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Research paper

The characteristics of source rock and hydrocarbon charging time of Precambrian granite reservoirs in the Bongor Basin, Chad

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ABSTRACT

The success of hydrocarbon drilling in Precambrian granite reservoirs expands the petroleum exploration boundary in the Bongor Basin which belongs to the Central and western Africa Rift System. This study integrated the analyses of geochemistry, fluid inclusion and 1D basin models to characterize and identify the source rock of the granite reservoirs, reconstruct the burial history and investigate the time of the hydrocarbon charging in the granite reservoirs. The results indicate all the 5 synrift intervals are organic rich deposition and the kerogen is dominated by type II_1 and type I. However, the Lower Cretaceous P, M and K Formations are regarded as potential hydrocarbon source rock intervals with a high richness of organic matters and thermal – evolution degrees. The close relationship in biomarkers between the crude oil in granite reservoirs and the source rocks in the P and M Formations indicates the P and M Formations are the most potential source kitchens for the granite reservoirs. Core samples obtained from 3 representative burial hills were used to conduct the fluid inclusion analysis. Constrained by the uplift history which was reconstructed based on the apatite fission track analysis obtained from the inner reports and the R_o-calibrated thermal history, four 1D basin models were carried out, and the model of the Well Baobab NE-1 indicates that the hydrocarbon generation began at the time of approximately 89 Ma. By projecting the homogenization temperature to the burial history of the corresponding wells, the hydrocarbon charging time was revealed: twice hydrocarbon charging in the granite reservoirs occurred simultaneously during 87 to 82 Ma and 76 to 72 Ma, corresponding to the uplifting episode in the Later Cretaceous.

1. Introduction

The Bongor Basin is situated in the southwest of Chad, Central Africa, which belongs to the Western and Central Africa Rift System (WCARS) (Fig. 1a). It formed in the Early Cretaceous because of the influence of Central African Trans-Current Slip Zone (CATSZ). The basin was filled by the sediments from the Cretaceous to Quaternary (Fig. 2). The adjacent basins related to the CATSZ, such as the Termit Basin, the Muglad Basin, are all hydrocarbon rich basins, and numerous studies reported source rocks, the hydrocarbon generation, migration and accumulation in sedimentary intervals (Tong et al., 2004; Harouna and Philp, 2012; Wan et al., 2014; Makeen et al., 2015, 2016; Liu et al., 2017). The Bongor Basin is one of important hydrocarbon rich basins in the WCARS, while little literature documents its petroleum system (Dou et al., 2013; Song et al., 2016). Some researches focus on the regional tectonic characteristics and evolution (Burke, 1976; Genik, 1992). In 2013, the success of hydrocarbon drilling in the north slope of the basin by the China National Oil Development Company (CNODC) targeting Precambrian granite reservoirs expands the boundary of petroleum exploration in the Bongor Basin, and industrial oil and gas have been obtained from the granite reservoirs of five buried hills. Although the previous studies involve describing the characteristics of reservoir features and the crude oil and brief introduction of the petroleum system in the buried hills (Dou et al., 2015), the studies about the source rock, burial history and hydrocarbon charging time of the granite reservoirs are scarce.

This paper aims to provide a reasonable understanding of the features of potential source rock intervals, the oil and gas source for the granite reservoirs, the burial history, and the time of hydrocarbon charging. In this study, 1D basin models of four wells were conducted to

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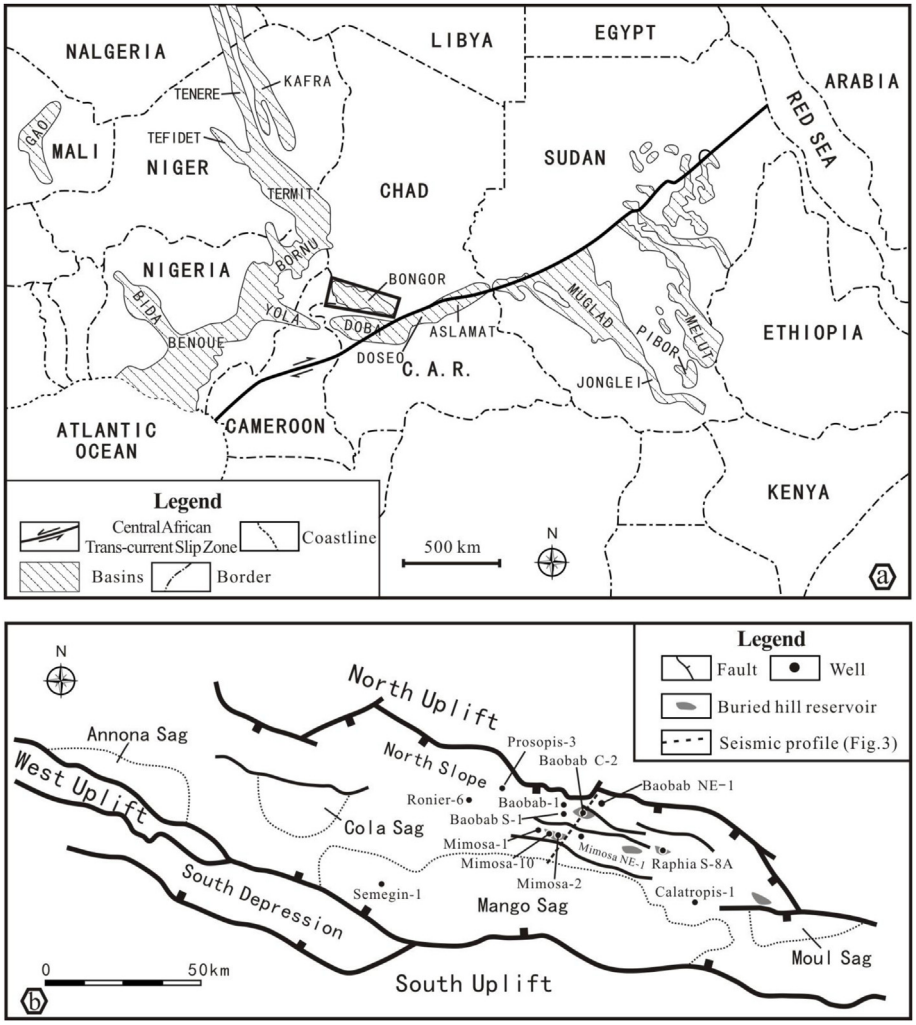

Fig. 1. Location map of the study area and study area with main faults. **a** showing the location of the Bongor Basin and Central African Trans-Current Slip Zone, and the adjacent petroliferous basins like the Termit, Muglad and Melut Basins. **b** showing the main faults, the tectonic division, the location of discovered buried hill hydrocarbon reservoirs with wells.

determine the burial history and investigate the hydrocarbon charging time in the granite reservoirs combined with the analysis of fluid inclusion. The study of source rock evaluation, oil – source correlation, burial history and hydrocarbon charging provide an important guidance for the further study on the petroleum system in the Bongor Basin, and decrease the exploration risk in the granite reservoirs of buried hills. This research also provides an opportunity to complement the understanding of the petroleum system in the Western and Central Africa Rift System.

2. Geological settings

The Bongor Basin is formed in the Early Cretaceous and its evolution is closely linked with that of the CATSZ. The basin developed on the Precambrian basement formed about 500 Ma associated with the pan-african movement which resulted in thermal metamorphism and granitization of the basement. Due to the strong rift during the Early Cretaceous, over 10 km thick sediments were deposited in the basin which were dominated by non-marine sediments (Genik, 1992). The Early Cretaceous involves Barremian, Aptian and Albian, which is divided into five formations including the P, M, K, R and B Formation (Fig. 2). Unconformities occurred between the basement, Cretaceous and Tertiary, respectively, and the top of the Cretaceous was eroded in most areas of the basin (Fig. 3).

The development of WCARS synrift can be divided into three phases (Genik, 1992). The first phase, corresponding to the Early Cretaceous (Fairhead, 1988), was a strong rifting stage with continental sediments of the maximum thickness of over 6 km in the Bongor Basin which was revealed by well drilling, and it was closed by a regional unconformity (Genik, 1992). The second rifting phase, which corresponds to the Late Cretaceous, was weak associated with a short lived period of rift followed by a long period of marked thermo-tectonic subsidence (Genik, 1992). During about 85–80 Ma, an important tectonic event termed the Santonian “squeeze” separated the Doba, Doseo, Salamat, and Bongor into four discrete basins and created potential hydrocarbon traps (Guiraud et al., 1985, 1987; Fairhead and Binks, 1991; Genik, 1992). The record of this phase is mainly in the West Africa rift basins with the thickness of about 6 km (Genik, 1992). By contrast, rift subsidence in the Bongor Basin is less than 3 km. The second phase was ended by a regional unconformity. The rift of the third phase (74 Ma – 30 Ma) only occurred in the West Africa rift basins, and the Bongor Basin was emergent with subsiding no more than 200–300 m. The third phase was terminated by a regional unconformity (Genik, 1992).

The Bongor Basin involves 6 structural units including the North Uplift, the South Uplift, the West Uplift, the North Depression, the North slope and the South Depression. The North Depression is divided into the Moul, Mango, Cola, Annona Sags (Fig. 1b). The hydrocarbon discovery in granite reservoirs of buried hills is mainly located in the