

## **Assessment of Geochemical Variability in the Vaca Muerta Unconventional Play, Argentina: An Analogue for the Middle East?**

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### **Abstract**

Shale formations can be hundreds of meters thick exhibiting significant vertical variabilities in mineralogy, petrophysical and geomechanical properties [Passey et al., 2010]. In addition it was shown meanwhile that also kerogen and fluid qualities can vertically vary in unconventional reservoirs [Elias et al., 2014]. As it is likely that many of the thin and low permeability shale layers are hydraulically disconnected before being fracked, many of these self-sourced “micro-reservoir-layers” may initially host fluids of variable composition. As a consequence unconventional petroleum exploration nowadays aims to identify sweet-spots based on fluid composition and quality not only on a lateral but also on a vertical scale.

Petroleum fluid compositions and properties basically result from the original kerogen composition, the thermal history of the sedimentary basin, the hydrocarbon expulsion efficiency and the present-day reservoir pressure and temperature conditions. It is also well-known that produced fluids can significantly differ in composition and quality compared to the in-reservoir fluids. Based on analyses of fluid and rock extract samples derived from exploration wells we have developed a simple approach to assess the producible fluid composition ahead of production in development wells. Our approach is based on a systematic comparison of bulk, molecular and isotopic compositions between rock extracts and produced hydrocarbon fluids.

The rock, dead oil and mud gas samples analysed for this study are derived from six different wells (well A-D) targeting the Upper Jurassic / Lower Cretaceous Vaca Muerta Formation in the Neuquén Basin, onshore Argentina. The Vaca Muerta Formation was deposited during the Tithonian and Berriasian times and is characterized by a rhythmic alternation of marls, shales and limestones (Kietzmann et al. 2011). The wells are located in geographically different areas of the basin, and therefore the Vaca Muerta Formation reached basinwide distinct thermal maturities, whereas samples analysed for this study represent the peak oil to gas / condensate window. Core extracts, dead oils and mud gases were analysed for their bulk and molecular composition by Iatroscan, GPC-UV, GC-FID, GC-MS and for their stable carbon isotopic composition by compound-specific-isotope-analysis (CSIA).

The results of our study show that the Vaca Muerta Formation is characterized by a significant vertical variability in organic-richness. Moreover, we show that not only the kerogen quantity but also the original kerogen quality can vary significantly in vertically distinct intervals. This implies that also the quantity and composition of generated hydrocarbon fluids can vary vertically at well scale. Consequently, some intervals of the Vaca Muerta unconventional play must be hydraulically disconnected before being fracked. Our data also clearly show that on a regional scale within the Neuquén Embayment fluid compositions are mainly controlled by the thermal maturity. It appears likely that lateral

organofacies changes occur also beyond the area covered by the studied wells and can lead to remarkable variations in the composition of the generated hydrocarbons. In this study we also demonstrate that well-established geochemical parameters such as the Hydrogen Index and the mud gas composition can be used to roughly estimate the thermal maturity, and hence, the fluid quality at well site. Geochemical parameters such as the newly suggested GPC-ratio can be defined in cuttings or SWC samples from any development well to assess quickly the producible oil composition and quality. Consequently, we believe that that it will also be possible to allocate the vertical intervals contributing to the produced hydrocarbon liquid (production allocation in unconventional reservoirs). The geochemical data from the Vaca Muerta Formation suggest that it is important to perform high-resolution sampling and analysis in any unconventional play. We believe that the Vaca Muerta case study can be used as analogue also for potential unconventional plays in the Middle East such as the basinal facies of the middle Cretaceous Shilaif (Khatiyah) Formation.