Objective

Calcareous shale in semi-deep and deep lacustrine facies is regarded as an oil shale exploration target, because these shale formations possess excellent storage capacity caused by widely developed internal particle pores and dissolution pores and are responsive to hydraulic fracturing due to the high content of carbonates. Generally, the dissolution pores are considered to be caused by the interaction between calcite, dolomite, albite and organic acid generated from kerogen maturation. However, there have been no systematic experiments to study the formation mechanism of dissolution pores in calcareous shale. Thus, a series of simulation experiments were conducted on a semi-closed system to investigate the relationship between kerogen maturation and dissolution pore development in the Lucaogou Shale, Santanghu Basin, northeast Xinjiang Province, China.

Methods

The mineral compositions were analyzed using X-Ray Diffraction (XRD). The simulation experiments were performed to obtain artificially matured shale samples across a maturation gradient. The maturity of the pyrolyzed shale was calculated using the easy%Ro model. And Field Emission-Scanning Electron Microscopy (FE-SEM) analysis combined with Energy Disperse Spectroscopy (EDS) analysis were carried out to identify the size, shape, location and connectivity of dissolved pores.

Results

The original Lucaogou shale from the Santanghu Basin was dominated by albite (30%) and carbonate (24.4% dolomite + 5.4% calcite) with lesser quartz (17%) and illite (10.4%) content. Albite (Fig. 1a) in the FE-SEM image is recognized by its characteristic element compositions (Na, Al, Si, O) displayed in the EDS data. Similarly, calcite and dolomite were identified by their unique chemical compositions. Intraparticle pores in calcite and dolomite were rarely observed in the original shale. As the maturity increased (Fig. 1b), dissolution pores in the calcite appeared when the easy%Ro reached 0.79%, which corresponds to the early oil window stage and the main generation of organic acid. More widely distributed and interconnected dissolution pores in the calcite occurred when the easy%Ro was 1.0%.

Conclusions

In the Lucaogu Shale, the dissolution pores were mainly found in calcite, which was mixed with the organic matter. These pores were observed after the maturity reached 0.79% easy%Ro. The interaction between the calcite and organic acid accounted for the dissolution pores in the artificially matured Lucaogou Shale. These abundant dissolution pores in the calcareous shale show good pore connectivity and contribute significantly to the storage capacity, which guarantees the good quality of the oil shale reservoir at the marginally mature stage.

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Fig. 1. FE-SEM results of the calcareous Lucaoguo Shale at different maturities. (a) The original shale, (b) easy $R_o = 0.79\%$, (c) easy $R_o = 1.0\%$. The EDS results illustrate the element components of minerals labelled in the FE-SEM images: alb = albite; dol = dolomite; cal = calcite.