Origin of Discharged Water from a Shale Gas Reservoir of the Xujiahe Fm in the Sichuan Basin, China

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The fifth member of Xujiahe Formation (T_{3X}^5) located in the Chuanxi sag, Sichuan Basin is a typical continental shale gas reservoir. No water was produced from the wells prior to hydraulic fracturing, but cumulative water production is significantly more than the injected fracturing fluid afterward. This suggests that the fracturing fluid have been mixed with formation Fm water. The origin of the discharged water was investigated by detailed water chemistry analysis. The results (e.g., rNa^+/rCl^-:0.85±0.7; $(rNa^+-rCl^-)/rSO_4^{2-}$:-150±-1200; $(rCl^- - rNa^+)/rMg^{2+}$:10±6) show that the discharged water is of a $CaCl_2$ type when the flow-back ratio is over 100%. The rNa^+/rCl^- ratios range from 0.7 to 0.85, suggesting that part of the discharged water may be from T_{3X}^4. The Steve Hydrochemical Facies (SHF) diagram indicates that the discharged water from the T_{3X}^5 shale gas reservoir in the Xinchang gas field is dominated by released bound water from the T_{3X}^5 member, and to a lesser extent, from T_{3X}^4. In addition, the Fm water in T_{3X}^5 was originally immobile and bound to the minerals by high Fm pressure with pressure coefficients of ~1.2–1.7 and poor permeability. The enrichment of high-valence cations and low rK^+ and rNa^+/rMg^{2+} ratios, combined with Fm rock XRD data, suggest that the impact of pressure-triggered ion exchange processes may have caused the primary immobile water to transform into free water during the fracturing process. The Alkali Exchange Index (IBE) of 200 to 400, indicates a strong water-rock reaction. Additionally, the improvements of reservoir permeability and a sudden Fm water reduction during the fracturing also play a key role in this alteration.