LACUSTRINE SHALE RESERVOIR CHARACTERISTICS AND OIL OCCURRENCE IN THE QINGSHANKOU FIRST MEMBER OF NORTHERN SONGLIAO BASIN, CHINA

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Introduction

The Songliao Basin is a large-scale lacustrine basin, which has developed two sets of excellent source rocks during the Late Cretaceous, that is, the Qingshankou formation and the Nenjiang 1^{st}-2^{nd} members. The exploration of the Qingshankou shale in recent years obtains several wells with commercial oil flow, suggesting that the Qingshankou shale has prosperous oil resources. The objective of this study is to study the characteristics of shale pore space and oil occurrence.

1. Geological and geochemical characteristics of the Qingshankou first member shales

The shales are mainly deposited in deep and semi-deep lake facies with the thickness between 50-100m. There are usually two layers of oil shale with thickness from several centimetres to tens of centimetres. The lamellation is well developed but with less structural fractures. Cores observation shows that there are thin interlayers of siltstone, muddy siltstone and marlstone. The thin interlayers of siltstone are more developed in the west which is close to the source material, whereas in the east there are less siltstone interlayers. The siltstone interlayers have thickness in the range of 2cm-100cm. The mineral analyses show that the shales are dominated by quartz, feldspar and clay, whereas the calcareous content is less. The average quartz content is 36%, the clay 36%, the feldspar 18% and the carbonate 7.3%.

The shales are rich in organic matter, with the average TOC at 2.30%, the chloroform bitumen "A" at 0.47% and the S_1+S_2 at 16.02mg/g. The kerogen is type I dominated by lamalginite. Reaction kinetics show that the main oil window is at 0.8-1.2% (Ro). As to the source rock maturity in the central depression, it ranges 0.7%-1.1% in the Qijia depression, 0.8-1.4% in the Gulong depression and 0.7-1.2% in the Sanzhao depression.

The oil content analyses show that in the Gulong depression the S_1 ranges 0.2-5.94mg/g with the average at 1.94mg/g, and the chloroform bitumen "A" ranges 0.061-1.67% with the average at 0.6%, whereas in the Qijia depression, the S_1 ranges 0.2-4.54mg/g with the average at 1.52mg/g, and the chloroform bitumen "A" ranges 0.015-1.52% with average at 0.44%. As to the TI value (S_1/TOC), it ranges 50-130mg/gC in the Gulong depression while it ranges 20-80mg/gC in the Qijia depression.

2. Reservoir characteristics of the Qingshankou first member shales

The total porosity ranges 4.06-11.9% with the average at 7.94% and the dominant range at 6-10%, while the effective porosity ranges 0.3-9.7% with the average at 4.79% and the dominant range at 3-7%. FIB-SEM analyses show that there are groundmass inter-crystal pores, organic pores, dissolved pores, inter-granular pores and micro-nano scale fractures. The groundmass inter-crystal pores are ubiquitous in the shales and the pore diameter between illite sheets is

dominated by 1.0-3.5μm. There are abundant framboidal pyrite, of which the inter-crystal pore diameter is dominated by 0.5-2.5μm. The organic pores, generally with long strip or irregular shape, increases with maturity and are mainly from residual space derived from alginite cracking, and the pore scale is dominated by nanometre. Based on mass balance calculation, it is suggested that at maturity of 1.0-1.3%, the oil generation can attribute 2.3-2.7% porosity.

The porosity evolution analyses of the shales show that with increasing depth, the porosity decreases, except that at depth below 2000m, the porosity increases and there are two peaks at 2100m and 2380m, respectively. The abnormal porosity increase is in accord with mass oil generation and the depth where there are minerals dissolved by organic acids, indicating that post alteration may play an import role in improving shale reservoir quality.

3. Shale oil occurrence in the Qingshankou first member shales

Based on BSEM secondary ion images of argon milled shale, shale oils are observed in the form of membrane present in pores deprived from organic matter contraction and in inorganic pores such as inter-crystal pores of illite and pyrite, indicating that shale oil is in free phase at subsurface, which is in favour of exploitation. As shown in Fig. 1, by comparing 2D NMR results of the shales with those shales extracted by chloroform, it is suggested that free oils are with longer relaxation time in the up-right region of the image, whereas kerogen and adsorbed oil are with shorter relaxation time in the lower-left region of the image, indicating that free oils are present in larger pores while adsorbed oils are mainly adsorbed by solid organic matter. In combination of higher pressure mercury intrusion and NMR analyses, as shown in Fig. 1 (right), the results show that shale oils mainly occupy pores with radius in the range of 5-500nm, whereas water mainly present in pores with radius less than 20nm. It seems that shale oils are mainly present in nano-pores, implying that successful exploitation needs advanced engineer and new fracturing technique.

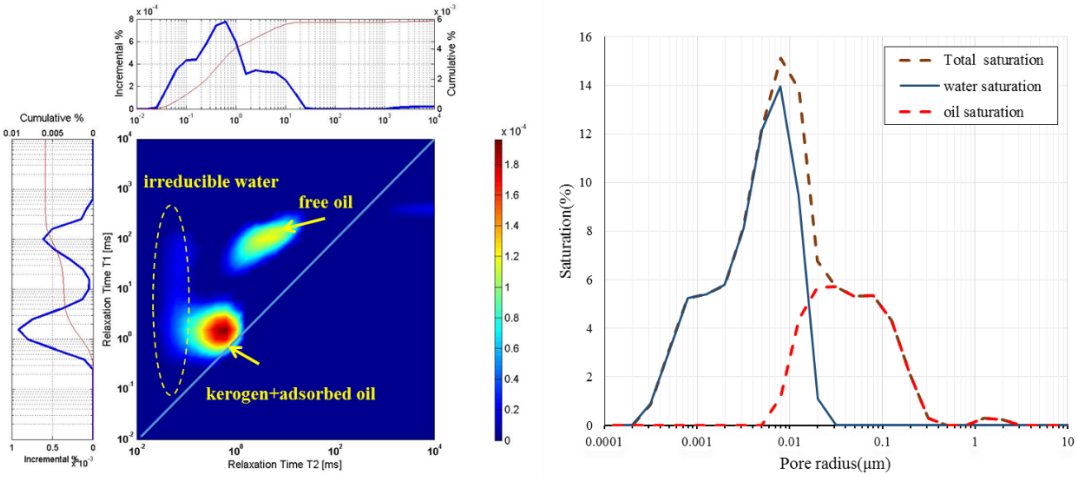

Figure 1 *Representative 2D NMR image and relationships between fluid saturation and pore radius of the Qingshankou first member shale*

References:

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