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Influence of Sedimentary Paleoenvironment on Nano-pore Structure of Lacustrine Unconventional Reservoirs-Using a Quantitative Evaluation Method of Geochemistry and Low Temperature N2 Adsorption

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Summary

Lacustrine shale is different from marine shale. Lacustrine shales experience more changeable sedimentary environments. Trace elements and low temperature N_2 adsorption (LTNA) were used to quantitatively study the relationships between environment and pores. BET surface area and BJH pore volume are positively related, and they are negatively related to BJH average pore diameter, which means smaller pores have a dominant contribution to the surface area and pore volume. Additionally, the relationships between sedimentary paleoenvironment and nano-pore structure are complex. Based on the study, paleo-weathering is the dominant factor with the relatively high correlation coefficients (Table 1, Figure1). The humid conditions and oxidation conditions have the weak positive correlations with the BET surface area and BJH pore volume. Conversely, the hydrodynamic force, deposition rate and salinity are negatively related (Table 1, Figure1).

Introduction

Lacustrine shales reservoir present greater complexity and were more easily affected by the paleoenvironment than marine shales. They also differ from marine shales in terms of the water depth, energy, medium, sediment type, biological effect, provenance, mineralogy, organic matter content, and reservoir type (Chen, 2015). The study of shale reservoirs plays an important role in the development of shale oil and gas resources (Curtis, 2002). Sedimentary paleoenvironment is an important factor of shale reservoir and its quantitative study is mainly based on geochemical methods, such as trace elements, major elements and isotopes (Hatch, 1992). In the above geochemical methods, trace element has a good correlation with the sedimentary environment and it is always used. Low temperature N_2 adsorption (LTNA), traditionally, can produce the adsorption pore (most of pore radius<100 nm) fractal characterization by Frenkel–Halsey–Hill (FHH) model and Neimark methods. It is a good way to quantify the nano- pore structure. We combine these two quantitative methods to study the relationships between sedimentary paleoenvironment and nano-pore structure of lacustrine shale.

Method

Trace elements can be a good quantitative inversion of sedimentary paleoenvironments. We chose Ni, Co, Th, U, V, Sc, Ce, Sr, Cu, Ba, Zr, Rb and rare earth elements (REE) to quantitatively study the paleoenvironments. The values of Ni/Co, V/Sc, δ Ce are positively correlated with the paleo-redox environment, and the ratio of Th/U, conversely, is negatively correlated (Hatch and Leventhal, 1992; Jones and Manning, 1994; Rimmer, 2004; Yan et al., 2009). The high values of Sr/Cu indicate a humid paleo-climate (Reheis, 1990; Chen et al., 2009). The values of LREE/ HREE, $(Ce/Yb)_N$, $(La/Sm)_N$ are positively correlated with the paleo-weathering (Roy and Smykatz-Kloss, 2007). The ratios of Sr/Ba, $(La/Yb)_N$ and Zr/Rb increases with the increasing of sanity, deposition rate and hydrodynamic force, respectively (Dypvik and Harris, 2001).

LTNA can be a good quantitative method to evaluate the nano-pore structure and the parameters BET surface area (S), BJH desorption cumulative volume of pores (V) and BJH desorption average pore diameter (D) are selected for this research.

Examples

All samples are selected from the Da'anzhai Member in the Sichuan basin of China. Correlation coefficients can be used to evaluate the relationships between these indicators of sedimentary paleoenvironment and nano-pore structure, and the results are as shown in Table 1.

Table 1. Correlation coefficients of between indicators of sedimentary paleoenvironment and nano-pore structure.

	Ni/Co	Th /U	V/Sc	δ Ce	Sr/Cu	LREE/ HREE	$(Ce/Yb)_N$
S	-0.52	0.72	-0.47	-0.69	-0.66	0.90	0.37
V	-0.69	0.65	-0.57	-0.77	-0.82	0.96	0.27
D	0.72	-0.60	0.70	0.73	0.78	-0.47	0.33
	$(La/Sm)_N$	Sr/Ba	$(La/Yb)_N$	Zr/Rb	S	V	D
S	0.87	-0.72	0.91	-0.74	1.00		
V	0.99	-0.85	0.90	-0.83	0.86	1.00	
D	-0.54	0.78	-0.43	0.69	-0.62	-0.52	1.00

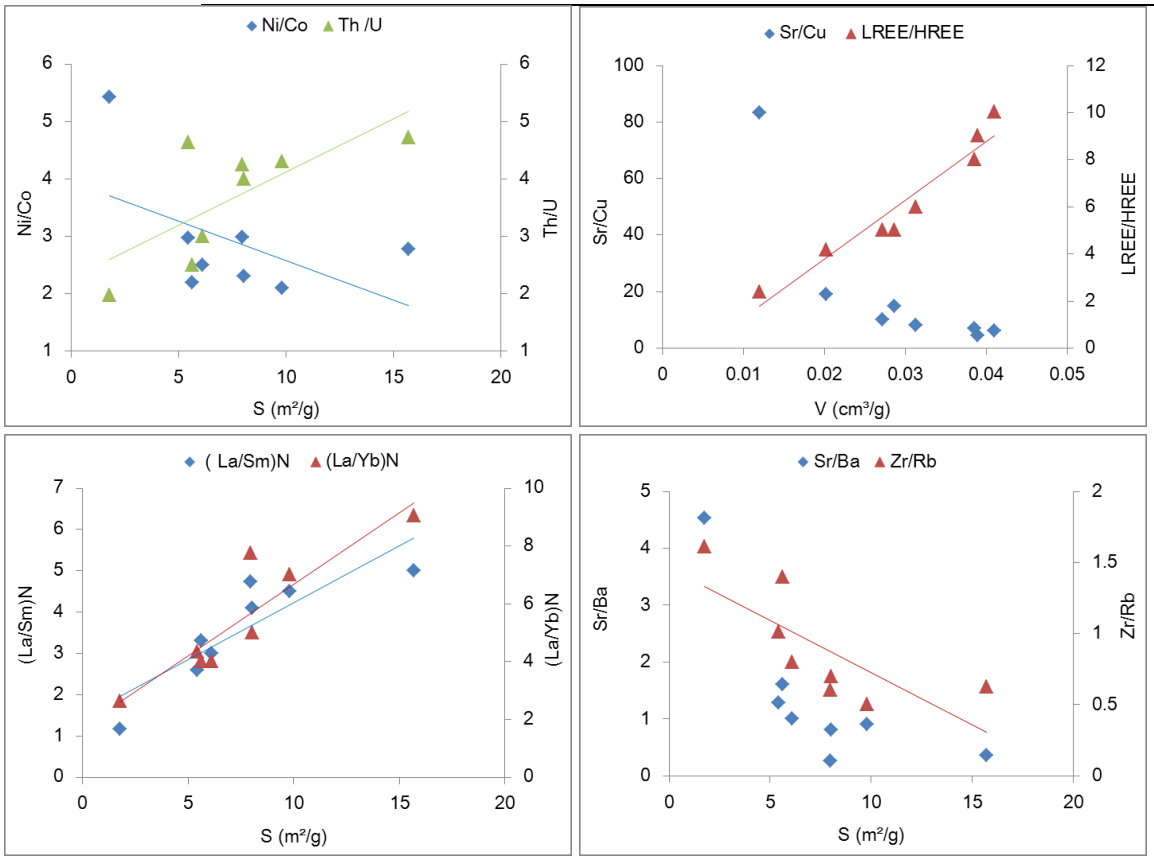

Figure 1. Correlation plots correlating the BET surface area(S) and BJH pore volume (V) with the indicators of sedimentary paleoenvironments.

Conclusions

The quantitative evaluation method of trace elements and low temperature N_2 Adsorption can be effective and useful. The relationships between sedimentary paleoenvironment and nano-pore structure are complex. Based on the study, paleo-weathering is the dominant factor with the relatively high correlation coefficients. The humid conditions and oxidation conditions have the weak positive correlations with the BET surface area and BJH pore volume. Conversely, the hydrodynamic force, deposition rate and salinity of water are negatively related.

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