Direct Oil and Gas Evidences from Punta Del Este Basin, Offshore Uruguay: New Data From Fluid Inclusions*

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Abstract

Fluid inclusion data is critical to better assess the real hydrocarbon potential off Uruguay. Recently, a detailed study using new technologies was performed by FIT (Fluid Inclusion Technologies) on more than 1,000 cutting samples from the Gaviotín and Lobo wells.

These new data indicate dominantly dry gas response in certain intervals, along with some wet-gas-range hydrocarbon species. Low, moderate, and/or high gravity oil inclusions were found in 28 thin sections of sandstones and volcanic materials with fluorescence colors including yellow, yellow-white, and blue-white. Additionally, common live (fluorescent) stain was noted. High oil inclusion abundance in certain horizons is indicative of possible paleo-oil accumulations, which were displaced.

The study suggests that migration took place in the Late Oligocene-Early Miocene. Removal of at least 2,000-2,800 ft of sediments is required to explain possible biodegradation of shallower accumulations. Efficiency of the regional seal (deposited in the Maastrichtian-Paleocene transgression) is evident from the available data.

Overall, these results demonstrate the generation of native hydrocarbons, migration pathways, and the existence of paleo-hydrocarbon accumulations. Probable source rocks for these hydrocarbons include lacustrine shales of Late Jurassic-Neocomian age and marine shales of Aptian, Turonian, and Paleocene age.

Introduction

The Uruguayan offshore basins are considered frontier areas for hydrocarbon exploration. A growing database of 2D seismic and, recently, near 40,000 square km of 3D seismic, has greatly improved the prospectivity of the basins. Although the only two wells drilled so far (Gaviotín and Lobo wells - Chevron, 1976) were declared dry and did not find source rock beds, it should be noted that both were located on structural highs in the proximal sector of the Punta del Este Basin and are not representative of the ~8 km thick fill of the basin.

In 1996, results from a study by AMOCO showed the presence of light (32º API), paraffinic oil inclusions as well as gas inclusions in Cretaceous sandstones of both wells (Tavella and Wright, 1996). Recently, a detailed study using new technologies was performed by FIT (Fluid Inclusion Technologies) on more than 1,000 cutting samples from the Gaviotín and Lobo wells. The main results are summarized herein.

Geological Setting

The Uruguayan continental margin (Figure 1) is a segmented, volcanic rifted margin (Soto et al., 2011). It is characterised by thick wedges of seaward dipping reflectors (SDRs) and more than 7 km-thick depocenters with volcano-sedimentary fill. Basin fill has been divided in four sequences (Soto et al., 2011; Morales, 2013): a) prerift (Paleozoic continental to marine sediments, as well as Proterozoic and older crystalline basement rocks), b) synrift (Late Jurassic-Neocomian volcanic rocks and continental sediments), c) transition (Barremian-Aptian continental to transitional sediments), and d) drift (which comprises Late Cretaceous transitional to marine sediments and Cenozoic marine sediments).

Besides the ill-defined Oriental del Plata Basin, two main basins are recognized offshore Uruguay of different ages (Fig. 2), with distinct Mesozoic and Cenozoic evolution: the Punta del Este Basin to the south, and the Pelotas Basin to the north (Soto et al., 2011). They are separated in shallow waters by a basement high, the so-called Polonio High, (PH, Fig. 2) which played an important role as sediment source area.

The Punta del Este Basin (Stoakes et al., 1991; Ucha et al., 2003) is a NW-SE trending, funnel-shaped aulacogen (related to the Salado Basin in northern Argentina). It displays a series of Late Jurassic-Early Cretaceous hemigrabens (with Paleozoic relicts in deeper sections) and a complex structural style, with both NW-SE and NE-SW faults controlling hemigraben development.

Following this stage of mechanic subsidence, there was an incipient thermal subsidence in the Barremian-Aptian. The Late Cretaceous sedimentation was mainly characterized by deposition of conspicuous prograding deltaic clinoforms, while the Cenozoic sedimentation was strongly controlled by Andean tectonics and uplift, as well as eustatic oscillations (Morales, 2013).

The Pelotas Basin, in turn, is a typical NE-trending passive margin that continues up to the Florianópolis Fracture Zone in Brazil. It shows poorly developed hemigrabens controlled by the simple, antitethic faulting style. Late Cretaceous sedimentation was scarce compared to the Punta del Este Basin (with the Pelotas Basin being a probable starved basin at this period), but entering the Cenozoic large volume of sediments reached the basin. Paleogene and Neogene sediments are very thick in southern and northern Pelotas Basin, respectively. All this means that from the Late Cretaceous onwards, a depocenter migration was recorded offshore Uruguay (Morales, 2013).

Materials and Methodology

Fluid Inclusion Stratigraphy or FIS is a technique envisaged by Norman and Sawkins (1987) and recently perfectioned (Norman et al., 1996; Hall, 2002; Hall et al., 2002) which involves the rapid, complete analysis of volatiles trapped as fluid inclusions in rock samples using quadrupole mass analyzers attached to an automated high vacuum sample introduction system. The technique documents the presence and relative bulk abundance of ionized volatile fragments (m/z 1-180) that have been released from fluid inclusions by crushing of natural samples. This includes most geologically important inorganic species as well as organic species with less than or equal to 13 carbon atoms (C_{13}), being comparable to the low molecular weight fraction of a Gas Chromatography-Mass Spectrometry (GCMS) analysis. Hence, the major classes of hydrocarbons (aromatics, naphthenes, paraffins, etc.) are represented (FIT, 2011a, 2011b).

What FIS lacks in compound specificity (given that all species are analyzed simultaneously) it makes up for in sensitivity and speed, allowing detection of petroleum in samples that are well beyond the reach of standard GCMS methodologies.

Fluid inclusions are the only direct records of paleofluids existing in the subsurface and as such have the potential to record conditions accompanying geologic processes including petroleum migration. By studying the subsurface distribution of paleofluid chemistries with FIS, valuable and unique information on three major exploration topics and two major production topics can be obtained: petroleum migration or paleocharge, seals, proximity to undrilled pay, pay zone and bypassed pay delimitation, and reservoir compartmentalization (FIT, 2011a, 2011b).

There are two parts to a conventional FIS data set, and each must be evaluated in detail. On one hand, individual mass spectra for each sample are presented. On the other hand, stratigraphic profiles of critical species and species ratios (totaling 25 tracks) with depth are presented.

FIS data were collected on 575 Gaviotín well samples, spanning the depth range 137-3630 m (450-11910 ft), and on 483 Lobo well samples (depth range 113-2713 m, or 370-8900 ft). In all cases, samples correspond to unwashed cutting samples and were provided to FIT by geologists from ANCAP, the National Oil Company of Uruguay.

Thin sections were prepared from Gaviotin (16 thin sections) and Lobo samples (12 thin sections) at selected depths, and examined under a petrographic microscope using a variety of fluid inclusion techniques (e.g., UV fluorescence, microthermometry, etc.; Figure 2). These analyses are intended to verify the presence of petroleum bearing inclusions, as well as to explore textural relationships that may yield additional information on the timing of hydrocarbon migration or generation.

Results and Discussion

The results of the new analysis indicate two dry gas anomalies in each well (associated with intermittent sulphur species of either bacterial or thermal origin), in Jurassic, Cretaceous, and Tertiary levels, with subordinated dry gas anomalies in the deeper parts of the column.

Weak wet-gas signal has been found in several Jurassic and Cretaceous intervals (also Permian in Gaviotín well). In shallow sections, dry gas and sulphur species of possible bacterial origin are interpreted as microseeps.

Low, moderate, and/or high gravity oil inclusions were found in 28 thin sections of sandstones and volcanic materials. Given the different gravities different oil charges (more so in the Lobo well than in the Gaviotín well) can be assumed. Fluorescence colors of these oil inclusions include yellow, yellow-white, and blue-white (Figure 2).

Common live (fluorescent) stain was noted in several Jurassic and Cretaceous intervals (again, also Permian in Gaviotín well). High oil inclusion abundance in most of these intervals is indicative of possible paleo-oil accumulations (i.e., oil accumulations that were later displaced). The Permian paleo-oil accumulation in Gaviotín well encourages further exploration of this interval.

The study suggests that migration took place in the Late Oligocene-Early Miocene. Efficiency of the regional seal (deposited in the Maastrichtian-Paleocene transgression) is evident from the available data.

Removal of at least 2,000-2,800 ft (roughly 600 to 850 m) of sediments is required to explain both possible biodegradation of shallower accumulations (to account for dry gas and sulphur species) and microthermometric data (aqueous inclusion temperature being considerably higher than expected at those depths).

Overall, these results demonstrate the generation of native hydrocarbons, migration pathways, and the existence of paleo-hydrocarbon accumulations. Probable source rocks for these hydrocarbons include lacustrine shales of Late Jurassic-Neocomian age and marine shales of Aptian, Turonian, and Paleocene age.

Conclusions

Analysis by FIT (2011a, 2011b) not only confirms the presence of fluid inclusions first reported by Tavella and Wright (1996), but also greatly expands the data and allow to extract a lot of information from it, allowing to increase our knowledge of hydrocarbon generation and migration through the drilled portion of the basin.

Prospective reservoir intervals include Jurassic-Early Cretaceous synrift sandstones and Late Cretaceous synrift sandstones in both wells. Additionally, the presence of an interpreted paleo-oil accumulation in the Permian prerift section of the Gaviotín well is interesting and suggests that this interval may be prospective in addition to the syn and postrift sections.

Data suggest emplacement of low to upper-low gravity, possibly biodegraded oil. This may have occurred when the structure was significantly shallower and would constrain migration to have occurred no later than the latest Oligocene to earliest Miocene. The section may have been buried 600-850 m deeper than present day.

Fluid inclusion stratigraphy is critical to better asses the hydrocarbon potential off Uruguay. Future works include apatite fission track analysis (AFTA) to constrain the amount and age of uplift, as well as Compound Specific Isotope Analysis (CSIA) and biomarkers to place the oil occurrences into context of source rock, maturity, and degree of biodegration.

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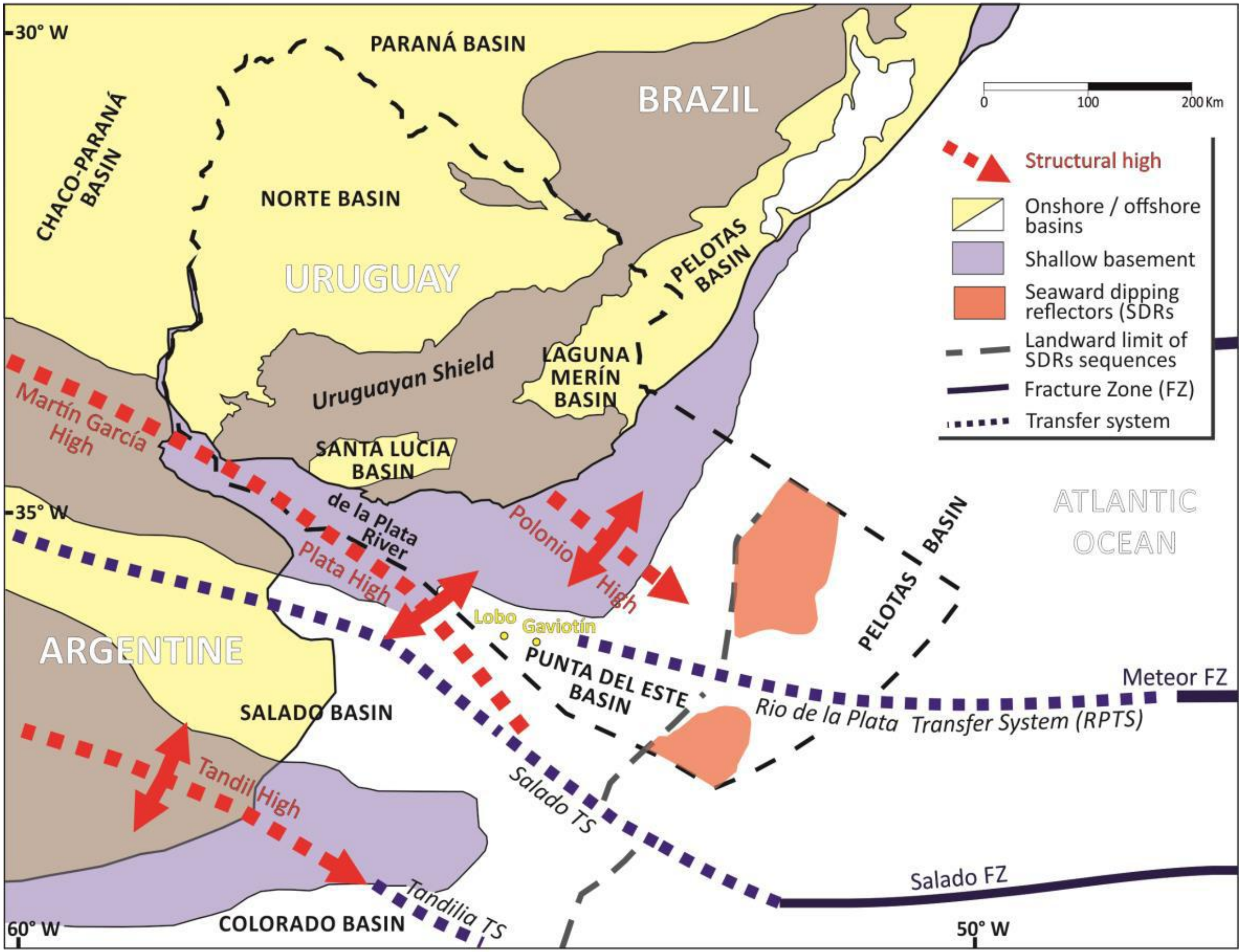

Figure 1. Tectonic and structural framework of the continental margin of Uruguay. After Hernández-Molina et al. (in press).

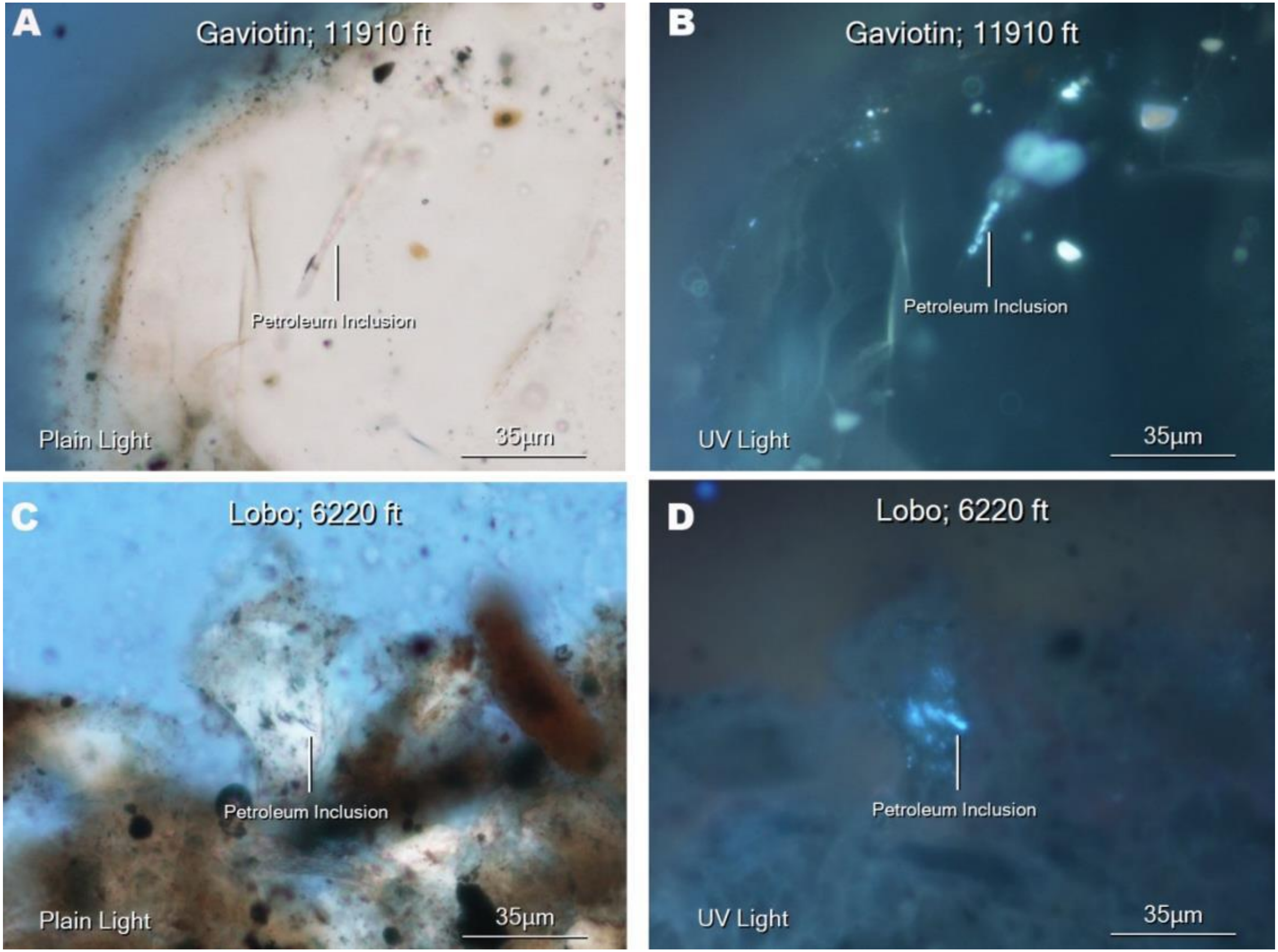

Figure 2. Examples of fluid inclusions from Uruguay offshore wells in both plain light (A, C) and UV light (B, D). A-B, Gaviotín well. C-D, Lobo well. Taken from FIT (2011a, 2011b).