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Coal-bed Methane Potential and Activity of the Western Interior Basin

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The Western Interior Basin is located in Southwestern Iowa, Southeastern Nebraska, Western Missouri, Eastern Kansas and Northeastern Oklahoma and is composed of the Cherokee Basin or Platform, Forest City Basin and the Northeast Shelf in Oklahoma. The coals in the Western Interior Basin are of Middle to Upper Pennsylvanian Age and generally are less than three feet thick but are laterally extensive. The primary coals of interest are in the Cherokee and Marmaton Groups of Middle Pennsylvanian Age. The coals have sulfur contents, moderate to high ash values, low moisture in nature and rank is medium volatile on the western side of the basin in Kansas and Oklahoma grading to High Volatile C in Southern Iowa and Eastern Missouri. Coal mining activity has been limited, began in the early part of the last century and most of it has been in the form of surface mines near where the coals outcrop. There have been documented mine explosions in the underground mines Eastern Kansas and Western Missouri. Economically important coal deposits in Illinois and Wyoming have limited the viability of the coal industry in the Western Interior Basin. The basin has historically produced gas from black shales or slates and coals from areas just north of Kansas City to northeast Oklahoma from as early as the 1920s. The exploitation of this resource diminished in the 1930s to an occasional completion or for providing gas for a house or local business. In the mid-1980s the revitalization of the exploitation of this resource began in Northeast Oklahoma and Southeast Kansas due Federal tax credits. However, because the coal bed methane model during this time was the San Juan and the Warrior basins. The thin nature of the coals in the Western Interior Basin, at the time, restricted gas markets and the presence of saltwater produced from the coals limited their exploitation and development. In 2001, Devon Energy purchased a Patrick Exploration project of 100 plus wells and associated acreage in Northeast Oklahoma and an acreage project for a Denver group in Southeast Kansas that sparked renewed interest in the area. Activity in the area was further accelerated in the basin with growing environmental opposition to coalbed methane development, problems with water disposal, federal and state inability to permit wells and a gas price differential that reached as high as $2.10 in July of 2002 in Wyoming, Montana and Colorado. In the Kansas City area which lies in the heart of the Western Interior Basin there is a growing gas market, product prices vary between Mid-Continent and NYMEX with minimal or no differential, declining product in the existing pipelines that extend from Western Kansas and Oklahoma to Kansas City and beyond, friendly regulatory bodies, lack of Federal acreage or involvement and limited to nonexistent environmental activity. The play is in the early stages of exploitation. Reported gas content values in the coals vary from 5 to 450 scf per ton. Gas quality varies from 96 to 98%% methane, 1% to 3%+ ethane +, .5+ CO2 to 92% methane, a few percent nitrogen and CO2 with BTU contents varying from 850 to 1050. Water rates vary from a few barrels to over 1,000 barrels a day. Initial completion practices began with single zone completions until 2002 when the State of Kansas vacated the rules preventing commingling several zones in the same well specifically being produced for coalbed methane and shale.

The Western Interior Basin (**Figure 1**) is an intercratonic depression located in Southwestern Iowa, western Missouri, Southeastern Kansas, Eastern Kansas and Northeast Oklahoma (Gordon and Bour III, 1988). The basin is a product of Late Mississippian to Early Pennsylvanian Age tectonic activity that separated the Kansas Basin into two basins, the Forest City and Salina Basins in the north and created the Cherokee Basin or Northeast Shelf to the south. The Nemaha Ridge forms most of the western boundary of the basin, the northern boundary is indeterminate, the eastern boundary is the Mississippi River Arch, the Ozark Mountains are to the southeast, and the Arkoma basin on the south. The Nemaha Ridge is part of a failed mid-continent rift system that extends from south-central Kansas, through southeastern Kansas, central Iowa and finally to the upper peninsular of Michigan. The Nemaha Ridge in Eastern Kansas formed an escarpment that prevented swamp development to the west of it. Deposition during Paleozoic time in the basin was noted for limited deposition of all geologic units accented by long periods of erosion and uplift.

The basin has been the subject of on-going thermal activity and heating along the Nemaha Ridge and low temperature hydrothermal events that have migrated through the basin.

The Western Interior Basin straddles five states and as such has had the stratigraphy of the Pennsylvanian Age rocks defined by five different state agencies through time (Landis, 1965; Zeller, 1968; Murphy, 1978; Derynck, 1980; Thompson, 1995; Brenner, 1999; Hemish, 2000). The Marmaton Group and younger rocks seem to have been consistently named and correlated through out the five states and can be tied to the Illinois Basin. The underlying Cherokee Group, is less well defined internally or between states but has the greatest thickness of coals (**Figures 2 and 3**). The nature of the Cherokee Group is more lower deltaic and near-shore than the overlying Marmaton Group. The lack of regional limestones is a major impediment for stratigraphic mapping as they are typically a major mapping component of a classic cyclothem. The basal section of the Pennsylvanian rocks were deposited on a karsted and erosional Mississippian surface. The Riverton coal is the first significant coal and is present predominately in Southeastern Kansas and Northeast Oklahoma and in the center of the Forest City Basin. The next group of coals, which is more common and covers most of Kansas, Missouri and Southwestern Iowa, is the Aw, Bw, Cw and Dw coals that lie within the McClouth-Warner Age depositional system. The McClouth-Warner system is overlain by a period of peat development and near shore quiet marine deposition that resulted in the Drywood, Rowe and Neutral coals. These coals may be absent in areas where Upper McClouth or overlying Bartlesville-Bluejacket Age sand channels are present either by erosion or non-deposition.

The Bluejacket or Bartlesville interval is the next overlying unit and is dominated by sandstone channel or barrier bar development in the south half of the basin and along the same trend as the McClouth system. There are a series of coals identified as the Abj, Bbj, Cbj and Dbj that are associated with this system. The overlying Cabaniss interval that is less clastic in nature but is dominated by the Weir-Pittsburg, Scammon, Mineral and Croweberg coal. Many of these coals have been extensively mined throughout the basin The overlying Banzet Interval or Formation represents the the youngest Cherokee Group sediments The common coals are the Mulky and Bevier coal and in some areas the Iron Post coal is present. The Cherokee Group is overlain by the Marmaton and is defined by several classic cyclothems. The predominate coals are the Summit, the Mystic, the Lexington, Mulberry, Jenks, Dawson and Laredo coals. The Summit and Lexington coals have historically produced gas in Southeastern Kansas and western Missouri.

The coals of the Cherokee Group based on ASTM ranking which is derived from BTU, volatile and moisture content corrected for a dry ash free basis is Medium Volatile in Western Kansas(?) and Western Oklahoma to High Volatile A from Northeastern Oklahoma through Eastern Kansas and into Northwestern Missouri. The BTU content varies from 13,500 to 15,500 based on a dry ash free basis. Coal rank diminishes into Eastern Missouri and Southern Iowa to High Volatile C.

Coal quality is highly variable with ash contents less than 5% to over 50%, moisture content averaging 4% to 10% and sulfur values ranging from 2% to 11%. The coals will typically be laminated with shale partings. Coal quality analysis has been restricted to data collected above 1,600 feet and the deeper coals in the western part of the basin, based on log analysis seem to have lower densities and maybe cleaner in nature.

Published desorption Scf per ton data has been limited (Stoeckinger, 1990; Tedesco, 1992; Bostic et al. 1993). Scf per ton data that has been reported has been in the range of 50 to 450 scf per ton in the Forest City Basin and 185 to 325 for Southeastern Kansas.

Adsorption data that has been reported indicates a range of 150 to 230 scf per ton using a pressure gradient of .43 psi and calculated for the depth and temperature in-situ of the coal. The basin is reportedly to be normally pressured.

Permeability measurements have only recently been taken by a variety of recent companies to the area. Permeability as high as 400 millidarcies have been reported on the Northeast Shelf by operators using their own injection fall off testing methods and this data is considered unreliable. Recent test data from Northeast Oklahoma and Southeastern Kansas have indicated a permeability range of 5 to 30 millidarcies for various coals. In the central and northern part of

the Forest City Basin coals have from 1 md to 200 md with a general range of 10 to 60 md from depths of 1,400 to 2,350 feet.

Gas quality data is limited, however, it is has been reported to be 92% to 96% methane 3% to 5% ethane and heavier hydrocarbons and the remainder is generally CO2 with nitrogen reported locally in some cases. The gas in the productive Pennsylvanian sandstones has been reported to be sourced from the coals and shales. The gas has also been reported to be a combination of thermogenic and biogenic methane.

In the early 1900s southeastern Kansas was the largest gas producing region in the country (Stoeckinger, 1990). Historically, mine explosions in underground mines have been reported both in Missouri and Kansas prior to the existence of and oil and gas industry (Bartow, 1906). The shale gas industry was started in the 1920s and 1930s in Eastern Kansas and Missouri as a result of depletion if conventional sandstone channels. Historically wells have produced in Eastern Kansas, Western Missouri and Northeastern Oklahoma. In the late 1980s and early 1990s because of Federal tax credits the industry received renewed life (Stoeckinger, 1990; Stoeckinger, 2000). The area of focus was Southeastern Kansas in Wilson, Labette, Neosho, Chautauqua and Montgomery counties and in Oklahoma in Craig, Washington and Nowata counties. In the year 2001Devon Energy Corp. bought an existing project from Patrick Exploration of Tulsa, Oklahoma and an acreage package located in Southeastern Kansas. This caused an ever increasing interest in Eastern Kansas and Northeastern Missouri whereby leasing and drilling activity.

Spacing of wells is on 40 to 160 acres depending upon the Operator. Production rates vary from 5 to over 500 MCFGPD and water rates of 5 to 0ver 1000 barrels of water a day. Peak water rates usually occur in the first six months and peak gas production occurs in the same time frame with a 1% decline per year after that.

The present play, taking into account all of the potential coal bearing lands in the Western Interior Basin, is in excess of 22 million acres. The potential coal bed methane resource for this area is generally defined by the presence of four or more seams in the Cherokee Group. It has yet to be determined how many of these coal seams in an individual well can be completed and produced. Individual well reserve estimates have varied from as little as .1 BCF per 160 acres to over .5 BCF per 80 acres.

The water quality in the Cherokee Group ranges from fresh water in Southern Iowa increasing regionally in total dissolved solids to salt water across most of Kansas, Missouri and Oklahoma. The Arbuckle of Ordovician Age provides the best disposal zone as it will go on vacuum and take several hundred if not thousands of barrels of fluid a day. There has been no published mapping of the hydrology or water quality for the Cherokee and Marmaton coals.

The land in most of the Western Interior Basin is held in fee. The play is estimated to be approximately 22 million acres in size, extending from southern Iowa to northeastern Oklahoma. There is a very small amount of Indian and Federal acreage present in the play. There are also at least two major cities, Kansas City and Tulsa that lie in the basin. There has been little if any opposition to date to the oil and gas, mining industry, and coal bed methane industry in the region. The land is typically either in pasture or crop and most tracts vary from 40 to 240 acres in size. Land tract size does increase from east to west. Presently, there are over 50 companies leasing in the basin. There are at least twenty companies planning to or are in the process of drilling test wells, pilot projects or development wells.

The negative aspects of coal-bed methane exploration in the Western Interior Basin are unknowns concerning completing multiple thin coal seams in the same well bore, areas that have been degassed by existing conventional sandstone reservoirs that have drained adjacent shales and coals over time and coal seams may be charged locally but not regionally. The positive aspects for developing coal bed-methane in the Western Interior Basin are location to strong and insulated gas markets, numerous competing pipeline companies and end-users; historical production from coals and black shales; the coal section contains anywhere from three feet to over 50 feet of net coal; multiple coals from 100 to 2,500 feet; permeability varies from 1 to 80 millidarcies; water disposal is generally underground avoiding the problems

associated with surface disposal; the land is predominantly fee; pro-industry regulators and minimal environmental opposition and actual gas contents becoming better defined.

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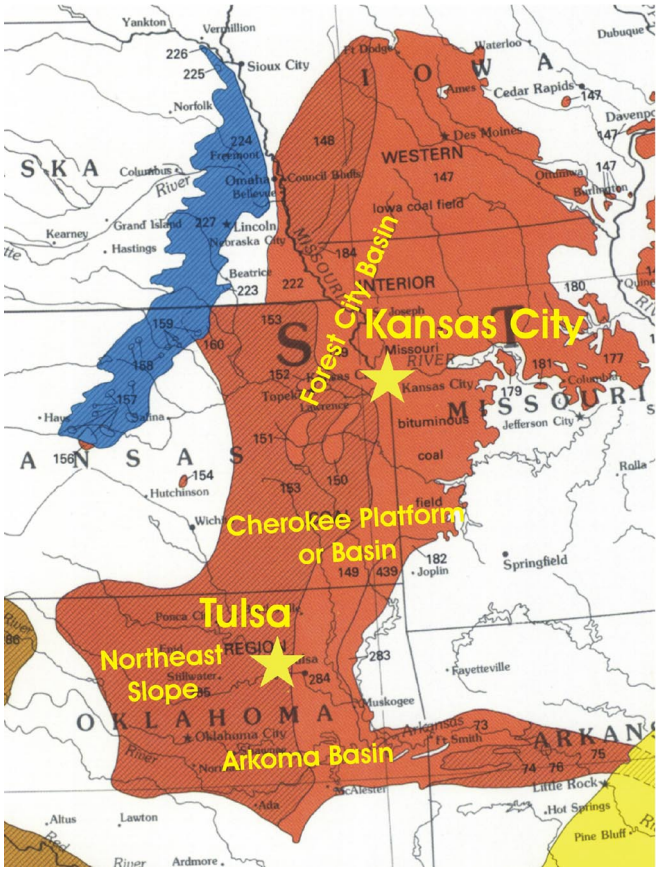


Figure 1 – Location of the Western Interior Basin in the United States that is further divided into the Forest City Basin, Cherokee Basin or Platform and the Northeast Slope. The Arkoma Basin lies along the southern boundary of the Western Interior Basin (Wood and Bour III, 1988)

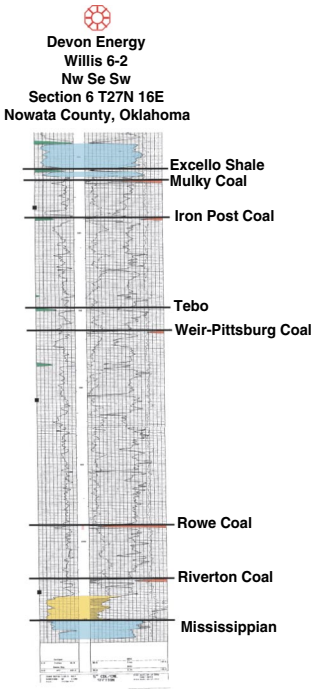


Figure 2 – Devon Energy Willis #6-2, Section 6 Township 27 North Range 16 East, Nowata County, Oklahoma.

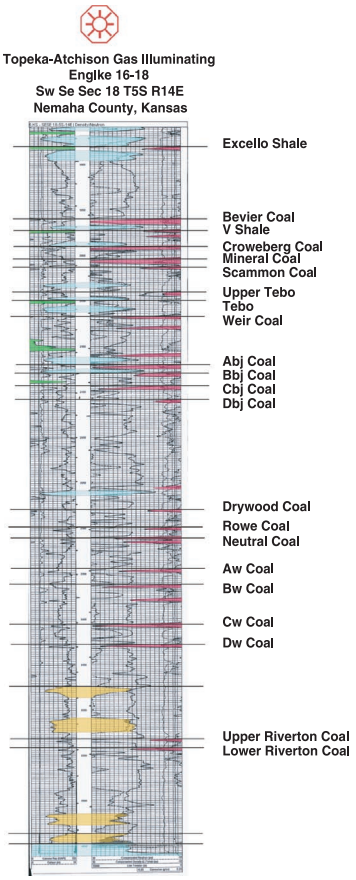
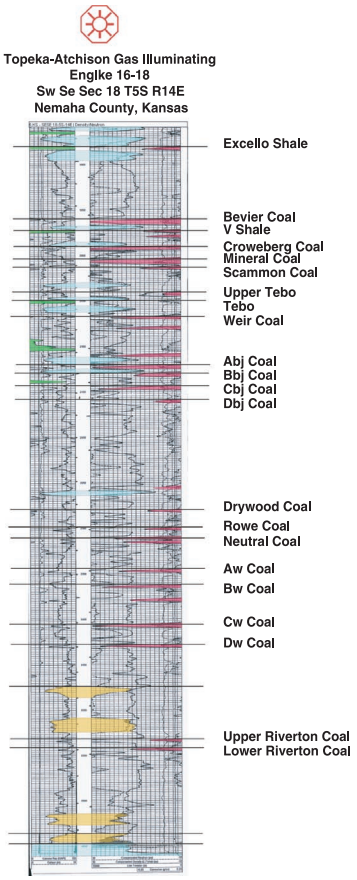


Figure 3 – Topeka Atchison Gas & Illuminating LLC Englke 16-18, Section 18, Township 5 South, Range 14 East, Nemaha County. Kansas.



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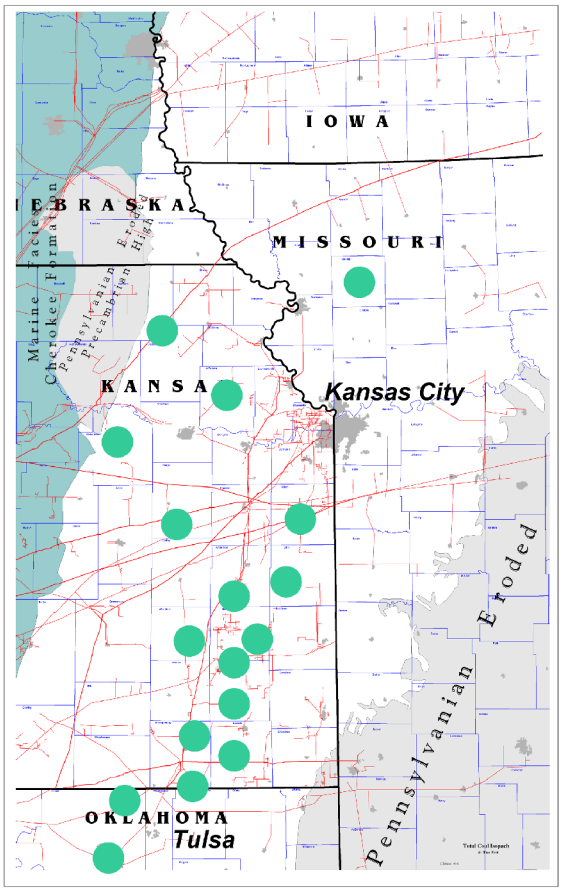

Figure 4 – Western Interior Basin, green dots indicate location of production and pilots.