International Journal of Coal Geology 125 (2014) 45–56

Contents lists available at ScienceDirect

International Journal of Coal Geology

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

The effect of megascopic texture on swelling of a low rank coal in supercritical carbon dioxide

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ARTICLE INFO

Article history:
Received 15 January 2014
Received in revised form 13 February 2014
Accepted 13 February 2014
Available online 22 February 2014

Keywords:
Coal swelling in CO_2
Megascopic texture
Low rank coal
CO_2–ECBMR

ABSTRACT

Swelling experiments in supercritical CO_2 have been conducted on two groups of samples of Miocene low rank coal with different megascopic textures (non-banded and banded) to address the different swelling behaviors. A block sample ($30 \times 10 \times 10$ mm) from core samples was used and a strain gauge was attached to the long axis of the sample block to measure the length of change. The actual maceral group compositions between these samples were similar and high in huminite. However, there is a subtle difference in suberinite and corpohuminite maceral where banded samples consistently have higher compositions compared to non-banded ones. The experimental results showed that banded coal samples tend to have anisotropic linear swelling where swelling perpendicular to bedding plane was always greater than that parallel. In contrast, non-banded samples showed more isotropic behavior without much preference to bedding plane orientation. The ratio of perpendicular to parallel swelling was around 1.28 and 1.05 for banded and non-banded coal samples, respectively. The difference in swelling characteristics was concluded as a result of different megascopic textures of coal samples with respect to bedding orientation.

1. Introduction

Studies in most basins have confirmed that permeability is one of the most important considerations in determining the economics of gas production (Bustin, 1997; Mavor and Gunter, 2006). Carbon dioxide (CO_2) injection in coal seams has the possibility to increase coal bed methane recovery and at the same time secure long term storage of CO_2. However, since CO_2 is adsorbed in higher concentration than methane (CH_4) for a given pressure, it may induce swelling and decrease permeability of coal.

Coal swelling caused by CO_2 adsorption has been investigated by numerous authors (Battistutta et al., 2010; Durucan et al., 2009; Harpalani and Chen, 1995; Levine, 1996; Liu and Harpalani, 2013; Majewska and Ziętek, 2007; Majewska et al., 2010; Seidle and Huitt, 1995). Mazumder and Wolf (2008) measured the axial strain using a linear variable differential transformer (LVDT) and investigated the effects of differential swelling on coal permeability. Levine (1996) used strain gauges attached to a coal block several centimeters in length and width to measure coal swelling under pressure up to 5.17 MPa and 3.10 MPa for CH_4 and CO_2 injection, respectively. Measurements were conducted under dry condition on a high-volatile C bituminous coal from the Illinois basin. Axial strains were observed to range up to 0.18% for CH_4 and up to 0.5% in CO_2.

Coal swelling of Australian bituminous and sub-bituminous coal in CO_2, CH_4 and various mixtures of two gases has been studied intensively by Day et al. (2008, 2010, 2011, 2012). Swelling of coal blocks (nominally $3 \times 1 \times 1$ cm), perpendicular as well as parallel to the bedding plane, was measured directly using a digital camera. The results show that swelling was greater with CO_2 than CH_4 and mixed gas and lower rank coals swelled more than higher rank ones. Identical results of Australian coal were shown by Pan et al. (2010) who measured swelling of coal cores up to 13 MPa pore-pressure and 20 MPa confining-pressure using a triaxial cell.

According to several studies, then, coal swelling is highly anisotropic with more swelling in the direction perpendicular to the bedding plane than parallel to it (Day et al., 2008; Levine, 1996; Pan et al., 2010). Levine (1996) conducted his experiments on Carboniferous, high volatile bituminous coal from the Illinois basin while Pan et al. (2010) used Permian bituminous coal from the Sydney basin. Based on literature review, most of the swelling experiments have been done on high rank coal (Levine, 1996; Seidle and Huitt, 1995) and only limited on low rank coal e.g. Reucroft and Sethuraman (1987). Reucroft and Sethuraman (1987) conducted swelling experiments on lignite–sub-bituminous coal but under very low CO_2 injection pressure (up to 15 atm $\approx$ 1.5 MPa).

Shearer et al. (1995) described the distinctive nature of coals from various ages and confirmed that those from the Carboniferous and

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http://dx.doi.org/10.1016/j.coal.2014.02.004

Permian ages are typically banded and that thick sequences of non-banded coals are uncommon. Non-banded coals are commonly cannel or splint coal lithotypes in these older coals. In contrast, Paleogene–Neogene coals can contain significant proportions of non- to poorly banded coal lithotypes that are also dominated by huminite group macerals. They can contain quite thick vitrain bands, and this compositional characteristic is interpreted to result from the accumulation of woody and angiosperm dominated peat in variable states of decomposition. These remnant plant remains, or phyterals, add a fabric to the coal that should influence the flow pathways of gases through the coals, and be reflected in swelling anisotropy. The objective of the study presented in this paper is to investigate the effect of megascopic texture on the swelling characteristics of a low rank Miocene coal from Indonesia at CO_2 supercritical condition.

2. Geological background

The samples for this study were taken from the Kutai basin. It is one of the prolific coal basins in Kalimantan, Indonesia with total coal resources of 40.67 Gt (Handbook of Energy and Economic Statistics of Indonesia, 2012), and much at depth which is a good target for potential sequestration. The basin is bounded to the north by the Mangkalihat high; to the south it hinges on the Adang-Flexure (Adang–Paternoster Fault); to the west it is terminated by the Kuching high-part of the Kalimantan Central Ranges; and to the east it opens into the Strait of Makassar (Satyana et al., 1999).

Coal bearing sequences in the Kutai basin are mainly Miocene to Eocene in age where the coal mines are mostly mining seams in the Miocene strata. The Neogene coals have huminite reflectance in the range of 0.30–0.57% (Daulay and Cook, 1988). The Lower Miocene succession is referred to as the Pulau Balang formation, the Middle–Late Miocene succession is called the Balikpapan formation and the Late Miocene to the Pliocene succession is called the Kampung Baru formation (Friederich et al., 1999).

The coal samples from the study area (Fig. 1) are Miocene in age and are deposited in the Balikpapan formation. The current interpretation of the coal bearing sequence shows that the seams are developed over 1300 m of vertical profile within the Balikpapan formation in the Pinang area. The stratigraphic boundary between this and the Palau Balang formation lies within a marine regressive sequence and is not very well defined. There are more than thirty principal seams with numerous splits developed from the main seams (Macmillan et al., 2000). Details of the stratigraphic column from the studied area can be found in Macmillan et al. (2000).

3. Samples and methods

3.1. Samples

Swelling experiments were conducted on banded bright luster sub-bituminous and non-banded dull luster lignite rank coal from Kutai basin, Indonesia. The samples were prepared from core samples from different wells with various depths from 35 to 135 m below surface.

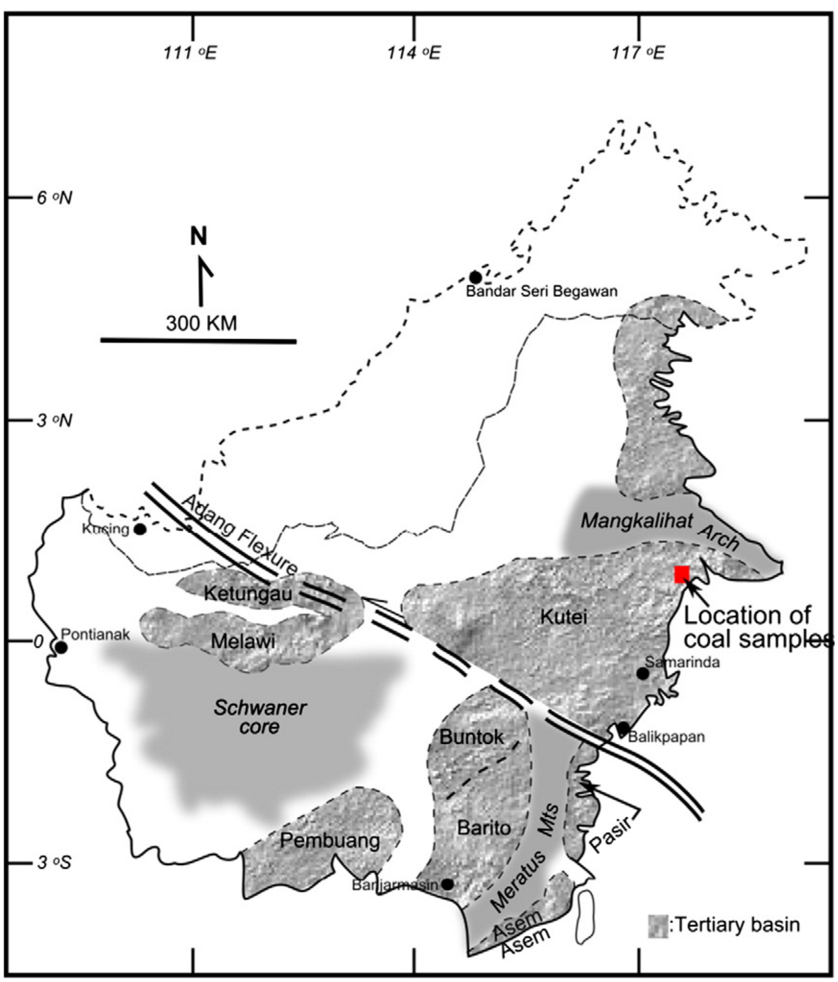

Fig. 1. Basin in Kalimantan and location of coal samples used in the study (compiled from Friederich et al., 1999; Moss and Chambers, 1999; Satyana et al., 1999).