A study on the prediction of critical water saturation of shale when it has sealing capacity

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Shale itself contains a certain amount of water, and the water reduces the seepage ability of shale. With the increase of water saturation (SW), the water in shale pores will change from water film to capillary water. Capillary water can block seepage channels, which gives shale the ability to seal. The current research work on shale gas preservation and carbon dioxide capture, utilization, and storage (CCUS) pays great attention to this capillary sealing phenomenon in shale, so the corresponding critical water saturation (CSW) is worth studying. However, the pore system of shale is complex. It contains both organic and inorganic pores, but due to the obvious difference in hydrophilicity between the two, water is mainly hosted in the inorganic pores. And shale has strong heterogeneity. The shale with different total organic carbon content (TOC) has different development degrees of organic pores and inorganic pores. Therefore, the TOC and pore structure pose a great challenge to predict the CSW of shale. In our study, the TOC of the Silurian Longmaxi Formation shale samples was tested first. Then, based on kerogen preparation technology and pore structure characterization methods, CO_2 and N_2 gas isotherm adsorption experiments were carried out on shale and its kerogen samples. Then, the pore volumes and proportions of organic pores and inorganic pores were calculated based on the data obtained from the isotherm adsorption experiments. Finally, the CSW of shale simples was calculated by the sum of the water content of organic and inorganic pores according to the defined boundary conditions of the geological model. The results show that the TOC of shale samples range from 0.89 % to 5.10 %. The pore volume of shale its kerogen samples range from 0.0185 to 0.0298 cm^3/g and 0.0020 to 0.0179 cm^3/g. With the increase of organic matter content, the pore volume of shale and its kerogen show an increasing trend. The proportion of organic pores ranges from 10.19 % to 67.63 %, and the proportion of inorganic pores ranges from 32.37 % to 89.81 %. The proportion of organic pores and inorganic pores both have a good correlation with TOC. This means that the shale with higher TOC has more organic pores and less inorganic pores. And the CSW of shale samples range from 19.42 % to 53.88 %, which is positively related to TOC. According to the fitting of CSW and TOC, a general formula for calculating critical water saturation when shale has sealing ability was obtained. This research provides effective guidance for predicting the CSW of shale when it has the sealing ability, and it deepens the understanding of the occurrence characteristics of water in shale and its influence on the sealing ability of shale. Usually, due to changes in depositional environment, the TOC of shale in a certain set of formations often has obvious changes. Therefore, in the actual geological model, the CSW of shale at different depths is different. Thus, this study can be used to further describe the preservation conditions of the geological model in more detail, so as to improve the theory of shale gas accumulation and guide the field work of shale gas exploration and development and CCUS.