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Analysis of the transfer modes and dynamic characteristics of reservoir pressure during coalbed methane production

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1. Introduction

Coalbed methane (CBM) is known as an important unconventional natural gas resource and it is a very important energy source in the energy sector. In addition, the mitigation and utilization of CBM can significantly reduce the gas-related mining hazards such as gas explosion and gas outburst and reduce greenhouse gas emission.[1–5]

The CBM reservoir pressure refers to the fluid pressure in the pores/fractures of CBM reservoir and it is also termed as pore-fluid pressure.[6] The transfer modes and dynamics of reservoir pressure are key factors to determine the effective desorption range, the interwell interference, and gas productivity.[7,8] A number of studies have been conducted to estimate the initial reservoir pressure since the 1980 s and the numerical simulation was widely used to define the pressure dynamics. Reis et al.[9] and Samaniego et al.[10] established the pressure transient models which involved the influences of fractures. Based on the fracture network model and tracer data, Bogatkov et al.[11] established a pressure transient model.[11] Some researchers have pointed out that the formation fluid flowing into the wellbore was an elliptic flow for the pressure transient behavior because of the permeability anisotropy of CBM reservoir.[12–15] These pioneer works laid the foundation for the initial reservoir pressure estimation. However, these investigations mainly focused on the process of well test, rather than the process of gas drainage and it is well known that these two processes are fundamentally different in terms of flow mechanisms.

Recently, extensive literature has been reported on defining the variation of reservoir pressure during gas production, Zhao et al.[16] studied the transmission law of reservoirs pressure with assumptions of the homogeneous formation and the infinite boundary for the single-phase flow stage. Based on the plane radial flow theory and the superposition principles of pressure depletion, Liu et al.[17] discussed the influencing factors of pressure drop funnel by analyzing 15 CBM wells in the southern Qinshui Basin (SQB). Zou et al.[7] classified the CBM reservoirs into three categories, namely, gas pressure reservoirs, water pressure reservoirs, and hybrid pressure reservoirs, and they studied the transfer process of reservoir pressure by simulation. The aforementioned studies were primarily based on the homogeneous reservoir or pore-cleat systems. Besides, the calculations of reservoir depressurization focused on the stage of water single-phase flow when the water is just the main transfer medium of depressurization. However, the effect of gas partial pressure on overall reservoir pressure transmission is persistently neglected and knowledge gap remains.

The objectives of this paper are to characterize the transfer process of reservoir pressure with two new proposed transfer modes and to establish the frame of the quantification of reservoir pressure profiles during gas production. Firstly, the transfer process of reservoir pressure was analyzed based on the practical description of different production stages and different-scale pore-

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fracture model. In the light of this, two new transfer modes of reservoir pressure were proposed in the fracture systems and coal matrix block. Then, the dynamics of reservoir pressure with continuous gas production were quantified with considerations of sorption and production data. Finally, two field cases were studied, from which the variation characteristics of reservoir pressure and gas content were summarized and compared. It is meant to provide a refer guidance for the diagnosis of CBM production and the controlling of bottom-hole pressure during gas production.

The studied field is in the SQB located in the southeast of Shanxi Province, North China. It is measured approximately 120 km from north to south and 80 km from east to west, with an area of about 7000 km^2, and the gas-in-place of CBM in this basin is approximately 3.28×10^{12} m^3.[18,19] The exploration and exploitation of CBM in the SQB has been initiated since 1990 s and the richness of data related this field helps to conduct this current study. The production blocks in the SQB include Panzhuang, Fanzhuang, Chengzhuang, Zhengzhuang, and so on.[20] The successful commercial exploitation of CBM here greatly promotes the national CBM industry in China.

2. Overview of the geology

2.1. Geological setting

Qinshui Basin is a large compound synclinal basin between Taihang uplift and Lvliang uplift, and the tectonic in this basin is relatively simple with only small amounts of faults.[19] After the uplift and erosion during the Triassic Indosinian and Jurassic-Cretaceous Yanshanian Orogeny, the Qinshui basin became a separate syncline with axial striking at NNE–SSW.[19,21] Folds with

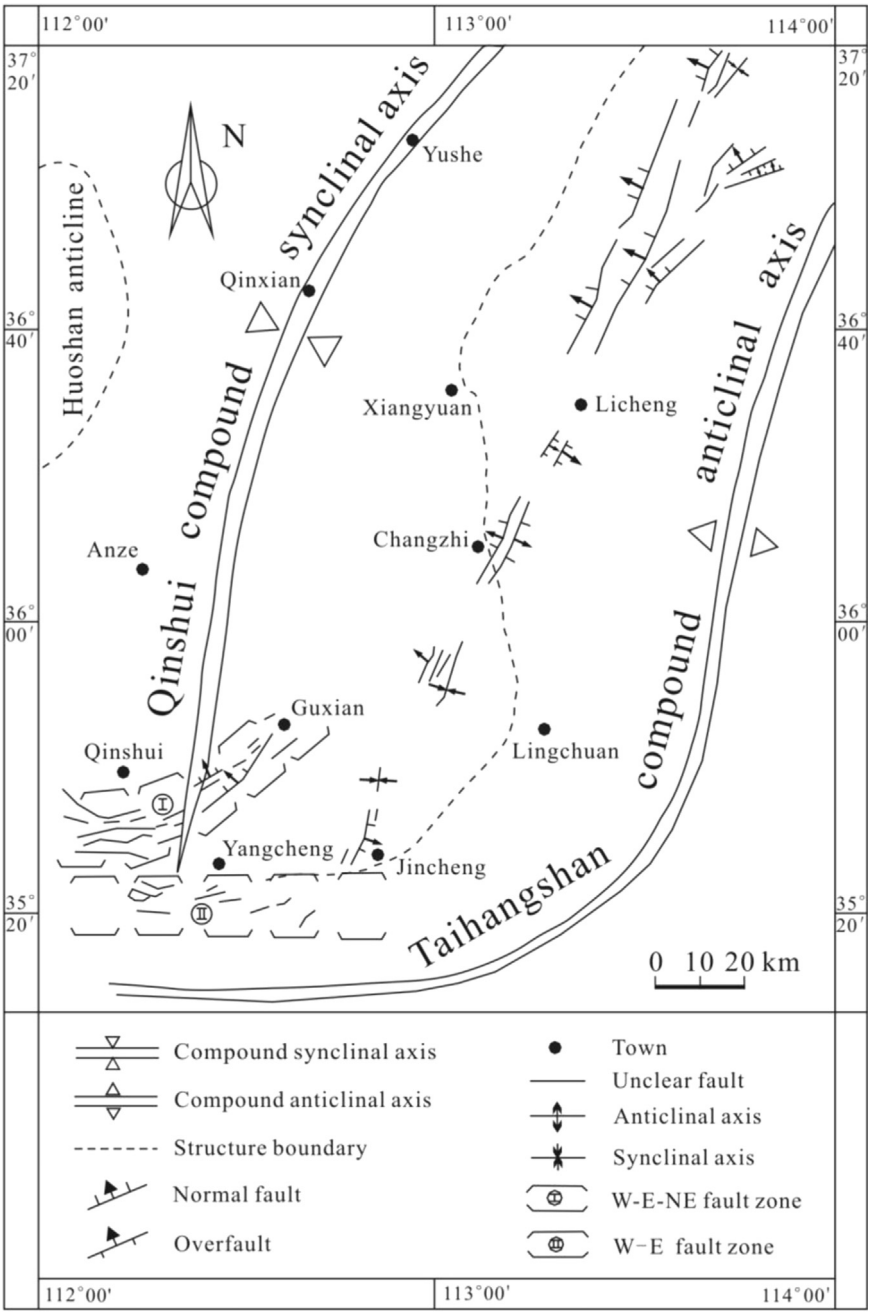

Fig. 1. Major geological structures of southeast Shanxi Province, North China.