Organic Geochemistry 101 (2016) 22–37

Contents lists available at ScienceDirect

Organic Geochemistry

journal homepage: www.elsevier.com/locate/orggeochem

Effects of tectonic compression on petroleum accumulation in the Kelasu Thrust Belt of the Kuqa Sub-basin, Tarim Basin, NW China

Xiaowen Guo [a,*], Keyu Liu [b,c,*], Chengzao Jia [c], Yan Song [c,d], Mengjun Zhao [c], Qingong Zhuo [c], Xuesong Lu [c]

[a] Key Laboratory of Tectonics and Petroleum Resources (China University of Geosciences), Chinese Ministry of Education, Wuhan 430074, China
[b] School of Geosciences, China University of Petroleum, Qingdao, Shandong 266580, China
[c] Research Institute of Petroleum Exploration and Development, PetroChina, Beijing 100083, China
[d] China University of Petroleum, Changping, Beijing 102249, China

ARTICLE INFO

Article history:
Received 15 February 2016
Received in revised form 7 August 2016
Accepted 10 August 2016
Available online 17 August 2016

Keywords:
Hydrocarbon origin and maturity
Fluid inclusions
Basin modeling
Tectonic compression
Kuqa Sub-basin

ABSTRACT

The Kelasu Thrust Belt is a favorable hydrocarbon accumulation zone in the Kuqa Sub-basin with several known giant gas fields including the Dabei and Kela-2 gas fields as well as the Dawanqi oil field. The origin and accumulation process of the hydrocarbons were investigated through an integrated petroleum geochemistry and fluid inclusion analysis, and basin modeling. Geochemical parameters indicate that the light oils from the Dawanqi oil field and Dabei gas field were generated from different sources as compared with light oils from the Kela-2 gas field. Light oils from the Dawanqi oil field and Dabei gas field are primarily derived from the terrestrial mudstones in the Jurassic Qiakemake (J_2q) Formation with a maturity level of 1.4–1.6 %Ro, whereas light oils from the Kela-2 gas field are mainly derived from the terrestrial mudstones in the Triassic Huangshanjie (T_3h) with a maturity level of 1.6–1.8 %Ro. Gases in the Kelasu Thrust Belt are dominated by coal-type gas and are primarily generated from the Jurassic coal measures. Carbon isotope ratios suggest that gases in the Dawanqi oil field and Dabei gas field were generated at a thermal maturity level of 1.6–2.3 %Ro, while gas in the Kela-2 gas field was generated at a thermal maturity level of 2.1–2.5 %Ro.

Two episodes of oil and one episode of gas charge were delineated in the Dabei gas field. The second episode of oil charge occurred around 5–4 Ma, while gas charge occurred around 3–2 Ma. Three episodes of oil and one episode of gas charge were identified in the Kela-2 gas field. The latter two episodes of oil charge occurred around 5.5–4.5 Ma and the gas charge occurred around 3–2 Ma. The timing of the petroleum charge was also confirmed by the correlation between the maturity of the source rocks during the times of charge and the maturity levels of the light oil and gas in the reservoirs. The later oil and gas charge occurred at the same period in both the Dabei and Kela-2 gas fields, possibly relating to structural reactivation caused by regional tectonic compression, because intense tectonic compression and rapid uplift of the Tianshan Mountains occurred during the same period, which may have caused thrust fault activation and opening. Hydrocarbon expulsion from the source rocks during the period was possibly also related to the regional tectonic movement, providing hydrocarbon sources for the reservoirs.

1. Introduction

The Kuqa Sub-basin is a Mesozoic-Cenozoic basin located in the northern Tarim Basin near the foothill of the South Tianshan mountains (Jia and Wei, 2003). It is a major gas producing area in the Tarim Basin with minor associated oil. The sub-basin is interpreted to be a peripheral foreland basin (Jia, 1992; Wang et al., 1994; Chen et al., 1996a; Tang, 1996; Tian, 1996; Tian et al., 1996) or a collisional successor foreland basin (Hendrix et al., 1992; Graham et al., 1993). Numerous thrust faults and folds are present the Kuqa Sub-basin, displaying intense compressional deformation. The timing of the Kuqa Sub-basin compression was previously thought to be from the late Oligocene to the Early Pleistocene (Sun et al., 2004; Sun and Zhang, 2009; Qiu et al., 2012). A series of thrust fault-related folds form major hydrocarbon traps in the Kuqa Sub-basin. The Kelasu Thrust Belt is a favorable zone for hydrocarbon accumulations. The salt and gypsum unit in the Paleogene Kumugeliemu ($E_{1-2}km$) and Neogene Jidike (N_1j) Formations forms an excellent regional seal for preserving hydrocarbon accumulations within the Cretaceous and Paleogene reservoirs. The

* Corresponding authors at: School of Geosciences, China University of Petroleum, Qingdao, Shandong 266580, China (K. Liu).
E-mail addresses: cuggxw@163.com (X. Guo), keyu_liu@icloud.com (K. Liu).

http://dx.doi.org/10.1016/j.orggeochem.2016.08.008
0146-6380/

Jurassic coal-bearing sequence is currently at its peak dry gas generation stage, providing ample charge for the gas accumulations in the Kuqa Sub-basin (Liang et al., 2003). Tectonic compression in the area was suggested to have an important impact on the reservoir properties and the development of shear fractures and thrust faults, acting as possible major migration pathways for hydrocarbons (Zeng et al., 2010; Zhang et al., 2011). The reservoir properties, petroleum generation, migration, accumulation and preservation in the Kuqa Sub-basin are believed to have been broadly controlled by the regional tectonic compression (Jia and Li, 2008; Jiang et al., 2010; Zeng et al., 2010) because tectonic compression caused: (1) rapid uplift and denudation of the mountainous area, (2) sedimentation and thrust fault activation in the adjacent basin area, and (3) trap development and reservoir pressure buildup in the Kuqa Sub-basin. However, despite those postulations, so far there has been no concrete evidence documented regarding the direct link between tectonic compression, petroleum charge and accumulation in the Kuqa Sub-basin. Accurate reconstruction of hydrocarbon charge history in a basin is crucial for any successful petroleum exploration.

The objectives of this paper are to: (1) determine the origin and maturity of the light oil and gas in the Kelasu Thrust Belt; (2) investigate the petroleum charge history in the belt through fluid inclusion analysis; (3) reconstruction of the petroleum generation history of the Triassic and Jurassic source rocks by basin modeling; (4) document the relationship between tectonic compression and petroleum charge history in the Kelasu Thrust Belt.

2. Geologic setting

The Tarim Basin is located at the southern Xinjiang Ugar Autonomous Region, NW China. It is an important hydrocarbon-producing basin in China. The basin is bordered with the Tianshan mountains to the north and the Kunlun and Altun mountains to the south and covers an area of approximately 560,000 km^2 (Fig. 1A). The Kuqa Sub-basin, one of the most productive gas provinces in China, is located in the northern part of the Tarim Basin as a secondary tectonic unit (Fig. 1B). The sub-basin is bounded to the north by the South Tianshan mountains and the south by the Northern Tarim Uplift. It comprises six tectonic units, namely, the Northern Monocline Belt, the Kelasu-Yiqikelike Structural Belts, the Baicheng-Yangxia sags, the Qiulitage Thrust Belt, the Southern Gentle Slope and the Wushi Sag (Fig. 1C). The Kelasu-Yiqikelike Thrust Belts and the Qiulitage Thrust Belt are favorable zones for hydrocarbon accumulations. In the Cretaceous and Tertiary reservoirs several giant gas fields, including the Kela-2, Dina-2, Dabei and Keshen gas fields, have recently been discovered (Zou et al., 2006; Zhang et al., 2011).

The tectonic evolution of the Kuqa Sub-basin can be divided into three stages: a peripheral foreland basin stage, an extensional rift basin stage and a rejuvenated foreland basin stage (Graham et al., 1993). The basin was filled with Late Permian to Quaternary terrestrial clastic rocks. The main hydrocarbon source rocks are the Middle-Lower Jurassic coal seams, carbonaceous mudstones, lacustrine mudstones, and the Upper Triassic lacustrine mudstones (Liang et al., 2003; Jia and Li, 2008). The Jurassic source rocks are composed of 400–1100 m coal-bearing clastic rocks deposited in swamp-lacustrine settings (Liang et al., 2003). Organic matter in the Jurassic and Triassic source rocks are primarily dominated by Type III and Type II kerogens (Liang et al., 2003), respectively. Potential reservoirs include sandstone units in the Triassic Ehuobulake (T_1oh), Kelamayi (T_2k), Jurassic Ahe (J_1a), Yangxia (J_1y), Kezilenuer (J_2k), the Cretaceous Baxigai (K_1b), Bashijiqike (K_1bs), the Paleogene Kumugeliemu ($E_{1-2}km$), Neogene Jidike (N_1j), Kangcun (N_1k), Kuqa (N_2k) and Quaternary formations (Fig. 2). The $E_{1-2}km$ salt and gypsum unit forms an excellent regional seal for the

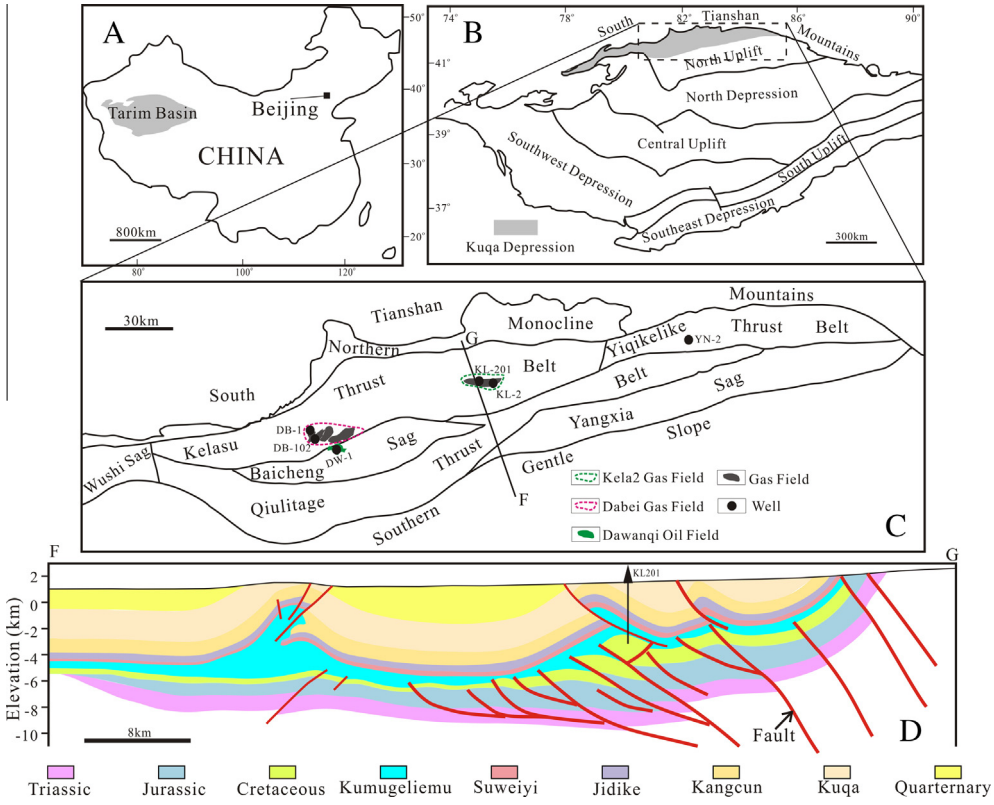

Fig. 1. (A) Map showing the location of the Tarim Basin in western China; (B) tectonic units of the Tarim Basin and locations of the Kuqa Sub-basin and the South Tianshan mountains; (C) distribution of major gas fields in the thrust belts, tectonic sub-units, locations of some sampled wells and cross-section FG; (D) cross-section FG showing numerous thrust faults and related folds developed in the Kuqa Sub-basin.