The Challenges of Natural Shale Gas Exploration and Extraction in order to facilitate feasibility analysis in Libya

[1]Dr. Suleman Hamed, [2]Mr. Saleh Emhanna, [3]Mr. Gamal Khalifa and [4]Eng. Bobaker Alkorgaly (*)

[1] Faculty of Economic & Political Science - University of Ajdabiya
[2] College of Engineering - University of Ajdabiya
[3&4] Exploration Department - Sirte Oil Company

Abstract

The main object]tive of this paper to provide a comprehensive in-depth analysis of the current status of shale gas explorations in Libya. It is examines the possible potential for shale gas in and the technical and institutional obstacles. The paper analyzes the characteristics of the shale gas revolution that developed its precarious nature, the requirements for

(*) Email: Sulieman.hamed@uoa.ly

its initial exploration, and future prospects and also turns to the significant obstacles to shale gas future exploration and production in the regions, why successfully addressing those challenges are problematic in key countries, in such countries the challenges are likely to be successfully engaged, and what it all means for how markets and trade in shale gas will evolve.

The paper concludes that while Libya have abundance of shale gas reserves could well prove a boom for the region, the myriad political and institutional obstacles faced by national governments mean that a shale gas revolution of the nature seen in the Libya remains a distant prospect. However, shale gas exploration still in the initial stage and has been confronted with many challenges.

This paper systematically analyzed the current status of Libya's shale gas exploration from four aspects for the first time resource situation, exploration status, policy and, technology status. Barriers to the shale gas industry mainly include objective factors, such as geological and surface conditions, shale gas proven reserves, technology innovation and environmental concerns and financial and legislation. Establishing a national shale gas comprehensive experimental zone; enhancing scientific and technological research; and establishing shale gas regulatory system with an emphasis on environmental protection and supervision.

Keywords: *Natural Shale Gas, Economic, Environmental, Fracking, Exploration and Extraction.*

1. Introduction

Shale gas is a kind of unconventional natural gas trapped within shale formations representing the sedimentary rocks containing a great quantity of organic matter required for petroleum and gas formation and consisting mostly of methane and shale gas also contains ethane, propane, butane, and some non-hydrocarbon compounds (Zhiltsov and Semenov, 2017).

The importance of unconventional shale gas has grown up quickly in the world after evolving into an important resource play for the United States, accounting for more than 14% of produced gas by the end of 2004 (EIA, 2010) and it is expected to become a major source of natural supplies in the United States by 2020. Libya includes three hydrocarbon provinces known to be the most important basins to challenge this kind of unconventional resource play. These are in order of decreasing resource importance are the Sirte, Ghadames and Murzuq basins (Fig, 1). Most of Libya's hydrocarbon was generated from Silurian and Cretaceous shales.

The Silurian and Cretaceous shales presented in all Libyan produced basins at depth reached to more than 8000 feet with different thickness with good TOC and maturity when they correlated to world basins which allowed the shale will be good shale gas source and with estimated reserve as much as more than 200 tcf which is trapped within tiny pore space of high clastic content shale's are brittle and shatter providing multiple dentric fractures (Table 1). Over 90% of Libyan oil was sourced from the Campanian Sirte Shale and the Silurian Tanzuft Shale (Hallet and Clark-Lowes, 2016).

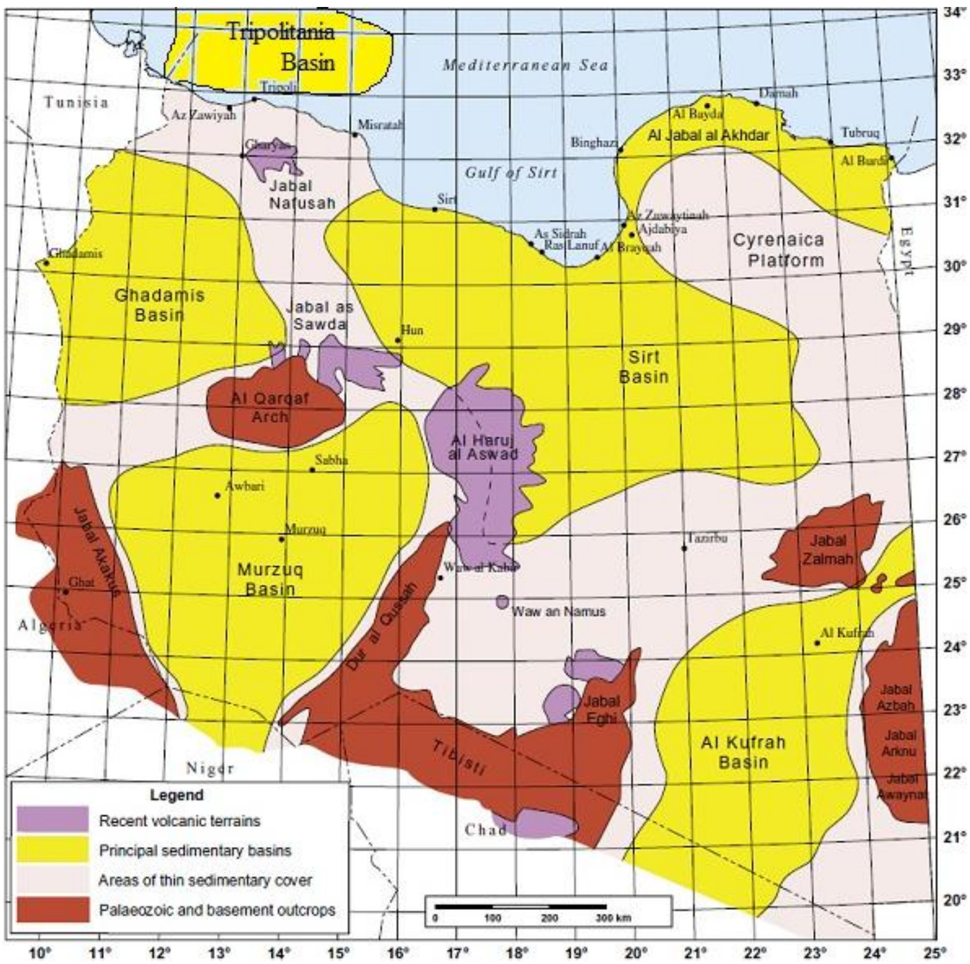

Figure 1: The Principal Libyan Basins (Hallet and Clark-Lowes, 2016).

The Silurian shales in the Ghadames Basin in North Africa have served as the most important petroleum source rock in the entire Saharan Platform. The gross thickness of Silurian shale is more than 300 m; however, the thickness of organic-rich shale ranges from 10 to 65 m. The total organic carbon (TOC) of this type II kerogen marine shale averages 5% (Kamel Dadi and et al, 2019).

Table 1: Main Source rocks in the Libyan basins (Hassan and Kendall, 2014).

Sedimentary Basin	Source Rocks	
	Age	Formation
Sirte	Cretaceous	Sirte Shale
		Rachmat
		Etal
		Harash
Ghadames	Silurian	Tanezzuft
	Devonian	Awinat Wanin
Murzuq	Silurian	Tanezzuft

1.1.Conventional and unconventional gas

There are several types of geological formation that trap naturally occurring gas. They are categorized as either conventional or unconventional gas reserves. The term “unconventional” has been used by the industry for a wide range of play types (Fig, 2). The conventional resources, which correspond to light crude oil and sweet natural gas trapped into porous and permeable reservoirs.

These resources can be produced at a relatively low cost because hydrocarbons flow out of the reservoir by natural depletion and no expensive upgrading processing is required. On the other hand, when the reservoir or the fluid properties, or both deteriorate, it becomes necessary to apply specific technologies to extract and/or to upgrade these resources. The application of these technologies comes at an increasing financial and environmental risk, which makes unconventional resources more challenging to develop (Euzen, 2011). Gas fields are differentiated in: Conventional gas and Unconventional gas.

Conventional gas:

Gas originated somewhere else (the "source" or "mother" rock) and migrated to a porous and permeable formation such as a sandstone or limestone sealed on the top by an impermeable cap layer (the "reservoir rock" or "reservoir")

Unconventional gas:

- **Coalbed Methane (CBM)** gas (gas formed and yet present in low permeable coal layers)
- **Tight gas** (gas migrated to a low permeability reservoir rock)
- **Shale gas** (gas originates in the shale and is still present in the shale)
- **Gas hydrates** (crystalline ice-like molecular complexes formed from mixtures of water and gas molecules) present in the top few hundred meters of sediment beneath continental margins at water depths between a few hundred and a few thousand meter, and in permafrost sediments in Arctic areas.

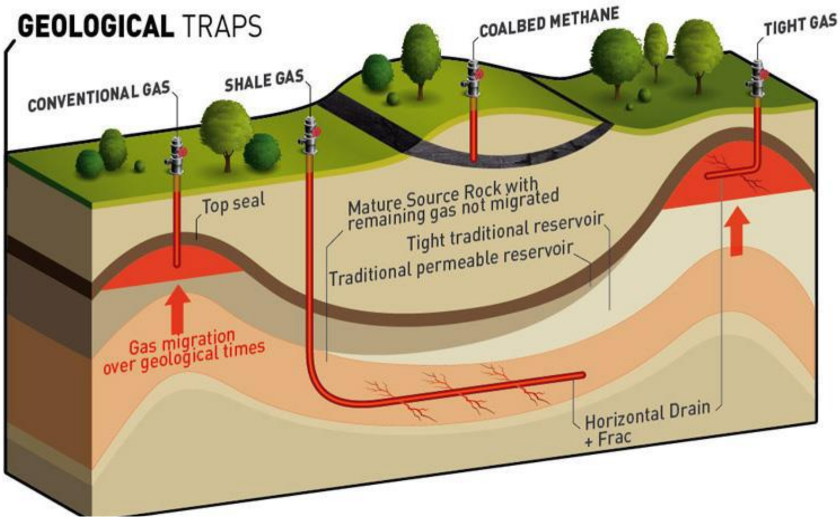

Figure 2: Schematic geology of natural gas resources (EIA, 2010).

1.2.Hydraulic Fracking

Extraction of natural gas from sources of organic, rich and tight shales is inherently challenging. Due to the it's permeability, hydraulic fracturing is performed at an initial phase during the development of shale gas reservoirs. The gas production from the well will typically decrease rapidly, demanding regular stimulation of the wells to maintain production. Several techniques exist for performing this stimulation.

Development of horizontal drilling and hydraulic fracturing is crucial for the economic production of shale gas reservoirs, but, it must be performed with caution and with a multidisciplinary approach (Li W, 2019). Hydraulic fracturing has revolutionized the (Fig, 3) way we drill for gas. It has allowed us to retrieved gas from tough shale that were difficult to reach in the past. Today there are two primary extraction processes of natural gas from shale formations: hydraulic fracturing or fracking, and horizontal drilling, both processes present their own set of safety and environmental concerns. In the simplest of terms, horizontal drilling is the process of first drilling vertically down into the earth, and then turning to drill horizontally, this process is used primarily for improved access to hard-to-reach deposits and vastly expands the area of exploration.

The downside: some believe the wider the area of exploration, the greater potential for the drill to cross a geological fault line and possibly ignite an earthquake, although this theory has been widely debated. Fracking involves making fractures in deposits by use of a pressurized liquid, namely water. This process requires quite a large amount of water and, in many parts country droughts have driven the need for conservation of this most precious natural resource. Secondly, fracking poses concerns for groundwater contamination and ultimately the surrounding communities' drinking water supply.

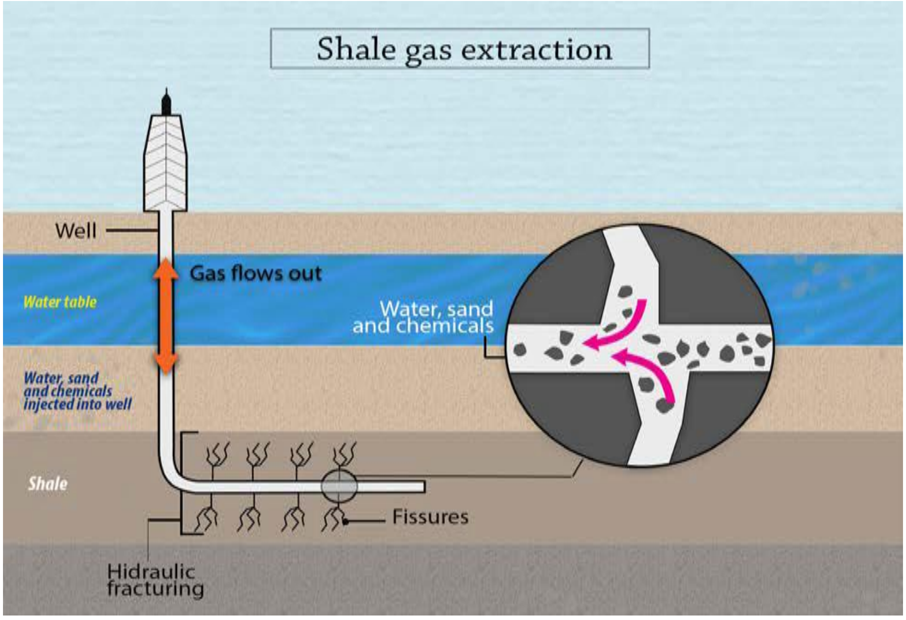

Figure 3: Illustration of shale gas extraction by hydraulic fractures (Nuno Ferreira and Li Wu, 2019).

So extract the trapped gas in shale by using method which is called fracturing [fracking], it is technique where the shale source rock trapped the gas at depth below the surface is fractured open by pressurized liquid made up of sand, water and chemicals [proppant] to keep the generated fractures open to allow the gas and fluid to escape from the small porous porosity and to flow up after fracs horizontally to may be hundred distance within the shale layer. The use of horizontal drilling in conjunction with hydraulic fracturing has greatly expanded the ability of producers to profitably produce natural gas from low permeability geologic formations, particularly shale.

Application of fracturing techniques to stimulate oil and gas production began to grow rapidly, although experimentation dates back to the 19th century, Starting in the mid-1970s, a partnership of private operators, the U.S. Department of Energy and the Gas Research Institute endeavored to develop technologies for the commercial production of natural gas from the relatively deep or shallow Cretaceous and Silurian shale deposited.

The advent of large-scale shale gas production did not occur until Mitchell Energy and Development Corporation experimented during the 1980s and 1990s to make deep shale gas production a commercial reality in the Barnett Shale in North-Central Texas. As the success of Mitchell Energy and Development became apparent, other companies aggressively entered this play so that by 2005, the Barnett Shale alone was producing almost half a trillion cubic feet per year of natural gas. As natural gas producers gained confidence in the ability to profitably produce natural gas in the Barnett Shale and confirmation of this ability was provided by the results from others basin. The development of shale gas plays has become a “game changer” for world natural gas market.

2. Scope and Evaluation

In total, the assessed 48 shale gas basins in 32 countries, containing almost 70 shale gas formations, these assessments cover the most prospective shale gas resources in a select group of countries that demonstrate some level of relatively near-term promise and for basins that have a sufficient amount of geologic data for resource analysis. Figure 4 shows the location of these basins and the regions analyzed (EIA, 2011). The map legend indicates four different colors on the world map that correspond to the geographic scope of this initial assessment:

- Red colored areas represent the location of assessed shale gas basins for which estimates of the 'risked' gas-in-place and technically recoverable resources were provided.
- Yellow colored area represents the location of shale gas basins that were reviewed, but for which estimates were not provided, mainly due to the lack of data necessary to conduct the assessment.
- White colored countries are those for which at least one shale gas basin was considered for this report.
- Gray colored countries are those for which no shale gas basins were considered.

Although the shale gas resource estimates will likely change over time as additional information becomes available, the information shows that the international shale gas resource base is vast.

The National Oil Corporation (NOC) conducted a preliminary meeting and evaluation of the potential of Libyan shale gas resources in 2014 in Tripoli Libya. The evaluation result was widely cited by Libyan company and one foreign company. Since it was the only prediction released estimate is about 200tcf, from a provincial perspective.

In Libyan shale gas exploration has not started yet. Libya will follow North America's and the others progress to study its shale gas geological characteristics. Libyan government, oil companies and universities conducted basic research and focused on analyzing the geological conditions.

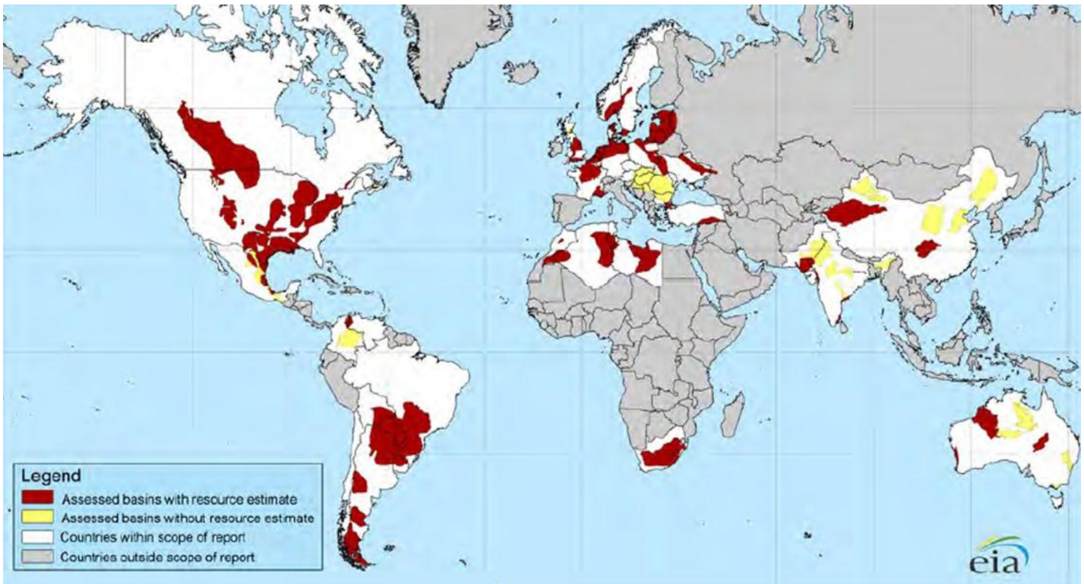

Figure 4: Map of 48 major shale gas basins in 32 countries (EIA, 2011).

3. Obstacles Stand in Way

It has been known that natural shale gas is plentiful in Libya, but the cumbersome task of finding and extracting it from deep below the earth's surface proved to be cost-prohibitive. However, intense research by the government should be continued, technological advances have eased the exploration and extraction process. Environment should be consider and its one of the main issues with laws and financial.

Libya has not yet entered or made progress in shale gas resources survey. But overall, the shale gas is still in its infancy with many serious problems, these mainly includes: shale gas exploration and exploitation and geological condition, shale gas proven reserves, technology innovation, environmental concerns in the internal square constrain the shale gas sector. The other factors such as pipeline monopoly, technology transfer, and geological data use mechanism, water scarcity.

3.1Geological Status

The geological and surface conditions for the shale gas are complicated. Where there are many geological obstacles that makes shale gas exploration and development more difficult such as; depth of target zone and their maturity and thickness as well as water availability. The depths, thickness and total organic matter (TOC) of the target shale zones various from basin to basin and from location to location in the same basin (Table, 2).

Table 2: Geological conditions for the shale gas formations in Libya (Rusk, 2001, Hassan and Kendall, 2014 and Hallet and Clark-Lowes, 2016).

Basin	Formation	Depth (ft)	TOC	Thickness (ft)
Sirte	Sirte/Rachmat	10,000 - 12,000	2.8%	200-1500
	Etal	11,000 - 16,400	3.6%	600
Ghadames	Tanezzuft	10,000 - 14,500	5.7%	115
	Awinat Wanin	8,000 - 12,000	6.0%	197
Murzuq	Tanezzuft	3,300 - 10,000	7.0%	67

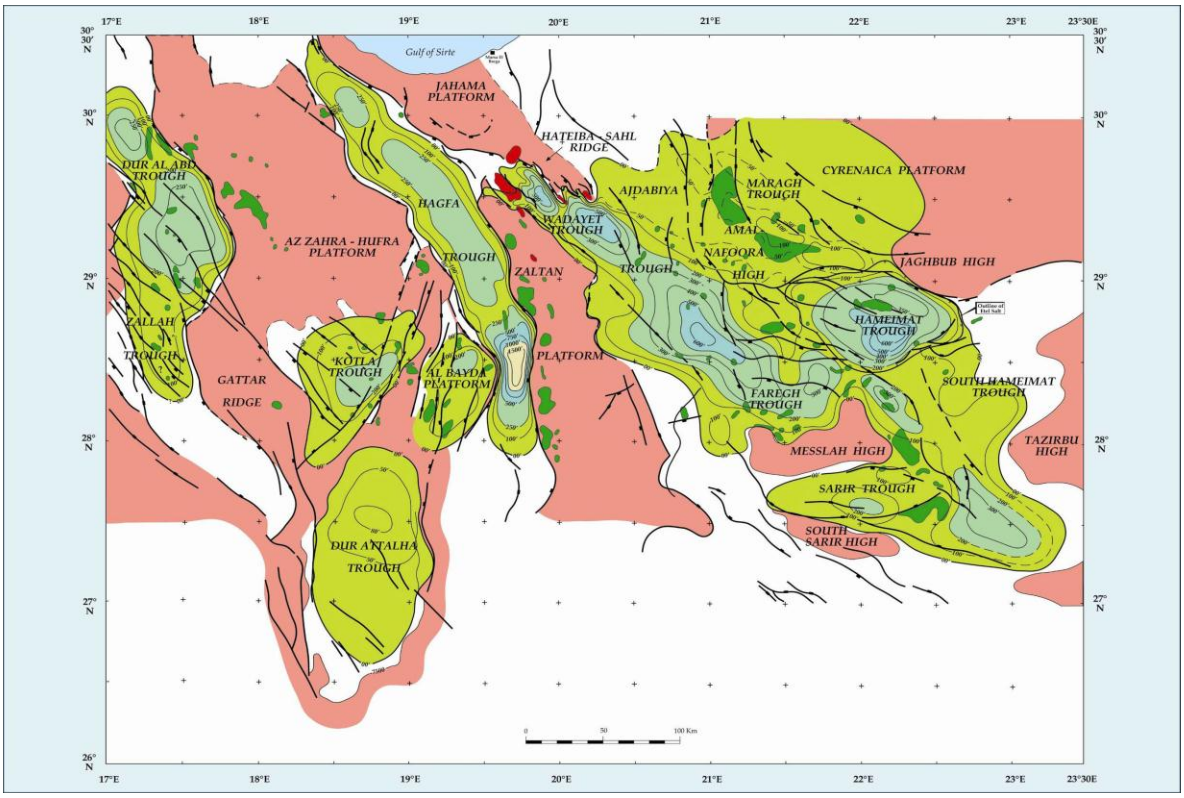

Figure 5: Map showing net cumulative thickens of Upper Cretaceous Cenomanian Etel and Campanian Rachmat-Sirte source-shales, Sirte Basin, Libya (Sikander, and et al., 2010).

Where the depth and distribution of the target shale formations are controlled by tectonic and setting of the interested areas. For example in the Sirte basin the presence of the shale (Green color) only in the low area (Graben), while they are thin or absent in the high area (Horst). The figures 5 and 6 shows the interested area for natural gas exploration in the basin in Ajdabiya and Hameimat troughs. While in both Ghadames and Murzuk basins the main source rock is Tanezzuft shale (Abualkhir, 2016). The interested area for exploration for shale gas in the depocentres in the basins (Fig, 7).

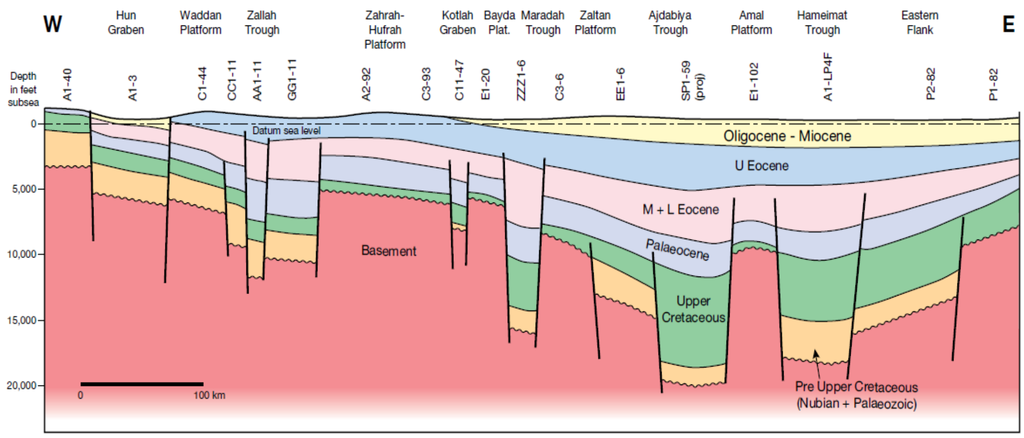

Figure 6: Sirte Basin W–E Regional Cross Section (Hallet and Clark-Lowes, 2016).

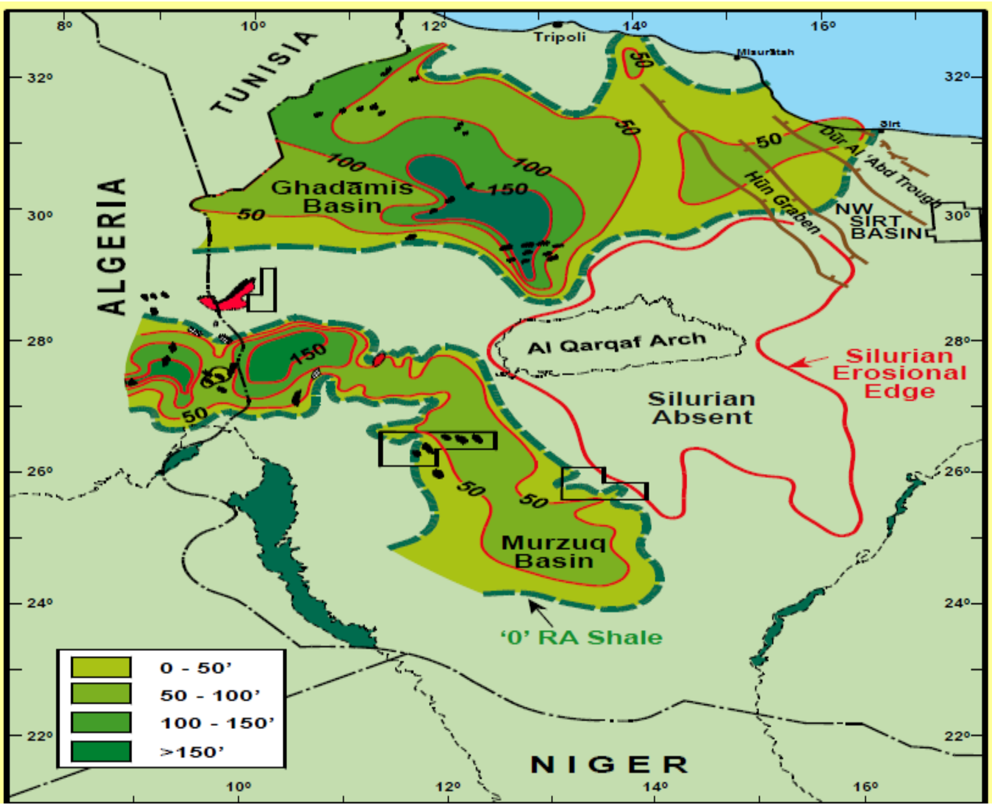

Figure 7: Map shows net thickness of basal Tanezzuft source rock in Gahdames and Murzuq basins (Abualkhir, 2016).

3.2 Water availability

The main water sources in Libya come from four sources which are groundwater supplies almost 95% of Libya's needs; surface water only with 2% comprising rainwater and dam constructions; desalinated from sea water provides 2% and wastewater recycling 1% (Gouda and et al, 2017). So, the critical problems that hinder the sustainable development in Libya is the lack of renewable water resources. The problem of water supply raised here because Libya does not have surface water resources to be used for gas extraction.

The most important groundwater resources in the Ghadames Basin are represented by the two main aquifer systems which are the Kiklah sandstone aquifer and Upper Cretaceous carbonate aquifer systems (Rashrash and Farag, 2016). In the Sirte Basin the main source of water is Cretaceous Nubian sandstone aquifer (Wright and et al, 1982). While in the Murzuq basin two main groundwater reservoirs are considered; the lower groundwater reservoir includes the Siluro-Devonian and Cambro-Ordovician sandstones (Acacus and Tadrart) and the upper groundwater reservoir includes the continental formations of Triassic, Jurassic and Lower Cretaceous usually known as the post-Tassilian and Nubian series (Ibeda and et al, 2014).

3.3Technology Status and innovationn

The key shale gas technologies and equipment in world still underdeveloped, which leads to a high cost of exploration and development. According to shale gas technologies in Canada are at the market promotion stage, while China has just optimized a batch of applicable shale gas techniques and carried out technical research. Many shale gas key technologies {horizontal wellbore trajectory control, fracture detection} need to be imported. To make use of foreign technologies and equipment, you still require improvements and innovations according to complex geological and surface conditions, and this represents a great challenge.

These techniques have been mainly mastered by few companies covering the method of the characteristics of the shale gas reservoir and accumulation, shale gas geological evaluation and favorable block selection, the assessment method for shale gas resources, and well-logging identification and interpretation technology, method of seismic data acquisition and processing, horizontal well drilling technology, However, none of these companies fully grasp the whole set of exploration technologies and only have certain advantages in some aspects of shale gas techniques at present(Charles F. Mason & et al, 2015).

Libyan companies, it should have actively participated in overseas shale gas acquisition to absorb foreign experience and techniques.

3.4Environmental concerns

Environmental issues should ideally be weighed against the benefits of shale gas production, then debated in the political process, and trade-offs among these costs and benefits made through the democratic process. The decision making process, however, is made problematic to the degree that scientific evaluation of the risks is weak, the public is largely uninformed about the scientific state of the debates, and the political process for making the trade-offs is considered illegitimate by significant sectors of society. Partly because the fracking process used in shale gas is relatively new there is no scientific consensus on the degree of associated risks (Stefan & et al, 2011).

Believe that the other side controls the legislative process through its lobbying, the political process is decreasingly able to serve as the legitimate forum for making the trade-offs between protecting the environment, public health, and promoting economic activity. Nevertheless, we do know that fracturing of wells requires large amounts of water, generating opportunity costs for the use of that water. The water used in fracking contains potentially hazardous chemicals and its use must be managed properly. Large amounts of toxic wastewater must be treated and disposed of. Disposal of such wastewater into deep wells can cause noticeable earthquakes and damage.

The Following Some of Environmental Risks

- Competition for water affects drinking water, wildlife habitat, recreation, agriculture, industrial.
- Air emissions, including NOX (mono-nitrogen oxides), volatile organic compounds, particulate.
- Normally occurring radioactive material may be brought to the surface during shale gas drilling and production operations.
- Methane leakage into groundwater.
- Pollution from produced frack water disposal on the surface.
- Induced earthquakes from frack water injection into disposal wells.

3.5 Legislative concerns and policies:

- Private land and mineral rights ownership (the interests of all relevant parties: the owners, investors, banks, local administration and central government).
- Natural gas price deregulation.
- Tax exemptions to attract foreign investors.
- Facilitate procedures for obtaining the necessary licenses.

Facilitate procedures for obtaining the necessary licenses. Shale gas geological conditions are complicated, and the preliminary exploration cost of enterprises is huge with high risks, especially for non-oil-and-gas companies. Although the existing shale gas industry policies concentrate on the encouragement of shale gas production, the support for exploration work is not enough. Therefore, we recommend that a national shale gas exploration fund should be established and that the shale gas preliminary exploration work should be financed by the government, so as to identify the proven reserves of shale gas and collect shale gas geological.

3.6Political concerns:

- Geopolitical considerations (the rapid increase in shale gas production around the world maybe profoundly change energy markets , and has led to a significant decrease in conventional natural gas prices).
- The restrictions on joint ventures with foreign partners in this field

3.7Infrastructure availability:

Gas Pipeline Network Monopoly in the short term, infrastructures, such as the pipeline network, are barriers to shale gas industry. In the medium and long term, however, the pipeline network may constrain the exploration of shale gas.

3.8Economic & financial constrains (Aurélien Saussay, 2018, Valentina Ivan, 2015):

- Barriers to Project Financing Shale Gas Development
- Finance: Large financial markets that provide capital through joint ventures or loans to finance developments of shale oil and shale gas fields.

- Development of the existing infrastructure (roads, airports, pipelines....etc.) between the production fields and processing and exporting areas.
- High costs of drilling, production and treatment of environmental impacts.
- Availability of conventional oil and gas which is relatively cheaper than the unconventional ones in some countries.
- The Financial policies (local currency exchange rates; restrictions on remittances).

3.9Economic feasibility of shale gas in Libya:

Libya highly dependent on oil and gas resources, 95% of Libya’s economy is dependent on the revenues coming from oil industry while rest of the 5% is earned from non-oil industries, despite the availability of large reserves of conventional oil and gas, those sources are not renewable, and given the increasing global demand for gas, and its comparative advantages compared with oil and coal, in addition to easily transportation to the consumers in Europe (Ibrahim & et al, 2013).

Although there are indications of large reserves of shale gas in Libya, it is not expected in the short and medium term to exploit this resource economically because there are several challenges facing the industry not only in Libya, but in the world except the American experience, which is encouraging but may not be reproducible anywhere in the world due to the different circumstances from one country to another (Abualkhir, 2016).

Geological characteristics: (depth of targeted formations, availability of water); environmental considerations (water disposal & its potential effect on rivers, surface water and cities); infrastructure and technologies used; economic policies and legal system: (Land ownership, tax incentives, general acceptance of this type of industry, availability of conventional oil and gas at relatively low cost).

All these factors are reflected in the cost of shale gas production. However, development in this promising industry should not be left behind; some of the challenges prevailing today may not be the same in the future. Updating of the technologies continuously and they will be available at a cheaper cost in the future. Its extraction must be economically feasible as extracting unconventional resources is financially expensive and riskier than conventional (Marcelo Nunes Fonseca & et al, 2016).

4 Establish a National Shale Gas Comprehensive Experimental Zone

Before promoting large-scale shale gas exploitation activities, the government should establish a national shale gas comprehensive experimental zone in regions with a certain basis of shale gas exploration. The major work in the experimental zone should be developed from three aspects: conducting further research on shale gas basic geology and exploring appraisal methods and key geological parameters for screening shale gas plays, exploring the factory mode of operation and perfecting theory and technology systems for shale gas exploration and utilization; and conducting trials on the reform of shale gas management systems.

5 Establish Shale Gas Regulatory System and Strengthen Environmental Supervision

An effective regulatory system serves as an important safeguard to shale gas exploration and development. Government must accelerate the building of a supervision system to promote sound and orderly progress in the shale gas exploration industry. First, laws need to be formulated. Second, a unified energy supervision institute and professional regulatory team is needed to strengthen supervision of shale gas market access, access to the natural gas pipeline network, land utilization and the process of shale gas production. Third, a system of on-site verification should be set up, and operating rules and industry standards of the overall process of shale gas exploration and development should be regularly checked and established. Severe environmental problems may occur in shale gas exploration and development, and thus, strengthening environmental supervision is necessary. What is more, Government should strengthen the environmental enforcement of local environmental protection bureaus and establish a comprehensive punishment mechanism to increase the costs to enterprises for illegal activities and decrease the possibility of environmental accidents.

6 Conclusions

Hydrocarbons will remain an important source of energy for decades, Shale gas resource has huge potential in Libya, and its exploration and development will increase natural gas supply, optimize the energy structure and safeguard the security of energy supplies, in an effort to boost the shale gas industry. However, shale gas exploration and development is still in its infancy and faces many challenges.

By looking to the shale gas industry barriers mainly include objective factors, such as geological and surface conditions, shale gas proven reserves, technology innovation and environmental concerns as well as legislation fanatical while pipeline monopoly, water scarcity, technology transfer and an imperfect geological data use mechanism may be the obstacles. To this end, the policy recommendations proposed as follows.

For Strengthening and Sustainability investigation and evaluation work to obtain confirmed shale gas proven reserves in Libya; perfecting shale gas policy and stimulating shale gas exploration work; building a national shale gas comprehensive experimental zone; enhancing scientific research to form a technological system for exploration and exploitation matching for shale gas geological characteristics; and establishing a shale gas regulatory system with emphasis on environmental protection and supervision.

This study will help researchers get picture of Libyan shale gas exploration, as well as accurately understanding different barriers to the shale gas barriers in the future. In addition, it will help the Libyan government formulate more suitable development strategies and policies for the exploring shale gas.

7 Recommendations

Based on the experiences of developed countries, namely the United States of America, developing countries, Algeria in particular, the researchers provide the following recommendations:

i. Libyan authorities involved to oil and gas production should encourage specialized companies to conduct in-depth studies of shale gas to determine geological characteristics, environmental considerations, and infrastructure for the industry.

ii. Updating relevant laws that did not address shale gas; such as Libyan oil law; environmental law; tax law to fit the nature of the industry through tax exemptions in order to encourage investors.

iii. Explain the comparative advantages available in Libya to investors, such as the proximity of markets, the geographical impact of the targeted areas and distance from the residential and agricultural areas, geological characteristics (depth of the target formations, availability of water).

iv. Investment in this promising industry by allocating the necessary funds to conduct the necessary studies in partnership with international partners specialized in shale gas production.

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