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High heat flow effects on a coalbed methane reservoir, East Kalimantan (Borneo), Indonesia

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ABSTRACT

The Balikpapan Formation (Miocene age) in Sangatta, East Kalimantan is thick (>1500 m) containing abundant coal seams that range in thickness from less than a meter to over 5 m. Coal seams are distributed throughout the section and may represent 5 to 7% of the total formation thickness. Measured gas contents range from <1 to 13 m^3/t (as received basis). The variation is both stratigraphically and geographically controlled. In samples from three drill cores, trends of vitrinite reflectance, calorific value, and moisture content indicate that rank increases down hole. Measured gas content also increases down hole in each core locations. However the rate of change down hole for all of those parameters increases with proximity to the southwestern corner of a geological feature known locally as the Pinang Dome. The Sangatta area has a higher geothermal gradient (50 °C/km) than most other parts of East Kalimantan (25–40 °C/km). It is well documented that the southwest part of the Pinang Dome has elevated organic maturation levels. It is concluded that there is higher heat flow in this area and thus coal beds in proximity have been thermally altered. This is evident not just in the increased rank and measured gas contents but also in the higher CO_2 and C2+ gas composition found adjacent to the southwest corner of the Pinang Dome. It is hypothesized that the gas origin in the higher rank area could be thermogenic while gas isotopes from the well furthest from the Pinang Dome, with the lowest rank coals, indicate biogenic origins.

1. Introduction

Organic materials are especially prone to physico-chemical changes with even the slightest increase in burial depth. The degree, rate and magnitude of change in the maturation of organic material are mostly determined by temperature and time (Taylor et al., 1998). Coal beds are composed almost entirely of organic material and are primarily classified by their level of maturation (or 'rank'). Simplistically, in any sedimentary basin, the rank of coal beds will follow Hilt's Law; that is, the deeper the coal bed, the higher the rank (Thomas, 2007). Rank increases through a process of chemical de-volatilization that involves the thermokinetic generation of large volumes of methane (Hunt, 1979). Methane in coal beds has historically been regarded as a hazard in coal mining (see Flores, 1998). Although the hazard very much remains, methane has also been demonstrated to have large commercial value (see reviews by Flores, 2013; Moore, 2012).

Initially, coalbed methane (CBM) extraction was targeted at higher rank coals (bituminous and greater) because of the generally higher gas contents and pressures. Methane derived from the chemical de-volatilization of coal is termed thermogenic (Whiticar, 1994; Whiticar et al., 1986). However, a coal bed may contain substantial (and economically producible) volumes of methane even before de-volatilization occurs and be unrelated to rank (maturity) processes. This type of methane is derived through microbial processes and is termed biogenic (Flores, 2013; Flores et al., 2008; Moore, 2012; Rice, 1993; Strąpoć et al., 2011; Whiticar, 1996). Under normal basinal processes, coal beds may contain microbial-derived gases at low temperature (less than ~55 °C) and rank. These gases are often termed secondary biogenic gas, to distinguish it from microbial gas formed during peat formation. With continued burial and temperature increase, thermogenic gas will eventually be generated. There may be a period of overlap when microbes are still able to generate some gas and where thermogenic gas is also being produced. Biogenic gas may again occur, even after thermogenesis, if the coal seam is uplifted and re-inoculated with a consortium of methane-producing microbes (Ayers, 2002; Faiz et al., 2003; Flores, 2013; Flores et al., 2008; Moore, 2012; Pashin, 2010; Smith and Pallasser, 1996; Vinson et al., 2012).

As described above, most CBM plays are likely to follow 'simple' burial/maturation trends. However, occasionally other processes, such as intrusives or shallow-seated heat sources, can cause localized increases to the geothermal gradient with concomitant rank elevation.

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Although the influence of intrusives on coal seams has previously been reported (Amijaya and Littke, 2006; Cooper et al., 2007; Crelling and Dutcher, 1968; Gurba and Weber, 2001; Mastalerz et al., 2009; Murchison and Raymond, 1989; Stewart et al., 2005; Susilawati and Ward, 2006), there are few documented cases (e.g. Faiz et al., 2007a) of the effect of localized high heat flow on CBM reservoir attributes.

The Sangatta area of East Kalimantan (Borneo), Indonesia (Fig. 1) is well known for significant coal rank increase (subbituminous to bituminous) over a relatively short lateral distance (within a few kilometers) proximal to a geological structure called the Pinang Dome (Fukasawa et al., 1987; Herudiyanto, 2006; Moore and Nas, 2013; Santoso and Daulay, 2009); however, there are no published accounts of igneous intrusives in either outcrop or in the subsurface (Moore and Nas, 2013). The Sangatta area produces some of the highest quality exported bituminous coal in Indonesia (Nas, 1994), a level of maturity that is rare in Indonesia especially in East Kalimantan (Anonymous, 2012).

The objective of this study is to determine if normal burial processes are the only influence on the Miocene CBM system in the Sangatta area or if other processes are at work as well. The data coverage in this study is admittedly not ideal; however, there is virtually no documentation of CBM reservoir properties or an assessment of their variability in Indonesia. Observations made in this study should provide an initial understanding of a localized CBM system that can be tested as more information is gathered.

1.1. Background

Indonesia is currently the largest exporter of thermal coal in the world, with total coal production of over 350 million tons in 2011 (Anonymous, 2012). Sumatra and Kalimantan account for 99% of that coal production, all from Tertiary age coal seams. The Tertiary basins in these two regions have an estimated resource in excess of 105 billion tons (Anonymous, 2012; Fig. 2). Most of these resources are subbituminous and lower in rank. With this scale of resource it is no wonder they are of interest for CBM development.

Exploration for CBM in Indonesia began in earnest in 2009. Although commercial production has yet to be established, there are over fifty CBM exploration blocks, and a few dozen wells have been drilled. Pilot production testing is now beginning in some of the permitted areas. There was an early government-sponsored CBM test pilot conducted in the mid-2000s, which was reported on by Sosrowidjojo and Saghafi (2009). The wells were completed within coals of subbituminous rank in the Muara Enim Formation of the South Sumatra basin and the results represent a significant step forward in the knowledge of Indonesian coals as gas reservoirs. However, these wells were conventionally drilled, with all core samples taking over 14 h to reach the surface. Lost gas estimates, thus, make up the bulk of the total gas volume, and because of the long travel time, lost gas will be prone to substantial error. In addition, adsorption samples were taken after the coal in the canisters was desorbed over many weeks; low rank coals may lose moisture during the desorption process resulting in unreliable estimates in maximum gas holding capacity (Crosdale et al., 2008). Other CBM reservoir data has been published (Saghafi and Hadiyanto, 2000), but these samples were taken from outcrop or non-fresh core and therefore suffer from the same issue of moisture loss as the samples reported on by Sosrowidjojo and Saghafi (2009).

Government and industry sources often cite CBM gas in-place in the hundreds of TCF (trillion cubic feet) range, but no peer-reviewed assessment of potential CBM resources in Indonesia has yet been conducted. It will only be through systematic exploration efforts that will determine more reliable estimates, with corresponding uncertainty factors (e. g. Anonymous, 2011; Crovelli, 2003; Moore and Friederich, 2010; Moore et al., 2009; Scott et al., 1995) of Indonesian's CBM resource and reserve base.

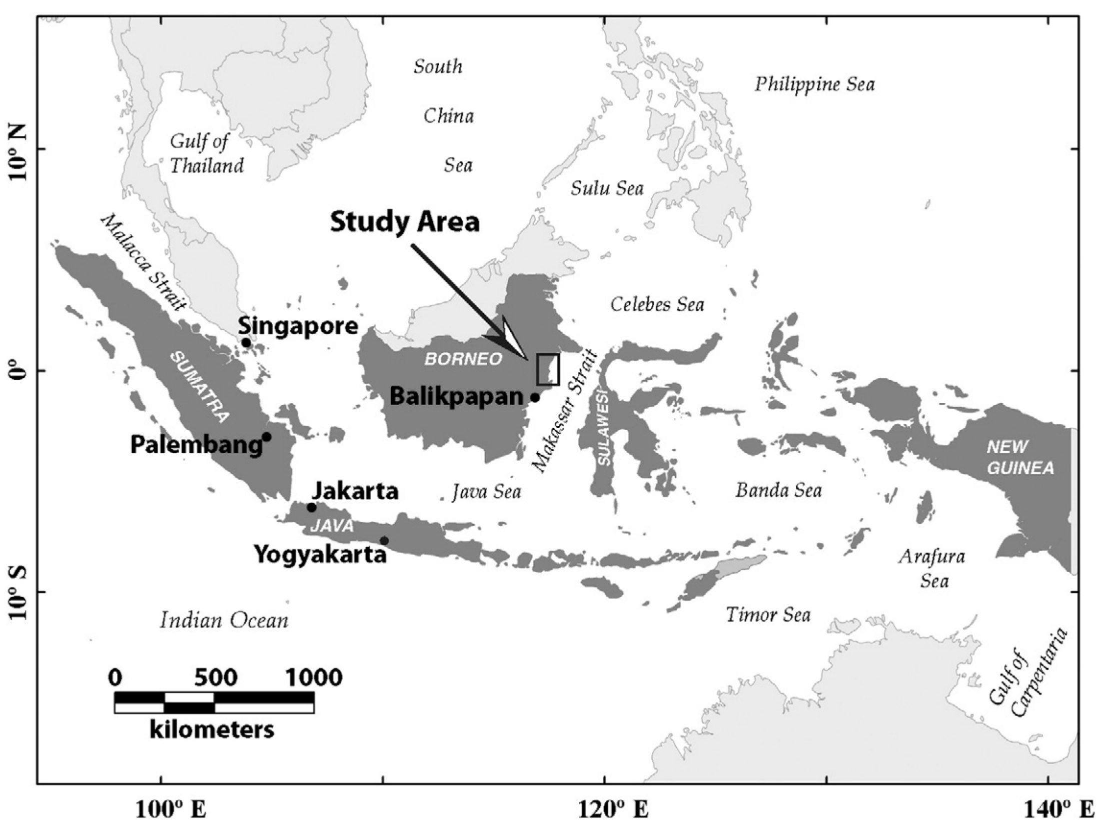

Fig. 1. Index map showing Indonesia (dark gray shading) and location of study area.