Geophysical characterization of unconventional reservoirs: new limits for the exploration and production in Brazil

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Abstract

This paper discusses non conventional reservoirs characterization based on Geophysics. The goals are shale gas in Amazonas basin and gas hydrates in Foz do Amazonas basin and their importance for Brazilian Energy Sector.

Introduction

Research reservoir is crucial to a better understanding about energy reserves. The increasing energy demand drives the research for new energy sources as a way to prevent future oil depletion.

Some options currently being studied are the non-conventional reservoirs (NCR's), especially natural gas ones. Their resources are twice as high as oil gas conventional resources. For this reason, NCR's is major study field for Geophysics, because it is possible to infer global zones with potential for hydrocarbon generation.

This paper emphasizes non-conventional reservoirs due to growing role, reserves forecasting and geographic distribution around the world (FARIA, 2010).

Further growth of a Brazilian Gas Sector focused on shale gas or gas hydrates could be a lever for economic development.

Reservoir characterization

Reservoir characterization is based on a descriptive model of a subsurface specific area and its petrophysical properties (OLIVEIRA, 2015) for evaluate hydrocarbon resources given surrounding heterogeneities. Because of that it is very important for research and subsequent reserve exploration.

Main petrophysical parameters used in reservoir characterizations whether conventional or non conventional ones are permeability and porosity. Geophysics is applied for subsurface lithology survey and to describe shape and composition (LUCZYNSKI, 2014).

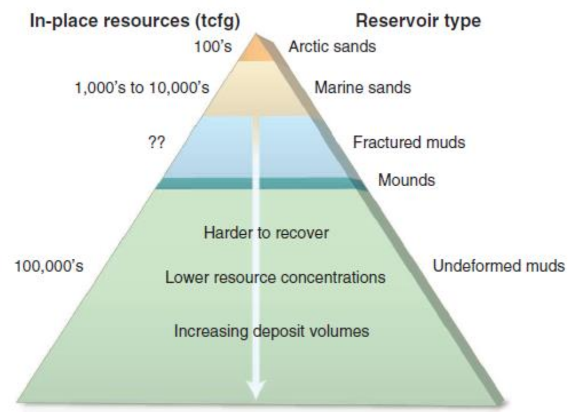

Figure 1: *Pyramid of resources. Source: Energy Skeptic, 2019*

Physical properties of reservoirs

One of most widely used classification of non-conventional and conventional reservoirs is based on two petrophysical parameters: porosity and permeability (MELANI, 2015) both of them considered as key indicators for oil and gas exploration.

Porosity is the ratio between void spaces and total volume and it is described as a percentage (from 0% to 100%). It is classified as (NERY, 2013): a) primary (depositional): it comes with rock deposition, b) secondary (post-depositional): it occurs after deposition with chemical leaching and/or fracturing, c) absolute: total volume of void (empty spaces), d) connected: when the pores are connected.

Porosity can also be affected by poorly sorting, framework, cement and clays.

On the other hand, permeability is characterized as the flow rate of the water in a porous medium, being directly proportional to the transversal section of the medium, the difference of hydraulic load between two points and, inversely, the distance traveled by the fluid as demonstrated by Darcy (1856) (NERY, 2013).

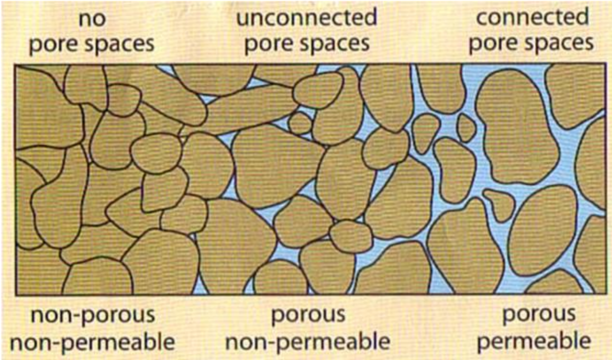

Figure 2: *Relation between porosity and permeability. Source: Institute of Geophysics Polish Academy of Sciences.*

In addition, reservoirs can also be classified according to economic aspects, technical viability or logistic demand in the exploration (DOS SANTOS, 2002), consequently, an oil system can be classified as:

From the identification of these parameters, an oil system can be classified as:

a) conventional: permeability is suitable for migration and oil/gas trapping stratigraphically above in sandstones or carbonates reservoirs sealed by a capping rock with low permeability;

b) unconventional: the rock has the ability to be the rock source, reservoir and trap at the same time, resulting in the hydrocarbon reserve generated in its own parent rock or in fine sandstone lenses distributed laterally by the formation (sweet-spots); this configuration is characteristic of low permeability sandstones (LINK, 1982).

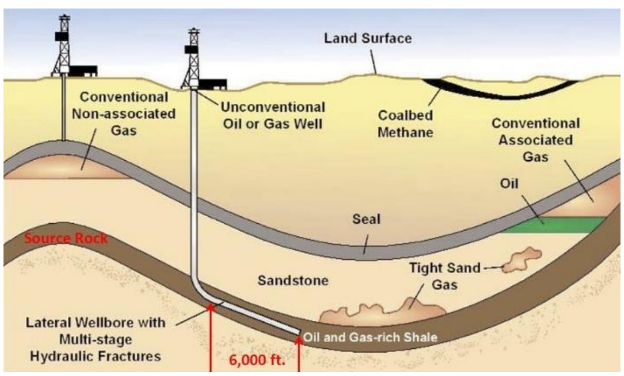

Figure 3: *Conventional and unconventional reservoirs of hydrocarbons. Source: U.S. Energy Information Administration*

The NCR's are considered as important hydrocarbon reserves, however, their viability of exploration and production is linked to technical difficulties of recovery of their hydrocarbons, due to their extreme permeability, requiring different methods for the development of fields and also more accurate studies on prospection than those commonly made for conventional exploratory campaigns, which reflects a further integration of geophysical survey data (MONTEIRO, 2013).

Geophysical characterization of reservoirs

For a detailed study of the area, it is necessary to apply a series of geophysical methods. However, the most efficient method for the quantitative and qualitative characterization of porosity and permeability is the well log profiling method, which can determine depth, fluid differentiation (gas, oil, water) and estimate the occurrence of hydrocarbons with Gamma ray profile (GR), and resistivity profiles (Res) together with the neutron profiles (NPHI) (OLIVEIRA, 2015). Seismic methods also help in the characterization, imaging faults, traps, dikes, salt domes and other geological features; all of them with well data can result in high-resolution regional surveys of the geophysical profile data collected points (PONTE FILHO, 2012).

Usually, non-conventional reservoirs have sizeable values of radioactivity in shales (NERY, 2013), so gamma ray logs can be used, because it detects potassium, uranium and thorium.

In resistivity profiles, it is measured how much a material resists the passage of electric current. The function of resistivity is associated with the identification of fluids that accumulate in the pores of rocks. This type of profile also assists in the maturation of generation rock (AUTRIC & DUMESNIL, 1985). In the neutron profiles, the porosity of the rock is estimated from the amount of hydrogen present in the rock, which helps to identify porosity, permeability and presence of gas zones (NERY, 2013).

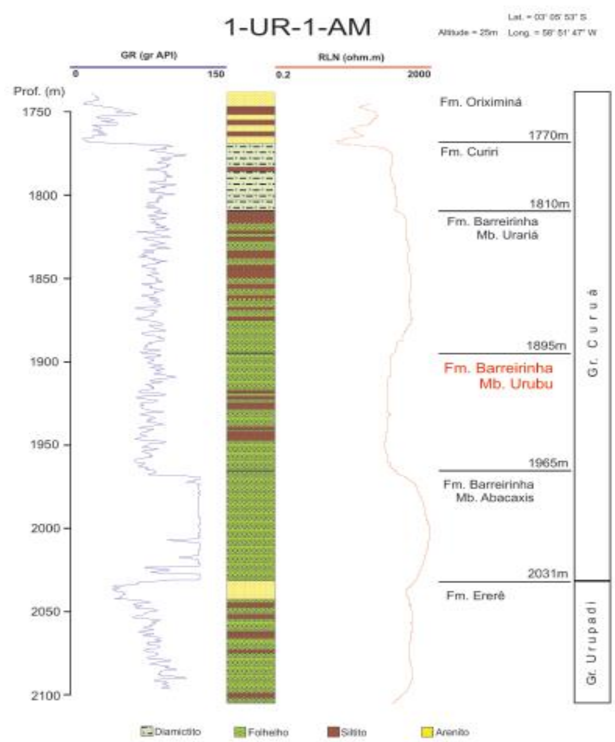

Figure 4: *Well profile associate to the region's lithology, demonstrating a profile's type of unconventional reservoirs. Carrier of shale gas in Abacaxis Member. Source: Cunha, 2007*

In the research of unconventional resources, the use of these two methods is valid, since by the profiling it is possible to distinguish the existence of generation and reservoir rocks oil and gas, such as shales. In addition, a seismic section assists the identification of methane hydrates by BSR (Bottom Seismic Reflection), in which an image is generated parallel to the seafloor indicating the existence of target zones (EIRAS, 2003).

Geophysical characterization of unconventional reservoirs

Some studies show that Brazil has potential for unconventional reservoirs. The resources are: shale gas, methane hydrates, low-permeability sandstones and CBM (coal-bed methane). Some prospective shale gas reservoirs are: Amazonas, Paraná, Recôncavo and São Francisco basins.

It is worth highlighting Curuá Group of Amazonas basin has Barreirinha Formation, which consists mostly of shales, subdivided (CUNHA, 2007) in three segments (memb): Urariá, Urubu, Abacaxis. A well log was studied to better characterize the Barreirinha Formation in order to obtain potential shale gas reserves since the occurrence of kerogen type II, which is oil and gas prone.

Of particular note here is the Amazon Basin, where we find the Curuá Group, which presents the Barreirinha Formation, lithologically formed mostly by shales, subdivided (CUNHA, 2007) in: Urariá Member, Urubu member and Abacaxis member. In this specific Basin, a well profile was studied to better characterize the Barreirinha Formation in order to obtain potential shale gas reserves. Considering that this Basin is of biogenic origin, due to generation from plankton and algae, the kerogen of this is type II, which presents potential for gas and oil.

Based on well profiles 1-UA-2-AM (CUNHA, 2007), it was possible to infer the lithology of Barreirinha Formation.

Abacaxis member (lower) has black shales, with good lamination and characteristic of fissibility, of high radiation, rich in organic matter (CUNHA, 2007). The gamma ray profile shows high radiation degree which indicates shales vertically present interspersed with siltstones. Profile resistivity oscillates from high to low values, which indicates the presence of hydrocarbon fractions. According to Nery (2013), calculation of gas carrier sandstone shows that the transit time value of a sonic profile is approximately 90 µs/ft , which is close to the value referring to the profile studied (considering that the transit time is approximated for shale). It presents values of Carbon Organic Total (COT) varying from 3%-8% (CAPUTO, 1984, GONZAGA et al, 2000, NEVES, 1990), which states for a potential generating rock.

Urubu member (intermediary) consists of dark shales with low fissibility, but in comparison with the Abacaxis they are less radioactive, a low resistivity from 3100m to 3150m, after that from 3150 to 3200 there is an increase of these values and have lower concentration of organic matter as well (CUNHA, 2007).

Urariá member (upper) has siltites below shales and sandstones with wavy and lenses structure (CUNHA, 2007).

Uraria and Urubus present COT values ranging from 1% to 2% and type III organic matter (LOBOZIAK et al, 1996).

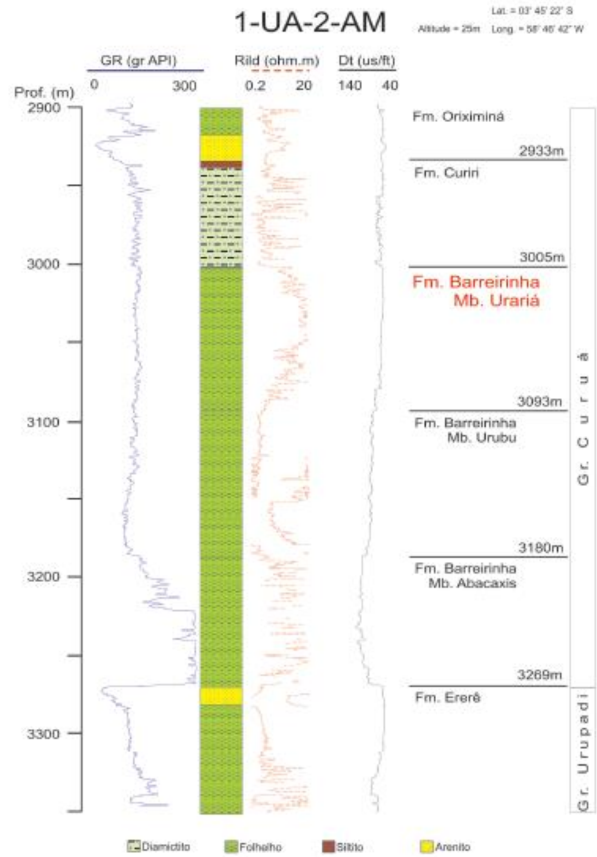

Figure 5: *Well profiling that demonstrates the Barreirinha Formation and its members: Urariá, Urubu and Abacaxis. Source: Cunha, 2007*

Concerning to gas hydrates, they have the biggest reserves of fossil fuels when compared to other ones. However, technological constraints but above all environmental scenarios are hampering the exploration. Brazilian coastline has occurrences of clathrates from north (Foz do Amazonas basin) (Sad et al., 1998) to south (Pelotas basin) (FONTANA & MUSSUMECI, 1994).

The reserves in Foz do Amazonas basin have an estimated volume of 450 trillion cubic feet, equivalent to 13 trillion cubic meters of surface gas (SILVEIRA FILHO, 2003).

Seismic profile performed in the Amazon Cone shows the presence of a high reflection surface that is a characteristic of the methane hydrates, called BSR, which opens to a possibility of hydrates presence be considered. Seismic attributes such as envelope, average energy, and instantaneous phase aid to the identification of BSR (CANÁRIO, 2013). This profile was carried out in the southeast portion of the Amazon Cone, showing a line marked in blue almost constant that indicates the BSR reflectors. The occurrence of this one with double time of 4s-6s, based on the speed of the seismic wave in the sea of 1500m/s, points to a depth of approximately 3000m-4500m. The green-marked region demonstrates a possible formation of hydrates, because this discontinuity indicates that new nodules may be forming to reach the solid phase.

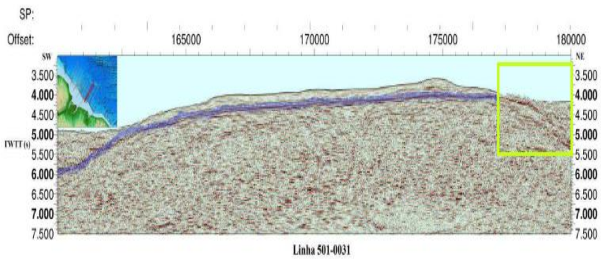

Figure 6: *Seismic section indicating the presence of the BSR reflector (in blue) and a region with possible formation of methane hydrates (in green). Source: Canário, 2013.*

New frontiers in Brazil

Following other countries Brazil has begun to research energy alternative sources as a way to diminish its dependence on hydroelectric power. One of them was the non-conventional natural gas reservoirs.

Brazil has some basins with potential NCR's reserves, especially shale gas. The most promising basins are Amazonas, Parana and Recôncavo.

However, there is also other alternative, the methane hydrates which occur throughout the Brazilian coastline, especially in Foz do Amazonas basin and Pelotas basins, which were previously investigated by PETROBRAS (EIRAS, 2003).

Conclusions

Due to the need to renew the global energy grid, Brazil has been seeking for alternative energy sources for oil. Therefore, the study of non-conventional reservoirs is important to lead to new directions to companies and industries.

As one of the regions with great focus on these reserves, the northern region has a potential for natural gas in the Amazon basin (shale gas) and in the Foz do Amazonas Basin (gas hydrates). This energy would provide the region with more job places, new oil and gas industries and energy self-sufficiency.

This situation also takes place other Brazilian regions with same potential for NCR's. If it comes true, Brazil can become a strong and independent economy and even be a new energy exporter.

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