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Study of hydrochemical characteristics of CBM co-produced water of the Shizhuangnan Block in the southern Qinshui Basin, China, on its implication of CBM development

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ABSTRACT

Coalbed methane (CBM) co-produced water is primarily coal seam water. It may be mixed with fracturing fluids, especially during the early drainage stage, or with other aquifer water if the coal seam is connected with an aquifer via artificial or natural fractures/faults. If the impacts of fracturing fluids and other aquifer water can be removed, the chemical characteristics of CBM co-produced water can act as effective indicators for CBM exploration and development. Based on the water chemistry analyses of 119 samples collected from 47 CBM wells over four years (quarterly sampling) in the Shizhuangnan Block, Qinshui Basin, the dynamic characteristics of the CBM co-produced water chemistry that were influenced by fracturing fluids were studied in this study. Relationships between the major CBM co-produced water ions were determined, and the relationship between the CBM co-produced water ions and gas production were investigated. The results suggest that the CBM co-produced water chemical signature of the Shizhuangnan Block is similar to that of other coal seam waters from around the world, being characterized by the sodium-chloride-bicarbonate water types that are depleted in calcium and magnesium ions and exhibit highly lowered sulfate concentrations. Due to the mixing with the fracturing fluids and coal seam water, the TDS, sodium, chloride, and calcium and magnesium ion concentrations decrease during the early drainage stage following a power law function. However, bicarbonate and sulfate concentrations do not significantly vary. The Na and Cl, Na/Cl and alkalinity/Cl, and Na/Cl and Na/alkalinity ratios exhibit a positive linear relationship, strong positive linear relationship and exponentially decaying relationship, respectively. Additionally, 10 meq/L of Cl may serve as a dividing line for the presence or absence of the fracturing fluid affect. Na and Cl may release organic-bound chlorine complexes from the coal during coal metamorphism. The TDS and bicarbonate concentration of the CBM co-produced water produced by the gas production wells are all > 1000 mg/L and 8 meq/L, respectively. The bicarbonate concentration is influenced by both the LCH, which is the height of the liquid level compared to the coal bed surface at the onset of water production at a CBM well, and hydraulic conductivity fault, and its distribution controls the distribution of the high gas yield wells.

1. Introduction

Coalbed methane (CBM) is an adsorption gas stored on the inner surface of the micropore structure in underground coal beds due to the potentiometric pressure. Meanwhile, the coal beds are often saturated with groundwater. Due to the adsorption accumulation mechanism, CBM production requires depressurizing the coal reservoir via the removal of the aquifer water within the coal (Kaiser et al., 1994). As a result, CBM production also produces large quantities of water, which are discarded as co-products, especially during the early drainage stage. In most cases, the CBM co-produced water is coal seam groundwater. However, the CBM co-produced water is typically mixed with an incomplete flowback of fracturing fluid, particularly during the early drainage stage. In addition, the CBM co-produced water may mix with groundwater outside of coal beds if the CBM well has been incorrectly operated, such as drilling or fracturing processes that result in the connection of coal beds and other aquifers. Previous studies have demonstrated that the hydrochemistry of groundwater within coal seams is generally similar worldwide, being characterized by the near absence of sulfate, low calcium and magnesium concentrations and high sodium, bicarbonate and chloride concentrations (Golding et al., 2013; Kinnon et al., 2010; Owen et al., 2015; Taulis and Milke, 2013; Taulis and Milke, 2007; Van Voast, 2003; Wang et al., 2015; Yao et al., 2014). Coal seam water attains these chemical characteristics through a variety of processes, including salt dissolution, salt precipitation,

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pyrite oxidation, ion exchange, sulfate reduction and methanogenesis (Elizabeth L. Brinck, 2008; Taulis and Milke, 2013; Taulis and Milke, 2007; Van Voast, 2003). Because coal seam water is involved in a variety of CBM processes, its chemical composition serves as a record of the physical and chemical processes it has experienced. Thus, the simple hydrochemistry of coal seam water can be considered a universal signature for use in CBM exploration, testing and development. At an exploratory level, coal seam waters can provide insight into aquifer processes, CBM preservation and production potential. At the production level, identifying the type of water being extracted is essential for preventing future environmental problems linked to CBM production operations (Taulis and Milke, 2007).

Because CBM co-produced water reflects the characteristics of coal seam waters, CBM co-produced water samples are typically collected within a specific period after well pumping begins, such as three months, six months or a year. This collection schedule is performed to avoid contamination via fracturing fluid flowback. However, the contamination time of the fracturing fluid remains largely unknown. In addition, Owen et al. (2015) noted that coal seam groundwater may also evolve in a number of other environments not associated with coal seams, and simple CBM co-produced water hydrochemical descriptions alone are insufficient to indicate hydrochemical processes within gas-bearing coal seams. Therefore, an analysis of the shifts in the ratios of cation and anion species is needed to identify the hydrochemistry of the CBM co-produced water. In addition, most current coal seam water researches focus on low-rank coals, with methane originated from biogenic or mixed biogenic and thermogenic gas. Research on hydrochemistry of the CBM co-produced water from high-rank coal is relatively rare. This is particularly true in China, where CBM co-produced water research has just started and few public studies are available.

In the Qinshui Basin of north China (Fig. 1), especially the southern part of the basin, there has been a growing interest in exploring and developing commercially viable CBM reserves from the Carboniferous-Permian sedimentary formations of the Shanxi and Taiyuan Coal Measures. The Shizhuangnan Block encompasses an area approximately 168 km^2 and is bounded by the Fanzhuang block to south and east. It is a relatively new CBM block in the southern Qinshui Basin, in which commercial development began in 2010. Nearly 600 CBM wells have been drilled in the block. This study utilizes over four years of continual (quarterly) co-produced water samples and quality tests from CBM wells in the Shizhuangnan Block to explore the hydrochemical evolution of groundwaters within the Shanxi and Taiyuan Coal Measures, with a particular focus on identifying the simple hydrochemical relationships of ions in CBM co-produced water. The main objectives of this study were to a) investigate the hydrochemical characteristics of CBM co-produced waters from the Shanxi and Taiyuan Coal Measures of the Shizhuangnan Block in the southern Qinshui Basin; b) identify simple CBM co-produced water hydrochemical relationships and the influence of the fracturing fluid on CBM co-produced water hydrogeochemical characteristics; and c) explore the relationship between the CBM co-produced water ions and gas production.

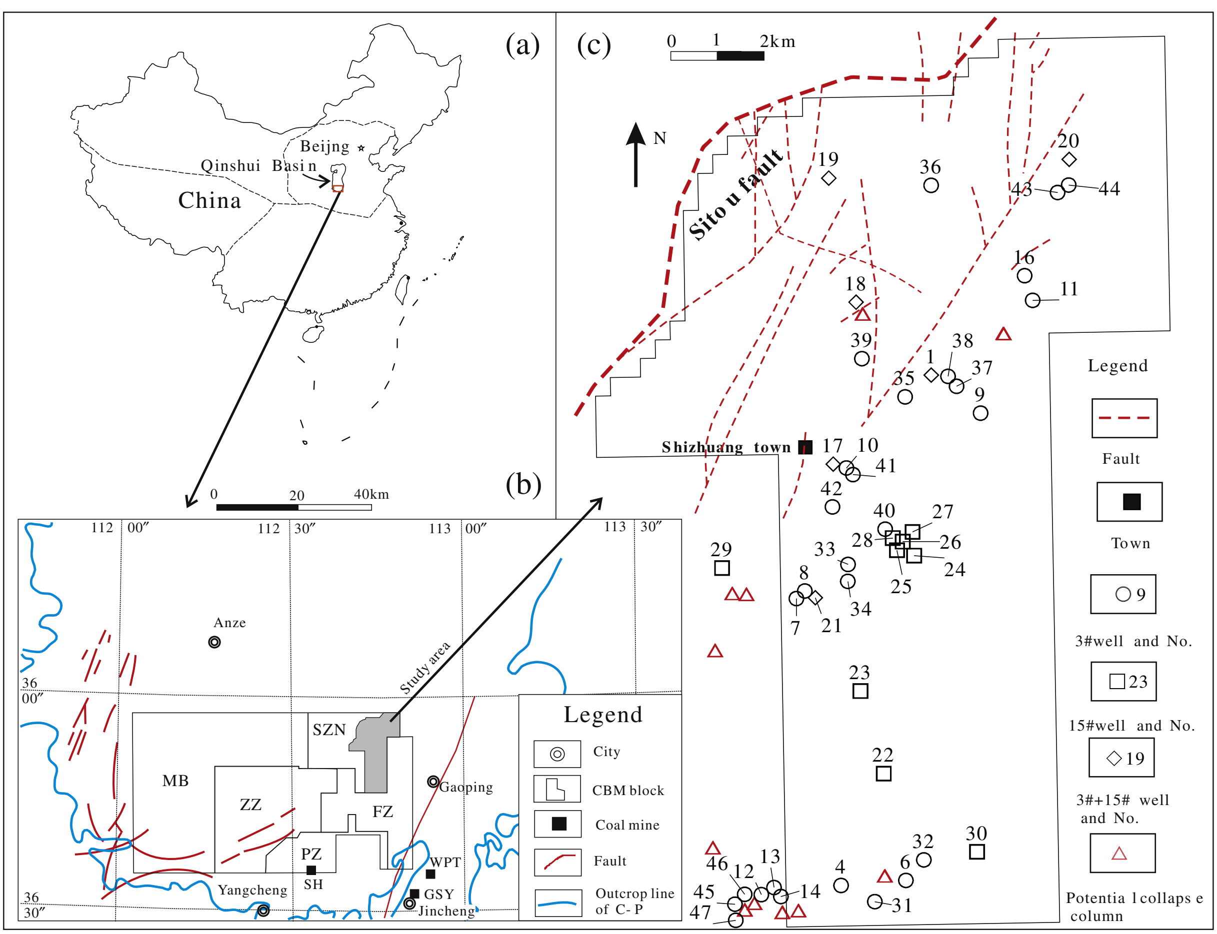

Fig. 1. Location of the sampling and study area. (a) Location of the study area in China; (b) The study area, showing CBM blocks in the southern Qinhsui basin; and (c) structure outline of the study area and the wells where water samples were collected. SZN, Shizhuangnan CBM Block; MB, Mabi CBM Block; ZZ, Zhengzhuang CBM Block;FZ, Fanzhuang CBM Block;PZ, Panzhuang CBM Block.