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Analysis of Hydrocarbon accumulation period of Yanchang Formation and Yan 'an Formation in Zhenjing-Shuangcheng area, Ordos Basin

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Abstract: Zhenjing-Shuangcheng is located in the northern Shaanxi region of the Ordos Basin, which is relatively far from the Chang 7 hydrocarbon generation center. The mechanism of oil and gas accumulation has become a difficult point in oil and gas exploration in the northern Shaanxi region. The study of oil and gas reservoir formation stages aids in assessing the process of oil and gas accumulation. To comprehend the reservoir formation stages of the target strata in this area, the homogenization temperature method of fluid inclusions is employed, coupled with analyzing inclusion characteristics to ascertain the reservoir formation stages. The experimental results show that the fluid inclusions in the sandstone of the Yan'an Formation and the Upper Yanchang Formation in the Zhenjing-Shuangcheng area are mainly saline inclusions and hydrocarbon bearing saline inclusions. The main peak of the homogenization temperature of fluid inclusions in the upper segment of the extension group is 90-120 ℃; The main peak of the homogeneous temperature of fluid inclusions in the Yan'an Formation is 80-110 ℃. Based on the burial history map of the work area, it is believed that the oil and gas filling period in the upper part of the Yanchang Formation was in the middle and late stages of the Early Cretaceous, from 124 to 109 Ma ago; The Yan'an Formation is from the late Early Cretaceous period, dating back to 112-94 Ma ago; This indicates that the oil and gas reservoirs of the Upper Yanchang Formation and Yan'an Formation in the Zhenjing-Shuangcheng area were formed during the same period of the Early Cretaceous (124-94 Ma). This understanding provides assistance for the study of oil and gas accumulation mechanisms in the Triassic and Jurassic periods in the Yuanyuan area of northern Shaanxi.

Keywords: Accumulation period; Yanchang Formation; Yan 'an Formation; northern Shaanxi region.

1. Introduction

With the continuous deepening of exploration, the Ordos Basin presents an overall situation of "full basin gas, half basin oil"[1]. Vertically, it has the characteristic of "upper oil and lower gas". Natural gas is mainly distributed in the Upper Paleozoic, while oil is mainly distributed in the Yan'an Formation of the Upper Triassic and the Yan'an Formation of the Middle Jurassic in the Mesozoic. The Zhenjing Shuangcheng area is located in the northern Shaanxi region of the Ordos Basin, far from the Chang 7 hydrocarbon generation center and beyond the boundary of Chang 7 source rocks. The logging data of oil wells in the northern part of the work area shows oil spots, indicating that the oil has migrated further north to the Yan'an Formation in the study area, providing confidence for oil exploration in northern Shaanxi. This article studies the characteristics of fluid inclusions in two oil reservoirs in the work area to understand the reservoir formation stages of the Upper Yan'an Formation and Yan'an Formation oil reservoirs, providing a basis for the subsequent study of reservoir formation mechanisms in northern Shaanxi.

2. Geologic Aspects

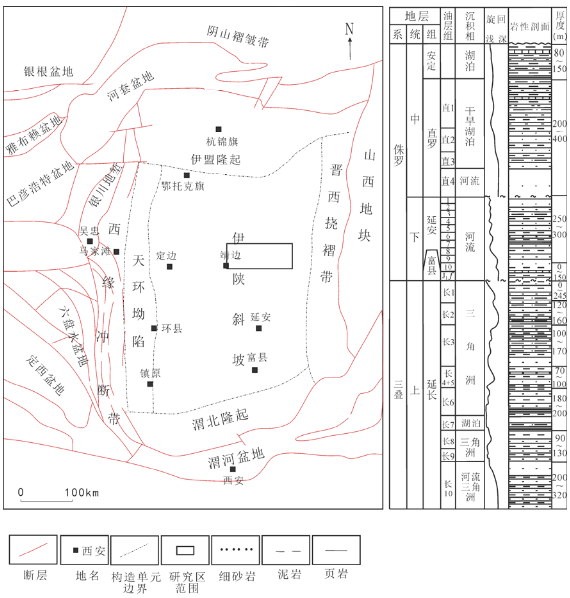

Figure 1. Location map of the research area

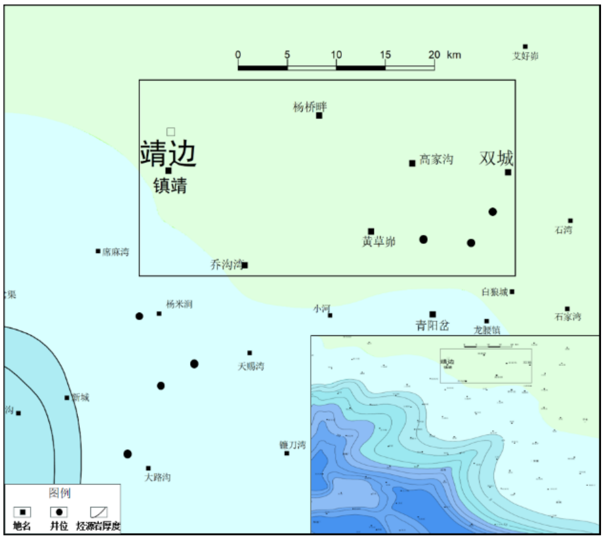

Figure 2. The location of the coring well and the thickness of the Chang 7 source rock

The Ordos Basin spans across four provinces of Shaanxi, Gansu, Ningxia, and Mongolia, and is a large intracontinental craton basin. According to previous research, the internal strata of the basin are gentle and the structure is simple, with well-developed faults in the edge areas. Based on the structural morphology of the basin, six primary structural units have been divided (Figure 1), among which the Yishan Slope is located in the middle of the basin and is an important oil and gas producing area.

The Zhenjing-Shuangcheng area is located in the central western part of the Yishan Slope, between Jingbian County and Hengshan County, with Zhenjing Township in the east, Shuangcheng Township in Hengshan County in the west, Bailangcheng Township in the south, and Yangqiaopan Township in the north, with a total area of 1300km2 (Figure 2). The work area is far from the hydrocarbon generation center, and currently there are industrial oil flows in oil formations such as Chang 6, Chang 4+5, Chang 2, and Yan 8. The current difficulty in oil and gas exploration in northern Shaanxi lies in the study of reservoir formation mechanisms, and the understanding of reservoir formation stages will provide a basis for it.

3. Sample Collection and Analysis Testing

Fluid inclusions are enclosed systems formed by mineral lattice defects during mineral formation, which do not undergo internal or external material exchange and do not change their original physical properties [2]. Fluid inclusions, as physical factors that record geological history in oil and gas reservoirs, have important indicative significance for studying reservoir characteristics. During the evolution of the basin, the paleotemperature increases with the depth of the strata, and the homogenization temperature of the captured inclusions remains almost unchanged, indicating the paleotemperature of the target layer. Hydrocarbon inclusions contain a large amount of organic matter, and the decomposition of organic carbon chains under heat and pressure results in measurement errors. Therefore, saltwater inclusions associated with hydrocarbon inclusions were selected for testing, and the minimum temperature at which gas and liquid phases transform into a homogeneous liquid phase was determined [3]. Simulating the burial history of a single well through the homogenization temperature of fluid inclusions, combined with structural movements, has become the mainstream method for analyzing the stages of oil and gas reservoir formation [4].

Due to the limited number of coring wells in the work area, this study selected sandstone from the oil-bearing reservoirs of Yanchang Formation 6, Yan'an Formation 10, Yan-9, and Yan-8 in the work area and adjacent areas for experiments, with a total of 7 wells and 12 core samples (Table 1).

After sampling, the sample is made into thin slices and identified by an optical microscope to record the location, size, shape, and fluorescence characteristics of fluid inclusions. Suitable inclusions are then selected for experiments, and the homogenization temperature and freezing point temperature are recorded. The salinity is calculated based on the freezing point temperature. Finally, the oil and gas accumulation period is determined by combining the homogenization temperature of fluid inclusions obtained from the experiment with the sedimentary burial history map of the northern Shaanxi region of the Yishan Slope.

Table 1. Source of Fluid Inclusions

Sample number	Deep/m	Layer	Lithology	Oil content grade
ZJ54	992.6	Yan8	Gray fine sandstone	Oil-dip
ZJ43	642.3	Yan 8	Gray fine sandstone	Oil-dip
ZJ9	1053.1	Yan 9	Gray fine sandstone	Oil-dip
ZJ4	1350.4	Yan 10	Grayish-white fine sandstone	Oil spot
ZJ2	1340.8	Yan 10	Dark gray fine sandstone	Oil spot
ZJ1	1347.6	Yan 10	Dark gray fine sandstone	Oil spot
ZJ29	965.0	Chang6	Dark gray fine sandstone	Oil spot
ZJ23	1262.7	Chang 6	Grayish-white fine sandstone	Oil-dip
ZJ22	1271.5	Chang 6	Grayish-white fine sandstone	Oil-dip
ZJ7	1570.8	Chang 6	Gray fine sandstone	Oil-dip
ZJ6	1908.5	Chang 6	Gray fine sandstone	Oil-dip
ZJ5	1918.7	Chang 6	Gray fine sandstone	Oil-dip

4. Characteristics of Fluid Inclusions

Through microscopic observation and statistics, fluid inclusions mainly develop within quartz particles, with a small amount occurring in the secondary enlarged edges of quartz. The types of sample inclusions include liquid hydrocarbon inclusions, gas hydrocarbon inclusions, asphalt inclusions, hydrocarbon containing salt water inclusions, and salt water inclusions. Among them, liquid, gas hydrocarbon, and asphalt hydrocarbon inclusions are relatively few, with hydrocarbon containing salt water inclusions and salt water inclusions being the main types.

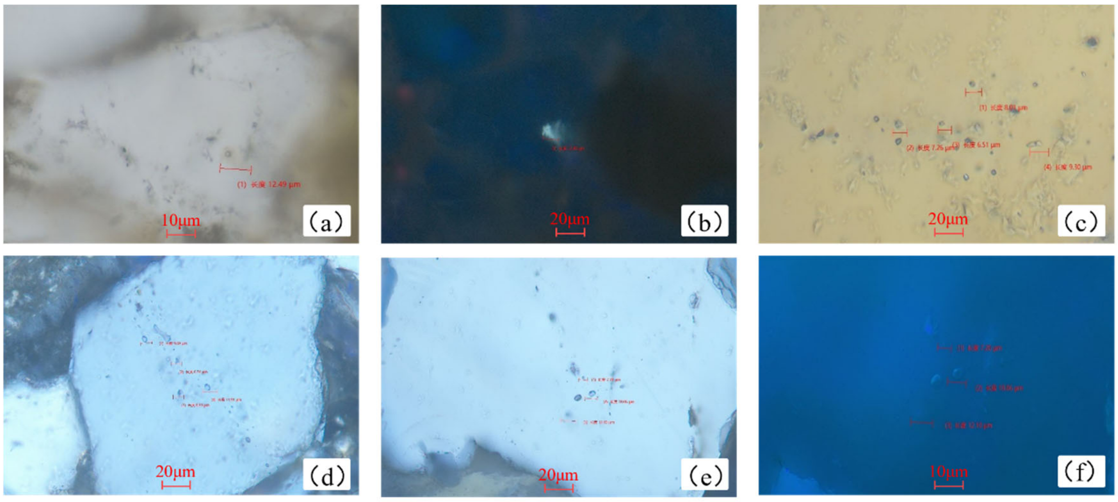

Figure 3. Microscopic characteristics of fluid inclusions in Chang6, Yan10, and Yan9 in the Zhenjing Shuangcheng area

(a) and (b) ZJ6, Chang 6, sporadically distributed liquid hydrocarbon inclusions, fluorescence shows yellow white; (c) ZJ1, Yan 10, clustered saltwater inclusions and coexisting gas hydrocarbon inclusions, no fluorescence display; (d) ZJ2, Yan 10, shows bead like distribution of hydrocarbon salt water inclusions and coexisting asphalt inclusions, with no fluorescence display; (e) and (f) ZJ9, Yan9, clusters of light brown hydrocarbon containing saline fluid inclusions and symbiotic saline fluid inclusions, fluorescence shows extremely dark blue white

Under single polarization, liquid hydrocarbons appear light brown, gaseous hydrocarbons appear gray, and saltwater is colorless and transparent. The fluorescence display of liquid hydrocarbon inclusions is yellow white, while that of hydrocarbon containing saline inclusions is blue white. A lighter fluorescence color indicates a higher maturity of organic matter inside the inclusions [5]. Most of the packages are distributed in groups, with a few scattered and bead shaped. Its shape is mostly regular, nearly circular, with a few irregular polygons (Figure 3).

5. Homogenization Temperature and Salinity

The homogenization temperature of fluid inclusions is the temperature at which two-phase or multi-phase inclusions are transformed into a homogeneous single-phase fluid through heating. During the evolution of the basin, the paleotemperature increased with the depth of the strata, and the homogenization temperature of the captured inclusions remained almost unchanged. The homogenization temperature of saltwater inclusions and hydrocarbon containing saltwater inclusions associated with hydrocarbon inclusions is often selected, combined with the burial history of a single well, to determine the oil and gas injection time [6].

99 measurement points were selected from 12 samples in the Zhenjing-Shuangcheng area for fluid inclusion homogenization temperature experiments. The homogenization temperature and freezing point were recorded, and the fluid inclusion salinity was calculated based on the relationship between salinity and freezing point. The data is shown in Table 2. Create histograms based on the homogenization temperature data of the extended group and Yan'an group inclusions obtained.

Table 2. Details of Homogenization Temperature of Fluid Inclusions in Zhenjing-Shuangcheng Area

Number	Deep/m	Layer	Type	Phase	Salinity/%	Homogenization temperature	
						Average temperature/°C	Test Points
ZJ54	992.6	Yan8	salt water with hydrocarbon	liquid	4.32~17.65	106.2	14
ZJ43	642.3	Yan8	salt water with hydrocarbon	liquid	7.02~15.32	112.3	12
ZJ9	1053.1	Yan9	salt water with hydrocarbon	liquid	7.02~18.94	148.9	9
ZJ4	1350.6	Yan10	salt water with hydrocarbon	liquid	8.68~15.86	125.9	6
ZJ2	1339.5	Yan10	salt water with hydrocarbon	liquid	4.31~16.75	115.0	9
ZJ1	1347.6	Yan10	salt water with hydrocarbon	liquid	3.1~10.56	99.4	11
ZJ29	967.1	Chang6	salt water with hydrocarbon	liquid	8.73~19.68	172.5	8
ZJ23	1262.7	Chang6	salt water with hydrocarbon	liquid	4.46~19.68	151.6	10
ZJ22	1271.5	Chang6	salt water with hydrocarbon	liquid	4.96~16.12	131.6	5
ZJ7	1570.8	Chang6	salt water with hydrocarbon	liquid	11.80~19.65	184.2	2
ZJ6	1908.5	Chang6	salt water with hydrocarbon	liquid	8.76~16.86	125.2	6
ZJ5	1915.3	Chang6	salt water with hydrocarbon	liquid	7.56~18.8	111.6	7

The results of homogenization temperature of inclusions indicate that the homogenization temperature of inclusions in the Chang 6 sandstone sample is continuously distributed between 80-130 ℃ and 140-200 ℃, with two peaks of 90-120 ℃ and 160-190 ℃ (Figure 4). The homogenization temperature of the Yan10-Yan-8 inclusions in the research area is continuously distributed between 70-200 ℃, and a peak appears in the range of 80-110 ℃ (Figure 5).

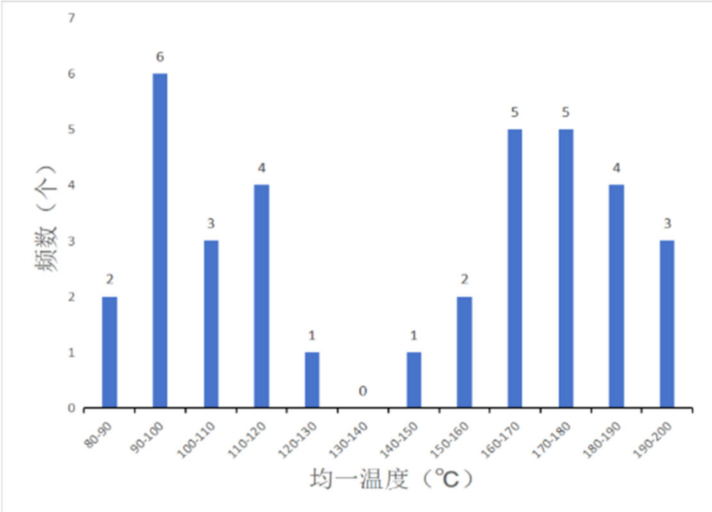

Figure 4. Homogenization temperature distribution of package with length 6

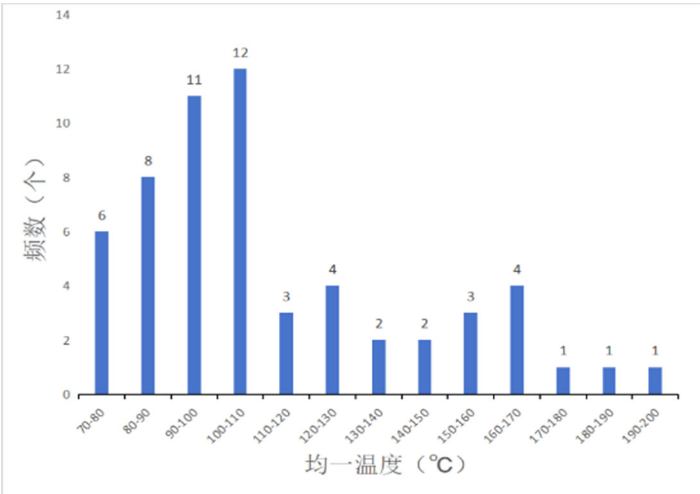

Figure 5. Homogenization temperature distribution of package bodies from Yan 10 to Yan 8

The salinity of fluid inclusions can indicate the physical and chemical properties of oil and gas reservoir fluids, and can approximately represent the salinity of solutions in mineral pores [7]. According to the salinity homogenization temperature relationship diagram, the salinity of the Long-6 inclusion ranges from 4.46% to 19.68% (Figure 6), and the salinity of the Yan10-Yan-8 inclusion ranges from 3.41% to 18.94% (Figure 7). Moreover, the salinity of fluid inclusions is positively correlated with homogenization temperature. The higher the maturity of source rocks, the higher the content of organic acids dissolved in pore water. The increase in acidity of pore water can lead to dissolution of surrounding rocks, causing K^+ and Na^+ ions to migrate into the pore water. At the same time, as the temperature rises, the relative openness of the diagenetic environment decreases, weakening the exchange of other fluids and increasing the salinity of fluids in the formation [8].

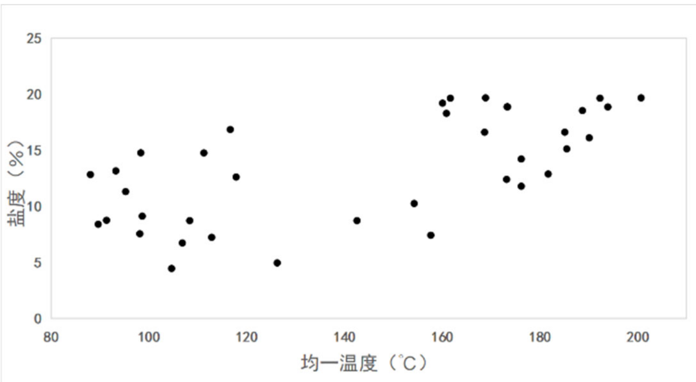

Figure 6. Salinity distribution map of fluid inclusions in Chang 6 reservoir

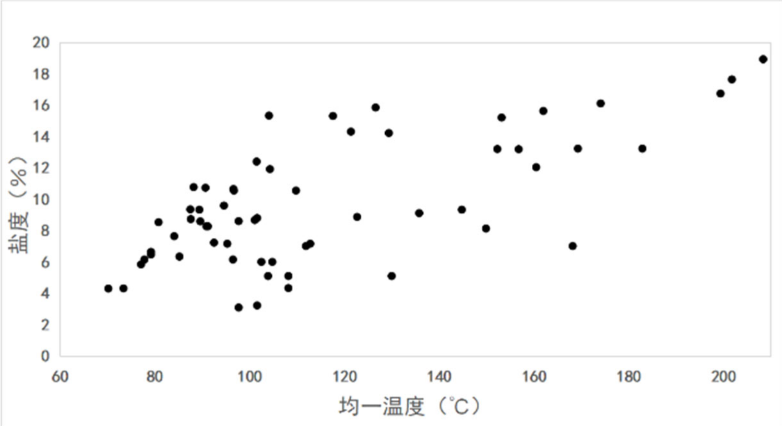

Figure 7. Salinity distribution map of fluid inclusions in reservoirs Yan 10-Yan 8

6. Analysis of Accumulation Stages

The homogenization temperature method of fluid inclusions is currently the main method for determining the period of oil and gas accumulation. By combining the characteristics of fluid inclusions and homogenization temperature with the thermal evolution history of the basin, the time of oil and gas filling can be determined [9]. Utilize the stratigraphic stratification data, erosion thickness, and geothermal gradient in the study area to reconstruct the thermal evolution history. By projecting the peak temperature data of fluid inclusions in the work area onto the burial history map of the study area (Figure 8), the following conclusions were drawn: the peak temperature range of the Chang 6 fluid inclusions was projected onto the burial history map, and the oil and gas injection time was estimated to be between 124 and 109 Ma ago, which is in the middle and late stages of the Early Cretaceous. The projection time corresponding to 160~190 ℃ is unreasonable, so it is abandoned. There may be two reasons for this, one is that the measured package is an inherited package [10], Secondly, it is related to the abnormal thermal events that occurred in the Early Cretaceous of the Ordos Basin [11]. The peak temperature range of the Yan10-Yan-8 package is projected onto the stratigraphic burial history map, and the oil and gas injection time is estimated to be 112-94 Ma ago, which is the Late Cretaceous period. This indicates that the oil and gas reservoirs in the upper section of the Yanchang Formation and Yan'an Formation in the study area were formed during the same period, from 124 to 94 Ma ago, in the Early Cretaceous.

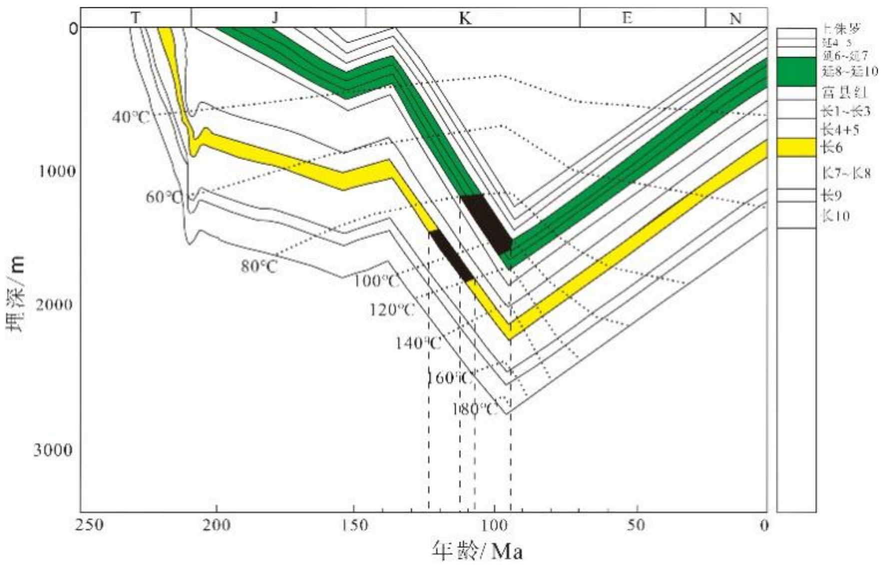

Figure 8. Burial History of Strata in Northern Shaanxi Region

7. Conclusion

(1) The fluid inclusion types in the reservoirs of the Triassic Yanchang Formation and Jurassic Yan'an Formation in the Zhenjing-Shuangcheng area include hydrocarbon inclusions (liquid hydrocarbon inclusions, gas hydrocarbon inclusions, asphalt inclusions), hydrocarbon containing saline water inclusions, and saline water inclusions, with hydrocarbon containing saline water inclusions being the main type. Fluid inclusions are distributed in groups within quartz particles, with rare bead like and scattered distributions.

(2) The homogenization temperature of the extended package is between 80-130 ℃, with a peak at 90-120 ℃ and a salinity of 4.46%-19.68%. The homogenization temperature of the Yan'an Formation package is between 70-120 ℃, with a peak of 80-110 ℃ and a salinity of 3.41% -18.94%

(3) Based on the homogenization temperature peak of the package and the burial history map of northern Shaanxi, it is believed that the oil and gas filling period of the Yanchang Formation in the Zhenjing Shuangcheng area corresponds to 124~109 Ma ago; The corresponding time for oil and gas injection in Yan'an Formation is about 112-94 Ma ago. This

indicates that the oil and gas reservoirs in the upper section of the Yanchang Formation and Yan'an Formation in the study area were formed during the same period, from 124 to 94 Ma ago, in the Early Cretaceous.

References

[1] He Faqi, Zhang Yu, Wang Fubin, et al. Petroleum exploration progress and new field of Sinopec in Ordos Basin during the 13th Five-Year Plan period[J]. China Petroleum Exploration, 2022,27(05):1-12.

[2] Lu Xiaolan. Application of fluid inclusions in the study of oil and gas reservoir formation[J]. China Petroleum and Chemical Standard and Quality, 2019,39(02):103+105.

[3] Li Bo, Cui Junping, Li Ying, et al. Hydrocarbon accumulation phases of Yanchang Formation in Wuqi area,Yishan slope[J]. Lithologic Reservoirs, 2021,33(06):21-28.

[4] Ren Zhanli, Li Wenhou, Liang Yu, et al. Tight oil reservoir formation conditions and main controlling factors of Yanchang Formation in southeastern Ordos Basin[J]. Oil & Gas Geology, 2014,35(02):190-198.

[5] Ye Song, Zhang Wenhuai, Zhang Zhijian. Introduction to fluorescence microscopy of organic inclusions[J]. Bulletin of Geological Science and Technology, 1998,(02):77-81.

[6] J. BOURDET, J. PIRONON, G. LEVRESSE, et al. Petroleum type determination through homogenization temperature and vapour volume fraction measurements in fluid inclusions. Journal [J] Geofluids. Volume 8 , Issue 1 . 2008. PP 46-59.

[7] Tian Yaming, Shi Zejing, Song Jianghai, et al. Fluid Inclusion Characteristics of Chang 6-Chang 8 Reservoirs in the Triassic Yanchang Formation of the Yichuan-Xunyi Area[J]. Bulletin of Mineralogy,Petrology and Geochemistry, 2011,30(01):80-87.

[8] Li Yanxia, Liu Hongjun, Yuan Dongshan, et al. The influence of petroleum injection on the evolution of diagenetic minerals in reservoirs[J]. Oil & Gas Geology, 2003,(03):274-280+295.

[9] Ren Zhanli, Zhang Shihuan. Research on the Thermal Evolution History and Oil Gas Relationship of Sedimentary Basins in Northern China[C]. Chinese Geological Society. Proceedings of the Fourth National Symposium on Young Geologists. Department of Geology, Northwest University; Tuha Oilfield;, 1999:6.

[10] Liu Chao, Wang Zhenliang, Liu Chiyang, et al. Characteristics of Fluid Inclusions in Yanchang Formation of the Yanchang Oilfield,Ordos Basin [J]. Acta Geoscientica Sinica, 2009, 30(02): 215-220.

[11] Shi Baohong, Zhang Yan, Zhang Lei, et al. Hydrocarbon accumulation dating by fluid inclusion characteristics in Chang7 tight sandstone reservoirs of Yanchang Formation in Ordos Basin[J]. Petroleum Geology & Experiment, 2012, 34(06): 599-603.