Tight Gas: a contribution to identification by using geophysics.

[1]Gabriela Pantoja Passos, [2]Estanislau Luczynski. Federal University of Pará; Nucleus of Research in Oil and Natural Gas in the Amazon

This paper was prepared for presentation during the 16th International Congress of the Brazilian Geophysical Society held in Rio de Janeiro, Brazil, 19-22 August 2019.

Abstract

Terminology applied to the nonconventional gas reservoirs has no unanimity. Sometimes it refers to lithology or rock properties. Such differences make difficult the appropriate use of a proper meaning for nonconventional gas reservoirs. This situation happens in case of tight gas, because there is no consensus about it. This paper focus mainly on distinct reservoir that have the same terminology applied to them and in particular, how the Geophysics can supports the identification.

Introduction

The development of a nonconventional gas industry has not lessen the similarities about reservoirs terminology. At first, the focus was on lithology or rock properties. However, the increase knowledge in geological data brought some overlaps: one only terminology describes differing reservoirs as well as some terminologies deal with a single reservoir. One of most frequent situation is tight gas terminology. This paper discuss the proper terminology with reference to geology aiming the identification of reservoir type without ambiguity.

In general, a nonconventional reservoir has low porosity and permeability (less the range of 1 mD to 100mD). However, in order to be specific, there are fundamental parameters to identify any reservoir: connected porosity, viscosity, fluid saturation, capillarity, etc. Although two fundamental ones (porosity and permeability) support the nomination of some nonconventional gas reservoirs (NCGR) as tight gas. Usually tight gas reservoirs have low permeability (<1 mD) and, sometimes, non-connected porosity.

Their common occurrence is at Paleozoic basins, however showing different depths and various pressure zones. Additionally, they exhibit lenticular or tabular geometry and fractures. Such characteristics bring difficulties to a better identification as well as to a proper terminology, because there are many geological gas settings that share the same aspects.

Theory

Tight Gas Terminology

Originally, the word "tight" referred primarily to sandstones (example: tight gas sandstones). Therefore, most of typical tight gas reservoirs are sandstone with gas and low permeability. Due the burial and diagenetic processes, there is cementation and clay minerals, both of them fill the porosity and diminishes the permeability.

However, the progressive identification of new reservoirs with low permeability, but with different rocks (carbonates) create a need for a terminology update. Thus, tight gas is suitable to various lithologies and not only for sandstones.

An example of overlapping is a sandstone reservoir referred as basin centered gas (BCG), which is a low permeability gas reservoir located at basin depocenter of gas basins with low permeability zones and regional porosity, sometimes with sweet spot gas reservoirs. The later ones may also hold for targets for gas exploration (Naik, 2003). In continuation, terminology fits two reservoir types: the gas prone (direct) and the oil prone (indirect). Consequently, a BCG reservoir can be predominantly gas reservoir and in a minor scale oil reservoir.

A BCG reservoir has four characteristics: low permeability, anomalous pressure, gas satured reservoirs and (usually) lack of downdip. (Figure 1). Moreover, it also has blurred boundaries, fractures, low water production and diffuse seal rocks.

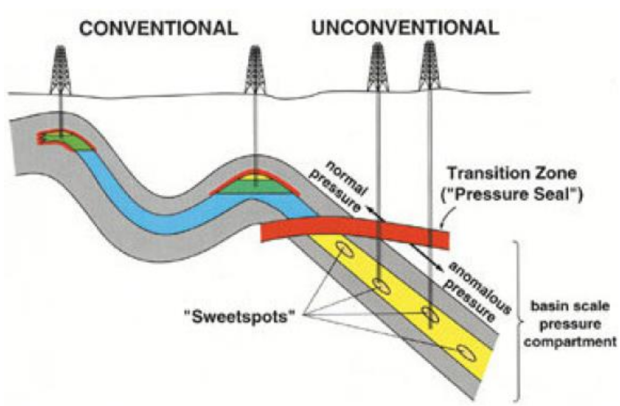
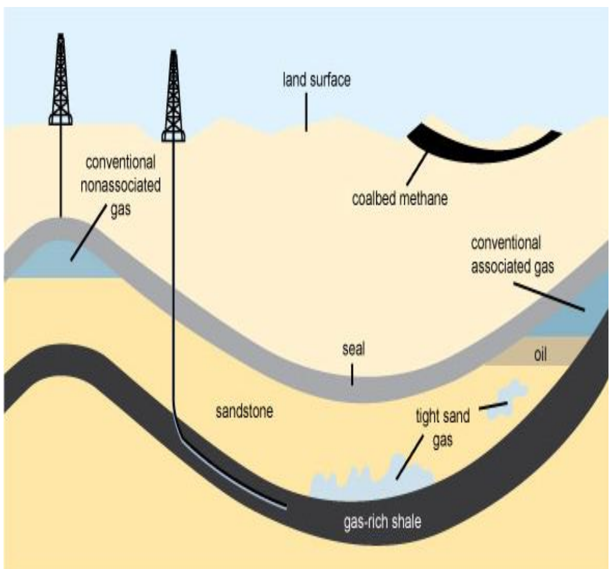


Figure 1: Occurrences of basin centered gas and nonconventional reservoirs. (Hartley, 2019).

Notwithstanding, due the multiplicity of applications of terminology some other overlaps also happen. For example, sweet spot: it embodies the understanding of a natural gas with low H_2S and CO_2 (sweet gas). Although, the uncovering of such resource is difficult, because there are fewer variable acoustic properties.
Recently, some new discoveries of gas players showed a range of permeability from 0,1mD to 1 mD. Clearly, such reservoirs have exploration constraints and they demand enhanced recovery, however they are not entirely tight gas. Actually, they deserve the classification of complexity of gas reservoir. Their geological formations have sandstones with condensate gas and permeability less than 1 mD. Their depths can be shallow or deep ones with normal or anomalous pressures (Halliburton, 2019).

Over the years, some others gas occurrences also received the classification of tight gas: carbonates with low permeability, shales with oil/gas and coal. Hence, there are tight carbonates (with low permeability), tight coal (coalbed methane reservoirs) and the usage of tight gas as a synonym of tight gas (Figure 2).



Source: Adapted from *United States Geological Survey factsheet 0113-01* (public domain)

Figure 2: Differences among various nonconventional reservoirs. (EAI, 2018).

It is possible to identify a tight reservoir by the association between geological studies and petrophysics studies. The data generated can show specific information about composition and structure of the reservoir.

For example, the identification and characterization of shale gas reservoirs using lithologic studies. Commonly, the study applies well logging. However, due the complexity of shale lithology, it is commendable an association of various loggings as density and neutron porosity, both of them to determine rock porosity and moisture (Rabe, 2003). Therefore, by using porosity values is possible to split tight gas from shale gas. Thus, they are not bywords. Moreover, along with well logging there some other geophysical methods to apply. They will discussed later.

Consequently, the terminologies aim to be specific to a rock type of a reservoir. However, all of them refer to tight reservoirs; in other words, they have low porosity as much as permeability. Therefore, they are not the best choice in terms of reservoir identification, because they deal more with rock type than with the hydrocarbon that occurs in the reservoir.

As a result, this paper proposes a consensus for tight gas terminology usage. Such terminology refers to reservoir type and consequently to major characteristics, which support the classification and gas content specification. However, a single word not suits a definition, since tight used refer to sandstones and later to all types of rock.

The proposal is to tittle a tight reservoir as *complex gas reservoir with low permeability*, accordingly geological setting and exploration variables. Thus, such reservoirs demand a cautious approach to characteristics previously quoted as well as their main particularity: a permeability ranging from low to extreme (<< 1mD).

Geophysics for Complex Reservoirs with Low Permeability

Most of tight gas reservoirs occurs at onshore basins, which are analysed with waves or reflection seismic and well logging. It is also important to study the reservoir petrophysics, a set of information the supports the trap localization.

For vertically drilled wells or with closed exploration phase, it is necessary enhanced recovery to improve gas production with economic viability. To this end, fracking and acidification are applied. Both techniques can be under monitoring by microseismic (Figure 3), because the injected fluids from fracking modify the tension field of reservoir. Fault in reservoirs can appear and the released energy spreads as microwave seismic with low scale (Maxwell, 2010; Shemeta and Anderson, 2010). The geophones register the microseismic data, which supports localization and characterization of fractures (Yang, 2013).

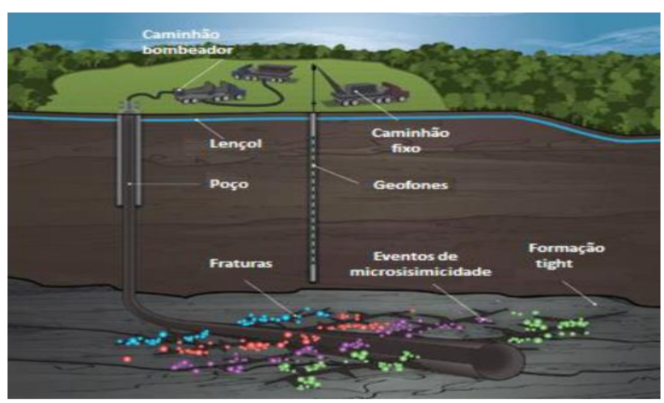


Figure 3: Microseismic monitoring of fracking (Oliveira, 2014).

For a better understanding of reservoir heterogeneities, seismic 3D is applied. It shows small faults and fractures, which contributes in determine the directions of local horizontally stresses and to identify some barriers that hamper the spread of a hydraulic fracture. Combined use of micro seismic and 3D seismic permits a more precise mapping of a reservoir with tis heterogeneities, so improving the interpretation (Yang, 2013).

Well logging has also a broad usage to identification and characterization of reservoirs. Generally, more than one logging is necessary. Electronic density, neutron porosity, sonic logging and resistivity logging lead to accurate results (Figure 4).

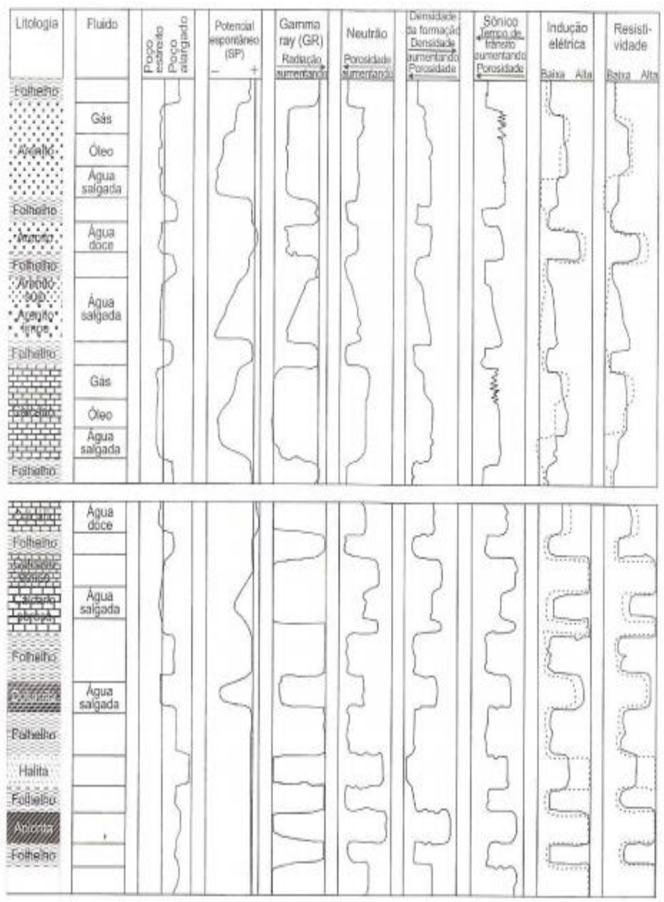


Figure 4: Example of comparison of various well loggings to porosity analysis (Souza, 2014).

Density logging register the densities variations of rocks. Thus by gamma ray natural radioactivity and electronic density of geological formation are measured. On the other hand, neutron porosity register water content in porosity, because it detects hydrogen presence. In addition, sonic logging show velocity versus time of compressional waves in their trajectory along the geological formation. They are partial indicators of porosity. At last, resistivity logging show the rock resistance to conductivity, which depends on porosity, presence of fluids in porosity and salinity (Souza, 2014, Miranda, 2004).

Conclusions

Many papers about nonconventional gas have no consensus on definition or use of tight gas terminology. Geological settings and their particularities and variations hamper the identification of NCGR.

However, due the increasing exploration of nonconventional gas around the world is necessary to approach unanimity about terminology. For this reason, this paper proposes the terminology: *complex gas reservoir with low permeability* based on the various occurrences of gas reservoirs.

Geophysics can support the permeability and complexity studies, which are important to identify nonconventional reservoirs. For example, seismic/micro seismic and reflexion seismic are the most applied to monitoring reservoirs. On the other hand, well logging helps to improve the accuracy of reservoir knowledge.

Porosity analysis and its application to permeability studies supports the well logging and the density logging, neutron porosity, sonic logging and resistivity logging. All of them contribute to porosity studies, although the later logging is responsible for indicates the presence of fluids.

Connected porosity links to permeability, thus all of loggings previously cited support the register of a potential low permeability situation, although they do not dispense petrophysics studies.

Nonetheless, the major contribution be on to distinguish the various tight reservoirs and those inferred as shale (oil/gas), neutron porosity and density logging support the measurement of porosity and wet content (Rabe, 2003). Thus, porosity helps to define what is shale gas/oil and tight gas/oil.

Combined methods of Geology and Geophysics lead to an accurate analysis of reservoir features and diminish costs and liabilities.

References

HARTLEY, R. **What is Tight Gas?** Disponível em: <https://www.geoexpro.com/articles/2012/10/what-is-tight-gas>. Acesso em: 09 mar. 2019.

CRAIN’S PETROPHYSICAL HANDBOOK. **Special Cases:** Tight Gas Reservoirs. Disponível em: <https://www.spec2000.net/17-tightgas.htm>. Acesso em: 10 mar. 2019.

CRUZ, C. E. S. **Recursos não convencionais de petróleo (óleo e gás) e seu potencial nas bacias sedimentares brasileiras.** Brasília: Empresa de Pesquisa Energética; Fundação Getúlio Vargas; Universidade de Brasília. 2015.

NAIK, G. C. **Tight gas reservoirs–an unconventional natural energy source for the future**, v. 1, n. 07, 2003.

HALLIBURTON COMPANY. **About Tight Gas.** 2019. Disponível em: <https://www.halliburton.com/en-US/ps/solutions/unconventional-resources/tight-gas-complex-gas/about-tight-gas.html>. Acesso em: 10 mar. 2019.

U.S. ENERGY INFORMATION ADMINISTRATION. **Natural Gas Explained: Where Our Natural Gas Comes From?** 2018. Disponível em: <https://www.eia.gov/energyexplained/index.php?page=natural_gas_where>. Acesso em: 09 mar. 2019.

YANG, Rui-Zhao et al. Integrated application of 3D seismic and microseismic data in the development of tight gas reservoirs. **Applied Geophysics**, v. 10, n. 2, p. 157-169, 2013.

MAXWELL, Shawn. Microseismic: Growth born from success. **The Leading Edge**, v. 29, n. 3, p. 338-343, 2010.

OLIVEIRA, V. A. A. **Caracterização de Reservatórios Não Convencionais/ *Tight Gas.*** Niterói, Universidade Federal Fluminense, 2014.

CARACTERIZAÇÃO DE UM FOLHELHO DA BACIA DE CAMPOS A PARTIR DE PERFILAGEM DE POÇOS E ENSAIOS DE LABORATÓRIO Claudio Rabe, Ewerton M. P. de Araújo, Karina V. B. Gaggiotti, Sérgio A. B. da Fontoura, 2º Congresso Brasileiro de P&D em Petróleo & Gás, 2003

MIRANDA, A. I. F. **Imageamento da porosidade através de perfis geofísicos de poço**. Universidade Federal do Pará, Belém, 2004.

SOUZA, C. O. **ANÁLISE DE CORRELAÇÃO LITOLÓGICA A PARTIR DE DADOS DE PERFIS DE POÇOS CONVENCIONAIS DO CAMPO DE NAMORADO USANDO SOFTWARE COMERCIAL.** Universidade Federal Fluminense, Niterói, 2014