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Review article

CBM and CO2-ECBM related sorption processes in coal: A review

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ABSTRACT

This article reviews the state of research on sorption of gases (CO_2, CH_4) and water on coal for primary recovery of coalbed methane (CBM), secondary recovery by an enhancement with carbon dioxide injection (CO_2-ECBM), and for permanent storage of CO_2 in coal seams.

Especially in the last decade a large amount of data has been published characterizing coals from various coal basins world-wide for their gas sorption capacity. This research was either related to commercial CBM production or to the usage of coal seams as a permanent sink for anthropogenic CO_2 emissions. Presently, producing methane from coal beds is an attractive option and operations are under way or planned in many coal basins around the globe. Gas-in-place determinations using canister desorption tests and CH_4 isotherms are performed routinely and have provided large datasets for correlating gas transport and sorption properties with coal characteristic parameters.

Publicly funded research projects have produced large datasets on the interaction of CO_2 with coals. The determination of sorption isotherms, sorption capacities and rates has meanwhile become a standard approach. In this study we discuss and compare the manometric, volumetric and gravimetric methods for recording sorption isotherms and provide an uncertainty analysis. Using published datasets and theoretical considerations, water sorption is discussed in detail as an important mechanisms controlling gas sorption on coal. Most sorption isotherms are still recorded for dry coals, which usually do not represent in-seam conditions, and water present in the coal has a significant control on CBM gas contents and CO_2 storage potential. This section is followed by considerations of the interdependence of sorption capacity and coal properties like coal rank, maceral composition or ash content. For assessment of the most suitable coal rank for CO_2 storage data on the CO_2/CH_4 sorption ratio data have been collected and compared with coal rank.

Finally, we discuss sorption rates and gas diffusion in the coal matrix as well as the different unipore or bidisperse models used for describing these processes.

This review does not include information on low-pressure sorption measurements (BET approach) to characterize pore sizes or pore volume since this would be a review of its own. We also do not consider sorption of gas mixtures since the data base is still limited and measurement techniques are associated with large uncertainties.

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1. Introduction

The technical development of coalbed methane (CBM) and secondary CO_2 enhanced CBM (CO_2-ECBM) production and CO_2 storage in and from coal seams requires detailed and reliable information on fluid transport and gas sorption as well as their inter-dependent interaction. An improved understanding of these processes from the macroscopic to the microscopic scale is important for the accurate prediction of gas and water production as well as CO_2 injection rates. The mechanisms of storage and transport of gas and water in coal differ significantly from conventional gas reservoirs. Commonly, gas transport in coal is considered to occur at two scales (Fig. 1): (I) laminar flow through the cleat system, and (II) diffusion and sorption in the coal matrix. Flow through the cleat system is pressure-driven and may be described using Darcy's law, whereas flow through the matrix is assumed to be concentration-driven and is modeled using Fick's law of diffusion. Gas storage by physical sorption occurs mainly in the coal matrix (e.g. Harpalani and Chen, 1997).

Various articles address laboratory or field research performed in the context of primary coalbed methane (CBM) or secondary CO_2 enhanced CBM (CO_2-ECBM) recovery and reviews are provided by e.g. White et al. (2005).

There are many factors that need to be addressed when attempting to understand the complexity of the interaction of CH_4, CO_2 and water with coal in the cleat system and the coal matrix, and research has diversified substantially, especially since CO_2 storage in coal is considered as a potential way of permanently immobilizing CO_2 in the sub-surface.

CBM recovery projects are currently developed commercially all over the world with a main focus on countries like Australia, China and the United States, and exploration is ongoing in many further regions in e.g. Europe, Ukraine, or Indonesia. One of the first CO_2-ECBM micro-pilot field tests was set up in Alberta, Canada (Gunter et al., 2004) which was similarly performed in China some years later (Wong et al., 2007). One operation with a two-well test setting was carried out in Japan (Ohga et al., 2006; Yamaguchi et al., 2004). The

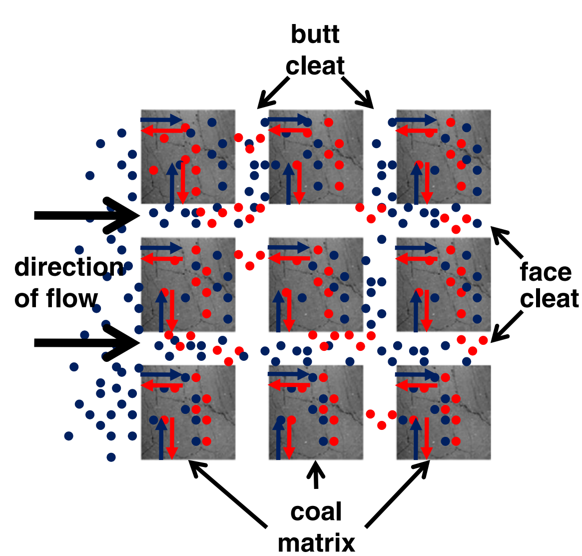

Fig. 1. Illustration showing coal matrix blocks and cleat system of a coal.