Three-dimensional imaging of tight gas host rock – Observations and conceptual models

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Unconventional reservoirs such as shales and tight sandstones contain large reserves of natural gas. Natural gas production from these formations is becoming more and more common. The behavior of the reservoirs is markedly different from conventional gas reservoirs, which have greater porosity and permeability. In order to develop a greater understanding of gas production from tight gas reservoirs, we are studying samples at various scales ranging from centimeter to nanometer. Examination across scales allows us to better infer processes that occur at different scales. Iimaging at larger scales allows us to select regions for more detailed examination.

To understand gas flow and production in tight gas, several questions must be answered. First, what is the location of the gas in place – is it compressed within the pore space, contained within a solid or liquid (brine, organic, or mineral phase), or adsorbed on solid surfaces. Second, how does the gas move through the tight rock formation to wells. We primarily focus on the second question, while trying to provide data to answer the first.

In our studies, we nondestructively image appropriate samples at several scales (centimeter – millimeter and millimeter-micron) using x-ray computed tomography (CT), x-ray computed microtomography at the Advanced Light Source at LBNL. To examine the rock and pore structure at micron to nanometer scale, we sequentially mill our sample and then image it using focused ion beam (FIB) and scanning electron micrscopy (SEM).

Pore spaces in shales appear fracture-like in nature and poorly connected. In tight sandstones, pores may be visible on the several-micron scale, but may be partially occluded by high-surface area clays or other material, raising questions as to the effect of partial brine or gas condensate saturation on the permeability to gas.

Numerical modeling of flow in tight formations has been initiated using the Maximal Inscribed Spheres technique [1].

[1] Silin & Patzek (2006) *Physica A* **371**, 336–360.

Organic-rich facies of the top Ibex–Margaritatus zones (Pliensbachian) of the Lusitanian Basin (Portugal): TOC and biomarkers variation

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The on-shore hemipelagic record of the top Ibex–Margaritatus zones (Lower-Upper Pliensbachian) of the northern part of the Lusitanian Basin (Portugal) is characterized by the occurrence of organic-rich marly facies, including several black-shale intervals [1] with a proven high potential for hydrocarbon exploration [2]. In this study, we present the lateral and temporal variation of the Total Organic Carbon (TOC) content (over 100 samples) and of several selected source and thermal maturity related biomarkers (over 55 samples) from that organic-rich facies, at a basinal scale.

Usually, the highest TOC values, around 15–20%, are recorded in the distal areas of the basin (western, namely at Peniche and S. Pedro de Moel). However, one black-shale level, located at the Ibex–Davoei transition, systematically has higher TOC values (reaching up to 27%), even in the proximal hemipelagic sectors. Preliminary palynofaciological observations suggest that this level may correspond to microbial mats. In the most proximal sector (eastern, Tomar), no organic-rich facies are recorded.

Source-related biomarkers, like the *n*-Alkane distribution pattern and the C_{27}-C_{28}-C_{29} $\alpha\alpha\alpha$ (20R) ternary plot, show that organic matter consists of a mixture of marine and continental components, preserved in a marine depositional environment. Thermal maturity related biomarkers (CPI, $H_{32}S/(R+S)$, M_{30}/H_{30}) indicate that these sections have a low thermal maturity.

The high-resolution correlation of these black-shales, at a basinal scale, will enable modelling organic matter production, accumulation and preservation. Therefore, our results are crucial to the prediction of the occurrence of such facies in the Portuguese off-shore, in the deep-sea areas beyond the Berlengas Horst.

[1] Duarte *et al*. (2010) *Geologica Acta*, in press. [2] Oliveira *et al*. (2006) *B. Geoci. Petrobras* **14**, 207–234.