Experimental analysis on heating of oil inclusion in Gucheng area of East Tarim

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Abstract. In this paper, the formation and preservation conditions of crude oil cracking gas reservoirs are analyzed by heating experiments of oil inclusions. The study of tectonic development history shows that Gucheng low uplift mainly undergoes three evolutionary stages: early extension, middle uplift and late subsidence. Up to the end of Devonian and early Hercynian, the southeastern Altun compression resulted in warping plate uplift and denudation in Gucheng area, with denudation thickness of about 1000-2800m. The experimental results show that no inclusion rupture occurs during the whole process of heating to 600°C. It was observed that the phase state of inclusions changed obviously during heating process, and the fluorescence of inclusions weakened obviously after natural cooling, reflecting the cracking process of crude oil. The results of high resolution laser-raman spectrum measurements of oil inclusions after heating experiments show that methane is the main component of gas inclusions, while carbon dioxide is small. According to the microscopic comparison of oil inclusions before and after heating, it is inferred that the sample has not undergone this high temperature process. Theoretically, it is assumed that oil and gas inclusions will rupture when heated to a certain temperature. It is possible that this experiment did not reach the limit temperature of inclusion rupture.

1. Research background
Crude oil cracking gas is an important genetic type of natural gas reservoirs in Gucheng area. The carbon isotope characteristics of natural gas in Gucheng area show that the natural gas in Gucheng area is highly mature crude oil cracking gas, and the parent material is Cambrian-Ordovician marine sapropelic kerogen. Analyzing the formation and preservation conditions of crude oil cracking gas reservoirs in Gucheng area can provide basis for oil and gas exploration and deployment in Gucheng area.

The hydrocarbon generation history of the source rocks in Gucheng area shows that the main source rocks in Gucheng area are Cambrian, and the oil generation reaches its peak in the middle of late Ordovician, and then the cracking gas, and the crude oil cracking ends at the end of middle Devonian. The research on the tectonic development history shows that the low uplift of the Gucheng mainly experienced three evolution stages: early extension, middle uplift and late settlement. Until the end of Devonian period and early Hercynian period, the arjin compression in the southeast direction caused the “seesaw” type up in the Gucheng area and a large amount of denudation. The denudation thickness was about 1000-2800m, and the long-term inherited ancient uplift was the favorable direction for oil and gas migration.
A large number of observation and analysis results of inclusions indicate that the capture conditions of high-density methane inclusions in samples may be related to the production and enrichment of cracked gas in reservoirs [1]. A large number of pyrobitumen with high thermal evolution degree and mesophase structure with pellet structure often exist in reservoirs containing high density methane inclusions [2]. It is found that most of the gas inclusions cannot be detected by laser-raman spectrum analysis. It is speculated that the reason may be that after the accumulation of oil and gas in Gucheng area, the buried depth increases greatly, the maximum is more than 3000m, the temperature increases, and the liquid hydrocarbon cracking in the oil inclusions leads to the rupture of the original oil inclusions. However, the gas pressure in the inclusions in the laboratory is too low to detect the components. In this paper, the formation and preservation conditions of crude oil cracking gas reservoirs are analyzed by heating the oil-bearing inclusions.

2. Oil inclusion heating experiment

2.1. The experimental scheme
The content of gas inclusions in Gucheng area is low. The results of laser-raman detection of gas inclusions showed that the methane content was low or no composition could be detected. It is speculated that the formation experienced settlement, uplift and denudation in the accumulation process of Gucheng area with a large range (about 3000m). The sudden change of temperature and pressure in the inclusions led to the rupture of oil and gas inclusions, gas loss, less gas inclusions and low content of methane in inclusions. Aiming at the above situation, the heating experiment scheme of oil-bearing inclusions was developed.

2.2. The experimental sample
The experimental sample is a Silurian carbonate reservoir containing oil and gas inclusion thin section with a depth of 4470.10m. The oil-bearing inclusions are mainly oil inclusions which are distributed in the micro-fissures without passing through the quartz enlargement edge, the quartz enlargement edge, the early calcite cement between grains and the late calcite cement. The homogenization temperature of brine inclusions associated with oil and gas inclusions is mainly distributed between 95℃ - 115℃.

2.3. The experimental conditions
The heating rate is 10℃/min, and the temperature is continuously heated to 600 ℃ (the upper limit of the instrument is 600 ℃), after which the temperature is naturally cooled to around 25 ℃ at room temperature.

2.4. The experimental process
Capture the photos of the heating process of oil-bearing inclusions and observe the characteristics of fluorescence characteristics of the oil and gas inclusions during the heating process ‘figure 1’.

3. Discussion of experimental results
The results showed that the inclusion did not break during the heating to 600 ℃. It has been reported that iceland crystal columns heated to 450 ℃ can burst the primary inclusions [3,4]. In this study, it was observed that the phase states of the oil inclusions changed significantly during heating. After natural cooling, the fluorescence of inclusions became weaker, reflecting the cracking process of crude oil.

The high resolution laser-raman spectrum detection results of the oil inclusion after heating experiment show that the gas composition in the gas inclusion is mainly methane with a small amount of carbon dioxide ‘figure 2’.
Figure 1. Changes of fluorescence status of oil containing inclusion during heating experiment.
(a,a₁ Heating before; b,b₁ Heated to 600 °C; c,c₁ Natural cooling to room temperature 25°C)

Figure 2. Gucheng6,7,8 wells high resolution laser-raman spectrum of crude oil cracking gas inclusions.

According to the comparison of oil inclusion state before and after heating, it is inferred that the sample has not experienced such high temperature process. Theoretically, it is speculated that the oil and gas inclusions will break when heated to a certain temperature, and the analysis may be that the temperature did not reach the breaking limit temperature of inclusions in this experiment. Whether Gucheng area has experienced the process of higher temperature and pressure remains to be further experimental research.

4. Geological significance
The oil and gas inclusions were studied by reservoir cores and cuttings samples in Gucheng area. Research on the inclusion characteristics of crude cracking gas in Gucheng area, the uniform temperature and accumulation time analysis of crude cracking gas inclusions show that the oil and gas accumulation in Gucheng area is divided into two stages, the first stage is mainly oil, the accumulation stage is late Ordovician, the second stage is mainly natural gas, and the accumulation stage is late Tertiary.

The hydrocarbon source rocks in Gucheng area are mainly Cambrian and middle Ordovician. Cambrian source rocks Ro reached 1.0% in the middle of late Ordovician and entered the peak of oil generation. Due to the large thickness and rapid deposition of upper Ordovician strata, the maturity (Ro) of source rocks evolved to 1.3% in a short time, crude oil began to crack, the amount of oil was
rapidly reduced, natural gas was rapidly generated, and oil cracking ended at the end of middle Devonian (Ro was 3.0%). From the perspective of burial history, the buried depth of Cambrian hydrocarbon source rocks is greater than the historical burial depth. However, from the Ro evolution curve, the Ro of Cambrian has been unchanged in the later stage, that is, the maturity has not increased. This is because although the present buried depth is greater than the ancient buried depth, the present geothermal gradient is smaller than the ancient geothermal gradient, and the geothermal temperature has not increased. Therefore, the source rocks in Gucheng area were mainly generated from the middle late Ordovician to the end of middle Devonian, that is to say, before the uplift and denudation of the strata at the end of Devonian, the ancient oil reservoir had undergone crude oil cracking, and the ancient oil reservoir was converted into gas source kitchen.

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