

Origin and accumulation of high-maturity oil and gas in deep parts of the Baxian Depression, Bohai Bay Basin, China

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Abstract: Great quantities of light oil and gas are produced from deep buried hill reservoirs at depths of 5,641 m to 6,027 m and 190 °C to 201 °C in the Niudong-1 Well, representing the deepest and hottest commercial hydrocarbons discovered in the Bohai Bay Basin in eastern China. This discovery suggests favorable exploration prospects for the deep parts of the basin. However, the discovery raises questions regarding the genesis and accumulation of hydrocarbons in deep reservoirs. Based on the geochemical features of the hydrocarbons and characteristics of the source rocks as well as thermal simulation experiments of hydrocarbon generation, we conclude that the oil and gas were generated from the highly mature Sha-4 Member (Es₄) source rocks instead of thermal cracking of crude oils in earlier accumulations. The source kitchen with abnormal pressures and karsted carbonate reservoirs control the formation of high-maturity hydrocarbon accumulations in the buried hills (i.e., Niudong-1) in conjunction with several structural–lithologic traps in the Es₄ reservoirs since the deposition of the upper Minghuazhen Formation. This means the oil and gas exploration potential in the deep parts of the Baxian Depression is probably high.

Key words: High mature oil and gas, origin, accumulation, deep part of Baxian Depression

1 Introduction

The Bohai Bay Basin contains the largest oil resources with the highest oil and gas production in China (Zhou et al, 2009). In the basin, the hydrocarbons are mainly distributed in middle and shallow reservoirs buried at depths of less than 3,200 m (Niu et al, 2002). The produced hydrocarbons are of low–middle maturity because the major source rocks are of low–middle maturity. The Bohai Bay Basin is a rift basin (Jin and McCabe, 1998) and the Baxian Depression in the basin is a typical semigraben (Fig. 1) filled with Eocene lacustrine sediments; the Kongdian, Shahejie, and Dongying Formations (Fig. 1). From the bottom to the top, the Shahejie Formation is divided into four members: Sha-4 (Es₄), Sha-3 (Es₃), Sha-2 (Es₂), and Sha-1 (Es₁). The major source rocks are in Es₃ and Es₄ as well as several reservoirs in the Baxian Depression. Near the source rocks in the Es₃ and Es₄ members are buried hills formed by Tertiary normal faults. The buried hills consist of Precambrian carbonates, which are good reservoir rocks with a large number of caves and fractures because of karstification before burial in the Eocene.

Because of technical advances, significant hydrocarbon accumulations were discovered at depths greater than 4,000 m or even 5,000 m. In particular, highly productive hydrocarbon accumulations were found in buried hills at a depth of about 6,000 m in the Baxian Depression. In the Niudong-1 Well, the Precambrian buried hill reservoirs at depths of 5,671 m to 6,027 m record a daily flow of light oil of 642.9 m³ and natural gas of 56×10⁴ m³, which indicates that there are abundant hydrocarbon resources in the deep reservoirs of the Bohai Bay Basin and these reservoirs are important exploration targets.

Compared with deep accumulations outside China (Pusey, 1973), the Niudong-1 Well is similar to them in terms of reservoir temperature and production rate. Presently, there is an ongoing debate regarding the genesis of deep hydrocarbons. Opinions include the genesis of crude oil from cracking of deeply buried ancient oil accumulations (Schenk et al, 1997; Tsuzuki et al, 1999), organic matter pyrolysis of deeply buried source rocks (Hunt, 1979; Mango, 1991; Price, 1993), crack and pyrolysis genesis (Quigley and Mackenzie, 1988; Domine et al, 1998), and inorganic genesis (Schoell, 1980). Hydrocarbon accumulation in deep reservoirs is quite complex and many controlling factors have been considered for different geological settings (Hunt, 1990; Al-Shaieb

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