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Investigations on the methane and carbon dioxide sorption capacity of coals from the SW Upper Silesian Coal Basin, Czech Republic

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ABSTRACT

High-pressure sorption experiments with methane (CH_4) and carbon dioxide (CO_2) were performed on coals from different mines in the SW Upper Silesian Basin in the Czech Republic. The coals were of high- to low-volatile bituminous rank, representing the late stage of catagenesis. The influence of different factors on the sorption capacity of these coals was evaluated by varying the experimental conditions. Excess sorption capacities of moisture-equilibrated coals ranged from 0.3 to 0.8 mmol/g daf for CH_4 and from 0.8 to 1.2 mmol/g, daf for CO_2. Excess sorption capacities of as-received (air dried) coals were on average 34% higher for CH_4 and 17% higher for CO_2 as compared to the moisture equilibrated state. Sorption capacity shows a weak positive correlation with coal rank and a negative correlation with temperature. The CO_2/CH_4 sorption capacity ratio is larger for moisture-equilibrated coal, while it decreases with increasing pressure as well as increasing coal rank. From the experimental data, correlations were derived between sorption capacity, and coal rank and temperature. These correlations were used to estimate the "static" variation of sorption capacity with coal seam depth. Estimated sorption capacities increase towards a maximum value between 600 and 1000 m depth, followed by a decrease due to the predominance of the temperature effect. Temperature and pressure data derived from the reconstructed (1D) burial history were used to calculate the "dynamic" variation of sorption capacity during basin evolution. These computations show that initial sorption capacity was significantly higher than the one estimated from present day pressure and temperature gradients. Uplift of coal seams resulted in under-saturation of the coal.

1. Introduction

Methane is the most common gas associated with bituminous coal seams worldwide (Rice et al., 1993). It is primarily generated during coalification, but also through anaerobic microbial activity in coal seams. Coal mine methane (CMM) is released during underground and surface mining operations as well as during post mining activities and from abandoned mines. Especially in underground mines it represents a major safety hazard and its concentration has to be controlled by ventilation. When released to the atmosphere, methane acts as a potent greenhouse gas. It is estimated that about 6% of global methane emissions originate from coal mining activities (EPA, 2006). On the other hand methane represents an important energy source when extracted during coal mining as mine gas or gob gas. Coalbed methane (CBM) from unmined coal seams also represents an unconventional hydrocarbon source, if efficient extraction is possible.

Carbon dioxide, as a greenhouse gas in the atmosphere, has also been observed commonly in coal seams. It can be of geologic origin but may also be produced by chemical or microbial oxidation of methane and other organic substances in active and abandoned coal mines, where oxygen is present. The sequestration of carbon dioxide in unmined coal seams has been evaluated as a means to reduce industrial CO_2 emissions (e.g. from power plants) and to enhance coalbed methane recovery (ECBM) (White et al., 2005). Consequently, there is growing demand for a better understanding of occurrence, transport and reactivity of coalbed methane and coalbed carbon dioxide.

To improve knowledge of the influence of adsorption/desorption processes on the amount and composition of coal-related gas, the work presented in this paper was focused on the determination of the methane and carbon dioxide sorption capacity of bituminous coals, as well as the characterization of coal maturity and composition, which can have an effect on the sorption capacity. The Upper Silesian Coal Basin (USCB) in Czech Republic was chosen as a "natural laboratory" for this study. Samples from three different underground coal mines in the Ostrava–Karviná coalfield (OKC) in the SE USCB were analysed. Based on the experimental results, a simple model was developed to estimate the in situ methane sorption capacity of coals as a function of inherent coal properties such as ash yield and rank as well as pressure, temperature and moisture content.

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2. Study area and previous work

2.1. Geological setting

The Upper Silesian Coal Basin is one of Europe's major hard coal basins. It is located at the eastern edge of the Variscan Bohemian Massif, representing the eastern extension of the Moravo-Silesian Basin (Fig. 1). The USCB occupies a known area of more than 7000 km², of which more than two thirds are located in Poland, whereas the southern part of the basin, the Ostrava–Karviná coalfield (OKC), with a known area of 1550 km², is situated in NE Czech Republic (Sivek et al., 2003). Most coal bearing strata of the OKC are of Namurian A-C age. A simplified map of Carboniferous geology of the OKC is given in Fig. 1 and a stratigraphic table is shown in Fig. 2.

Economically important coal reserves of the OKC occur within the Upper Carboniferous Ostrava and Karviná formations.

The paralic Ostrava Formation (Upper Mississippian) contains 168 coal seams with an average thickness of 0.73 m. The most important unit is the Petrkovice Member, which contains more than 60% of the coal reserves of the Ostrava Formation (Dopita and Kumpera, 1993).

The coal content of the limnic Karviná Formation (Lower Pennsylvanian) is up to four times higher than that of the paralic Ostrava Formation. The largest coal reserves of the basin are found in the Saddle and Sucha Member of the Karviná Formation, which contains a total of 87 seams with an average thickness of 1.76 m. The most important seam is the Prokop (504) seam of the Saddle Member, which alone contains about 14% of all coal reserves. With a thickness of more than 10 m it is the thickest coal seam of the OKC (Dopita and Kumpera, 1993).

The gas content of coal-bearing sequences in the Czech part of the USCB mostly ranges between 2 and 10 m³/t and shows an overall decline with increasing depth (Hemza et al., 2009). Geochemical and carbon isotopic investigations of coal related gas provide evidence of co-occurrence of thermogenic and microbial gas in the Ostrava–Karviná Coalfield, showing no clear relationship between gas composition and stratigraphy or thermal maturity of associated coal beds (Franců et al., 2007; Weniger et al., submitted for publication). Similar observations were made in the Polish part of the USCB by Kotarba (2001). Kandarachevová et al. (2009) report that the occurrence of gas deposits found in Carboniferous rocks and overburden strata in the OKC is spatially related to zones of elevated thermal maturity.

McCants et al. (2001) observed a zone of "gassy coal" below ca. 1000 m during CBM exploration in the Polish part of the USCB. They found a link between the occurrence of gas rich coal seams and changes in the local depth/rank gradient and emphasised the importance of coal rank information for CBM exploration.

2.2. Thermal maturity of coal from the Ostrava–Karviná Coalfield

In the Czech part of the Upper Silesian Basin, intense exploration for coal was conducted in the course of the 20th century. During this exploration phase, maturity was primarily determined based on volatile matter yield (VM, daf). Only recently, during the final stage of exploration, vitrinite reflectance (VRr) measurements have been used for thermal maturity assessment (Hemza et al., 2009; Sivek et al., 2003; Sivek et al., 2008). Coals in the Czech part of the USCB are mostly of bituminous rank and show the highest thermal maturity in the WNW part of the OKC, where Variscan orogenic processes were most intense and coals locally reach anthracite rank. The degree of coalification decreases towards the ESE and S to SSW (Kandarachevová et al., 2009; Sivek et al., 2003). Sivek et al. (2008) report a good correlation of thermal maturity

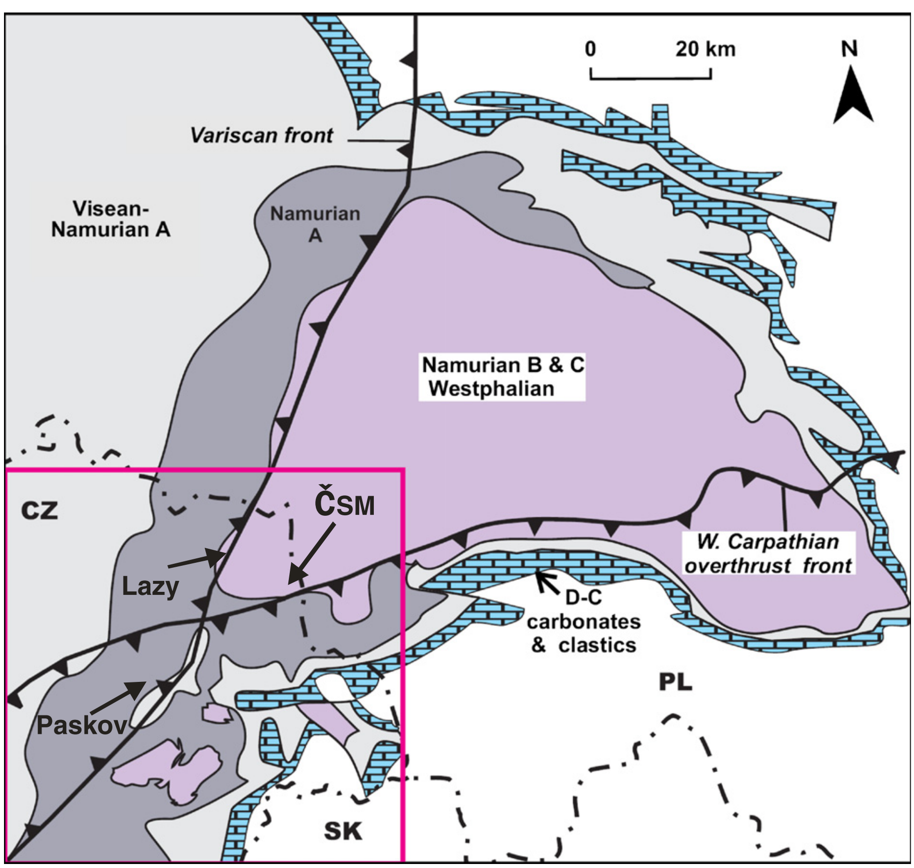

Fig. 1. Location of the study area in the Southern Upper Silesian Coal Basin, Czech Republic. Adapted from Sivek et al. (2003).