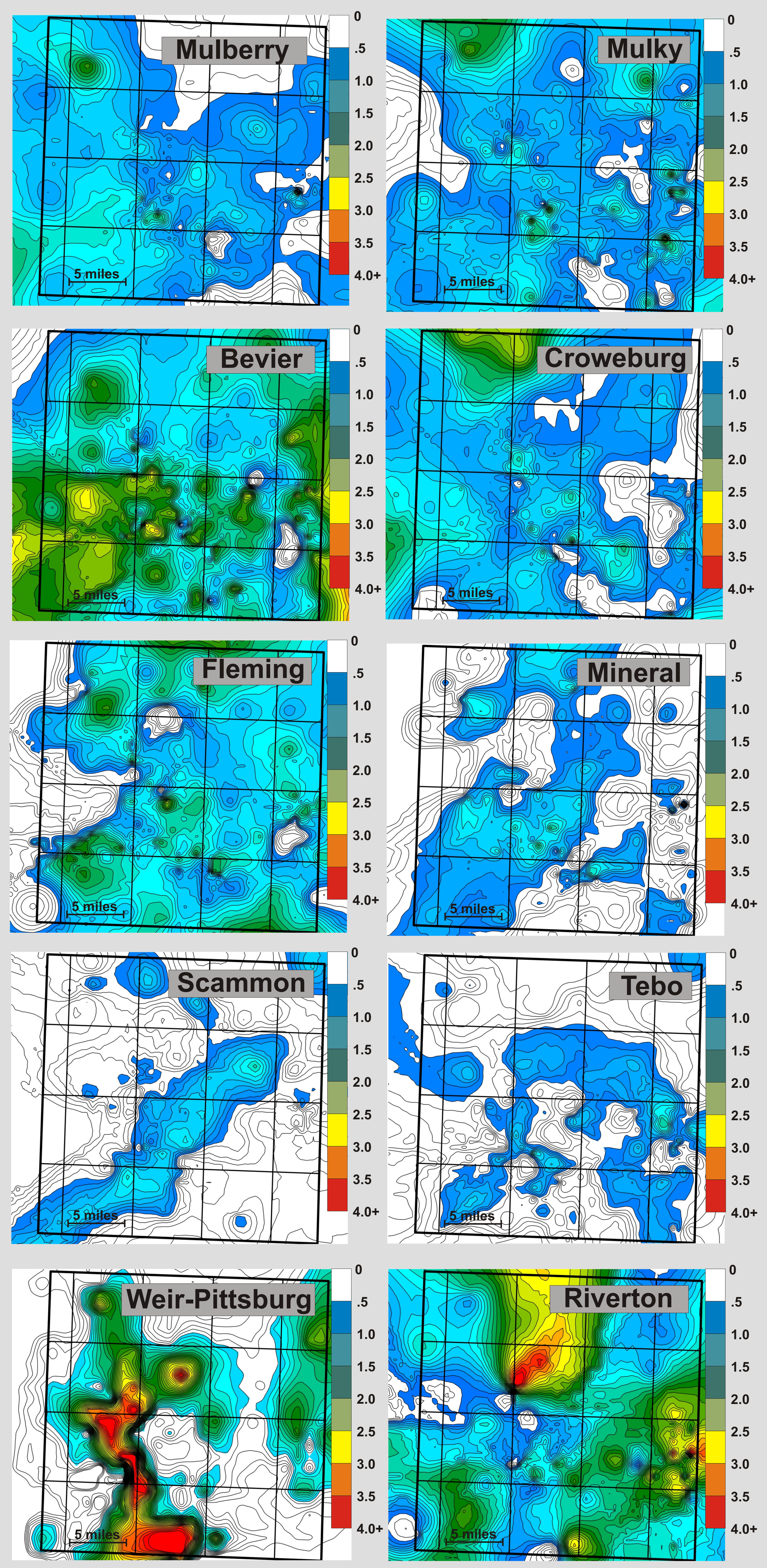
Integrated Subsurface Carbon Sequestration and Enhanced Coalbed Natural Gas Recovery Using Cement Kiln Emissions, Wilson County, Kansas

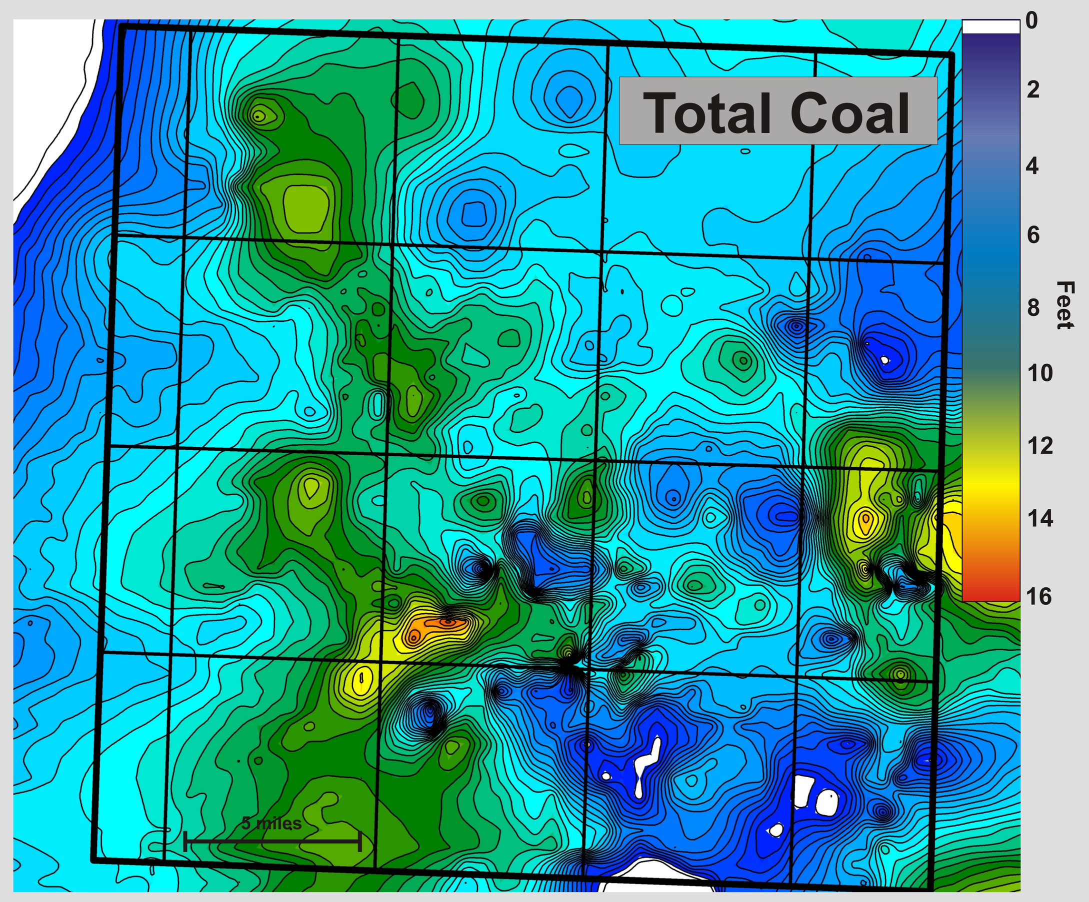
Stephen G. Schurger[1], K. David Newell[1], James G. Blencoe[2], and Timothy R. Carr[1]
[1]Kansas Geological Survey, University of Kansas, Lawrence, KS 66044
[2]Oak Ridge National Laboratories, Oak Ridge, TN 37831

AAPG 2006, Houston Texas

Coal Distribution

Note: All units are in feet



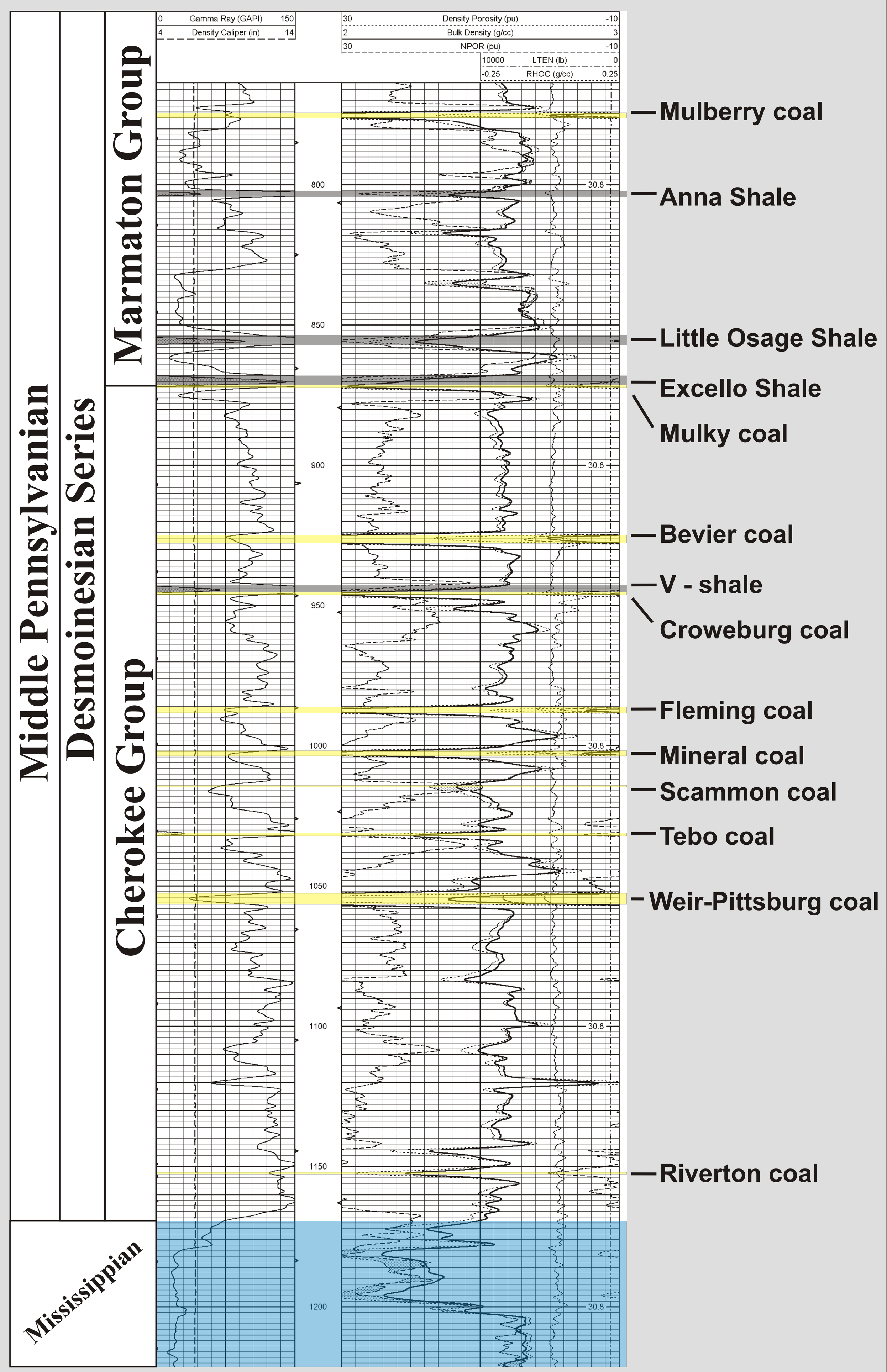


The thickness and distribution of coal is influenced by both the tectonic and structural setting, as well as the depositional environment in which peat accumulates.

The Cherokee and Marmaton groups of southeastern Kansas contain upwards of 20 named coals, as well as several more that are unnamed. The distribution and lateral continuity of many of these coals is such that commonly less than half are found in any one locality. These coals are commonly less than two feet in thickness, and rarely exceed five feet. General practice in industry is that a coal must be a half of a foot thick before it is considered viable for CBNG production. With the abundance of new wells being drilled targeting these coals, it is becoming apparent that the distribution of many of these coals is much more variable than once thought.

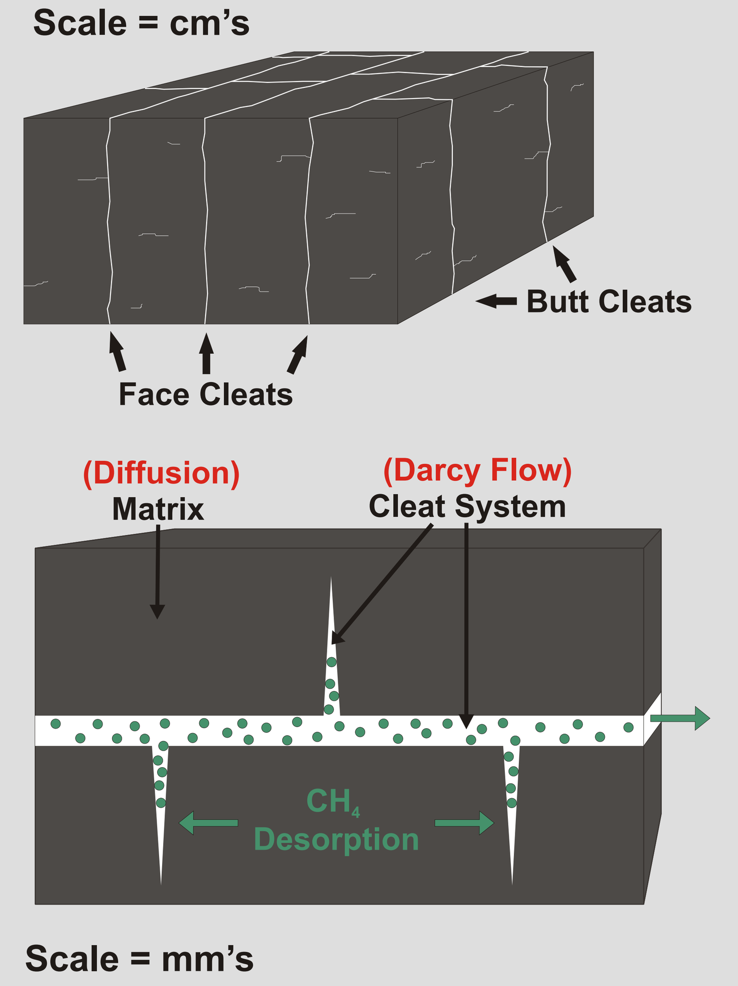
Comparison of coal isopachs to the structure on the top of the Mississippian indicates total coal thickness tends to be the greatest on the structural highs. These highs likely provided the correct balance of conditions for accumulating larger quantities of coal-forming peat, or possibly control reducing sedimentary processes that would reduce or remove peat accumulations.

Gas Bearing Units



A typical well log (from Wilson County, Kansas) showing the log response of the Cherokee and Marmaton groups, that would be found within the study area. Gas-bearing units are highlighted. (coals in yellow, black shale in gray)

Permeability

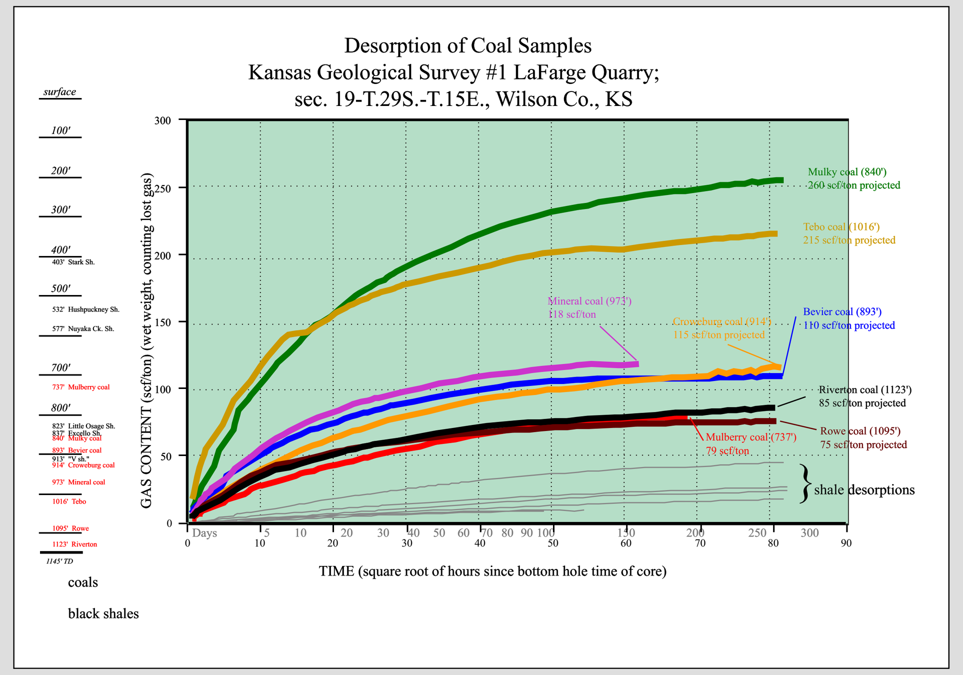


One of the most important factors governing the producibitlity of CBNG is permeability. Coalbeds are considered to be dual-porosity, dual-permeability systems, represented by the cleats and matrix. Cleats are naturally occurring, regularly-spaced fractures that occur nearly perpendicular to bedding. A cleat system consists of an orthogonal set of fractures: the face cleats, which are the dominant through-going fracture set, and butt cleats, which terminate upon their intersection with the face cleats or any dull band in the coal. Cleating is mainly a function of rank, ash content, and geological structural.

Flow within the cleat system can be described by Darcy's Law. It is important to note that permeabilities can be significantly different depending if the flow is in the direction of the face cleats or butt cleats. The coal matrix, where most of the gas is stored, is characterized by diffusion of gas through the matrix, which is controlled by concentration gradient, and modeled by Flick's Law.

During the initial production of a CBNG well, the rates of fluid and free gas are mainly a function of the permeability of the cleat system. As dewatering continues and the drop in reservoir pressures leads to gas desorption, the rate of gas production becomes more of a function of the rate of diffusion of the coal matrix rather than the permeability of the cleat system. For these reasons diffusion rates and cleat spacing can be critical controls on the producibility of CBNG.

Gas Content

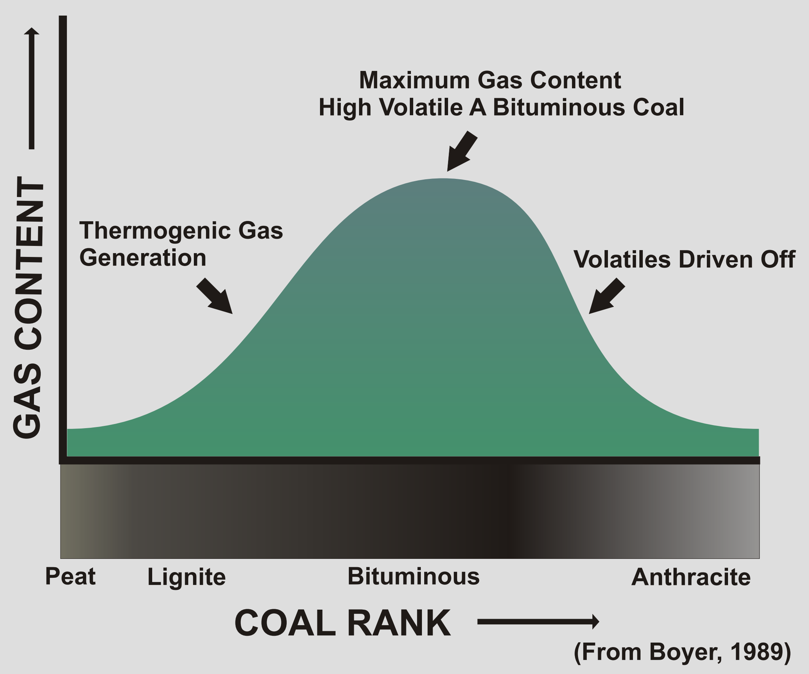


Coal gas content is a critical variable needed for setting the initial conditions of the reservoir model. It can easily be determined through simple desorption experiments. Coal samples from the LQ #1 core were collected and allowed to desorb for a sufficient length of time to obtain an accurate gas content for each coal.

Gas content is also important for determining whether a coal is saturated or under saturated with respect to gas, at reservoir conditions. Understanding gas saturations can help to predict the gas production characteristics during pressure drawdown. The shape of the desorption curves can also be used to estimate the rate of diffusion, by analyzing the time it takes to desorbe 63.7 percent of the maximum gas content.

Coals from the LQ #1 core had gas contents ranging from 75 scf/ton up to 260 scf/ton, which are consistent with gas contents values from core and cuttings data from the surrounding region.

Coal Rank and Gas Generation



(From Boyer, 1989)

Coal Rank	Reflectance (%)	Volatile matter (%)	Carbon (% dry ash-free, volume)	Bed moisture (%)
Peat	0.3	64 60	60	75
Lignite		56		35
Sub-bituminous C	0.4	52		
Sub-bituminous B		48	71	25
Sub-bituminous A	0.5	44	77	8-10
High-volatile bituminous C	0.6			
High-volatile bituminous B	0.8	40		
High-volatile bituminous A	1.0	36 32		
Medium-volatile bituminous	1.2 1.4	28 24	87	
Low-volatile bituminous	1.6 1.8	20 16		
Semi-anthracite	2.0	12 8	91	
Anthracite	3.0 4.0	4		

(From Rice, 1993)

Rank, or a coal's thermal maturity, is an important control on the gas generation and final gas content of a coal. During the coalification of peat and the continued thermal maturation processes of coal, the total amount of gas generated increases. Coals are unique in that they are not only the source of the gas but also the reservoir. At a particular point in the maturation process, coals lose their capacity to store gas. Maximum gas contents can be found in high-volatile A and B bituminous coals. Further maturation beyond this point will lead to compaction of the pore spaces in which gas is stored. It is important to recognize coal rank in estimating potential maximum gas content and storage capacity for a CO_2 injection.