Modeling Petroleum Expulsion / Retention from the Vaca Muerta Formation, Argentina

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Abstract

Improved understanding and prediction of petroleum expulsion, retention, and producibility from source rocks were achieved through 3D basin modeling, integrating compositional kinetics and geochemistry of the Vaca Muerta Formation, Neuquén Basin, Argentina. Source rock data show both lateral and vertical heterogeneities. Model results indicate that basin wide expulsion likely started between 90 and 25 Ma, when active primary and secondary petroleum generation exceeded the retention capacity of the source rock and associated pore pressure exceeded the hydraulic fracturing threshold. Expulsion likely ceased between 50 and 15 Ma when pore pressure decreased due to the completion of primary generation and secondary cracking of polar components. Through continuous burial, thermal cracking continued from aromatics and saturates to lighter components and coke. However, petroleum retention decreased as coke has less retention capacity than active kerogen. Geological evidence and modeling indicate that tectonic uplift likely started ~15 Ma, which relaxed thermal stress and pore pressure and terminated secondary cracking. Model results also suggest that during the thermal maturation process, adsorbed HCs always exceed free HCs retained in the source rock. Produced oils have similar composition to free hydrocarbons in the source rock pore space, and rock extracts have similar composition to total retained (adsorbed and free) oil. The basin model indicates that (1) polar components are preferably adsorbed in source rock at <0.75%R_o, then cracked throughout maturation, and mostly consumed by about 1.40%R_o. (2) At <1.15%R_o, saturates and aromatics are generated in about equal proportion and stored within the source rock. (3) Saturates gradually

increase relative to aromatics in both free and adsorbed oil due to preferential generation of saturates by thermal cracking and preferential thermal cracking of aromatics, which are mostly consumed by about 1.65%R_o; (4) the preferential adsorption of aromatics causes a higher saturates-to-aromatics ratio in the free oil. The model for a closed system predicts that further maturation would consume residual oil (light saturates) by 2.60%R_o; and that wet gas components would be depleted by 3.35%R_o. The methodology and the insights of this study not only improve the fundamental understanding of petroleum expulsion and retention within the Vaca Muerta Formation, but also can be applied to global unconventional oil and gas plays.