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Natural gas constituent and carbon isotopic composition in petroliferous basins, China

Guangyou Zhu [a,*], Zhengjun Wang [b], Jinxing Dai [a], Jing Su [a]

[a] PetroChina Research Institute of Petroleum Exploration & Development, Beijing 100083, China
[b] PetroChina Jidong Oilfield, Tangshan 063004, China

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ABSTRACT

There are abundant gas resources in petroliferous basins of China. Large to midsize gas fields are found in Eastern, central and Western of China. However, origin, constituents and isotopic composition of natural gas in different gas fields are varied distinctly, and some present strong chemical secondary alteration and show variation both in age and space. Based on the systematic analysis of constituents and carbon isotope of a large number of gas samples, combined with the geological characteristics, this paper classifies the origins of the gases, explores the gas isotope characteristics and evolutionary regulation with the variation time and space, and further discusses the distinctive geochemistry of the gases in China. These gases are dominated by dry gas, its methane carbon isotope values range from −10‰ to −70‰, ethane from −16‰ to −52‰, propane from −13‰ to −43‰, and butane from −18‰ to −34‰. The carbon isotopes of most gases show the characteristics of humic-derived gas and crude oil cracked gas. In addition, large primary biogenic gas fields have been discovered in the Qaidam basin; inorganic-derived alkane gases have been discovered in deep of the Songliao Basin. Half of these gas fields are characterized by the alkane carbon isotope reversal in different degrees. Research indicates there are several reasons can result in carbon isotope reversal. Firstly, gas charge of different genetic types or different source in one gas reservoir may cause carbon isotope reversal. Besides, high-over mature evolution of gas can also lead to the carbon isotopic reversal of alkanes. Thirdly, secondary alteration of hydrocarbons may also result in abnormal distribution of carbon isotope, isotope transforms to unusual light and heavy.

1. Introduction

In long geologic history, hydrocarbon gases generated by bacterial activity or thermal transformation of organic matter accumulated and formed gas reservoir (Prinzhofer and Pernaton, 1997; Dai et al., 1992b; Mango and Hightower, 1997; Schoell, 1996; Zhang et al., 2011a); and gas from thermal cracking of crude oil or mantle-derived origin gas may accumulated to form gas reservoir (Prinzhofer and Pernaton, 1997; Dai et al., 1992b; Mango and Hightower, 1997; Schoell, 1996; Zhang et al., 2011a). Besides, non-hydrocarbon gas of thermal genetic or mantle source-derived origin may accumulate and form gas reservoirs.

Hydrocarbon gas and non-hydrocarbon gas mixed and accumulated to form gas reservoir, this may lead to complexity in natural gas genesis (Schoell, 1980, 1988; Jenden et al., 1993; Xu, 1994; Dai et al., 2000a, 2004, 2008a,b). The gas formation and accumulation is dynamic process accompanied with multiple gas recharging and variation of carbon isotope regularly, with an isotope composition of the corresponding gas changing regularly (Stahl, 1974; James, 1983; Jenden et al., 1988; Carpentier and Ungerer, 1996), so that gas isotope fingerprints have been used as sensitive tracers to history of petroleum charge and kinetic processes (Stahl and Carey, 1975; Schoell, 1984; Galimov, 1988; Sun et al., 2009a; Zhu et al., 2009). Formation mechanism and migration of natural gases may also affect their compositions and isotopes (James and Burns, 1984; Wilhelms et al., 1990; Larter et al., 2003). In addition, mixing of gases are generated by various processes (Dai et al., 1992a; Dai, 1986; Worden et al., 1996). At various stages, such as high thermal maturity level (the reservoir temperature overs 120 °C) secondary alteration (biodegradation or TSR) may also lead to variation in compositions and carbon isotopic fingerprint (Tang et al., 2000; Krouse et al., 1988; Zhang and Huang, 2005; Zhang et al., 2005a,b; Zhu et al., 2005a,b). Consequently, it is challenging to determine natural gas origins, to trace gas-generating parent material types, to compare gas sources, to identify maturity of natural gases, and to clarify migration directions and distances of natural gases based

* Corresponding author. Address: CNPC Key Laboratory of Petroleum Geochemistry, Research Institute of Petroleum Exploration & Development (RIPED), Mail Box 910, No. 20, Xueyuan Road, Beijing, China. Tel.: +86 18601309981.
E-mail address: zhuguangyou@petrochina.com.cn (G. Zhu).

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on the analysis of gas constituents and carbon isotope characteristics.

Natural gas geochemistry integrated with comprehensive geologic studies is being accepted as an effective way to determine origins of natural gas in areas with complex geologic features (Sun and Püttmann, 1996, 2000; Sun et al., 2009a). Natural gases in petroliferous basins of China have diverse origins, complex gas accumulations, wide-range distributions of carbon isotopes, and they are differing significantly in times and space (Dai et al., 2000b, 2003, 2009a; Song and Xu, 2005; Liu and Xu, 1996; Zhu and Zhang, 2009; Zhu et al., 2010a,b; Fu et al., 2005).

Especially, the natural gas industry in China has developed rapidly in recent years (Dai et al., 2010; Zhang and Zhu, 2008). It has been improved that there are abundant natural gas resources with great potential for future exploration in China. Meanwhile, the genesis of natural gases remain uncertain, such as diversity in types of natural gases, complexity in compositions and isotopes, intensive secondary alteration (Zhu et al., 2007a; Zhang and Zhu, 2008) and difficulties encountered during determination of gas sources and generation. These problems stunted the further exploration and development of natural gas in China. Considering these problems, this paper presents systematically the results of the compositions and carbon isotopes of tens of thousands of natural gas samples taken from different large to midsize gas fields in China, and clarifies the origins of the gases with considering geologic features. In addition, it is summarized the features and rules on evolution of natural gas isotopes and compositions with time and space.

2. Distribution of natural gas in Chinese petroliferous basins

After almost three decades' exploration, the natural gas industry in China has entered a stage of rapid development (Dai et al., 2009b). By 2011s, the total proven natural gas geological reserves are 8 tcm. Forty-five large-scale gas fields, each with reserves over 30 bcm, have been discovered (Fig. 1 and Table 1), and the total reserves in these gas fields are over 6000 bcm. There are 18 gas fields with reserves over 100 bcm respectively in China. The total reserves of these gas fields are almost 5000 bcm. Most of these large-scale gas fields are distributed in the Ordos, Sichuan, Tarim, Qaidam, Songliao, Junggar and Yingqiong basins (Fig. 1).

It is worthy to mention that gas-bearing strata are steady widely distributed, except for the Silurian, strata from the pre-Sinian to the Quaternary contain hydrocarbon gas reservoirs accumulations. Large to **midsize** gas fields are distributed mostly in the strata of Permian, Triassic, Tertiary, Quaternary, Carboniferous and Ordovician.

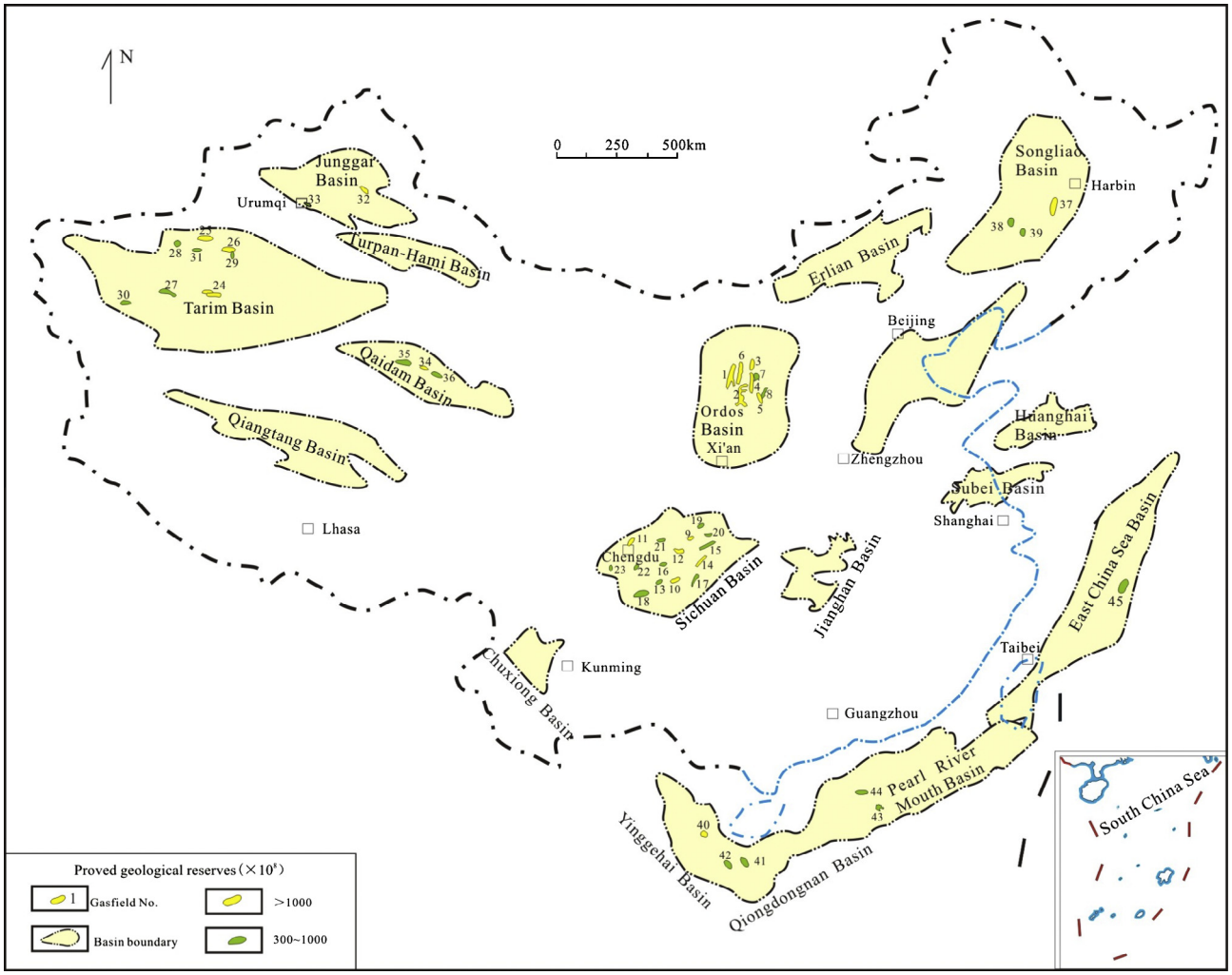

Fig. 1. Distribution of petroliferous basins and large to midsize gas fields in China (Zhao et al., 2005; Dai et al., modified in 2010).