The Joaquim Tavora case study, Parana basin, Brazil : From live oil show to upside potential estimate in a frontier exploration basin

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Abstract

Oil exploration efforts in the huge Paleozoic Parana basin of Brazil waxed and waned since 1892 without a commercial discovery. The recent serendipitous find of live oil in a water well at a basin-flank position does demand explorationists´ attention, however. In the Joaquim Tavora area, surface geology, magnetotelluric and airmag surveys point to the existence of large, untested structural traps for the Devonian to Permian section present. Unraveling their geometry is a task for seismic surveys to tie the subsurface data of only 12 wells drilled for oil, coal or water purpose. At the northern flank of Ponta Grossa Arch, the study area is located between the São Jeronimo and Guapiara lineaments, important conduits for dikes, sills and lava outflows in the Jurassic to Early Cretaceous. Igneous activity helped to enhance generation, focus fluid migration and entrap hydrocarbons. By integrating the available data, our estimate of upside potential for this 3,600 sq. km area is of 100 MMBOE, further investment in geological, geophysical and geochemical work being required.

Introduction

The working principles for frontier exploration are very simple. Starting from one trying to explain the reasons why an oil show occurred at a certain position in a particular basin. This obviously requires a certain amount of field, lab and library research. Working hypotheses are then raised in order to tie the information gathered. Most of all, optimism has to be a factor under consideration.

The 1,000,000 sq. km area of Parana basin began to be explored in 1892 (Collon, 1897), but efforts along the years only met frustration. However, in March 2005, a 300m TD water supply well found oil instead (Figure 1).

Figure 1 – SANEPAR´s water well in study area (modified from newspaper Gazeta do Povo, Apr. 6th, 2005).

Investigating the reasons for such an unexpected occurrence of (heavy) oil, the authors arrived at the following optimistic geological scenario, with a view to motivating further exploration investments.

Geology

Surface geology is fairly well known for the Joaquim Távora area (Figure 2). Paleozoic sediments crop out in most of the region, except for the NW sector, where they are hidden by the younger Serra Geral lava flows.

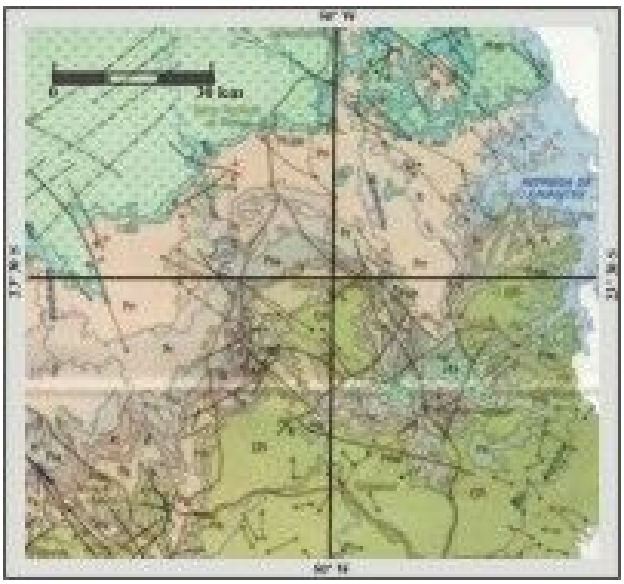

Figure 2 – Surface geology by DNPM / MINEROPAR.

Subsurface geology is scanty. Three dry wildcats by Petrobras were drilled in the 1950´s to maximum TD 2,664m, based only on surface geology. They contributed however to a better understanding of the tridimensional geometry of the basin (Figure 3).

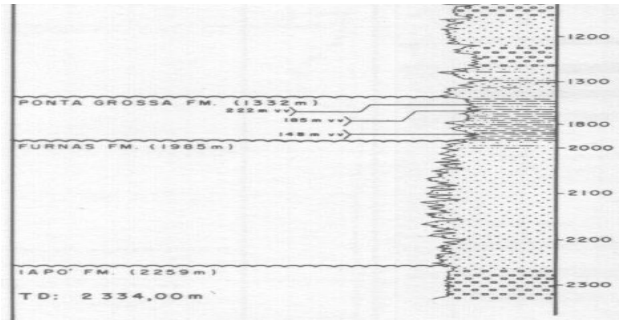

Figure 3 – Wildcat 1-JT-1-PR at J. Tavora showing massive sandstones close to TD, capped by also Devonian shales, inserted sills excluded (after Ramos and Formoso, 1976).

Geophysics

Several geophysical methods have been applied to the Joaquim Távora region with varying purposes. These include gravity, airmag (Figure 4) and magnetotellurics (Fig. 5), but nothing of the more expensive seismic surveys. Notwithstanding the lack of more detailed structural control, valuable information was acquired regarding the broad structural grain, by revealing the important NW/SE-trending São Jerônimo and Guapiara lineaments, which limit the Joaquim Távora tectonic megablock on both sides.

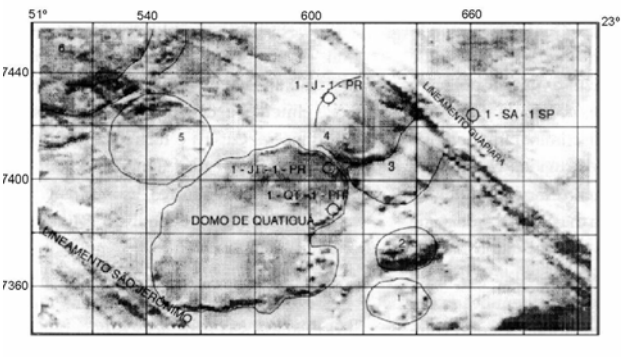

Figure 4 – Airmag residual map, clearly showing NW/SE lineaments injected with basic igneous dikes (modified from Ferreira, 1993 in Licht et al., 1997)

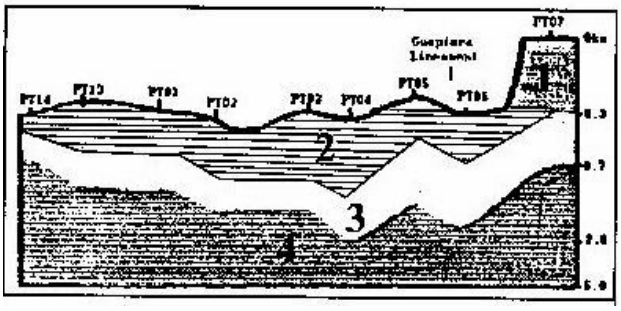

Figure 5 – Magnetotelluric survey in the Joaquim Távora area tied to results of wildcat 1-JT-1-PR. Legend: 1 – Serra Geral basalts; 2 – Permian; 3 - Permo-Carboniferous to Devonian; 4 – Silurian sediments and substratum (simplified from Menezes et al., 1994). This cross-section runs normal to the Guapiara lineament and suggests appreciable structural relief of the Paleozoic sedimentary cover in the Joaquim Tavora tectonic megablock.

By running from deep-basin to shallow-basin, these two lineaments tend to provide adequate connection and focussing of hydrocarbon migration fairways towards the shallower realms.

One should expect local complications induced by faults, sills etc. as Rostirolla et al. (2000) found in outcrops. But in the Joaquim Távora area this will be an easier and less expensive task for reflection seismic surveys acquisition, processing and interpretation since the elsewhere widespread cover of Serra Geral basalts is generally absent.

Geochemistry

Published geochemical studies about other areas of the basin indicate the Permian Irati shales as the best potentially source rock, the Devonian Ponta Grossa shales being lesser ranked. One should consider however that in the deep basin exactly in front of the Ponta Grossa Arch, is where the Ponta Grossa formation were found to be thickest, with up to 500 meters.

Surface geochemical studies have been performed mainly for an environmental control purpose (Licht et al., 1997) and may be useful for a first evaluation of hydrocarbon prospectivity underground. Specific surveys are needed of course.

Heat flow evidence

Meister (1973) and Hamza (2001) mapped and listed geothermal and heat flow data for Parana basin. Our contouring of such data suggests that north and eastward from the 1-JT-1-PR wildcat there should be a local increase in geothermal gradient and heat flow values.

Since the real origin of this evidence of a thermal anomaly is still not firmly established, one may use a working hypothesis of allochthonous temperatures due to long distance lateral migration of hotter fluids from the basin deep, similarly as reported for the Paleozoic Murzuq basin (Meister et al., 1991a).

Integrated geological model

In a landmark geological report, Oliveira (1971) had already called attention to the possibility of late oil generation and migration of hydrocarbons in Parana basin, with some contribution given by the basic igneous intrusions in the form of heat provided and of additional burial of Paleozoic source rocks.

We envisage the possibility of focussed fluid migration and selective entrapment of hydrocarbons as analogous to an inverted “pinball-game” effect.

The beneficial effect of the igneous intrusions on creation of hydrocarbon traps was adequately pointed out by Conceição and Zalán (1990).

In the synchronous Solimões basin of northern Brazil, circa 50,000 bbls/day oil equivalent are already being produced in relatively close association with diabase sills.

Since Parana basin was not provided with the good seal of evaporites, one must look for areas and reservoirs with adequately sealing shales. Soares et al. (1977) have shown that the Itararé subgroup in the present study area is highly sandy, lacking sufficient interbedded sealing shales.

This restricts the prioritary search of commercial oil fields in this frontier exploration basin flank to one main objective: the Devonian Furnas sandstones and their overlying Ponta Grossa shales.

Thus, our working model for oil entrapment in the area considers as more positive the influence of dike and sill combinations in the lower part of the section (Figure 6).

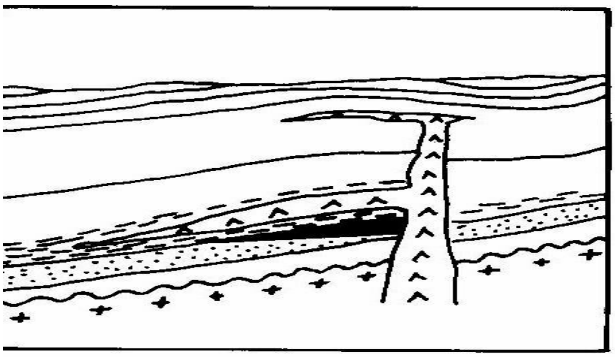

Figure 6 – A model trap for oil and gas in the Joaquim Távora region.

Integrated exploration approach

The integrated exploration approach recommended (Meister, 1990; Meister et al., 1991b) for solving the problem of establishing commercial production in Parana basin included renewed and intensified investigation of the shallower realms of the basin, where the Paleozoic sediments are well exposed, and technologically and environmentally restraining conditions are much easier. The Joaquim Távora area meets such conditions.

Additional gravity surveys, surface geochemical studies and mostly seismic surveys, are required.

In line with current Brazilian petroleum legislation, interested parties will need to be attracted either for conducting spec surveys or for bidding in future oil exploration bid rounds in this new and risky frontier area.

A first hint to the special interest of the Joaquim Tavora area is given by the old-fashioned subsurface structural map based only on scarce well control. Contouring the top of Carboniferous diamictites of the Itarare subgroup (Figure 7) based on eight shallow wells drilled for coal investigation, the presence of a shallow structural nose or high of the order of 100 sq. km areal extent can be interpreted.

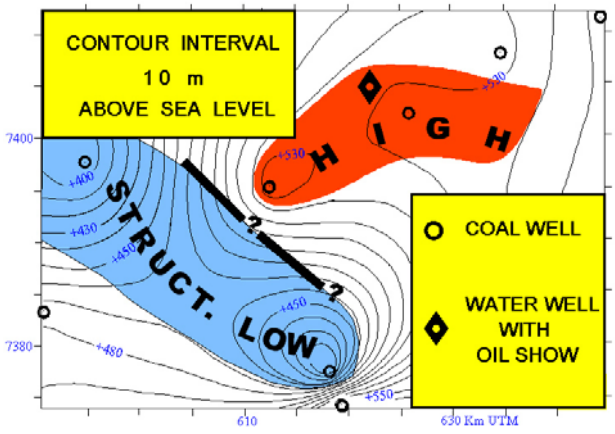

Figure 7 – Computer-contoured structure map of top Itararé subgroup diamictites, as met in 8 wells of CPRM (1976). Influence of NW/SE lineaments is evident.

Towards an upside potential estimate

Worthy of further investigation is an area of about 3,600 sq. km around Joaquim Távora city, in Parana State (see Figure 8). From the standpoint of subsurface knowledge, this comprehends three deeper wells for oil, eight wells for coal and the SANEPAR well that hit oil by chance seeping into the wellhole.

Based on surface geology, one can visualize the four largest structures apparent in the area as summing up about 514 sq. km. Shallow subsurface data suggest there is one of over 100 sq. km. Structural control of the subsurface is in fact practically inexistent. Nevertheless, sizeable traps in the deeper subsurface are deemed to be present.

Therefore, one must recur to general statistical speculations similar to those postulated by L. G. Weeks for frontier exploration areas.

We chose to apply a factor of one percent hydrocarbon-bearing potential for the Joaquim Távora region, in order to forecast size of the largest field therein. Applying Zipf´s Law to rank the projected field size of oil and gas fields (Figure 8), and then using conservative parameters for net pay, porosity, oil saturation and primary recovery factor, we achieved an estimated upside potential value of 100 million barrels oil equivalent to be recovered from the four largest fields waiting to be discovered.

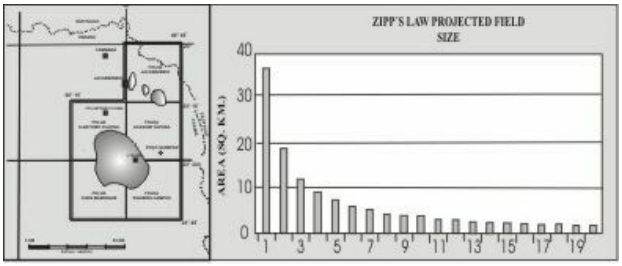

Figure 8 – Study area delineated around Joaquim Távora city and estimate of upside potential for this region in Parana State.

Conclusions

An oil show may be very important in the long run, as regards exploration frontier areas. This is why all such occurrences need to be thoroughly checked by explorationists.

To those eventually interested in investigating this area, the authors strongly recommend preparing their own assessment of risk to reward ratio. And wish the best of luck, which is always needed in frontier exploration. This is a good chance for making the first commercial oil discovery in Parana basin, so we firmly consider.

Acknowledgements

In memoriam, this report is dedicated to early deceased geophysicist Marco Antonio Mendonça Astolfi and geologist Elder Sinésio Tocci Pierobon, for their enthusiasm about the petroleum possibilities of Parana basin. Thanks are also due to geologists Paulo César Soares, for valuable comments, as well as to geologists João Horácio Pereira and Marcos Justino Guarda, of the

SANEPAR staff responsible for locating and drilling a water "wildcat" which ended "dry" but whose result may hopefully help renew oil exploration efforts in Parana basin towards its first commercial hydrocarbon discovery.

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