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Compositional variabilities among crude oils from the southwestern part of the Qaidam Basin, NW China

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ABSTRACT

A suite of crude oils have been analyzed by GC/MS in order to understand compositional heterogeneities in the oilfields located in the southwestern part of the Qaidam Basin, NW China. The oil samples investigated in this study can be grouped into two broad groups, A and B, based on the distributions of pentacyclic triterpanes. Group A oils predominately occurred in the northwestern part of the study area contain relatively high amounts of gammacerane and C_{35} hopanes with the ratio of gammacerane to C_{30} hopane (G/H) >0.7 and the C_{35}/C_{34} hopane ratio (C_{35}/C_{34}) >1.2. In contrast, Group B oils mainly occurred in the southeastern part of the study area have relatively low values of G/H (~<0.7) and C_{35}/C_{34} (<1.2). Furthermore, Group A oils can be subdivided into three subgroups (A1, A2, and A3) by detailed investigation of molecular compositions of steranes, hopanes and aromatic sulfur compounds. Subgroup A1 oils, which mainly occurred in the westernmost corner, contain low amounts of dibenzothiophene (DBT) and methyldibenzothiophenes (MDBT) relative to C_{30} hopane with the ratio of (DBT+MDBT)/C_{30} hopane (DBT+MDBT/H) <~0.25 and display high abundances of ααα20R C_{28} sterane relative to C_{29} compound with the C_{28}/C_{29} sterane ratio >~0.90. In contrast, subgroup A3 oils, which mainly occurred in depression areas, have relatively high values of (DBT+MDBT)/H (~>0.25) and relatively low ratios of C_{28}/C_{29} sterane (~<0.90). Subgroup A2 oils, occurring in Gasikule and nearby oilfields, seem to have intermediate amounts of aromatic sulfur compounds and C_{28} steranes relative to A1 and A3 oils, indicating a mixing signature of the two subgroups. The oil groups or subgroups revealed by the compositional heterogeneities and genetic affinities, as well as their regular occurrence in different oilfields, may indicate secondary petroleum systems existing within the Tertiary saline lacustrine petroleum in the southwestern Qaidam basin.

1. Introduction

The Qaidam basin is an interior basin with an area of about 120,000 km^2. With over 50 yr of petroleum exploration, three petroleum systems have been discovered, a Jurassic system in the northern margin, a Tertiary system in the west and a Quaternary system in the east. Of the three systems, more than ten oil–gas fields have been discovered in the Tertiary petroleum system, which represent 90% of the petroleum resources discovered in the basin. Therefore, the Tertiary petroleum system is the main target for petroleum exploration in the basin.

Most of the limited petroleum geochemical studies conducted in the Qaidam basin focused on the Tertiary petroleum system in the western part of the basin (often called the western Qaidam basin). Most oils produced in the area were reported to be characterized by low values of Pr/Ph, high abundances of gammacerane, even *n*-alkane preferences, and enhanced abundances of C_{35} homohopanes (Huang et al., 1989; Philp et al., 1989; Ritts et al., 1999; Hanson et al., 2001), suggesting hypersaline lacustrine environments for the oils. Heavy carbon isotope signatures for the oils from the western Qaidam basin were reported by Huang et al. (1989) and Philp et al. (1991), which were related to typical saline lacustrine environments. Biomarker distributions in the oils and rocks from the same area were previously reported by Huang et al. (1991, 1994) to describe the maturity changes and to discuss the origins of 4-methyl steranes and pregnanes in the Tertiary strata. More recently, a lot of oils, as well as related source rocks from the western Qaidam basin, were analyzed by Zhu et al. (2005), displaying the characteristics of light

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hydrocarbons, compound-specific C isotopes, saturate and aromatic compounds. The detailed geochemical characteristics reported by Zhu et al. (2005) confirmed the previous work on the compositional variations amongst the oils in the western Qaidam basin. However, a detailed classification and occurrence for the oils have not been presented yet.

In this study, we will focus on the southwestern part of the Qaidam basin, representing the most prolific petroleum province in the Tertiary system. The purpose of this study is to investigate the compositional heterogeneities across the oilfields in order to understand oil groups and/or subgroups in the area, which may be helpful in understanding the possible sub-petroleum systems within the Tertiary saline lacustrine petroleum system.

2. Geological setting

The Qaidam basin is situated at the northeastern corner of the Qinghai–Tibetan Plateau, NW China and surrounded by the Kulun, Arjin and Qilian mountains (Fig. 1). The basin was developed on a pre-Mesozoic basement during the Mesozoic and Cenozoic. A relatively complex structural movement resulted in different tectonic evolution histories in different parts of the basin with the formation of three petroleum systems: the Jurassic freshwater lacustrine oil system in the north (Ritts et al., 1999), the Tertiary saline lacustrine petroleum system in the west (Hanson et al., 2001) and the Quaternary biogenetic gas system in the east (Pang et al., 2005).

The Tertiary saline lacustrine petroleum occurred in the western Qaidam basin, which was developed during the Cenozoic with three main development stages: (1) the Himalayan movement stage I, resulting in rapid subsidence of the western basin and the deposition of the Lulehe (E_{1+2}) and Lower Gankaigou (E_3) Formations; (2) depression stage of the basin center from the Late Oligocene to Middle Pliocene, resulting in the development of the Upper Gankaigou (N_1) and Lower Youshashan (N_2^1) Formations, and (3) the Himalayan movement stages II and III during the Pliocene and Quaternary times with the development of the Upper Youshashan (N_2^2), Shizigou (N_2^3) and Qigequan Formations. During that time, the climate was arid, the water supply was limited, the lake water became very saline and so saline lacustrine sediments became widely developed, with an area of about 30,000 km^2 and a maximum thickness up to 7000 m. The depocenter was in the southwestern part during the early stage and was progressively shifted northeastward after the Mid-Miocene to the centre part of the Qaidam basin, accompanying with uplift in the west and subsidence in the east.

The Cenozoic strata were composed of sandstone, shale and calcareous rocks. The source rocks were mainly among the Lower Ganchaigou (E_3) and Upper Ganchaigou (N_1) Formations within the Tertiary strata, which were developed in saline lacustrine environments (Huang et al., 1989; Zhu et al., 2005). The source rocks, predominantly characterized by laminated to massive calcareous mudstones, mainly contained type-II kerogens with major organic input from algae and bacteria and little from terrigenous matter (Hanson et al., 2001). The oil reservoirs mainly occurred within the Oligocene Lower Ganchaigou Formation (E_3) and the Miocene Upper Ganchaigou Formation (N_1) and Pliocene strata (N_2) with sandstones. The shale and calcareous rocks in the Miocene and Pliocene strata acted as the regional seals. For more detailed geological information, see Huang et al. (1989), Jin and Zha (2000), Qiu et al. (2000) and Hanson et al. (2001).

3. Samples and experimental

The crude oils in this study were sampled from the oilfields in the southwestern part of the western Qaidam basin. Fig. 1c displays the locations of the oilfields from which oil samples were taken. General information for the oils was given in Table 1.

The method for oil analysis was previously reported by Zhang et al. (2004). Briefly, after 2 mg oil was extracted with 2 ml 2,2,4-

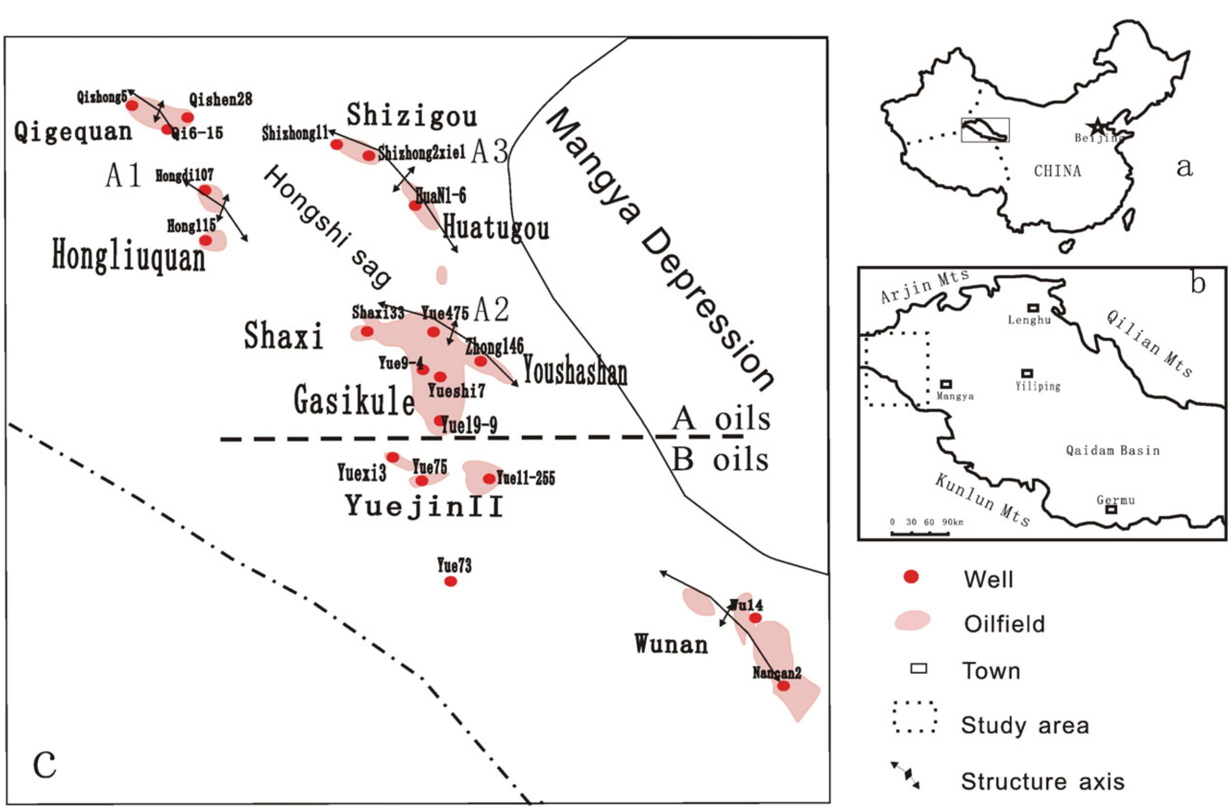

Fig. 1. General map of the study areas showing the oilfields where the oil samples were taken and the distributions of the oil groups and subgroups.