Coalbed Methane Production Potential in the Hartshorne Formation (Oklahoma)

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EXTENDED ABSTRACT

An important source of energy for the generation of electricity and process heat in the petroleum industry is coal. Coal is also a significant reservoir and source rock for natural gas, in which context the gas is known as coalbed methane. The Hartshorne Formation in the Arkoma Basin of Oklahoma contains the lowermost sediments within the Desmoinesian Series, middle Pennsylvanian in age. In 1900, two distinctive coals were found above the Hartshorne sandstone in the southern part of the Arkoma Basin, referred to as the upper and lower coal beds (Taff and Adams, 1900). North of this area, the two coals merge and are referred to simply as the Hartshorne coal. The rank of the coals increases from medium- and high-volatile bituminous in the western part of the basin, to low-volatile bituminous in the center, to anthracite in the east. The upper and lower Hartshorne coals have been the major coalbed methane target in the basin because of their high mine-methane emission rates and desorbed gas contents of 200 to 675 cubic feet per ton (CF/T), which rank amongst the highest in the United States. Assuming an average gas content of 200 to 450 CF/T, Rieke and Kirr (1984) estimated the potential coalbed methane resource at 1.58 to 3.55 trillion cubic feet (TCF).

Folding and faulting greatly affect the Hartshorne Formation within the Arkoma Basin. Most structures are approximately parallel to the east-west trending Choctaw fault. Along with the folds and faults, natural fractures are present which are associated with permeability and porosity enhancement in some gas fields (Andrews, 1998). The coal of the Hartshorne Formation has been a target of coalbed methane exploration for more than a decade with hundreds of productive coalbed methane wells drilled. Coalbed methane production in the Arkoma Basin, Oklahoma can have large variations in Initial Potential (IP) rates. It is questionable as to whether this is due to physical rock properties, completion techniques, or other variables.

Cardott (1998) conducted a study on the coal properties of the Hartshorne Formation in Oklahoma. He studied the production and properties of the gas source rock and reservoir rock over the southern portion of the Arkoma Basin, and presented a summary of Oklahoma coal desorption analyses. The summary showed a gas content range of 70-560 (CF/T) over a depth interval of 175 to 3,651 feet. He determined that gas content increases with depth and increasing coal rank. Chemical analyses of the Hartshorne coal were also studied. Data were collected for moisture (%), ash (%), volatile matter (%), fixed carbon (%), total sulfur (%), and coal rank. It was concluded that Hartshorne coals generally have medium-sulfur (average 1.5%) and low to medium ash (average 7.7%) concentrations. With these data, Cardott (1998) was able to reconfirm that the rank of the Hartshorne coal increases within the basin from west to east, to-

wards the Ouachita orogenic front. Cleat fractures are the main reason for directional permeability of the coal beds, an important aspect for coalbed methane extraction and production (Cardott, 1998). Cleat spacing (frequency) is also important because cleat frequency increases with increasing rank, therefore a higher ranked coal has the potential to yield a higher producing well. Cardott (1998) also studied the coalbed methane production in the Spiro SE Field in northern LeFlore County. This field contains the discovery well for the Hartshorne coal as well as the being the location for earliest phase of coalbed methane production. Twenty-eight vertical wells show initial potential rates ranging from 45 to 185 thousand cubic feet of gas per day (MCFGPD). Cardott did not compare IP rates to coal properties, therefore no analysis was made. A study of Hartshorne coal horizontal wells was conducted by Williams (2005). This study was done to confirm an increase in initial rates of production from vertical wells to horizontal wells. Williams stated that vertical wells were an economic challenge, as completions usually resulted in wells with initial rates of less than 100 MCFGPD. Williams (2005) found that horizontal wells with an average lateral length of 1,800 ft can produce as much as 2 million cubic feet of gas per day (MMCFGPD). Understanding the conditions and characteristics of natural gas reservoirs is essential to the successful development for methane production from coal beds (Cardott, 1998). The production potential of the upper coal bed seam found within the Hartshorne Formation can be used to compare with a variety of rock properties. Kemp *et al*. (1993) suggested that there are several factors influencing methane producibility, such as coal thickness, thermal maturity, ash content, and reservoir pressure. The primary controls also include water content, permeability, cleat intensity, and tectonic fracturing (Suneson, 1998). The present author's study was intended to help find a method to maximize the production of coalbed methane by finding trends within the rock properties. In order to decipher which properties play a major role in the CBM production rates of the coal, all rock properties (*i.e*., bulk density, gamma ray, thickness, photoelectric, structure, overburden, vitrinite reflectance, and cleat orientations) were characterized for the Hartshorne Formation.

This study demonstrated that there is not one single decisive property responsible for higher initial potential rates in gas wells of the Hartshorne Formation (Arkoma Basin, Oklahoma). However, the analysis of rock properties obtained from logging data, surface outcrops, and coal maturity data shows a number of factors that influence the initial potential rates and that will help well planning and the selection of the best location for maximized production rates.

Initial potential values are not the best production values to use for the analysis. The initial potential values only show the initial rate of the well. Since gas production often increases over the first few months because of dewatering of the coal cleats, an average production value for the first three months may be a better indicator to use for the comparisons. Therefore, a more accurate production value to use would be an average over a designated time period.

Coals from the producing wells with the highest IP rates (>2.0 MMCFGPD) exhibit bulk density values between 1.4 and 1.5 g/cc and typically have a coal thickness between 5 and 6 ft. Coal thickness ranges from 4 to 8 ft in wells with rates greater than 1.0 MMCFGPD; these wells are still very economical. Therefore, a Hartshorne coal thickness of 5 ft appears to be the optimum, but 4 to 8 ft of coal can potentially produce exceptionally high IP rates. Wells with IP rates greater than 1.0 MMCFGPD contain coals with gamma-ray values between 16 and 48 API units, and wells with IP rates greater than 2.0 MMCFGPD exhibit gamma-ray values ranging from 17 to 40 API units. A correlation between coal thickness and gamma-ray intensity was made. Therefore, the thicker a coal the lower the gamma-ray intensity. The drop in gamma-ray intensity with increasing coal thickness occurs at a rate of $y = -4.5871x + 58.255$, where x = coal thickness and y = gamma-ray intensity. Wells with IP rates greater than 1.0 MMCFGPD are also characterized by photo-electric values between 1.5 and 2.0 barns/electron.

A basemap was made to represent the geographical area in which all ideal parameters between bulk density values, coal thicknesses, gamma-ray intensities, and photo-

electric values were met. The map indicates areas with the most promising locations to drill coalbed methane wells that will potentially yield IP rates greater than 1.0 MMCFGPD.

Lateral well length does not show a linear correlation with IP rates. There are no data to prove that a long lateral length of a horizontal well will produce more methane gas than a short lateral length.

The geological structure plays a major role in the drilling for coalbed methane. Wells on structural highs contain less water and thus gas production is much easier and more economical. However, the main concern with drilling a well on top of a structural high is the increased possibility of faulting.

Overburden is a key factor in coalbed methane production. The ideal depth for gas production from the Hartshorne coal is between 1,500 and 2,500 ft. Coals found at these depths normally have higher production than those from shallower and greater depths. Although not all gas wells drilled at these depths exhibit high production rates, the chance of encountering higher production rates is better.

Surface lineaments show no apparent correlation with the direction of the cleat or joint systems. Linear features with similar azimuths as the cleats and joints exist, but are statistically not significant. This feature appears not to be a useful parameter in the location of major fractures.

Cleat systems are well developed and relatively uniform throughout the basin. Therefore, it should be easy to drill perpendicular to the face cleats, which will usually result in wells with higher IP rates than those drilled parallel to the cleats.

Vitrinite reflectance values correlate to the maturity of the coal. Typically, a more mature coal will produce better, but this appears not to be the case in the Hartshorne coal. There is no apparent correlation between the vitrinite reflectance and the associated IP rates.

In summary, IP rates are most strongly influenced by a combination of physical rock properties. There is no one characteristic that leads to higher producing wells.

One other geologic coal characteristic needs to be studied to grasp the full understanding of the methane gas production variations. Total organic carbon is important in knowing the organic richness of the coal. Unfortunately, data were not available from the study area.

Conventional and oriented cores are other methods of acquiring data that can be used to better the understanding of the coal cleats and fractures as well as other geochemical parameters, but presently not available.

There are potentially some other factors that may influence the initial production of a well. This study only looked at the geology of the coal, but the completion and production practices used for a well are key factors to understanding how the methane gas is released from the ground. A more in-depth study of the engineering aspects of coal production needs to be completed for a full understanding of varying gas rates.

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