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Determination of Methane Concentrations in Shallow Ground Water and Soil Gas near Price, Utah

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Methane from Coal Beds is an Important Energy Source in Central Utah

Methane gas, commonly referred to as "natural gas," is being produced from coal beds in central Utah (fig. 1) at an increasing rate since the early 1990s. The methane was generated over millions of years during the formation of coal in the area. Coal originates as plant matter that has been deposited in a swamp-like environment and then decays as it is buried and compressed over geologic time. Giant fossilized footprints in the coal provide evidence that dinosaurs roamed and fed among the plentiful plants in these swamps (Hintze, 1979). Methane and carbon dioxide gas and water are produced in the coal as byproducts of coal formation (Sommer and Gloyn, 1993).

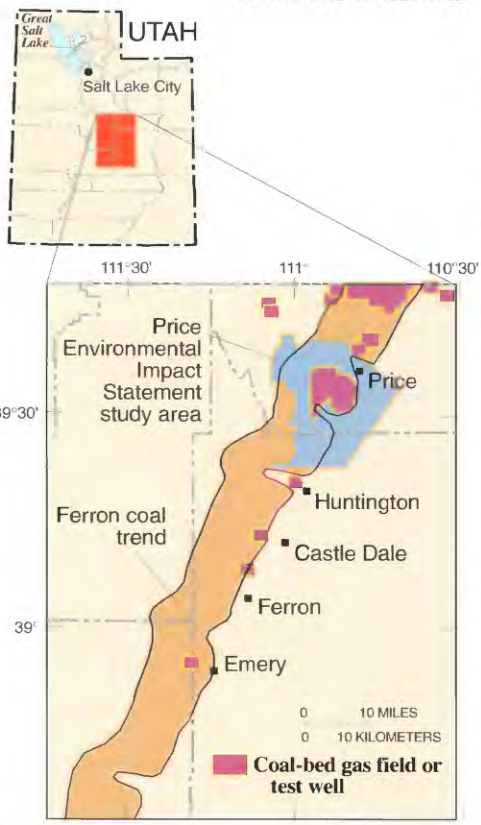


Figure 1. Generalized area of coal-bed-methane development near Price, Utah. Modified from Tabet (1995).

Recent advances in production technology have allowed cost-effective extraction of coal-bed methane resources. Boreholes are drilled into the coal beds to extract the methane using several different drilling, completion, and extraction technologies (Stevens, 1993). Methane gas is released from the coal when water is removed by pumping (Colorado Oil and Gas Conservation Commission and Bureau of Land Management, 1995). When the hydrostatic pressure has been reduced by pumping water from the coal bed, the methane gas flows from the coal into the well bore. Because methane gas is lighter than air, the gas rises through the well to land surface where it is gathered into a subsurface pipeline system, compressed, and then transported from the production areas by pipeline. Ground water pumped from the coal is currently (1997) disposed of in evaporation ponds and by deep-well injection.

Methane in the Price area is produced from coal beds in the Ferron Sandstone Member of the Mancos Shale and in the Blackhawk Formation and overlying Castlegate Sandstone of the Upper Cretaceous Mesaverde Group.

Depth to the coal beds from land surface ranges from 1,000 to 4,000 feet in the Ferron Sandstone (Tabet and others, 1995) and from between 4,000 and 4,485 feet in the Blackhawk Formation and overlying Castlegate Sandstone (Stevens, 1993).

Baseline Methane Data Are Useful to Assess Future Environmental Effects

Release of methane from coal beds during dewatering activities creates the potential for methane to migrate into near-surface environments through natural and human-made pathways (fig. 2). Natural pathways include fractures through the rock layers and voids between the grains of the rock. Human-made pathways can be created when wells are drilled. Information on the methane concentration in soil and water prior to substantial development of coal-bed methane resources is required to determine possible sources and (or) processes that cause increases in methane concentration.

In 1995, the U.S. Geological Survey, in cooperation with the Utah Division of Oil, Gas, and Mining, began a baseline methane-monitoring program to collect shallow ground-water and soil-gas samples in the area of current and proposed coal-bed methane development near Price, Utah. The objective of this ongoing study is to determine pre-development and early-development methane concentrations in ground water and soil gas prior to full-scale

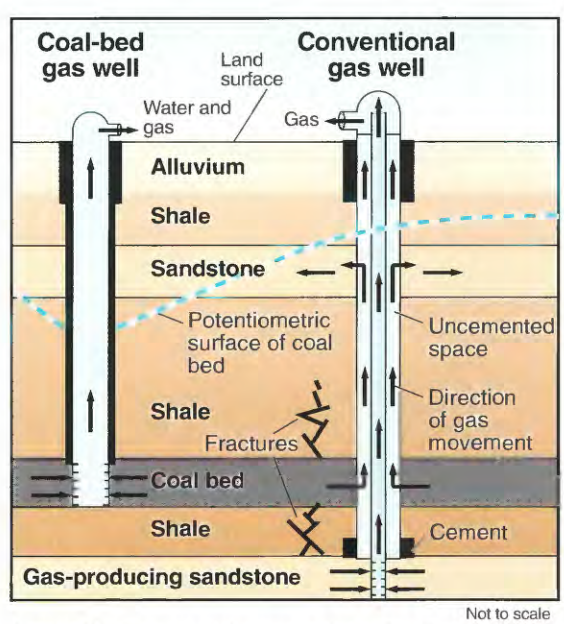


Figure 2. Examples of human-made and natural pathways for methane migration (from Chafin, 1994).

development of the coal-bed methane resources in the vicinity of Price, Utah.

Collection and Analysis of Methane Samples

Water samples for methane analysis were collected by filling two 43-milliliter (ml) vials with water. After filling, 20 ml of water was removed to create an air space. The methane was allowed to diffuse into the headspace for 20 minutes. At the end of this time period, the headspace gas was sampled with a gas-tight syringe (Chafin and others, 1993).

Soil-gas samples were collected by inserting a perforated steel tube 3 to 4 feet into the ground (fig. 3). A battery-powered vacuum pump was connected to the tube. Air was pumped from the steel tube for 2 minutes. After pumping, a gas sample was removed from the steel tube with a gas-tight syringe (Chafin and others, 1993).

After sample collection, the amount of methane was determined with a sensitive analytical instrument (fig. 4) called an organic vapor analyzer (OVA). Calibration of the OVA was required before the methane concentration in a sample of unknown concentration could be determined. The OVA was calibrated with a 95-parts-per-million (volume-to-volume basis) methane-in-air standard used in conjunction with a Teflon gas-sampling bag. Standard calibration plots (fig. 5) were made by injecting three different volumes of the methane standard into the OVA and recording the response. The instrument response is unitless and referred to as peak height. A new calibration plot was produced once a week and checked daily during sampling trips.

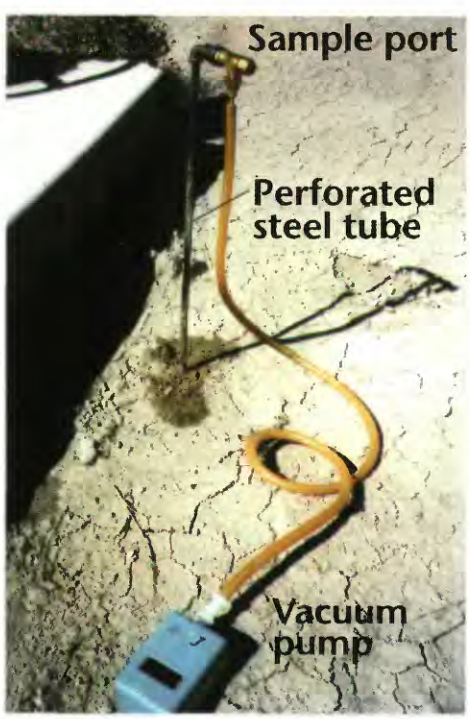


Figure 3. Equipment used to collect soil-gas samples.

Figure 4. Century OVA-128GC Organic Vapor Analyzer with a flame-ionization detector used for analysis of methane.

Once the OVA was properly calibrated, the concentration of methane in soil-gas and water samples could be determined. For example, the sample of unknown soil-gas concentration shown in figure 5 had a peak height of 27, which corresponds to a methane mass of 0.004 microgram. This methane mass was then divided by the sample volume of 0.150 ml to obtain a methane concentration of 0.030 mg/L (g).

The equilibrium concentration of methane in water was calculated using a series of equations. These equations are not presented here; however, a complete listing of the equations and assumptions used in the determination of the dissolved methane concentrations can be found in Chafin and others (1993).

Dissolved Methane Concentration in Water Samples is Low

Fourteen ground-water samples from springs, wells, and drains were collected within the study area and analyzed for methane concentration. Only one water sample contained a detectable methane concentration (0.061 mg/L). This sample was collected in a pond downstream from the discharge from a spring. The detectable methane in this sample likely resulted from bacterial decomposition of organic matter in the bottom of the pond. Methane concentrations in the remaining water samples did not exceed the minimum reporting limit of 0.005 mg/L.

Concentrations of Soil-Gas-Methane Determined at 96 Sites

Since 1995, 121 samples of soil-gas (3-ft depth) have been analyzed for methane concentration at 96 sites in the vicinity of Price, Utah (fig. 6). Soil-gas-methane concentrations ranged from the minimum reporting limit of 0.005 mg/L(g) to 1,400 mg/L(g) at a pumping coal-bed-methane well north of Price, Utah over a period of 1 ½ years. Seventy-nine percent of the soil-gas samples had a methane concentration less than the reporting limit of 0.005 mg/L(g). The soil-gas-methane reporting limit was equaled or exceeded in 21 percent of the samples. All sample sites with detectable methane concentrations were limited to either conventional natural gas or coal-bed-methane development wells.

Soil-gas-methane concentrations measured adjacent to gas-well casings near Price, Utah, and the Animas River Valley in Colorado and New Mexico were compared (table 1). The Animas River Valley was used for comparison because this is an area where intense development of methane from coal beds since the mid-1980s has created public concern about the possibility of increasing concentrations

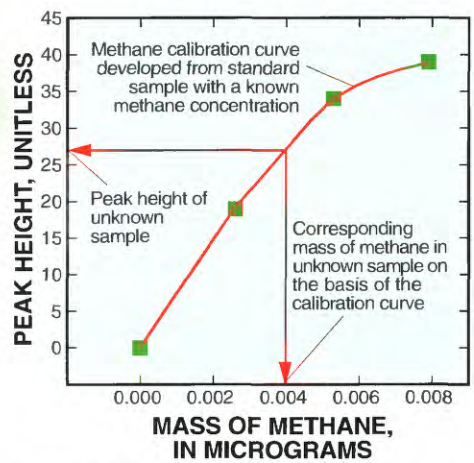
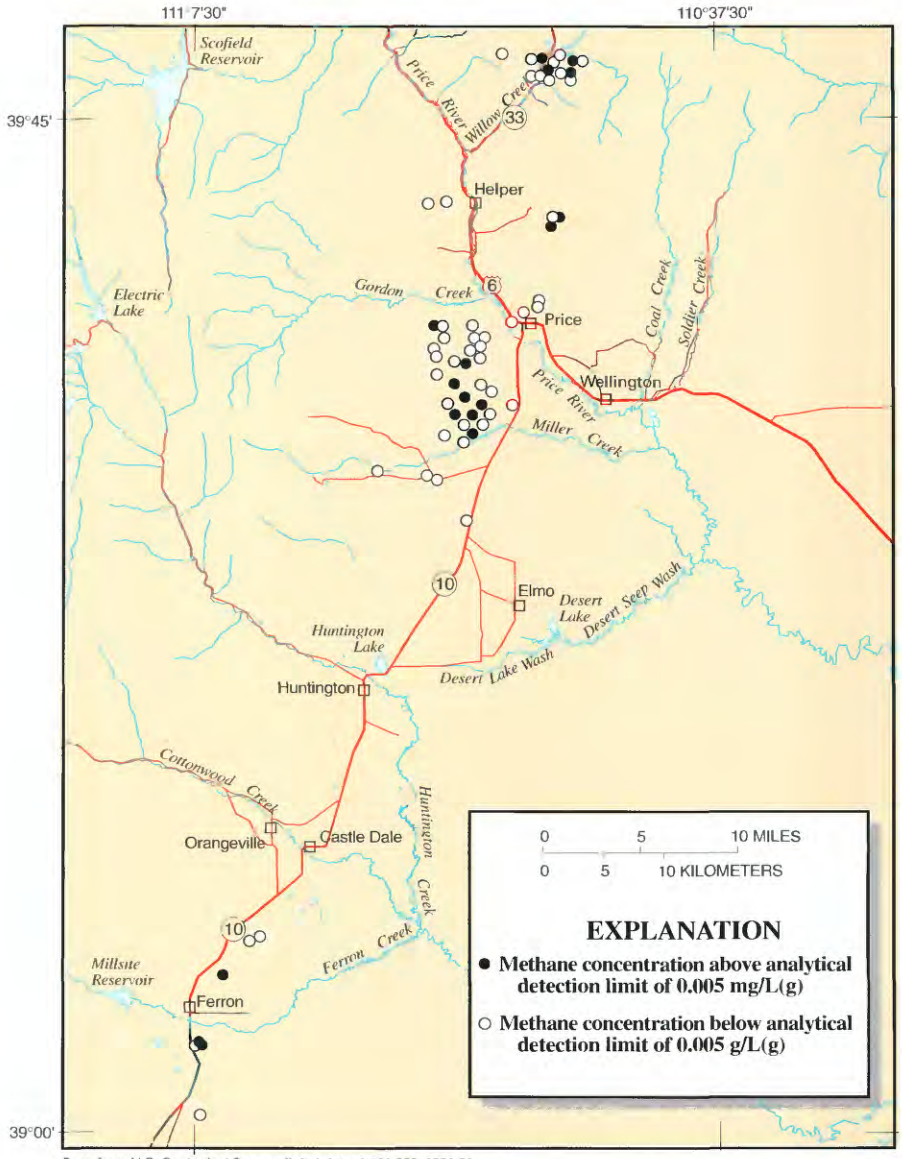


Figure 5. Example of a weekly calibration curve used to determine the methane concentration in samples of unknown concentration. In this example, a 0.150-milliliter volume of a sample of unknown concentration was injected into the calibrated organic vapor analyzer and a peak height of 27 (unitless) was obtained. On the basis of the calibration curve, this peak corresponds to a methane concentration of 0.004 microgram per 0.150 milliliter.

of natural gas in domestic water supplies (Chafin, 1994). The mean methane concentration in soil-gas samples collected from the Price area was less than 0.005 mg/L (g) and in soil-gas samples collected in the Animas River Valley was 29 mg/L(g) (table 1). The reason(s) for the lower soil-gas-methane concentrations in the Price area is unknown. Chafin (1994) did not notice a significant difference in methane concentrations when he compared older with newer wells in the Animas River Valley; however, coal-bed-methane development has occurred



Base from U.S. Geological Survey digital data, 1:100,000, 1980,81
Universal Transverse Mercator projection, Zone 12

Figure 6. Location of sites where methane was detected in soil-gas samples collected near Price, Utah, during monitoring period from September 1995 through April 1997.

Table 1. Summary statistics for soil-gas-methane concentrations measured adjacent to gas-well casings near Price, Utah, and the Animas River Valley, Colorado and New Mexico

[N, number of samples; Q.25 (for example), quantile with subscripted number showing fraction of samples with concentration less than or equal to concentration shown; <, less than; concentration reported in milligrams per liter of gas]

Study area	N	Mean	Q.25	Q.50	Q.75	Q.95	Maximum
Near Price, Utah	112	<0.005	<0.005	<0.005	<0.005	3.5	1,400
[1]Animas River Valley	352	29	<.005	<.005	.009	200	1,200

[1]Statistics from Chafin (1994).

for a longer time period in the Animas River Valley, thereby increasing the time available for gas migration through natural and human-made pathways. Similar rock types (sandstone, shale, and coal beds) are found in both areas. Evaluation of the different characteristics of these rock types, such as bed thickness, amounts of clay and sand proportions within each rock type, and fracturing, could aid in determining the difference in methane concentrations found in samples collected from both areas.

Methane Concentrations in Soil-Gas Samples Decrease Away from Wells

The variation of methane concentration in soil-gas with lateral distance from the gas-well casing was investigated at two sampling sites. During October 1995, soil-gas samples were collected at various distances from the gas-well casing at two active methane producing wells (sites SG19 and 65). The highest concentrations of methane were found within 30 feet of the gas-well casing, and the concentrations decreased to less than detection limits at distances greater than about 50 feet from the gas-well casing (fig. 7). The well at site SG19 was drilled in 1992 and the well at site SG65 was drilled in 1985. During a study of methane migration pathways in Colorado and New Mexico, Chafin (1994) determined that the age of gas wells did not control the concentration of methane in soil-gas samples collected adjacent to gas wells.

Subsequent soil-gas samples collected at sites SG19 in September 1996 and April 1997 and SG65 in September 1996 contained less than the reporting limit of 0.005 mg/L (g) of methane. With the data collected to date (1997), the cause(s) of the accumulation and subsequent decrease of soil-gas methane is not apparent. It is possible that limited amounts of methane were released to the soil during well-construction activities and that methane might be slowly degassing to the atmosphere or might be consumed by a biologic process(es) in the soil zone, which would cause a decrease in concentration with time. Coal-bed gas wells in the Price area have cement over part of or the entire depth of the well between the rock and the well casing (referred to as the annular space) to prevent methane migration from deeper geologic formations to the surface.

Methane Concentrations in Soil-Gas Samples Vary With Time

Soil-gas methane concentrations were monitored over time at 16 sites in the study area. Samples were collected during four different time periods from September 1995 through April 1997. Generally, soil-gas methane concentrations decreased to less than the reporting limit over time (table 2). For example, site SG52 had detectable methane concentrations during September 1995 and 1996; however, the April 1997 concentration was less than the reporting limit of 0.005 mg/L (g). The observed decrease to background concentrations with time does not indicate continuous leakage of methane from the well into the surrounding soil and backfill. Changes in the weather can affect the mass movement of gases such as methane in the soils surrounding the sampling sites. Changes in temperature, pressure, and moisture can affect the flow of air

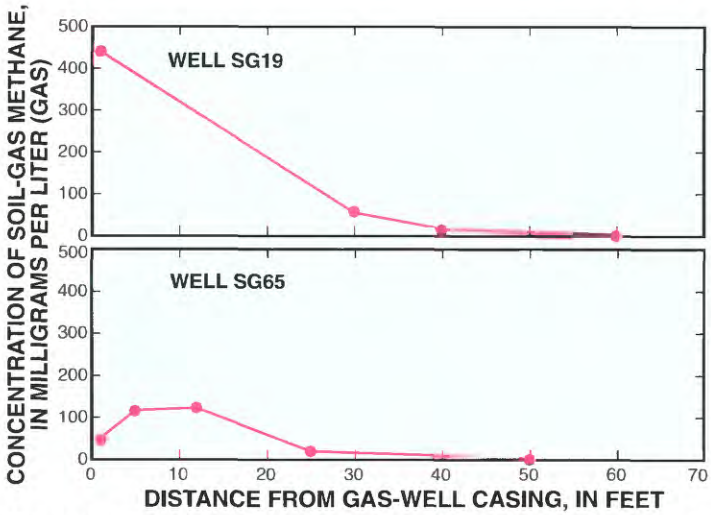


Figure 7. Changes in the soil-gas methane concentration at two gas wells near Price, Utah.

Table 2. Variation in the concentration of methane in soil-gas samples collected near Price, Utah, during different time periods

[methane concentration reported in milligrams per liter (gas); <, less than reporting limit; >, greater than; —, sample not collected]

Site number	SEP 1995	OCT 1995	SEP 1996	APR 1997
SG13	.363	—	<0.005	—
SG19	[1]>1.0	440	<.005	<.005
SG22	[1]>2.7	<.005	—	—
SG25	[1]>2.7	<.005	<.005	<.005
SG28	<.005	—	<.005	<.005
SG32	.14	—	<.005	<.005
SG33	.12	—	<.005	<.005
SG34	.009	—	—	<.005
SG35	.052	—	<.005	—
SG51	.013	—	—	<.005
SG52	21	—	1,400	<.005
SG65	—	46	<.005	—
SG72	—	—	<.005	<.005
SG76	—	—	.026	.035
SG77	—	—	.013	<.005
SG83	—	—	10.8	<.005

[1]Because of lower dilution ratios, samples collected during September 1995 had a lower maximum reporting limit than samples collected during subsequent trips.

in the soil (Rose and others, 1979). Seasonal changes in temperature and rainfall could cause seasonal changes in methane content of near-surface materials. Additional monitoring data are required to better evaluate the seasonal variation in soil-gas methane.

Coal-Bed Methane Development Near Price is Projected to Increase

River Gas Corporation, Texaco, Anadarko Petroleum, Chandler and Associates, and Questar are principal companies developing the gas resource in the Price area. Since 1992, about 100 wells have been installed south and west of Price, Utah (fig. 1). As of April 1997, these wells were producing about 1,831,600 thousand cubic feet of gas per month. The Price Coal-bed Methane Environmental Impact Statement (EIS) projects a total of about 975 possible additional wells within the study area (fig. 1). Another EIS for 375 possible wells and a 40-mile north-south gas pipeline is being written for areas that are just north and east of Price and to the south of Price near the town of Ferron. This second EIS is scheduled to be completed in late 1999.

Continued monitoring of methane in soil gas and water is needed to assess the possible effects of the proposed natural gas development in this area of central Utah. The magnitude of this monitoring program will depend on the continued availability of funding and the level of activity that occurs.

References

Chafin, D.T., Swanson, D.H., and Grey, D.W., 1993, Methane-concentration and methane-isotope data for ground water and soil gas in the Animas River Valley, Colorado and New Mexico, 1990-91: U.S. Geological Survey Water-Resources Investigations Report 93-4007, 86 p.

Chafin, D.T., 1994, Sources and migration pathways of natural gas in near-surface ground water beneath the Animas River Valley, Colorado and New Mexico: U.S. Geological Survey Water-Resources Investigations Report 94-4006, 56 p.

Colorado Oil and Gas Conservation Commission and Bureau of Land Management—San Juan Resource Area, 1995, Final report, 1994 Groundwater monitoring, San Juan Basin, La Plata County, Colorado, Comprehensive infill testing, p. 1-24 and 56-71.

Hintze, L.F., 1979, Geologic History of Utah: Brigham Young University Geology Series, v. 20, pt. 3, 120 p.

Rose, A.W., Hawkes, H.E., and Webb, J.S., 1979, Geochemistry in mineral exploration (2nd ed.): Academic Press, New York, 657 p.

Sommer, S.N., and Gloyn, R.W., 1993, Coalbed methane activity: New energy source being developed, *in* Survey Notes: Utah Geological Survey, v. 25, no. 3-4, p. 13-15.

Stevens, S.H., 1993, Exploration and development, Uinta Basin, Utah: Quarterly Review of Methane from Coal Seams Technology, v. 11, no. 1, p. 38-42.

Tabet, D.E., 1995, Utah's 1994 coalbed methane gas developments: Utah Geological Survey, Survey Notes, v. 27, no. 2, p. 7-9.

Tabet, D.E., Hucka, B.P., Sommer, S.N., 1995, Depth to top of Ferron Sandstone: Utah Geological Survey Open-File Report 329, map.

Teichmuller, Marlies, 1987, Organic material and very low-grade metamorphism, *in* Frey, M., ed., Low temperature metamorphism: Blackie & Son Limited, London, p. 114-161.

Sources of Additional Information

Hydrologic and additional methane concentration data near Price, Utah, can be obtained from:

U.S. Geological Survey
Utah District
1745 West 1700 South
Salt Lake City, Utah 84104
(801) 975-3350

Utah Department of Natural Resources, Division of Oil, Gas, and Mining
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