[PS]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} μm^2 to 0.1098×10^{-3} μm^2 (averaging 0.0378×10^{-3} 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 Xiye-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 systematical analyses 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

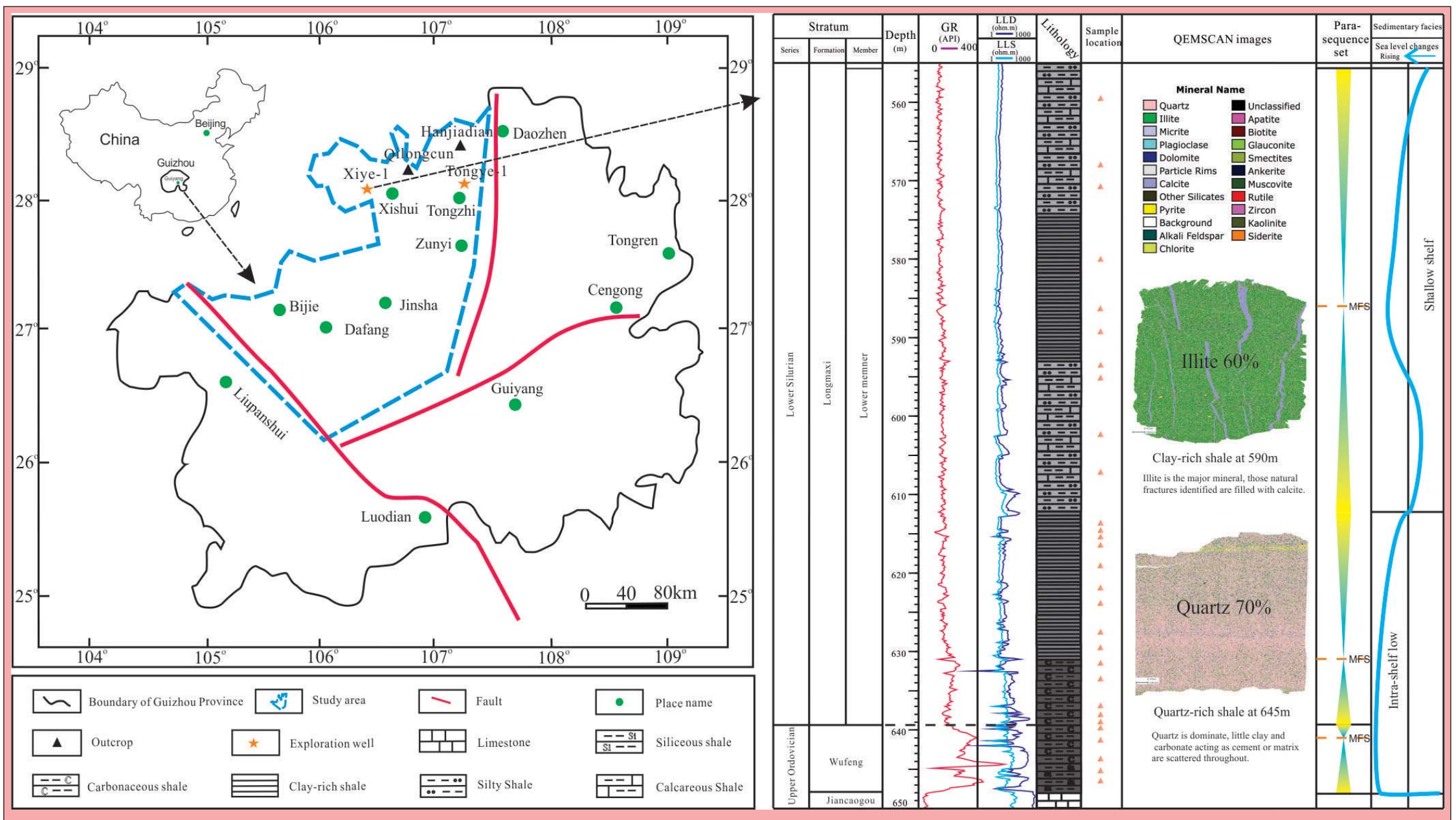


Fig 1. Location map of the study area and comprehensive column of lithofacies for the well Xiye-1.

- 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 Xiye-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 Formarion .
- 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/Th and V/(V+Ni), showing that the Wufeng-Longmaxi shale deposited in variable redox conditions, with the degree of anoxia decreasing upward.

Mineralogy

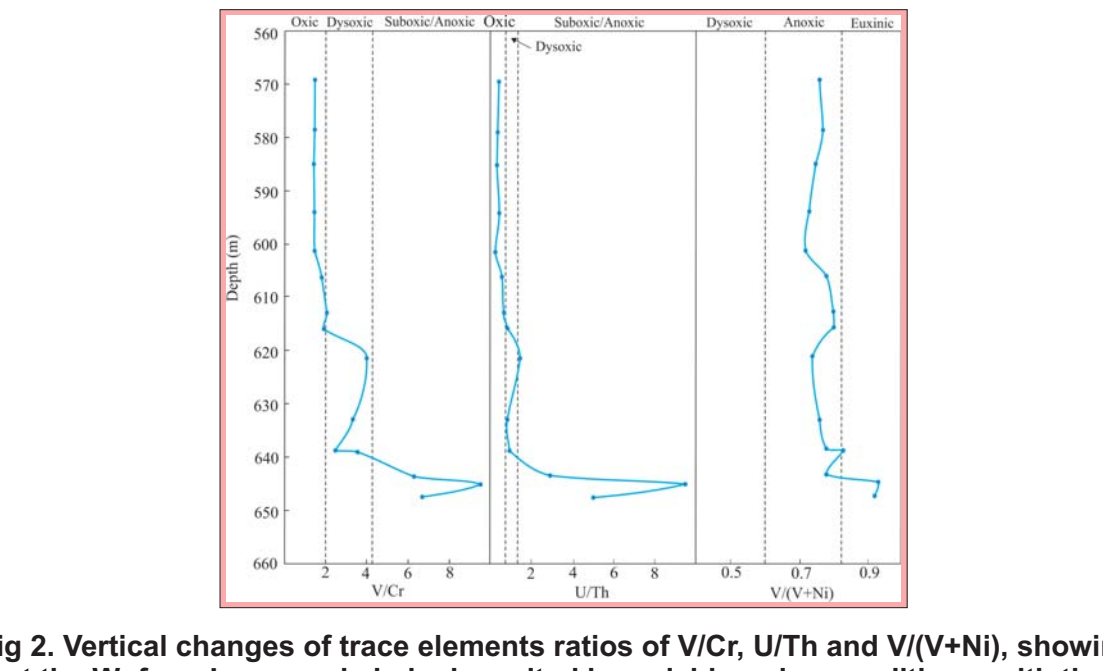


Fig 4. Percentage of mineral composition for the Wufeng-Longmaxi shale.

- 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 the them in the lower section are biogenesis.

Geochemistry

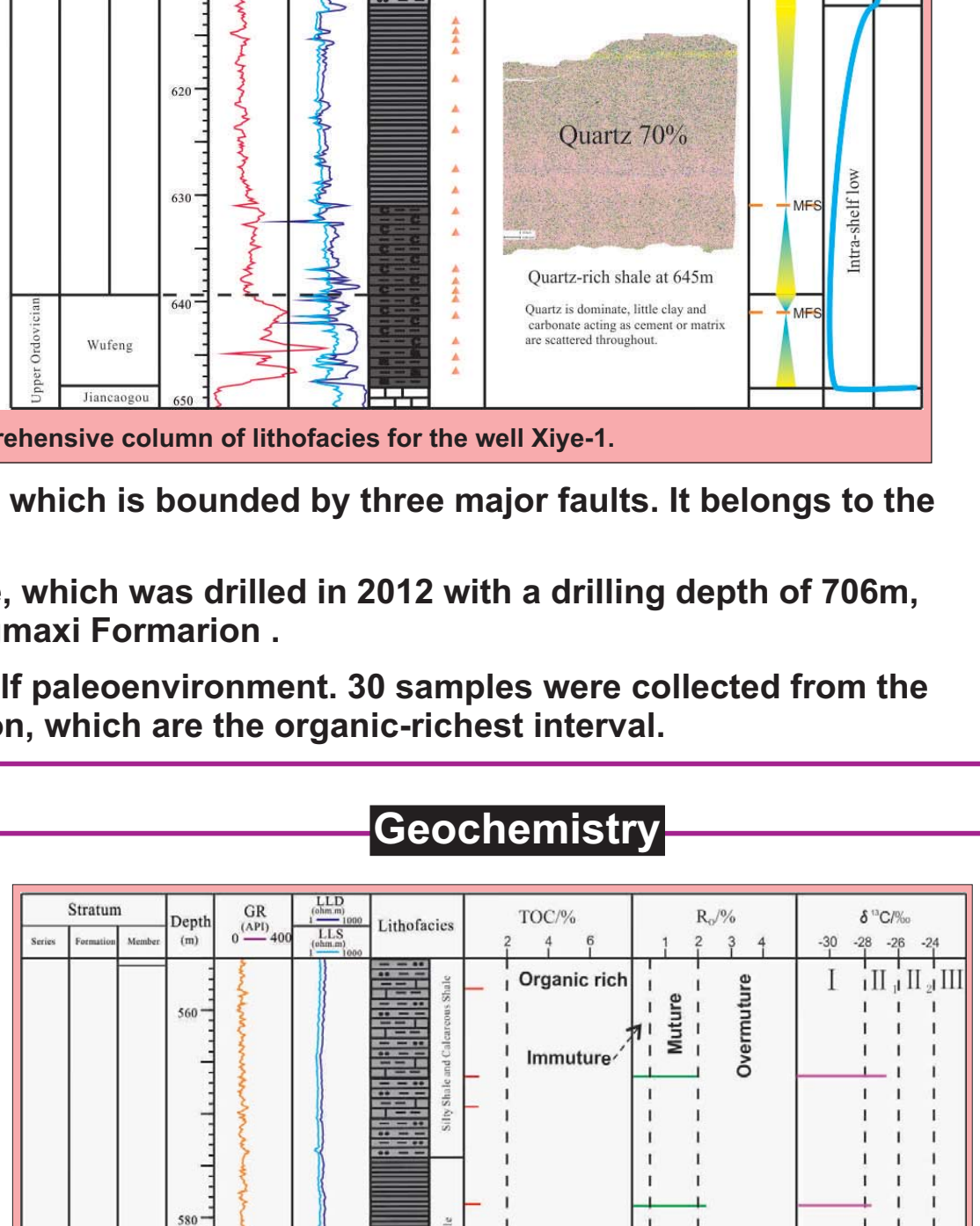


Fig 3. Geochemical profile for the Wufeng-Longmaxi shale.

Note: I means sapropelic, II_1 means humic-sapropelic, Ii_2 means sapropelic-humic, III means humic.

- The TOC content ranges between 0.36% and 6.73% (2.02% on average), increasing towards the base.
- The Ro value ranges between 2.94% and 3.65% (3.38% on average), indicating an overmature stage of the shale.
- The $\delta^{13}C$ value ranges from -30.4‰ to -28.7‰, inferring the kerogen type I and II_1 for the shale.
- This shale is good gas-producing shale in terms of geochemistry.

Petrophysics

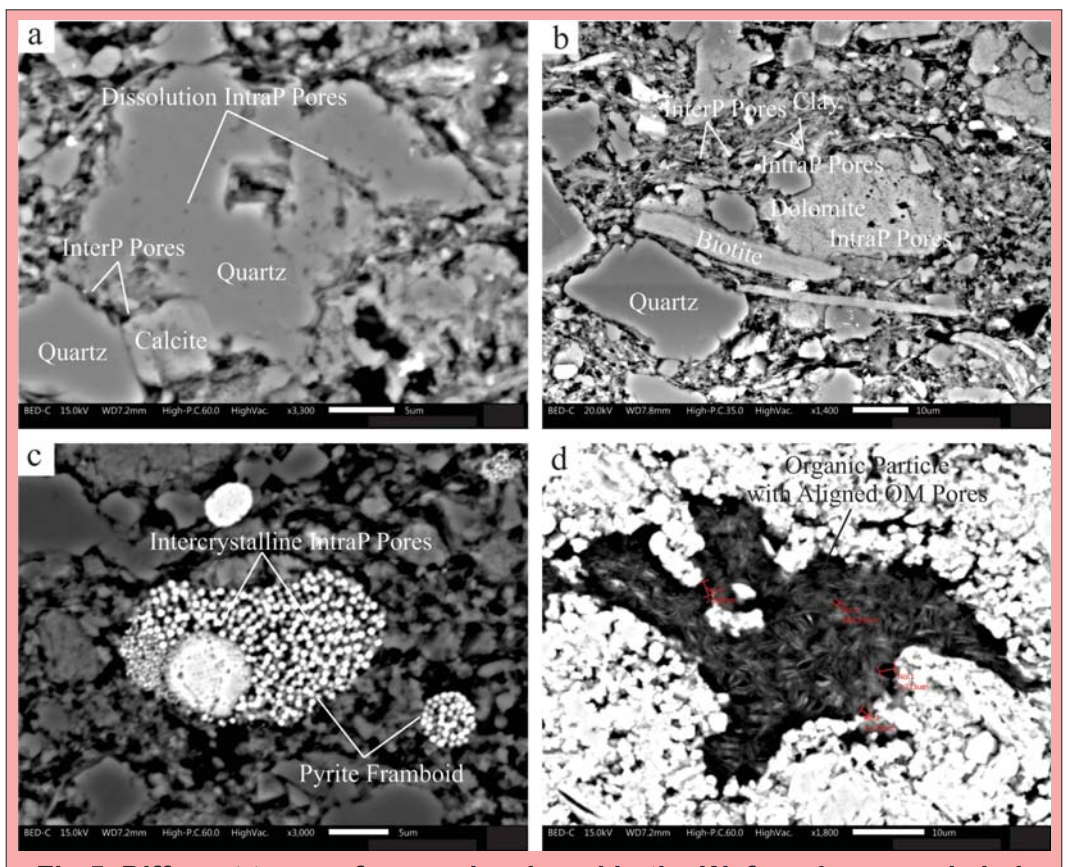


Fig 5. Different types of pores developed in the Wufeng-Longmaxi shale revealed by SEM, most of them are in Nano to Micro-meter scale.

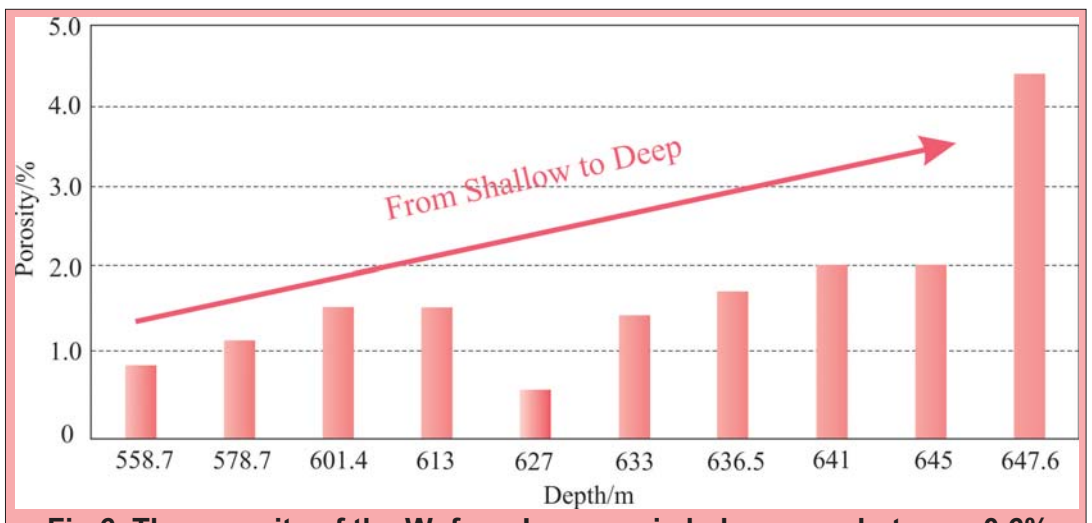


Fig 6. The porosity of the Wufeng-Longmaxi shale ranges between 0.6% and 4.4% (1.8% on average), increasing with the depths.

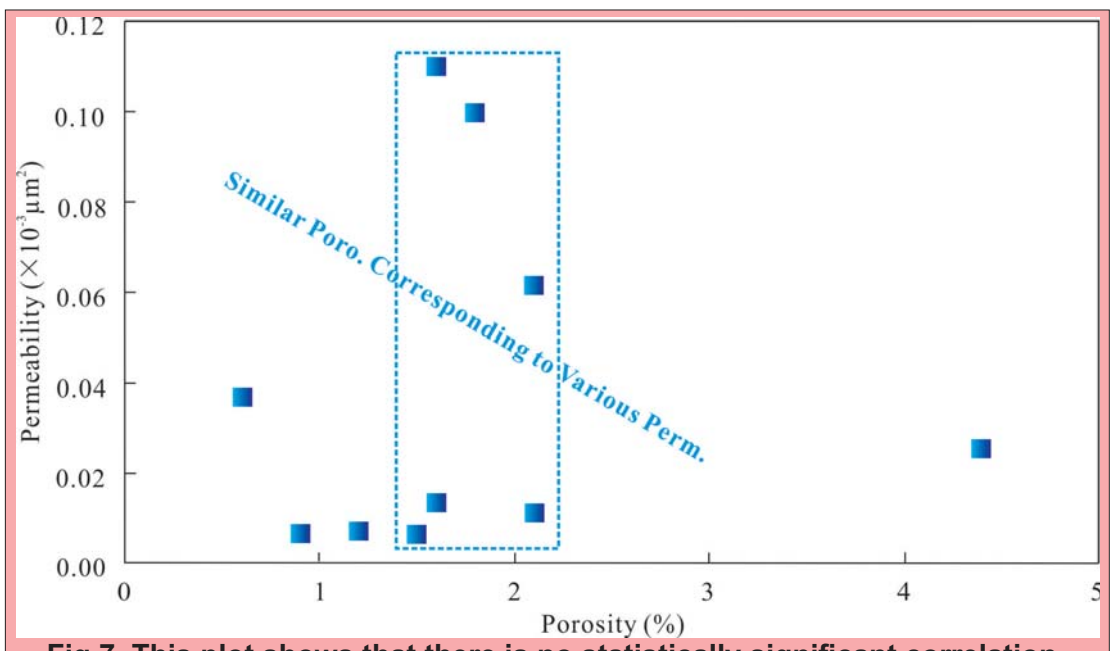


Fig 7. This plot shows that there is no statistically significant correlation between the porosity and permeability, indicating a complex pore system in the Wufeng-Longmaxi shale.

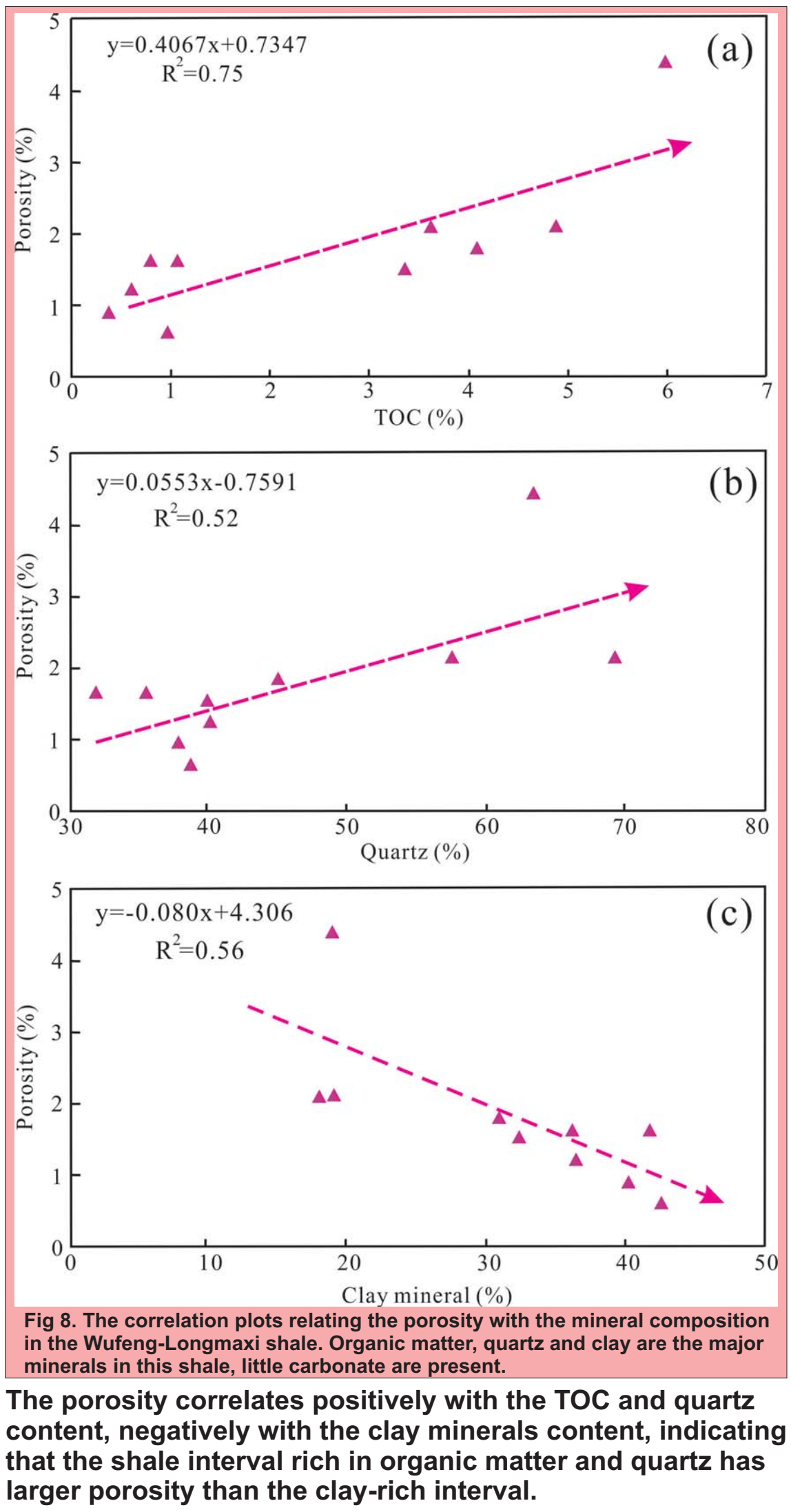
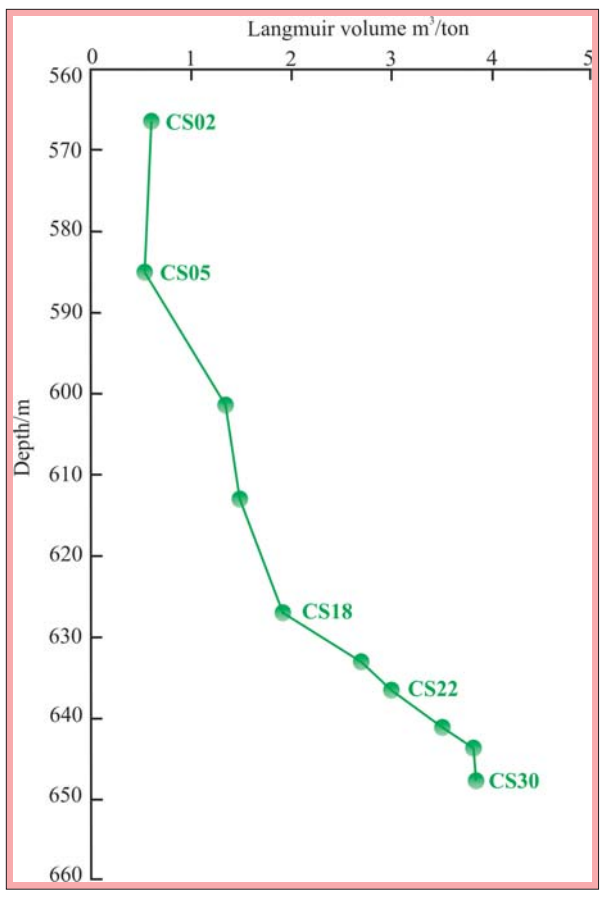


Fig 8. The correlation plots relating the porosity with the mineral composition in the Wufeng-Longmaxi shale. Organic matter, quartz and clay are the major minerals in this shale, little carbonate are present.

- **The porosity correlates positively with the TOC and quartz content, negatively with the clay minerals content, indicating that the shale interval rich in organic matter and quartz has larger porosity than the clay-rich interval.**
- **These poor to moderate correlations suggest that there are other factors influencing the porosity of the shale.**

Gas Adsorption Capacity



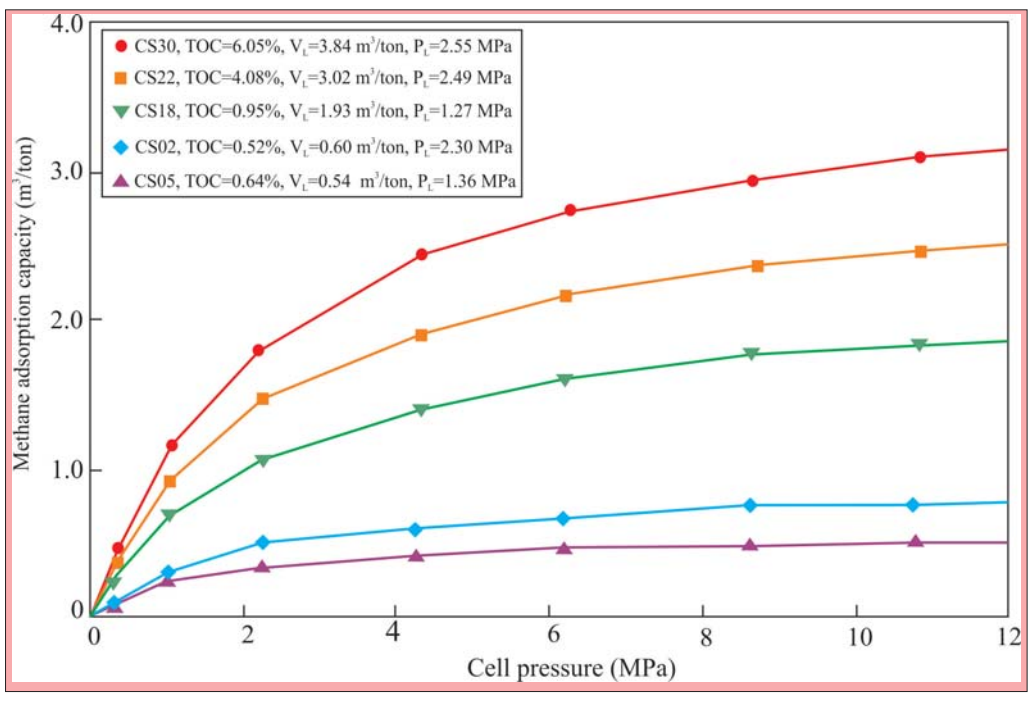


Fig 10

Fig 9. The Langmuir volume of the Wufeng-Longmaxi shale ranges from 0.54 m^3/ton to 3.84 m^3/ton (2.28 m^3/ton on average), increaing towards the bottom.

Fig 10. The methane adsorption isotherms of representative samples with different TOC contents, the locations for these samples are shown in Fig 9. The large gas adsorption capacity is generally related to the organic rich shale sample, indicating that organic matter is responsible for adsorbing gas in the study shale.

Fig 11. The 3-D plots relating the Langmuir volume with the TOC content, clay minerals content and moisture content. The clay minerals content shows a negative correlation with the Langmuir volume, which could be ascribed to the presence of moisture. The moisture in shales would remove a large proportion of potential gas adsorption sites.

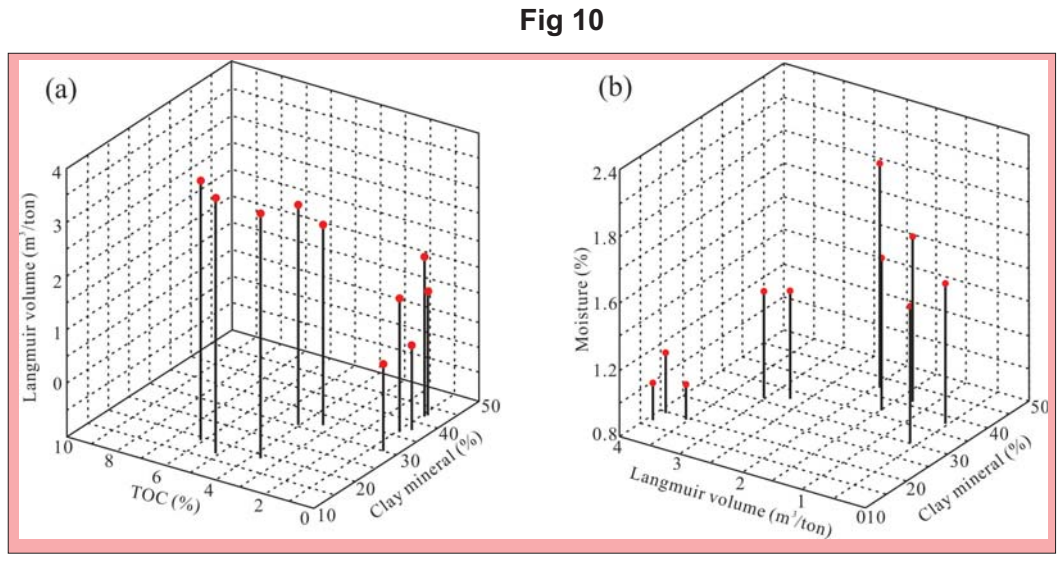


Fig 11

Conclusions

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_1). 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.

Acknowledgements

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