

Characteristics of Jurassic Fluid Inclusions in the hinterland of Junggar Basin

Zhaoyong Ping

School of Earth Sciences and Engineering, Xi'an Shiyou University, Xi'an 710065, China
Shanxi Key Lab of Petroleum Accumulation Geology, Xi'an Shiyou University, Xian 710065, China

Abstract: The Mosuowan area in the Junggar Basin has huge oil and gas resources. The reservoir accumulation process of the Badaowan Formation and the Sangonghe Formation is complex, and fluid inclusions are one of the main means. Based on the observation of the petrographic characteristics of fluid inclusions in 40 reservoir samples of Sangonghe and Badaowan Formations in 3 wells, the study of fluid inclusions was carried out. The results show that there are five types of inclusions in the study area, including gas-liquid two-phase brine inclusions, pure liquid brine inclusions, liquid hydrocarbon inclusions, gas-liquid hydrocarbon inclusions and gaseous hydrocarbon inclusions. From the Badaowan Formation to the Sangonghe Formation, the abundance of hydrocarbon inclusions decreases step by step.

Keywords: Fluid inclusions; Jurassic; Junggar Basin.

1. Introduction

Hydrocarbon fluid inclusions and associated saline inclusions in reservoirs record the process of oil and gas migration and accumulation^[1]. The division of hydrocarbon accumulation periods is of great significance for studying the process of hydrocarbon accumulation and the distribution of oil and gas reservoirs. In recent years, great progress has been made in the study of fluid inclusions, which has become a key technical method for geologists to study oil and gas accumulation period, pore fluid evolution, oil and gas migration and filling time, as well as paleogeothermal and paleopressure^[2]. By measuring the homogenization temperature of brine inclusions associated with hydrocarbon inclusions, the formation temperature during inclusion capture can be analyzed. The composition and occurrence state of hydrocarbon inclusions are analyzed by inclusion composition and combination characteristics. Combined with the reservoir burial-thermal evolution history and hydrocarbon generation history, the oil and gas filling period and accumulation period can be determined, and the accumulation process can be restored^[3-7].

The oil and gas in Mosuowan area mainly comes from the adjacent hydrocarbon generation sag, which is an important oil and gas accumulation area. However, due to its complex tectonic background and multi-stage tectonic movement and oil and gas filling, exploration is difficult. At present, the proven oil and gas are mainly distributed in the Jurassic reservoir, which is the key exploration horizon. Although the predecessors have done a lot of research on the hydrocarbon accumulation period and filling history in the hinterland of Junggar Basin, the accumulation period and process of Mosuowan area are still controversial and need to be further studied. It is generally believed that the hydrocarbon charging history in the hinterland of the Junggar Basin includes multiple stages. Jiang Lin believes that there are three stages of accumulation in Mosuowan area, which are at the end of Middle Jurassic, the end of Early Cretaceous and the end of Tertiary. Yang Zhi believes that the area has experienced two stages of accumulation in the early and late stages, and has experienced two large-scale oil and gas fillings in the late

stage; ablimiti Yiming believed that there were two stages of oil and gas filling in the Mosuowan area, respectively in the middle and late Cretaceous and Neogene.

In view of this, the reservoir samples in the Mosuowan area were selected to analyze and study the characteristic accumulation stages and processes of fluid inclusions in the Sangonghe and Badaowan Formations in the study area. Through this study, the purpose is to provide a basis for understanding its accumulation mechanism and deepen the Jurassic oil and gas exploration. It has certain guiding significance for the oil and gas exploration of the Jurassic Sangonghe and Badaowan Formations in the Mosuowan area.

2. Overview of the Study Area

The Junggar Basin is located in the northwest of Xinjiang (Figure 1). It is one of the four major petroliferous basins in China. It is a multi-stage tectonic movement superimposed petroliferous basin formed on the pre-Hercynian basement. The Mosuowan area is located in the central uplift of the Junggar Basin, with an exploration area of 3800 km². The area is adjacent to the Permian Fengcheng Formation and Wuerhe Formation source rocks in the west sag of Well Pen-1 in the north, and the Jurassic source rocks in the Shawan and Fukang sags in the south, with unique accumulation conditions. The main source rocks are the Permian Wuerhe Formation and Fengcheng Formation.

The organic matter type of the source rock of the Fengcheng Formation is mainly I-III kerogen, with an average hydrocarbon generation potential of about 4.29 mg / g, an average total organic carbon content of about 0.92 %, and an effective thickness of 100-330 m. It is a set of medium-good source rocks; the organic matter type of the source rock of the Lower Wuerhe Formation is II2-III kerogen, the average hydrocarbon generation potential is about 1.21 mg / g, the average total organic carbon content is about 0.57 %, and the effective thickness is between 80 and 400 m. It is a set of poor-medium source rocks. The source rocks of the Fengcheng Formation are deeply buried and have high maturity, which is in the high mature-over mature stage, while the source rocks of the Lower Urho Formation are at the end of the high mature stage.

The Jurassic was deposited in the intracontinental depression period. The main strata are Jurassic Badaowan Formation and Sangonghe Formation from bottom to top, Middle Jurassic Xishanyao Formation and Toutunhe Formation, Upper Jurassic Qigu Formation and Kalazha Formation. The reservoir is mainly the delta sand body of the Sangonghe Formation, and the caprock is the mudstone of the third member of the Sangonghe Formation. The target layers are mainly Sangonghe Formation and Badaowan Formation. The lithology of Sangonghe Formation is mainly sandstone and mudstone, which is close to the Lower Jurassic Badaowan Formation and Permian source rocks. The hydrocarbon accumulation conditions are good, and it is the main production layer in the hinterland of Junggar Basin. The Badaowan Formation is mainly composed of sandstone, mudstone and coal seam, which is the main coal-bearing strata of Jurassic in Junggar Basin.

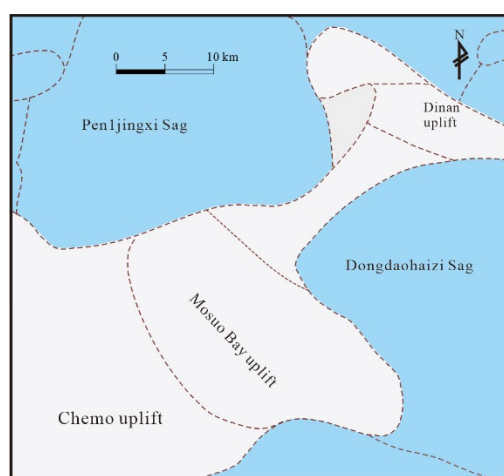


Figure 1. The location of the hinterland of Junggar Basin

3. Fluid Inclusion Features

3.1. Petrographic characteristics of inclusions

Fine microscopic observation shows that gas hydrocarbon inclusions, liquid hydrocarbon inclusions, gas-liquid hydrocarbon inclusions and hydrocarbon-bearing brine inclusions are developed in the reservoirs of Badaowan and Sangonghe formations. The average diameter is generally between 0.5-15 μm , mostly irregular or oval. The host minerals of inclusions are mainly quartz particles. Liquid hydrocarbon inclusions and gas-liquid hydrocarbon inclusions are mainly distributed in micro-cracks and quartz secondary enlarged edges. They are colorless or brownish yellow under transmission light, and most of them emit blue-white fluorescence under ultraviolet fluorescence. Gas hydrocarbon inclusions are mainly distributed in healed micro-cracks, which are often distributed in beaded clusters into bands, and are mostly associated with brine inclusions. It is black under the transmitted light and has no fluorescence under the ultraviolet fluorescence. In some samples, the phenomenon of healing micro-fractures cutting through micro-fractures and quartz increasing edge can be observed. It shows that the formation time of inclusions in healed microcracks is later than that of the enlarged edge of microcracks. It is preliminarily believed that the gas hydrocarbon inclusions distributed in healed microcracks are later than the liquid hydrocarbon inclusions distributed in the secondary enlarged edge of quartz. It can also be seen that the

late cracks cut through the early cracks. It can be seen that there are many stages of micro-cracks. Most of the micro-cracks cut through quartz particles, and their formation time is later than the healing of micro-cracks and enlarged edges. It is shown that the inclusions in the quartz enlarged edge are captured earliest, followed by the inclusions in the healing microfractures, and the inclusions in the microfractures are formed latest. However, microscopic observation can only preliminarily divide the relative period of inclusions.

Liquid hydrocarbon inclusions and gas-liquid hydrocarbon inclusions can be distinguished by the fluorescence display characteristics of the fluorescence channel of the microscope, but gas hydrocarbon inclusions have no fluorescence display under the fluorescence channel, and it is difficult to distinguish them from other types of fluid inclusions in composition, occurrence, shape and size. Therefore, the laser Raman spectrometer can effectively analyze the internal composition characteristics of a single fluid inclusion.

It is found that there are many types of gas-hydrocarbon inclusions in the study area, and there are single-phase and two-phase fluid inclusions. For example, methane inclusions only have obvious methane characteristic peaks, and the Raman shift has a single peak at 2905 ~ 2911 cm^{-1} . The asphalt inclusions only show the double peaks of asphalt, which are 1369 ~ 1399 cm^{-1} and 1605 ~ 1607 cm^{-1} , respectively. These inclusions are irregular in shape, black under transmission light, and mainly distributed along cracks. The CO_2 inclusions are less distributed, and the Raman spectrum shows the typical Fermi resonance double peaks of CO_2 (1160 cm^{-1} and 1387 cm^{-1}). The bitumen-bearing methane inclusions not only found obvious asphaltene double peaks but also detected CH_4 characteristic peaks. The ' D ' peak was mainly in the range of 1311 ~ 1370 cm^{-1} , the ' G ' peak was mainly in the range of 1607 ~ 1611 cm^{-1} , and the Raman shift peak of methane was mainly in the range of 2915 ~ 2917 cm^{-1} . This type of inclusions is transparent as a whole but the edge is black, mainly in the healing microcracks of quartz particles. The appearance of methane inclusions indicates that the source rocks entered the gas generation stage during this period, and the organic matter has undergone thermal evolution.

3.2. Temperature characteristics of inclusions

The homogenization temperature can approximately represent the temperature of the original formation when the fluid inclusions are captured. Therefore, the determination of the homogenization temperature of the brine inclusions associated with the hydrocarbon fluid inclusions can not only obtain the original formation temperature when the hydrocarbon fluid inclusions are formed, but also determine the oil and gas filling time period in combination with the burial history and thermal evolution history of the study area. Since the subsequent use of hydrocarbon fluid inclusions to restore ancient pressure, the homogenization temperature of hydrocarbon fluid inclusions was also tested during the temperature measurement of the associated brine of hydrocarbon fluid inclusions.

The homogenization temperature of 40 fluid inclusion samples from 3 wells in Mosuowan area was measured. The results show that the homogenization temperature of brine inclusions associated with hydrocarbon inclusions is 90 ~ 132.4 $^{\circ}\text{C}$, and the main frequency band of temperature is well distributed. The homogenization temperature of liquid

hydrocarbon inclusions and gas-liquid hydrocarbon inclusions associated with brine inclusions are distributed in M28 well, and the brine inclusions associated with gas hydrocarbon inclusions are distributed in 97.3 ~ 111.4 °C. The homogenization temperature of liquid hydrocarbon inclusions and salt water inclusions associated with gas-liquid hydrocarbon inclusions in Well M21 is 91.1 ~ 111.2 °C, and the salt water inclusions associated with gas hydrocarbon inclusions are 91.3 ~ 117.3 °C (Fig.4b); the homogenization temperatures of liquid hydrocarbon inclusions and brine inclusions associated with gas-liquid hydrocarbon inclusions in Well PC2 are 91.5 ~ 119.2 °C, and the homogenization temperatures of brine inclusions associated with gas-hydrocarbon inclusions are 96.7 ~ 111.1 °C. According to the results of homogenization temperature, the homogenization temperature of hydrocarbon inclusions and brine inclusions associated with gas-liquid hydrocarbon inclusions is generally lower than that of brine inclusions associated with gas-hydrocarbon inclusions, and a small part is higher than that of brine inclusions associated with gas-hydrocarbon inclusions. It may be that the maturity of source rocks is higher, and it has experienced multiple oil and gas migration and capture.

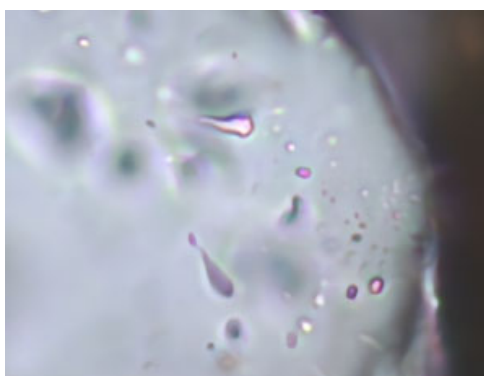


Figure 2. Microscopic characteristics of fluid inclusions in abdominal area

4. Summary

The Sangonghe Formation and the Badaowan Formation in the Mosuowan area have two stages of oil and gas filling. The overall homogenization temperature range of the associated brine inclusions is 90-132.4 °C. The homogenization temperature range of the associated brine inclusions during the condensate oil and gas filling period is 91.3-117.3 °C, and the homogenization temperature range of the associated brine inclusions during the gas filling period is 96.7-111.1 °C.

References

- [1] Lu, H. Z., Fan, H. R., Ni, P., et al.: Fluid Inclusions [M]. Beijing: Science Press, 2004. p.26-56.
- [2] Xie, N., Song, J. Q., Bai, D., et al.: Characteristics of fluid inclusions and hydrocarbon accumulation phases of the Sinian Dengying Formation in the central Sichuan Penglai area. *Unconventional Oil Gas*, 2023, 10(03).p.55-63.
- [3] Luo, F. W., Liu, S. B., Zhuo, Q. G., et al.: Hydrocarbon charging phases and accumulation models in the middle eastern section of the Qiulitage structural belt, Kuqa depression. *J. Northeast Petrol. Univ.*, 2024, 48(01).p.26-38.
- [4] Li, Y. G.: Characteristics of reservoir fluid inclusions and hydrocarbon accumulation phases during the Lishu fault depression period in the Songliao Basin. *Energy Environ.*, 2023, 45(10).p.135-144
- [5] Deng, B., Wu, J., Li, W. Z., et al.: U-Pb dating of carbonate minerals hosting hydrocarbon inclusions and its application in the study of hydrocarbon accumulation phases: A case study from the Sinian Dengying Formation in central Sichuan. *Nat. Gas Geosci.*, 2023, 34(11).p.1887-1898.
- [6] Zhang, Y., Cao, Z. C., Chen, H. H., et al.: Ordovician oil and gas accumulation periods and their contribution differences in different strike-slip fault zones in Shunbei area. *Earth Sci.* 48.p.2168-2188.
- [7] Jiao, Y. B., Li, Y. X., Chang, Y.: Composition and accumulation periods of shale gas inclusions in the Shanxi Formation in Yan'an exploration area by laser Raman spectroscopy. *J. Lanzhou Univ. (Nat. Sci.)* 59.p.151-156.