Characterization of the Upper Ordovician Wufeng-Lower Silurian Longmaxi Marine Shale of Well Xiye-1 in Northwestern Guizhou Province, Southwest China: Implication for Shale Gas Potential*

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Abstract

A detailed study of the Ordovician Wufeng-Silurian Longmaxi shale of well Xiye-1 in northwestern Guizhou province was conducted based on a systematic analysis of series of experimental measurements for core samples. Trace elements concentrations reveal that dysoxic to anoxic paleo-environmental setting prevailed during the deposition of the Wufeng-Longmaxi shale in northwestern Guizhou Province. The shale has high total organic matter content (TOC) with an average of 2.02% (ranging 0.36%~6.73%) and high maturity with vitrinite reflectance (Ro) ranging from 2.94% to 3.65% (averaging 3.38%). The organic matter type is sapropelic (I) to humic-sapropelic (II1), which has strong hydrocarbon generation potential. The mineralogy of the shale is mainly composed of 44.7% quartz and 32.6% clay minerals on the average. The shale is characterized by low porosity ranging from 0.6% to 4.4% (averaging 1.8%) and low permeability varying from 0.0066×10^{-3} \text{μm}^2 to 0.1098×10^{-3} \text{μm}^2 (averaging 0.0378×10^{-3} \text{μm}^2). The porosity shows a positive correlation with TOC and brittle minerals (quartz, feldspar, calcite and dolomite) content, but a negative correlation with clay minerals content. The relationship between TOC, clay minerals content and gas adsorption capability shows a positive correlation between TOC and absorbed gas content. This indicates that organic matter can adsorb large amount of gas in the shale besides the free gas in pores, but a negative correlation between clay minerals content and absorbed gas content, which may be caused by the presence of moisture and lower TOC of the clay-rich shale.
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Introduction

- The Upper Ordovician Wufeng-Lower Silurian Longmaxi marine shale in Guizhou province is one of the most active shale gas plays in China. However, the exploration for this black shale succession is still in the early stage.
- A series of measurements on core samples collected from a new drilling shale gas investigation well named Xiyé-1 were conducted. The experimental program includes TOC and Rock-Eval pyrolysis, XRF and CIP-MS, XRD and QEMSCAN, SEM and Mercury (Hg) injection, Methane isotherm adsorption.
- On the basis of the experimental data, an analytical systems regarding the studied shale was given in this presentation, with the hope of providing some useful geological information to evaluate the shale gas potential.

Geologic Setting

- The study area is located in the northwest of Guizhou province, which is bounded by three major faults. It belongs to the Upper Yangtze Platform tectonically.
- Well Xiyé-1 is located in the Xishui country of Guizhou province, which was drilled in 2012 with a drilling depth of 706m, aiming at the upper Ordovician Wufeng and lower Silurian Longmaxi Formation.
- The Wufeng-Longmaxi black shale was deposited in marine shelf paleoenvironment. 30 samples were collected from the Wufeng Formation and the lower Member of Longmaxi Formation, which are the organic-richest interval.

Paleoredox Conditions

- Fig 2. Vertical changes of trace elements ratios of V/Cr, U/Ta and V3+/V4+, showing that the Wufeng-Longmaxi shale deposited in variable redox conditions, with the degree of anoxia decreasing upward.

Mineralogy

- Fig 4. Percentage of mineral composition for the Wufeng-Longmaxi shale.
- Quartz and clay dominated the mineral composition in the Wufeng-Longmaxi shale, which are complementary vertically. Quartz are mainly from terrigenous clastic, while part of them in the lower section are biogenesis.

Geochemistry

- Fig 3. Geochemical profile for the Wufeng-Longmaxi shale.
- The TOC content ranges between 0.36% and 6.73% (2.02% on average), increasing towards the base.
- The R0 value ranges between 2.94% and 3.65% (3.38% on average), indicating an overmature stage of the shale.
- The δ13C value ranges from -30.4‰ to -28.7‰, inferring the kerogen type I and II for the shale.
- This shale is good gas-producing shale in terms of geochemistry.
Five detailed properties regarding the upper Ordovician Wufeng and lower Silurian Longmaxi marine shale in northwestern Guizhou province are concluded on the basis of experimental data: (1) Trace element ratios of V/Cr, U/Th, and V/(V + Ni) reveal that the shale deposited in variable paleoredox conditions, with the degree of anoxia decreasing upward. (2) The kerogen type is sapropelic (I) to humic-sapropelic (II). TOC contents range from 0.36% to 6.73% (averaging 2.02%), increasing with the burial depth. Ro values are between 2.94% and 3.65% (averaging 3.38%), indicating an overmature stage of the shale. (3) Quartz and clay minerals are the major mineral composition, with an average content of 44.7% and 32.6%, respectively. (4) The porosity is 1.8% on average (ranging from 0.6% to 4.4%), increasing toward the base. Correlation analyses between the porosity and rock composition indicate that the shale interval rich in organic matter and quartz has higher porosity than the clay-rich interval. (5) The gas adsorption capacity increases with the increasing of TOC content, indicating that organic matter is responsible for adsorbing gas. The contribution of clays to the gas adsorption capacity may be irrelevant because of the presence of moisture.

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