Analysis on Geological Conditions of Chang 7 Shale Gas Accumulation in Longdong Area in Ordos Basin

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Abstract. The geological conditions of Chang 7 shale gas accumulation in Longdong area are analyzed from sedimentology, petrology and organic geochemical characteristics in this paper. The study shows that Chang 7 shale in Longdong area is mainly deposited in deep lake and semi deep lake, with thickness ranging from 10 m to 40 m. The shale is mainly composed of quartz, feldspar, clay minerals and a small amount of carbonate and pyrite, and its brittleness is high. TOC ranges from 1.5% to 20.0%, with an average of 7.9%, and hydrocarbon generation potential (S1+S2) ranges from 0.67 mg/g to 33.53 mg/g, with an average of 15.81 mg/g. The main organic matter belongs to type I and II, Ro ranges from 0.7% to 1.2%. It can be concluded that Chang 7 shale in Longdong area possesses favourable conditions for shale gas accumulation.

1. Introduction

Shale gas is a kind of unconventional natural gas which is self-generated and self-stored in organic shale. According to Rogner et al., the total amount of shale gas in the world is about $456 \times 10^{12}$ m$^3$, which is equivalent to the sum of tight sandstone gas and coalbed gas [1, 2]. Due to the development of horizontal well drilling technology, shale gas production in the United States increased rapidly, reaching $4772 \times 10^8$ m$^3$ in 2017 and accounting for about 96% of global shale gas production. The geological conditions of shale gas accumulation in United States are characterized by high organic matter abundance (TOC > 2.00%), high maturity (Ro ranges from 1.1% to 3.2%), high brittleness (the amount of quartz, feldspar and other mineral content is greater than 40%), low clay mineral content (less than 40%) and effective shale thickness (> 10 m)[3–6].

Ordos Basin is an important petroleum area in China. Thick dark mudstones, an important source rock of Mesozoic strata, were widely deposited in the basin during the Chang 7 period[7]. Longdong area is located in the southwest of Ordos Basin. Chang 7 shale is widely developed in the study area, which is the precondition of shale gas accumulation. In this paper, the conditions of shale gas accumulation in Longdong area are analyzed from the aspects of shale spatial distribution, petrological characteristics and organic geochemical characteristics.
2. Geological Background

2.1. Structural features
Ordos Basin is a huge multi-energy mineral basin developed on a stable craton, which contains abundant coal, oil, natural gas and other resources. Longdong area is located in the southwest of Ordos Basin, which mainly spans the two first-order tectonic units: Tianhuai depression and Yishan slope(Fig. 1). The burial depth of Chang 7 shale in the study area ranges from 1200m to 2350m, and the components of overlying strata are mainly thick mudstone and silty mudstone, which is favorable for shale gas accumulation.

![Figure 1. The study area in Ordos Basin](image)

2.2. Sedimentary background
Chang 7 sedimentary period is the peak of lake basin development of Yanchang period in Ordos basin[8]. Strong tectonic activity and warm and humid climate in the study area resulted in rapid expansion of lake basin and deposited a lot of high-quality source rocks. Rapid expansion of lake basin, continuous and stable deep-water sediments, low salinity and oxygen deficit provide favorable geological conditions for large-scale development of Chang 7 source rocks.

3. Petrological characteristics

3.1. Lithological characteristics and spatial distribution
Chang 7 shale in study area is mainly dark gray, gray-black and black in color, and contains a large number of plant fossils (Fig.2) and a small amount of iron nodules, showing the characteristics of deep and semideeplake facies sediments.

According to the logging response characteristics of Chang 7 shale and combined with previous research results [9], the thickness plot of Chang 7 shale is obtained (fig.3). It can be seen that Chang 7 shale is widely distributed in the study area, and its sedimentary thickness ranges from 10m to 40m. Compared with the effective thickness (>10m) of American shale gas field, the study area also has good basis for shale gas generation.
3.2. Mineral Composition Characteristics
Chang 7 shale in the study area was tested by X-ray diffraction. The results show that the main minerals in the study area are quartz, feldspar and clay minerals, in addition to a small amount of carbonate and pyrite (Fig. 4). Quartz content ranges from 15% to 37%, with an average of 27%, feldspar content ranges from 17% to 41%, with an average of 29%, and clay mineral content is from 23% to 49%, with an average of 34%. The contents of carbonate and pyrite are 4%-15% and 1%-5% respectively, with averages of 8% and 2%. In general, Chang 7 shale has high brittleness and good fracability.
4. Organic geochemical characteristics

The amount of natural gas generated in shale is mainly dependent on the content of organic carbon, organic matter type and thermal evolution degree of organic matter. The content of organic carbon and the type of organic matter are mainly determined by the sedimentary environment and the thermal evolution degree is mainly dependent on the duration of it after sedimentation.

4.1. Organic matter abundance

Organic matter abundance is an important parameter for evaluating hydrocarbon generation potential of source rocks, and it also determines gas generation and gas content of shale\[10,11\]. Based on the test data of Chang 7 shale in previous researches and combined with the test results of 12 wells in the study area, the TOC of Chang 7 shale could be obtained (fig. 5). The results show that TOC of Chang 7 shale ranges from 1.21% to 25.2%, with an average of 7.9%. Meanwhile, according to the pyrolysis parameters of five samples (Table 1), the hydrocarbon-generating potential (S1+S2) of Chang 7 shale in the study area is 0.67-33.53 mg/g, with an average of 15.81 mg/g. The high TOC and hydrocarbon-generating potential prove that Chang 7 shale belongs to high quality source rocks.

![Figure 5. TOC and RO contour plot of Chang 7 shale in study area](image)

| Sample | Depth/m | S0/mg.g⁻¹ | S1/mg.g⁻¹ | S2/mg.g⁻¹ | S1+S2/mg.g⁻¹ | T_max/C° |
|--------|---------|-----------|-----------|-----------|-------------|--------|
| 1      | 2027.68 | -         | 0.66      | 0.74      | 1.40        | 317    |
| 2      | 2031.38 | 0.04      | 3.68      | 29.85     | 33.53       | 438    |
| 3      | 2035.13 | 0.20      | 3.06      | 27.48     | 30.54       | 445    |
| 4      | 2044.94 | 0.11      | 1.21      | 11.70     | 12.91       | 451    |
| 5      | 2058.44 | 0.01      | 0.17      | 0.50      | 0.67        | 457    |

4.2. Organic matter types

Microscopic observation of kerogen in Chang 7 shale shows that amorphous lipid bodies are dominant, and a small amount of echinococcus and spores also can be found. The main color of kerogen under transmission light is brown. The main sources of organic matter are lower organisms and algae. The results show that the main organic matter belongs to type I and II.

4.3. Maturity of organic matter

In sedimentary rocks, the abundance and type of organic matter are the material basis for hydrocarbon generation, but only when the organic matter reaches a certain degree of thermal evolution can the
hydrocarbon generate. Many studies on the maturity of source rocks show that Ro in Chang 7 shale in the Ordos Basin is mainly in the range of 0.6%-1.15%. In this study, the vitrinite reflectance of Chang 7 shale was tested (Fig. 5). The results show that Ro of most samples ranges from 0.7% to 1.2%. Compared with Ro in north American (from 1.1% to 3.5%), it is relatively unfavorable for shale gas accumulation, but favorable for tight oil accumulation. However, maturity is not the only factor to affect shale gas accumulation, for example, Ro of the Appalachian Basin shale is 0.4% to 4%, and that of Virginia and Kentucky is 0.6% to 1.5%, but a lot of shale gas is produced there.

5. Conclusion
The thickness of Chang 7 shale in Longdong area ranges from 10mto 40 m. The deep lake and semideep lake facies sediment provides good geological conditions for the large-scale development of high-quality source rocks. The organic matter content is large and hydrocarbon generation potential is huge. The kerogen mainly belongs to type I and II, Ro ranges from 0.7% to 1.2%. Although Ro here is slightly lower than that of North America, the essential conditions of shale gas accumulation still exist. Petrological characteristics show that Chang 7 shale has high brittleness and good fracability. Therefore it can be concluded that Chang 7 shale in Longdong area possesses favorable conditions for shale gas accumulation.

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