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Coexistence mechanism of multi-types of reservoir pressure in the Malang depression of the Santanghu basin, China

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ABSTRACT

This paper focuses on the distribution and coexistence mechanism of the various pressure systems in the Malang depression of the Santanghu basin, northeast of the Xinjiang Uyghur Autonomous Region, China. According to the classification standard of formation pressure, The calculated pressure coefficient showed that the Xishanyao Formation (J_2x) is underpressured, the reservoirs of the Lucaogou Formation (P_1l) are both normally and overpressured, and the Upper Pennsylvanian (C_2) presents the coexistence of a normally pressured system and an underpressured system. The permeability of the Xishanyao Formation (J_2x) improve from the southwest to the northeast of the basin, resulting in a relatively easy fluid supply to the reservoirs, and the pressure coefficient increases gradually. Tectonic uplift had a significant influence on the decrease in the reservoir pressure. However, a difference in source–reservoir assemblages caused a difference in fluid recharge and original pressure in reservoirs during hydrocarbon accumulation. The difference in reservoir connectivity causes a difference in the fluid supply during later tectonic movement, finally leading to the formation of different pressure systems. Thus, the basic mechanism for the coexistence mechanism of the various pressure regimes in this area is the disequilibrium of the fluid supply under the restriction of oil accumulation conditions.

1. Introduction

Abnormal pressure is a common geological phenomenon in the petroliferous basins worldwide. In recent years, consistent with the discovery of the coexistence of abnormal underpressure, normal pressure and overpressure in numerous basins in China and other countries (Belitz and Bredehoeft, 1988; Corbet and Bethke, 1992; Bachu and Underschultz, 1995; Karsten and Stefan, 2001; Liu and Xie, 2002; Dai et al., 2003; Raymond, 2005; Wang and Chen, 2007), the distribution and controlling factors of these different pressure regimes has generated interest among petroleum geologists and engineers (Luo and Vasseur, 1992; Parks and Toth, 1995; Xie et al., 2003; Jeirani and Mohebbi, 2006; Kabir and Izgec, 2009). Previous investigation has been carried out on the genetic mechanism of low pressure and high pressure systems (Powley, 1980; Law and Dickinson, 1985; Hunt, 1990; Hao et al., 1995; Warbrick and Osborne, 1998; Neuzil, 2000; Hao, 2005; Xu et al., 2009). However, few studies explain why the various pressure types of regimes could coexist in the same basin and even in the same formation.

The Santanghu basin lies in the northeast of the Xinjiang Uyghur Autonomous Region, China (Fig. 1). During more than 10 years of exploration and development, three series of main oil-bearing strata have been discovered in this area (Li and Zhang, 2000). However, the Malang depression of the Santanghu basin shows that multiple pressure systems coexist and that multiple types of reservoirs were produced together. The reservoirs are characterized by complex lithology and a high degree of heterogeneity. Previous investigations in this area have focused on the background geologic, hydrocarbon accumulations, reservoir characteristics and formation mechanisms of low-pressure Jurassic reservoirs (Tang, 1998; Li and Zhang, 2000; Sun et al., 2001; Liu and Liu, 2004; Zhang et al., 2009; Xu et al., 2010; Wen et al., 2011). Multidisciplinary and systematic studies on the above-mentioned issues are still required. This paper presents a comprehensive study of the distribution and reservoir properties, fluid recharge and tectonic evolution of the Malang depression to ascertain the mechanism of coexistence of the various pressure types of reservoirs and to guide the exploration and development of oil reservoirs.

2. Geologic background

The Santanghu basin presents two uplifts and one depression and can be divided into three tectonic units: the NE thrust fold belt, the central depression and the SW thrust fold belt. The central depression belt consists of four uplifts and five

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depressions, of which the Malang depression is the main area studied in this work (Fig. 1).

The basement of the basin is of Pennsylvanian and Permian ages, and the caprock is largely of middle Cenozoic age (Xu et al., 2010). The Pennsylvanian strata consist mainly of marine mudstone and volcanic rock. The overlying strata of the Pennsylvanian strata is the Permian lacustrine mudstone, marl and volcanic rock. The Triassic and Jurassic strata consist of fluvial and lacustrine deposits (Li and Zhang, 2000). The discovered oil reservoirs mainly exist in the volcanic rock of Upper Pennsylvanian (C_2), the mudstone and marl of Lucaogou Formation (P_2l) of the Upper Permian and the fine sandstone of Middle Jurassic Xishanyao Formation (J_2x). The source rock includes the marine mudstone of Upper Pennsylvanian and the lacustrine mudstone and marl of Lucaogou Formation, respectively (Fig. 2). So, the Lucaogou Formation (P_2l) is the self-generation and self-storage reservoirs, while, the volcanic rock of Upper Pennsylvanian (C_2) and the Middle Jurassic Xishanyao Formation (J_2x) are the lower-generation and upper-storage reservoirs.

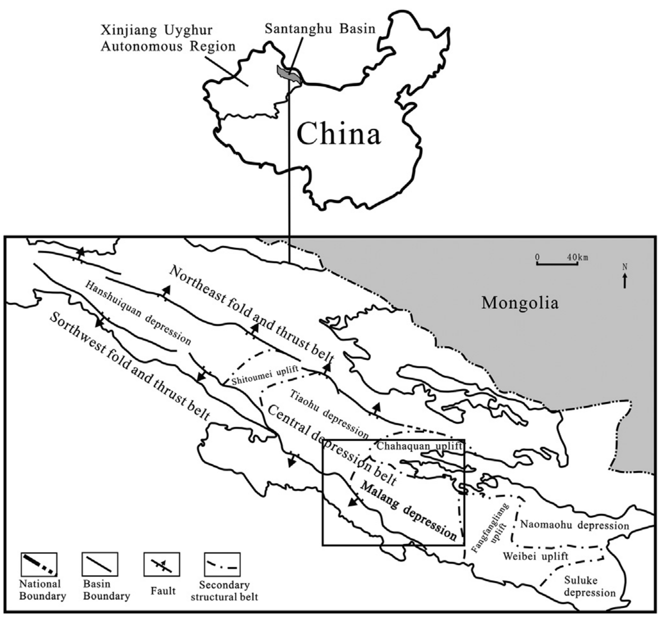

Fig. 1. Location map of the Malang depression of the Santanghu basin, China.

The structural evolution of the Santanghu basin can be divided into multiple stages, including extension after late Permian orogenesis, compression at the end of Triassic, and subsidence in the early to middle Jurassic and late Jurassic, and early Cretaceous compression (Sun et al., 2001). In terms of the whole basin's evolution, the two tectonic movements during the late Hercynian and late Yanshanian periods were the largest, and have the greatest influence on the formation pressure.

3. Materials and methods

Reservoir pressure data derived from drill stem tests (DST) and permeability test data in 30 wells in the Santanghu basin were compiled. These data were taken from sandstone reservoirs in the Xishanyao Formation (J_2x), marl reservoirs in the Lucaogou Formation (P_1l) and volcanic reservoirs in the Upper Pennsylvanian Formation (C_2), which are the main targets for hydrocarbon exploration in the area (Table 1). Water data from the different pressure reservoirs were collected to represent a retained hydrogeological condition. To reveal the difference of different pressure reservoirs, observation and the description of core and slice were carried out.

4. Distribution characteristics of pressure systems

According to the classification standard of formation pressure, the reservoir whose pressure coefficient is less than 0.9 is a under-pressured system, whose pressure coefficient is between 0.9 and 1.1

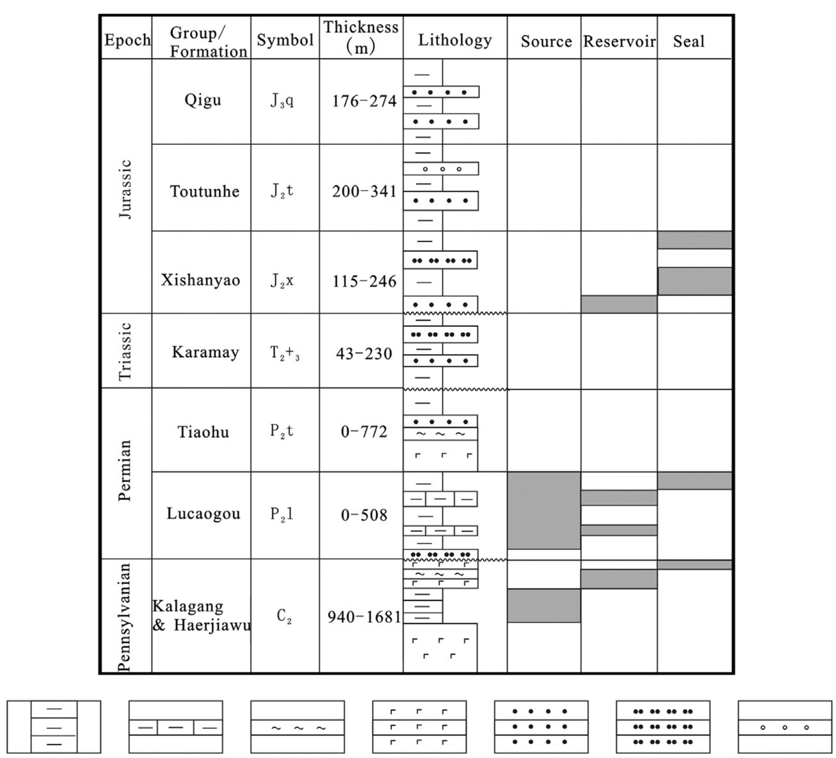

Fig. 2. Schematic stratigraphy of the Malang depression in the Santanghu basin.