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The Control Effect of Neotectonic Movement on the Phase Behavior of Marine Reservoirs and the Petroleum Properties in North Tarim Basin

SU Jin[1, 2, *], ZHANG Shuichang[1, 2], ZHU Guangyou[1], WANG Yu[1, 2], WANG Xiaomei[1, 2]

1 Research Institute of Petroleum Exploration and Development, PetroChina, Beijing 100083
2 State Key Laboratory of enhanced oil recovery, Beijing 100083

The Tarim Basin is a large-scaled petroliferous basin superimposed by the Palaeozoic craton and Meso-Cenozoic terrigenous basin developed on the pre-Cambrian metamorphic basement in western China (Zhang et. al., 2000; Li et. al., 2010). In the basin, two suites of the Cambrian-Ordovician major marine source rock are developed in the Manjiaer depression, and adjacent to which is the Tabei uplift where the Ordovician system is mostly enriched in marine hydrocarbons (Zhang et. al., 2002; 2006). However, acute structural activities of late Caledonian and late Hercynian, particularly the structural evolution of late Himalayan speedy and deep burial, have led not only to multi-stage hydrocarbon generation of these two suites of marine source rocks, but also to multi-stage hydrocarbon charge, adjustment and destruction of the related reservoirs (Wang et. al., 2006; Tian et. al., 2009). For example, the Lunnan area in the northern Tarim Basin has various hydrocarbon reservoirs characterized by the dominance of heavy oils in the west part, normal oils in the centre, and waxy oils and condensates in the east part. Particularly, the new tectonic movement of late Himalayan stage made the source rock generates hydrocarbons and paleo-reservoirs experience adjustment and second accumulation. This process was believed to be a principle factor affecting the variable properties of the Ordovician hydrocarbon reservoir and the formation of multi-phase reservoirs (Napitupulu et al., 2000). So, in the exploration and development of hydrocarbons, it was urgently need to research the formation mechanism of marine petroleum properties and reservoir phase under the background of the new tectonic movement.

Properties of the Ordovician crude oil indicate that heavy oils have a density ranging between 22.3~5.9°*API*, higher sulfur, colloid and asphaltene contents than normal oils and condensates, i.e. their sulfur content varies between 1.0%~2.3%, colloid and asphaltene contents range between 13.2%~20%, and kinematic viscosity alters between 18.9~223μm^2/s. In contract, condensates show a density varying between 54.7~33.0°*API*, appreciably heavier than the primary condensate, this suggests an origin of secondary mixture. Moreover, they contain very low sulfur, colloid and asphaltene, with a content of 0.2% ~0.9% and 2.3%~10.8%, respectively. However, compared with heavy oils, condensates show more wax, with a content of 10.3%~23.8%. The maximum gas-oil ratio of condensate reservoirs is up to 12400m^3/m^3, and PVT experiments demonstrate that condensate reservoirs with such a high gas-oil ratio should be unsaturated gas pools in subsurface. The planar distribution of PVT phase for oil-gas reservoirs indicates that the reservoir phase gradually changes from an unsaturated gas pool in the southeastern periclinal situs to an unsaturated oil pool in the western buried hill, correspondingly, critical points of oil-gas reservoirs also graduate from Tc=-88.0℃ and Pc=57.2Mpa (a low-temperature but high-pressure area) to Tc=412.3℃ and Pc=12.68Mpa (a high-temperature but low-pressure area). Thus, it can be presumed that condensates and natural gases may have a mixed origin.

Oils derived from the Ordovician carbonate rock in Tabei are commonly biodegraded and the level of biodegradation decreases gradually from the Well LG15 buried-hill area to the periclinal situs (Fig.1). However, the Ordovician system in Tabei has never uplifted and been eroded since the Indo-China Period, consequently, it has hardly ever been biodegraded since then. Differences in present-day hydrocarbons arise mainly from the admixture of various hydrocarbons, i.e. during the Himalayan speedy burial, the biodegraded oil mixed with the normal oil of local charge and gas cutting caused by the late hydrocarbon supply from the Cambrian-Ordovician source rock or paleo-reservoirs. The direct

* Corresponding author. E-mail: susujinjin@126.com

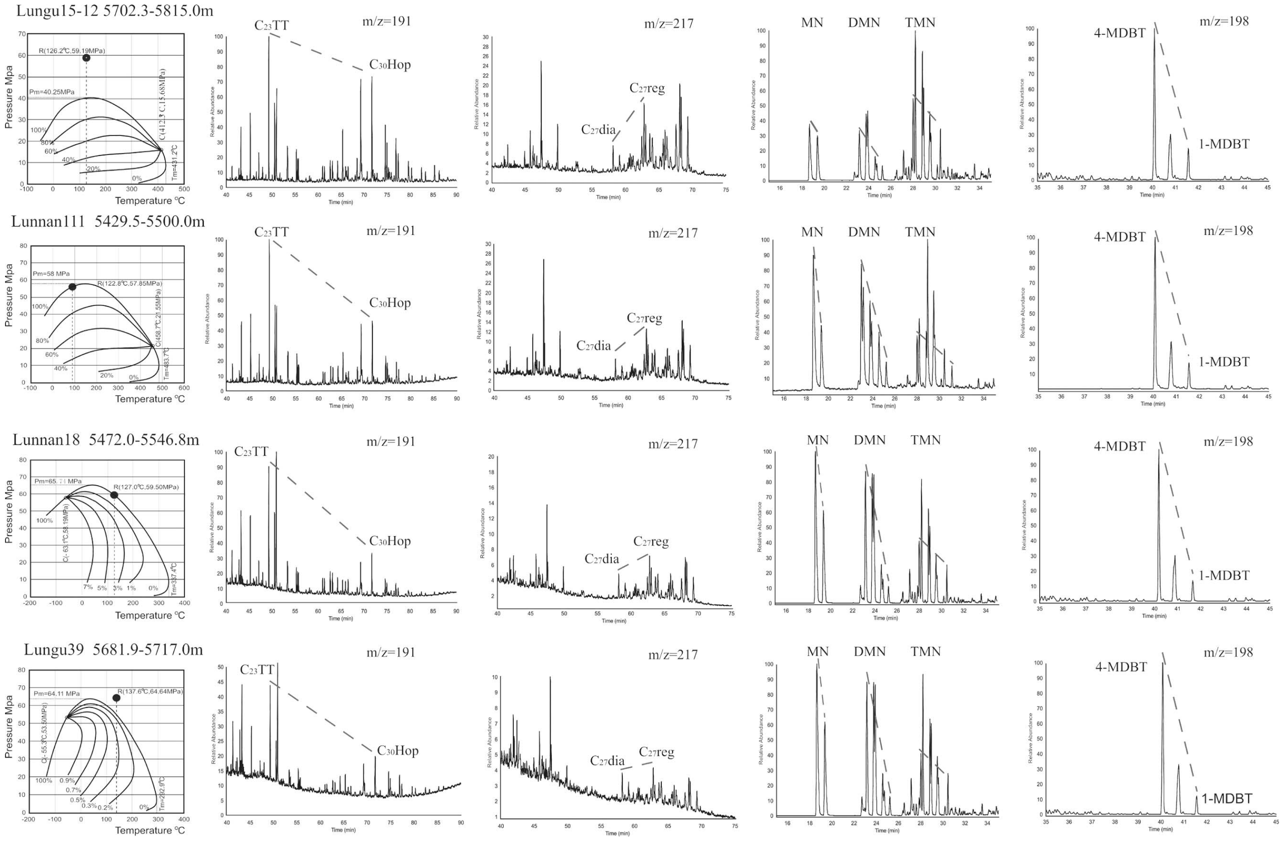

Fig.1. Geochemical comparisons of biodegradation levels with the admixture of highly mature natural gases in multi-phase hydrocarbon reservoirs

C_{23}TT—C_{23} Tricyclic Terpane; C_{30}Hop—C_{30}Hopane; C_{27}dia—C_{27} diasterane; C_{27}reg—C_{27} regular sterane; MN—Methylnaphthalene; DMN—Dimethylnaphthalene; TMN—Trimethylnaphthalene; 4-MDBT—4-Methyldibenzothiophene; 1-MDBT—1-Methyldibenzothiophene.

evidence for the hydrocarbon admixture in reservoirs is the decrease of oil density. For example, the oil density of Well LN18 and Well LG39 is 37.0°*API* and 47.6°*API*, respectively, and the saturated hydrocarbons have a comparatively complete series of normal alkanes, with Ts/(Tm+Ts)>0.6, Dia/(Dia+Reg)>0.3 and ββ/(αα+ββ)>0.54, suggesting high maturity. Moreover, it shows distinct 25-norshopane and 1,3,6-/1,2,5-TMN>1.4, indicating heavy biodegradation (Fig.1). It is just because the admixture of the late Himalayan normal oil and natural gas with the biodegraded heavy oil that the present-day condensate reservoir could be formed. Well LG39 adjacent to the hydrocarbon-supplying area is an unsaturated condensate pool that formed due to trapping the late-stage dry-gas more easily. Oils from the area where no admixture of the late-stage normal oil with natural gas ever occurred show characters of early-stage reservoir formation, such as Ts/(Tm+Ts)<0.4, Dia/(Dia+Reg)<0.25 and ββ/(αα+ββ)<0.50, indicating low maturity. While oils biodegraded later show less normal alkane series but the highest abundance of 25-norshopane in Tabei, they have 1,3,6-/1,2,5TMN>1.8. Moreover, in reservoirs where the degraded heavy oil has not mixed with the late-stage normal oil and natural gas (Matyasik et al., 2000; Luc et al., 2010), gas-oil ratio (GOR) is less than $100m^3/m^3$, especially for the severely biodegraded oil of Well LG15, where GOR varies between $40\sim60m^3/m^3$, wetness is about 85%, $\delta^{13}C_1$ is lighter than -45‰, and oil density is less than 12.9°*API*. However, the natural gas from condensate gas pools such as Well LG39 shows wetness>98%, $\delta^{13}C_1$>-31‰ and $\ln C_1/C_2$ varying between 3.5~5.5, indicating a highly mature gas cracked from crude oils in the late Himalayan (Fig.1). Moreover, the condensate from these condensate pools shows a density varying between 33.0~54.7°*API*, different from the condensate derived from the normal evolution of organic matter, it exhibits a character of mixing of the late-stage highly mature gas with the early-stage crude oil (Waples et al., 2000; Volk et al., 2002; Thompson et al., 2010). The relationship comparison between wax content of condensates and GOR of hydrocarbon reservoirs demonstrates that condensate pools with high GOR have a positive correlation of GOR with wax content, indicating that the late-stage gas cutting not only occurred in early-stage reservoirs but also resulted in the fractionation that enriches wax.

To sum up, analyses and measurements of geochemical

components and compositions of hydrocarbon fluids in reservoirs can not only determine origins of hydrocarbons, identify whether an oil reservoir is altered by biodegradation or water washing, but also reconstruct the mixing process of the late-stage normal oil and natural gas, define the mechanism of regional distributions of various oil properties as well as the formation time of reservoirs. The Ordovician marine oil-gas reservoir in Tabei, Tarim Basin, has two suites of marine source rocks to supply hydrocarbons. The late Caledonian and late Hercynian are the two important periods of structural activities, when the major generation and expulsion of hydrocarbons occurred. Oils generated at early stage were extensively biodegraded due to continual occurrences of the formation, elevation, erosion and destruction of reservoirs. Geochemical studies on hydrocarbon fluids of reservoirs indicate that the mixture of the late Himalayan highly mature normal oil with natural gas and the migration fractionation caused by gas cutting are major reasons for the present-day coexistence of various hydrocarbons in Tabei, i.e. heavy oils accumulates in the western part, normal oils in the centre, and waxy oils and condensates in the eastern part.

Key words: Neotectonic movement, petroleum properties, second accumulation, phase behavior, Tarim basin

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