Experimental Investigation of Oil Generation, Retention, and Expulsion Within Type II Kerogen-Dominated Marine Shales: Insights from Anhydrous Gold-Tube Pyrolysis of Barnett and Woodford Shales Using Miniature Core Plugs

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Abstract

Although oil retention has recently emerged as a key topic of unconventional-shale resource assessment, oil-retention and expulsion controls in organic-rich shales during thermal maturation remain poorly constrained. This study presents an experimental comparison of oil generation, retention, and expulsion in two immature, Type II kerogen-dominated marine shales, the Mississippian Barnett Shale and the Upper Devonian-Lower Mississippian Woodford Shale, mainly with respect to the combined effects of the organic macerals and rock fabric involved. In both cases, miniature core plugs drilled from the given samples were isothermally pyrolyzed at 130 to 425°C for 72 h under a confining pressure of 68 MPa during gold-tube pyrolysis, corresponding to the thermally immature, early stage of the oil window, the main stage of the oil window, the late stage of the oil window, the main stage of oil cracking to wet gas, and the late stage of oil cracking. Yields of generated oil, retained oil, and expelled oil for the two studied samples were systematically quantified on the basis of mass-balance calculation of measured oil and gas yields, as well as Rock-Eval analyses on pyrolyzed subsamples. Through the six stages of petroleum formation investigated, the principal difference in oil generation was observed in the two studied samples, with approximately 38 to 68% greater yields of

generated oil for the Woodford Shale when it evolved into the main and late stages of the oil window. These elevated yields of generated oil for the Woodford Shale were compensated for by additional oil generation resulting from conversion of abundant algae such as Tasmanites and Leiosphaeridia, which lag in onset and have a shorter period of petroleum generation upon maturation. As a response to the difference in oil generation, oil retention was found to be significantly enhanced for the Woodford Shale at equivalent stages, with 0.2 to 1.7 times more free oil and 0.7 to 3.9 times more sorbed oil being retained than that of the Barnett Shale, although this effect was not pronounced for oil expulsion. In contrast to the Barnett Shale, relatively low expelled oil yields and expulsion efficiencies both indicate highly limited oil expulsion in the Woodford Shale, implying that the Woodford Shale may have a relatively low permeability rock fabric to prevent oil from being expelled. Furthermore, not only significantly higher oil-saturation index values but also a wider range of maturity at which the oil crossover effect occurs is expected for the Woodford Shale when extrapolation to a geological setting occurs. These data suggest that the presence of abundant Type I kerogen-like algae and relatively low permeability rock fabric in the Woodford Shale are critical to significant oil retention during oil generation and expulsion, which jointly raise the possibility of potential commercial shale oil within Type II kerogen-dominated marine shales.