Contribution ID: **708** Type: **Oral 20 Minutes**

Comparative Study on Nano-scale Pore Heterogeneities of Marine and Lacustrine Shales by Multifractal analysis

Monday, 14 May 2018 10:23 (15 minutes)

The heterogeneous nano-scale pore structures have a significant effect on hydrocarbon properties and matrix mechanics in shale. Marine and lacustrine shales may have varying pore structures due to different depositional settings. Understanding the nano-scale pore structures in marine and lacustrine shales can provide important insights into fractal geometry theory. Therefore, we use the low-pressure nitrogen adsorption and new visual method of multi-scale field emission scanning electron microscopy (FESEM) to measure the geochemical and petrological characteristics of marine and lacustrine shale cores. Based on the fractal and multifractal analysis to study pore heterogeneities, we explicitly investigate the shale microstructures, including irregularities and distributions and their relations to transport phenomena.

In this work, we collect 32 lacustrine shale samples from Lower Jurassic Formation and 10 marine shale samples from Longmaxi Formation of Sichuan Basin in China. We carry out the spatial fractal analysis by nitrogen adsorption with Frenkel-Halsey-Hill (FHH) model, which has been widely applied in the characterization of the pore size distributions and properties. And use visible multi-scale FESEM images to investigate pore heterogeneities by multifractal analysis.

The results of low-pressure nitrogen adsorption with FHH model show that all samples, adsorption fractal dimensions can be classified into two regions based on fractal dimensions D1 and D2, corresponding to large pores and small pores, respectively. For both marine and lacustrine shales, D1 is generally larger than D2, indicating the weaker heterogeneity in small pore structures. Meanwhile, The fractal dimension D1 and D2 of lacustrine shale are generally lower than that of marine shale, indicating smaller heterogeneity in lacustrine shale, due to lower maturity and fewer organic pores.

Based on the features of multifractal spectrum curves, the results of the multifractal analysis show that the heterogeneities of lacustrine shale are generally lower than that of marine shale, which is the same as the FHH model. Meanwhile, the three multifractal parameters of multifractal spectrum curves depicted that the heterogeneities closely related to the shale composition, organic matter properties, and geophysical characteristics. The multifractal parameters of marine shale are generally larger than lacustrine shale, indicating that marine shale pore structures are more complicated.

Compared with results of FHH model by nitrogen adsorption, the results of multifractal analysis by multi-scale FESEM could provide more accurate information on the heterogeneity properties of shale samples. The measurements of petrophysical and geochemistry properties are closely associated and multifractal parameters. In addition, the quantitative analysis of multifractal parameters is in agreement with the field research, which is important for the evaluation of oil and gas flow system in shale.

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Session Classification: Parallel 1-G

Track Classification: MS 1.02: Fractal Theory and its Applications to Flow and Transport Properties of Porous Media