From Prehistory to the Pipeline – The Fingerprint of Coal Bed Methane.

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Coalification and Methane Production

Over several millions of years, heat and pressure transform decomposed prehistoric forests and swamps into coal beds. The rank of coal is determined by the depth of burial over time.

TIME (>Heat and Pressure)

peat lignite subbituminous bituminous anthracite

The coalification process generates methane-rich gas which often is held in pores, cracks, and spaces within the coal. This is know as methanogenesis and is represented by the formula below:

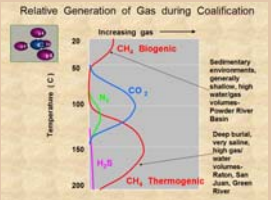
$$CH_3\text{--}|\text{--}CO_2^- + H \rightarrow CH_4 + CO_2$$

Reduction of carbon dioxide formed during respiration yields methane and water:

$$CO_2 + 8H \rightarrow CH_4 + 2H_2O$$

Water trapped within the coal seams has a distinct and diagnostic geochemical signature (Van Voast, 2003):

- Biochemical reduction of sulfate
- Enrichment of bicarbonate
- Calcium and magnesium precipitation



Types of methane produced:

Biogenic methane:
- Biologically driven as a result of microbial action.
- Found in shallow, freshwater sedimentary basins.

Thermogenic methane:
- Result of metamorphism of coal layers by pressure and heat due to increased depth of burial.
- Found in deep, marine sedimentary basins.

		Biogenic Methane	*Thermogenic Methane*
Geologic Depth	▶	Shallow	Deep burial
Sedimentary Envr.	▶	freshwater (continental)	marine to continental transitional
Coal Rank	▶	subbituminous	subbituminus to bituminous
Water Chemistry	▶	sodium and bicarbonate	sodium, bicarbonate, chloride rich
Gas/Water Ratio	▶	Low	High
Locations within US	▶	Powder River Basin	Black Warrior, San Juan, Raton, Piceance, Uinta

Adapted from Van Voast, 2003

Coal Bed Methane Worldwide

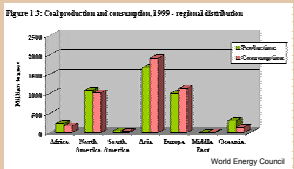
World wide coal bed methane exploration and development.
US, Canada, Mexico, UK, Germany, Czech Republic, Poland, Ukraine, Bulgaria, Russia, India, Kazakhstan, China, Japan, South Africa, and Australia.

Country	Estimated (TCM)
Canada	17-92
Russia	17-80
China	30-35
Australia	8-14
US	4-11
Ukraine	2-12
India	0.85-4.0
Germany	3.0
Poland	3.0
UK	2.45
Kazakhstan	1.1-1.7
South Africa	1.0
Czech Republic	0.38
Turkey	0.10

(Adapted from Talkington, 2002 – US EPA)

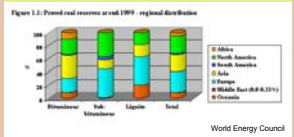
- Global estimates for coal bed methane production = 4,000-7,500 TCF
- Countries *actively* exploring and/or producing coal bed methane include US, Canada, Western Europe, Japan and Australia.
- Countries with highest potential for new coal bed methane exploration include India and Japan

World Market Research Center



World Energy Council

North America, Asia, and Europe are the largest coal producing and consuming countries, as well as harbor the highest amount of coal reserves worldwide.



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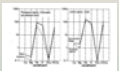
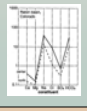
National Level

Data of Major US West Coal Bed Methane Development

Basin and Stratigraphy		Chemistry of Assoc Waters	Production (Boysen et al., 2002)		Water/Gas
San Juan CO/NM	Upper Cretaceous Fruitland Formation	Adapted from VanVoast, 2003	**Colorado** •1884 wells •25,303,772 BBL water •403,883,537 MCF Gas •13,772 BBL/Well/Year	**New Mexico** •18,252 wells •22,125,324 BBL water •1,046,109,179 MCF Gas •1212 BBL/Well/Year	BBL Water/MCF Gas **Colorado** 0.063 **New Mexico** 0.021
			Disposal – Injection		
Uinta-Piceance UT	•*Uinta* – Upper Cretaceous Ferron Sandstone Member of the Mancos Shale •*Piceance* - Upper Cretaceous Cameo zone of the Mesa Verde Formation		**Utah** •393 wells •2,320,000 MCF •78,475 BBL/Well/Year		**Utah** 0.42
			Disposal – Injection		
Raton CO/NM	Upper Cretaceous Vermejo Formation, and Upper Cretaceous to Paleocene Raton Formation		**Colorado** •613 wells •54,551,602 BBL water •85,841,189 MCF Gas •88,991 BBL/Well/Year	**New Mexico** •82 wells •2,116,464 BBL water •1,021,807 MCF Gas •25,811 BBL/Well/Year	**Colorado** 0.635 **New Mexico** 2.071
			Disposal – Injection		

- Coal Bed Methane exploration and development is increasing dramatically across the United States
- Major coal bed methane play in the US west includes: San Juan, Raton, Uinta-Piceance, and Powder River Basins.
- San Juan, Raton, and Uinta-Piceance have lower water/gas ratios and higher salinity water than the Powder River Basin.
- Recent exploration in the Wind River and Green River regions of western Wyoming has expanded the coal bed methane potential in the west.
- Energy Information Administration (EIA) 2002 Annual Energy Outlook states: "the Green River Basin is the largest potential source of natural gas in North America".

The Powder River Basin – Past to Present

Major Characteristics of the Powder River Basin

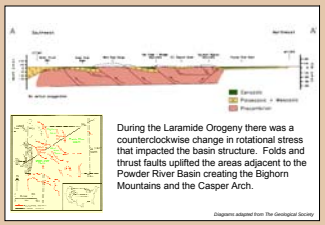
- ***Deep structural basin - 18,000+ ft at basin axis.***
- ***Shallow coal seam depth – no deeper than 4500 ft.***
- ***Coal seam thickness ranges from 5-190 ft.***
- ***Low ranking coal ranging from lignite to subbituminous.***
- ***Methane present is interpreted as biogenic.***

2000 Production Data – MT and WY

- ***~6,609 CBM wells in MT and WY.***
- ***154,815,825 MCF gas produced collectively in MT and WY.***
- ***113,577 BBL/Well/Year of water produced collectively in MT and WY.***

The Powder River Basin is a major geologic structural basin that was carved out during the Laramide Orogeny – a series of mountain building events in western North America that occurred in the Late Cretaceous and Early Tertiary time.

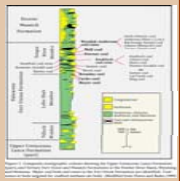
During this time, Wyoming and Montana had semi-tropical climates conducive to the growth of lush forests that would eventually become the present day coal fields.



During the Laramide Orogeny there was a counterclockwise change in rotational stress that impacted the basin structure. Folds and thrust faults uplifted the areas adjacent to the Powder River Basin creating the Bighorn Mountains and the Casper Arch.

Diagrams adapted from The Geological Society

The coal bearing Phanerozoic strata of the Powder River Basin is known as the Wyodak-Anderson and Knobloch zones of the Tongue River Member within the Paleocene Fort Union Formation. The sedimentary layers (sandstone, siltstone, mudstone, and limestone) of the Tongue River Member are fluvial and lacustrine in origin and were deposited into the basin during Tertiary tectonics. The methane present in these coal beds is biogenic and developed shortly after deposition during a time of rapid subsidence and deposition in the Laramide Orogeny or during a later stage in association with groundwater flow.



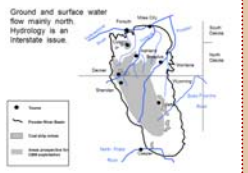
The issues of concern with coal bed methane extraction revolve around the disposal of large quantities of saline/sodic water released from wells. The Powder River Basin has a greater water/gas ratio than most other producing basins in the US – ***2.2 Bbls water/Mcf gas*** – in both Wyoming and Montana. With the projected increase of well production throughout the Powder River Basin, correct disposal of the large quantity of water will be imminent. Disposal options currently being practiced/researched include:

- **Discharge (primary)**
- **Reinjection**
- **Irrigation**
- **Evaporation Ponds**
- **Livestock watering**
- **Treatment**
- **Enhance wetland function**
- **Carbon Sequestration**

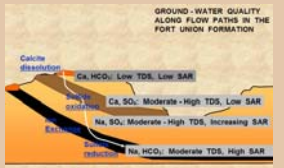
Changes in Production Over Time Powder River Basin

January, 1978	*January, 2003*
7,880 Wells	23,205 Wells
4,540,579 Mcf Gas	33,642,793 Mcf Gas
34,770,479 Bbls Water	87,262,172 Bbls Water

Projections: Projected lifetime of play is 15-20 years, 51,500 wells.



Statistics from the Wyoming Oil and Gas Conservation Commission



In the Powder River Basin, water chemistry changes with depth. In general SAR (sodium adsorption ratio) increases as you go northeast in the basin. This is of special concern in Montana, as the northeast corner of the basin extends into the state.

** Some graphics provided by Jim Bauder, MSU; John Wheaton, Montana Bureau of Mines and Geology; Cynthia Rice, USGS; Clark et al., USGS.*