

## HYDROCARBONS EXPULSION BEHAVIOR OF DIFFERENT ORGANIC-RICH SHALE LITHOFACIES: A MULTI-SCALE, MULTI-METHOD APPROACH

L. Di Paolo<sup>1</sup>, E. Di Paola<sup>1</sup>, E. Bonamini<sup>1</sup>, E. Previde Massara<sup>1</sup>, R. Galimberti<sup>1</sup>

<sup>1</sup> Eni S.p.A, San Donato Milanese, Italy

### Introduction

Several parameters influence hydrocarbon expulsion process such as pressure and temperature, sedimentary facies, mineralogy, rock texture and fabric, organic matter type, distribution and pore volume. The conventional approach to the study of the hydrocarbon expulsion is mainly based on geochemical parameters that, focusing on the organic matter and hydrocarbon generation process, fails to take account of inorganic fraction and macro-to nano scale structural features.

In this study we carried out an alternative integrated multi-scale, multi-method approach by combining hydrocarbon generation parameters with oil characteristics, mineralogy, macro and micro-scale rock texture and fabric, distribution and porosity of kerogen. In order to limit the influences of different parameters governing expulsion process, we focus on the study of an interval of middle mature type II marine source rocks.

The first-order objective of this study is understanding the lithotypes-lithofacies effect on the expulsion processes in a highly heterogeneous shaly source rock, establishing relationship between organic and inorganic elements. Understanding the lithofacies effect on the hydrocarbon expulsion processes is key for the expulsion model implementation and to better predict the fluid distribution in relation to the rock properties in source-reservoir systems.

### Methods

Several samples of organic-rich shale were analyzed including the lithofacies classification. The mineralogical composition was derived from X-ray diffraction (XRD). The source rock potential, kerogen-type, maturity and retained hydrocarbon yield were determined by means of Rock Eval pyrolysis and optical analysis. Selected samples were investigated in detail for kerogen distribution, rock fabric and texture, porosity type and size of organic matter by means of optical microscopy and High Resolution Scanning Electron Microscopy (HR-SEM). Analysis of the extract composition was performed by means of Gas Chromatography-Mass Spectrometry (GC-MS).

### Results

Sedimentological description based on grain size, texture and geometry of sedimentary structures allowed to recognize nine main lithofacies that on the base of mineralogical and geochemical characterization, were grouped in four main clusters: i. fine clay-rich argillaceous and siliceous mudstone, ii. Fine/medium silica-rich argillaceous and siliceous mudstone, iii. Medium/coarse carbonate and siliceous mudstone, iv. Coarse carbonate-dominated lithotype. The Total Organic Carbon (TOC) values correlating with mineral content and lithotype show that organic matter quantity increases generally from the coarse carbonate dominant lithotypes to the fine/medium argillaceous ones but seems to be: i. independent on quartz content for all the lithotypes, ii. slight negative dependent on total carbonates for medium/coarse carbonate and siliceous mudstone and for coarse carbonate-dominated lithotypes, iii) slight positive dependent on clay content for fine/medium silica-rich argillaceous and siliceous mudstone, medium/coarse carbonate and siliceous mudstone and coarse carbonate-dominated lithotypes.

In the Jarvie's (2012) free oil (S1) versus TOC plot, S1 is scattered dependent on TOC. Furthermore, two trends are visible: a trend constituted mainly by the fine/medium argillaceous siliceous mudstone placed in the "low oil content" area and a trend composed mainly by the coarse carbonate and siliceous mudstone that is placed in the "oil shows/producing oil" areas. The Oil Saturation Index (S1 free hydrocarbons normalized to TOC content) plots versus mineral contents shows a negative trend with clay and quartz content for the fine/medium argillaceous and siliceous mudstone and for the medium/coarse carbonate and siliceous mudstone.

Biomarker analysis shows very similar character of the analyzed oils, molecular differences are observed only in the n-alkanes: the retained petroleum associated to the carbonate and siliceous samples is slightly enriched in long-chain n-alkanes, whereas the retained petroleum in the argillaceous siliceous mudstone is characterized by abundant short chain n-alkanes.

The optical microscope and HR-SEM images highlight the organic matter (OM) distribution and porosity in the different layers of selected samples: A) Discontinuous lens of OM associated to fine-matrix (argillaceous siliceous layers) are usually slightly porous, fracture or complex type typically in the 1 $\mu$ m length range are also present. B) Slight mesh network squeezed OM, associated to relative medium/fine matrix (siliceous argillaceous layers), shows often fracture and complex type porosity. C) Big discrete mesh network of OM (clearly migrated) is associated to granular matrix and shows micrometer fracture-like pores.

In both fine argillaceous/siliceous matrix and medium/fine siliceous/argillaceous layers there is also OM associated with clays, which is really finely dispersed and characterized by nanometric porosity (always less than 100 nm),

## Conclusion

The results obtained from this case study show that fine grained clay-rich levels have higher expulsion efficiency compare to medium/coarse grained carbonate and siliceous layers, in detail: i. the kerogen and solid bitumen content is the main factor controlling free hydrocarbons (S1) retention/storage capacity, ii. For equal kerogen content, an important role is played by mineralogy: the shaly intervals exhibit slightly lower storage capacity of free oil, iii. the molecular signature of the retained petroleum indicate expulsion of long chain in the clay levels and preferential migration and storage of long chain n-alkanes in carbonate siliceous layers, iv. Organic matter particles dimension and pore size increase with increasing granular texture favoring the accumulation of expelled long chain hydrocarbons in coarse grained quartz and carbonate-rich levels and expulsion in fine grained clay-rich levels that reach saturation level first.

## References

Jarvie, D. M., 2012. Shale resource systems for oil and gas: part 2 — shale-oil resource systems. In: Breyer, J.A. (Ed.), Shale Reservoirs—Giant Resources for the 21st Century. AAPG Memoir 97, pp 89-119.