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Is It Time to Focus on Unconventional Resources

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Abstract

Trinidad and Tobago is a small country and our remaining known reserves now stand at 570 million barrels of oil and about 27 trillion cubic feet of gas. These reserves are both on land and offshore. The challenge of ensuring long-term growth of the energy sector has been great. This country has been endowed with energy resources and as a result, oil and natural gas play a central role in the socio-economic development of the country. Simultaneously they provide the necessary infra-structural economic base for the country becoming an attractive host for foreign investments in the energy sector.

In the face of declining crude oil production, relatively modest natural gas prices and no deepwater success to date, the development of our unconventional resources should now be placed into the forefront of our energy future. The large volume and long-term potential of our unconventional resources pose a big challenge today but increasing prices and improved technology is the key to their development in the future. The current worldwide trend is a move from conventional to unconventional resources due to technology advances.

This paper will evaluate the potential of developing our unconventional resources which include heavy oil, tar sands, tight sands and gas hydrates. The demand for oil and natural gas will continue to increase for the foreseeable future and we must now rely on unconventional resources to fill the gap between demand and supply. This analysis looks at the implications for the future and the technologies required for developing our unconventional resources. The research required and the technology advancement would also be discussed.

Key words: Unconventional resources; Heavy oil; Tar sands; Tight sands; Gas hydrates; Trinidad and Tobago

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BACKGROUND

Unconventional resources of both liquids and natural gas have seen tremendously growth contributing to increasing oil and gas production worldwide.

Unconventional liquid resources (including oil sands, extra-heavy oil, biofuels, coal-to-liquids, gas-to-liquids, and shale oil) grow on average by 4.6 percent per year. Sustained high oil prices allow unconventional resources to become economically competitive. World production of unconventional liquid fuels, which totaled only 3.9 million barrels per day in 2008, increased to 13.1 million barrels per day and will account for 12 percent of total world liquids supply by 2035 (Gruenspecht, 2011). The largest components of future unconventional production are 4.8 million barrels per day of Canadian oil sands, 2.2 and 1.7 million barrels per day of U.S. and Brazilian biofuels, respectively, and 1.4 million barrels per day of Venezuelan extra-heavy oil. Those four contributors to unconventional liquids supply account for almost three-quarters of the increase over the projection period.

World production of liquid fuels from unconventional resources in 2009 was 4.1 million barrels per day, or about 5 percent of total liquids production. In the future projections, production from unconventional sources is expected to grow and account for about 10, 12, and 17 percent of total world liquids production, which represent low, medium and high case scenarios.

Increasing supplies of unconventional natural gas, support growth in projected worldwide gas use. Global natural gas consumption grows by 1.6% per year. Shale gas production in the United States grew at an average annual rate of 48 percent over the 2006-2010 periods (Gruenspecht, 2011). Rising estimates of shale gas resources have helped to increase total U.S. natural gas reserves by almost 50 percent over the past decade, and are expected to supply 47 percent of U.S. natural gas production by 2035. Adding production of tight gas and coalbed methane, U.S. unconventional natural gas production is expected to increase from 10.9 trillion cubic feet in 2008 to 19.8 trillion cubic feet in 2035. Unconventional natural gas resources are even more important for the future of domestic gas supplies in Canada and China, where they would account for 50 percent and 72 percent of total domestic production, respectively, by 2035.

1. INTRODUCTION

With the passage of time we can clearly see now the decline of production and increase in demand of fossil fuel which is shifting our focus from reservoirs known as conventional reservoirs to those called unconventional reservoirs. Conventional reservoirs are those that can be produced at economic flow rates and that will produce economic volumes of oil and gas without large stimulation treatments or special reservoir processes. On the other hand, an unconventional reservoir is one that cannot be produced at economic flow rates or that does not produce economic volumes of oil and gas without assistance from massive stimulation treatments or special recovery processes and technologies, such as steam injection.

As the easy and conventional light oil gets depleted, a move towards more difficult hydrocarbon resources should already be well under way. However, this is not the case in Trinidad. These resources include heavy and extra-heavy crudes, and oil sands. Typically, the conventional oil recovery for these resources is generally low. An Enhanced Oil Recovery (EOR) method has to be implemented relatively early in these reservoirs. This has been, and will be, a primary driver for EOR, especially thermal, in the more difficult resources.

Economically producing gas from unconventional sources is a great challenge today. The large volume and long-term potential, and unprecedented interest in world markets, brings the unconventional gas into the forefront of our energy future.

2. TRENDS TOWARDS UNCONVENTIONAL RESOURCES

One useful way to view the size and nature of the resource base is a resource triangle (Figure 1). At the top of the triangle are conventional resources which are easy to develop and in smaller volumes. As we move down the pyramid, we find more unconventional resources which are difficult to develop and are in larger quantities. In the middle of the triangle are unconventional resources such as heavy oil and tight gas that have been producing for some time. These are followed down the pyramid by currently developing unconventional resources. At the base of the triangle are resources that are presently technologically challenging but emerging unconventional resources. These include shale oil and gas hydrate where gas hydrates present enormous gas potential accumulation around the world.

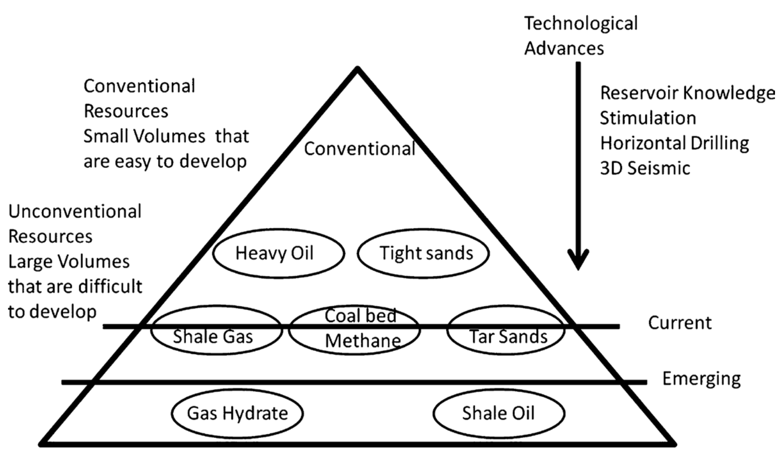

Figure 1
Resource Pyramid Focusing on Unconventional Resources (Holditch, 2006)

3. THE RESOURCE PYRAMID FOR TRINIDAD

If we evaluate the unconventional resource base for Trinidad, we will consider the resources that we think exist here. These include tight sands, heavy oil, tar sands and gas hydrates. Figure 2 shows the resource pyramid with estimated resources for these unconventional sources.

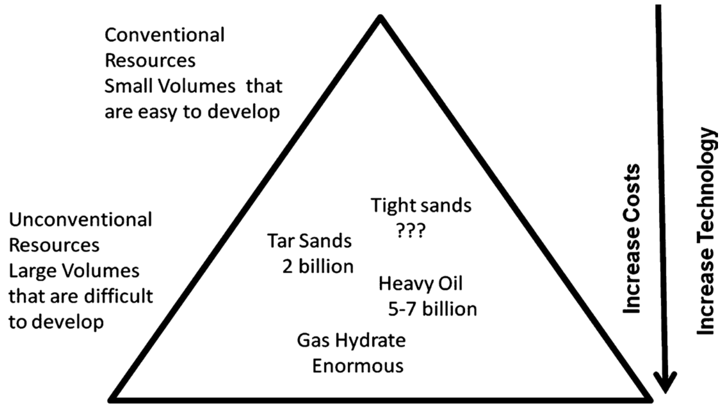

Figure 2
Unconventional Resource Triangle for Trinidad (Modified from Holditch, 2006)

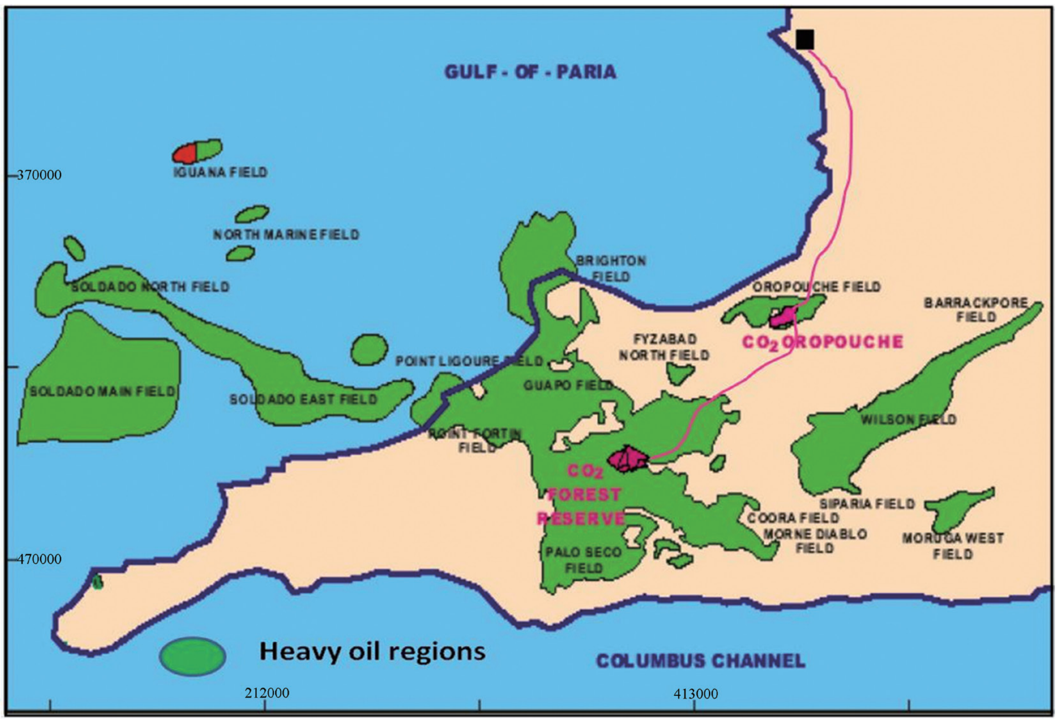

Figure 3
Heavy Oil Regions in Trinidad (Mohammed-Singh, 2010)

4. HEAVY OIL

Heavy oil reservoirs present a good alternate to conventional oil reservoirs to meet increasing energy demand. But producing from heavy oil reservoirs still remains challenging. Primary production yields less than 10% of original oil in place (OOIP). Hence, various enhanced recovery methods are used which may help in recovering as high as 80% of OOIP. These methods include Steam assisted gravity drainage, in situ combustion, solvent flooding, thermal methods, and chemical/polymer injection. With the advancement in technology, various hybrid methods have been developed, which are basically combination of various enhanced recovery methods suited for any particular condition.

In Trinidad, heavy oil production represents 5% of daily oil production (Hosein *et al*., 2010) from small steam injection and cyclic steam injection projects. The heavy oil areas on land and offshore are highlighted in Figure 3. The land reservoirs are found in the depth range of 350 ft to 3000 ft. The estimated heavy oil reserves on land are 1.7 billion barrels (MEEA). The offshore reservoirs are in the depth range of 2800 ft to 4000 ft and reserves are estimated to be 3.65 billion barrels. If we assume a recovery factor of 5%, then it is expected that we can recover close to 270 million barrels of oil from primary recovery. Obviously more can be recovered using enhanced oil recovery and the amount would vary depending on the method used and the characteristics of the reservoir. The main challenge for technology is to optimize heavy oil production with cost-effective and environmentally sound methods. Several very different production technologies have been developed for commercial exploitation of heavy oil; there are more techniques in research or pilot development.

Table 1 is a compilation showing the EOR processes with estimated recovery and costs. The potential recovery from heavy oil exploitation is tremendous; however, large investments are required for EOR methods. It is important to have screening criteria to establish which EOR method is required for the different heavy oil areas. Additionally, other pilot projects and research into the use of Vapor Assisted Petroleum Extraction, Steam Alternating Solvent, Steam Assisted Gravity Drainage (SAGD) and In-situ Combustion can be evaluated.

Table 1
EOR Methods with Estimated Recoveries

Process		Recovery factor (%)	Estimated recovery for trinidad MMBBLS	Extraction cost (US$/bbl)
Primary Production	Cold Production (CHOPS)	5-10	35	14-16
EOR	Steam Flood	Up to 60	4200	
	Cyclic Steam Stimulation (CSS)	15-20		18-21
	Steam Assisted Gravity Drainage (SAGD)	Up to 60	4200	16-18
	Vapor Assisted Petroleum Extraction (VAPEX)	Up to 50	3500	Pilot
	Steam Alternating Solvent (SAS)	Up to 75	5250	Pilot
	In situ Combustion	Up to 60	4200	R&D

Figure 4 highlights the various stages of deployment of the different EOR methods and their maturity. The diagram shows the processes that are presently commercial, those under pilot projects and research and development. Steam, SAGD and gas injection are commercial and mature EOR processes. Microbial EOR technique is still in the infant stages.

Comparison of the heavy oil classification for some heavy oils in Trinidad, Canada and Venezuela are shown in Figure 5.

Most of Trinidad's heavy oil samples are considered Extra Heavy Oils having API gravity greater than 7° but less than 20 and viscosity greater than 100 cp but less than 10,000 cp at reservoir conditions. This is based on the Heavy Oil Definition by Cupic (Cupic, 2003).

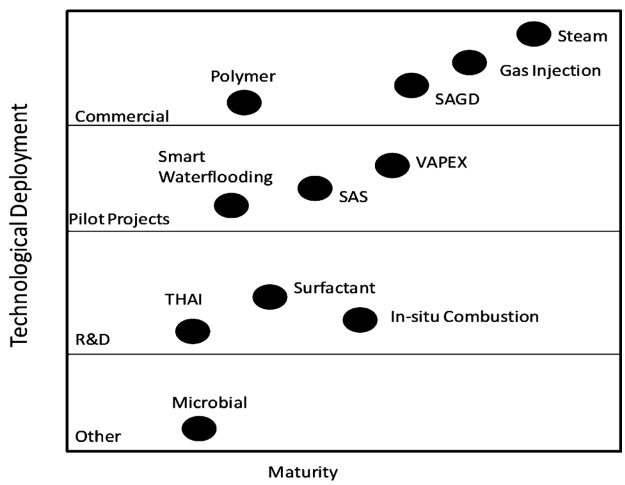

Figure 4
Technological Deployment of EOR Methods

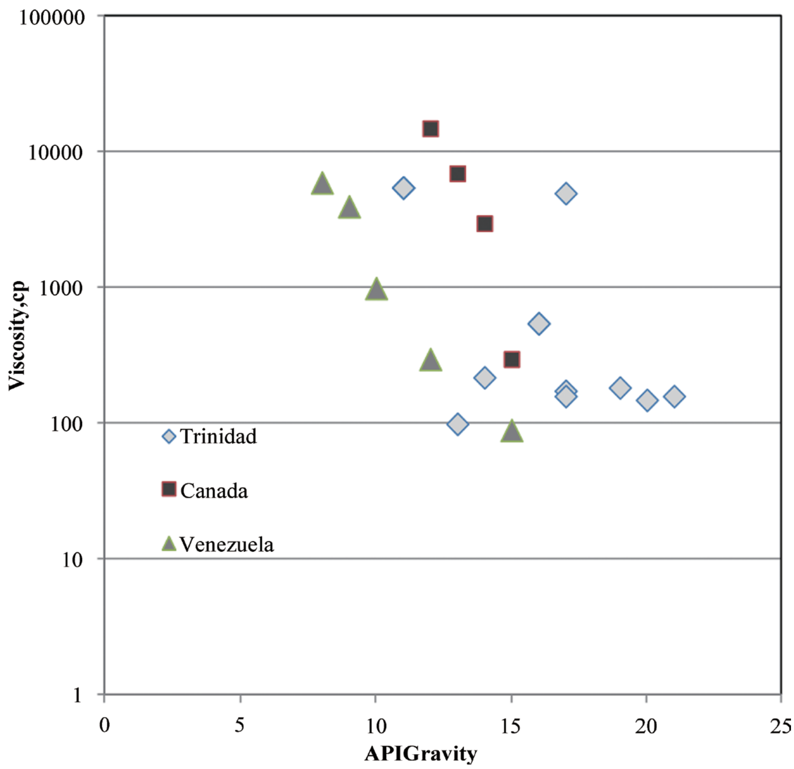

Figure 5
Heavy Oil Classification Comparison for Trinidad, Canada and Venezuela

5. TAR SANDS

Tar sands reserves in Trinidad are estimated to be about 2 billion barrels. These Tar Sands are contained in surface and near surface deposits in the south-western peninsular of Trinidad (Sukhu, 2011). The resource straddles sandstone reservoirs Pliocene in age spanning an aerial extent of 12.84 square kilometres (3,179 acres) of which 6.26 square kilometres (1,550 acres) are found outcropping at surface while 6.58 square kilometres (1,629 acres) exist near surface at depths no greater than 210 metres (700 feet). A substantial portion may be exploitable by a surface mining/extraction type process.

The largest of these deposits is located within the Guapo, Parrylands and Forest Reserves Fields currently leased to Petrotrin. This deposit contains approximately one-half of the total bitumen resources. If 500 MM barrels of the bitumen can be extracted; it will substantially increase the reserves of petroleum and maintain production levels within the sector. For example, it implies that an increased production of 30,000 BPD can be sustained for about fifty (50) years.

Tar sands can prove to be a new source of oil in an effort to maintain this country's oil revenues in light of sustained low oil production. A study should be done to quantify the exact size of the reserves and determine the amount of recoverable bitumen, including identifying the technology to extract the bitumen and produce synthetic crude. It should also look at environmental risks, including local aquifers, and the project's financial feasibility.

While there are environmental challenges to the mining and processing of tar sands, there are many countries that have been successfully mining tar sands in a safe and environmentally acceptable manner. Canada and Venezuela have been very successful in monetizing tar sands reserves. Other methods of exploiting these tar sands (SAGD) should be evaluated to determine the best approach for producing these extra-heavy oils.

6. GAS HYDRATE

Hydrates are a special combination of two common substances, water and natural gas, which under low temperatures and high pressures join to form a solid ice-like substance commonly referred to as gas hydrates, methane hydrates, or clathrate (Collett, 2001).

The petroleum industry took interest in hydrates in the 1930s when they were found to cause pipeline blockage. It was discovered through drilling operations in later years that gas hydrates were found to occur in sub oceanic sediments in polar regions (shallow water) and continental slope sediments (deep water).

7. HYDRATE AS AN ENERGY RESOURCE

World population and energy consumption have increased substantially over the last century. This increase has led to the industry focusing and exploring unconventional resources such as the gas hydrate.

The estimated amount of gas in the hydrate accumulations of the world greatly exceeds the volume of conventional gas resources. Estimate of the global resources of natural gas hydrate range from 100,000 to almost 300,000,000 trillion cubic feet (tcf).

Published estimates of the total energy reserves trapped in methane hydrate vary considerably, but all the numbers emphasize this single point-the resource potential of methane in gas hydrate exceeds the combined worldwide reserves of conventional oil and gas reservoirs, coal, and oil shale by a wide margin. This resource might become a major energy resource if the industry can address some of the technical challenges to extract the methane.

The discovery of gas hydrate accumulations in terrestrial permafrost regions of the artic and beneath the sea along the outer continental margins of the world increased interest in gas hydrates as a possible energy resource.

Gas hydrates exist where water depths exceed 300 to 500 meters (depending on temperature). The base of the layer is limited by increasing temperature. Gas hydrates have also been found to be stable in low temperature and high pressured environments.

Gas hydrates have been inferred to occur in about 50 areas throughout the world (Figure 6).

Amongst all the areas where gas hydrates have been found only a couple of them have been examined in details. Some of these best known marine and onshore permafrost-associated gas hydrate accumulations include; (1) the Blake Ridge along the southeastern continental margin of the United States, (2) along the Cascadia continental margin off the pacific coast of Canada, (3) near the Nankai Trough off the eastern coast of Japan, (4) on the North slope of Alaska, and (5) in the Mackenzie River delta of northern Canada. It can be seen in the figure that (6) Trinidad is in the inferred region of hydrate accumulation in the Atlantic (Collett, 2001).

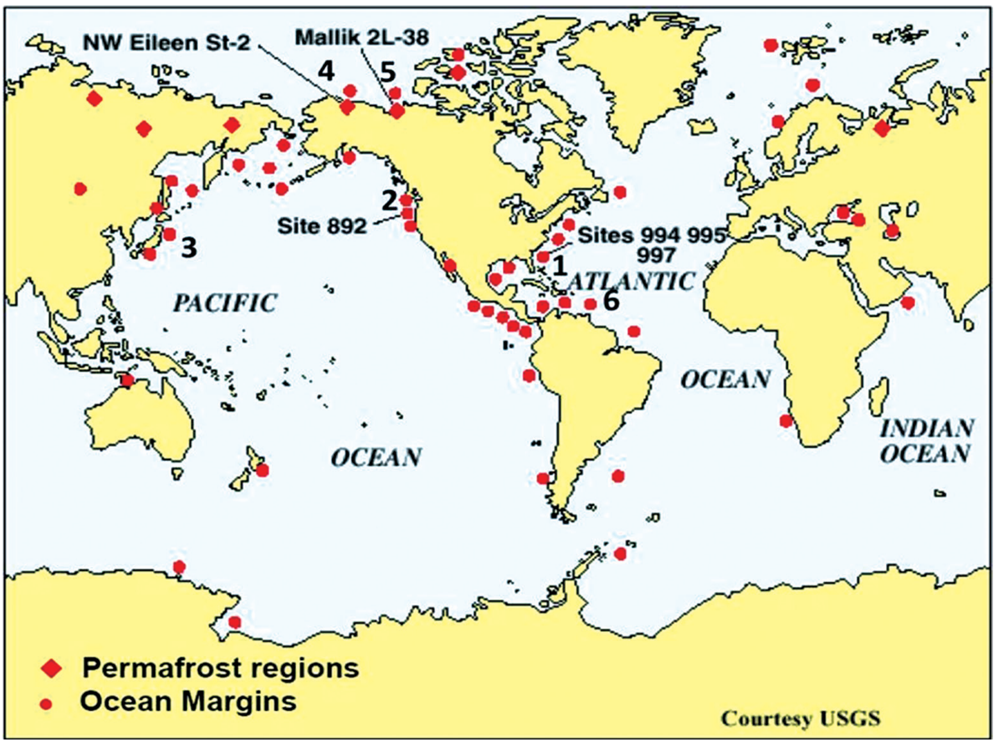

Figure 6
Known and Inferred Natural Gas Hydrate Occurrences in Marine (Red Circles) and Permafrost (Red Diamonds) Environments (Collett, 2001)

8. GAS HYDRATE POTENTIAL IN TRINIDAD

Presently, research work is being done on hydrates at the University of the West Indies. Evaluation of the potential Bottom Stimulating Reflector (BSR) delineation in the deepwater blocks is currently the focus of the study in deepwater blocks 25a, 25b, 26 and 27 (Figure 7) where 3D seismic data are available. Ideas varied as to the tectonic setting of the blocks. It was generally recognized that the structure of the Block reflected its position adjacent to 3 tectonic terrains. The Barbados Accretionary complex lies to the east and north of the Blocks. Its boundary with the South American plate to the south and west is poorly understood. Both these terrains further interact with the Caribbean Plate to produce a complex of fault styles and sedimentary basins. Typically, the blocks were recognized as deformed by contractional and oblique slip tectonics with a possible detachment in the Cretaceous (ExxonMobil, 2000).

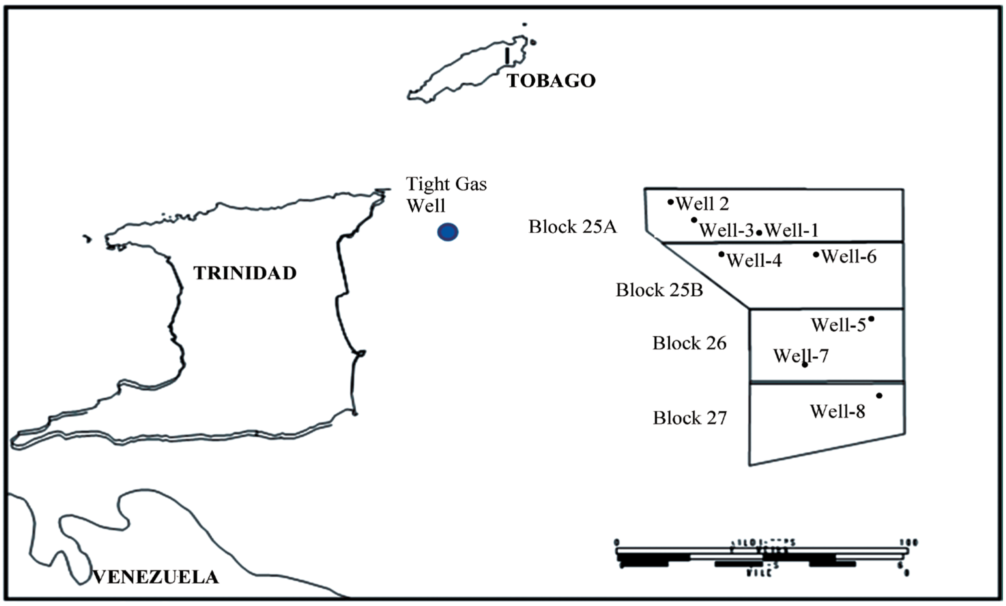

Figure 7
Location of Deepwater Blocks 25a, 25b, 26 and 27

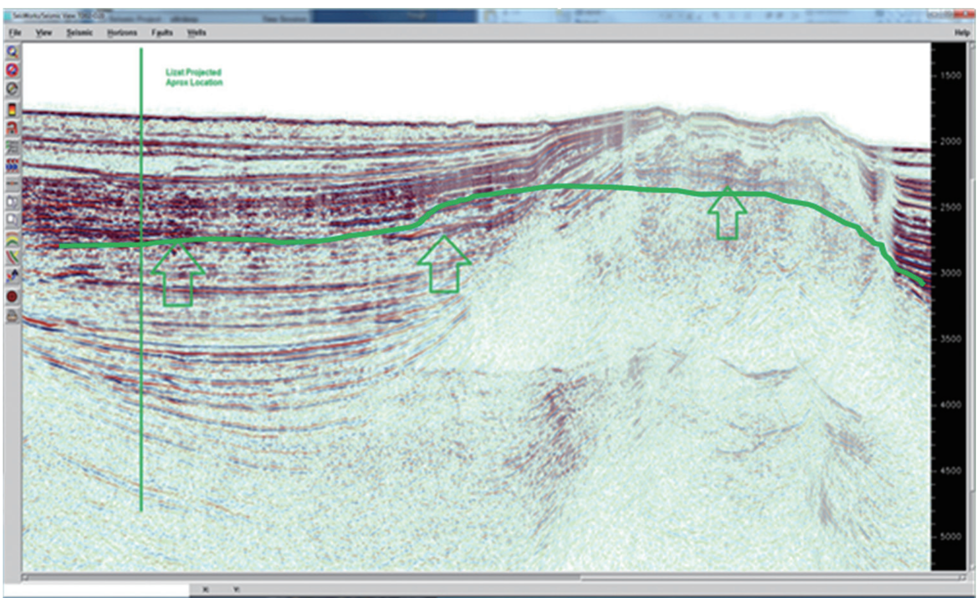

Figure 8
BSR Indication Deepwater Trinidad

In most marine locations where hydrates are known to exist, a well-defined BSR marks the base of the HSZ (Hydrate Stability Zone) on seismic reflection data.

Figure 8 is a seismic depiction showing BSR indication in deepwater Trinidad. The closest deepwater well in the area is also shown in the diagram. The arrow below the line shows the trend of the BSR across the block and indicates accumulation of gas hydrate in the region.

There are other areas of gas hydrate research that require focus in Trinidad. These include:

(1) Resource estimates
Specialists disagree over the estimates of gas hydrate resources present in accessible portions of the subsurface when considering the fact that some of these deposits may be sparsely distributed in the sediments rather than concentrated.

(2) Exploration
Significant capital investment in technological development is needed to convert this non producible unconventional gas resource to a producible one. And the industry has been slow in channeling funds towards recovery of methane from gas hydrates.

(3) Seafloor stability
Dissociation of hydrates can cause instability in seafloor sediments on the continental slopes. The hydrates apparently cement sediment and therefore have a significant effect on the sediment strength.

(4) Production methods
The production options include depressurization, thermal injection and inhibitor injection.

9. TIGHT GAS

Tight reservoirs are those which have low permeability, often quantified as less than 0.1 mD (Milli Darcy). However, a generally accepted industry definition is reservoirs that cannot be produced at economic flow rates or that do not produce economic volumes of natural gas without assistance from massive stimulation treatments or special recovery processes and technologies. Poor permeability is primarily due to fine-grained nature of the sediments, compaction, or infilling of pore spaces by carbonate or silicate cements precipitated from water within the reservoir.

Some reservoirs in Trinidad with permeabilities > 0.1 mD cannot be produced at economic rates and hence are considered tight reservoirs. The permeabilities of these reservoirs are in the range 3 mD to 10 mD.

Tight gas sands are often characterized by complex geological and petrophysical systems and present heterogeneities at different scales. They often need hydraulic fracturing to improve gas recovery.

Table 2
Properties of Tight Sand Well in Trinidad

	Depth range, ft	Net interval, ft	Avg. porosity %	Avg. perm. (mD)
Sand 1	6075-6160	68	14.6	7.5
Sand 2	6160-6842	592	14.9	10.3
Sand 3	7540-7836	100	12.1	3.3
Sand 4	8491-8498	3.5	17.1	117

Table 2 shows the reservoir properties of one of the wells drilled offshore Trinidad (Figure 7) that exhibit tight sands (MEEA, 2004). This well was tested in the Naparima hill formation and the analysis indicates tight reservoirs and hence fracturing may be required to improve gas recovery. The well flowed at 17.8 MMSCF/D with a maximum flow of 22 MMSCF/D and a condensate yield of 6 bbls/MMSCF was obtained.The Cretaceous Gautier and Naparima Hill Formation are considered the generative source rock in this drainage area. To evaluate and develop a tight-gas-sand play properly, considerable data must be collected from cores, logs, drilling records, and well tests. Often, more data are needed to evaluate tight gas sand than are needed to evaluate conventional gas sand. The technology needed to evaluate, develop, and produce tight gas reservoirs have been under development for many years.

CONCLUSION

There is need for more focus on unconventional resources in Trinidad and Tobago. Many countries around the world have seen tremendous growth in production arising out of exploitation of unconventional resources. Over the last decade, focus on unconventional resources has seen tremendous growth in worldwide production. A substantial increase in oil production can be obtained from exploring heavy oil and tar sands.

Enhanced oil recovery processes have the potential for producing substantial amounts of heavy oil in Trinidad. SAGD method can be evaluated and tested for use in Trinidad. This method is well advanced and worldwide field trial data is available.

In the future, gas hydrate can be a potential source for natural gas in Trinidad. Preliminary research and data gives indication of the existence of gas hydrate in the deep-water. A greater effort into gas hydrate research is needed since the estimated amount of gas in the hydrate accumulations of the world greatly exceeds the volume of conventional gas resources. Drilling wells in gas hydrate areas are required to obtain data to evaluate this enormous amount of gas accumulations.

Tight gas reservoirs in Trinidad need further evaluation to determine the best method to monetize these reserves. Stimulation methods are available; however, extensive work is needed in developing a tight gas play in Trinidad.

Tar sands present some challenges for exploitation. However, enough technology is available worldwide to assist in exploiting these reserves. Mining tar sands in Trinidad would meet severe resistance due to environmental concerns; however, other methods such as SAGD can be used as a pilot to recover tar sands.

NOMENCLATURE

bopd = Barrels of Oil per Day
BSR = Bottom Simulating Reflector
CHOPS = Cold Heavy Oil Production with Sand
CSS = Cyclic Steam Stimulation
EOR = Enhanced Oil Recovery
HSZ = Hydrate stability Zone
mD = Milli Darcy
MMSCF = Million Standard cubic Feet per Day
OOIP = Original Oil in Place
SAGD = Steam Assisted Gravity Drainage
SAS = Steam Alternating Solvent
tcf = Trillion Cubic Feet
VAPEX = Vapor Assisted Petroleum Extraction

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