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Geochemistry and origins of natural gases in the Zhongguai area of Junggar Basin, China

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ABSTRACT

The petroliferous Permian system of the western margin of the Junggar Basin in northwest China is predominantly an oil exploration region. To assist in the gas exploration, the geochemistry and origins of the gases in the Zhongguai area are discussed based on compositions, light hydrocarbon, and carbon isotope of the gases, combined with the investigation of the biomarkers of the retrograde condensates, rock extracts, and oils from the Permian section. The results indicate four representative types of gases in the area. The first type is the pure sapropel-type gas derived from the Permian Fengcheng mudstones containing types I–II kerogen mainly in the Shawan sag. This gas has representative geochemical features of $\delta^{13}C_2$ ranging from −30.96‰ to −28.76‰, with normal heptane content higher than 50% and methylcyclohexane content lower than 30%. The second type is the pure humic-type gas sourced from the Permian Wuerhe mudstones with types II–III kerogen mainly in the Mahu and Penyijingxi sags. This gas has *n*-heptane content less than 30%, methylcyclohexane content greater than 50%, and $\delta^{13}C_2 \geq -25$‰. The third type is a gas mixture composed of sapropel- and humic-type gases. In this type of gas mixture, the dryness coefficient floats around 0.95, the *n*-heptane content varies from 50% to 70%, the methylcyclohexane content varies from 30% to 50%, and the $\delta^{13}C_2$ values vary from −26‰ to −28‰. The fourth type is a gas mixture of inorganic gas and sapropel-type gas, with the latter being dominant. This inorganic gas has low methane content (71.56%), abnormally high N_2 content (10.99%), and the order $\delta^{13}C_1 > \delta^{13}C_2 > \delta^{13}C_3 < \delta^{13}C_4$. Among the four types of gases, the gas mixture (types) is the main type of gas in the study area, while the amount of other three types is limited. Most of the gases vary from mature to high mature. It is believed that these gases exist as condensates in the subsurface. The dominant sapropel-type gas is most likely to be cracked from the kerogen rather than the cracks of oils at high maturity.

1. Introduction

The exploration of natural gas has become increasingly important. The study of natural gas geochemistry and origin is a focus for natural gas exploration (Wang, 2004; Song et al., 2004; Cai et al., 2005; Aali and Rahmani, 2011; Liu et al., 2012; Cao et al., 2012). The Junggar Basin is a petroliferous basin in northwest China, covering an area of approximately 13×10^4 km^2 and is surrounded by mountains, including the Yilinheibiergen Mountain in the south, Halalate Mountain in the north, Zhayier Mountain in the west, and Kelameili Mountain in the east (Fig. 1). The current focus is on oil exploration. However, exploration for natural gas also appears prospective. A total reserve of approximately 2.1×10^{12} m^3 was estimated according to the latest third-round assessment of hydrocarbon resources in the basin (Wang et al., 2000). The gas resources are mainly located in the central basin, western margin, and southern margin of the basin, and are enriched in the Permian and Jurassic sequences. In recent years, numerous studies have been carried out for these natural gases (Ren et al., 2007; Zhu et al., 2008; Xun et al., 2009; Wu et al., 2010). Consequently, progress and success were achieved in natural gas exploration. For example, the discovery of the large Kelameili gas field in the eastern part of the basin increased attention and enthusiasm to the Junggar Basin. The Kelameili gas field has a natural gas reserve of 1033×10^8 m^3 and is the biggest gas field discovered so far (Kuang et al., 2010).

Among the favorable natural gas exploration areas in the basin, the Zhongguai region in the western margin of the basin is distinctive because it is close to three oil-generating sags (Penyijingxi, Shawan, and Mahu sags) and it is positional favorable for oil and gas gathering (Fig. 1). The natural gases in this area are mainly distributed in the Permian units, including the Jiamuhe Group (P_1j), Fengcheng Group (P_1f), and Wuerhe Group (P_2w). This area has a natural gas resource of 1850×10^8 m^3 (Yang and Chen, 2006; Chen et al., 2007), but the current proven gas is only

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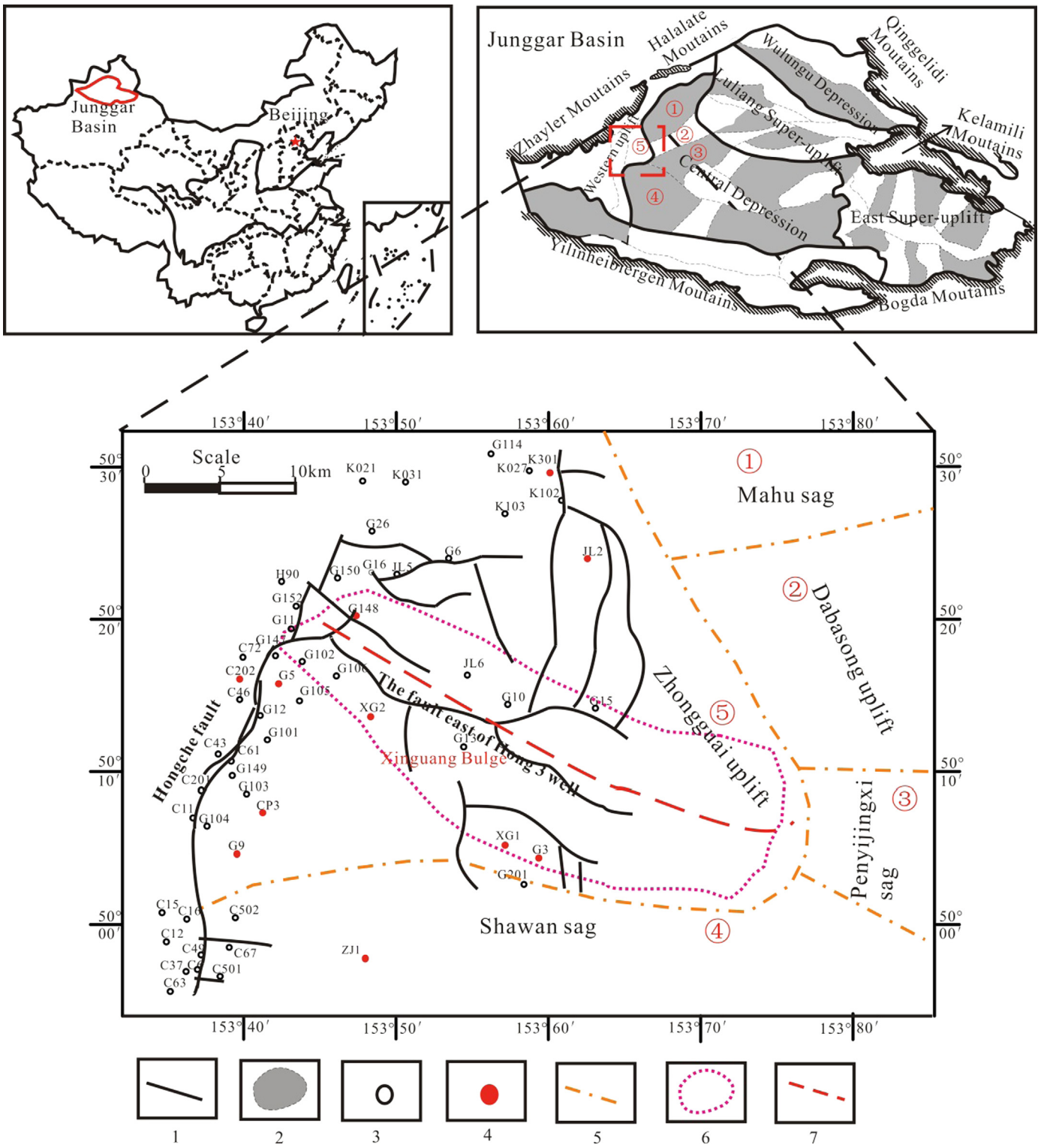

Fig. 1. Location of tectonic units of Zhongguai area in the western margin of Junggar Basin, China. (1) Fault; (2) sag; (3) well; (4) wells highlighted in the text; (5) boundary of tectonic units; (6) Xinguang bulge in the Zhongguai area; and (7) axis of the Xinguang bulge.

approximately 206.72×10^8 m^3, which is approximately 11.2% of the total gas resource (Yu et al., 2006). The gases may have complex sources and origins. They may be sapropel-type gas derived from the Permian P_1f, humic-type gas from the Permian P_2w and P_1j, or inorganic gas derived from the mantle. The sapropel-type gas may have originated from primary kerogen cracking or from the secondary cracking of oil. However, only few studies have been conducted on the sources and origins of natural gases.

We conducted a comprehensive geochemical study on gases of the Permian age to expand our understanding of gas accumulations in the Permian section of the Zhongguai area in the Junggar Basin. The gas geochemistry study included gas composition, carbon isotopes, and light hydrocarbon distributions. In addition,