International Journal of Coal Geology 127 (2014) 56–74

Contents lists available at ScienceDirect

International Journal of Coal Geology

journal homepage: www.elsevier.com/locate/ijcoalgeo

Organic petrology, geochemistry, gas content and gas composition of Middle Pennsylvanian age coal beds in the Eastern Interior (Illinois) Basin: Implications for CBM development and carbon sequestration

Sarah M. Mardon [a], Cortland F. Eble [b,*], James C. Hower [a], Katherine Takacs [b], Maria Mastalerz [c], R. Marc Bustin [d]

[a] Countrymark Energy Resources, LLCEvansville, IN 47715, United States
[b] Kentucky Geological Survey, University of Kentucky, Lexington, KY 40506, United States
[c] Indiana Geological Survey, Indiana University, Bloomington, IN, United States
[d] Department of Earth & Ocean Sciences, University of British Columbia, British Columbia V6T 1Z4, Canada

ARTICLE INFO

Article history:
Received 5 August 2013
Received in revised form 3 February 2014
Accepted 4 February 2014
Available online 28 February 2014

Keywords:
Coal
Shale
Maceral
Methane
Carbon dioxide

ABSTRACT

Fifty four samples of coal and organic-rich roof shale strata were collected as part of a coal bed methane exploration program. Following canister desorption to document gas contents, the samples were analyzed by geochemical and petrographic methods. Coal samples were found to have moderate ash yields (avg. 13.5%, dry basis), and high total sulfur contents (avg. 4.3%, dry basis). The average gas content was 1.91 m^3/ton. Petrographically, the coals were dominated by vitrinite macerals (avg. 81.6%, mmf), especially telovitrinite. By comparison, liptinite (avg. 7.1%, mmf) and inertinite macerals (avg. 11.3%, mmf), were minor in occurrence. Coal samples ranged from high volatile C to high volatile A bituminous in rank (avg. Ro maximum, 0.76%).

Shale samples had higher ash yields (avg. 76.1, dry basis), though total sulfur contents were comparable to the coal samples (avg. 4.2%, dry basis). Gas contents were lower than the corresponding coal samples (avg. 0.65 m^3/ton). Petrographically, the shale samples contained decreased amounts of vitrinite (avg. 25.6%, mmf), and higher amounts of liptinite (avg. 45.4%, mmf) and inertinite (avg. 29.0%, mmf) macerals, relative to the coal samples.

Gas obtained from coal and shale beds in the Illinois Basin was relatively pure (high CH_4 content). Limited data also indicated that Illinois Basin coals have the ability to adsorb fairly significant amounts of CO_2. This suggests that CO_2 injection to enhance methane production (ECBM), and/or to sequester CO_2 may have some potential. Mineralization in the coals could negatively impact CBM production, but it was found that the majority of the mineralization was present in the roof strata.

1. Introduction

Research has addressed a variety of issues related to coal bed methane (CBM) production and CO_2 sequestration. Coal bed methane production is impacted by many factors, including maceral content (Bustin and Clarkson, 1998; Chalmers and Bustin, 2007; Crosdale et al., 1998), rank (Taylor et al., 1998; Teichmüller and Teichmüller, 1966), and cleat structure (Walker et al., 2001). Reservoir qualities such as temperature (Barker, 1989; Taylor et al., 1998; Teichmüller and Teichmüller, 1966), pressure (Barker, 1989; Taylor et al., 1998), and stratigraphy (Pashin, 1998) are also important factors.

In this study, the CBM and CO_2 sequestration potential in a number of coals from the Western Kentucky portion of the Illinois Basin (Eastern Interior Basin) are evaluated.

* Corresponding author. Tel.: +1 859 323 0540.
E-mail address: eble@uky.edu (C.F. Eble).

http://dx.doi.org/10.1016/j.coal.2014.02.002
0166-5162/

1.1. Factors that influence coal bed gas content

The degree of coalification or organic metamorphism is one factor that may have an impact on whether or not a CBM reservoir produces gas. Coalification depends mostly on the maximum rock temperature reached, and how the temperatures vary with time. Studies have indicated that hydrothermal fluids may impact the degree of coalification beyond the level of maturity resulting from factors due to normal burial (Hower and Gayer, 2002).

Maceral composition impacts adsorption and desorption properties of coals, with the majority of vitrinite-rich coals having greater adsorption capacities than their inertinite-rich rank equivalents (Crosdale et al., 1998). Based on modeling, bright coal desorption is mostly controlled by the micropore system, whereas dull coal desorption is controlled by a bi-disperse pore system. Petrographic analysis suggests that the presence of collotelinite has a positive correlation with mesopore and micropore volumes. Collodetrinite appears to contribute to a decrease in micropore and mesopore volumes. The presence of inertinite leads to an increase in the mesopore volume (Mastalerz et al., 2008).

As cleats are responsible for most of the permeability and porosity in a coal bed, the understanding of cleat orientation, and fracture style, is important in determining whether or not a coal seam will produce methane (Laubach et al., 1998). Gas production in geologic reservoirs is also impacted by structural geology (Pashin and Groshong, 1998). In the Deerlick Creek and Cedar Cove fields, located in Alabama, normal faults and hanging-wall rollovers were found detached in the lower portion of the Pottsville Formation, and were believed to contribute to large amounts of gas production. In the Gurnee and Oak Grove coalfields, also located in Alabama, the productivity of wells depended on the location along an anticline and syncline in the area.

1.2. CO_2 sequestration

Many researchers have assumed preferential sorption of CO_2 over CH_4 in coal seams. However, Busch et al. (2005) found that preferential sorption of CO_2 over CH_4 does not occur all of the time, suggesting that storing CO_2 in coal seams may not work in all parts of every basin, and that each situation should be evaluated individually. Mazumder and Wolf (2008) observed differential swelling of coal in the laboratory, and determined that water hinders the CO_2/CH_4 exchange; at the pore level, CO_2 is preferentially adsorbed over CH_4 in the primary porosity system. Based on this study, CO_2 sequestration in dry coals is probably more likely to be successful than in wet coals.

2. Geologic setting

The Western Kentucky Coal Field is the southern tip of the Eastern Interior, or Illinois Basin (Fig. 1). Pennsylvanian rocks in the Western Kentucky Coal Field consist of conglomerates, medium- to fine-grained sandstones, siltstones, shales, limestones and coal beds. Sandstones and siltstones account for 50% to 80% of the total rock package, while shales make up between 20% and 40%. Limestones and coals account for 5%, or less, of the total strata, but are very important from an economic standpoint, and also for stratigraphic correlation (Greb et al., 1992). Collectively, these strata were deposited in a wide array of depositional environments at a time when Western Kentucky was located close to the paleoequator (Bambach et al., 1980).

Coal-bearing strata in the Western Kentucky Coal Field (WKCF) are all Pennsylvanian in age, with the youngest beds (Mauzy Formation) perhaps being earliest Permian. In stratigraphically-ascending order, Early and Middle Pennsylvanian-age rocks in Western Kentucky are assigned to the Caseyville, Tradewater, Carbondale, and Shelburn Formations (Fig. 2). Further discussion of the coal measures can be found in Greb et al. (1992).

Fluid flow in the Illinois Basin occurred as a consequence of the Ouachita orogeny (Hower and Gayer, 2002; Oliver, 1986). Samples evaluated in previous studies indicate coals from Union and Webster counties, south of the Rough Creek Fault system and northwest of the Central Fault system, have higher reflectances than those located elsewhere in the coalfield. Flow of thermal brines through the region is considered to be a factor influencing the rank of coals in that area (Hower and Gayer, 2002).

3. Materials and methods

Fifty four samples of coal and organic-rich roof shale strata were collected from five CBM drill core locations in Western Kentucky (Fig. 1). All of the samples are from the Tradewater, Carbondale, and Shelburn Formations (WKY # 4 through WKY #13 coal interval, Fig. 2). These

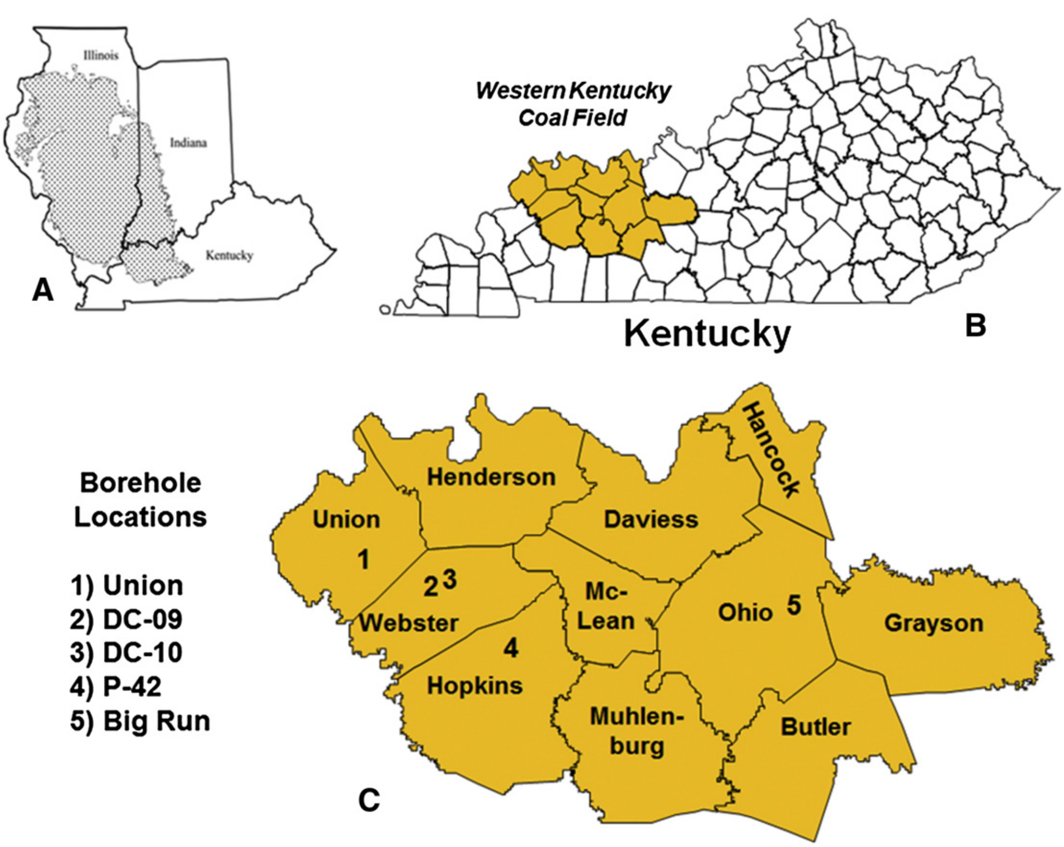

Fig. 1. Location maps. A) outline of the Eastern Interior (Illinois) Basin, B) position of the Western Kentucky coal field in Kentucky, and C) position of boreholes in the Western Kentucky coal field.