

The Origin of Bitumen-Filled Horizontal Microfractures in Immature Maastrichtian Carbonate Source Rocks of Jordan New Insights from a Modelling Perspective

Akbar Wicaksono¹, Israa Abu-Mahfouz^{1,2}, Erdem Idiz³, Joe Cartwright³, J. Carlos Santamarina¹, Volker Vahrenkamp¹

¹King Abdullah University of Science and Technology (KAUST);

²King Fahd University of Petroleum and Minerals (KFUPM);

³University of Oxford

Abstract

Understanding the very first generation of microfracturing and expulsion of bitumen from source rocks is critical, as this process provides the first network of pathways for primary migration of hydrocarbons and pore-matrix connection in unconventional reservoirs. It is likely that early pathways are reused repeatedly during later phases of maturation laying thus governing in general expulsion pathways from source rocks. The immature source rock deposits of the Maastrichtian-Early Eocene age in Jordan (TOC 3 to 34 %wt, Ro ~0.34) provide an excellent opportunity to characterize and model the initiation of the bitumen-bearing horizontal microfractures formed prior to maturation. They are comparable and analogous in composition (low clay and high carbonate content, type I/II S kerogen) to other prolific and producing source rocks of the Middle East such as the Tuwaiq, Hanifa, and Jubaila Fm of the Upper Jurassic, and the Shilaif, Natih Fm of the Late Cretaceous. An integrated observation and modeling approach was performed to assess the possible scenarios leading to the bitumen microfracturing. The idea is to back-calculate how much overpressure and bitumen generation was needed in the past to initiate horizontal microfracturing, and then compare those simulated parameters with the actual generation potential from the source rock samples. The results show that the simulated overpressure caused by bitumen generation alone was inadequate to induce horizontal microfracturing. We conclude that the increase of internal pressure must have been caused by the inability of isolated bitumen to be squeezed and compacted into existing pore space during burial. This failure in compaction and restriction in flow, consequently led to an increase of the bitumen load-bearing internal pressure to rise above the overburden loading pressure. The resulting overpressure caused a disturbance to the stable-state stress distribution around the kerogen boundary. This eventually led to the first initiation of horizontal microfractures along the tip of bitumen flakes, followed by a short-distance migration and a significant decrease in pressure. This shows that the primary migration in source rock can occur already at comparatively shallow burial (< 500 m), during the immature and early catagenesis stage. This very first expulsion provides the initial framework pathways and flow pattern control for later migration at higher maturity level that are constraint by the precursor horizontal bitumen microfractures. Understanding these factors is critical to predicting the impact of these microscale fractures on overall hydrocarbon expulsion and storage, and hence likely also productivity of an analogous unconventional reservoir in the subsurface.