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The thermal history and hydrocarbon source rock potential of the mid Carboniferous Quebradas Formation in SW Portugal and its correlatives in eastern Atlantic offshore basins

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ABSTRACT

The mid Carboniferous Quebradas Formation of the 'South Portuguese Zone' (SPZ) *comprises 80m of post-mature black mudrocks with a mean TOC of 2.5%. Lithostratigraphic units of similar facies and age such as the Holywell Shale, the Edale Shale and the Bowland Shale are important HC source rocks in the UK, having sourced a considerable proportion of the hydrocarbons in the East Irish Sea, East Midlands and Formby oilfields respectively. The kerogen content of the Quebradas Formation is mixed but slightly more oil-prone in its lower part. At outcrop, it is strongly post-mature with vitrinite reflectance (R_r) ca. 4%. Illite crystallinity results from the Quebradas Formation and associated units suggest lower maturity than vitrinite reflectance. Analysis of the optic fabric of very thin coal lenses within the Brejeira Formation which overlies the Quebradas Formation suggests that peak temperatures were attained before the Variscan (late Carboniferous – early Permian) deformation. Triassic rocks unconformably overlying the Carboniferous sequence are much less mature, with R_r ca. 1.2%. Although the the Quebradas Fm has no HC source potential onshore due to its high maturity, Carboniferous rocks offshore may not have experienced the same extreme thermal history as the SPZ.*

KEYWORDS: Portugal, Quebradas Formation, Carboniferous, Maturity, Thermal history.

1. Introduction

The mid Carboniferous Quebradas Formation of the 'South Portuguese Zone' (SPZ) comprises 80m of post-mature black mudrocks with a mean TOC of 2.5% (based on 65 analyses). The TOC of this unit when within the oil window is estimated to have been *ca.* 3 – 4%. Lithostratigraphic units of similar facies and age such as the Holywell Shale, the Edale Shale and the Bowland Shale are important HC source rocks in the UK, having sourced a considerable proportion of the hydrocarbons in the East Irish Sea, East Midlands and Formby oilfields, respectively. Palynofacies analysis of samples from the Quebradas Formation indicates a mixed kerogen content but slightly more oil-prone in its lower part.

2. Thermal History

At outcrop near Murração, the Quebradas Formation is strongly post-mature with vitrinite reflectance (R_r) *ca.* 4%, as it presumably also is throughout the SW part of the SPZ, where it is overlain by a thick sequence of post mature late Carboniferous turbidites, principally of the Lower – Middle Pennsylvanian Brejeira Formation. Several lines of independent evidence shed light on the thermal history of the southern part of the SPZ:

1) Vitrinite reflectance (R_r) is uniformly high throughout the thick Upper Palaeozoic sequence in the SPZ, with no apparent correlation between stratigraphic position and VR (McCormack, 1998, McCormack *et al*., 2007). A poorly-constrained trend of decrease in maturity from N to S exists.

2) Illite crystallinity (Kübler Index) results from Upper Palaeozoic mudrocks throughout the SPZ indicate a position spanning the Deep Diagenetic Clay Maturity Zone and Low Anchizone Clay Maturity Zone of Merriman (2005), suggesting lower maturity than the vitrinite reflectance and palynomorph colour data.

3) Analysis of the optical fabric (*sensu* Levine and Davis, 1984 and 1989) of very thin coal lenses within the Brejeira Formation at Arrifana (figure 1) suggests that peak temperatures were attained before the Variscan (late Carboniferous – early Permian) deformation that has strongly affected the Carboniferous succession throughout the region. These results do not preclude a subsequent thermal event raising temperatures close to, but not exceeding those attained during the first event.

4) No Permian sediments are preserved in the region but Triassic rocks unconformably overlying the Carboniferous sequence are much less mature, with R_r *ca.* 1.2%.

An interpretation of Palaeozoic thermal history consistent with the evidence outlined above entails an intense but short-lived late Carboniferous heating event prior to the main phase of Variscan deformation. This timing is supported by the optical fabric results and the short duration of this event is supported by the mis-match in maturity between the illite crystallinity and VR results. Post-tectonic heating during the latest Carboniferous elevated temperatures in the Upper Palaeozoic rocks currently at or near surface to temperatures close to, but not exceeding, those attained during the earlier thermal event. This did not result in the 'overprinting' of the optical fabric of the coals.

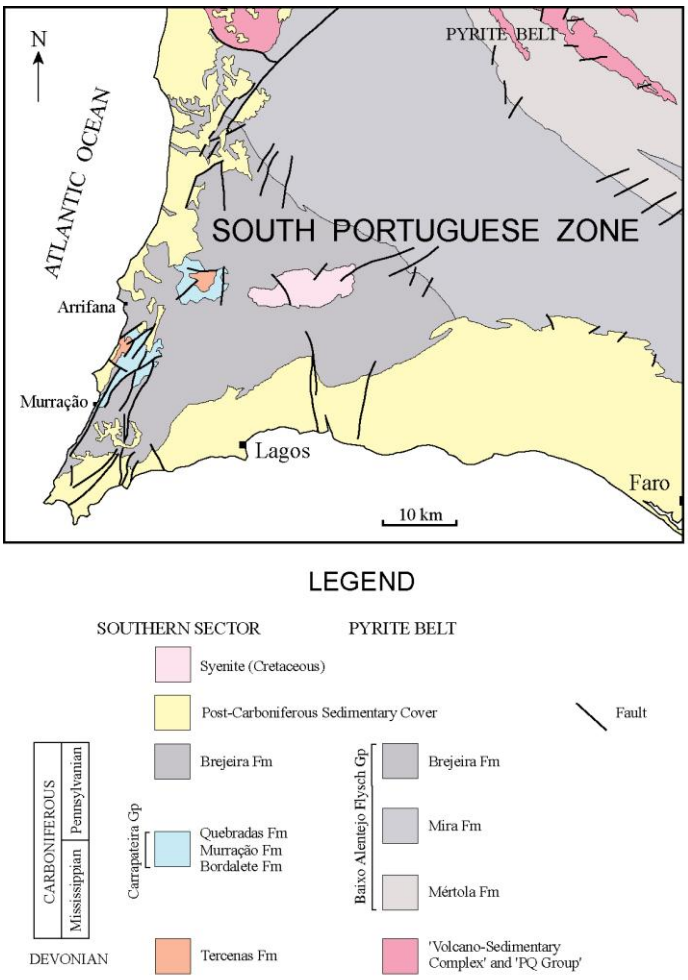

FIG. 1 - Outline geology of the 'South Portuguese Zone' with locations of the Arrifana and Murração sections shown (after McCormack *et al*. 2007).

3. Hydrocarbon source rock potential

Although the Quebradas Formation has no HC source potential onshore due to its high maturity, Carboniferous rocks offshore may not have experienced the same extreme thermal history as the SPZ. The widespread distribution of mid-Carboniferous black mudrocks throughout Western Europe suggests that these may be present in many offshore basins where Carboniferous rocks have been preserved.

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