Characterization of the Lias of the Lusitanian Basin, Portugal, as an Unconventional Resource Play*

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Search and Discovery Article #80376 (2014)
Posted May 26, 2014

*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG 2014 Annual Convention and Exhibition, Houston, Texas, April 6-9, 2014, AAPG © 2014

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Abstract

Porto Energy recognized the potential of the Lias (Lower Jurassic) as an unconventional resource play while drilling Triassic pre-salt prospects in Portugal's Lusitanian basin. Through its subsidiary Mohave O&G, Porto then embarked on a program to acquire additional geological data to characterize that potential and to address questions raised by previous work about TOC, thermal maturity, and environment of deposition. This program included drilling 23 shallow wells (160 m average depth up to 451 m) to collect cuttings and cores in the Lias section over a wide geographic area. Each well was logged, and Geolog with a geochemical field unit analyzed over 500 samples for TOC, Tmax, and other geochemical parameters. Geolog also ran each sample through XRD and XRF, and cuttings from 15 old oil and gas wells were included in the effort. Part of the challenge was addressing issues of TOC (1) differences between outcrop, cuttings, and cores, (2) how to determine average TOC values, (3) Tmax differences between sources of data; and (4) bias in Ro data due to basinal location. Based on these analyses, additional work done in the program and past analyses, Porto ascertained the extent of the resource play in the basin, its environment of deposition (carbonate deposition in a sag basin versus an open marine carbonate ramp as previously thought), its resource play parameters, and “sweet spot” areas to drill in the next phase of its exploration of the Lias. The Lias is characterized throughout the basin by a TOC average range of 2.3 to 5.9%, Ro values of 0.5 to 1.8 and quartz-carbonate content of 63.8 to 83.7%. Also, porosity (from shallow wells) ranges from 0.2 to 19.8% over a total thickness of up to 400 m (average 200 m). Kerogen type II is dominant in the Lias in the prospective middle of the basin with drilling depths of 1000 to 3500 m. The identified sweet spots

of the Lias play cover over 3000 sq km (over 800,000 acres). The Lusitanian basin's Lias shares many of the properties of other unconventional resource plays in North America (Eagle Ford, Niobrara, and Utica), as well as other Lias plays in Europe.

Background

Porto Energy recognized the potential of the Lias (Lower Jurassic) as an unconventional resource play while drilling Triassic pre-salt prospects in Portugal's Lusitanian basin. The section of primary interest is an Upper Sinemurian/Lower Pliensbachian carbonate section which consists of alternating, shallow to deep marine argillaceous limestones and marls. There are two organic-rich marls, the Vale das Fontes Formation and the Polvoeira Member of the Agua de Madeiros Formation separated by a limestone interval of varying thickness (Figure 1). Through its subsidiary Mohave O&G, Porto then embarked on a program to acquire additional geological data to characterize that potential and to address questions raised by previous work about TOC (total organic content), thermal maturity, and environment of deposition.

The University of Coimbra had measured TOC values greater than 20% in outcrop samples, and the Lias interval is well known as a major source rock in the basin. However, additional studies of TOC from exploration well cuttings show TOC values most often below 1%. Early reports from various sources, such as Shell in the 1970s on their offshore wells, cast some doubt on the interval's thermal maturity, with values consistently below 1.0%. Previous work done on the environment of deposition of the Lias led many to believe that the environment was that of a carbonate ramp deepening to the north-northwest from the center of the basin. Recent seismic data, mostly not available to academia, indicate a sag basin environment was more likely, resulting in a basin-wide distribution of the Lias organic-rich interval rather than a restricted area in the northwest. One major contribution from previous work at the University of Coimbra is that they show very thin intervals sampled in outcrop can be correlated over great distances, consistent with a stable basin environment and consistent with the interval uniformity seen in the seismic data.

Results of Recent Program

The program to acquire additional data included drilling 23 shallow wells (160 m average depth, one well 451 m deep) to collect cuttings and conventional cores in the Lias section over a wide geographic area. Each well was logged by an automobile-conveyed logging system for SP, induction, and gamma ray. Geolog, with a geochemical field unit, analyzed over 500 samples for TOC, Tmax, XRD, XRF, and other geochemical parameters, as the cuttings and core were delivered to them, allowing for real-time decisions on adjustments to the drilling program and decisions as to which samples for further study. Cuttings from 15 old oil and gas wells were also included in the effort. Other work included seismic data reprocessing, core descriptions, thin-

section analyses, and porosity and permeability measurements. Porto and its partners completed all of this work in 8 months with a budget of $1 million. The evaluation program used by Porto can be a model for efforts in other basins, especially where well control is limited.

Porto faced challenges in addressing issues of TOC differences between outcrop, cuttings, and cores, the best way to determine average TOC values, Tmax differences between sources of data, and bias in Ro data due to basinal location. The well documented differences between core and outcrop TOC values (generally higher) and values derived from legacy well cuttings (generally lower) can be explained several ways. There can be a natural outcrop and core sampling bias toward sampling the darkest zones (those that appear to be the most organically rich). Samples of cuttings on the other hand are homogenized and somewhat diluted by the drilling process and tend to greatly underestimate the potential richness in an interval. To overcome these biases, an average TOC value for each well was derived by sampling conventional core at regular intervals and normalizing TOC values of cuttings from correlative section which exhibited TOC values one-third of core TOC values. To use the most data possible, Porto had to reconcile Tmax data obtained in its program with another study which tended to show higher Tmax values. Finally, most Ro data obtained in the past had been from outcrop and shallow oil and gas exploration wells in areas that had never been buried deeply. These locations were most often near inversions and salt movement.

Based on the analyses of cores and cuttings, detailed seismic interpretation, additional work done in the program, and past analyses, Porto determined the extent of the resource play in the basin, its environment of deposition (carbonate deposition in a sag basin versus an open marine carbonate ramp as previously thought), its resource play parameters, and “sweet spot” areas to drill in the next phase of its exploration of the Lias. Porosity (from shallow wells) ranges from 0.2 to 19.8% over a total thickness of up to 400 m (average 200 m) (Figure 2).The Lias is characterized throughout the basin by a TOC average range of 2.3 to 5.9%, Ro values of 0.5 to 1.8%, and quartz-carbonate content of 63.8 to 83.7% (Figure 3). Organic matter in the Lias is dominantly kerogen type II in the prospective middle of the basin, with drilling depths of 1000 to 3500 m, where Tmax mapping also shows the thermal maturity necessary for oil and gas generation (greater than 450 degrees in the prospective areas) (Figure 4). Additional information, such as oil and gas shows in old wells throughout the basin, oil seeps at the surface, and live oil in shallow Lias cores verify a viable resource interval. The identified sweet spots of the Lias play cover over 3000 sq km (over 800,000 acres). The Lusitanian basin’s Lias shares many of the properties of other unconventional resource plays in North America (Eagle Ford, Niobrara, and Utica) as well as other Lias plays in Europe.

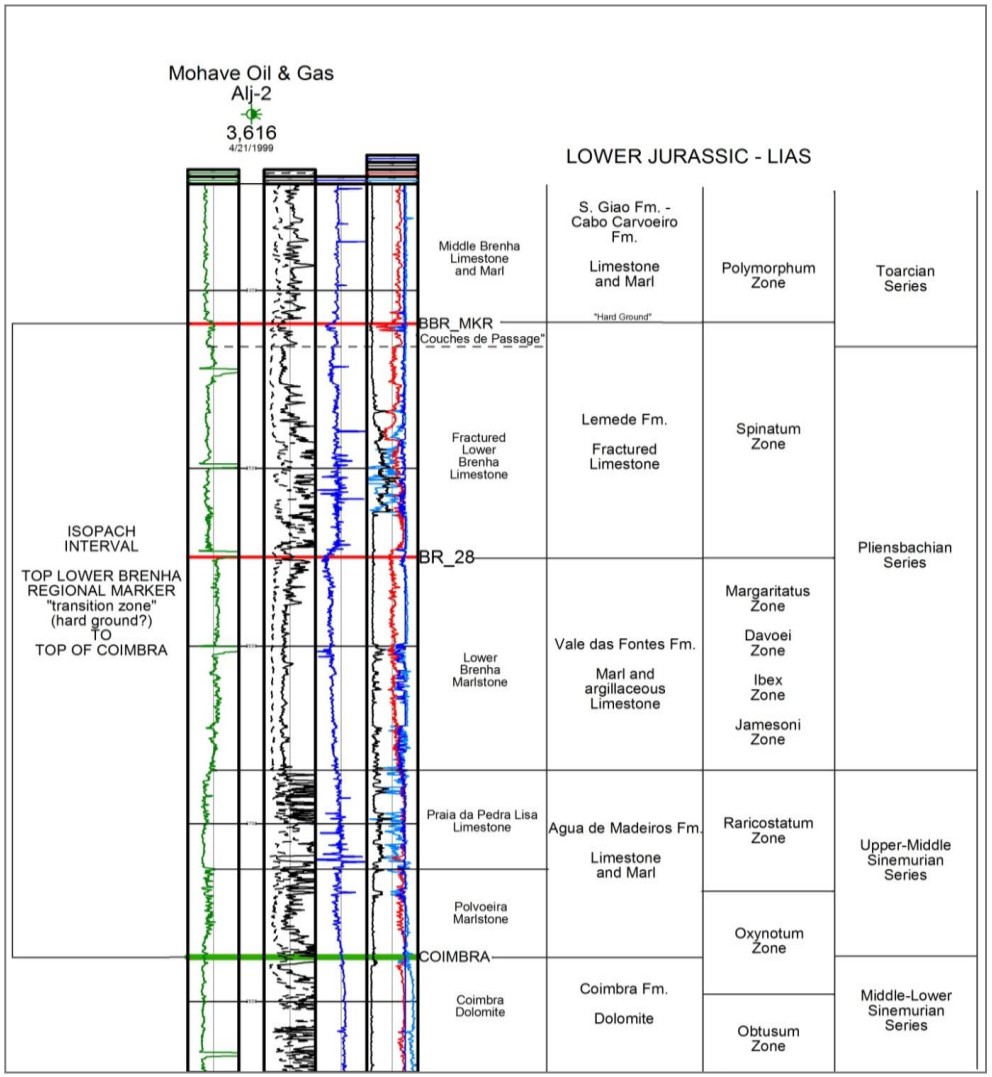

Figure 1. Lias stratigraphy and isopach interval.

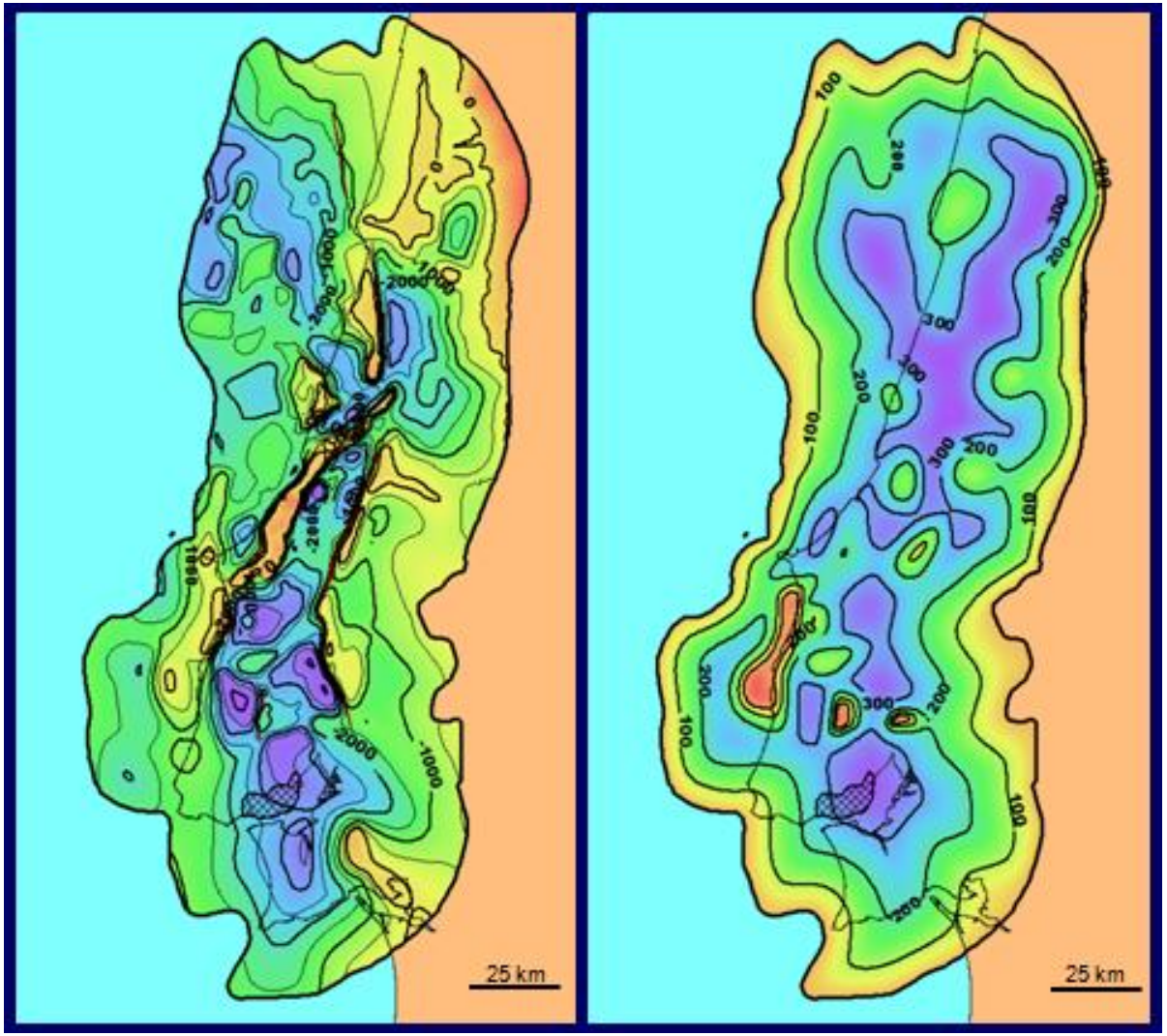

Figure 2. Structure map (left) and isopach map of the Lias in Portugal.

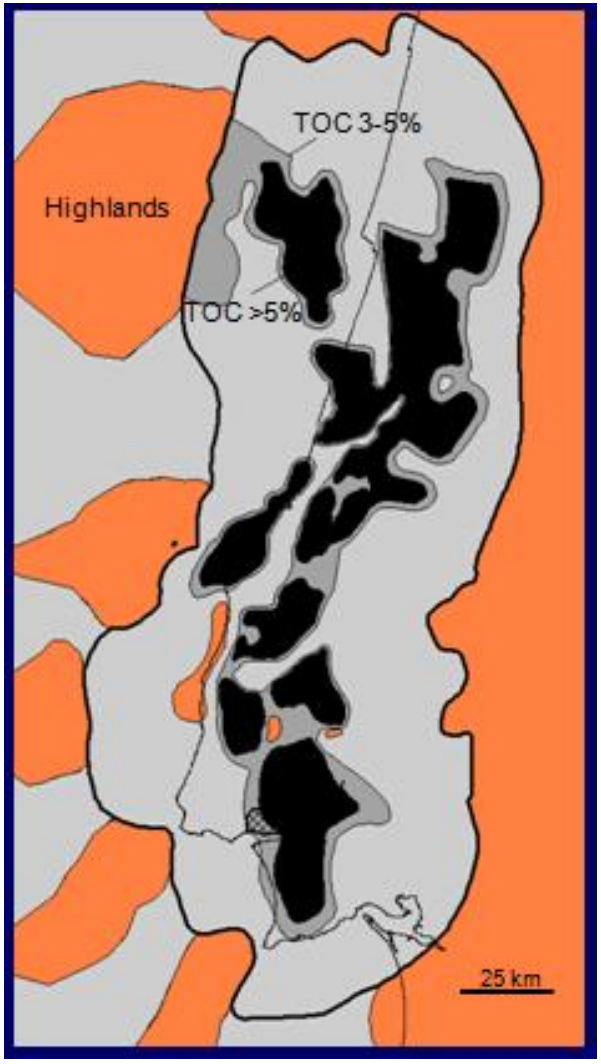

Figure 3. Average TOC in the Vale das Fontes Member of the Lias (light gray areas exhibit background TOC values of less than 3%).

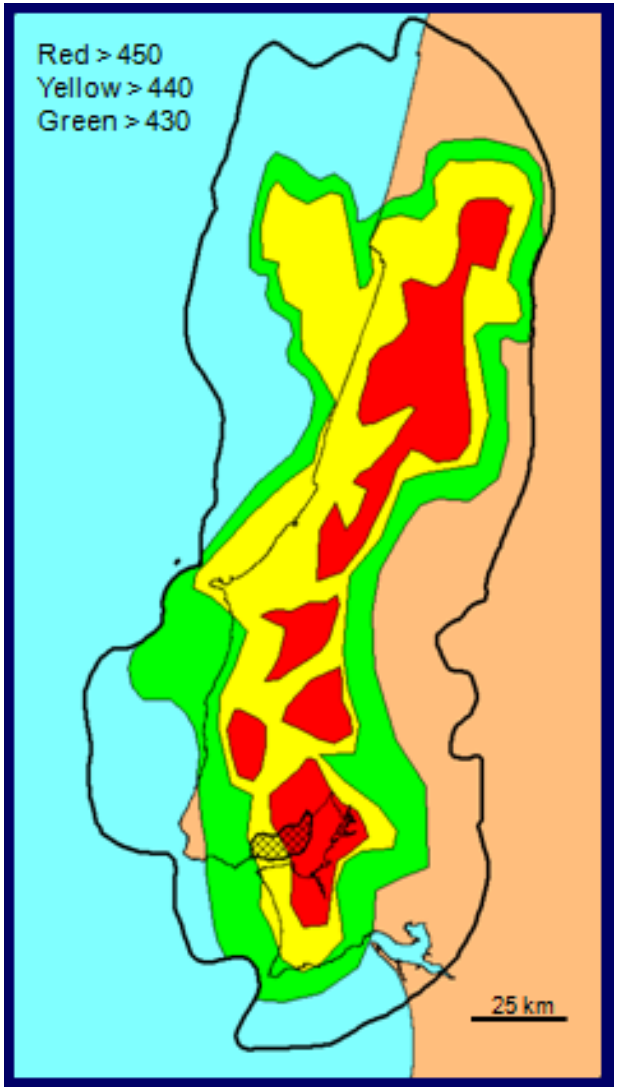

Figure 4. Tmax for the Vale das Fontes Member of the Lias.

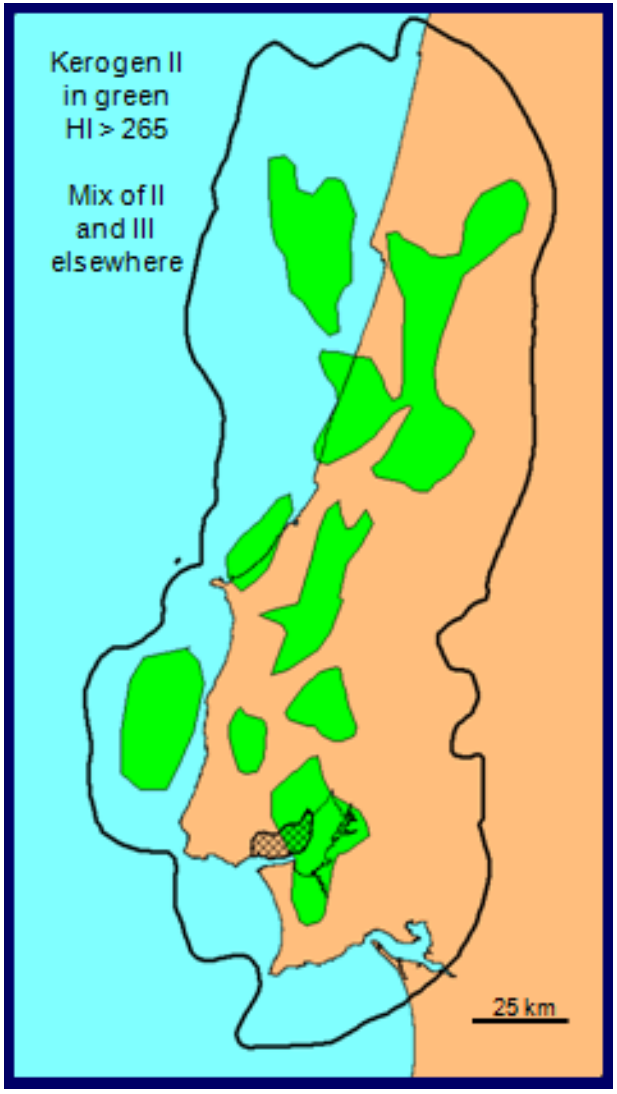

Figure 5. Kerogen type of the Lias.

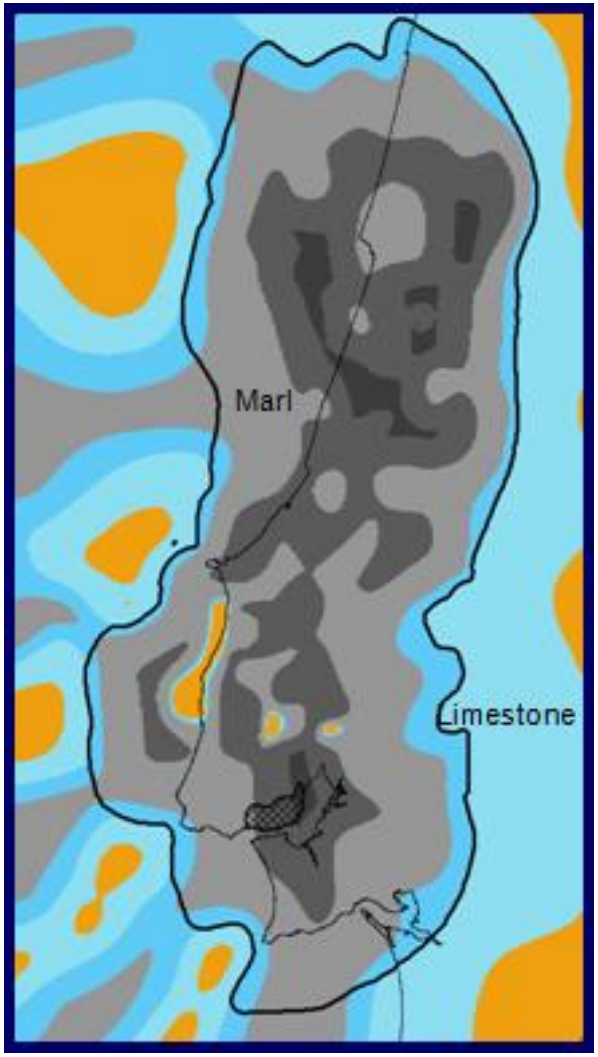

Figure 6. Environment of deposition of the Vale das Fontes member of the Lias.