

# Relationship between shale gas reservoir pores structures/connectivity and organic matter/inorganic matrix in Wufeng-Longmaxi formation of Southeast Sichuan basin, China

Jianyang Song<sup>1</sup> and Luofu Liu<sup>2</sup>

<sup>1</sup>China University of Petroleum-Beijing

<sup>2</sup>China University of Petroleum Beijing

November 26, 2022

## Abstract

**Abstract:** In Sichuan basin, the Longmaxi-Wufeng formation is rich of the shale gas, and the study of control factors of pores structure and connectivity are extremely significant for exploration of shale gas. Organic matter and inorganic matrix attribute to shale reservoir characters strongly. Though this work has been carried out by others before, it still has some arguments for this topic. In this project, we collected rock samples from oilfields, we did SEM, CO<sub>2</sub> adsorption CH<sub>4</sub> adsorption N<sub>2</sub> adsorption, high pressure mercury injection, microscope observation, NMR, XRD, TOC test some related experiments. Analytical results show that TOC contents of the samples range from 0.96% to 6.12%, and the Wufeng-Longmaxi formation shale organic matter content is high. The samples porosity and permeability range from 0.49%-9.55% and 0.0006mD-0.73mD respectively, and the I/S of clay mineral amount ranges from 10%-60%. A plenty of graptolites were observed in the formation under microscope, and reflectivity of graptolites and solid bitumen can reveal that organic maturity is high in the formation. The higher the TOC percentage of sample, the higher the graptolite reflectance is. There are hydraulic fractures under microscope and SEM observation, and some of hydraulic fractures formed by stress, and some of them formed by hydrocarbon generation. Inorganic pores including bedding fracture, structural pores, intercrystalline pores, intergranular pores and dissolved pores and organic pore including corrosion pores, gas pores, bitumen spherulite pores can be observed. We observed quartz, calcite, feldspar under SEM to identify their cementation, filling, different periods' growth, and aeolotropism. Based on these analysis data, authors inferred the shale diagenetic evolution is at the diagenetic B period, the mineral bitumen mass and solid bitumen macerals organic matters are contributed to the shale gas mainly, and by calculating the plane porosity by MATLAB, the fractal dimension is about 2.57. Pores diameters of these samples range from 1-55nm, and the maximum is 4nm. Most pores are around medium pores. In summary, shale gas migrates obeying non-Darcy flow along pores/fracture several nanometers, and gas migration affected by organic matter mainly in Wufeng-Longmaxi formation in Southeast Sichuan basin, China.



Relationship between shale gas reservoir pores structures/connectivity and organic matter/inorganic matrix in Wufeng-Longmaxi formation of Southeast Sichuan basin, China

Jiayang Song<sup>1, 2</sup>, Luofu Liu<sup>1\*2\*</sup>

1. State Key Laboratory of Petroleum Resources and Prospecting, China University of Petroleum (Beijing), Changping, Beijing 102249, China

2. College of geosciences, China University of Petroleum (Beijing), Changping, Beijing 102249, China



China University of Petroleum-Beijing

American Geophysical Union Fall Meeting

Abstract

In Sichuan basin, the Longmaxi-Wufeng formation is rich of the shale gas, and the study of control factors of pores structure and connectivity are extremely significant for exploration of shale gas. Though this work has been carried out by others before, it still has some arguments for this topic. In this project, we collected rock samples from oilfields, we did SEM, CO<sub>2</sub> adsorption N<sub>2</sub> adsorption, high pressure mercury injection, microscope observation, TOC test some related experiments. A plenty of graptolites were observed in the formation under microscope, and reflectivity of graptolites and solid bitumen can reveal that organic maturity is high in the formation. The higher the TOC percentage of sample, the higher the graptolite reflectance is. There are hydraulic fractures under microscope and SEM observation, and some of hydraulic fractures formed by stress, and some of them formed by hydrocarbon generation. Inorganic pores including bedding fracture, structural pores, intercrystalline pores, intergranular pores and dissolved pores and organic pore including corrosion pores, gas pores, bitumen spherulite pores can be observed. We observed quartz, calcite, feldspar under SEM to identify their cementation, filling, different periods’ growth, and aeolotropism.

Introduction

Nowadays, China has already utilized the shale gas from southeast Sichuan Basin to contribute the nation. China has become more and more attached importance to the shale gas. The Ordovician and Silurian Wufeng-Longmaxi formation shale is rich in graptolite organic matter shale. The graptolite content of this shale is higher, and the TOC content is also higher. Graptolites occurred in the lower Palaeozoic marine ocean, and they lived globally, graptolites fossils can be found in many places Ordovician and Silurian formatins, such as Sichuan Basin and Ordos Basin. (Bustin 1989) Graptolite is concludes the fusellar, cortical bandage, parasacula, periderm, and which is depending on their growth segmented structure (Crowther 1981). Graptolites grew from Ordovician Katian, Hirnantian to Silurian Rhuddanian, Aeronian, and graptolite structure is anisotropy (Chen 2006). However, what kind of maceral yields to hydrocarbon is not well in graptolite-rich shale study recently. Organic pores of graptolites are not quantitative, this paper will demonstrate the issue of graptolite shale pore structures of organic and inorganic and their conjunction and agreement.

Geological background

The Sichuan basin locates in the southwest of China; it is the significant natural gas basin in China, the natural gas transfer to the east of China for utilizing. The boundary of Sichuan Basin is Longmenshan, Micangshan, dabashan, Qiyueshan, daloushan, daliangshan fault. The Wufeng-Longmaxi group is Ordovician and Silurian formation, occurred 400 million years ago. During this period, the mountains occurred in Sichuan Basin, and the ocean become smaller, it is the passive continental margin, the sedimentary is huge, and the Yangzi continent and the inner basin nature changed a lot (Cai 2016). Sichuan Basin, the boundary uplifted and the water body is shallow, the silicon shale sedimentary in Ordovician and Silurian time. We can see the formation of Wufeng-Longmaxi formation shale in the open-field, the brown and grey shale weathering by chemical, physical and biological factors, besides there are bentonite generated parallel with the shale formations.

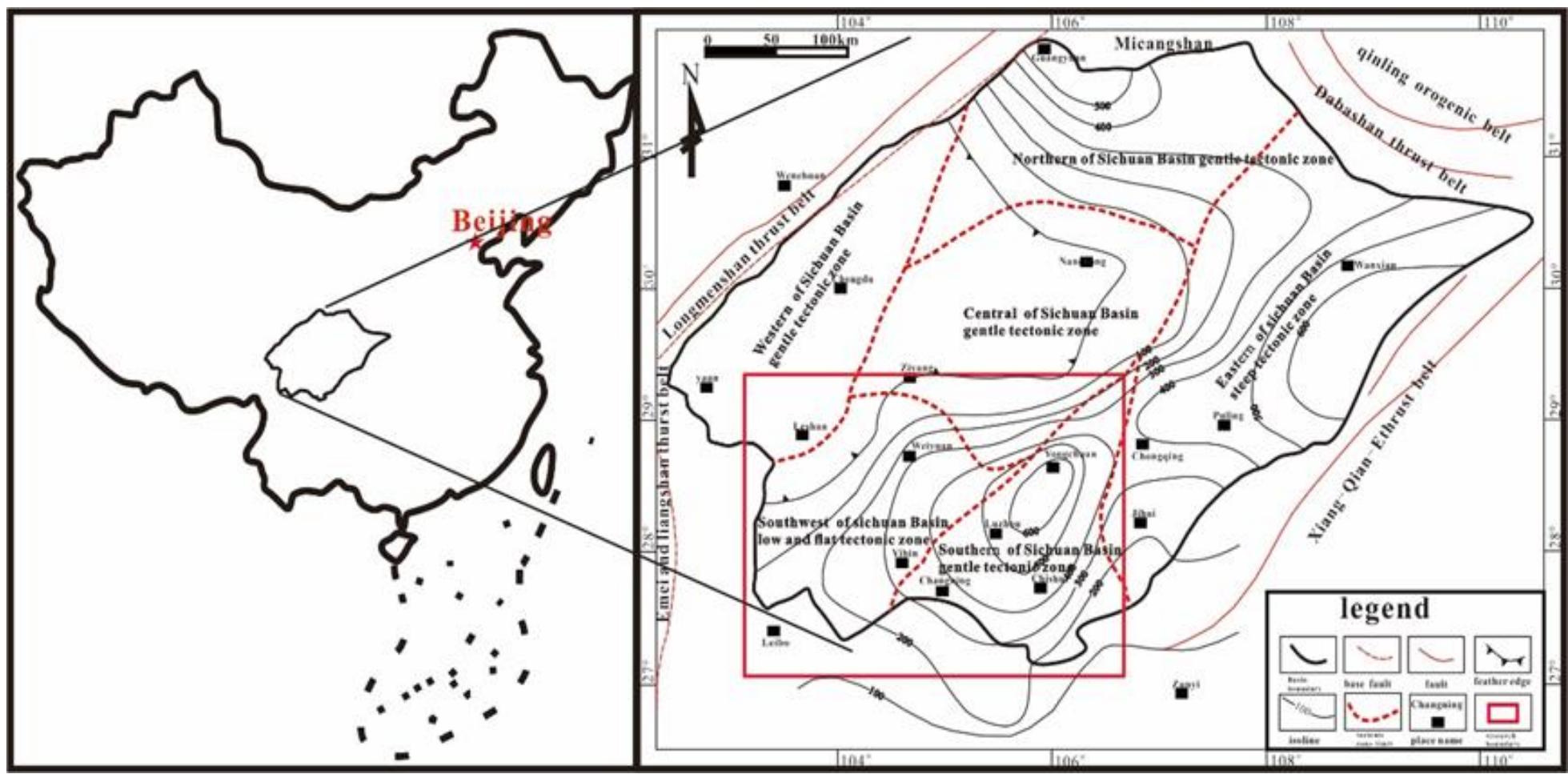


Figure 1. Map of southeast Sichuan Basin, China



Figure 2. The open-field sections of Wufeng-Longmaxi Formation in Southeast Sichuan Basin, China

Sample and Methods

The samples were taken from the Chengdu oilfield core rocks, then we chose some of the samples, cut, polished and we did microscope observation, and SEM, some of samples were cut, then we make the samples into the 60-100 mesh, then we did the CO<sub>2</sub> and N<sub>2</sub> absorption test for research the graptolite shale absorption desorption characteristics.

Results and discussion

Analytical results show that TOC contents of the samples range from 0.96% to 6.12%, and the Wufeng-Longmaxi formation shale organic matter content is high. The graptolites morphology is clear under microscope observation, Figure 3 “a, b and i” shows the graptolites under microscope, we can observe graptolites fusellar, cortical bandage, parasacula, periderm there are iron pyrite also can be observed, because of the quarts, feldspar, calcite, the graptolites the straight graptolite, the symmetrical graptolite, the graptolite shale combine with the solid bitumen quarts, minerals, and the graptolite and organic matter relationship is confused. We observed the fluid inclusion, which indicate that the hydrocarbon migration from fractures and the solid bitumen also is observed, it means that the hydrocarbon occurred pyrolysis and migrated in the shale formation. We observed many fractures under microscope, referred that shale gas could migrate along these tiny fractures. Some of the fractures are formed by forces of tectonic, but some of them are formed by sedimentary procedure, they are bedding fracture parallel the formation stratification. The solid bitumen, under microscope it is aeolotropism, and sometimes it is confused with graptolite. We can observed the graptolite virgella, sicula, asymmetrical structure under microscope, we also can observed the pores margin of graptolite in Figure 3 “a and b” (Chen 2005). These fractures and pores margin would provide migration pathways for shale gas in Figure 3 from “e” to “i”. TOC and clay content relationship is positively, and the quartz and TOC content relationship is tiny negatively, the marine graptolite-rich shale deposited in the deep water. Organic matter is from the lower planktonic algae and graptolites . The quartz originated from the marine matrix. The fractal dimension ranges from 2.035 to 2.777 about the samples. Relationships of surface area, pore volume are positive. These pores formed by the thermal procedure. The marine shale macerals are graptolies, mineral matrix, we refered the kerogen pyrolysis into the solid bitumen. Clay content is higher, quartz is lower, and the plagioclase, pyrite, calcite contents are not higher. We oserved the oganic pores, graptolite pores in the samples (Figure 3 h and i), organic pores can conserve shale gas.

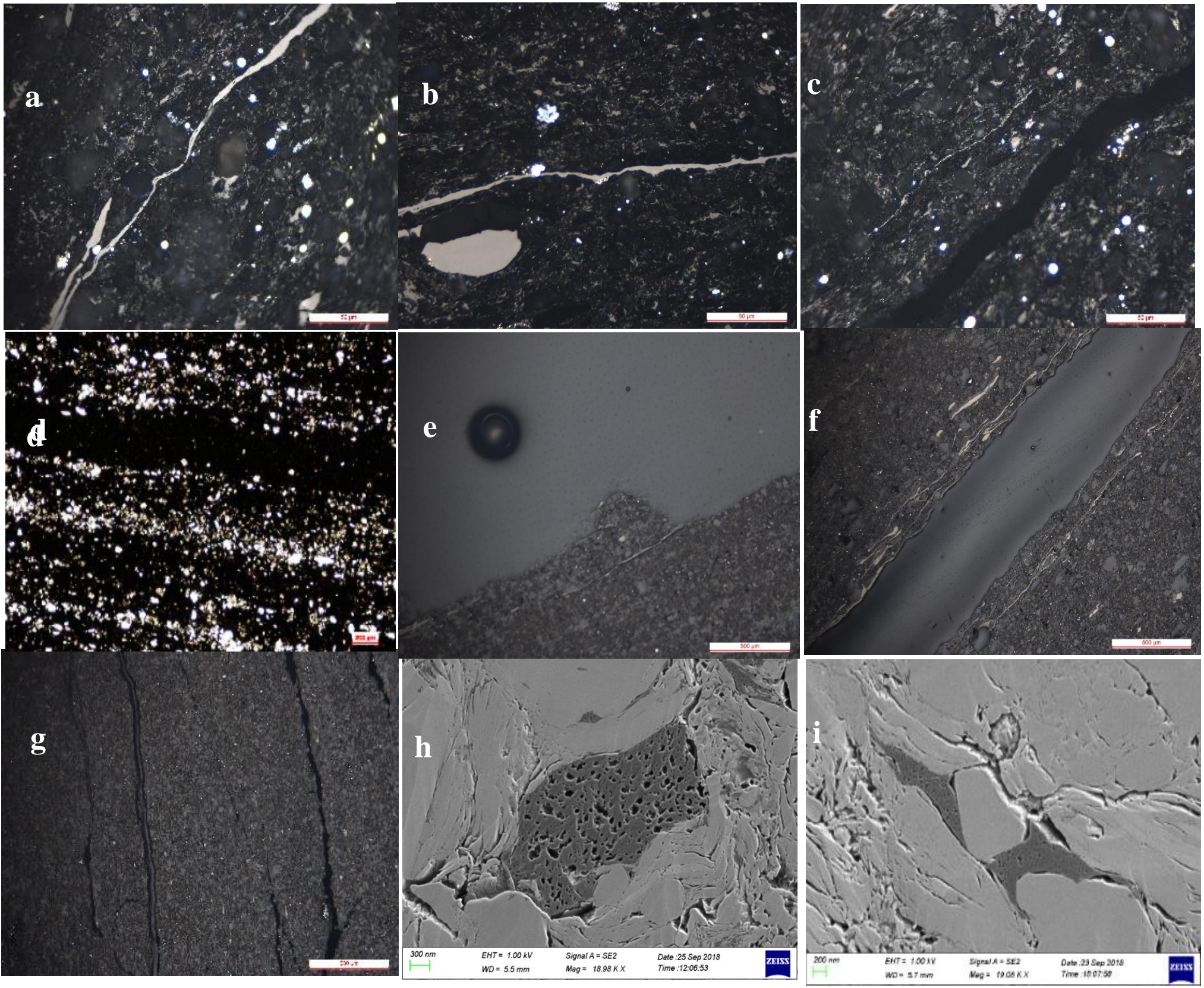


Figure 3. The Wufeng-Longmaxi formation shale microscope section picture and SEM, “a” “b” the graptolites and solid bitumen, “c” “d” “e” “f” “g” “h” the fracture of shale, “i” SEM picture, and “e and f” fluid inclusion.

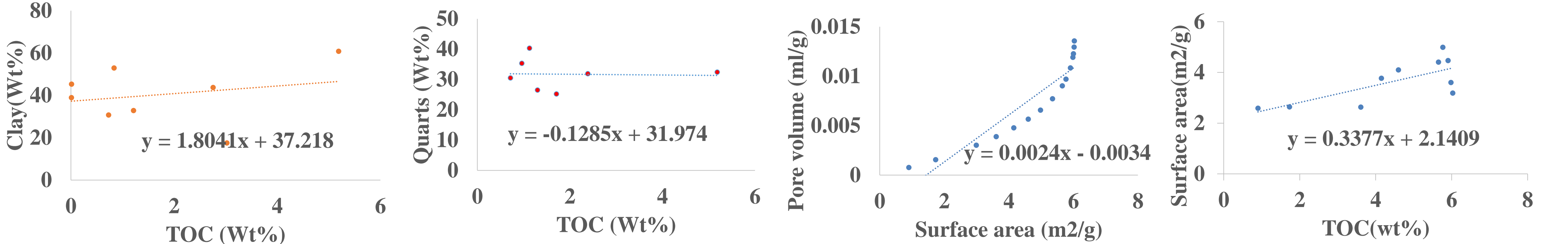


Figure 4. The relationships between TOC content and clay, quarts content, surface area pore volume of Wufeng-Longmaxi formation

CONCLUSIONS

1. We refer fractures are good for the shale gas migration, pores structures, organic and inorganic matrix, Organic matter and inorganic matrix attribute to shale reservoir characters strongly.
2. Authors inferred the shale diagenetic evolution is at the diagenetic B period, the mineral bitumen mass and solid bitumen macerals organic matters are contributed to the shale gas mainly, and the fractal dimension is about 2.619. Pores diameters of these samples range from 1-55nm, and, most pores are around medium pores 10nm.
3. In summary, shale gas migrates obeying non-Darcy flow along pores/fracture short distance, and gas migration affected by organic matter mainly in Wufeng-Longmaxi formation in Southeast Sichuan basin, China.