GEOCHEMICAL VARIATION IN THE HIGH THERMAL MATURITY LONGMAXI SHALE GAS, SICHUAN BASIN

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Introduction

Shale gas, as one of the most important and abundant unconventional energy resource trapped within shale in the form of free gas, adsorbed gas and dissolved gas, has been paid much attention during past decade. The shale gas production in 2018 has exceeded 100×10^8 m^3 in China. The Upper Ordovician-Lower Silurian Longmaxi Fm. in the Sichuan Basin, as a key exploration target currently, are characterized by good geological conditions for the shale gas reservoirs, including great thickness, high total organic content (TOC>2%) and gas content, high thermal maturity (Ro>2.0%), suitable present burial depth, good petrophysical properties, preservation conditions and reservoir types (Chen et al., 2016). Significant breakthrough of shale-gases has been made in the Weiyuan, Jiaoshiba, Pengshui, Dingshan and Yongchuan areas. A time series of produced shale gas samples from different blocks mentioned above were collected during 4 years period of shale gas production from year 2014–2018. On the basis of molecular composition, stable carbon and hydrogen isotopic data analyses by an integrated method of gas chromatography combined with mass spectrometry, the shale gas geochemical features from different blocks were comparatively studied. Moreover, shale gas genesis and carbon isotopic reversal causation were discussed as well.

Results

The result has shown that all the shale gases are dominated by CH_4 (95.6–99.6%) with minor C_2H_6 (0.28%–0.99%) and non-hydrocarbon gases (mainly CO_2, N_2 each 0.03%–3.81%, 0–1.03%), belonging to typical dry gas with low wetness (0.43–4.37%). The carbon isotopes of CH_4 ($\delta^{13}C_1$) and C_2H_6 ($\delta^{13}C_2$) are -35.4‰–-28.5‰, -38.9‰–-32.4‰ respectively, with a reversal pattern of carbon isotopic compositions ($\delta^{13}C_1 > \delta^{13}C_2$), indicating that the residual oil cracking gas at high-over thermal maturity level is an important source (Zhang et al., 2018). In addition, some shale gases display completed reversal pattern of carbon isotopic compositions with carbon number (i.e., $\delta^{13}C_1 > \delta^{13}C_2 > \delta^{13}C_3$) based on the detection of C_3H_8. The hydrogen isotopes of CH_4 are in the range of -154‰–-132‰. The δ^2H reversals between C_1 and C_2 in some shale gases might be caused by isotopic exchange between CH_4 and H_2O due to High temperatures and mineral-fluid reactions during maximum burial (Burruss and Laughrey, 2010).

Small fluctuations of isotopic and molecular compositions display during 4 years shale gas production in the same well and block, showing an adequate gas supply from matrix to fracture network. However, differences in carbon isotopes among various blocks have been shown. The shale gases in the Weiyuan block display lighter $\delta^{13}C_1$ (-35.9–-35.3‰) and $\delta^{13}C_2$ (-38.9–-37.5‰) values than those in the Yongchuan ($\delta^{13}C_1$ -33.4– -33.1‰, $\delta^{13}C_2$ -35.4–-34.6‰) and Dingshan block ($\delta^{13}C_1$ -32.9– -32.0‰, $\delta^{13}C_2$ -37.0–-36.0‰), then Pengshui block ($\delta^{13}C_1$ -30.4– -28.5‰, $\delta^{13}C_2$ -34.3–-32.4‰) and Jiaoshiba block ($\delta^{13}C_1$ -32.3– -28.9‰, $\delta^{13}C_2$ -36.9–-32.8‰). The difference in carbon isotopic compositions mainly attributes to mixing between varied proportion of oil cracking gas and kerogen cracking gas because of the regional heterogeneity of the Longmaxi marine shale, in particular amount of residual oil retained in organic matter rich shale.

Conclusions

This study further confirmed that the shale gas mainly attributes to the mixing of oil cracking gas and kerogen cracking gas at high-over mature stage in Sichuan Basin. The tectonic uplifting might be other reason to cause the abnormal distribution of carbon isotopes for some blocks.

References

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