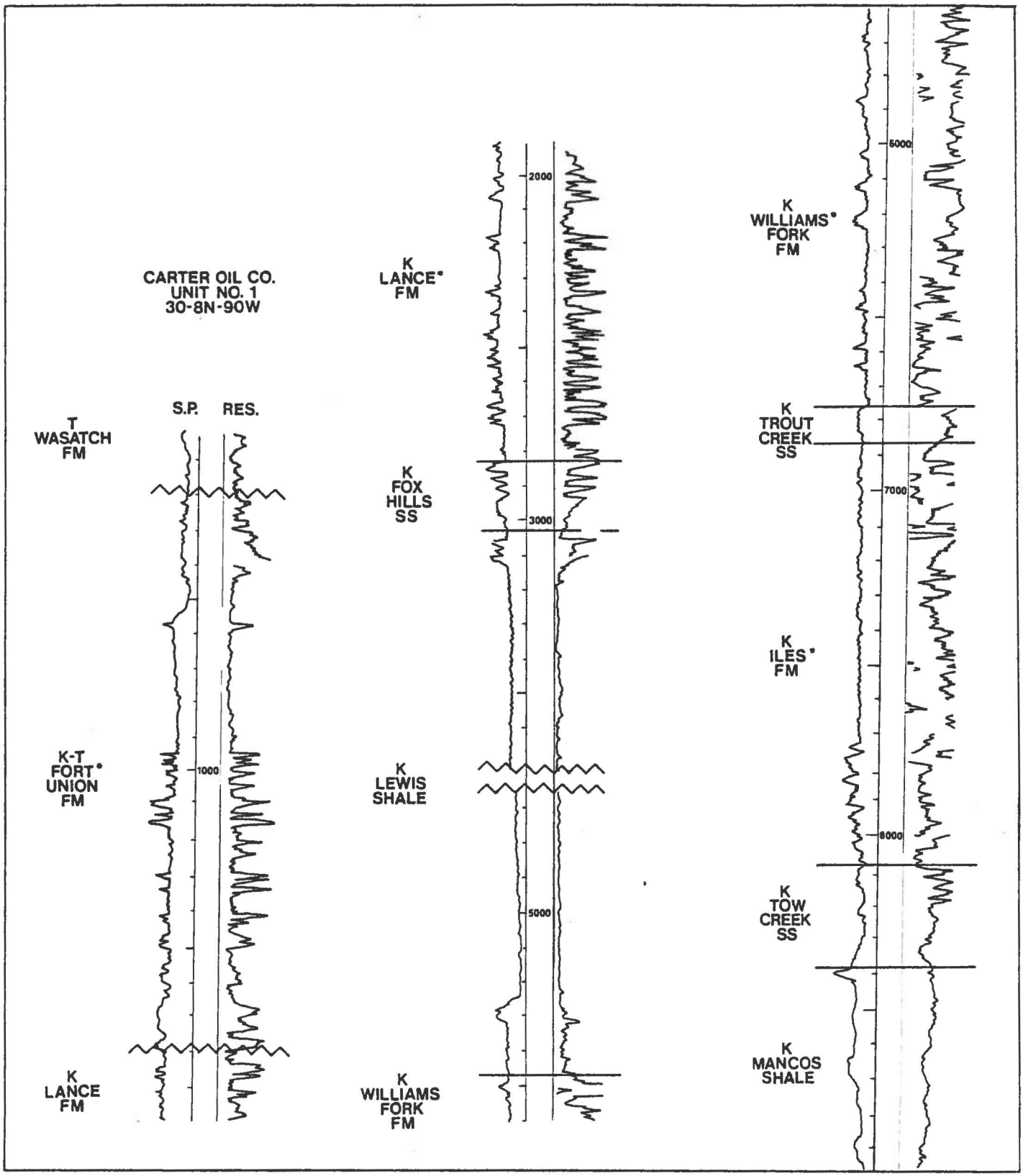


Figure 4. Type log of the coal bearing interval in the Green River coal region, Colorado. Asterisks mark the coal bearing formations (from Tremain et al, 1981, p. 247).

These Fort Union coals are the thickest coal beds in the Sand Wash Basin. Coal ranks from near surface samples are subbituminous B and C (see Murray, 1980, p. 16). Planimetering the 1177 sq. mi. mapped area of Map 4 yields 52 billion tons of coal in place.

The Fort Union is unconformably overlain by the Wasatch Formation. The Wasatch consists of fluvial gray and pink arkosic sandstones, mudstones, conglomerates, and a few coals. It was deposited as alluvial debris along the margins of the vast lake that occupied the area. Rapid influx of sediment during Wasatch time permitted little accumulation of peat along river margins and deltas; therefore, coals found within the Wasatch are generally thin and sparse. Due to the relative scarcity of these coals they were not mapped in this study.

COAL PRODUCTION

In the 1800's, many small mines in the Sand Wash Basin provided coal for homesteaders and ranchers. The first commercial coal produced in the basin came from a Routt Co. mine in 1889. Commercial production of coal in Moffat Co. did not begin until 1922. The area had no opportunity to become a coal exporter until 1906, when the Moffat Railroad connected the coal field with Denver.

Production in the Yampa coal field, the only named field in the basin, temporarily peaked during the war years of 1942-1945, reaching a high of 1,325,631 short tons in 1944 (Landis, 1959, p. 176). Coal production declined rapidly in the following years and did not start to noticeably rise again until the 1970's. With renewed interest in coal, production has soared to a total of 9,914,724 short tons in 1980. From 1889 through 1980, approximately 200 mines (Figure 5) produced 100,030,460 short tons from the basin. This is merely 2% of the original demonstrated reserve base of 6,683.14 million short tons (Boreck, 1979, p. 40).

This area is now the largest producer of coal in Colorado. In 1980, the 14 coal mines operating in the region accounted for 52.8% of Colorado's total 18,770,318 short ton coal production.

OIL AND GAS PRODUCTION

The Sand Wash Basin (and the Axial Basin Anticline) have produced a large amount of hydrocarbons from oil and gas fields shown in Figure 6. Routt and Moffat Counties, most of whose oil and gas fields are in the basin or on the anticline, had cumulative productions of 60,183,734 BO (barrel of oil) and 544,952,800 MCFG (thousand cubic feet of gas) by the end of 1980. Production in that year alone was 605,193 BO and 22,518,605 MCFG. Most of the producing rocks, including the coal bearing Mesaverde Group, and the Lance, Fort Union and Wasatch formations, are upper Cretaceous to Eocene in age (refer to Figure 3).

The hydrocarbon traps are structural, stratigraphic, or a combination of both.

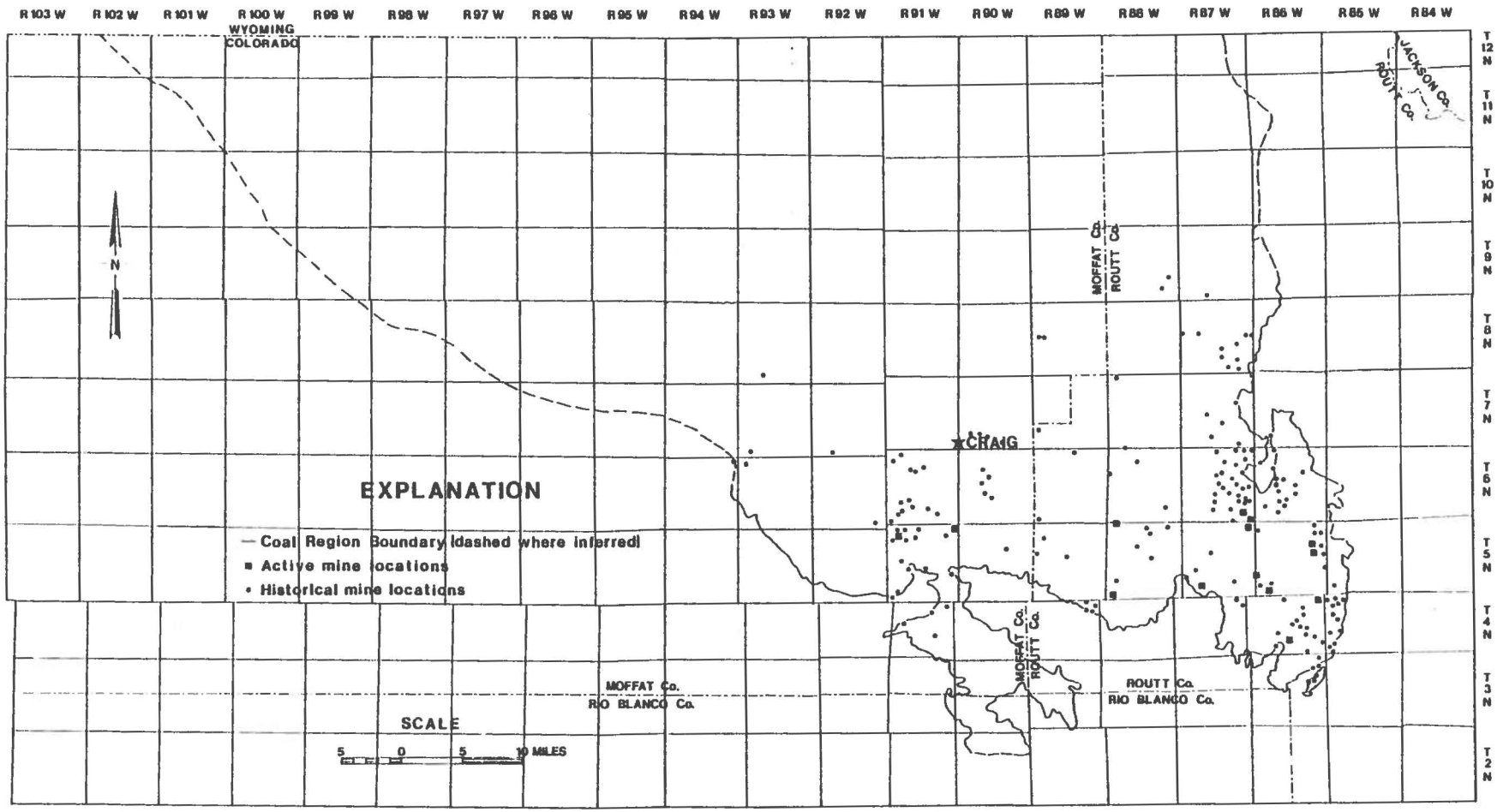


Figure 5. Coal mines in the Green River coal region, Colorado.

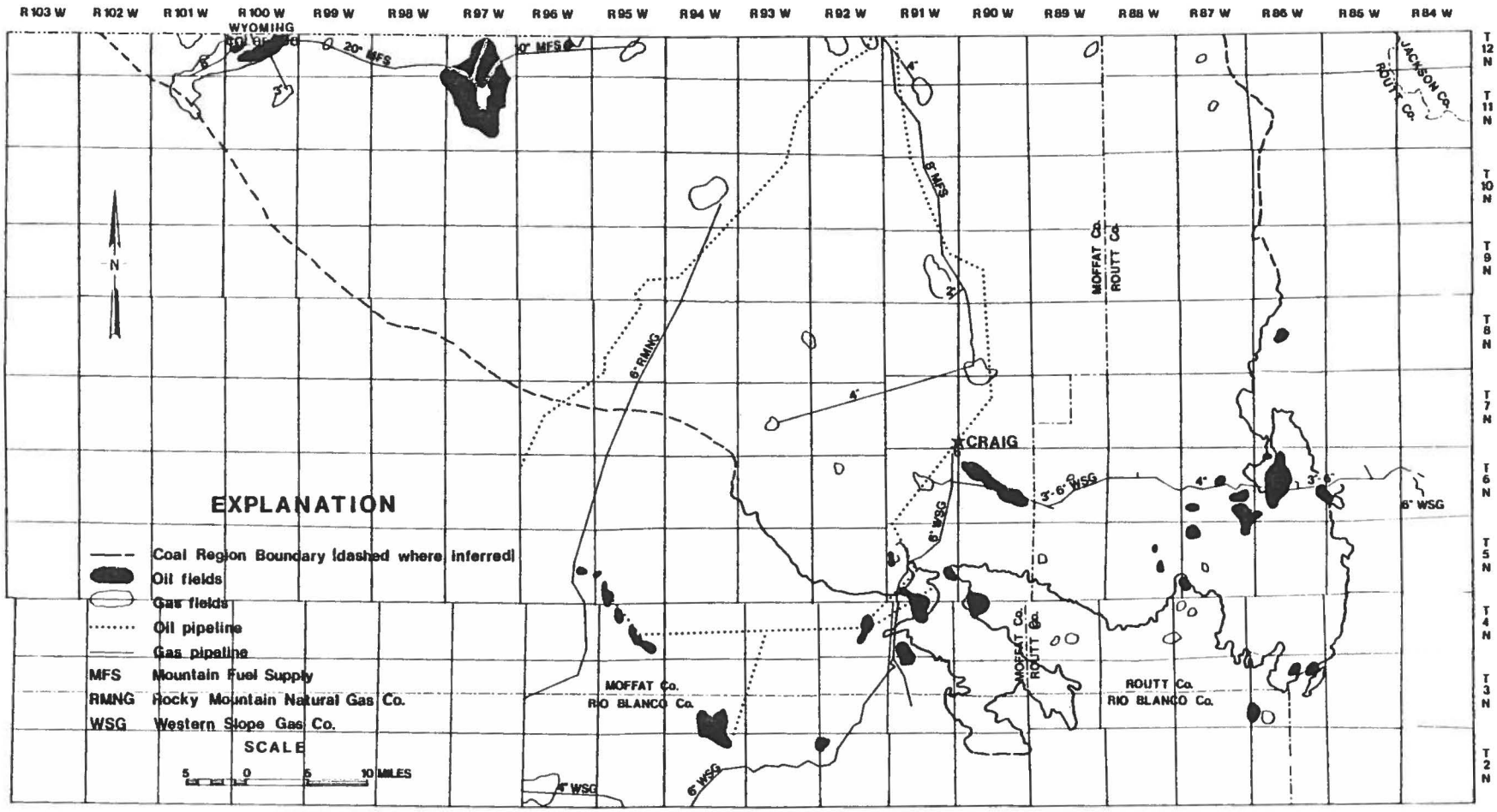


Figure 6. Oil and gas fields and pipelines in the Green River coal region, Colorado.

Most of the structural traps are anticlines or domes. Fault closure, by itself, accounts for only a minor amount of oil and gas occurrences although faults may provide vertical avenues for hydrocarbon migration into reservoir rocks. Fracture traps are most important in the shales of the area, making the Lewis Shale a producer in the Sand Wash Basin.

Stratigraphic traps are found where rocks of differing permeabilities are juxtaposed. This condition occurs frequently due to the shifting of Cretaceous seas across the region. These permeability changes are often found atop anticlines with the result that combination traps are formed.

COAL BED METHANE

One type of gas reservoir that has been largely ignored in the past is coal beds. Coal has long been recognized as a source of methane generated during coalification (see Figure 7). In fact, L.A. McPeek (1981, p. 1078) and Law et al (1980, p. 29) consider coal a likely source for the gas trapped in Mesaverde and younger sandstones. Only recently, however, has it been widely recognized that coal beds can also be reservoirs of this dry gas.

At least three lines of evidence point to the probable occurrence of a coal bed methane resource in the Sand Wash Basin: 1) coal mine gas occurrences, 2) direct desorption data, and 3) gas shows reported in oil and gas drill holes.

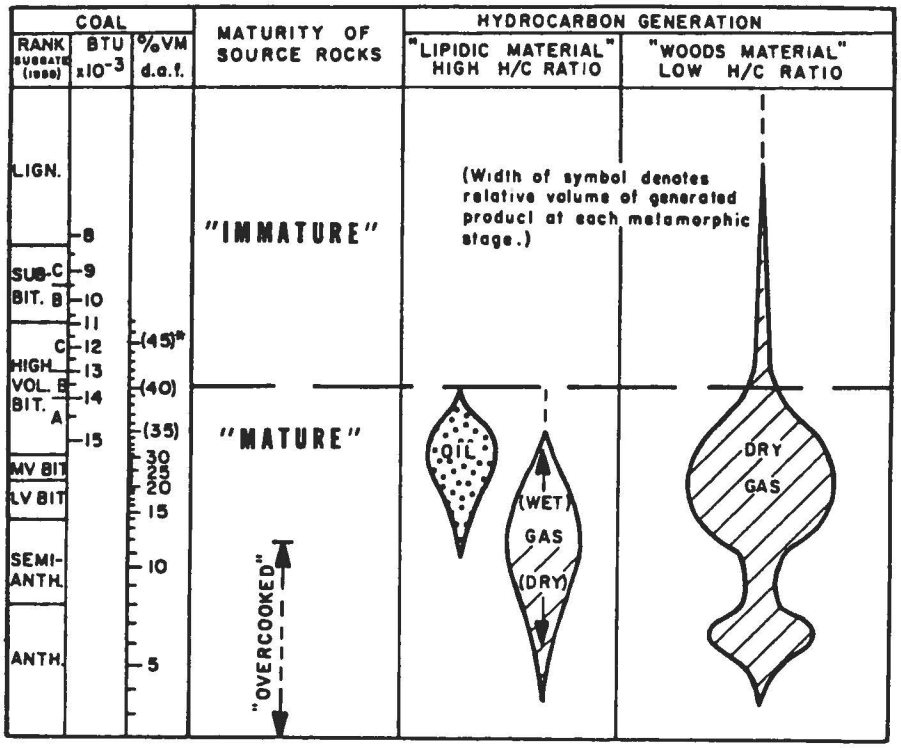
Coal Mine Gas Occurrences

One of the most hazardous gasses that can be present in a coal mine is the methane generated by coal during coalification. This gas can be up to 99% methane and is highly explosive at concentrations of 5-15%. Fender and Murray (1978) reported 5 mines bordering the basin (of approximately 200) that had recorded gas related fires and explosions (Figure 8). (However, some of this problem causing gas may have been brought into the mines from deeper strata via faults.)

Although the 3 underground mines currently operating in the basin are not now emitting measurable amounts of methane (Archie Vigil, personal communication), one of them, the Apex #2, had an average methane emission rate of 11,400 cf/day (cubic feet/day) or 190 cf of methane per ton of coal mined in 1974 (Fender and Murray, 1978). However, 190 cf/t could be up to 9 times the in place gas content of the coal since the ribs, floor, roof, gob, etc. also contribute to the methane emitted during mining (Kissel et al., 1973, p. 8).

The Direct Method

To solve the problem of measuring the actual gas content of a coal bed, the U.S. Bureau of Mines developed the direct method in which the gas emitted by (or desorbed from) an encapsulated sample of coal core is measured by water displacement (see Appendix 1 for further details). Table 1 lists the total gas contents (determined by the direct desorption method) of 23 coal samples and 2 carbonaceous shale samples from the Sand Wash Basin. The gas contents range from 0 to 376 cf/t.



After Vassoyevich, et al (1970) and Hood, et al (1975), in part.

*% VOLATILE MATTER IN PARENTHESIS IS SUITABLE ONLY FOR HUMIC, VITRINITIC COALS.

Figure 7. Coal rank related to hydrocarbon generation (from Dolly and Meissner, 1977, p. 261).

However, a close look at Table 1 and the coal rank map which includes desorption samples (Figure 9), shows that this desorption data does not give a representative gas content distribution for the entire Sand Wash Basin. The samples are: 1) only from the Williams Fork Formation (with none from the coal bearing Iles, Lance or Fort Union), 2) only from the southeast quarter of the basin, and 3) only from depths less than 5000 ft while coals occur below 10,000 ft (see Plate 2, Map A).

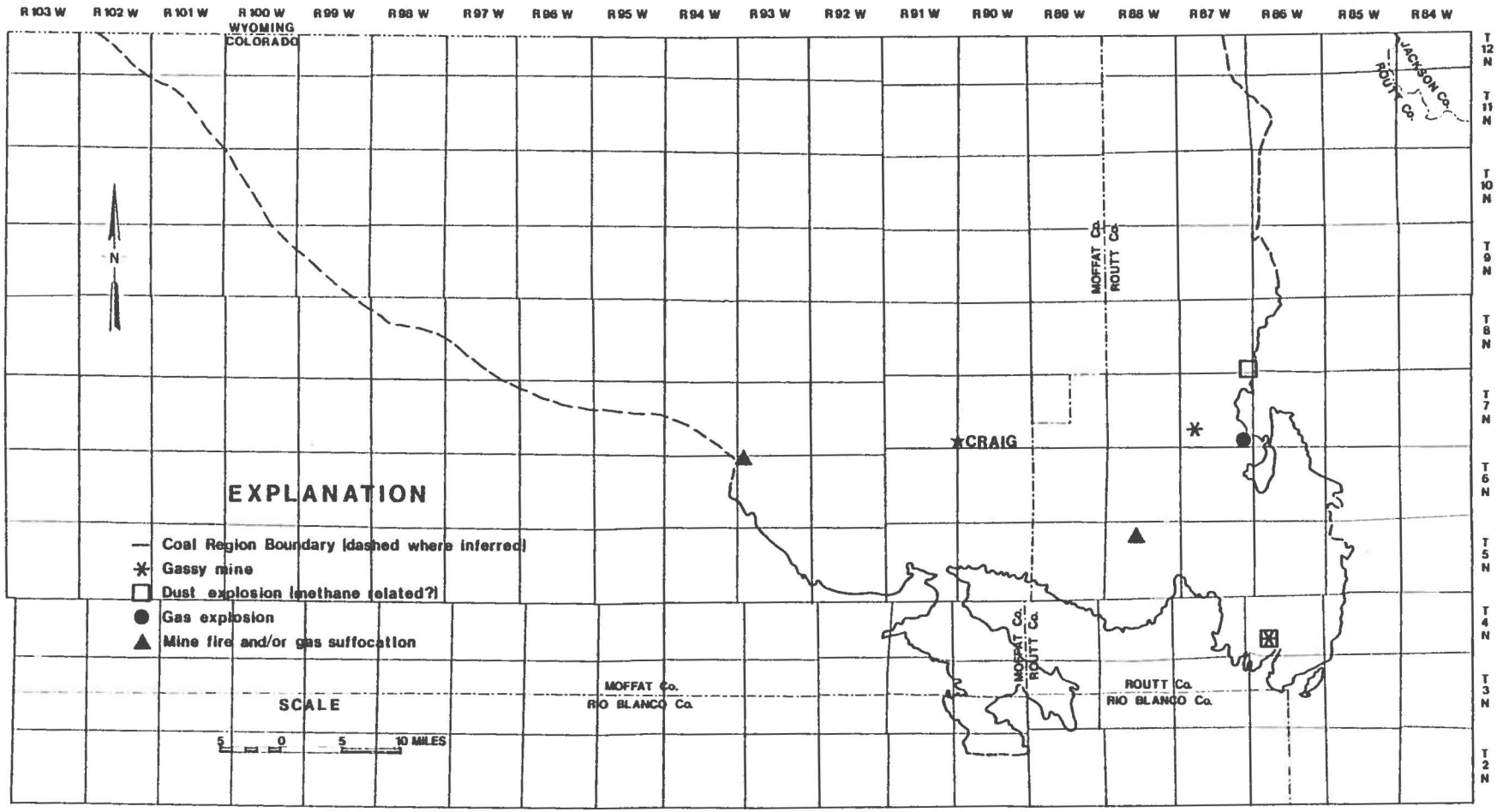


Figure 8. Coal mines with reported gas occurrences in the Green River coal region, Colorado (after Fender and Murray, 1979, Plate 1).

TABLE I
Green River coal region desorption data.

TEST NO.	FORMATION NAME	DEPTH TO COAL BED (FT)	BED THICKNESS (FT)	TOTAL GAS (cc/g)	TOTAL GAS (cf/t)	APPARENT RANK OF COAL	% METHANE IN GAS	HEATING VALUE OF GAS (Btu/cf)
1	Williams Fork	1283	11.5	NC2	NC	hvCb		
2	Williams Fork	1393	11.0	.48	15	hvCb		
3	Williams Fork	488	1.3	NC	NC	hvCb		
4	Williams Fork	335	8.5	.24	8	hvCb		
5	Williams Fork	1104	4.5	NC	NC	hvCb		
6	Williams Fork	1123	9.7	NC	NC	hvBb		
7	Williams Fork	176.5	20.6	0.11	4	subA-hvCb		
8	Williams Fork	644.0	3.6	0.09	3	hvCb		
9	Williams Fork	720.9	3.0	0.0	0	hvCb		
10	Williams Fork	766.3	9.0	0.50	16	hvCb		
11	Williams Fork	799.8	7.3	0.18	6	hvCb		
12	Williams Fork	3660	3	7.84	251	hvBb	81.78	825
13	Williams Fork	3663	6	0.58	18	shale	53.21	538
14	Williams Fork	3684	4	7.99	256	shale		
15	Williams Fork	3929	5	3.77	121	hvBb		
16	Williams Fork	3947	.2	3.86	124	hvBb		
17	Williams Fork	3958	1	2.72	87	hvBb		
18	Williams Fork	4658	15.6	9.01	288	hvBb		
19	Williams Fork	4658	15.6	8.41	269	hvBb		
20	Williams Fork	4658	15.6	9.26	296	hvBb		
21	Williams Fork	4658	15.6	9.4	301	hvBb		
22	Williams Fork	4658	15.6	8.56	274	hvAb	74.41	769
23	Williams Fork	4658	15.6	10.08	322	hvBb		
24	Williams Fork	4716	10	10.50	336	hvAb	69.45	741
25	Williams Fork	4716	10	11.76	376	hvBb		

1. blanks indicate gas analyses not run
2. NC = not calculated

Gas Shows in Drill Holes

Coal bed gas shows in oil and gas drill holes throughout the basin supplement the gas occurrence data from coal mines and desorption measurements. Five different types of these gas shows are indicated on Plate 1, Map B and summarized below:

1) Mud log shows occur in coals in 21 holes indicated on Map B. The shows are in all four coal bearing formations across the study area and at depths of 1000-9000 ft.

2) Mixed coal and sandstone zones were drill stem tested in 26 holes. Sixteen of the holes reported gas shows ranging from slightly gas cut mud to 1074 MCFGPD (thousand cubic feet of gas per day) in Hole #418.

3) A 15 foot coal bed in Hole #176 was fraced and production tested. However, a 24 hour test yielded only .5MCFG and $\pm$ 6 BW (barrels of water).

4) The two production tests in mixed sandstone and coal zones were more successful, yielding 5690 MCFGPD in Hole #459 and 2500 MCFGPD and 144 BO (barrels of oil) in Hole #420.

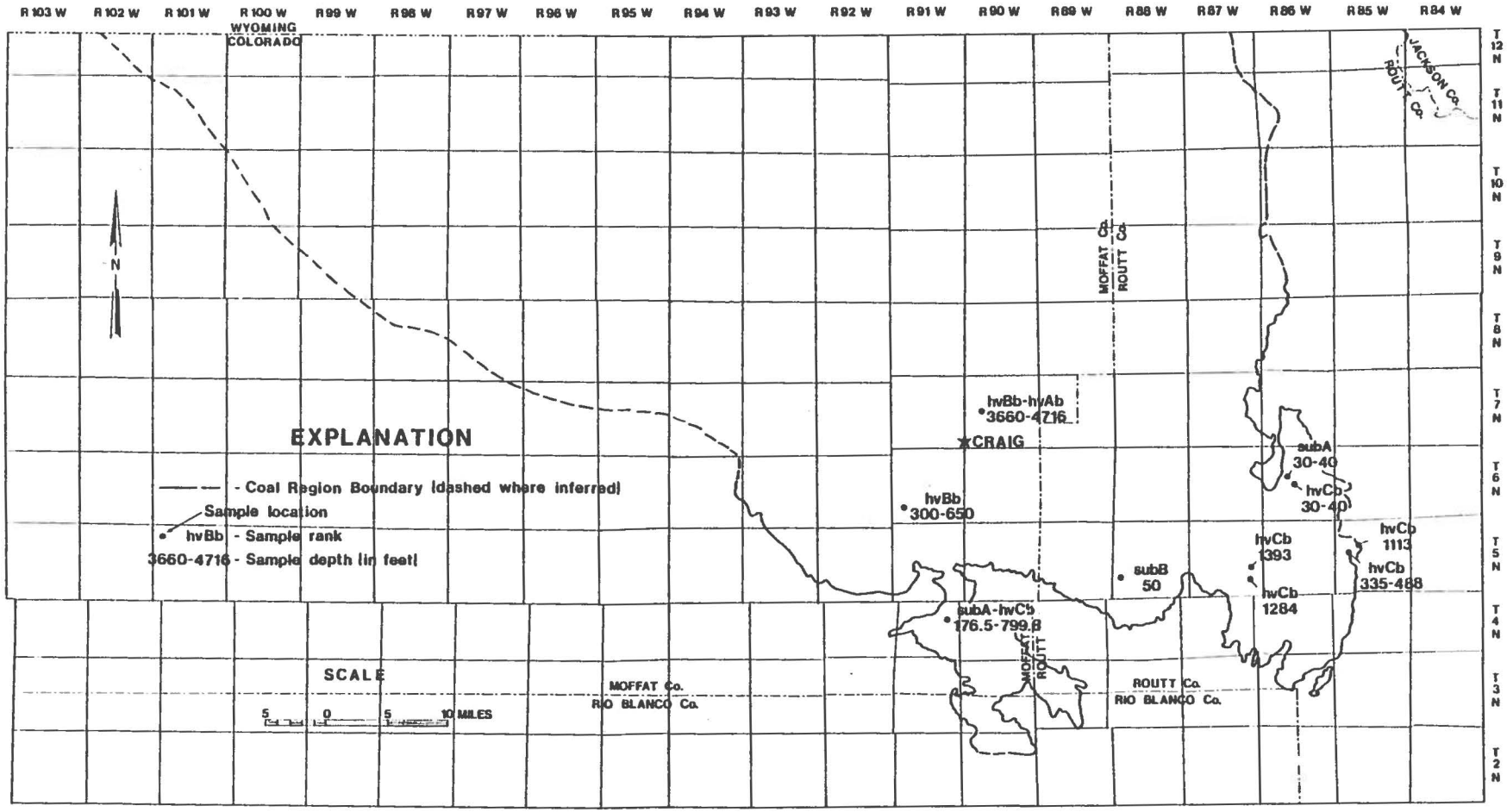


Figure 9. Coal sample ranks and depths in the Green River coal region, Colorado. All samples are from the Mesaverde Group.

5) Nine wells had production tests solely in sandstones sandwiched between coal bed source rocks. Initial productions ranged from 495 MCFGPD + 650 BOPD (Hole #410) to 5690 MCFGPD (Hole #459).

Details of these shows are listed in Appendix 2, with well names and locations listed in Appendix 3.

Methane Resource Estimates

Although mud logs and/or desorption data indicate gas generation by fairly shallow Mesaverde, Lance, and Fort Union coals, these coals were not considered likely to have very high gas contents. No gas content data was available for the deeper Lance and Fort Union coals. Therefore, methane resources were only estimated for the Mesaverde coals in the 414 sq mi area shown in Plate 2, Maps A and B. This area was delineated since it contained: 1) sufficient drill hole and gas content data, 2) the greatest known net thickness of Mesaverde coals, and 3) coals sufficiently deep to retain gas. The boundaries of the area were formed by simply connecting the drill holes in which the majority of the Mesaverde coals are at depths of 5000 ft or greater. If the 34.5 billion short tons of coal in this area are assumed to contain coal with an average gas content of 400 cf/t (a reasonable assumption from Table 1), then nearly 14 trillion cubic feet of gas could be present in the area.

In addition, new data in the vast unexplored Mesaverde area shown on Plate 2, Map B could increase the gas resources in the Mesaverde Formation. Furthermore, although the available data indicates these deep Mesaverde coals have the best current potential for development, more favorable economic conditions could make shallower coals possible targets.

CONCLUSIONS

Although excessive coal bed methane generation may not be too serious a problem for coal mines in the Sand Wash Basin, methane from deep coals could provide an additional source of natural gas in the basin. Not only coals, but also adjacent sandstones charged with coal generated gas could become significant in the gas producing future of the sand Wash Basin.

DISCLAIMER

"Part of this report was prepared with the support of the U.S. Department of Energy (DOE), Grant No. DE-FG21-80MC14256.

However, any opinions, findings, conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of DOE."

REFERENCES CITED

Beaumont, E.A., 1979, Depositional environments of Fort Union sediments (Tertiary northwest Colorado) and their relation to coal: Am. Assoc. Petroleum Geologists Bull., vol. 63, no. 2, p. 194-217.

Boreck, D.L., and Murray, D.K., 1979, Colorado coal reserves depletion data and coal mine summaries: Colorado Geol. Survey Open-File Rept. 79-1, p. 47-50.

Diamond, W.P., and Levine, J.R., 1981, Direct method determination of the gas content of coal: procedures and results: U.S. Bur. of Mines Rept. Inv. 8515, 36 p.

Dolly, E. D., and Meissner, F.F., 1977, Geology and gas exploration potential, Upper Cretaceous and Lower Tertiary strata, northern Raton Basin, Colorado, in Exploration frontiers of the Colorado and Southern Rockies: Rocky Mtn. Assoc. Geologists, p. 247-270.

Fender, H.B., and Murray, D.K., 1978, Data accumulation on the methane potential of the coal beds of Colorado: Colorado Geol. Survey Open-File Rept. 78-2, p. 25.

Haun, J.D., 1962, Introduction to the geology of northwest Colorado in Exploration for oil and gas in northwestern Colorado: Rocky Mtn. Assoc. of Geologists, p. 7-14.

Kissell, F.N., McCulloch, C.M., and Elder, C.H., 1973, The direct method of determining methane content of coalbeds for ventilation design: U.S. Bur. Mines Rept. Inv. 7767, 17 p.

Landis, E.R., 1959, Coal resources of Colorado: U.S. Geol. Survey Bull. 1072-C, p. 131-232.

Law, B.E., Spencer, C.W., and Bostick, N.H., 1980, Evaluation of organic matter, subsurface temperature and pressure with regard to gas generation in low-permeability upper Cretaceous and Lower Tertiary sandstones in Pacific Creek area, Sublette and Sweetwater Counties Wyoming, in The Mountain Geologist, vol. 17, no. 2, p. 23-25.

McPeek, L.A., 1981, Eastern Green River Basin: a developing giant gas supply from deep, overpressured Upper Cretaceous sandstones: Am. Assoc. Petroleum Geologists Bull., vol. 65-6, p. 1078-1098.

Murray, D.K., 1980, 1979 Summary of coal resources in Colorado: Colorado Geol. Survey Special Publication 13, 24 p.

Tremain, C.M., Boreck D.L., and Kelso, B.S., 1981, Methane in Cretaceous and Paleocene coals of western Colorado, in New Mexico Geological Society Guidebook, 32nd Field Conference, Western Slope Colorado, p. 241-254.

Tweto, Ogden, 1975, compiler, Preliminary geologic map of east half of Vernal 1° x 2° Quandrangle, Colorado, scale 1:250,000, U.S. Geol. Survey Open-File Rept. 75-588.

_____1976, compiler, Geologic map of the Craig 1° x 2° Quandrangle, northwestern Colorado, U.S. Geol. Survey Map I-972, scale 1:250,000.

APPENDIX 1
THE U.S. BUREAU OF MINES DIRECT METHOD

In this method, a coal core sample (approximately 2 lbs in weight) is sealed in an airtight plastic or aluminum cannister and the gas it emits (desorbs) is measured by water displacement in an inverted graduated cylinder (see Figure 10). The coal sample is weighed so its gas content can be stated in cc/g (cubic centimeters/gram) or cf/t. Gas lost by the sample before it is sealed in the cannister can be estimated using a back calculation method. Gas remaining in the structure of the coal sample after natural desportion ceases is measured by crushing the sample in a sealed ball mill and again using water displacement. The desorbed, lost, and remaining gas are all added to give the total gas content. Diamond and Levine (1981) describe the direct method in greater detail.

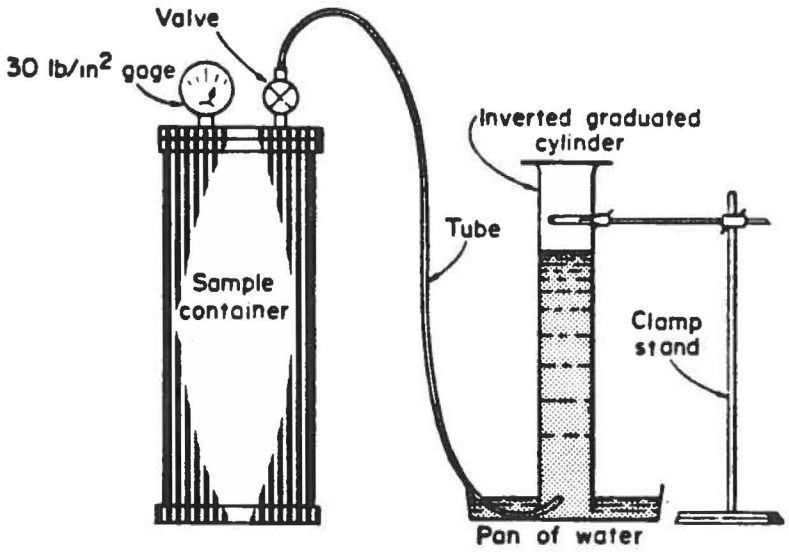


Figure 10. U.S. Bureau of Mines equipment for direct method desorption of coal samples (after Diamond and Levine, 1981, p. 6).

APPENDIX 2

MUD LOG SHOWS IN COALS

Well No.	Details
214a	"3530-3550 Lignite (90 units gas from 3534'-3537'); interbeds siltstone"*
220a	"Slight gas increases were noted thru out the Lance, but most were in coal stringers or beds". "A 200 plus unit gas increase was noted at 3036 to 3044 in a coal seam. Several smaller increases were noted below it, all being in smaller coal seams."
227	1065-1075 Coal to 54 units maximum 1865-1875 Coal to 30 units maximum 2100-2120 Coal to 90 units maximum 2120-2135 Coal to 230 units maximum 2150-2170 Coal to 264 units maximum 4150-4160 Coal to 25 units maximum 4255-4265 Coal to 75 units maximum
278	5065-5125 "Coal blk bldg gas" to 90 unit maximum 6535-6550 " " " to 40 unit maximum 6605-6625 " " " to 90 unit maximum
279	"6660-80 Coal: 15%, black (from very fast drlg at 6620-28) Registered 70 methane units on mud log." "6700-20 Coal: 10%, black, (from fast drilling 6664-68). Registered 95 methane units on mud logger" "8756-59 Coal: with interbedded ss. 35 unit gas kick from coal" "9087-9095 Coal: 22 unit gas kick 9107-09 Coal: 18 unit gas kick 9149-50 Coal: 14 unit gas kick 9216-20 Coal: 45 unit gas kick 9232-34 Coal: 15 unit gas kick 9236-38 Coal: 11 unit gas kick"
283	5130-5150 "Coal sbbit, bldg gas," to 130 unit maximum 5200-5225 "Coal sbbit, bldg gas," to 30 unit maximum 5460-5485 "Coal sbbit, bldg gas," to 25 unit maximum 6552-6570 "Coal bit, bldg gas," to 65 unit maximum 6680-6692 "Coal sbbit-bit, bldg gas," to 175 unit maximum 6725-6750 "Coal bit, bldg gas," to 155 unit maximum

```
291    5265-5290  "Coal"  to 10 unit maximum
       5340-5360  "Coal"  to 10 unit maximum
       5665-5680  "Coal"  to  6 unit maximum
       5700-5705  "Coal"  to 10 unit maximum
       5735-5745  "Coal"  to 20 unit maximum
       6610-6615  "Coal"  to 11 unit maximum
       6625-6630  "Coal"  to 12 unit maximum
       6670-6675  "Coal"  to 15 unit maximum
       6680-6685  "Coal"  to 40 unit maximum
       6715-6730  "Coal"  to 60 unit maximum
       6750-6760  "Coal"  to 60 unit maximum

320    4950-4995  "Coal"  to 60 unit maximum

323    4980-5040  "Coal blk bldg gas" to 120 unit maximum

326    5075-5100  "Coal blk bldg gas"  to 60 unit maximum
       5155-5180  "Coal blk bldg gas"  to 60 unit maximum
       6625-6635  "Coal blk bldg gas"  to 15 unit maximum

331   "5760-5765  20  Total gas units   Coal - Fort Union
       6800-6805  16  Total gas units   Coal - Lance
       6845-6848  25  Total gas units   Coal - Lance
       6898-6900  16  Total gas units   Coal - Lance
       6922-6924  10  Total gas units   Coal - Lance
       6930-6932  14  Total gas units   Coal - Lance
       6950-6954  22  Total gas units   Coal - Lance
       6991-6993  160 Total gas units   Coal - Lance
       7049-7053  40  Total gas units   Coal - Lance
       7065-7070  36  Total gas units   Coal - Lance"

334   "5160-5170  20  Total gas units   Fort Union formation, coal.
       5220-5230  18  Total gas units   Fort Union formation, coal.
       5307-5320  33  Total gas units   Fort Union formation, coal.
       5360-5365  35  Total gas units   Fort Union formation, coal.
       6800-6805 300  Total gas units   Lance formation, coal.
       6865-6870 100  Total gas units   Lance formation, coal."

340   "5589-5603  48 units   1st Tfu coal
       5640-5650  40 units   2nd Tfu coal
       5673-5675  11 units       Tfu coal
       5780-5788  30 units       Tfu coal
       5995-6000  20 units       Tfu coal
       6910-6915  20 units       Kl coal
       7090-7095  14 units       Kl coal
       7150-7155  20 units       Kl coal
       7180-7184  18 units       Kl coal
       7195-7197  26 units       Kl coal
       7255-7260  10 units       Kl coal"

363    1910-1930  to 260 unit maximum "Coal"
       2060-2090  to 200 unit maximum "Coal"
```

368	"8125-8128	Coal...8 unit increase over 4 unit background"
	8136-8138	Coal...28 unit increase over 4 unit background:
	8257-8260	...Probably coal, 68 unit increase over 2 unit background
	8382-8388	...Probably coal, 60 unit increase over 8 unit background
	8416-8420	...Probably coal, 59 unit increase over 6 unit background
	8433-8437	...Probably coal, 90 unit increase over 10 unit background"
	8519-8521	Coal...10 unit increase over 6 unit background
	8546-8559	Coal...bleeding gas, 144 unit increase over 6 unit background: 13,700 PPM Methane, 4164 PPM Ethane, 325 PPM Propane, 105 PPM Butane"
482	no details	
485	"1370-1380	Coal...140 unit gas kick"
496	no details	
497	"4606-4613	Coal 88 units total gas above background
	4774-4778	Coal 17 units total gas above background
	4839-4841	Coal 16 units total gas above background
	4851-4852	Coal 11 units total gas above background
	6421-6426	Coal 92 units total gas above background
	6494-6500	Coal 200 units total gas above background"
508	"4815-4822	Coal seam - very gassy."
619	"Coal, lignitic, ... building gas... 3090-3100"	

*Quotes mark direct quotations from mud logs; unquoted material is author's interpretation of mud logs.

DRILL STEM TESTS OF ZONES CONTAINING COAL

Well No.	Details
18	"DST 1342-86, op 10 SI 30, op 60, SI 90, rec. 55 fluid, FP 18-24, SIP 496-439, HP 674-684, no further details."* (3' coal @ 1353')
176	"DST 3709-3809, IF op 5 min, FP 59-70 psi; ISI 20 min, ISIP 426 psi; FF 60 min, FFP 82-110 psi; FSI 240 min, FSIP 1591 psi; Rec 256' of mud cut water - no GTS" (5' coal @ 3727', 4' coal @ 3742')
**	"DST 4646-4726, IF op 5 min, IFP 118-331 psi; ISI 20 min, ISIP 2011 psi; FF op 60 min, 1/8" ck, 313-1964 psi, GTS at end of 58 min; FSI 240 min, FSIP 2020 psi; Rec. 1478' of mud and gas cut water, 1477' of gas cut water" (14' coal @ 1458')

222a	"DST 3902-4007, op 10, SI 60, op 60, SI 190, rec 110 SGCM, FP 65-55, 69-77, SIP 347-470, HP 1906-1877". (4' coal @ 3090')
236	"DST 4150-4250, SI 45 mins., open 1 hr 15 mins, SI 1 hr 30 mins, rec 550 WCM, 3225 fresh wtr, FP 577-1722#, SIP 1722-1722" HP 2263-2244#" (4' coal @ 4744')
249	"DST 6195-6245 op 10, SI 60, op 60, SI 120, GTS in 5 min @ 79 MCFGPD, rec 90 GCM, FP 42-50, SIP 2070-2258, HP 3009-2997" (4' coal @ 6733')
250**	"DST 2178-2201, 1 hr, weak blow thruout, rec 265 sli GCM, FP 106-147#, SIP (30 min) 966-685#, HP 115#." (4' coal @ 2182', 10' coal @ 2194')
307	"DST 6374-6675, SI 30 mins, open 1 hr, SI 90 mins, rec 1800 sli GCM, 780 GCM, 268 HGCM, FP 1370-1547#, SIP 2880-2686#, HP 3255-3216#." "Wireline test 6382 1/2-85, rec 1.35 cu ft shot gas 4200 cc wtr, SIP 2875-2755#, HP 3175#. Wireline test 3787-89 1/2, rec 3450 cc wtr, FP 5#, SIP 1305-1305#, HP 1840#." (6' coal @ 6449', 4' coal @ 6588)
308**	"DST 2420-2525 op 16, SI 60, op 30, SI 64 rec 403 mud, FP 426-807, 390-800 SIP 891-819, HP 1226-1185." (4' coal @ 2446', 10' coal @ 2504') "DST 6540-6750, op 15, SI 60, op 60, SI 180, rec 1325 SGCM, 134 GCM, 132 mud, FP 131-110, 185-231, SIP 2177-1591, HP 3223-3214." (3' coal @ 6565', 2' coal 6574', 6' coal @ 6582', 4' coal @ 6605')
311**	"DST 6482-6507, op 10 min. SI 30 min, op 1 hr, SI 5 hr, rec 115 mud, FP 35-83#, 83-83#, SIP 14-2419#, HP 3147-3147# (4' coal @ 6491')
368*	"DST 8469-97, op 1 hr, SI 1 hr, op 1 hr, SI 2 hr rec 210 SGCM, 820 SM & HGCW, FP 353-307#, 353-323#, SIP 35-78#, HP 4427-4349#." (10' coal @ 8478')
371	"DST 8515-8616, GTS in 45 min @ 10 MCFGPD, misrun. DST 8518-8616, op 15, SI 75, op 60, SI 180, GTS @ 20.7 MCFGPD, rec 1000 GC mdy wtr, 1800 wtr, FP 378-445, 1000-1202, SIP 3237-2732, HP 4212-4212." (3' coal @ 8580')
394	"DST 5691-5780, SI 30 mins, open 30 mins, SI 1 hr rec 60 SGCM, FP 59-56#, SIP 80-80#, HP 2986-2975W#" (6' coal @ 5740')

408**	"DST 6605-44 op 45 mins, SI 1 hr, op 1 hr. SI 90 mins, gas in 22 mins gauged 63 MCFGPD @ end of test rec 60 mud, FP 43-71#, SIP 2475-2432#, HP 3511-3439#." (5' coal @ 6632')
409	"DST 6620-60, SI 1hr, op 2hr, SI 4hr, rec 30 mud, FP 45-60# SIP 120-150#, HP 3525-3495#." (2' coal @ 6658')
418	"DST 6695-6959, SI 30 mins op 1 1/2hrs, SI 1 hr, gas in 5 mins @ 1074 MCFGPD rec 750 HGCM w/trace oil, FP 189-414#, SIP 2588-2466#." (5' coal @ 6820', 8' coal @ 6840', 8' coal @ 688', 4' coal @ 6912')
431	"DST 7325-7403, op 2 1/2 hrs, SI 1 1/2 hrs, rec 190 sli O & G CM, FP 102-131#, FSIP 971#." (4' coal @ 7394')
481	"DST 3555-3664, SI 1 hr, open 1 hr, SI 1 hr, gas in 32 mins too small to measure, rec WCM, 2650 fresh wtr, FP 535-1350# SIP 1162-1162#, HP 2059-2048#." (7' coal @ 3564')
510	"DST 6092-6197, op 2 hrs, SI 1 hr, rec 200 mud, FP 151-194# SIP 863#." (6' coal @ 6118')
	"DST 6324-6489, op 1 3/4hrs, SI 1 hr rec 300 SG&WCM, 770 GCM salt wtr, FP 73-484#, SIP 2441#." (6' coal @ 6460')
530	"DST 6114-59, SI 45 mins op 30 min SI 5 mins. rec 110 mud, FP 60-60#, SIP 180-105#, HP 3152-3137#." (3' coal @ 6140')
531**	"DST 6226-6376, 1 hr, rec 120 mud, FP 87-87#, SIP (60 min) 140#, HP 3305#." (5' coal @ 6240', 4' coal @ 6270', 7' coal @ 6375')
542**	"DST 2229-65, op 30 mins, SI 45 mins op 45 mins, SI 60 mins rec 30 mud, 1400 wtr, FP 135-520#, 533-648#, SIP 667-667#, HP 1155-1140#." (4' coal @ 2262')
559	"DST 5552-5621, op 60 min, strong blow. Rec 100' sli gas-cut mud and 700' sli gas-cut salt wtr." "FP 500# SIP 2200#." (Coal @ 5670-5')
**	"DST 6655-6705, op 60 min, good puff, fair blow rec less than 90' mud, FP 95#, SIP 118#." (Coal @ 6560-10')

	"DST 3007-67, op 30 min, SI 89 min, op 121 min, SI 242 min, rec 312 mud, FP 111-137#, SIP 918-887#, HP 1507-1499#." (4' coal @ 3046')
**	"DST 4882-4910, op 31 min, SI 93 min, op 132 min, SI 220 min, rec 45 mud, FP 40-52#, SIP 1821-1801#, HP 2556-2506#." (5' coal @ 4886')
619	"DST 2900-3005, op 30 mins SI 90 mins, op 120 mins, SI 180 mins, rec 370 O&GCM, FP 36-54, 54-90#, SIP 578-1066#, HP 1374-1356#." (4' coal @ 2942')
658	"DST 2960-3167, op 15 min SI 1 hr, op 1hr, SI 1 hr rec 270 mud, FP 60-150#, SIP 1316-1226, HP 1525-1525#." (6' coal @ 3108, 6" coal @ 3160')
686	"DST 3668-3718, op 30 mins, SI 90 mins, op 75 mins, SI 3 hrs rec 470 SGCM, FP 124-139, 161-188#, SIP 1581-1600# HP 1830-1830#." (6' coal @ 3696')

* quoted material from PI completion cards ** coal forms 10% or more of DST interval

PRODUCTION TESTS IN COAL BEDS

Well No.	Details
176	Perf: 4863-4873 w/2JSPF. Fraced w/57,920 gals Versagel + 67,200# 10-20SD + 920 MCF of N_2 IP 12-28-79 24 hr test OBO, .5MCF, 6 $\pm$ BW, P&A (15' coal @ 4862')

PRODUCTION TESTS IN MIXED SANDSTONE AND COAL ZONES

Well No.	Details
420	"Perf: 6780-96 w/2 pf. Sdoilfract. Perf 6598-6615 w/2 pf. Sdoilfract. Perf 6472-94 w/2 pf. Sdoilfract. IPF 144 BO, 2500 MCFGPD, TP 25#, CP 1550#." (6' coal @ 6790')
459	"Perf: 5028-66, 5070-79, 5089-5100, 5118-60 w/4 per ft; Sd oil fract. 1PF 5690 MCFGPD, 20/64"ck." (4' coal @ 5118)

WELLS PRODUCING FROM SANDSTONES IN COAL BEARING ZONES

Well No.	Details
410	"Prod. Zone: Wasatch 3518-46. Ft. Union 6224-6494 gross" "Init Prod: IPF 650 BOPD, 495 MCFGPD (natural)." IPF 1750 MCFGPD (Natural)." (8' coal @ 6375')
418	"Prod Zone: Ft. Union 6704-7141." "Init Prod: IPF 30 BO, 1880 MCFGPD 12/64" CK, TP 1975# CP 2150#." (5' coal @ 6820', 8' @ 6840', 8' @ 6888, 4' @ 6912, 5' @ 6980', 5' @ 7010', 4' @ 7040', 10' @ 7060, 10' @ 7105')
420	"Prod Zone: Ft Union 6472-6796." "Init Prod: IPF 144BG, 2500 MCFGPD, TP 25# CP 1550#." (6' coal @ 6790')
421	"Prod Zone: "Fort Union 6580-6978." "Init Prod: IPF 32 BO, 1536 MCFGPD, TD 1650#, CP 1950#, COR 480001, 44 gty. (SI gas well)." (4 coal @ 6785', 4' @ 6846', 6' @ 6880', 6' @ 6900', 6' @ 6920')
459	"Prod Zone: "Mesaverde 5028-5160." "Int. Prod:" "IPF 5690 MCFGPD, 20/64"ck." (4' coal @ 5118, 6' coal @ 5108')
549	"Prod Zone:" Ft Union 6187-6648 (gross)" "Int Prod:" "IPF 3360 MCFGPD." (5' coal @ 6299')
619	"Prod Zone:" Ft Union 3520-4515 (gross)" "Init Prod: "IPF 1979 MCFGPD." (2' coal @ 3632, 5' coal @ 3748', 10' coal @ 4448)
652	"Prod Zone: Ft Union 4462-4719 Wasatch 3015-80" "Init Prod: 1PF 1497 MCFGPD, 3/4" ck, TP 62#; IPF 116 BOPD, 3BWPD, CP 40#, 43 gty, GOR 302-1." (4' coal @ 4642')
669	"Prod Zone: Ft Union 4262-4750." "Init Prod: 1PF 4418 MCFGPD, 3/4" ck, TP 180#, CP 550#." (4' coal @ 4509')

APPENDIX 3

C.G.S. NUMBERED WELLS, NAMES, AND LOCATIONS

CGS Well No.	Well Name	Location Qtr Qtr Sec. Twp. Rge.
18	Southland Royalty 1 Dry Creek Unit	e/2 nw, 22, 5n, 88w
100	Energy Reserves Group 1 John Eilts	nw nw, 23, 6n, 87w
113	Trend Exploration Ltd. 1-6 State	ne se, 6, 6n, 89w
115	Trend Exploration 1-15 State	nw ne, 15, 6n, 89w
116	Trend Exploration 1 Lyons	sw sw, 29, 6n, 89w
129	Trend Exploration 1-16 State	sw ne, 16, 6n, 90w
135	Malco Ref. 1 Paulovich	c nw sw, 24, 6n, 90w
138	Malco Ref. 1 Kowach	c nw nw, 25 6n, 90w
144	Cabeen Exploration 1 Seeley	nw ne, 31, 6n, 90w
147	Trend Exploration Bilsing 1-8	sw sw ne, 8, 6n, 91w
153	Hyland Oil & Gas 1-4 Govt	c se sw, 4, 6n, 92w
159	Fuel Res. Dev. 3-1 Robertson	se sw, 3, 6n, 92w
160	Fuel Res. Dev. 10-1 Robertson	nw nw, 10, 6n, 92w
168	Texas Pacific Oil 1 Bear	nw ne, 26, 7n, 89w
170	Chandler & Assoc. 2-5 Pleasant	nw ne, 5, 7n, 90w
176	Engery Reserves Group 1 Van Dorn	sw sw, 29, 7n, 90w
177	Great Western Drilling 1 Beckett	se nw, 6, 7n, 91w
179	Pan American Pet 1 Dorough-Govt	c se sw, 3, 7n, 92w
184	Fuel Res. Dev. 1 Big Gulch-Fed.	se sw, 11, 7n, 93w
192	Tesoro Pet 2-21 Culverwell et al.	e 2 nw, 21, 7n, 93w
196	U.S. Smelting, Refining & Mining 2 Federal-McIntyre	se sw, 3, 7n, 94w
197	U.S. Smelting, Refining & Mining 1 Federal-McIntyre	se sw nw, 3, 7n, 94w
198	McMoran Exploration 15-1 USA	nw nw, 15, 7n, 94w
203	Great Eastern Energy & Dev. 1-34 Federal	sw ne, 34, 8n, 87w
205	Jerry Chambers 1-14 Murphy Ranch-Govt	ne sw, 14, 8n, 88w
206	Forest Oil 22-1 Panak	sw sw, 22, 8n, 89w
207	Chandler & Assoc. 4-13 Zschach	nw nw, 13, 8n, 90w
207e	Chandler & Assoc. NE Craig State 14-15	se sw, 15, 8n, 90w
208	Chandler & Assoc. 16-10 Hutchers	se se, 10, 8n, 90w
209	Chandler & Assoc. 8-22 State	se ne, 22, 8n, 90w
210	Chandler & Assoc. 15-22 McWilliams	sw se, 22, 8n, 90w
211	The Carter Oil Co. 1 Unit	c se se, 30, 8n, 90w
213	CIG Expl. 1-2-8-91 Visintainer Sheep	ne sw, 2, 8n, 91w
214	C & K Pet 1 Stouffer-Federal	sw ne, 12, 8n, 91w
214a	Anadarko Prod. Co. APC #1 Smith "A"	se sw, 15, 8n, 91w
218	Mountain Fuel Supply 2 Cottonwood Gulch Unit	ne nw, 17, 8n, 91w
220a	Anadarko Prod. Co. Smith "B"-1	nw se sw, 24, 8n, 91w
221	Anadarko Prod. Co. A-1 Federal	se ne, 25, 8n, 91w
222	Anadarko Prod. 2 Cottonwood Gulch Federal-A	ne sw, 25, 8n, 91w
222a	Anadarko Prod. Co. 1 Cottonwood Gulch-Federal-B	ne ne, 26, 8n, 91w

222b	Anadarko Prod. Co. Cottonwood Gulch-Fed-C-1	se ne, 35, 8n, 91w
226	Sun Oil 1 Lowe	sw ne, 6, 8n, 92w
227	Texas Gas Exploration 1 Federal	se sw, 18, 8n, 92w
231	Sinclair Oil & Gas 1 C. Sturman Estate	c ne ne, 23, 8n 92w
232	Fuel Res. Dev. 1 Morgan	sw sw, 12, 8n, 93w
234	Humble Oil & Refining 1 Lay Creek	nw se, 13, 8n, 93w
235	Imperial Amer. Management 2 Lay Creek Unit	sw ne, 14, 8n, 93w
236	Belco Pet 1 Peroulis	sw ne, 24, 8n, 93w
238	U.S. Smelting, Refining & Mining 1-31 Govt	nw nw, 31, 8n, 94w
240	J.M. Huber Corp; Wainoco, Inc. 3 Godiva Rim	ne ne, 27, 8n, 96w
244	Gulf Oil 1 Madera-Federal	se nw, 16, 9n, 88w
247	Murfin & Sutton 1 Govt	c se sw, 35, 9n, 89w
248	CIG Exploration 3-9-90 Villard-Little Buck Mtn.	se ne, 3, 9n, 90w
249	Cities Service Oil CD-1 Daniels-Federal	ne nw, 6, 9n, 90w
250	Gulf Oil 3 Madera	c nw nw, 8, 9n, 90w
251	Colorado Oil & Gas 31-9 AXY-Fed.	nw ne, 9, 9n, 90w
253	Occidental Pet 1 Govt	nw nw, 23, 9n, 90w
254	Gulf Oil 2 Madera-Federal	ne ne, 26, 9n, 90w
259	Equity Oil; C & K Pet. 1 Federal 7-20	sw ne, 20, 9n, 91w
260	Equity Oil; C & K Pet. 1 Federal 4-22	ne nw, 22, 9n, 91w
264	C & K Petroleum 2 23X Federal	se nw, 23, 9n, 91w
267	Jack Grynberg & Assoc. 1-24 Govt	ne sw, 24, 9n, 91w
270	C & K Pet 1-26 Federal	se nw, 26, 9n, 91w
271	Jack Grynberg & Assoc. 1-36 State-Blue Gravel	ne nw, 36, 9n, 91w
272a	Devon Corp. Housel Gulch Fed 1-4	w 2 se, 4, 9n, 92w
273a	Champlim Petrol. Co. CPC 11-20 Villard	nw nw, 20, 9n, 92w
274	Lion Oil (Monsanto) 1 Evertson	c sw ne, 31, 9n, 92w
275	Champlin Petrol. 1 CPC 14-2 Wilson	sw sw, 2, 9n, 93w
278	Northwest Expl. 1 Bruder	ne ne, 4, 9n, 93w
279	Northwest Expl. 1 Weaver	ne sw, 4, 9n, 93w
280	Northwest Expl. 1 Randolph	se ne, 5, 9n, 93w
283	Northwest Expl. 1-Beckett	ne ne, 9, 9n, 93w
288	Kemmerer Coal Co. 12-1 Govt	sw ne, 12, 9n, 93w
290	Champlin 1-Champlan Sunmark	se nw, 24, 9n, 94w
291	Quadrant Oil; Westrans Pet 32-27 Govt	sw ne, 27, 9n, 94w
292	Quadrant Oil 14-11 State Game & Fish-G	sw sw, 11, 9n, 95w
293	J.M. Humber Corp; Wainoco Inc. 30-1 Godiva Rim	sw ne, 30, 9n, 95w
294	C & K Pet 1-19 Gulf-Federal	e 2 ne, 19, 9n, 96w
303	Pan Amer. Pet. 1 USA-R.G. Davis	se sw, 14, 10n, 90w
305	Anadarko Prod. 1-27 Villard	sw sw, 27, 10n, 90w
307	Belco Petroleum 1 Welba Peak Unit	sw sw, 28, 10n, 90w

308	Anadarko Prod. 1-33 Villard-B	se ne, 33, 10n, 90w
310	Pan Amer. Pet. 1 USA-Yates	nw nw, 12, 10n, 91w
311	Tenneco Oil 1 Mud Springs	sw nw, 14, 10n, 91w
312	The California Co. 1 State	ne se, 16, 10n, 91w
313	Wainoco; J.M. Huber Corp. 25-1 Fortification-Federal	sw nw, 25, 10n, 91w
314	Midwest Oil; Kewanee Oil; Jack Grynberg 1 Baggs Land & Livestock	se se, 8, 10n, 92w
316	J.M. Huber Corp; Wainoco Inc. 3 Timberlake	sw ne, 15, 10n, 92w
317	Tenneco Oil 1-10 Pilgrim	c sw, 10, 10n, 93w
318	Mountain Fuel Supply 1 Great Divide Unit	se nw, 17, 10n, 93w
319	The California Co. 1 Calco-Govt.	nw nw, 18, 10n, 93w
320	Sun Oil Co. 1-27 Federal C-4654	nw sw, 27, 10n, 93w
321	Sun Oil 2-27 Mtn. Fuel-Federal	sw sw, 27, 10n, 93w
323	Northwest Expl. 1 Natural Res.	ne sw, 28, 10n, 93w
325	Mountain Fuel Supply 2 Great Divide Unit-Govt	sw ne, 30, 10n, 93w
326	Northwest Exploration 1 Sterrett	se ne, 32, 10n, 93w
327a	Tenneco Oil 1 Martin	c sw, 33, 10n, 93w
327b	Northwest Expl. Elbert Ave. 1	sw ne, 33, 10n, 93w
328	Sun Oil 1-34 Mar-Win Little	ne ne, 34, 10n, 93w
330	Kemmerer Coal 9-1 Govt	se se, 9, 10n, 94w
331	Kemmerer Coal 10-1 Govt	sw sw, 10, 10n, 94w
332	Kemmerer Coal 11-1 Moffat County	sw se, 11, 10n, 94w
333	Kemmerer Coal 13-1 Federal	ne nw, 13, 10n, 94w
334	Kemmerer Coa 14-2 Govt	ne se, 14, 10n, 94w
336	Kemmerer Coal 15-2 Federal Land Bank	ne ne, 15, 10n, 94w
338	Big Hole Ventures 1 Colorado-C	ne ne, 16, 10n, 94w
339	Kemmerer Coal 16-2 State	ne se, 16, 10n, 94w
340	Kemmerer Coal 21-1 Monahan-Govt	ne ne, 21, 10n, 94w
342	Kemmerer Coal 23-1 Federal Land Bank	nw nw, 23, 10n, 94w
346	Jack Grynberg 1 Greasewood-Govt	sw ne, 18, 10n, 95w
347	J.M. Huber Corp; Wainoco Inc. 23-1 Godiva Rim	ne se, 23, 10n, 95w
348	Pacific Natural Gas Exploration 33-29-1 Govt	nw se, 29, 10n, 95w
349	Belco Pet 1-5 Yellow Cat Federal	ne ne, 5, 10n, 97w
349a	Anschutz Corp. USA 4946 #4-9	c nw nw, 10n, 98w
350	The California Co, 1 Calco-Govt	ne nw, 2, 10n, 99w
352	Kirby Pet 1 Gold Blossum-Govt	se se, 9, 11n, 87w
353	Sunray Mid-Continent Oil 1 Colorado-Federal "B"	ne sw, 33, 11n, 87w
355	Kirby Royalties 1 East Gibralter Peak	sw nw, 24, 11n 88w
357	Harper Oil 2 Slater Creek Unit II	ne sw, 5, 11n, 89w
358	Gulf Oil 1 Slater Creek Unit	nw ne, 7, 11n, 89w
359	Kirby Royalties 1 Peek-Govt	nw nw, 31, 11n, 90w
360	Donald I. Foster; Hal A. McVey 5 Four Mile Creek Unit	nw nw, 3, 11n, 91w
363	Empire State Oil 1 State	se ne, 10, 11n 91w

365	Midwest Oil; Skyline Oil 1 Colorado 22-11-91	nw sw, 22, 11n, 91w
366	HLM Drilling; Ashland Oil & Refining 3 Unit	ne ne, 2, 11n, 92w
367	Pure Oil 1 Timberlake Creek-Govt.	se nw, 25, 11n, 92w
368	J.M. Huber, Wainoco Inc. 2-1 Timberlake Unit	ne sw, 2, 11n, 93w
369	Phillips Pet. 1-Moffat A	nw sw, 6, 11n, 93w
370	Champlin Pet 1 CPC Sunmark Expl-14-16 State	sw sw, 16, 11n, 93w
371	J.M. Huber Corp; Wainoco 26-1 Timberlake Unit	nw se, 26, 11n, 93w
374	Davis Oil Company 1 Verna-Fed	se se, 27, 11n, 94w
378	Energy Reserves Group 1-USA-Gebhard	nw se, 11, 11n, 96w
379	Ambassador Oil 1-Unit-State	sw ne, 16, 11n, 96w
394	Mountain Fuel Supply 10 Musser	ne sw, 4, 11n, 97w
408	Mountain Fuel Supply 1 Govt	sw se, 8, 11n, 97w
409	Mountain Fuel Supply 21 B.W. Musser	ne ne, 9, 11n, 97w
410	Mountain Fuel Supply 15 Musser	nw nw, 9, 11n, 97w
418	J.M. Huber Corp 1 Chapman-State	ne se, 16, 11n, 97w
420	J.M. Huber Corp 2 Chapman-State	se sw, 16, 11n, 97w
421	J.M. Huber Corp 2 State	se nw, 16, 11n, 97w
428	Amoco 1 USA Amoco A-B	ne nw, 20, 11n, 97w
431	J.M. Huber Corp 21-1 Chamberlain	ne se, 21, 11n, 97w
445	Champlin Pet 1 USA 41-12	ne ne, 12, 11n, 100w
449	C.R.A. Inc.; Jack Grynberg 1-A Govt	el 2 ne, 17, 11n, 100w
459	Mountain Fuel Supply 10 Govt	se nw, 4, 11n, 101w
464	Grayrock Corp 1-8 Federal	ne sw, 8, 11n, 101w
467	Mountain Fuel Supply 12 Govt	ne sw, 10, 11n, 101w
468a	Chandler & Associates 1-B Nightingale-Govt	nw nw, 11, 11n, 101w
473	Northwest Expl. 1 Cantling Creek	se nw, 35, 12n, 88w
480	Kirby Pet 2 CF&I Corp	ne nw, 24, 12n, 89w
481	Pan American Pet 4 Unit	nw ne, 18, 12n, 91w
482	Pan American Pet 3 Four Mile Creek-Govt	sw nw, 27, 12n, 91w
483	Equity Oil 1 Unit-Govt	ne nw, 31, 12n, 91w
484	Pan American Pet 2 Unit	se ne, 33, 12n, 91w
485	Pubco Pet 4 Pole Gulch Unit-St	ne ne, 13, 12n, 92w
486	Kirby Royalties 5 Pole Gulch Unit	ne nw, 13, 12n, 92w
489	Calvert Drilling & Producing 1 Baggs Land & Cattle	nw ne, 15, 12n, 92w
492	Westrans Pet 11-23 State	nw nw, 23, 12n, 92w
493	Coquina 1 State A	ne nw, 27, 12n, 92w
496	Rainbow Resources 1-19 Federal	sw nw, 19, 12n, 94w
497	Rainbow Resources 24-19 Federal	se sw, 19, 12n, 94w
500	Houston Oil & Minerals 21-27 Federal	ne nw, 27, 12n, 94w
504	Universal Resources 1-15 Govt	ne se, 15, 12n, 95w
505	True Oil 1-19 Govt	sw se, 19, 12n, 95w
506	Wolf Exploration 1 Union et al Govt	se se, 21, 12n, 95w

508	Wolf Exploration 2 Union Govt	ne ne, 24, 12n, 95w
509	Houstion Oil & Minerals 42-28 Federal	se ne, 28, 12n, 95w
510	J. M. Huber Corp. 1 Kemmerer-Govt	se sw, 14, 12n, 96w
530	Mtn. Fuel Supply 9 Unit	sw nw, 27, 12n, 97w
531	Mtn. Fuel Supply 1 Jacks Draw Unit	c sl 2 se, 27, 12n, 97w
542	Mtn. Fuel Supply 8 Donnell-Govt	nw se, 29, 12n, 97w
549	Mtn. Fuel Supply 11 Donnell-Govt	ne se, 30, 12n, 97w
559	Mtn. Fuel Supply 8 Carl Allen	ne ne, sw, 32, 12n, 97w
580	George R. Brown 1 Federal	sw sw, 34, 12n, 98w
589	Champlin Pet 2 Shell Creek Unit	se se, 27, 12n, 99w
599	Mtn. Fuel Supply 24F Wilson-Govt	nw ne, 14, 12n, 100w
619	Mtn. Fuel Supply 22 Wilson	se ne, 22, 12n, 100w
652	Texaco Inc 5 Schaick-B Govt	nw nw, 28, 12n, 100w
658	Texaco Inc 7 Van Schaick-B NCT-2	se ne, 29, 12n, 100w
669	Texaco Inc 2 Van Schaick-Govt	ne se, 23, 12n, 101w
684	Texaco Inc 1 Govt A-D	se se, 27, 12n, 101w
686	Mtn. Fuel Supply 13 Sugarloaf-Govt	sw nw, 33, 12n, 101w
695	Texaco Inc 1 Diamond Unit	nw nw, 36, 12n, 102w

4539/5

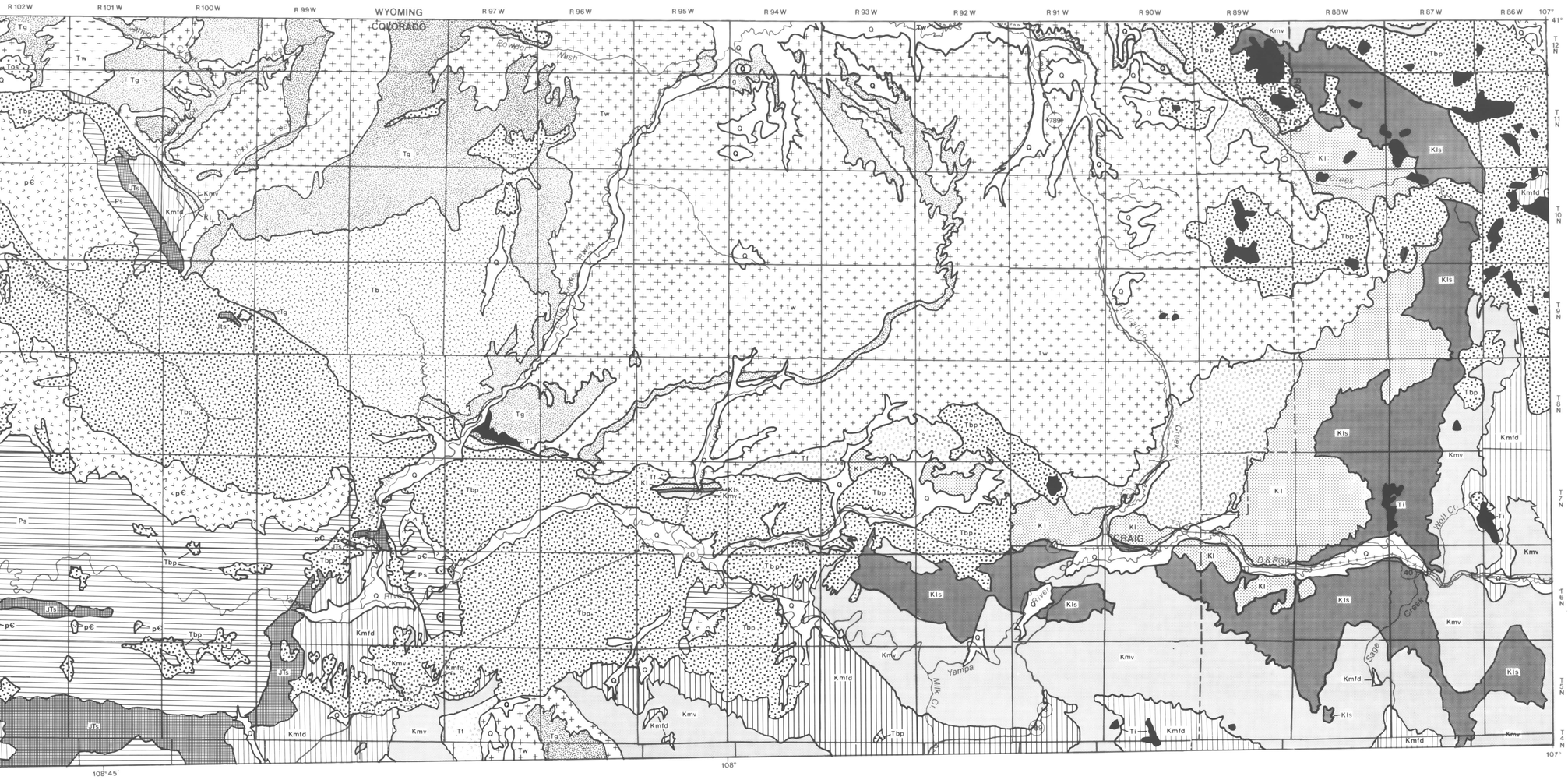
EOLOGICAL SURVEY
OF NATURAL RESOURCES
ORADO

The Coal Bed Methane Potential of the Sand Wash Basin, Green River Coal Region, Colorado

by Donna L. Boreck, Carol M. Tremain, Linda Sitowitz and Thomas D. Lorenson

OF81-6
PLATE 1
1981

GEOLOGIC MAP



EXPLANATION

QUATERNARY
- Q — Undifferentiated

TERTIARY
- Tbp — Browns Park Formation
- Tos — Oligocene Sedimentary Rock
- Tg — Green River Formation
- Tb — Bridger Formation
- Tw — Wasatch Formation
- Tf — Fort Union Formation
- Ti — Tertiary Igneous Rocks (volcanic and intrusive)

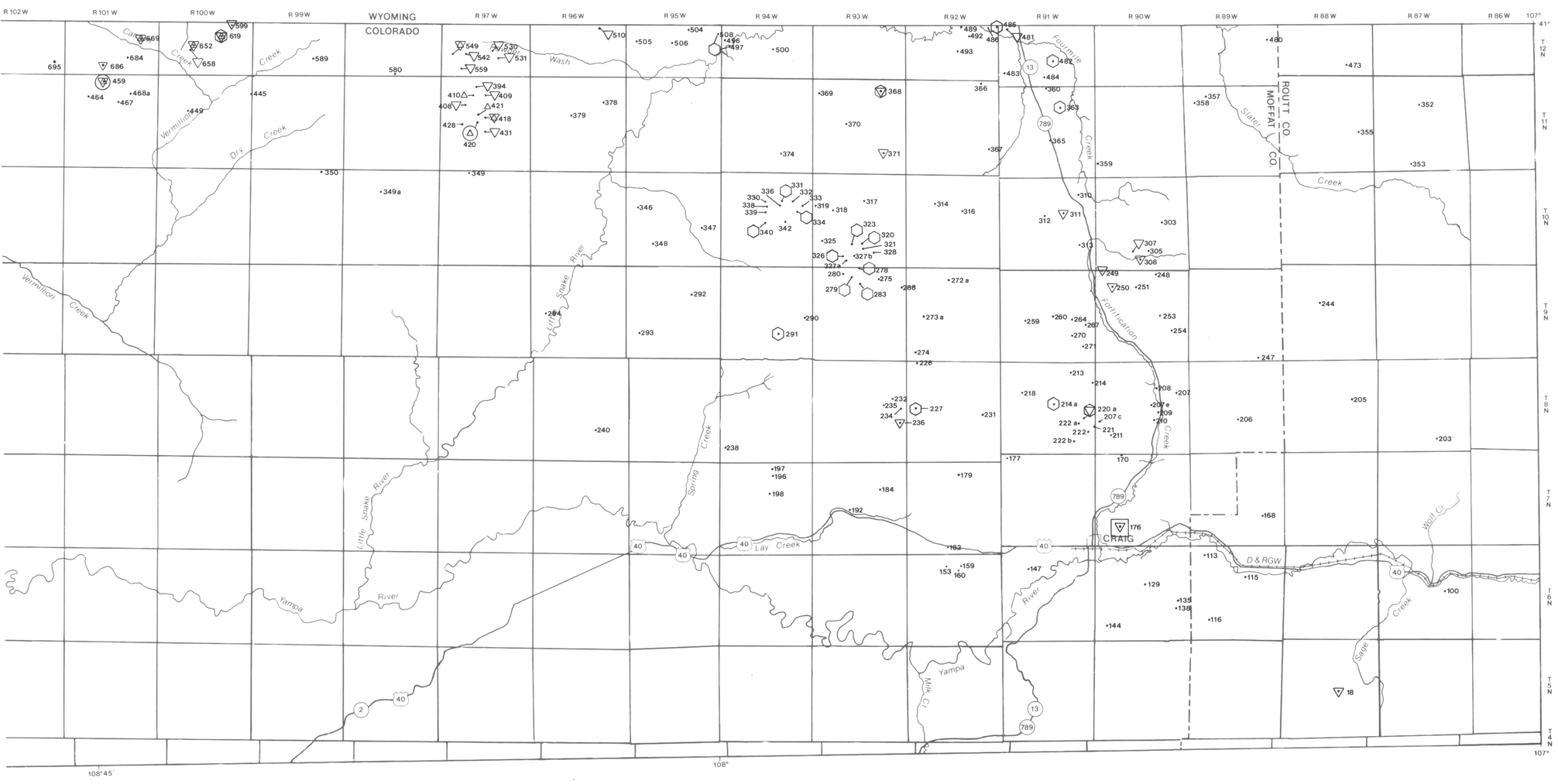
CRETACEOUS
- Kl — Lance Formation
- Kls — Lewis Shale
- Kmv — Mesaverde Group
- Kmfd — Mancos, Frontier, Dakota, Morrison and Sundance Formations

JURASSIC AND TRIASSIC
- JTs — Undifferentiated

PALEOZOIC
- Ps — Undifferentiated

PRECAMBRIAN
- p€ — Uinta Mountain Group

DRILL HOLES AND METHANE SHOWS



EXPLANATION

- • — Oil or gas drill hole and number
- ⬡ — Mud log shows gas in coal
- ▽ — Drill stem test of zone containing coal
- ◯ — Production tests in mixed sandstone and coal zones
- △ — Wells producing from sandstones in coal bearing zones
- □ — Production test in coal bed

INDEX MAP

BASE MAP ADAPTED FROM U.S.G.S.
VERNAL AND CRAIG 1°x 2° SHEETS

DRAFTED BY LISA MARX

SCALE 1:250 000

5 0 5 10 MILES

5 0 5 10 KILOMETERS

DATUM IS MEAN SEA LEVEL

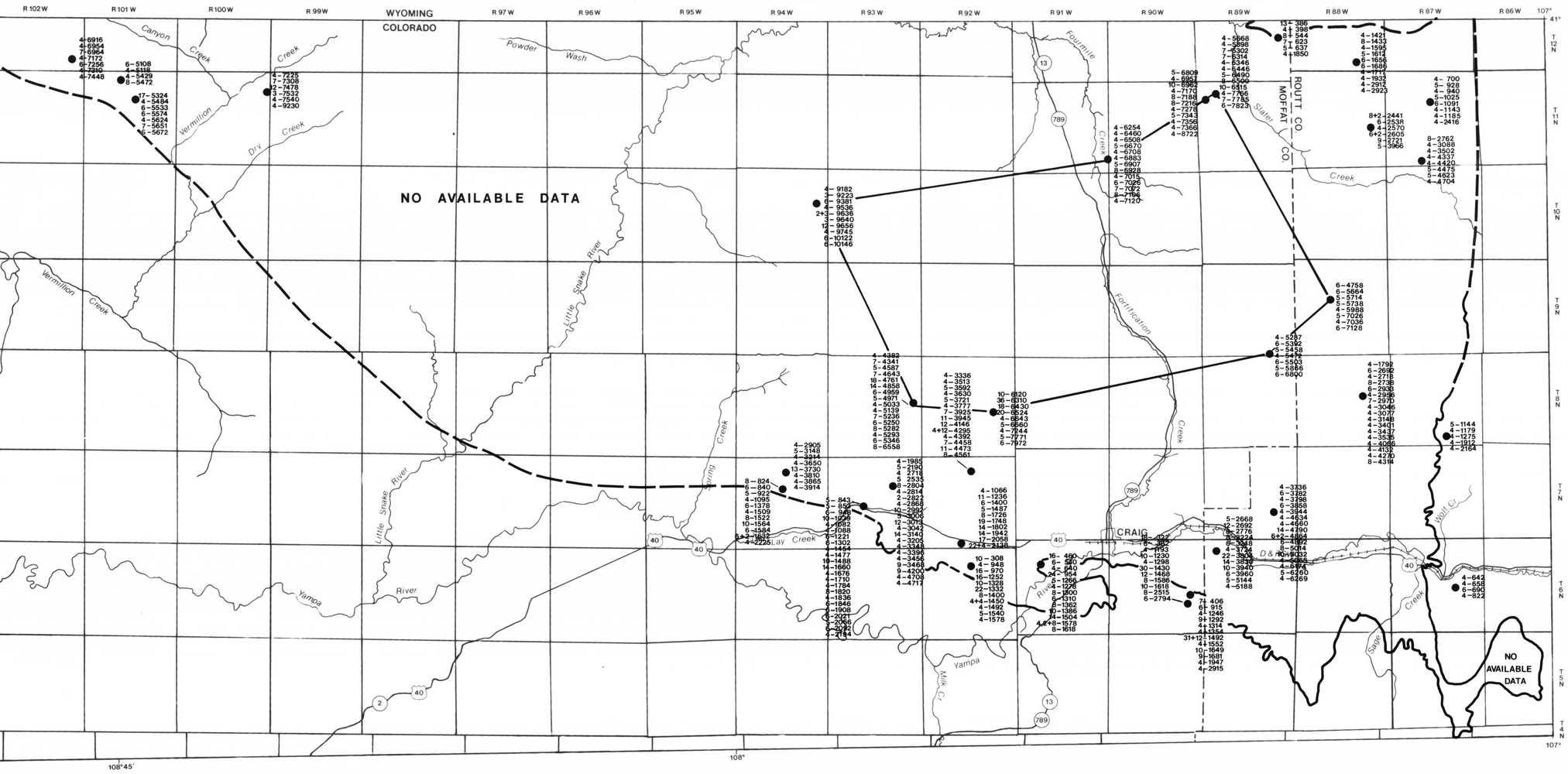
O GEOLOGICAL SURVEY
ENT OF NATURAL RESOURCES
COLORADO

The Coal Bed Methane Potential of the Sand Wash Basin, Green River Coal Region, Colorado

by Donna L. Boreck, Carol M. Tremain, Linda Sitowitz and Thomas D. Lorenson

OF81-6
PLATE 2
1981

A: COAL THICKNESSES AND DEPTHS, MESAVERDE GROUP



EXPLANATION

Mesaverde-Lewis shale contact; dashed where inferred

Oil or gas drill hole

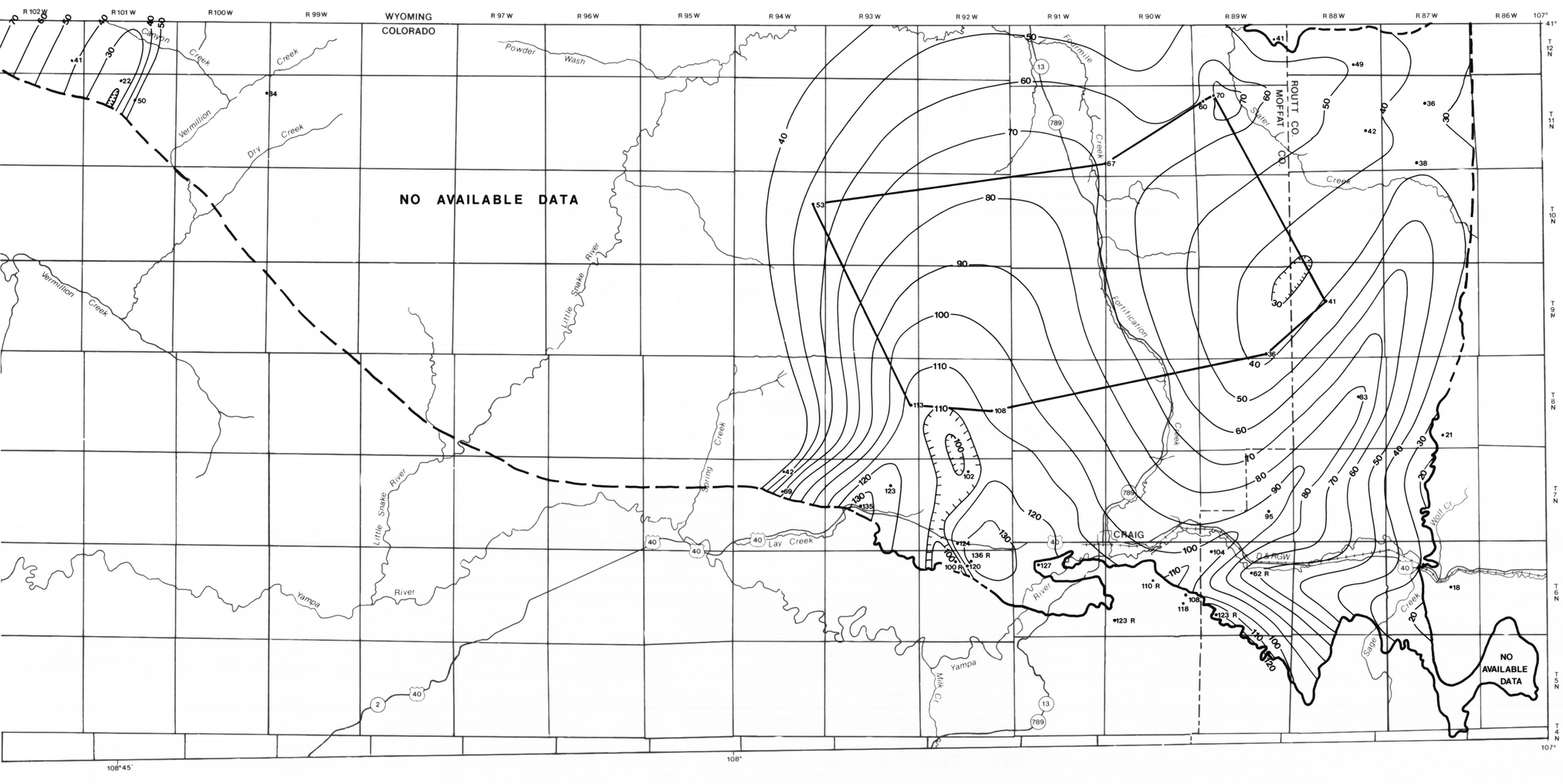
Coal bed thickness in feet (only beds 4 ft or thicker)

4-630
4-642
4-658 — Depth to top of coal bed in feet
2+3-9636

5 ft coal split into 2 ft and 3 ft beds

The polygon in the center of the map encloses a 414 sq. mi. area for which methane resources have been estimated (see p. 15 of text).

B: NET COAL THICKNESS , MESAVERDE GROUP



EXPLANATION

Mesaverde-Lewis shale contact; dashed where inferred

30 — Net coal thickness contour (for coals 4 ft or thicker); contour interval 10 ft

•38 — Oil or gas drill hole with net thickness in feet

•123R — Coals picked on resistivity log

The polygon in the center of the map encloses a 414 sq. mi. area for which methane resources have been estimated (see p. 15 of text).

INDEX MAP

BASE MAP ADAPTED FROM U.S.G.S.
VERNAL AND CRAIG 1°x 2° SHEETS

DRAFTED BY LISA MARX

SCALE 1:250 000

5 0 5 10 MILES

5 0 5 10 KILOMETERS

DATUM IS MEAN SEA LEVEL

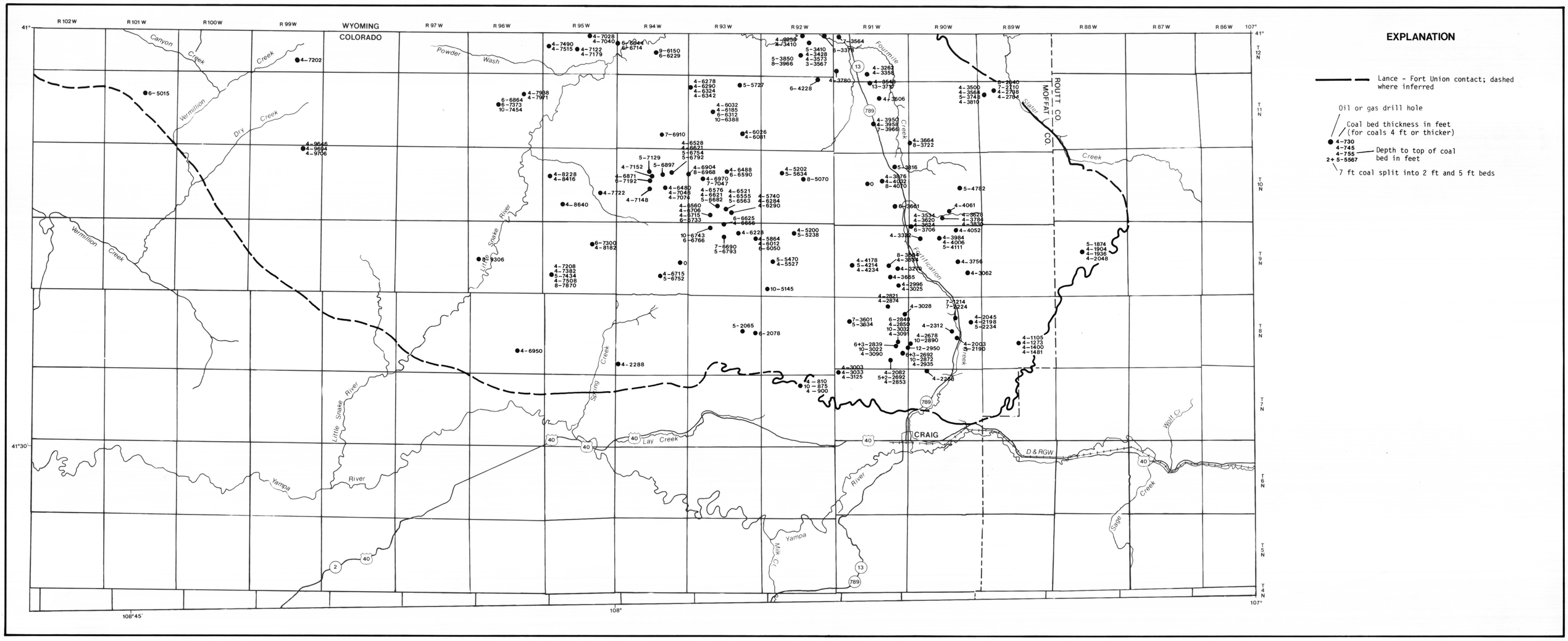
COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO

The Coal Bed Methane Potential of the Sand Wash Basin, Green River Coal Region, Colorado

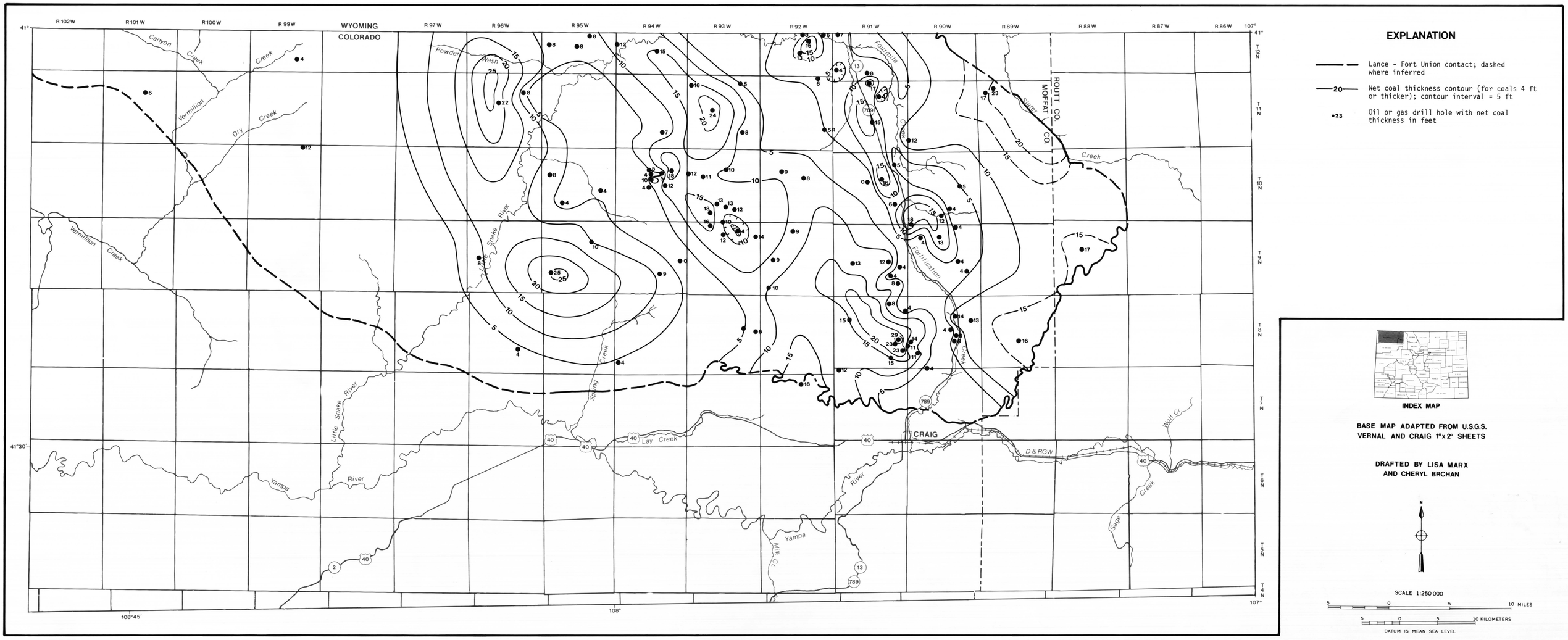
by Donna L. Boreck, Carol M. Tremain, Linda Sitowitz and Thomas D. Lorenson

OF81-6
PLATE 3
1981

MAP A: COAL THICKNESSES AND DEPTHS, LANCE FORMATION



MAP B: NET COAL THICKNESS, LANCE FORMATION



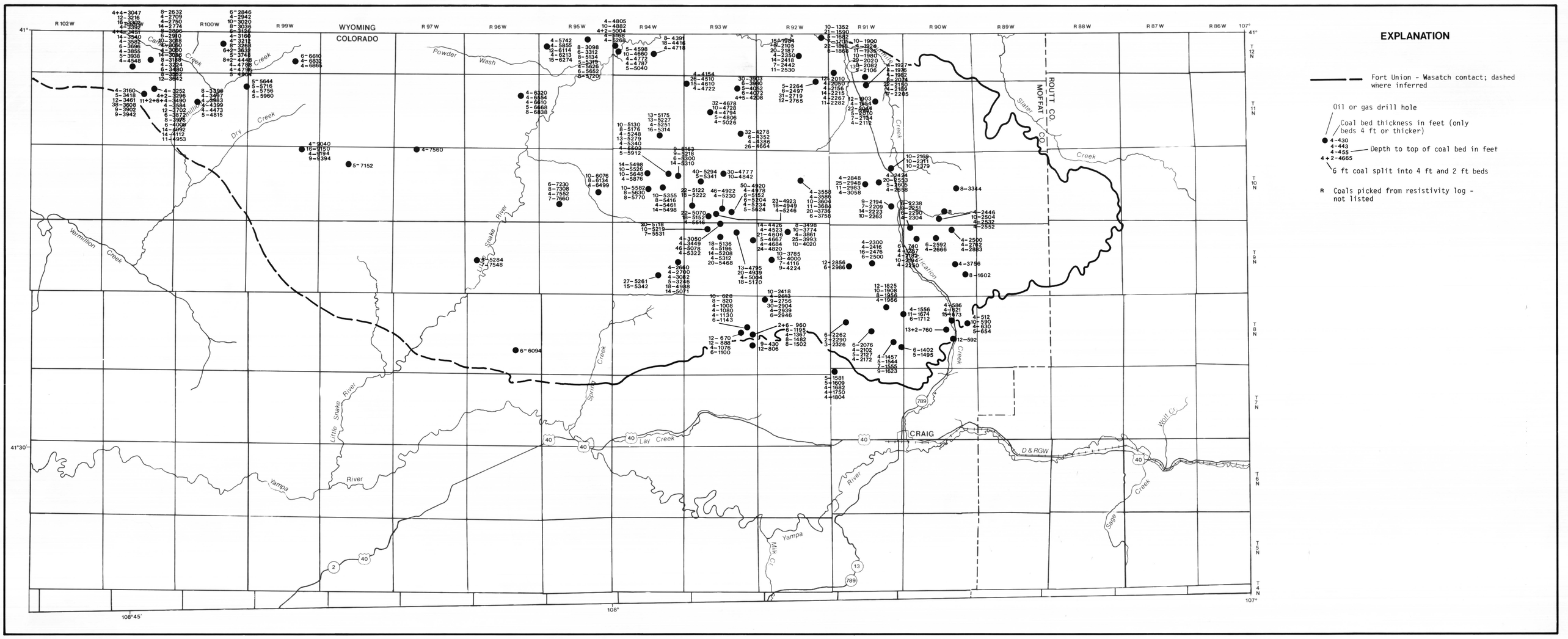
COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
DENVER, COLORADO

The Coal Bed Methane Potential of the Sand Wash Basin, Green River Coal Region, Colorado

by Donna L. Boreck, Carol M. Tremain, Linda Sitowitz and Thomas D. Lorenson

OF81-6
PLATE 4
1981

MAP A: COAL THICKNESSES AND DEPTHS, FORT UNION FORMATION



MAP B: NET COAL THICKNESS, FORT UNION FORMATION