ISSN: 1813-4890

Analysis of fluid inclusions and accumulation period in the Zhidan area

Feng Chen

[1]School of Geosciences and Engineering, Xi 'an Shiyou University, Xi 'an 710065, China;

[2]Shaanxi Provincial Key Laboratory of Petroleum Accumulation Geology, Xi 'an Shiyou University, Xi'an 710065, China

Abstract

The oil and gas resources in the Zhidan area of the Ordos Basin have the characteristics of wide distribution and are the key areas of oil and gas exploration. The systematic scientific study of the accumulation time and accumulation period of the Chang 2 and Chang 6 reservoirs in the Zhidan area is not only conducive to the fine exploration of the oilfield, but also improves the understanding of the Triassic oil and gas accumulation in the Ordos Basin. The characteristics of inclusions were observed under microscope and fluorescence, and the reservoir fluid inclusions were divided by the homogeneous temperature experiment of inclusions and freezing point experiments. The results Showed that there were three main types of inclusions in the Zhidan area of the Ordos Basin, namely brine inclusions, liquid-containing hydrocarbon inclusions and hydrocarbon inclusions, and hydrocarbon inclusions were yellow-green and orange-yellow under fluorescence irradiation, which indirectly indicated that the maturity of organic matter in the Chang 2 and Chang 6 oil formations in this area reached a medium level. The fluid inclusions of the Chang 2 and Chang 6 reservoirs were mainly distributed in the quartz enlarged edge and quartz healing microfissures, and the uniform temperature distribution continuously indicated that the Chang 2 and Chang 6 reservoirs were primary. The uniform temperature of fluid inclusions in the Chang 2 and Chang 6 reservoirs in the Zhidan area of the Ordos Basin is mainly distributed between 85 °C ~ 130 °C, the peak is between 90 °C ~ 110 °C, and the inclusions have the characteristics of high temperature, medium salinity and medium and high density, which are derived from the oil and gas fluids formed during the thermal evolution of organic matter, the accumulation time is between 111~100 Ma, and the accumulation time is the Early Late Cretaceous.

Keywords

Petroleum geology; Yanchang Formation; homogeneous temperature; hydrocarbon charging period.

1. Introduction

Inclusion is the part of the mineral lattice defects or cavities that are wrapped in the rock-forming solution (gas-liquid-bearing fluids) during the mineral crystallisation process, which are still sealed in the host minerals and have phase boundaries with the host minerals . Inclusions can not only retain the information of hydrocarbon composition and physicochemical conditions during the hydrocarbon formation period, but also retain the important information of hydrocarbon generation, transport and formation process . In recent years, the inclusions analysis technology has been applied in a large number of solid mineral exploration, geologists also apply it to the exploration of oil and gas resources and deduce the period of oil and gas reservoirs, nowadays the inclusions analysis technology has become an important part of oil and gas exploration, and plays an indispensable role in the exploration of oil and gas formation mechanism . Fluid inclusion analysis technology is mainly applied to the following directions: ① hydrocarbon source rock hydrocarbon discharge history investigation; ② hydrocarbon source rock organic matter type and maturity inference investigation; ③ hydrocarbon formation period of physicochemical conditions investigation; ④ hydrocarbon evolution degree and reservoir history investigation, etc. [10-12].For the exploration of the oil and gas formation period in the Ordos Basin, there have been rich results, for example, Cheng Kezhang et al. conducted a detailed investigation on the characteristics of inclusions in the reservoir of Yan'an Formation in the Wuji area and the period of oil and gas formation, and put forward that there are two consecutive oil and gas injection in the reservoir of Yan'an Formation in the Wuji area of the Ordos Basin: the first one is from 112 to 106 Ma before present, the second is from 102 to 97 Ma before present, both of which are in the early stage of formation. 102～97 Ma, both at the end of the Early Cretaceous. Liu Ling et al. investigated the reservoir densification history and hydrocarbon formation history of the long 6-long 9 section in Zhidan area of Ordos Basin, and concluded that the reservoirs of the long 6-long 9 section in this study area have the petrogenesis-reservoir formation characteristics of "densification first, and then formation of reservoirs" . These researches provide some help for the study of reservoir formation history in the central region of Ordos Basin. Therefore, in order to enrich the study of reservoir formation history in the central and western part of the Ordos Basin, the author selected the upper and middle assemblages of the Extension Formation, and chose its main producing layers, Long 2 and Long 6, and carried out a systematic study by using the technique of inclusions analysis. In this paper, a total of 9 samples from sandstone reservoirs in 4 wells were selected for experiments to analyse inclusions characteristics, including type, morphology, size, petrographic features, homogeneous temperature, density, salinity and other studies. And then, we make a rich and in-depth analysis of the reservoir formation period of the long 2 and long 6 sections of the Triassic Extension Formation in this area, with a view to providing a certain basis for the improvement of the oil and gas formation law of the Upper and Middle Triassic assemblage in the Ordos Basin.

2. Geological overview

The Ordos Basin has now become an important energy base in China, with huge exploration potential for oil and gas, and it is rich in buried solid mineral resources [15]. The Zhidan area in northern Shaanxi is located in the west-central part of the northern slope of the Ordos Basin , in the background of the west-tilted monoclinic, and at the same time, the development of obvious nasal uplift zones, which provides a certain basis for the aggregation and storage of hydrocarbons in the area. Through data analysis, it is found that: ① the crude oil producing layers in the area include Jurassic Yan'an Group, Triassic Long 1, Long 2, Long 4+5, Long 6, Long 7, Long 8 and other 7 oil layer groups, of which the Yan'an Group, Long 2 and Long 6 oil layers account for more than 94% of the total cumulative production, with a strong potential for exploration. The Triassic depositional system in this area is mainly deltaic, mainly deltaic frontal phase deposition and deltaic plain phase deposition, of which the long 2 depositional period is located in the middle of Zhidan delta, belonging to the deltaic plain phase deposition; the long 6 depositional period is in the front of Zhidan delta, belonging to the deltaic frontal phase depositional phase.

3. Petrological characteristics

According to the methods of thin section identification, scanning electron microscope, XRD whole rock+clay, and particle size analysis, the purpose layer in this area was analysed , and the rock type of the Long 2 reservoir in this area is grey medium-fine grained rocky feldspathic sandstone, with a small amount of greyish-white medium-fine grained feldspathic sandstone, and filler contents are mainly ferro-calcite, chlorite, and hydrous kaolinite, which account for 3.0%, 2.5%, and 3.0%, respectively, followed by siliceous The rock type of the Long 6 reservoir is fine-grained feldspathic sandstone, and the filler content is 13.6% on average, mainly water kaolinite, chlorite, calcite, iron calcite and siliceous, and the cement content is 8.2% on average.

According to the pore penetration statistics of core samples, the porosity of the long 2 reservoir is concentrated between 10% and 18%, with an average value of 14.6%, and the permeability is concentrated in $(1\sim5)\times10^{-3}\mu m^2$, with an average value of 6.01×10-3μm2, which is a low-porosity and extra-low-permeability reservoir; the porosity of the long 6 reservoir is concentrated between 4% and 16%, with an average of 10.2%, and the permeability has an average value of $0.88\times10^{-3}\mu m^2$, compared with long 2, the physical properties are obviously poorer, belonging to the low～extra-low porosity, dense reservoir extra-low porosity, dense reservoir.

4. Inclusion body experiments and results

Experimental conditions: ZEISS dual-channel fluorescence-transmission light microscope was selected as the experimental observation instrument, Linkam THMS 600 hot and cold stage was selected as the temperature measurement instrument, with an error of ±0.5 ℃, the initial heating rate was 5 ℃/min, and it was adjusted to 2 ℃/min when approaching the homogeneous temperature in order to read the homogeneous temperature of the inclusion body. The experiment was completed by the Key Laboratory of Oil and Gas Formation and Reservoir of Xi'an Petroleum University, and the experimental environment was: room temperature of 20℃ and relative humidity of 20%.

Experimental steps: firstly, the inclusions samples were sliced, and after the slicing was completed, the evolutionary characteristics of the experimental constituent rocks were observed by microscope, and the distribution, size, morphology, and fluorescence reaction of the inclusions were analysed in depth; and then, the inclusions mean temperature and freezing temperature were tested by the hot and cold table, and the salinity of inclusions was inferred by the freezing temperature; and finally, the period of hydrocarbon reservoir formation was analysed by combining with the history of stratigraphy and thermal evolution in the Zhidan area. Finally, the period of oil and gas formation is analysed in combination with the burial history and thermal evolution history of Zidan area.

4.1. Types of inclusions

To classify the types of fluid inclusions, it is necessary to observe and analyse their petrographic characteristics under the transmitted light microscope, classify the brine inclusions with different production conditions, and clarify their characteristics and types; then identify the brine inclusions and hydrocarbon inclusions under the fluorescence microscope, under the micro-fluorescence irradiation, brine inclusions don't emit light, and hydrocarbon inclusions emit fluorescence, and the distribution characteristics and the production conditions of hydrocarbon inclusions can be observed according to the fluorescence characteristics of hydrocarbon inclusions; finally, the two results will be analyzed together to clarify their petrographic characteristics, which will provide credible evidence for the subsequent identification of the period of oil and gas reservoirs. According to the fluorescence characteristics of hydrocarbon inclusions, we can observe their distribution characteristics and production status; finally, the two results are analysed together to clarify their petrographic characteristics, which can provide credible petrographic evidence for the subsequent identification of the hydrocarbon formation period.

ISSN: 1813-4890

According to the comprehensive analysis of microscopic observation, there are mainly three types of inclusions in the reservoirs of Long 2 and Long 6 sections in Zhidan area, which are brine inclusions, liquid hydrocarbon inclusions and liquid hydrocarbon inclusions, and the specific microscopic features are as follows:

(1) brine inclusions: the long 2 and 6 sections in this area are mostly such inclusions, which are colourless and transparent under the transmitted light of the mirror, in the form of lens, and do not emit light under the fluorescence irradiation, and they are mainly produced in the secondary quartz plus large margins, quartz healed microfissures, quartz dissolution joints and carbonate cement; the size of such inclusions varies, with individuals ranging from 2 to 7 μm, and the gas-liquid ratio from 4% to 16%, with different shapes, most of which are ellipsoidal. The shapes are different, most of them are oval and irregular, and there are also a few round ones, which are mainly distributed in the form of beads, bands and stars, and a few of them are distributed in the form of isolation.

(2) Inclusions containing liquid hydrocarbons: these inclusions are commonly developed in the long 2 sections and long 6 sections in the region, and are light brown under the transmission light of the mirror, and faint yellow under the fluorescent light; they are mainly produced in the quartz healing microfissures, and a small number of them are produced in the quartz secondary plus large margins; these inclusions are mostly produced in conjunction with brine inclusions, and their sizes are different, ranging from 2 to 6 μm, with the gas-liquid ratios ranging from 10% to 30%, and the shapes are mostly elliptical, with a small amount of isolated distributions. The shape of these inclusions is mostly oval, with a few rounded ones, and they are mainly produced in the form of beads and bands .

(3) Liquid hydrocarbon inclusions: these inclusions are also commonly developed in the long 2 sections and long 6 sections in the study area, and they are pale yellow, light brown, brown, etc. under microscopic light projection, and bluish-white, yellowish-green, and orange-red under fluorescent light projection; they are mainly produced in quartz microfractures; these inclusions are of different sizes, ranging from 2 to 4 μm, with gas-liquid ratios of more than 50%, and their shapes are mostly elliptical, with banded and star-shaped distributions.

4.2. Morphology of inclusions

Compared with conventional reservoirs, the lithology is dense and the rock particles are tightly arranged , which makes the search for inclusions under the microscope more difficult. Inclusions are more common in quartz particles, this experiment through the scanning electron microscope and microscope observation of the initial screening of the quartz particles under the microscope for the obvious thin section for observation, and in the process marking the size, location, etc. suitable for temperature measurement of the brine inclusions . Long 2 and long 6 sections of reservoir sandstone can be seen in the quartz secondary increase in the phenomenon, increase the edge of the main distribution along the edge of the particles, and some of them are to the pore internal growth, can be distinguished between the two phases of the secondary increase. The inclusions are mainly distributed along the microfractures , and for hydrocarbon inclusions, they are more difficult to be found under direct microscopic observation, and need to be observed with the assistance of UV excitation. Under UV excitation, hydrocarbon inclusions in this area were found to be mostly yellow-green and orange-red in colour . The size of fluid inclusions is between 2~4 μm, and the individual can reach 12 μm, mostly produced in quartz healing microfractures, often in bead-like groups distributed in bands, and the morphology is mainly sub-circular, triangular and irregular .

4.3. Fluorescence spectral characteristics

The fluorescence colour of liquid hydrocarbon inclusions under the microscope can reflect the evolution degree of organic matter in the region to some extent, according to the evolution of organic matter from low maturity to high maturity, its corresponding fluorescence colour is also changed, in the UV excitation of the colour change sequence: weak blue-grey → blue-green → blue-white → white, in the blue excitation of the colour change sequence: dark brown → orange → yellow green → dark green . yellow-green → dark green; under the fluorescence irradiation of microscope, hydrocarbon inclusions in the long 2 and long 6 sections of this area are mostly yellow-green and orange-red, which can indicate that the maturity of organic matter in the long 2 and long 6 oil layer groups can reach a medium level.

The difference of the test equipment, the light wave it excites also exists, which will cause the colour of liquid hydrocarbon inclusions under fluorescence irradiation also exists, if the author's research results are compared with those of the peer research workers, it will cause certain errors, secondly, due to the difference of the test personnel, the use of the naked eye observation to judge the fluorescence colour of liquid hydrocarbon inclusions will also have errors; therefore, it can be different fluorescence spectra corresponding to the differences in the physicochemical properties of hydrocarbon inclusions can be used to distinguish liquid hydrocarbon inclusions of different properties .

The fluorescence spectrum analysis of liquid inclusions in the reservoirs of the long 2 and long 6 sections in the Zhidan area of northern Shaanxi found that the main peak wavelengths of liquid hydrocarbon inclusions in the reservoirs of the long 2 and long 6 sections in this area were between 465 and 570 nm, reflecting the medium maturity of organic matter in this area; in addition, it was found that fluorescence reactions of different colours appeared in the quartz plus large margins in the fluorescence test and the probability of fragmentation of the quartz plus large margins was much higher than that of other parts, indicating that they might have been damaged in the later stage. In addition, the fluorescence test found that the quartz plus large margin will have different colours of fluorescence reaction, and because the probability of quartz plus large margin broken is much larger than that of other parts, which indicates that it may be formed in the later stage by the damage, so it is not suitable to be used as the basis for judging the multi-phase formation of oil and gas .

5. Analysis of reservoir formation period

5.1. Uniform temperature and freezing temperature

Fluid inclusions uniform temperature is a two-phase or multi-phase inclusions at room temperature, through artificial heating, so that the inclusions into a single-phase fluid instantaneous temperature is called uniform temperature. Saline inclusions accompanying hydrocarbon inclusions are generally selected for temperature testing, which represents a more accurate period of formation of hydrocarbon inclusions in the reservoir .

In the region of 9 samples of 148 temperature measurement points for inclusions uniform temperature test, the freezing point temperature is generally selected for easy observation under the microscope, in the centre of the field of vision range, good morphology, jumping more stable brine inclusions for testing, and ultimately selected uniform temperature test in the 56 temperature measurement points to further freezing point temperature experiments, and based on the results of the experiments to further plot the uniform temperature histograms and the uniform temperature and freezing point temperature Based on the results, the histogram of mean temperature and the intersection of mean temperature and freezing point temperature were plotted.

The analysis results show that the mean temperature distribution of brine inclusions in the reservoirs of Long 2 and Long 6 sections in this area is between 85℃ and 130℃, and the mean temperature is continuously distributed, indicating that there is no obvious interruption in the sedimentation-rock-forming evolution of the inclusions. However, the peak locations of reservoir inclusions in section 2 and section 6 are different. The mean temperature of brine inclusions in section 2 is more concentrated at 90℃~120℃, and the peak occurs at 90℃~100℃; the mean temperature of inclusions in section 6 is concentrated at 90℃~130℃, and the peak is between 100℃~110℃. The mean temperatures are all "single peak" type, and the mean temperature of brine inclusions has a gradual increase from the long 2 to the long 6 section. The mean temperature has a good negative correlation with its corresponding freezing point temperature . As the mean temperature increases, the freezing point temperature decreases, which reflects that it is less affected by the deep thermal fluid, and no obvious thermal anomalies have been observed. Comprehensive judgement, Zhidan area long 2, long 6 section reservoir oil and gas filling for a continuous process [5].

5.2. Salinity and density characteristics

Generally speaking, parameters such as initial melting temperature and freezing point temperature are an important part of inclusions testing, because the salinity can be derived by calculating the freezing point temperature of fluid inclusions, which is comparable to the salinity of the solution in the mineral pore space, and can indicate the chemical nature of the fluids and their origins, and the initial melting temperature can indicate their salt-containing system . The test results show that the initial melting temperatures of the long 2 and long 6 sections in the Zhidan area are greater than -20.8°C, which can be judged that the composition of its salt-bearing system is NaCl [5]; the freezing point temperatures are greater than -5°C, which can be judged that the fluid captured in its body is a brine solution with salinity less than 8% of the NaCl-H2O system; the freezing point temperatures range between -4.9°C and -3.4°C, which can be determined by the NaCl-H2O system salinity -freezing point empirical formula [14] calculated its salinity between 5.56%~7.70%, for medium salinity fluid.

There is a certain functional relationship between the density, temperature and salinity of the brine solution, and related scholars have calculated the relationship between the three through a large number of experiments, while this paper adopts the "two-point formula" to calculate the density of inclusions in the long 2 and 6 sections of the Zhidan area . The calculation results show that the density varies little, ranging from 0.91 to 1.11g/cm3.

In summary, the reservoir inclusions of the long 2 and long 6 sections in this area have the characteristics of medium salinity and medium-high density, originating from the hydrocarbon fluids formed by the thermal evolution of organic matter, and representing the hydrocarbon fluids formed during the main formation period.

5.3. Determination of oil and gas filling period

For the study of the formation period of the Triassic Extension Formation in the Ordos Basin, whether the single-phase or multiple-phase filling is the focus of debate among scholars at present , through the analysis of the microscopic characteristics of fluid inclusions, fluorescence optical characteristics, homogeneous temperature, freezing point temperature, and salinity and density of the long section 2 and long section 6 in the study area, the recognition of the formation period of hydrocarbons in this area has a certain basis, and then combined with this The comprehensive analysis of the buried-thermal evolution history of the region will accurately clarify the oil and gas filling period of the region.

So far, it is most accurate to infer the oil and gas formation time by the uniform temperature of fluid inclusions. The specific methods are as follows: ① Determine the mean temperature of inclusions through experiments, which represents the palaeotemperature of the oil and gas injection period at that time. ② Determine the burial depth of the inclusions during the formation period from the palaeotemperature gradient. ③ Draw the thermal evolution history map and sedimentary burial history map of the study area to determine the period of inclusions formation. Through the restoration of the burial history and thermal evolution history, the time to reach the corresponding temperature can be determined, and thus the time of oil and gas injection can be finally determined. Therefore, whether the thermal evolution history of the basin is accurate or not is an important factor in determining the accuracy of the charging period.

According to the stratification data of L228 well, lithology data, paleotemperature gradient data, and the thickness of stripping in the area, we used PetrolMod software to recover the burial history and thermal evolution history, and finally projected the peak mean temperature interval of inclusions in the long 2 and long 6 sections of the experimental group in the burial-thermal evolution history map, and the results showed that the charging period of the long 2 and 6 sections of the Zhidan area was 111 Ma~100 Ma, which was the early White Mountains. ~100 Ma, the late Early Cretaceous, of which the long 6 section is slightly earlier than the long 2 section, 111 Ma ~ 102 Ma, while the long 2 section has a filling period of 109 Ma ~ 100 Ma, and the reservoir formation period is the first stage.

6. Conclusion

(1) The fluid inclusions in the reservoirs of the long 2 and long 6 sections of the Yanchang Formation in the Zhidan area of northern Shaanxi Province are divided into three categories, mainly brine inclusions and liquid hydrocarbon inclusions, with the size of inclusions ranging from 2 to 7 μm, and individually up to 12 μm; the salinity of the inclusions ranges from 5.56% to 7.70%, which is medium-low salinity; the density of the inclusions ranges from 0.91 to 1.11 g/cm^3, which is medium-high density; and the inclusions are mainly distributed in the quartz plus edge and quartz plus edge and quartz plus edge and quartz plus edge. The density of inclusions is between 0.91~1.11g/cm^3 , which is medium-high density; they are mainly distributed in quartz plus large margins and quartz healing microfissures.

(2) Through the uniform temperature distribution and the relationship between uniform temperature and salinity, it can be judged that the oil and gas filling of the inclusions of the long 2 and long 6 reservoirs in the Shidan area of northern Shaanxi is a phase. And the temperature of reservoir inclusions in section 6 is slightly larger than that in section 2.

(3) Through the combination of mean temperature, thermal evolution history and burial history, it can be judged that the charging period of the long 6 section is slightly earlier than that of the long 2 section, in which the long 6 section is slightly earlier than that of the long 2 section, with the period of 111 Ma~102 Ma, while the charging period of the long 2 section is 109 Ma~100 Ma, and the reservoirs are of the first stage of the Early Cretaceous period.

References

[1] X.D.Li , Y.Zhang , R.s.Han: Runsheng,Research progress of fluid in-clusions and its application in ore deposit[J]. Geological Revieve,2022,68(06):2305-2318.

[2] B.H.Shi , Y.Zhang , L.Zhang . Hydrocarbon accumulation dating by fluid inclus-ion characteristics in Chang7 tight sandsto-ne reservoirs of Yanchang Formation in OrdosBasin[J].Petroleum Geology and Experiment,2012,34(06):599-603.

[3] H.Tao,J.M.Wang. Characteristics of Late Triassic inclusions and hydrocarbon sour-e charging stages in Fuxian area,northern Sha-anxi[J].Journal of Xi'an University of Scien-ce and Technology, 2022,42(03):537-545.

[4] J.Xu,X.Z.Shi,Y.H.He , et al.Comparative analysis of reservoir characteristi-cs of Yan'an and Yanchang Formations in Ze-ngcha Area， Ordos Basin[J].Journal of Xi'an University of Science and Technology,2017,37(05):697-705.

[5] Y.Liang, Z.L.Ren , Y.L.Wang , et al.Characteristics of fluid inclusions and reser-voiring phases in the Yanchang Formation of Zichang area，the Ordos Basin[J].OIL＆GAS GEOLOGY,2011a,32(02):182-191.