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The composition, pore structure characterization and deformation mechanism of coal-bearing shales from tectonically altered coalfields in eastern China

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ABSTRACT

Organic rich shales in coal-bearing strata deposited from marine to lacustrine environments are well developed in China. The Paleozoic coal-bearing shales have been significantly altered by a series of tectonic movements. Based on XRD, SEM, MICP, and a nitrogen adsorption experiment and in combination with other parameters in this paper, the mineral composition and pore structure characterization and deformation mechanism of coal-bearing shales were surveyed. The coal-bearing shales in eastern China undergo various types of deformation, including brittle, ductile, and brittle-ductile deformation. In eastern China, the macro pore size of shales grew with increasing quartz content under different types of structural deformation, while the specific surface area decreases as the quartz content increases in different types of structural deformation; With the increasing of clay mineral content, the average pore size and the specific surface area of BET became larger in the various types deformation shale, while the pore volume decreased in the brittle and brittle -ductile deformation shale and increased in the ductile deformation shale. The ductile and brittle-ductile deformation increase the specific surface area, the total pore volume of nano-pores, and the adsorption capacity of liquid nitrogen, and decrease the nano pore diameter. The micropores in the brittle-ductile and ductile shearing of clay minerals may the main factors affecting pore volume and total specific surface area. And it is the mesoporous structure that undergoes evolution in brittle-ductile-deformed shales, leading them to have the maximum pore volume and pore-specific surface area for pore-fracture systems. Brittle shear results in micro-fractures or large pores and thus has an impact on the desorption and percolation capability of shale gas, Ductile deformation increases the specific surface area of shales and enhances their shale adsorption capacity.

1. Introduction

Organic-rich shale, including mudstone and shale, was conventionally considered as source rock of hydrocarbon in sedimentary basins [1], and shale has more recently been recognized as an important reservoir rock for unconventional shale gas, which is becoming a key onshore exploration target worldwide [2]. Over the past few decades, thanks to innovative technology, horizontal drilling and hydraulic fracturing, and improved integration of geosciences and engineering, shale gas production has been increasing rapidly in North America [3]. According to the US Energy Information Administration, shale gas production accounted for 56% of total US natural gas production in 2015 [4,5]. Outside of America, China has also achieved notable success in this field, with production increasing from $0.25 \times 10^8\ m^3$ in 2012 to $78.8 \times 10^8\ m^3$ in 2016 [6,7]. Organic-rich shale is deposited in both marine and non-marine environments, including marine-continental transitional and continental areas (mostly lacustrine facies) [8,9]. To date, almost all the world's shale gas has been extracted from marine shale at locations such as Barnett Shale in Fort Worth Basin, USA and Longmaxi Shale in the Sichuan Basin, China. However, the vast geological reserve of shale gas in non-marine shale is also important for shale gas exploration and production. This is

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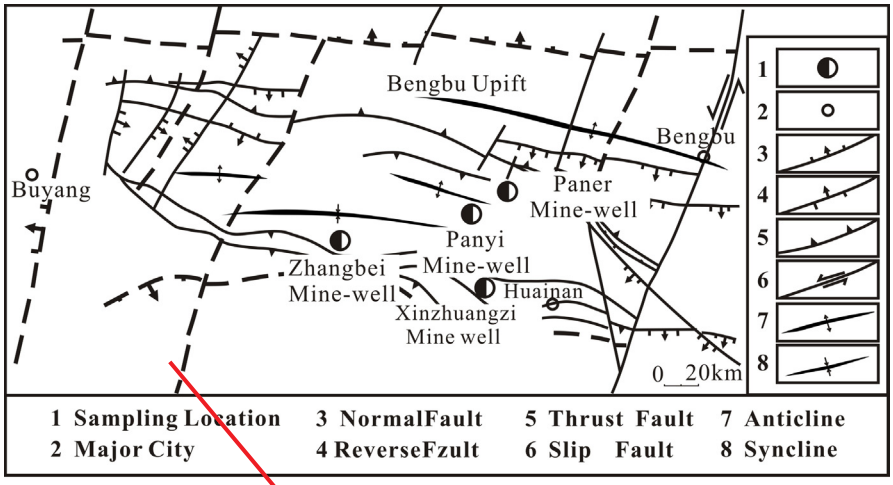
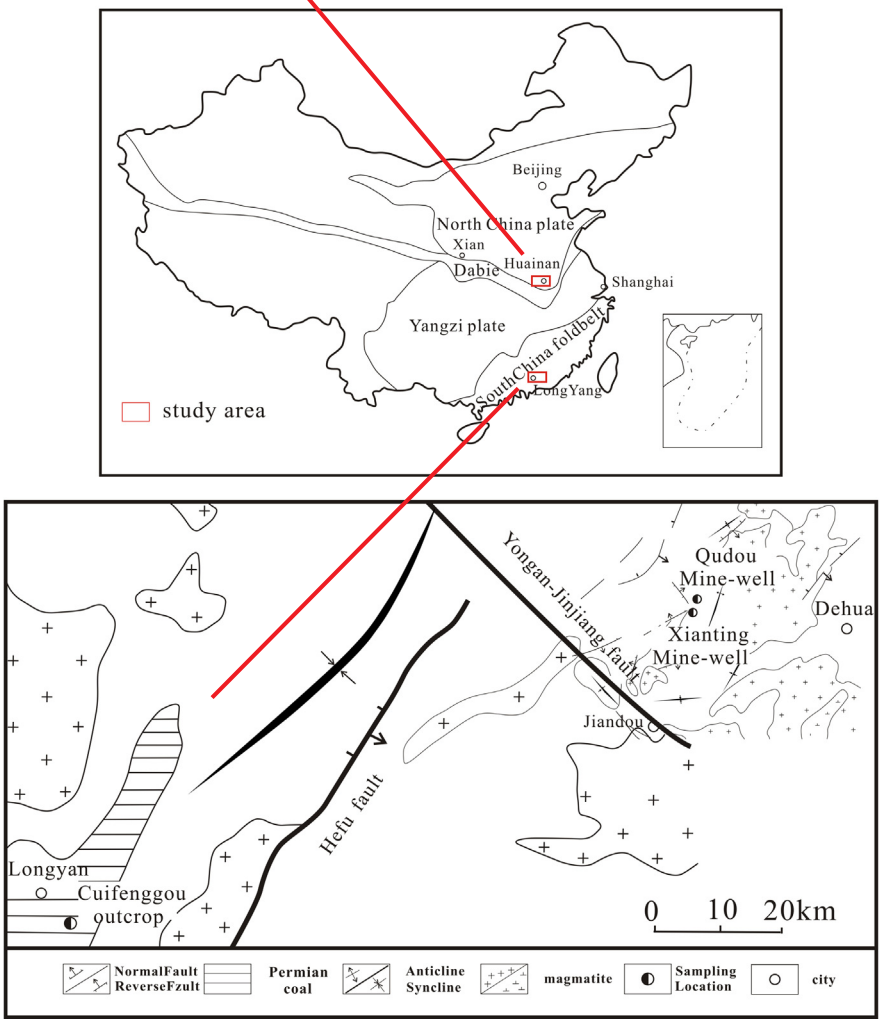


(a). The structure features and sampling locations in the Huainan Coalfield



(b). The structure features and sampling locations in the Longyan Coalfield

Fig. 1. The structure features and sampling locations in the Huainan and Longyan Coalfield, southeastern North China Plate (modified from) [33–35]. (a) The structure features and sampling locations in the Huainan Coalfield; (b) The structure features and sampling locations in the Longyan Coalfield.

particularly the case in China, where non-marine organic shale contains two-thirds of all recoverable shale gas resources [1,6]. We have already witnessed a breakthrough in coal-bearing (non-marine) shale gas exploration in North China and production in certain regions such as the Erdos basin [10,11].

In recent years, the deformation mechanism of shale has attracted increasing attention [12–14]. Based on their study of interlayer shear and the ductile rheology of coal seams, Ju et al. [12] proposed a ductile