THE POTENTIEL OF SHALE GAS PLAYS IN ALGERIA

Mohamed KACED & Mohamed ARAB (SONATRACH Exploration)

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INTRODUCTION

In the light of what was made in the prolific provinces of North America, SONATRACH (the Algerian National Oil Company) is very closely interested in the unconventional resources associated with shale gas plays, according to their considerable potential with the economic production known in North America.

The Saharan platform having an overall surface area of 1 143 600 km² is the site of most of the hydrocarbon resources discovered in Algeria. It consists of Precambrian basement on which thick sedimentary series have been deposited in basins that have undergone more or less separate geological evolution with structures formed during the Palaeozoic. The sedimentary cover is mainly siliciclastic and comprises the main source rocks which consist of the Silurian and Frasnian hot shales rich in organic matter.

These two main source rocks can be mapped across most of the Algerian basins within the Saharan Platform. They present good gas shows while drilling and have characteristics of first class worldwide source rocks. In some parts, the hot shale intervals display more than 100 m in thickness and Total Organic Contents (TOC's) of over 10%. The present day maturity of these shales is within dry gas window, over extensive areas. They are at moderate depths (1000 to 3000m) within the marginal zones of several basins, i.e. Illizi, Mouydir, Ahnet, Reggane and Gourara.

AIMS AND METHODS

The Algerian mining domain offers promising prospects for unconventional gas reservoirs and so SONATRACH intensifies its exploration efforts in order to highlight the resource potential associated with shale gas plays.

Preliminary investigation was carried out on all available data from cores, logs and mud logs to map the areas: 1) where shales have high TOC, 2) where hot Shales have high thickness, 3) where shale objectives occur at low depth and 4) areas of high thermal maturity.

In order to evaluate reservoir properties and gas in place, specific open hole logs shale gas logging have been performed in shale gas sections, which were also partly cored for specific measurement and calibration, in some new wells drilled in the prospective zones targeting both the Silurian and Frasnian shales. These wells were primarily implemented for conventional objectives in sandstone reservoirs. First analysis of this data confirms the potential held by these non conventional reservoirs and analogies can be deduced in comparison with North American plays (Haynesville shale and Barnett shale).

This complementary data was used further into the understanding of the shale gas resource potential in multidisciplinary integrated studies carried out on three sedimentary basins. The main goals of these study projects are: 1) characterization of the reservoir quality and completion quality of the Frasnian and Silurian Shales; 2) estimate gas in place; 3) identifying and ranking of shale gas prospects and 4) design and location for pilot wells.

RESULTS

Organic Geochemistry and Thermal Maturation Overview

The hot shales occurring at the basal Silurian (Landovery) are present across all the Saharan platform, their thickness varies from 10 to 100m in the eastern sedimentary basins, i.e. the Illizi, Berkine, Oued Mya, Mouydir and West Hassi Rmel Basins. The richness in organic matter is good to excellent and the residual TOC's vary generally from 2 to 10%. For both source rocks the organic matter is of type II marine Kerogen.

In regard to maturity, the Silurian is in dry gas phase in the centre of the Berkine Basin and the Western and Northern zones of the Illizi Basin. The Silurian is in oil phase in the Tin Fouyé area and in the central part of the Illizi Basin, as well as in the northern border of the Berkine Basin. Further West, the organic matter reached the oil maturity stage within the East and North surrounding areas of Hassi Messaoud, the surrounding area of Hassi R'mel, as well as within the Northern part of Oued Mya Basin. The degree of maturity increases towards the south until reaching the dry gas phase within the Mouydir Basin, and this while passing by the wet gas window and condensate in the west Hassi R'mel, the Djofra saddle and the southern part of the Oued Mya Basin.

In the centre of the Berkine Basin, the Marfeg trough and the Western part of the Illizi Basin, the totality of the oil potential was achieved during the Palaeozoic. Elsewhere, depending on places, the expulsion is generally Cretaceous-Tertiary age. In the Illizi Basin, the expulsion of gas occurred during the Cretaceous Tertiary period. In the Berkine Basin and the Triassic South-eastern province, the timing of the expulsion of gas is as follows:

- Carboniferous -Lower Jurassic in the centre of the basin and Upper Jurassic-Lower Cretaceous in the western part of the basin.
- Upper Cretaceous – present, towards the North and south edges of the Berkine Basin and towards the edges of the Triassic South-eastern province.

The timing of oil expulsion is Upper Cretaceous-Present in the surrounding areas of Hassi Messaoud and Hassi R' mel, as well as, in the Northern part of the Oued Mya Basin. Lower Cretaceous in the South of the Oued Mya Basin and Djoufra saddle, and Lower Cretaceous - Jurassic towards the Benoud through. The expulsion is exclusively Palaeozoic in the Mouydir Basin and the Allal Dome.

The Frasnian hot shales, regarded as the second important source rock, is eroded by the Hercynian unconformity in the North-West of the Illizi Basin, the South-eastern Triassic province, the Northern part of the Berkine Basin and in the major part of the Central Sahara Basins. The thickness varies from 0 to 50 m in the Berkine Basin and from 10 to160 m in the Illizi Basin. The hot shales generally located at the basal Frasnian are very rich in organic matter; the TOC's vary from 2 to 6% in the Illizi Basin and from 3 to 10% in the Berkine Basin. These hot shales are in the maturation state of gas in the centre of the Berkine Basin and in the oil phase, immature by places, in the Illizi Basin.

In the Western province, the Silurian and Frasnian hot shales constitute the main source rocks in the Reggane Basin. The thickness of Silurian hot shale varies from 40 to100 m with a thickening towards the North (centre of the basin); its high content in organic matter is materialized by TOC's from 3 to 5%. Both source rocks are in the gas phase within the Ahnet-Gourara Basins, the North of Reggane Basin, the centre of the Sbaa Basin, the major part of the Tindouf Basin, the central-Eastern and the North-East zones of the Bechar Basin. Apart from these zones, the source rocks cited above are in the gas phase.

The generation and expulsion of hydrocarbon from both source rocks took place at the end of Palaeozoic, before the Hercynian paroxysmal phase; nevertheless, considerable quantities of gas were expelled during this uplift according to a model of adsorption and desorption from BP (1998), which makes it possible to the accumulation of the Hercynian structures being formed. In addition, the expelled gas would have been trapped in the Visean structures generated by the early Hercynian phase, as in the Ahnet and Timimoun.

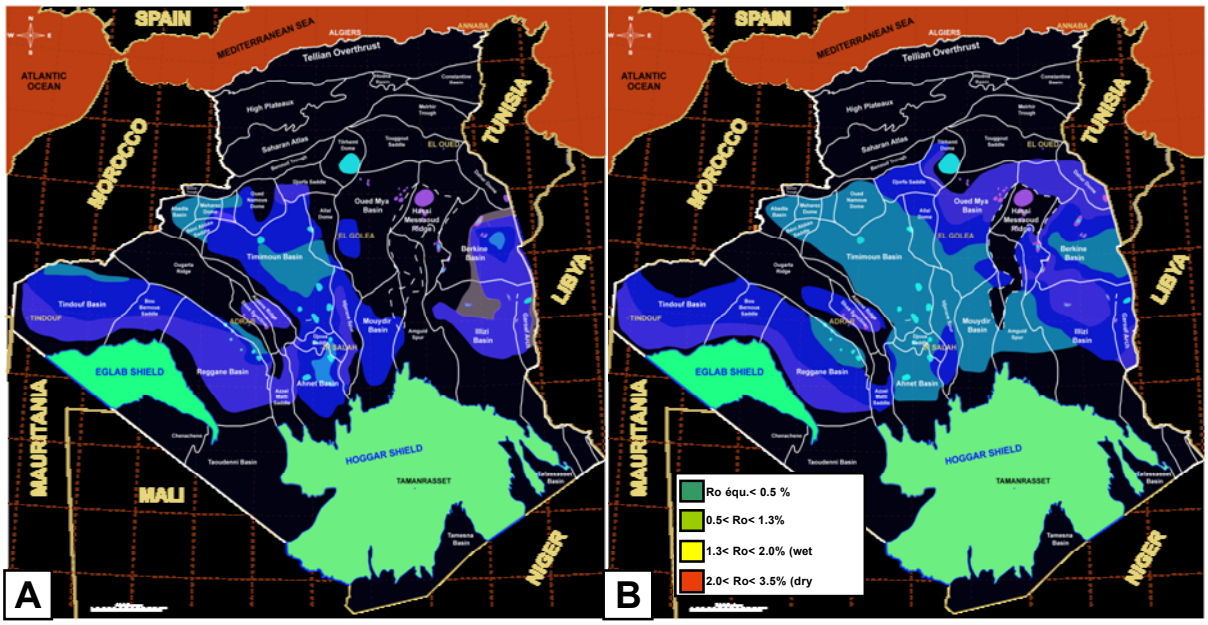

Figure 1: Thermal Maturity of (A) Frasnian and (B) Silurian hot Shales

Prospective zones

The potential prospective zones within the Saharan platform have been identified from a regional mapping based on: 1) thickness higher than 20m; 2) depth < 3000 m; 3) residual TOC higher than 3%; 4) Maturity of gas materialized by vitrinite reflectance potential (PRV) and equivalent Reflectance in oil (Ro%) between 1.7 and 3% and so, the prospectivity maps allow to locate the favourable basins or zones for shale gas plays in terms of geology.

The maturity map of one type of organic-rich facies to another is different, depending on the Kerogen kinetics, for instance in the Barnett shale (USA), the dry gas window starts at 1.4% while for the Saharan Silurian hot shale it is about 1.7 - 2%.

The prospectivity maps allow locating the favourable basins or zones for shale gas plays in terms of geology.

– *Illizi Basin:* Silurian is prospective in the Western part of the Illizi Basin (Flatters trough), it has a good thickness (>30 m), a very good organic richness (TOC > 3%) and thermal maturity of dry gas. In the Ahara High, the southern part of In Amenas, this source rock is in the phase of wet gas. In this case, the gas and liquids could be produced.

– *Berkine Basin:* contains the best qualities source rocks of the Saharan platform, they are mature in dry gas phase and organic-rich, but they are very deep (>4000 m, even 6000 m) and the pressure is higher than 4000 psi, even 11000 psi. These conditions are constraints for hydraulic fracturing and for the production costs.

– *Mouydir Basin:* In spite of its modest characteristics in terms of richness in organic matter (2 > TOC <3%), It can be prospective, except within zones of high vitrinite reflectance (> 3%) there is of possibility of high CO^2 content.

– *Ahnet-Gourara Basins:* these are the most potential basins of shale gas plays. Both of Silurian or Frasnian hot shales have a very good richness in organic matter (TOC= 1.5 - 5%), great thicknesses reaching locally 160m and the maturity of gas on vast surface areas.

– *Reggane Basin:* it is the median part which has an average potential for the Frasnian. It shows a medium richness of 2% and a thickness varying from 30 to 200 m; this area presents a state of maturation of dry gas. The Silurian is of a certain interest, but it is deep (>3500 m).

– *Bechar Basin* (in a broad sense): it contains excellent qualities source rocks with thicknesses varying from 20 to140 m. These organic-rich formations reached the gas window in the whole basin. The advantage is that they are at relatively shallow depth, less than 3000 m for the Silurian and less than 2000 m for the Frasnian hot shales.

– *Tindouf Basin:* the prospectivity of Silurian shale gas is fairly average in the North of the basin. It is characterized by medium richness to good with TOC's generally lower than 2%, reaching 6% in one well (not enough data available). In the North, it is in a dry gas phase, but in the South it is in oil and condensate window. Based on the data of the few wells drilled until now, the Frasnian is not really potential; it can be perspective on a very limited surface area in the North.

Shale Gas Resource Potential

In order to assess reservoir quality, specific open hole logs have been acquired in shale gas sections of few wells drilled for conventional objectives in sandstone reservoirs. The evaluation tools comprise: Elemental device (spectroscopy), Array induction, Magnetic Resonance, Sonic with anisotropic determination, GR, Sonic, Resistivity, Image log & Neutron Density that enables to quantify in particular mineralogy, volume of adsorbed and free gas, matrix permeability…

Evaluation of the Silurian and Frasnian shale Gas Formations of wells in the Ahnet and Gourara Basins indicate that good reservoir quality are present over large area and comparison can be made to the US shale gas plays.

Preliminary estimates of total GIP in the Frasnian hot shales of a well from the Ahnet Basin indicate a potential of 65 Bcf/mi² (25 Bcf/km²) and net reservoir thickness 131 m, average permeability 292 nD. However, complementary laboratory work is needed to calibrate these data with core analyses.

From geochemical modelling, the resources of shale gas in the two main source rocks of the Algerian Sahara (the Silurian and Frasnian hot shales) in the 2650 to 10585 Tcf range from a total generated of 26450 Tcf, seeing that the proportion of residual gas remaining in source rocks after expulsion is from 10 to 40% of the generated volume.

SUMMARY

Although some basins like Illizi and Berkine have best qualities in terms of the generation potential, but the potential of shale gas depends on the relations between maturity of gas and depth. The western Saharan basins have just an average potential, they have relatively low to medium generation potential. The best zones (basins) for the exploration of shale gas plays in the Saharan platform are the western part of Illizi, the Ahnet-Gourara and Bechar basins.

In the Illizi Basin, there are some prospects which are in a favourable environment for Silurian shale gas, but none for Frasnian shale gas which is in the oil window at present. The interesting zones for Silurian shale gas are located in a narrow Western Northern band.

In the Berkine Basin, some prospects are located in potential zones for both Frasnian and Silurian shale gas, in the same time; however, the depth of the objectives is too high. Silurian hot shales are well developed in the central part of the basin where values of Ro going up to 1.6 % were recorded.

In the Ahnet and Gourara Basins, there are zones interesting for both Frasnian and Silurian, with respect to the maturity and the depth of the objectives. Preliminary estimates of total GIP in the Frasnian hot shales of one well from the Ahnet Basin indicate a potential of 65 Bcf/mi². Resource estimates from geochemical modelling for both Silurian and Frasnian shale gas plays in the Saharan basins is 2650 Tcf.

In terms of choice of source rocks, Frasnien of the Ahnet basin having already shown strong gas concentrations in mud during drilling, also in the Gourara and Berkine basins are considered as the best candidate to prove the concept with performance indicators (drilling and stimulation feasibility, minimum tested gas, …). For the Silurian shale gas , the interesting zones are identified in the Ahnet and Gourara basins and to lesser degree in the Illizi basin.

Future work will relate to the drilling of pilot wells planed during 2012 on which a thorough evaluation will be carried out, in terms of core analyses, logging and stimulation to answer the questions of the volume of gas in place, manner of producing it, production and economic viability.

As far as the development of shale gas reservoir is concerned in the view of the important expertise needed and the costs involved, it is necessary for SONATRACH to go into partnership with companies having a well established knowledge.