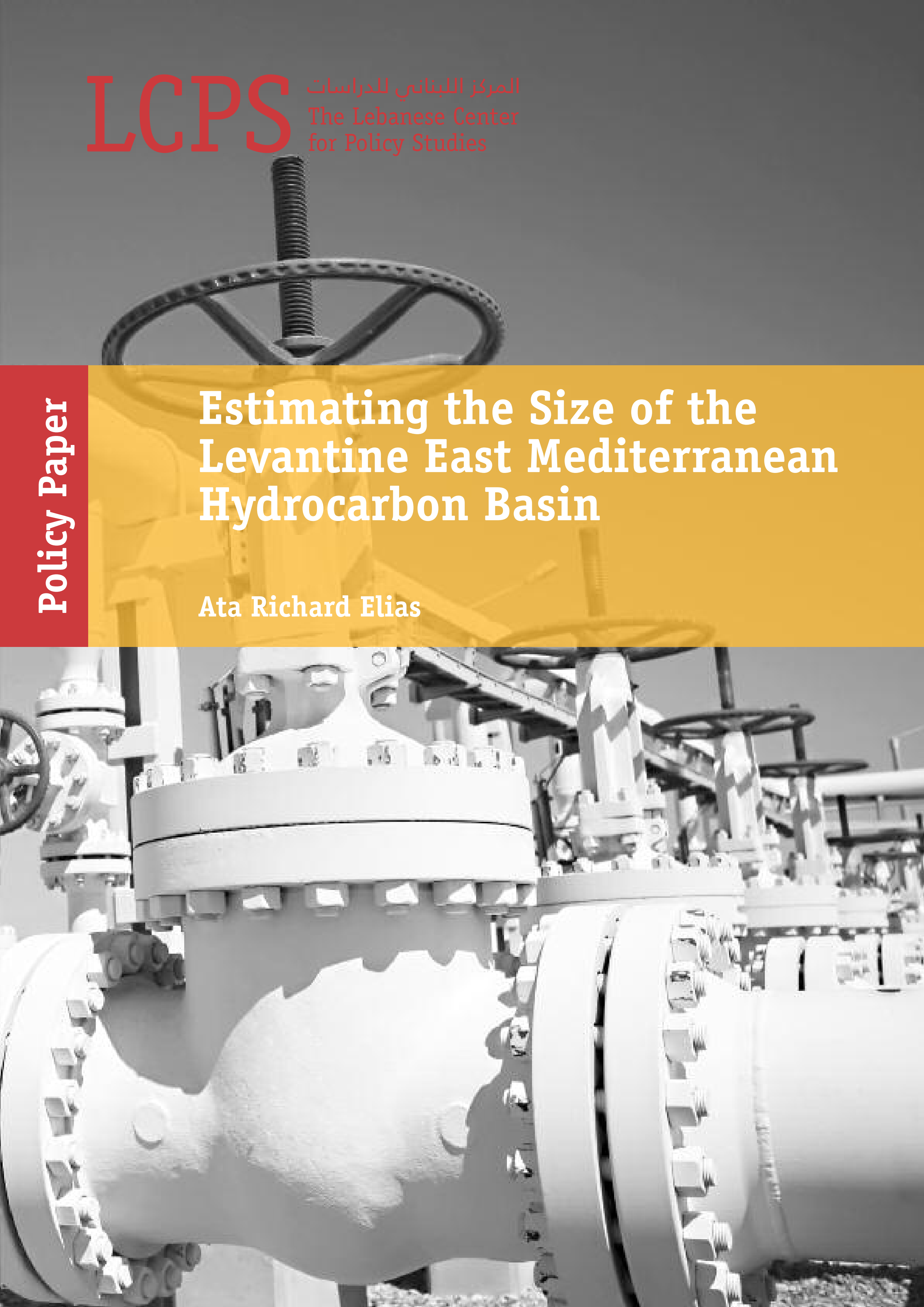

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Policy Paper

Estimating the Size of the Levantine East Mediterranean Hydrocarbon Basin

Ata Richard Elias

Founded in 1989, the Lebanese Center for Policy Studies is a Beirut-based independent, non-partisan think tank whose mission is to produce and advocate policies that improve good governance in fields such as oil and gas, economic development, public finance, and decentralization.

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Estimating the Size of the Levantine East Mediterranean Hydrocarbon Basin

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Executive Summary

Estimates of subterranean petroleum deposits are an important indicator of whether a commercial extraction venture is viable. Any state seeking to capitalize on such a resource will need to go through a series of exploration stages to determine the size of a given reserve. In the case of the Lebanese offshore, there is a large amount of data that has been gathered on the Levantine Basin, where the country's potential reserves are believed to be located. Other exploration phases, in particular exploration wells, and independent assessments of data are necessary before decision makers will be able to formulate sound and informed policy on the country's oil and gas sector. Consequently, publicly touted reserve estimates should be understood as speculative in nature.

Introduction

Increased demand for oil and gas resources worldwide has spurred hydrocarbon exploration activities in various ways. Exploration and production companies are motivated and being solicited to search for additional resources. New, outside-the-box ideas and concepts in geology and geophysics are being tested in the search for new discoveries and higher productivity, pushing the limits of exploration activities into frontier areas that are becoming accessible thanks to the latest technological improvements. Increasingly higher recovery factors are being achieved in many developed fields and enhanced oil recovery techniques are key to understanding the percentage of oil produced worldwide. Remote areas and sanctuaries on Earth are being explored or prepared for hydrocarbon drilling and exploitation activities, while the relative increase in oil and gas prices of the past decade justifies ventures in higher-than-usual risky investments.

Hydrocarbon resources in the region have been exploited throughout history. In Lebanon, the trade of asphalt from the Hasbaya mines survived until the end of the nineteenth century (Nissenbaum 1994). Around the middle of the twentieth century a modern phase of exploration for hydrocarbons began in the region. These exploration efforts proved successful in other countries but for various reasons did not lead to a commercial discovery or production activity in Lebanon. Significant amounts of petroleum resources—mostly of natural gas—were in fact discovered during the past two decades in neighboring parts of the Eastern Mediterranean. Large estimates of reserves offshore the Palestinian, Israeli, and Cypriot coasts have been trumpeted, and the Levantine Basin is now considered a promising petroleum province.

This paper will focus on different aspects of the petroleum resource potential of the Levantine Basin in the context of its geology. First, the concept of petroleum systems will be presented, and the key geological parameters and conditions that influence the formation and availability of petroleum resources will be explained. The geology of the Levant Basin will then be explained in a succinct and clear manner, emphasizing the basic concepts needed to understand the potential and the challenges of petroleum exploration and production activities in the basin. Information on the geological setting of the area and some of the main parameters needed for resource estimation will be presented, highlighting the strong and weak points for Lebanon's case. Additionally, estimations of and the reliability of estimations which have already been made will be examined using geological data and information on neighboring states already extracting petroleum. The paper will conclude with an assessment of the current reality, namely what challenges lie ahead for petroleum exploration in Lebanon, what a relative lack of understanding of the region means for the accuracy of resource estimates in Lebanon at this still early stage of the exploration process, and what will be needed to overcome this shortfall in geographic knowledge of the region. The paper will conclude by recommending a deeper study of different geological aspects of hydrocarbon resources and their estimates in the region, which should assist decision makers as they formulate their plans and strategies for the future of Lebanon's petroleum sector.

I Petroleum Systems

Petroleum resources are the result of a long chain of natural events occurring within the geological context of a region but at the intersection of two different realms: Biology and geology. The formation of petroleum resources starts with the availability of requisite amounts of organic material resulting from biological activity on land or sea. The transportation and burial of these compounds mixed with debris and fragments of rocks inside basins is the next event required at a specific point in the process. During their burial under increasing thickness of overlying material, organic compounds mixed with other rock components are put under increasing pressure and temperature conditions at the bottom of basins. The result is the transformation of the chemical composition of the organic chains into that of hydrocarbon resources. This phase of 'cooking' can happen at different rates and durations depending on the evolution of the basin and its fill. The rocks where these transformations take place are referred to as source rocks.

After the generation process, the more or less fluid hydrocarbon resources, driven primarily by their density, start rising along cracks of the rocks within the basin layers. Migration of these fluids will stop when along their way the compounds face a layer with insignificant or no cracks or voids. Such a migration barrier or seal retains the fluids on its lower side. Ultimately, hydrocarbon molecules of different types are trapped within this configuration of layers. The last rock unit under the seal, where they accumulate inside its cavities and pores, acts as a reservoir for petroleum substances, storing the generated and migrated molecules of hydrocarbons, thus forming a resource.

All these processes of burial, cooking, generation, migration, trapping, and accumulation must occur in a specific order, for a specific duration, and at a certain intensity in order to reach the last phase of accumulation of hydrocarbon compounds and formation of petroleum resources. The entire set of processes and elements is called a petroleum system. Any missing step or element will result in the failure to produce a working petroleum system. For example, the absence of a good seal rock in many instances prevents the formation of petroleum resources, as the produced hydrocarbon migrates all the way up to the surface and is entirely lost along seeps. Also, the inadequate intensity or timing of a process can significantly alter or prevent the formation of the system. For example, overcooking occurs when organic compounds are exposed to excess heat or prolonged exposure to thermal energy. The induced chemical reactions result in the total modification of the chemical composition of compounds and the loss of their economic value in most cases.

The accumulation of hydrocarbons in a trap with a reservoir rock behind a seal is not the ultimate gauge for the existence of resources. In many instances, the geological processes that keep occurring result in the destruction of the trap and the—slow or sudden—release and loss of the compounds, or in the modification of the chemical and physical properties of the resources or of the hosting rocks, making them of less value or completely impossible to exploit.

II From Resources to Reserves

Natural resources accumulated in a reservoir or a trap can be exploited if the exploration and production activities reach them in due time. For exploration and production companies to locate these resources, they make use of a variety of indirect tools. For example, exploration combining different geophysical methods such as the use of seismic techniques along with measurements of gravity, magnetic, or electrical fields or other remote sensing methods, are most frequently employed. They are extensively used to explore the subsurface and delineate the lateral and vertical extent of any geological structures. Exploration also entails geological modeling of basins using all possibly known parameters related to the infill and burial of rocks and their source. Some of the used parameters can be the type, depth and thickness, chemical composition and organic content, age, transportation history, porosity, density, and water content of different rock units. Moreover, information about the geological evolution and history of the area are important factors used to assess petroleum potential. Similarly, changes in climatic conditions during the period of the basin deposition and burial are to be accounted for in some cases. A large number of parameters and environmental conditions that could have influenced the type or characteristics of the deposits that filled the explored basin are considered. For their models, experts also need to estimate the geothermal gradient of the area and its evolution over time, as it greatly influences the cooking time and the generation windows of different petroleum products.

In their effort to identify potential accumulations of resources, geoscientists also look for indicators of the presence of hydrocarbons that can be directly observed in different geophysical datasets acquired from the subsurface of the explored area or sometimes in surface geology. These direct hydrocarbon indicators (DHI) are helpful in guiding companies in their exploration efforts.

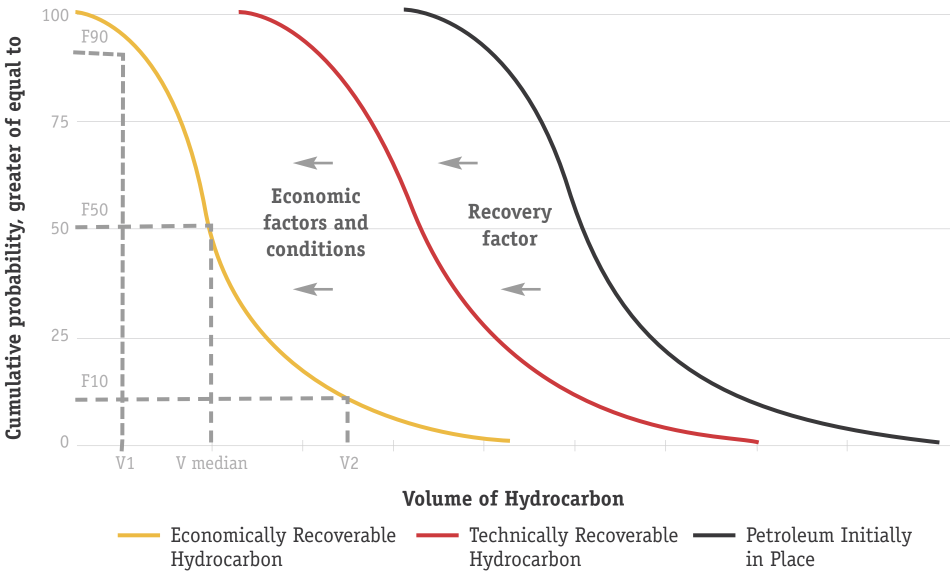
In the absence of direct insight into the subsurface of the explored area—such as in the case of a pre-existing exploration well—experts rely on analogs from neighboring and better-known areas in order to constrain the modeling of the petroleum system. Correlations of nearby offshore zones with more advanced exploration phases can also be made. Cuttings and rock samples from rocks exposed on land in suitable positions can be taken as possible analogs for offshore counterparts. These parameters are inputs to the modeling process that virtually reproduce the geological events and conditions of the basin and assesses whether the area has the potential to host a working and viable petroleum system that produces and preserves hydrocarbon resources, and to estimate the volume of these resources.

All these required geological parameters are understood with a level of uncertainty that translates into risks associated with any of the petroleum systems models' results. Therefore, petroleum system model results for any exploration activity cannot be more accurate than their input parameters. Consequently, it is clear that the best way to reduce the geological risk associated with petroleum exploration is through improving the geological understanding of a given area.

Reserve estimation methods are classified three different ways: Performance-based, analogy-based, and volumetric-based (Demirmen 2007). Performance-based methods allow for estimations of available resources based on the previous performance of the same field. Therefore, it is applicable in fields that have a long history of production. Analogy methods refer to known production histories from similar (analog) geological reservoirs in estimating the volumes of reserves, meaning they can be used in undrilled areas. Volumetric methods involve knowledge of the volume and physical properties of the reservoir to estimate the volume of available reserves.

Two main approaches can be used in volumetric estimations of these resources: Probabilistic or deterministic. In the first case, the uncertainty of each of the different input parameters are taken into consideration and dealt with in a statistical manner (figure 1). A resulting probability distribution of the available amounts of resources is then obtained. In the deterministic approach, volumes of resources are calculated using a set of individual values for each of the input parameters, resulting in a single value for resource estimates. The deterministic computation is done three times, with values of each parameter representing successively the low, best (intermediate), and high estimates. The low estimation is a conservative one, reproducing the conditions least favorable for the resources to exist. However, they are associated with the highest probability of existence. The high estimation is the most favorable for resource accumulation while being the least probable. The intermediate is usually the best probabilistic estimate of the given parameter. Three results for the three deterministic runs are obtained that report different probabilities of available resources (least, best, and highest). However, the low and high estimates should be carefully interpreted, as they can result in large underestimation or overestimation respectively of the present volumes.

Figure 1 **Expectation curves for the volume of hydrocarbons in a reservoir**



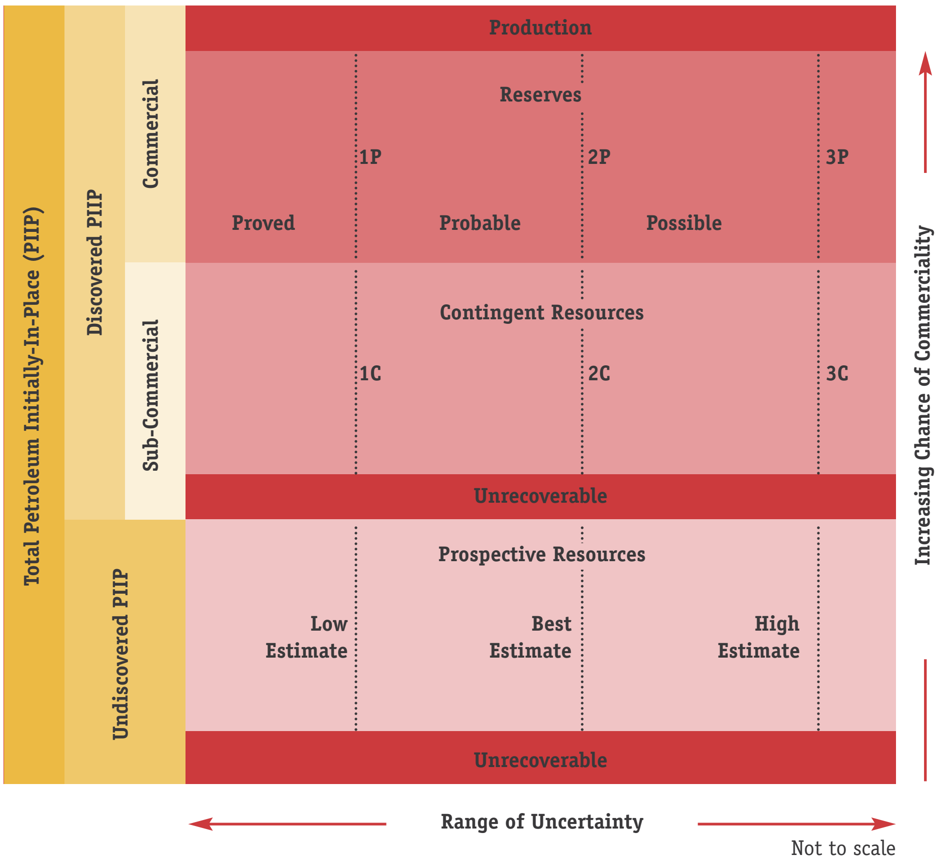
Of the PIIP only a smaller volume is expected to be economically recoverable (green curve). The probability of existence of different volumes of reserves is a lognormal function. (F%) is the probability in % of existence of at least a volume (V) of reserves. The highest probabilities are associated with the least volumes of expected reserves. The dimensions and values are not to scale.

Source **Modified from USGS fact sheet 045-02 http://pubs.usgs.gov/fs/2002/ fs045-2/figure4.html**

In the petroleum industry the term resources refers to the total estimated volume of hydrocarbons formed and trapped in-place in an explored area before any quantity is removed during the production phase. Of all this volume initially in place, exploration and production companies will be physically able to extract only a part. This depends on technological advancements in extracting oil from a reservoir, a parameter known as ‘recovery factor’, representing the percentage of petroleum extracted from the amount of petroleum initially in a given location. Although this factor is different from one reservoir to another depending on the characteristics of rocks, the type of petroleum, and the reservoir conditions, on average worldwide it is estimated to be about 35% at present (Schulte 2005). Future developments in exploration and production activities will surely improve this number.

The remaining smaller volume of technically recoverable petroleum, however, is not necessarily commercially exploitable in whole or in part. The portion of petroleum accumulation known to be technically recoverable and commercially viable is termed 'reserves'. Reserves are further classified as proven (1P), probable (2P), or possible (3P) according to the associated increasing degree of uncertainty. It is clear though that the estimation of reserves is dynamic and can change over time due to technological advancement, changes in economical conditions, or even strategic planning. Discovered amounts of technically recoverable petroleum that are not commercial are considered 'contingent resources'. In the absence of any discovery the estimations of potential amounts of accumulated petroleum in the explored area are considered to be 'prospective resources' (Society of Petroleum Engineers 2011).

Figure 2 **The two-axis Petroleum Resources Management System (PRMS) classification table by SPE (2011)**



The horizontal axis (increasing to the right) represents the increasing uncertainties in the estimates of potentially recoverable quantities. The vertical axis is for the different development levels of exploration and production project following an increasing chance of commerciality of their products. It takes into account the technical and commercial aspects of the production, such as current prices, required or available technologies needed for extraction and commercialization, strategic planning, government or legislative regulations etc. The different components of the system are not to scale.

Source **Resources Classification Framework. ,in Petroleum Resources Management System http://www.spe.org/industry/reserves/prms.php**

III Geographic Framework and Geological Setting of the Levantine Province Within the Eastern Mediterranean

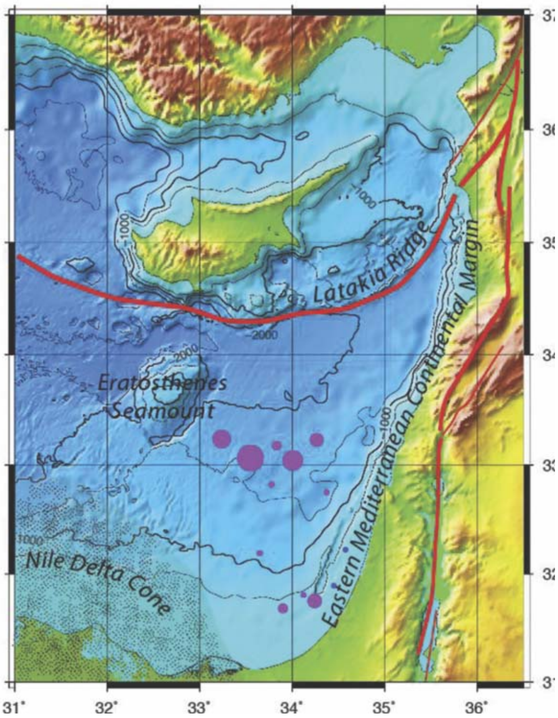
The Mediterranean seafloor and basin is a complex geological zone that can be subdivided into a number of smaller regions or basins based on the geology and the geography of these areas (figure 3). Between the East and West Mediterranean Basins lies a first-order separation due to the presence of an important submarine relief, the Mediterranean Ridge, which is located between the island of Crete in the north and the Libyan shelf to the south. This significantly reduces the depths of the Mediterranean Sea at this location and forms an important submarine divide. The Eastern Mediterranean extends east of this ridge and the Libyan offshore, surrounded by Egypt, Occupied Palestine, Lebanon, Syria, Turkey, and Cyprus from southeast, north, and west respectively. In turn the Levantine Basin is nestled inside the Eastern Mediterranean region. There are different geographic definitions for this second smaller basin. In this paper it is considered part of the Eastern Mediterranean bordered by the Nile Delta Cone province in the south, the (Eastern Mediterranean) continental margin to the east, the Latakia (or Tartus) Ridge and basin to the north, and the Cypriot Basin and the Eratosthenes Seamount to the west. In following with our definition no landmasses are considered part of this basin (figure 4).

Topographically elevated regions surround the Levantine Basin, making it among the deepest and lowest lying parts of the Eastern Mediterranean seafloor. It is a sink to most of the sediments and particles flowing into the larger Eastern Mediterranean region. This explains the thickness (12-14 kilometers) of deposits under its seafloor, a major attractive feature for hydrocarbon exploration.

Figure 3 **Map of the Mediterranean Sea showing its main geographic provinces and basins**

Source **Ata Elias**

Figure 4 **Map of the Levantine Basin**



Source **Ata Elias**

In figure 4, thick red lines represent the active plate boundaries surrounding the basin. Pink and blue circles represent gas and oil discoveries respectively. The size of the circle is related to the importance of the discovered amount. Major contour lines are shown in black with a contour interval of 500 meters below sea level.

For the oil industry, offshore activities are considered 'shallow' if they are conducted at depths of less than 400 meters, 'deepwater' if between depths of 400 meters and 1,500 meters below sea level, and 'ultra-deepwater' if water depths exceed 1,500 meters. The offshore section of the Levantine Basin, as defined above, is approximately 65,000 square kilometers (km^2). The majority of it is located in deep and ultra-deep waters with a maximum depth of about 2,100 meters toward the center of the basin (figure 4). The shallow areas of the seafloor are essentially restricted to the relatively wide Palestinian and Israeli continental shelf, reaching almost 25 kilometers offshore central Israel. The shelf narrows northward and is almost absent in the Lebanese offshore between Saida and Tripoli. North of Lebanon the shelf has a maximum width of 10-15 kilometers offshore the Akkar coastal plain and narrows down to 5-10 kilometers along the Syrian coast. With such a configuration, few shallow marine sections exist in this basin, and most of the petroleum exploration and production activities will need to operate in deep waters.

a Geologic evolution of the Levantine Basin

A number of geological events and processes structured the Levantine Basin as we know it today. Two major events have important implications for the petroleum potential of this area.

The earliest basin floor was created during a Mesozoic rifting phase that occurred over a number of pulses and culminated with the margin formation in the Upper Jurassic to Lower Cretaceous times (Carton et al 2009, Briais et al 2004). Rifting was accompanied by extension and vertical block movements around the basin (Bruner 1991, Garfunkel 1998). It may have resulted in the formation of oceanic-type crusts under a major section of the basin floor, mostly located to the north of a line directed NE-SW and joining Saida onshore next to the older continental (or stretched continental) crust offshore the southern part of the basin (Elias 2006, Carton 2009). Subsidence accompanied and followed this rifting phase, resulting in the deepening and filling of the basin with thick Mesozoic and Cenozoic sediments.

Later, in the Upper Mesozoic to Cenozoic periods a geologic episode of contraction occurred. It resulted in an increase in elevation of neighboring landmasses surrounding the basin as well as folding and deformation of the basin fill. The depocenter with the thickest accumulation of sediments was located offshore the present coastline and appears to have been closer to the center of the basin, between present day Lebanon and the Eratosthenes Seamount to the west (Gardosch 2008). The erosion of the growing landmass surrounding the basin resulted in significant amounts of debris being washed out into the deep basin and deposited among the sedimentary units in the form of clastic sediments of sand or conglomerates along submarine channels or fans.

In more recent geological times the Mediterranean sea level dropped during the Messinian salinity crisis approximately 5.6 million years ago. It resulted in the accumulation of important salt and gypsum layers associated with other special types of evaporitic sediments (Hsu et al 1973). The thickness of these sediments is variable in the basin. It usually thins toward the edges of the basin and is more than 2 kilometers thick at its center. These evaporitic units have very characteristic signatures within the sedimentary deposits of the area and can be used across the basin to correlate the relative age of different sedimentary layers. On account of their physical and mechanical properties, they represent a real challenge to oil exploration campaigns, as they require special exploration techniques in order to be able to explore the underlying structure.

Normal sea conditions resumed with the end of the salinity crisis and re-flooding of the Mediterranean basin. The sea level returned to its previous high stand and water covered the marginal areas of the basin about 5.3 million years ago. Since that time significant amounts of turbidites with clastics and clays were deposited in the Mediterranean above the Messinian salt. These well-stratified post-salt deposits have a variable thickness (1-2 kilometers) that increases in general toward the edge of the basin where terrigenous input is most important (Carton et al. 2009). In some particular locations close to the base of the continental slope, such as offshore central Lebanon, these sediments are particularly thick, as they are trapped in synclines between growing Messinian salt diapirs and ridges. Material accumulated over the slopes of the continental margin is unstable and ends up falling over west dipping listric normal faults into the deep basin.

In summary, the Levantine Basin is characterized by a relatively thick sedimentary infill easily separated into three groups relative to the Messinian evaporitic unit:

- Pre-salt units
- Salt and evaporitic units
- Post-salt units

These units can be correlated across the Levantine Basin and the Mediterranean Sea in general. The sedimentary units and the associated geological structure (faults and folds), are comparable across the Levantine Basin, although some of their characteristics (thickness, porosity, mineralogy) can be significantly different given the geological conditions. The presence of the thick sedimentary pile of layers in the basin is encouraging for hydrocarbon exploration as these layers are more likely to contain the organic material needed to generate hydrocarbon resources after burial and heating over time.

IV Petroleum Resources in the Levantine Basin

Exploration for petroleum resources in the Eastern Mediterranean has been taking place for decades. It was successful in finding oil mainly in onshore Syria, where proved reserves are estimated at about 2.5 billion barrels (BP 2013). Gas reserves were also discovered there. These discoveries in Syria were much bigger than those in neighboring countries, and Syria since then has enjoyed a leading position in proven petroleum resources in the area.

Exploration moved into the shallow part of the Levantine Basin in the mid 1970s. In Lebanon it concentrated on the structures in the near-offshore of Tripoli in northern Lebanon. All official petroleum exploration activities were halted during periods of instability in the country, mainly between 1975 and 1991. They resumed only at the beginning of the twenty-first century with offshore 2D and, later, 3D seismic exploration that enabled covering more than 80-85% of the Lebanese EEZ. The Lebanese EEZ that extends 22,000 km^2 is the central area of the Levantine Basin and represents about 33% of its extent. No exploration wells have been drilled in the Lebanese offshore, as the country just opened its first offshore licensing round in 2013.

The onshore exploration in Lebanon prior to 1975 led to the drilling of seven wells that did not result in any commercial discoveries, although some shows of bitumen and some quantities of gas were discovered (Beydoun 1977).

a Exploration in the Southern Levantine Basin

Sustained exploration activity in the southern Levantine Basin began in the 1960s and produced modest results. After many unsuccessful attempts, oil and gas were discovered in very limited commercial amounts in shallow targets offshore Sinai. The 1990s resulted in the first oil discoveries in the Yam and Yafo wells near southern Israel's offshore. The reservoir rocks where oil was found are the pre-salt mid-Jurassic to early Cretaceous layers. The source of the oil was not identified and may be the deeper Triassic to Lower Jurassic carbonates (Gardosh 2014). The discovered oil resources were not commercially significant.

With technological advances, offshore exploration was made possible in deeper waters and the first gas discoveries in the Levantine Basin were made in the supra-salt layers in the Israeli and Palestinian offshore by the late 1990s and early twenty-first century. The discovered gas is of bacterial origin, produced from organic rich layers in the sub-and post-salt layers and accumulated in the upper, shallow beds of post-salt layers. Large quantities of this gas were discovered, mostly confined to sand deposits from old submarine canyons and fans resulting from erosion of nearby landmasses in the southeast. About 4 trillion cubic feet (Tcf) of gas were discovered in the earliest wells drilled. A number of discoveries followed and confirmed the presence of shallow gas reserves of the same petroleum system in this province.

Drilling in the deeper sub-salt layers is another technical challenge that was overcome in 2003. First, a dry hole discouraged exploration activities and it was six years later, in 2009, when the oil company Noble Energy successfully drilled and discovered a working petroleum system in the Tamar well offshore Haifa, containing about 10 Tcf of gas, paving the way for a series of giant gas discoveries in the southern Levantine Basin. The discovered gas, very likely of biogenic nature, was found in sub-salt sand accumulations, also associated with submarine river channels and fans transporting material eroded from neighboring relief areas. The source of this eroded material can be any of Egypt or Sinai, Palestine, Lebanon, or Syria (Gardosh 2014). The relatively important thickness of these sands were uncovered in the Tamar Well (and therefore termed the Tamar sands) and estimated at about 250 meters of gross pay, with good porosity and permeability conditions, making them a very good and promising reservoir and petroleum system (Needham et al 2013). The traps are four-way closure folds in the upper Miocene that can be of extensive size.

A number of similar discoveries followed in the same area (southern Levantine Basin) targeting plays and systems similar to the Tamar sands. Giant gas discoveries were made between 2009 and 2013, among them the Leviathan field, with estimated gas reserves of 18 Tcf found in a number of sub-salt Miocene sand intervals. The field was drilled between 2010 and 2012, where there are a number of wells located more than 100 kilometers west of Haifa and in more than 1,600 meters of water column. It is noteworthy that estimates for the Leviathan field reserves changed significantly during the exploration process. The first estimates of the volume of reserves announced by Noble Energy operating the field were about 25 Tcf and were constantly decreased afterward. In March 2013 the operator announced reserve estimates of 18 Tcf of biogenic methane (Noble Energy March 2013).

An additional 600 million barrels of oil is thought to exist at deeper levels below the gas units but have not been tested yet due to a number of technical drilling problems related to an increase in well pressure and drilling depth.

The search for oil did not completely stop after the new gas discoveries. Reports in 2013 indicated the discovery of about 128 million barrels of recoverable oil in one of the shallow coastal wells, Yam-3, near Ashdod (Globes 08-09-2013).

b Exploration in Cyprus

After a first successful licensing round in Cyprus in 2008, Block 12 was awarded to Noble Energy. Exploration activities there resulted in another discovery made by the same exploration and production company Nobel Energy on the Cypriot part of the western Levantine Basin in Block 12, not far from the Israeli EEZ. The discovery was drilled in a water column greater than 1,600 meters and the field lies at a total depth greater than 7,000 meters. The producing geological levels are the same sub-salt sand layers as the Tamar sand. First estimated at around 9 Tcf, the reserves were cut to 4.1 Tcf due to refined appraisal results of thickness of target layers. Since its announcement in March 2012, the estimated size of this discovery was reviewed many times, but always to lower values. In October 2013, it was announced that commercial amounts of condensates estimated at about 8 million barrels were also discovered in this well (Delek October 2013).

In October 2012, a second licensing round was completed and four additional blocks located within or at the edge of the Levantine Basin were awarded.

c Exploration in Syria

The Syrian offshore spreads over a wide zone of which only a small part (15-20%) is located south of the offshore Latakia ridge inside the Levantine Basin. North and west of the ridge lay the Latakia, Iskenderun, and Cyprean basins respectively. Little exploration activity has taken place in this offshore area. Exploration in the Turkish offshore to the north made one oil discovery out of about thirteen exploration wells (Bowman 2011). A first licensing round for the Syrian offshore in 2007 was not successful in attracting bids. A second licensing round was announced in 2011 but was postponed later. Onshore exploration in coastal Syria within the limits of the extended Levantine Basin had uncovered the presence of some oil and gas shows, though not of commercial quantities.

V Estimates of Petroleum Resources in the Basin

The Levantine Basin is an underexplored province that became attractive for petroleum exploration and production activities primarily after the major discoveries of the past decade. Few efforts have been made to assess its overall petroleum potential, and very little—if none—of the results were made public.

In an attempt to assess the distribution of energy resources worldwide, the United States Geological Survey (USGS) World Energy Project conducted geologic studies for a number of 'priority petroleum basins' around the world in an effort to provide the general public, as well as policy makers and investors, with scientific and comprehensive information on the distribution of world oil and gas resources (USGS: World Petroleum Assessment). The assessment is based on a probabilistic approach strategy that estimates the amount of petroleum that is likely to be produced and added to reserves in a thirty-year time span. It is based on a gross delineation of sub-units considered homogeneous (the 'Assessment Units'), where the potential of undiscovered oil or gas is assessed individually. The project assessed a large number of provinces, making use of available exploration and production data and known geology. An assessment of the Levantine Basin was published in March 2010. It is likely the only assessment of the petroleum potential of the entire province to date, and surely the only one made public.

The assessment of undiscovered resources for the Levantine Basin was subdivided over three assessment units:

- The Levantine Margin (mostly onland masses, bound by the plate margin to the east)
- The sub-salt units of the Levantine Basin (Levant Sub-salt AU)
- The supra-salt unit of the Levantine Basin (Plio-Pleistocene AU)

For each of these three units the estimated undiscovered resources are presented with three different fractiles F95, F50, and F5. These represent respectively the 95%, 50%, and 5% chances of discovering at least the corresponding amounts of resources, for oil, natural gas, and natural gas liquids (NGL) (table 1).

Table 1 **Undiscovered oil and gas resources in some Middle East provinces as assessed by the USGS World Energy Project**

Basin (or AU)	Oil mean in MMBO		Oil minimum (F95)	Oil maximum (F5)	Gas mean in BCFG
Nile Delta	1763		491	4266	223242
AU-Nile Cone	475				219071
AU-Nile Margin	1288				4171
LB	1689	% of LB	483	3759	122378
AU- Levant Margin	857	51%	278	1765	6197
AU- LB sub-salt	548	32%	148	1242	81437
AU- LB Plio-Pleistocene	284	17%	57	752	34744
Offshore LB	832	49%	205	1994	116181
Offshore Sirte Basin	2267				2569
Sirte Basin	3545				32451
Zagros	38464				19179

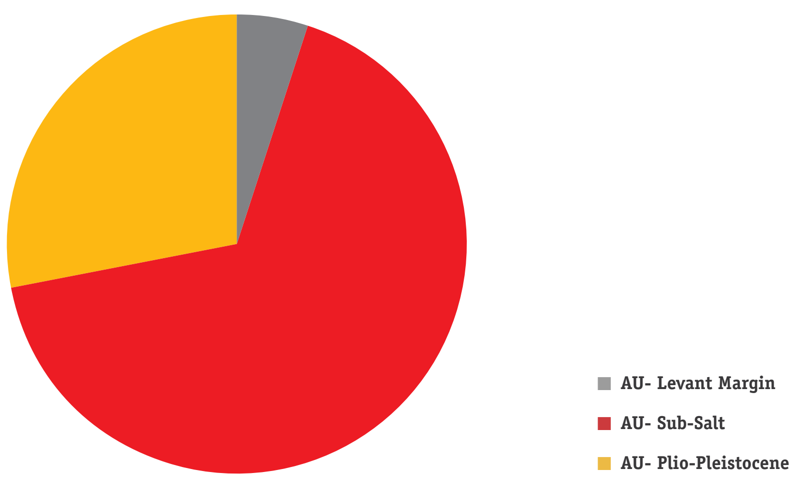
Basin (or AU)		Gas Minimum (F95)	Gas maximum (F5)	NGL mean in MMBNGL	
Nile Delta		92614	425935	5974	
AU-Nile Cone				5862	
AU-Nile Margin				112	
LB	% of LB	500614	227430	3075	% of LB
AU- Levant Margin	5%	2018	12796	182	6%
AU- LB sub-salt	37%	32641	152132	2533	82%
AU- LB Plio-Pleistocene	28%	15428	62502	360	12%
Offshore LB	95%	48069	214634	2893	94%
Offshore Sirte Basin					
Sirte Basin					
Zagros					

Source **http://energy.usgs.gov/OilGas/AssessmentsData/WorldPetroleumAssessment**

The estimated volumes should be considered an indicator of the prospectivity of the province compared to others, where the same method has been applied, and not as real value, or proof of the existence of stated amounts. These results suggest that the Offshore LB (the sum of the two offshore AUs of the Levantine Basin) has a higher potential for petroleum resources compared with the onshore Levant Margin AU, for both natural gas and NGL, and similar prospectivity for oil resources (figures 5 and 6). The LB sub-salt layers present the highest prospectivity for gas of all the assessment units of the Levantine Basin.

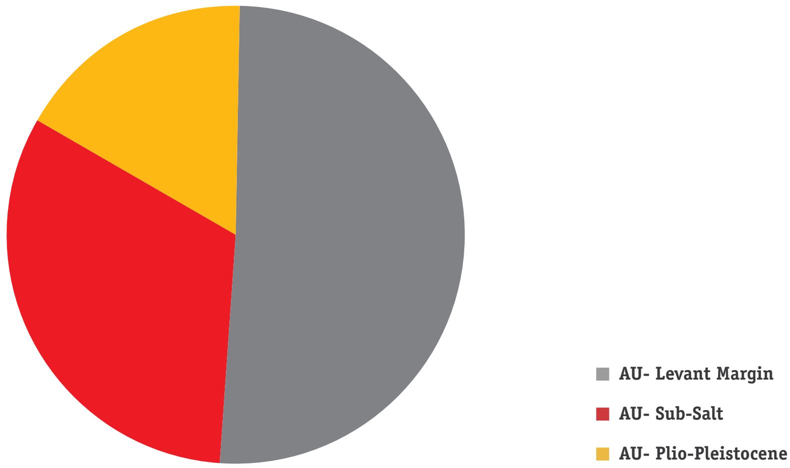
These results for the Levantine Basin were compared to similar results for other petroleum provinces in the Middle East obtained by the USGS using the same approach. For that purpose two other provinces from the Mediterranean Sea were selected (the Nile Delta in Egypt and the Sirte Basin in Lybia), in addition to the Zagros province from outside the Mediterranean (USGS fact sheets 2010-3027, 2011-3105, and 2012-3115). These three provinces are known to be prolific in petroleum resources and have a long and well-established history in petroleum exploration and production. The Nile Delta province is primarily a gas province where most of Egypt's 72 Tcf of gas reserves (BP 2013) are located. For the purpose of the assessment, it was divided into two assessment units: The Nile Cone and the Nile Margin. The results suggest that the mean volume of undiscovered technically recoverable gas in this province is around 223 Tcf and is located primarily (219 Tcf) in the Nile Cone unit. It also estimated a mean amount of undiscovered, technically recoverable oil resources of 1.7 billion barrels of oil (BBO).

Figure 5 **Mean undiscovered gas in BCFG for the Levantine Basin according to the USGS assessment report**



Source **Ata Elias**

Figure 6 **Mean undiscovered oil in MMBO for the Levantine Basin according to the USGS**



Source **Ata Elias**

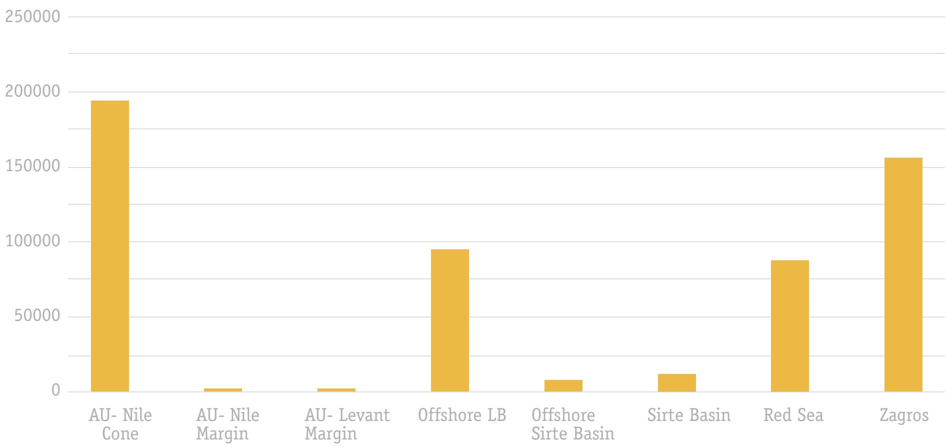
The USGS fact sheet 2011-3105 assessing undiscovered oil and gas potential for two provinces in Libya and Tunisia estimated resources of 32 Tcf of gas and 3.5 BBO of oil within the Sirte Basin in Libya. The Sirte Basin accounts for about 80% of Libya's 47 BBO proven oil reserves as well as a significant amount of its 53 Tcf gas reserves (EIA 2012).

Finally, the undiscovered resources of the Zagros province, one of the largest petroleum provinces in the world, hosting many giant fields, were assessed in the USGS fact sheet 2012-3115. The study suggested estimates for a mean of 191.7 Tcf of undiscovered gas resources and a mean of 38 BBO of undiscovered and technically recoverable oil.

Taken at face value the USGS estimations of undiscovered reserves confer to the offshore Levantine Basin an advanced position compared to the well-established gas provinces of the Mediterranean basin. The importance of the estimated resources is also clear from the relatively high values of minimal undiscovered gas volumes—F95—for the Levantine Basin offshore units, estimated at about 48 Tcf, still a high figure compared with estimates for other provinces.

Considering the total of 219 provinces throughout the world assessed by the USGS, the estimated mean of undiscovered gas resources in the Levantine Basin puts it in tenth place on the list of most promising gas provinces in the next thirty years worldwide, surpassed by the Nile Delta Basin, South Caspian Basin, and Zagros Fold Belt provinces of the Middle East region, respectively in the fourth, seventh, and eighth positions (figure 7).

Figure 7 **Mean undiscovered natural gas in BCFG for different petroleum provinces of the Middle East according to the USGS assessment report**



Source **Ata Elias**

VI Petroleum Systems and Prospectivity of the Levantine Basin

Many lessons about the Levantine Basin's prospectivity were learned from the different phases of petroleum exploration and production in the area. The Levantine Basin proved to have working petroleum systems at different levels within the sedimentary sequence.

Gas has been easier to find so far, and in larger quantities. This reflects the abundance of resources but also the difficulty in locating working oil systems in this geologically complex area.

Of the nearly fifty exploration and appraisal wells drilled offshore in the Levantine Basin through 2013, only ten resulted in gas discoveries, with three giant fields that count among the largest gas discoveries of the decade worldwide. About 40 Tcf of gas reserves are now proven solid in this province (table 2). This number doesn't necessary coincide well with the original estimates of different petroleum operators and stakeholders, but it clearly confirms the Levantine Basin as a gas province.

Table 2 **Summary of discovered gas reserves in the Levantine Basin as updated on May 2014. Values given for the Aphrodite Field highlight the changes in reserves estimates with time**

Date	Field name	Estimated reserves
1999	Noa	0.04
2000	Gaza Marine	1
2000	Mari-B	1.5
2009	Dalit	0.5
2009	Tamar	10
2010	Leviathan	18
2011	Aphrodite	7 → 5 → 4.1
2012	Shimshon	0.3
2012	Tanin	1.2
2013	Karish	1.8
Total		~40 (Tcf)

Source **http://energy.usgs.gov/OilGas/AssessmentsData/WorldPetroleumAssessment.**

A number of estimates for hydrocarbon resources done at early stages of exploration proved to be very optimistic and sometimes speculative in fact. The cases of the Myra and Sarah drilling licenses offshore Israel illustrate well these overestimations. Based on geological and geophysical surveys the fields were initially estimated, in 2010, to contain 6.5 trillion cubic feet of gas (Globes 30-06-2011). Netherland Sewell & Associates Ltd (NSAI) had announced that these two fields taken together have a high geological probability of success—around 54%—for the announced 6.5 Tcf of gas and 18% geological probability of success for approximately 150 million barrels of oil. The two fields located not far from the major Dalit discovery, were targeting the proven Tamar sands for the gas resources. Compared with other successful discoveries their prospects seemed very positive. However, the two wells drilled in these licenses in 2012 turned up dry.

Another similar case of unsuccessful estimations came from the Ishai license. Located between the 4.1 Tcf-Aphrodite-discovery in the Cyprus Block 12 to the west, and the 18 Tcf-Leviathan-field to the east of this acreage seemed promising. The discovery of 6.7 Tcf of unrisked gas resources in the upper part of the prospect and a less probable 13.5 Tcf of gas and 1.4 billion of barrels of oil at a greater depth was first announced in June 2012. The results were very disappointing for the market and the industry in January 2013, when Israel Opportunity Energy Resources LP announced that the drilling at the Aphrodite-2 well in the Ishai license would be stopped without carrying out any production tests (Globes 03-01-2013). Although significant signs of gas were discovered, the encountered net-pay gas interval was much thinner than expected. The total amounts of resources found were less than 1 Tcf (Hydrocarbon Exploration and Production 02-01-2013) and not deemed worth further developing the field.

In the light of these examples one can never be cautious enough when dealing with figures and numbers of resource estimations resulting from prospectivity reports not supported by appraisal tests. Such is the case of the 40 Tcf gas resources estimations within six licensed blocks offshore Cyprus, or the 60 Tcf of gas resources estimated for the entire Cypriot EEZ announced by the Cyprus National Hydrocarbon Company (Ellinas on Cyprusprofile.com, Kassinis 2013), or the 95.9 Tcf of gas estimated for about 45% of the Lebanese offshore with a probability of 50% as announced by the Lebanese Ministry of Energy and Water (Reuters 2013).

The Tamar sands concept is currently the most productive gas system in the southern Levantine Basin. The sand in alluvial fans and river channels represents a high-quality reservoir that has been targeted in different licenses of the southern Levantine Basin because of the net exploration and production advantages that it represents. Other plays present in the basin are also possibly as productive (Roberts and Peace 2007, Nader 2011, Lie et al 2011).

Research findings suggest that for many geological reasons the prospectivity of the northern Levantine Basin (offshore Cyprus and Lebanon) may be higher than that of the southern part (offshore Palestine and Israel), with higher probability for oil than in the south.

For example, results from geophysical surveys show that the geological layers containing equivalents to the Tamar sands are thicker in the central basin, which hints to possibly larger reservoirs and bigger plays in the area compared to the southern counterpart. The greater burial and thickening of the sedimentary infill in the central basin increased the cooking of the sediments and the maturity of the tertiary source rocks that may have started expelling oil and could be charging thick reservoirs and traps located above (Hodgson 2012). Therefore, some of the source rocks in the central Levantine Basin are likely to be more mature and in more favorable hydrocarbon generation windows than in the southern part. This maturity and charging issue may explain the relatively very small amounts of oil discovered in the south. Moreover, in the central basin the trapping structures are more abundant and diverse in age and styles due to the more complex geological setting and deformation phases of the central and northern Levantine Basin (Elias 2007, Carton et al 2009). This signals better chances at finding a functioning petroleum system in the central basin, where mature oil generated at depth migrated along the numerous fractures and faults and was entrapped and sealed in a rock unit with mechanical properties suitable for storing and production of the resource.

VII From Estimations to Discoveries

Over the past fourteen years a significant amount of seismic data has been acquired about the Lebanese offshore. Since 2007, Lebanon has acquired 3D seismics over more than 85% of its EEZ, placing it far ahead of all neighboring countries, while also possibly making it one of the rare countries worldwide with such a high percentage of 3D coverage. These exploration lines served well for executing assessment reports and setting the framework for the offshore licensing round. They represent an important asset for the country's capacity to execute a volumetric assessment of resources and direct exploration activities.

Despite the amount of 2D and 3D seismic data collected over the entire Lebanese EEZ, the absence of any exploration well drilled in the central part of the Levantine Basin corresponding to the Lebanese and Syrian offshore makes all attempts and issued reports on the estimation of the volumes of resources in the area non-reliable if not speculative. No discoveries have been made thus far in the Lebanese offshore and the numbers and estimates suggested by the different studies reported in the media such as the USGS or the Lebanese Ministry of Energy and Water are—at best—for 'prospective resources', and do not represent actual volumes of petroleum. The essential physical and chemical parameters needed to perform the basin modeling and analysis that characterize the geological units and formations in the central part of the basin can be very different from their counterparts in the southern basin. The analogy with similar fields or prospects in the southern basin is not reliable enough given the differences in geological settings that may exist over such a small area as discussed above.
Exploratory wells are crucially important to obtain reliable geophysical and geochemical 1D and 2D data before attempting any serious assessment of the resource potential.

Increased exploration activity in the basin has gathered tremendous amounts of geological and geophysical information about the area and has led to a much better understanding of its hydrocarbon potential. The discoveries made in other parts of the basin have significantly decreased the risk in petroleum exploration within the central region offshore Lebanon. It should be recognized, however, that geologists' understanding of some parts of the basin remains limited and depends on exploration activity, while most scientific reports and studies related to the basin are designed to answer industrial purposes and needs. Very little scientific work is being done independently of industrial control, which introduces a bias in the assessment of the geological setting and in guiding exploration activities. The majority of published material and data on available resources result from studies done in association with, or completely by, scientists from exploration companies. These reports or publications serve the purpose of promoting a company's dataset or assets. Scientific research should be encouraged in order to improve the geological understanding of this province and better assess its prospectivity. Governments should empower research institutions to access or acquire needed data in order to perform independent research and publish their results. Academic- and research-oriented exploration of the Levantine Basin is needed to encourage and develop groups of informed experts and produce public information that can be used to inform policy makers and public opinion, as well to monitor the process of exploration and production of this national resource, in addition to increasing awareness about it.

Exploration and production activities face many challenges in the Levantine Basin in general and the Lebanese offshore in particular. The determining and critical factor is likely to be the important water depths—mostly below 1,500 meters—associated with the presence of a shallow thick evaporitic unit. The ultra deep environment adds serious technical complications for exploration and production activities (Boesch D. 2012) and requires additional investments in security, infrastructure, and technical skills during the design, implementation, and operation phases. With these extra investments production cost will increase, preventing some proven resources from becoming a viable economic discovery or reserve. In these conditions only large or giant discoveries will be of commercial interest or attraction. As great water depths will favor large-scale field development, parts of the resources in the basin will lose their attraction.

Finally, the scarcity of reliable and publicly available estimates of resources in the different parts of the Levantine Basin contradicts with the large number of related political and commercial communications that accompanied this activity in past years. The high frequency of media releases and other published material related to oil exploration in the offshore reflects the importance that different public and private stakeholders recognize in this sector for their different political, economic, or environmental concerns. In the absence of any reliable data regarding the availability of resources and the size of reserves, false or exaggerated expectations are not only misleading but also dangerous, as they will only put the national economy and democratic process under pressure.

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