Characteristics of wufeng-longmaxi formation shale gas sweet layer: a case study of weiyuan-rongchang block in the south of sichuan basin, China

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Abstract. Taking the typical shale well of the Wufeng-Longmaxi Formation in the Weiyuan shale gas block of the South Sichuan Basin as an example, based on core observation, core slice, ar-ion milling SEM, physical property test, X-ray diffraction, geochemical analysis and on-site gas content test, the author systematically evaluated the Wufeng-Longmaxi geological sweet layer from the aspects of petrology, mineral composition, organic geochemistry, hydrocarbon-generating organism, physical property, pore type and gas content. The research shows that the lithology of the geological sweet layer in Weiyuan area is mainly composed of black carbonaceous shale, and laminae are developed. Compared with the Jiaoshiba area, the carbonate mineral content is higher and the quartz mineral content is relatively lower. The sweet layer has high TOC, and is at a stage of high maturity. It is rich in hydrocarbon-generating organism such as graptolites, algae, sponge bones and bacteria. The inorganic pores and organic pores of the sweet layer are well developed. The inorganic pores are mainly clay mineral pores, feldspar alteration pores and intercrystalline pores of pyrite. In terms of gas content, it has the characteristics of high gas content and high Initial dissipation rate, which provides a possibility for high yield and stable production of fracturing in this layer. The geological sweet layer has high organic carbon content, is rich in hydrocarbon-generating organisms, has a large potential for gas generation, and generated enough gas after a period of high mature evolution; at the same time, a large number of inorganic pores and organic pores generated in diagenetic evolution, these pores provide space for shale gas generation, as the same time, it increases the permeability of the sweet layer. The study area has good preservation conditions, it has favorable top and bottom Stratum conditions, and does not have large destructive fractures and destructive fluid activities, The above factors make the shale gas enriched and preserved, which provides the possibility of high and stable yield after fracturing.

1. Introduction
China has also made a series of major breakthroughs in shale gas exploration. Among them, the southern Sichuan region has become a hot area for shale gas exploration and development (Guo T, 2014; Wang Y, 2012; Borjigin T, 2017). However, due to the low natural productivity of shale gas reservoirs, it is necessary to undergo fracturing to have industrial value, resulting in higher exploration and development costs. Therefore, how to evaluate the best shale gas exploration and development areas and layers, namely the preferred “sweet area” and “sweet layer”, is the key to shale gas exploration and development (Wang S, 2018).

The main research object is the Wufeng-Longmaxi shale formation in the Weiyuan shale gas block of the South Sichuan Basin (fig 1). Based on core observation, core slice, argon ion milling SEM, physical property test, X-ray diffraction, geochemical analysis and on-site gas content test, the author systematically evaluated the Wufeng-Longmaxi geological sweet layer of WY23-1. The mechanism of shale gas enrichment in “sweet layer” was discussed. Core slice observation, argon ion polishing-scanning electron microscopy, physical property testing, X-ray diffraction, and geochemical analysis were all completed at the Sinopec Wuxi Institute of Petroleum Geology.

![Figure 1. Regional location and stratigraphic division](image)

According to the lithology, electrical properties, the distribution of graptolites, the change of TOC and the gas content, the Upper Ordovician Wufeng Formation-Lower Silurian Longmaxi Formation in Weiyuan area is divided into 9 small layers (fig 1). Exploration and development shows that the sweet layer is mainly distributed in the layer 1-4, and fracturing is selected in the layer 1-4, which can achieve better commercial yield.

2. Results

2.1. Lithologic characteristics and mineral characteristics
Taking WY23-1 well in Weiyuan block of southern Sichuan as an example, the lithology of the sweet layer is mainly composed of black carbonaceous shale, rich in graptolites and laminae, and experimental analysis shows that the more developed the laminae, the better the reservoir properties of the sweet layer. The lithology of the non-sweet layer is gray-black carbonaceous shale and light-gray sandy shale. The development of the laminae are reduced, and the reservoir properties are relatively poor. The siliceous content of the Wufeng-Longmaxi section of Well Wei 23-1 is higher. Among them, the siliceous content
of layer 1-4 is between 18.0% and 69.0%, with an average of 33.7%. The siliceous content of layer 5-9 is between 28.0% and 40.0%, with an average of 34.3%. The carbonate content is high. The mineral content of the carbonate in the Wufeng Formation-Longmaxi Formation is 2.0%-51%, with an average of 17.2%, significantly higher than the Jiaoshiba area.

2.2. Organic geochemical and hydrocarbon-forming organisms characteristics
The data shows that the TOC of the Wufeng Formation-Longmaxi Formation in Weiyuan shale gas field is between 0.06% and 6.04%, mainly distributed between 2% and 4%, with an average of 2.27%. The measured Rb of Well 23-1 is between 2.62% and 2.75%, with an average of 2.69%. The Ro is between 2.1% and 2.2%, with an average of 2.15%. The analysis results indicate that the thermal evolution of the Wufeng-Long shale in the area is at a high maturity stage, shale hydrocarbons are dominated by dry gas. The organic shale organic matter type in the study area is a saprolite organic matter formed by lower aquatic plankton and algae, mainly type I kerogen. The micro-component identification of kerogen and the argon ion polishing scanning electron microscope observation of Wei 23-1 showed that the hydrocarbon-forming organisms in the study area mainly include algae, graptolites, bacteria, acritarch and sponge spicule. The algae is the most important hydrocarbon-forming organism in the black shale of the Wufeng-Longmaxi Formation in Weiyuan area.

2.3. Reservoir characteristics
Under the argon ion polishing scanning electron microscope, the matrix pores of the 1-4 layer of the Wufeng Formation-Longmaxi Formation of Weiyuan shale gas field contain inorganic pores and organic pores. There are various types of inorganic pores, mainly including micropores in brittle minerals, clay mineral transformation pores, mineral dissolution pores, and intercrystalline micropores. The organic pores mainly include kerogen structure pores, asphalt cracking gas pores and graptolitides pores.

2.4. Gas content characteristics
Based on the rapid on-site desorption instrument independently developed by Sinopec Wuxi Petroleum Geology Research Institute, on the basis of desorption of typical shale gas in southeastern Sichuan, the IDR(indicating the initial dissipation rate) and total gas content are extracted. The combination of GIP and IDR can better identify the shale gas sweet layer. The high gas content and high initial dissipation rate of WY 23-1 are mainly concentrated in 3, 2, 4 and 1 layers. Among them, at the bottom of 3 layers, GIP and IDR are relatively high, which is the geological sweet layer.

2.5. Mechanism of the sweet layer
The Wufeng-Longmaxi shale gas “geological sweet layer” in the Weiyuan area of southern Sichuan has a high organic carbon content, is rich in hydrocarbon-forming organisms, and has great potential for generating natural gas; the sweet layer has a high level of maturity. At the same time, a large number of inorganic pores and organic pores are generated during the diagenesis, which provides space for the shale gas and improves the permeability of the layer. The Wufeng-Longmaxi shale in the study area has good preservation conditions and no large faults. The top and bottom formations are good cap rocks and there is no destructive fluid activity. The above factors provide favorable conditions for shale gas enrichment.

3. Conclusion
The geological sweet layer in Weiyuan area is mainly composed of black carbonaceous shale, and the laminae are developed; the organic carbon content is high, and it is in the stage of high maturity, rich in hydrocarbon-generating organism such as graptolites, algae, sponge spicule and bacteria fossil; The sweet layer develops inorganic pores (clay mineral pores, feldspar alterations pores, pyrite intergranular pores) and organic pores, and has the characteristics of high gas in place (GIP) and high initial dissipation rate (IDR).
The “Geological sweet Layer” of Wufeng-Longmaxi shale gas in Weiyuan area of southern Sichuan has high organic carbon content, is rich in hydrocarbon-forming organisms, and has great potential for gas generation; the sweet layer has a high level of mature evolution, generating a large amount of natural gas, and at the same time, during the diagenesis process. A large number of inorganic pores and organic pores are generated, which provide space for shale gas generation and improve the permeability of shale formation. The Wufeng-Longmaxi shale in the study area has good preservation conditions, no large fractures, no destructive fluid activity, the above factors provide favorable conditions for shale gas enrichment in the sweet layer, so that the sweet layer has a high initial dissipation rate (IDR) and a high gas in place (GIP). It is possible to produce high-yield and stable production of fracturing.

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