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Research Advances

A New Discovery on the Deformation Behavior of Shale Gas Reservoirs Affecting Pore Morphology in the Juhugeng Coal Mining Area of Qinghai Province, Northwest China

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Objective

The Juhugeng mining area in Qinghai Province of northwest China has attracted wide attention among geologists for it hosts typical coal measure gases. The shale gas reservoirs were reformed by intensive structural movements during geological periods, resulting in the deformation of shale pores. The different temperature-pressure conditions and the rock mechanics properties of shales have resulted in differences between brittle and ductile deformations, which led to different types of shale pore deformation affecting the physical properties of shale reservoirs. In this study, the deformed shales in the Middle Jurassic coal-bearing measures were investigated, with samples collected from fault-zone in typical boreholes. The pore characteristics of brittle and ductile deformations were observed at a microscopic scale, and then the deformed shale pores caused by brittle and ductile deformations were discussed.

Methods

Nine deformed shales taken from fault-zone were prepared for experiments. Five of them are brittle deformation samples, while the others are ductile deformation samples. Field Emission Scanning Eletron Microscope (SEM) was used to observe microscopic pore characteristics of brittle and ductile deformation samples, and then, the ratios of short to long axis of shale pores (designated λ for convenience), including primary texture shale samples and brittle and ductile deformation shale samples, were counted for the analyses of the brittle and ductile deformations effect on shale pores.

Results

The SEM results show that the shale pores are mainly composed of inter-particle pores which are associated with clastics and flaky clay minerals. There are also intra-particle pores and organic-matter pores. The effects of brittle and ductile deformations on shale pores are various: (1) pores in brittle deformation samples are usually cut by the microfractures, including inter/ intra-particle pores, which increase the pore volume and pore connectivity; (2) pores in ductile deformation samples are compressed by rumpled structures and irregularly overturned flaky clay minerals, with inter-particle pores being greatly influenced while intra-particle pores and organic-matter pores being less compressed. The connective channels of pores are compressed further by the ductile deformations, particularly occurred on inter-particle pores of flaky clay minerals. As a result, the pore connectivity is lowered.

Based on extensive ratios statistics of short to long axis (define λ of 0–0.3 as λ_1, 0.3–0.6 as λ_2, 0.6–0.9 as λ_3) of primary texture and brittle and ductile deformation shale pores (Fig. 1), it is found that the proportions of λ for brittle deformation shales are essentially the same with that of primary texture shales. However, the proportions of λ for brittle deformation shales are different from that of brittle deformation and the primary texture shales, indicating that the pores are greatly affected by the ductile deformations, and brittle deformations have little influence on the pores.

The variation values of λ for brittle and ductile deformation shales can denote the deformation strength of shale pores. According to the percentage of different λ in different pore-size ranges (Fig. 1), the deformation strength of shale pores can be obtained. (1) In the range of 0–100 nm in pore size, the proportion of λ_3 for ductile deformation shales is about the same with that of brittle deformation shales, however, the proportion of λ_2 of ductile shales is lower than that of brittle shales, with the proportion of λ_1 of ductile shales being higher than that of brittle shales, showing that the pores with λ of 0.3 to 0.6 are compressed into pores with λ less than 0.3. (2) Similarly, pores with λ of 0.3–0.9 are compressed into pores with λ <0.3 within the range of 100–1000 nm in pore size. (3) Pores with λ of 0.6–0.9 are compressed into pores with λ <0.6 in the range of pores greater than 1000 nm in

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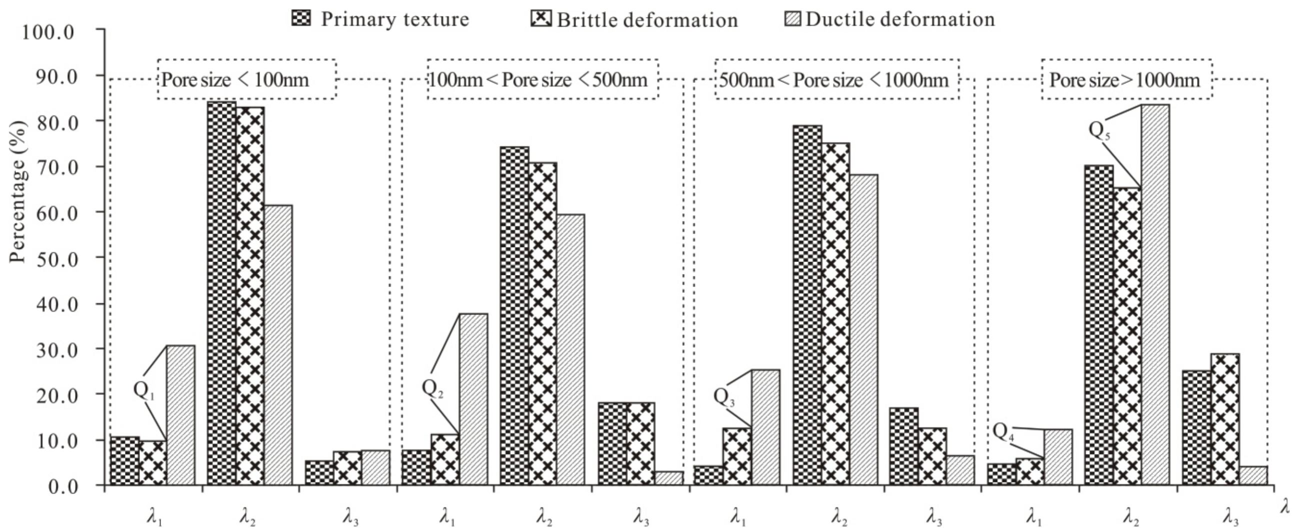

Fig. 1. Proportions of λ in different pore-size ranges.

Note: For convenience and as defined in the text, λ denotes the ratios of short to long axis of shale pores; λ_1 denotes λ value of 0–0.3; λ_2 denotes λ value of 0.3–0.6; λ_3 denotes λ value of 0.6–0.9.

size. Therefore, the λ change values in the range of 100–1000 nm in pore size are the greatest, suggesting that the deformation strength of pores with width of 100–1000 nm are the most obvious.

As shown in Fig. 1, the difference values of percentage of λ (Q), where the proportions of ductile deformation are higher than that of brittle deformation, can be regarded as the amounts of compressed pores. Comparing with values of Q in each pore-size range, the amounts of compressed pores with widths between 100 and 500 nm are the biggest (Q_2 = 26.64%), followed by the amounts of compressed pores that greater than 1000 nm in size with values of 24.67% (Q_4+Q_5).

Conclusions

(1) Shale pores in the Juhugeng mining area are dominated by inter-particle pores, followed by intra-particle pores, and the organic-matter pores are the least. The inter-particle pores are easily to be reformed, while the intra-particle pores and organic-matter pores are less reformed.

(2) The shale pores are greatly influenced by the ductile deformation, while the brittle deformation has little influence on shale pores. Pores with widths between 100 and 1000 nm have experienced the strongest deformation strength, and amounts of pores with widths between 100 and 500 nm are greater than that of other pores.

(3) The brittle deformation improved the shale pore connectivity by cutting all types of pores, while the ductile deformation mainly affected the inter-particle pores and lowered the shale pore connectivity.

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