CHARACTERISTICS AND HYDROCARBON GENERATION OF PRIMARY ORGANIC MATTER IN THE TIAOHU FORMATION TUFF, SANTANGHU BASIN, NW CHINA

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Introduction

A tuffaceous tight oil reservoir with considerable reserves has been found in the Santanghu Basin, northwestern China. This reservoir has the peculiar property of being a sedimentary organic-matter-bearing tuff characterized by high porosity (10%–25%) and very low permeability (0.01–0.50 mD). In this study, an integrated analysis of the organic geochemistry was conducted to determine the characteristics of depositional environment and hydrocarbon generation of the organic matter in the tuff.

Results

1. Depositional environment of primary organic matters in the tuff

1.1. Evidence of underwater deposition of tuff

The research shows that the Tiaohu Formation is characterized by "volcanic eruption and underwater deposition of tuff". Microscopic observation shows that there is a minor of andesite debris in the tuff, which represents the occurrence of mixture with tuff and obvious edges, indicating that the volcano is erupted underwater in the lacustrine basin without long distance transportation. That is, when it is in the period of volcanic activity, there are the collapsed products of neutral volcanic rock with volcanic ash at the crater. In addition, the thickness of tuff is generally small (usually the centimeter-magnitude and the interbedding with mudstone) if it is from allochthonous tuffs transported by the wind. That the thickness of generally 10–30 m strongly supports the perspective that the tuffs are mainly the deposition of volcanic ash in the lacustrine basin from underwater eruption and transported by the wind agent adjacently.

1.2. Formation environment of primary organic matter

The extracted tuff samples have total organic carbon (TOC) values of 0.5%–1.0%, total hydrocarbon yield values of 2–6 mg/g, and hydrogen index values of 20–336 mg HC/g TOC. The organic matter consists predominantly of Type III and II_2 kerogens, and the temperature of the maximum yield of pyrolysate varies from 420 to 450 °C, which reflects the oil-generating capacity of the tuff. Organic matter can be observed under scanning electron microscopy (SEM), and organic-hosted pores were developed, which is associated with pyrite, indicating that tuff is formed in a reducing environment. The biomarker characteristics of the kerogen pyrolysis product of tuff can reflect its true formation environment. The pyrolysis oil has lower Pr/Ph, medium gamma wax, and the not complete rising linear distribution pattern of regular sterane ααα20RC_{27}, C_{28} and C_{29} peaks, indicating that the deposition of tuff is in reducing environment with brackish water (medium salinity) and

showing the dual contributions of lower organisms and terrestrial organic matter. Further, the fossils of the fauna and flora can be observed in the core.

2. Hydrocarbon generation characteristics of primary organic matter

An experiment on artificial generation of oil via pyrolysis was conducted using an autoclave closed system (ST-120-II). The pyrolysis of isolated tuff kerogen samples was conducted using a high-temperature and high-pressure device with a gold tube (50 × 5 mm). The heating temperature was 335 °C, and the rate and characteristics of hydrocarbon generation for the tuff were analyzed.

The samples were collected from Wells M56-12 and M56-15, both of which were oil-bearing tuff intervals. Among them, the samples at 2112.52 m and 2115.38 m of Well M56-12 poorly contain oils and the isolated kerogen is black, and the organic carbon content of kerogen is over 90%. It is actually tuffaceous mudstone. The samples from 2127.24 m in Well M56-12 and 2259 m in Well M56-15 show high oil content and the isolated kerogen was earthy yellow color, showing TOC of 11.9% and 5%, respectively. From the perspective of hydrocarbon yield, the samples of 2112.52 m and 2115.38 m in Well M56-12 are less than 60 mg HC/g TOC, the hydrocarbon yield of Well M56-12 at 2127.24 m and Well M56-15 at 2259 m are all above 240 mg HC/g TOC. It can be seen that the true primary organic matter in tuff shows higher yield and the lower part of the oil-bearing section is much higher than the upper section. However, due to the low abundance of total primary organic matter in the tuff (TOC 0.5%–1.0%), even if the hydrocarbon yield is high, the crude oil generated by the tuff itself is difficult to achieve the oil saturation of the current tight reservoir.

The artificial generation of oil collected in the pyrolysis simulation experiment was separated. The results show that it contains an average saturated hydrocarbon of 16.9%, an average aromatic of 21.9%, an average resin of 46.9%, and an average asphaltene of 14.2%. This indicates that oil generated by the tuff is characterized by low content of saturated and aromatic hydrocarbons and high content of resin and asphaltene.

From the characteristics of biomarker compounds, the biomarker characteristics of oil collected from tuff kerogen pyrolysis are mainly characterized by lower gammacerane index, anti-“L” or asymmetric “V” distribution patter of regular sterane ααα 20RC_{27}, C_{28}, C_{29}, rather the rising linear distribution pattern. This is quite different from the crude oil of tuff oil reservoirs and extracts of source rock from the Lucaogou Formation.

Conclusions

The tuffs are mainly the deposition of volcanic ash in the lacustrine basin from underwater eruption and transported by the wind agent adjacently. The deposition of tuff is in reducing environment favorable for the preservation of organic matter with brackish water (medium salinity).

Although the hydrocarbon yield of the tuff is high, the crude oil generated by the tuff itself is difficult to achieve the oil saturation of the current tight tuff reservoir. The biomarkers of the saturated hydrocarbons of artificial generation of oil via the tuff pyrolysis differ significantly from those of crude oils in the tuff.