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Exploration Trends show continued promise in world's offshore basins. Growth expected in global offshore crude oil supplies.

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The oil industry has expanded consistently over the last decades from land operations to inland waterways and then to offshore. Offshore barges for exploration began to be used in 1950, deepwater drill ships in 1956, and semi submersible rigs in 1964. In the 1980s, deepwater exploration meant water depths of 800 feet. Today, depths below 1,500 feet are considered shallow, between 1,500 and 7,000 feet is considered deepwater, and over 7,000 feet ultra deepwater.

Offshore crude oil production started in the early 1940s and has grown from a modest 1 million barrels a day (mb/d) in the 1960s to nearly 25 mb/d in 2005 to represent one third of world crude oil production. Conversely, onshore crude production needed six decades to reach 25 mb/d in 1963. However, unlike onshore oil production, offshore production has never experienced sharp downward fluctuations and has grown consistently over the years (Fig. 1). In fact, it has been the main source of growth for world crude oil production as the onshore has essentially remained at a plateau for more than two decades. In 2005 the Persian Gulf/Middle East topped the list of offshore producers, followed by the North Sea, West Africa, the Gulf of Mexico (US and Mexico), Asia/Australasia, Brazil, China, Caspian and Russia/Artic (Table 1). Of the total world offshore crude, shallow water accounted for 20.3 million barrels a day (mb/d) and deepwater 3.5 mb/d. Other liquids such as natural gas liquids (NGLs) totaled 1.6 mb/d, mainly from the shallow offshore.

Up through 2005[1], a total of 503 Bb (455 of crude oil and 48 of NGLs) have been discovered offshore of which 204 Bb have been produced leaving the estimated remaining reserves at nearly 300 Bb. The most important offshore oil discoveries have been made in the largest producing regions. Offshore China, Caspian and Russia/Artic exploration has been relatively limited, whilst in other producing areas exploration has only yielded relatively limited success. In terms of yet-to-find (YTF) reserves, the only institution to have published undiscovered global estimates for oil that segregates offshore and onshore is the USGS[2 3]. The USGS world petroleum assessment (WPA 2000) puts the estimate for undiscovered crude oil at 306 Bb and NGLs at 95 Bb, representing 47% of total undiscovered oil in the world.

[1] Stark, P., Chew, C., "Global oil resources: issues and implications", The Journal of Energy and Development, Vol. 30, No. 2, 2005
[2] Ahlbrandt, T., et al., "Global resources estimates from total petroleum systems", AAPG Memoir 86, 2005
[3] Ahlbrandt, T., "Oil and natural gas liquids: global magnitude and distribution", Encyclopedia of Energy, 2004

From a resource and production perspective the importance of the offshore is paramount. However, most research fails to discern or disaggregate between offshore and onshore. There is no doubt that the growing significance of global offshore activities merits a reassessment of the classical Hubbert model predictions[4]. This decline model is solid and handles adequately severe events[5] such as sharp production fluctuations, new large discoveries, EOR, etc. However the result of pooling production from different types of provinces - mature onshore with a strong emerging offshore – with different histories introduces interpretative distortions which inevitably lead to off beam estimations of world oil resources, depletion, and associated peak oil estimates. In fact, the world crude oil (onshore and offshore) decline linear trend line has shifted[6] its course after 1995 following the impact of offshore production. Eventually a new trend line will develop once the offshore effect reaches steady state, some time in the distant future. A similar situation occurs with U.S. natural gas[7]. A stabilized production decline trend line from traditional gas fields began in the 1970s. A second trend line began in the 1990s reflecting the impact of the development of tight-gas sands.

The objective of this paper is to estimate the potential of the world's offshore oil provinces using an analogy of the size distributions of the giant onshore and offshore fields discovered to date, and provide a medium term production forecast for global offshore.

Geological setting of the largest offshore producing and non producing regions

It is no coincidence that the world's largest offshore oil producing regions are also endowed with rich onshore petroleum systems. The Persian Gulf/Middle East is the world's largest oil producer and has the largest concentration of reserves. West Africa primarily produces hydrocarbons from two large offshore provinces but it also has significant onshore reserves and production. The Gulf of Mexico is a world class province surrounded by two countries that have significant onshore petroleum systems. Asia/Australasia is a large region comprising several countries, but the petroleum resources are found in tectonically linked basins that originated in the same process (i.e. Sunda). Oil production in this complex region is primarily from offshore basins but it also has onshore oil provinces. The North Sea and Brazil are in a class of their own as most oil reserves and production are in offshore settings. The regions of China, Caspian and Russia/Artic share the following characteristics: a) onshore contains significant amounts of reserves and production, b) offshore oil production is presently either low or growing rapidly, c) limited number of offshore oil discoveries and exploration activity to date, and d) large geological petroleum systems.

Since the 1970s the setting of the giant fields ($\geq$ 0.5 Bbo) has been studied[8] [9] with the objective of understanding the geographical and geological settings of the world's petroleum systems. In one of the most comprehensive studies of this type, Mann et al[10]

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[4] Campbell, C.J. "The Golden Century of Oil 1950-2050: The Depletion of a Resource," Kluwer Academic Publisher, Dordrecht, 1991.

[5] Sandrea, R., "What About Deffeyes' Prediction that Oil will Peak in 2005?", MEES – Middle East Economic Survey, Vol. 49-11, Sept. 12, 2005.

[6] Staniford, S., "Hubbert Theory says Peak is Slow Squeeze", www.theoildrum.com/story/2005/12/5/133418/045, Dec. 05, 2005..

[7] Sandrea, R., "Global Natural Gas Reserves – A Heuristic Viewpoint", MEES – Middle East Economic Survey, Vol. 49 - No. 11, March 13,2006 (Part 1); Vol. 51 - No. 12, March 20, 2006 (Part 2).

[8] Halbouty, M. T., "Giant oil and gas fields of the decade 1990-2000", AAPG Convention, Denver, Colorado, 2001.

[9] Murray, A., and Latham, A., "Worlds artic basins pose array of unique work opportunities", O&GJ, Nov. 13, 2006

reviewed the setting of 877 giant oil and gas fields representing two-thirds of the petroleum resources and found that these were not only located in few geographical regions, but also concentrated in few tectonic settings. The three types of settings are: passive margins (304 giants), continental rifts (271 giants) and collisional margins between two continents (173 giants).

That study and the USGS WPA (2000) also concluded the following regarding the known petroleum systems of the world: a) the typical depositional environment of reservoir rocks is non-marine to marine (43%) and shallow marine (36%); b) less than 11% of the reservoir rocks have been deposited in deep marine environments (turbidites); c) the age of the reservoir rocks is commonly Mesozoic (65%) and Cenozoic (20%); less than 13% of the known reservoirs are Paleozoic or older; d) regarding trapping mechanisms, the most common traps are structural (70%); and only 5% of the resources have been found in pure stratigraphic traps.

For the world giant offshore oil fields only, no similar assessment has been made exclusively. This study attempts to do so based on 62 giant offshore oil fields representing 40% (180 Bb) of the total oil discovered offshore. A synthesis for each region is provided in Table 2. Some discernable general observations about offshore giants are: a) the tectonic setting is commonly passive margin (39 giants); b) the depositional environment of the reservoir rock is dominated by none marine to marine sands (38 giants); and c) the age of the reservoir rock is Cenozoic (32 giants) and Mesozoic (24 giants). Accumulations in deepwater giants are exclusively associated with turbidite reservoirs (26 giants) of Cenozoic age. The typical trap is structural (29 giants) and a combination of structural and stratigraphic (30 giants).

Global offshore E&P trends

Since offshore exploration began in the 1940's some 17,700 exploration wells have been drilled in shallow water resulting in 2,500 new oil discoveries. In deepwater, exploration began in the late 1970s and since then nearly 2,000 exploration wells have been drilled resulting in 400 new oil field discoveries (Figs. 2, 3). In shallow water the number of exploration wells drilled has remained fairly stable at around 500 per year over the last 25 years. In contrast the number of deepwater wells has been increasing steadily, over 100 wells per year since 1997. Over the last 25 years, the average number of new offshore oil field discoveries has remained stable at around 80 per year; the highest number was recorded in 1982 at 118. Two other record years include 1990 with 109 new oil discoveries and 2003 with 104 new offshore oil discoveries.

The above efforts have resulted in the discovery of nearly 500 Bb of oil in three exploration phases. The first identifiable phase is from the 1940's to 1972. This phase is characterized by the discovery of the super giants in the Persian Gulf and, in the later part of the period, by the first giant discoveries of the North Sea. Elsewhere, two giant discoveries were made in Australia and one in China. The first discovery in the US GoM was made in 1947. The cumulative oil discovered was 198 Bb, the yearly average discoveries average 7.3 Bb and average discovery size was 720 mbo.

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[10] Mann, P.L., Gahagan, L., and Gordon, M.B., "Tectonic setting of the world's giant oil and gas fields", in M.T., ed. Giant oil and gas fields of the decade 1990-99, AAPG Memoir 78, 2001.

The second phase is from 1973 to 1990. This phase is characterized by giant discoveries in the North Sea, Mexico, Caspian, Russia/Artic and the first deepwater discoveries in the US GoM (1983) and Brazil (1984). There are also two notable giant discoveries: Bombay High in India and Hibernia field in Canada. Elsewhere, several smaller discoveries continued to be made in shallow offshore West Africa, Asia/Australasia and shallow US GoM. During this phase the cumulative oil discovered was 171 Bb, the yearly average discoveries totaled 9.5 Bb and the average discovery size was 140 mbo.

The last phase began in 1991 and extends to today[11]. This phase is characterized by giant deepwater discoveries in Brazil, West Africa, and US GoM. However, several giant discoveries have been made in other regions including the North Sea, Caspian and China; smaller discoveries were made in Asia/Australasia, shallow water West Africa, and the Persian Gulf. During this recent period the cumulative oil discovered was 120 Bb, the yearly average discoveries totaled 8 Bb and the average discovery size was 120 mbo. Of the total oil discovered, deepwater and ultra deepwater fields accounted for 44 Bb or 3 Bb per year.

Measured in terms of cumulative exploration wells drilled and wells per squarer kilometer of sedimentary basin the regions more explored have been the US GoM, North Sea, Persian Gulf, Asia/Australasia and West Africa; Mexico, China, Caspian and Russia/Artic are the least explored. Offshore regions such as North Africa and eastern Canada have seen very limited exploration with some successes; others like the Red Sea, Pacific and North Atlantic have not seen any exploration. Fig. 4 shows the cumulative number of exploration wells drilled and oil discovered, worldwide offshore. As can be seen, the global offshore does not show the signs of a mature exploration play.

Overall the industry has been able to make each year as much discoveries in the offshore as in the early exploration phase. The average field size has remained broadly unchanged since the late 1970s; this is in great part due to technology which has allowed for the visualization and discovery of different types of plays. The previous facts combined with conclusions of different geological studies, including this one, clearly suggest that the global offshore has remained highly attractive for exploration. More importantly, there is no doubt that offshore has a significant upside. The obvious exception is the UK North Sea which is a very mature province and other basins such as shallow US GoM and Bass Strait in Australia.

Estimating the global offshore oil reserve base

What we know today…

The reserve base is the sum of cumulative production and remaining reserves; these two combined with a undiscovered potential or YTF give the ultimate recoverable reserve (URR). Estimates for the first two may be obtained from IHS Energy. IHS uses a consistent bottom up approach compilation of technically recoverable estimates (2P) for discoveries, but these numbers are also subject to uncertainty. Estimates for undiscovered oil (crude and NGLs) in offshore provinces are only available from the USGS WPA (2000). The USGS methodology is based on assessments of a total petroleum system (TPS) of known and frontier provinces, which is a less restrictive measure than field by

[11] Sandrea, I., "Deepwater oil discovery rate may have peaked; production peak my follow in 10 years", Oil & Gas Journal, July 26, 2004.

field estimates. Table 3 shows the global offshore reserve base at the end of 2005 based on a combination of these two sources adjusted for discoveries and type of liquid. But how can we get a second opinion?

Alternative 1: the Hubbert and parabolic Fractal distribution models

The world has consumed/produced one trillion barrels of crude oil over the last 150 years**.** Roughly 800 billion barrels came from onshore oil fields and 200 billion from offshore**.** Figure 5 shows the cumulative production growth patterns of each genre which are remarkably similar except for the phase lag in development. Offshore production started 40 years later. Characteristically the cumulative production curve begins growing exponentially up through the half-life point of the reserves (Q = K/2); thereafter it reverts to an exponential decline pattern, finally approaching asymptotically the value K - the ultimate reserves of the field. Overall it resembles a somewhat S-shaped curve which is best represented by the logistic equation[12]:

$$Q = \frac{K}{\left(1 + ae^{r_0 t}\right)} \qquad (1)$$

Q is the cumulative production, K the ultimate reserves, r_o the initial growth rate constant, and the constant *a* which has no physical significance. Unfortunately it is not possible to curve fit equation (1) and obtain a unique set of values for the three constants. However, the derivative of equation (1), namely:

$$(dQ/dt)/Q = r_o\,(1 - Q/K) \qquad (2)$$

defines a straight-line relationship between production decline, (dQ/dt)/Q, and Q. This constraint allows the establishment of definitive values for K and r_o.

Generally the straight line trend would kick off after a substantial volume of oil has been produced – at least 25% of the ultimate reserves. This has been the observed[13] decline behavior of oil production in the US, Russia and Saudi Arabia. However, global offshore production is still in its early exponential growth stage and this precludes the use of production decline analysis to establish its K-value.

Laherrere[14] developed an elegant parabolic fractal distributions approach to estimate the K-value for a region with only few estimates about the size of the largest fields, a condition very akin to the offshore environment which is in a nepionic stage of development. The methodology however assumes that the discovery of large fields has peaked and that no additional fields will be discovered. As discussed before, this is unlikely to be the case. The parabolic fractal method moreover requires the determination of three free constants, none of which has any physical significance; a physical tie would normally allow obtaining independent anchor values.

[12] Cavallo, A. J., Predicting the peak in world oil production, Natural Resources Research, Vol. 11, 187-195, 2002.
[13] Sandrea, R., "What About Deffeyes' Prediction that Oil will Peak in 2005?", MEES – Middle East Economic Survey, Vol. 49-11, Sept. 12, 2005.
[14] Laherrere, J., "Parabolic Fractal Distributions", presented at the French Academy of Science, April, 4, 1996.

Alternative 2: exploration by analogy

In order to establish a second estimate for the global offshore crude oil reserve base a heuristic approach[15] is proposed, using an assumed analogy of the size distributions of the giant oil fields discovered to date in both the onshore and offshore environments. The basis for the analogy stems from the premise and observation that oil fields are often found together in the most important hydrocarbon provinces or petroleum systems. Moreover, giant oil fields are the core of the oil industry because they provide a significant share of the world's production.

This methodology requires knowledge of the global onshore reserve base for comparative purposes. This was obtained by decline curve analysis. The oil production decline performance for global onshore crude since 1980 is shown in Figure 6. The linear trend line starts in the early 1990s and extrapolates to a K-value of 1,800 Bb, thus indicating that onshore production would reach its half life in the next six years at current production rates. The least squares-fitted trend line has a correlation coefficient of 0.984. IHS Energy estimates that at the end of 2005 the reserve base for the global onshore stood at 1838 Bb. It is worth mentioning that both estimates exclude undiscovered oil potential and reserve growth.

Table 4 summarizes the ultimate reserves and peak production capacity of the 63 giant offshore oil fields discovered to date. Fig. 7 compares the size distributions of the fifteen largest onshore and offshore fields. The largest onshore oil giants range in size from 80 Bb to 12 Bb of ultimate reserves. In comparison, the offshore giants range in size from 30 Bb to 2.5 Bb. In general, the mean size of the onshore giants is three times that of the offshore giants, 24 Bb versus 8 Bb. Consequently, the expected value of the offshore crude reserves would be around 600 Bb corresponding to one-third of the K-value estimated for the onshore.

Using the tail-end values of the offshore size distribution it is also possible to obtain a range of values. The high end corresponds to the oil fields of the Persian Gulf. They are the largest offshore oil fields in the world, varying in size from 30 Bb to 6 Bb. Their onshore counterparts are also the biggest in the world. The size ratio of onshore to offshore fields is estimated at 2.5. At the low tail-end of the distribution are the giant oil fields discovered in the Gulf of Mexico. With the sole exception of the fields in Mexico, the largest fields discovered in the GoM to date tend to be relatively small, less than 1 Bb and averaging 0.5 Bb. The onshore fields contiguous to the GoM also are relatively small. The ten largest onshore oil fields in the lower US states have sizes varying from 6 Bb to 1.4 Bb with an average of 2.5 Bb. The size ratio for the onshore GoM is 5 which is twice that for the Persian Gulf. These size ratios would indicate that the offshore reserve base can range from 720 Bb to 360 Bb.

The heuristic methodology shows that the average estimate for the global offshore oil reserve would be closer to 600 Bb, which is nearly 30% more than the IHS estimate; considering the difference in the approach the proximity of the results is reassuring. However, given that the methodology may not apply to unexplored regions with probably significant reserves and potential (i.e. China, Caspian, deep Mexico and Russia/Artic), it can be concluded that additional offshore reserves must exist over and above this new estimate.

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[15] Sandrea, R., "Global Natural Gas Reserves – A Heuristic Viewpoint", MEES – Middle East Economic Survey, Vol. 49 - No. 11, March 13,2006 (Part 1); Vol. 51 - No. 12, March 20, 2006 (Part 2).

By combining the average result of the heuristic approach with the USGS WPA (2000) estimate for undiscovered oil, the URR for the global offshore could be closer to 1000 Bb of which just 200 Bb have been produced (Fig. 8).

World offshore production potential of known provinces

Shallow offshore oil production in several under-explored hydrocarbon rich provinces including China and Caspian is just ramping up; it may be a slow ramp up but the fact is that it is increasing and there is medium term project visibility. The shallow offshore is expected to continue grow at a slower pace to the end of this decade, until the pressure from declining North Sea oil is reduced. At least three giant shallow offshore fields will contribute significant volumes in the medium term – ACG, Manifa, and Kashagan. On the other hand, deepwater oil production will double over the next five years underpinned by more than 60 projects globally. It is very possible that with the rapid rate of increase, deepwater will reach its maximum level in the medium term due to the nature of turbidities reservoirs. However, this scenario remains uncertain due to the potential impact of technology and unexplored deepwater provinces, both of which could extend the growth and certainly the post peak production level. Ultra deepwater oil production will remain constrained but in five years there will be several producing fields in the US GoM, Angola and Brazil. Offshore production in Russia/Artic is also just taking off with new production from Sakhalin, Pechora and Barents Sea. Fig. 9 shows historical and modeled future world offshore oil production. Deepwater is included separately given the importance of this source. The near to medium term has been modeled with known projects (over 200) and assumed decline rates. The model has also been calibrated so that projected R/P ratios remain stable.

There is no doubt that global offshore oil production will continue to grow strongly in the medium term; in fact various tests of the model show that global offshore crude oil production could continue to grow to 34 mb/d by 2020. Long term, once the R/P ratio reaches 10-15 and cumulative production exceeds 50% of the URR, it is expected that production will start to level off and then decline. The current global R/P is over 32, and by 2015 it will be 23. Based on an URR of 1000 Bb, we have produced 20% and by 2015 we would have produced 35%. Given that there are uncertainties about the timing of new oil, impact of potentially large discoveries and deliverability issues, the long term is not modeled here, but there is should be no doubt that offshore production will continue to grow.

Concluding Remarks

The performance of the global offshore has been remarkable. Globally, a total of 500 Bb of oil have been discovered in the offshore, of which 200 Bb have been produced. The URR for the global offshore could be closer to 1000 Bb. Over the decades, E&P trends have remained highly encouraging, particularly the reality that both yearly discoveries (~8 Bb per year) and average field sizes have remained the same over the last three decades.

Giant offshore fields represent 40% of the total oil discovered and these are located in several regions albeit in few geological settings. A heuristic approach developed in this paper based on exploration by analogy suggests that there could easily be 30% more oil than what is currently estimated. Additionally there is a large undiscovered oil potential, in the range of 300+ Bb, as several regions remain under explored and others have not been explored at all. To note are offshore China, deep Mexico, Russia/Artic, Red Sea, North Atlantic, Pacific and North Africa. Offshore is the next frontier in global oil supply. It's amazing what $50 oil will do!

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Biographies

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Table 1: Largest offshore oil producing regions in 2005

	Production Start-up	Daily Production (mb/d)	Cumulative Production (Bb)
Crude oil			
Persian Gulf/ME	1957	5.3	51
North Sea	1975	4.7	45
West Africa	1969	3.5	25
Mexico GoM	1960	2.6	20
Asia/Australasia	1960	2.1	21
U.S. GoM	1947	1.6	24
Brazil	1973	1.5	6
China	1980	0.6	2
Caspian	1950	0.4	1
Russia/Artic	1999	0.05	0
Others		0.8	2
Total NGls		1.6	7
World Offshore		25	204

Persian Gulf/ME: Iran, Saudi, Qatar, UAE, Iraq, Egypt, Neutral Zone, Kuwait
North Sea: Denmark, Norway, UK
West Africa: Angola, Gabon, Congo, Ivory Coast, Nigeria, Cameroon, Equatorial Guinea
Asia/Australasia: Australia, Brunei, Indonesia, Thailand, Myanmar, Malaysia, New Zeland, Vietnam
Caspian: Azerbaijjan, Kazhakastan, and bordering countries
Others: mainly Argentina, Canada, Germany, India, Nertherlands, Trinidad, Tunisia, Lybia
NGLs: mainly Norway, UK, Trinidad, EQ, Nigeria, US, Iran, Australia, UAE
Source: IHSE, OPEC

Table 2: Geological setting of largest offshore oil producing regions

	No. Offshore Giants	URR Giants (Bb)	% of Total Offshore Oil Discovered	Typical tectonic setting	Reservoir rock depositional enviroment	Typical reservoir rock age	Typical Trap
Persian Gulf	9	81	51%	Passive margin	Marine	Mesozoic	Structural
North Sea	12	26	42%	Continental rifts	Non marine	Mesozoic	Structural
West Africa	14	11	16%	Passive margin	Turbidites	Cenozoic	Combination
Mexico GoM	2	24	75%	Passive margin	Marine	Mesozoic	Combination
US GoM	5	3	11%	Passive margin	Non marine/ turbidites	Cenozoic	Combination
Asia/Australasia	3	3	8%	Strike slip/passive margin	Non marine to marine	Late Mesozoic / Cenozoic	Structural
Brazil	7	9	33%	Passive margin	Turbidites	Cenozoic	Combination
China	2	3	45%	Passive margin	Non marine to marine	Cenozoic	Combination
Caspian	2	17	68%	Collisional margin	Non marine	Cenozoic	Structural
Russia/Artic	1	1	20%	Continental rifts	Marine	Mesozoic and older	Structural
Sakhalin	2	3	94%	Strike slip	Marine	Cenozoic	Structural

For data on giant fields see table 2
Combination: structural, growth fauls, stratigraphic, salt domes, ect
North Sea mainly central graben
Mexico GoM main area around Cantarell complex
Asia/Australasia mainly Australia Brass Strait, Sunda
Russia/Artic mainly Barents Sea
Source: IHSE, OPEC, USGS, Mann, P., et al (2003)

Table 3: Global offshore oil resource estimates at 2005, Bb

	Cumulative production	Remaining Reserves	Total Discovered	% in Giants	Adjusted Undiscovered USGS	Composite URR
Crude						
Shallow offshore	190	205	395	41%	na	na
Deepwater	7	45	52	40%	na	na
Ultra deepwater	na	7.5	7.5		na	na
Total crude	197	258	455	40%	251	706
Total NGls	7	41	48	46%	95	143
Total Liquids	204	299	503		346	849

USGS Undiscovered has been adjusted to reflect discoveries in the 2000-05 period

Composite URR = total discovered + adjusted undiscovered URR

Source: IHSE, USGS, OPEC

Table 4: Giant offshore oil fields

Region/Field	Year Discovery / First Oil	Est. URR (Bb)	Est. Max Capacity (kb/d)	Water Depth	API
Persian Gulf/Middle East					
Safaniya-Khafji	1951/1957	30	1,200	Shallow	27-32
Zakum (Lower and Upper)	1965/1967/2006	20	750	Shallow	33-39
Manifa	1957/1964/2011	17	1000	Shallow	27-32
Zuluf	1966/1967	12	660	Shallow	27-32
Forouzan-Marjan	1966/1974/1994	10	750	Shallow	27-32
Abu Safah	1957/1967	7.5	300	Shallow	27-32
Um Shaif	1958/1962	4	280	Shallow	37
Doroud	1961/1964	3.4	220	Shallow	34
Soroosh/Norouz	1962/1967	1.2	190	Shallow	18
Abuzar	1969/1976/1994	1.1	220	Shallow	26
Fateh	1965/1969	1.1	300	Shallow	32
Al Shaheen	1992/1994	1	525	Shallow	30
Salman	1965/ 1969	0.5	135	Shallow	35
Belayim (Deep)	1997/2003	0.5	100	Shallow	28
North Sea					
Statfjord	1974/1979	4.5	740	Shallow	38
Ekofisk	1969/1971	3.8	300	Shallow	32
Oseberg	1979/1988	2.8	500	Shallow	35
Forties	1970/1975	2.7	520	Shallow	37
Brent	1971/1976	2.4	440	Shallow	38
Gullfaks	1978/1986	2.5	530	Shallow	31
Draugen	1984/1993	2	210	Shallow	39
Snorre	1979/1992	1.4	360	Shallow	68
Ninian	1974/1978	1.2	300	Shallow	37
Heidrun	1985/1995	1.1	225	Shallow	27
Valhall	1975/1982	0.8	168	Shallow	42
Buzzard	2001/2006	0.5	190	Shallow	32
West Africa					
Dalia	1997/2006	1	240	Deepwater	23
Bonga	1996/2005	1	220	Deepwater	29
Apko	2000/2008	0.9	180	Deepwater	>40
Girassol	1996/2001	0.8	220	Deepwater	32
Agbami	1998/2008	0.8	210	Deepwater	45
Bonga SW	2001/2012	0.7	150	Deepwater	30
Bosi	1996/2008	0.7	120	Deepwater	<40
Amenam-Kpono	1990/2003	0.7	125	Shallow	32
Erha	1999/2006	0.7	190	Deepwater	>35
Kuito	1997/2000	0.7	100	Shallow	>35
Benguela	1998/2006	0.7	100	Shallow	24-38
Kizomba A - Hungo	1999/2005	0.5	120	Deepwater	28-30
Kizomba A - Chocalho	1999/2005	0.5	120	Deepwater	28-30

Kizomba B - Kissanje	1998/2006	0.5	120	Deepwater	28-30
Kizomba B - Dikanza	1998/2007	0.5	120	Deepwater	28-30
Gulf of Mexico					
Cantarell (Complex)	1976/1979/2000's	19	2,000	Shallow	25
KMZ (Complex)	1970's/1979/2000's	5	800	Shallow	13-24
Thunder Horse	1999/2008	1	250	Deepwater	33
Atlantis	1998/2005	0.6	200	Deepwater	30
Mars	1989/1996/2006	0.7	220	Deepwater	30
Shenzi	2001/2009	0.5	100	Deepwater	>30
Ursa	1991/1999	0.4	150	Deepwater	30
Asia/Australasia					
Kingfish (Australia)	1967/1969	1.2	160	Shallow	46
Halibut (Australia)	1967/1970	1	160	Shallow	43
Bach Ho (Vietnam)	1975/1986	0.9	340	Shallow	34
Brazil					
Marlim	19851998	2.7	590	Deepwater	20
Roncador	1996/2002	2.3	480	Deep to Ultra Deep	25
Marlim Sul	1987/2004	1.2	150	Deepwater	26
Barracuda	1989/2002	1	150	Deepwater	24
Jubarte	2000/2002	0.8	180	Deepwater	17-20
Albacora East	1986/2006	0.7	180	Deepwater	20
Albacora	1984/1996	0.6	175	Deepwater	28
FSU/Artic					
Kashagan	2000/2008	12	1,200	Shallow/Ice	42
ACG (complex)	1984/1997	5	1000	Shallow/Deep	34
Sakhalin-1 (complex)	1979/2005	2.3	250	Shallow/Ice	>35
Sakhalin-2 (complex)	1979/1999	1	160	Shallow/Ice	>35
Priazlomnoye	1989/2008	0.7	100	Shallow	<30
Others					
Shengli complex of fields (China)	1961/1993	2.2	650	Shallow	<25
Bombay High complex of fields (India)	1974/1976	1.3	400	Shallow	39
Hibernia (Canada)	1978/1997	0.8	150	Shallow	30-34
Peng Lai (China)	1999/2006	0.5	180	Shallow	11.-20

Source: Mann, P., et al (2003), Company data, Sandrea, I., (2004), Secondary sources

Some fields have onshore/offshore reserves

Several fields complexes are undergoing re development or expansions despite that first oil may have been produced in the past.

Fig. 1 World onshore/offshore oil production, mb/d

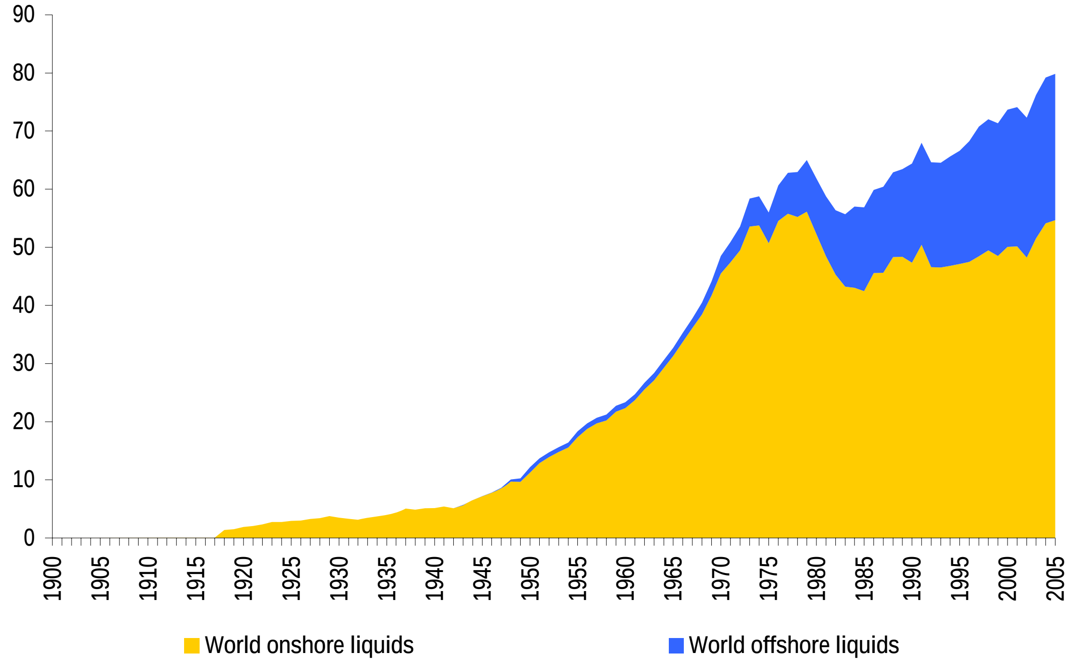


Figure 2: Offshore exploration wells drilled and new oil discoveries

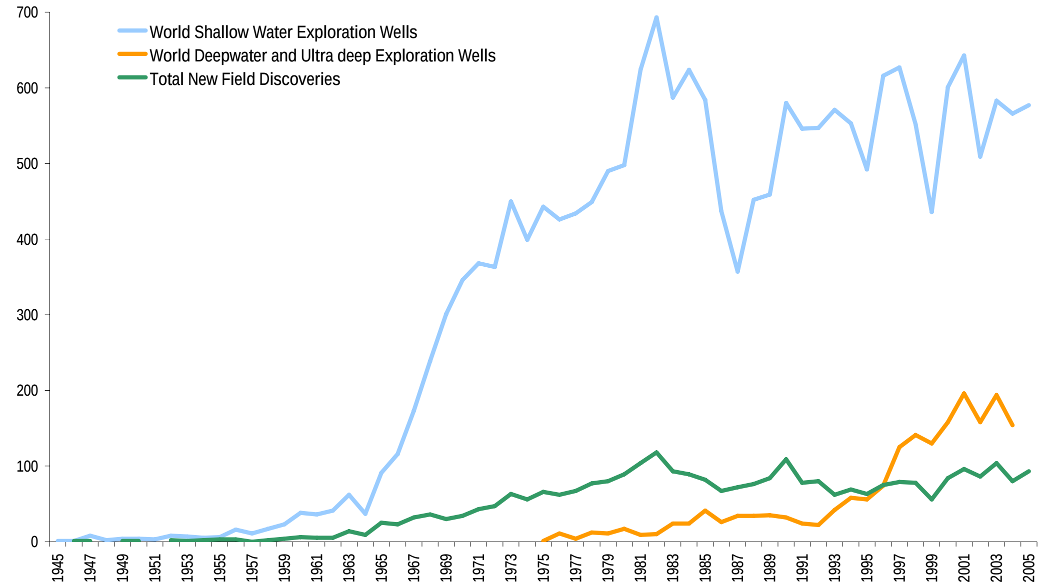


Figure 3: yearly oil discoveries and average field size

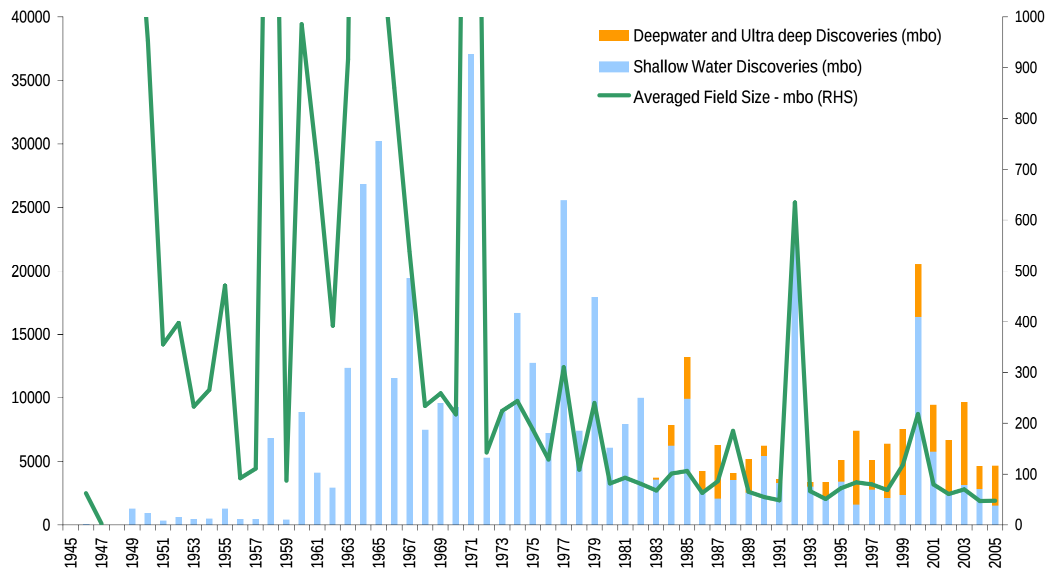


Figure 4: Global offshore – cumulative exploration wells and oil reserves

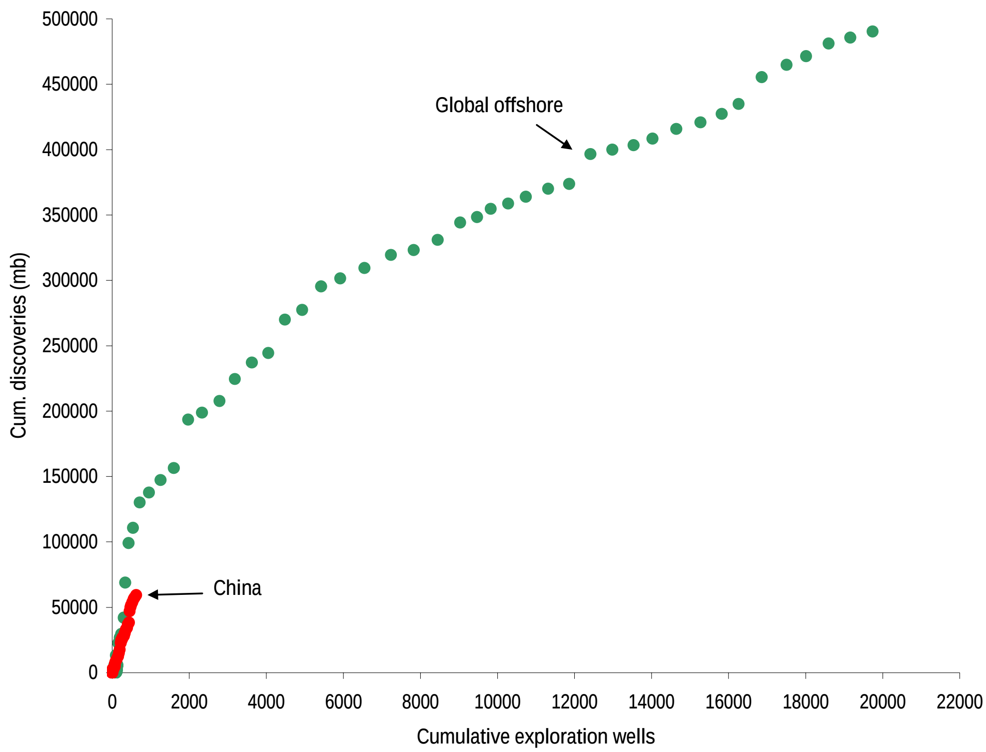


Figure 5: World cumulative crude oil production growth, Bb

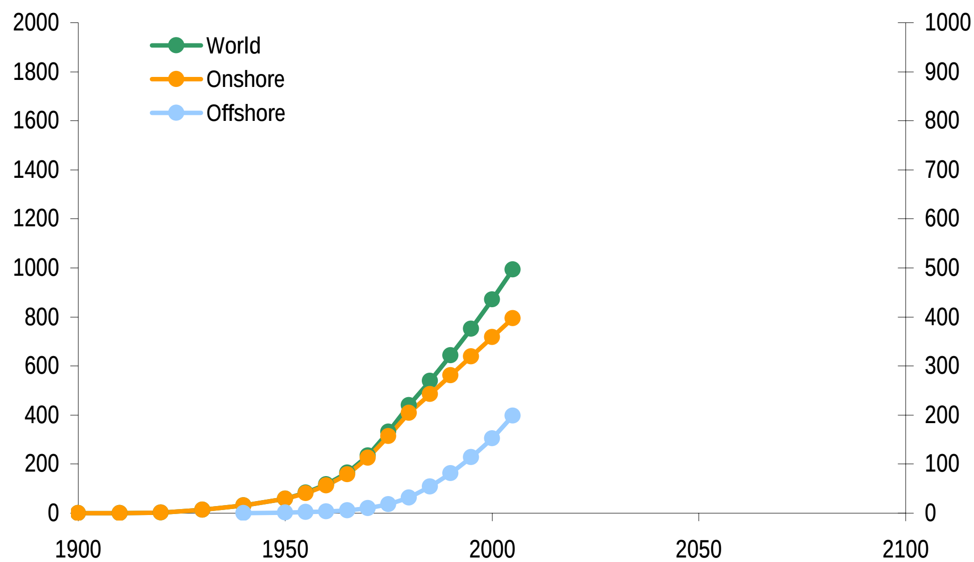


Figure 6: Production decline trend – World onshore crude oil

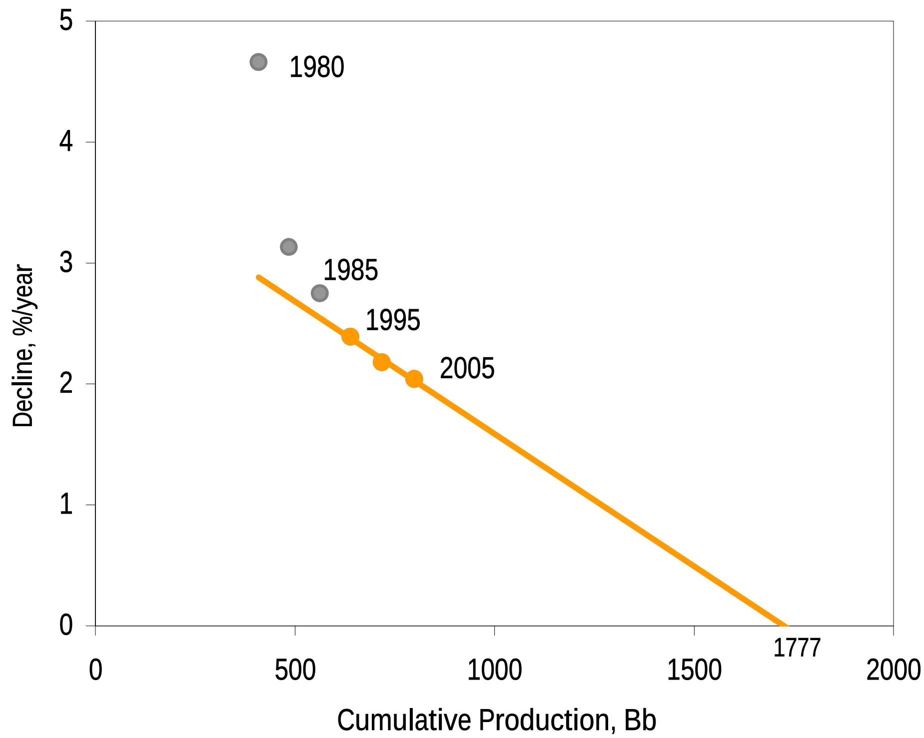
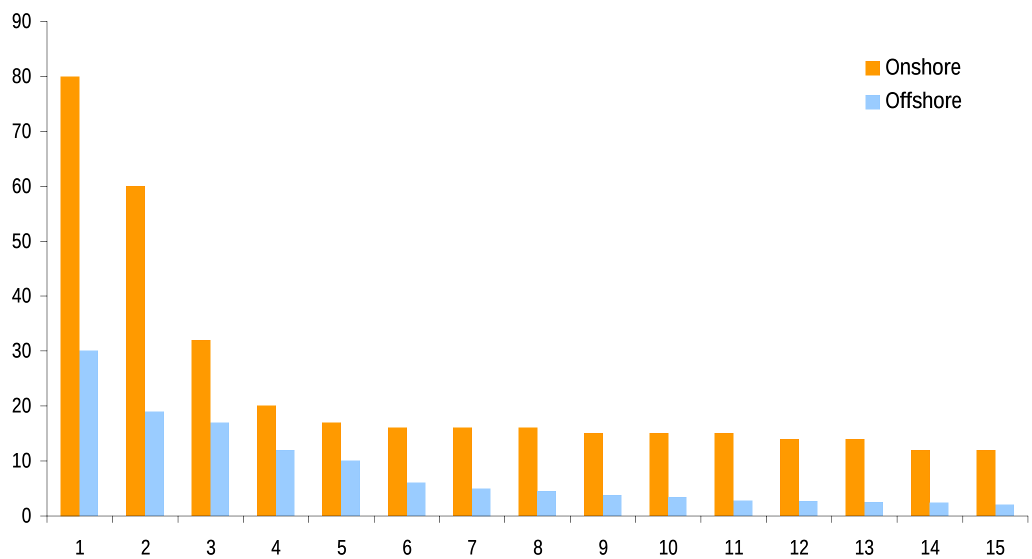


Figure 7: Largest 15 oil onshore and offshore fields



Onshore fields: 1. Ghawar, 2. Burgan, 3. Bolivar, 4. Rumalia, 5. Ahwaz, 6. Kirkuk, 7. Marun, 8. Daqing, 9. Romashkino, 10. Gachsaran, 11. Tengiz, 12. Aghajari, 13. Samotlor, 14. Abquaiq, 15. Berri
Offshore see Table 2.

Figure 8: Global offshore oil reserve base and URR

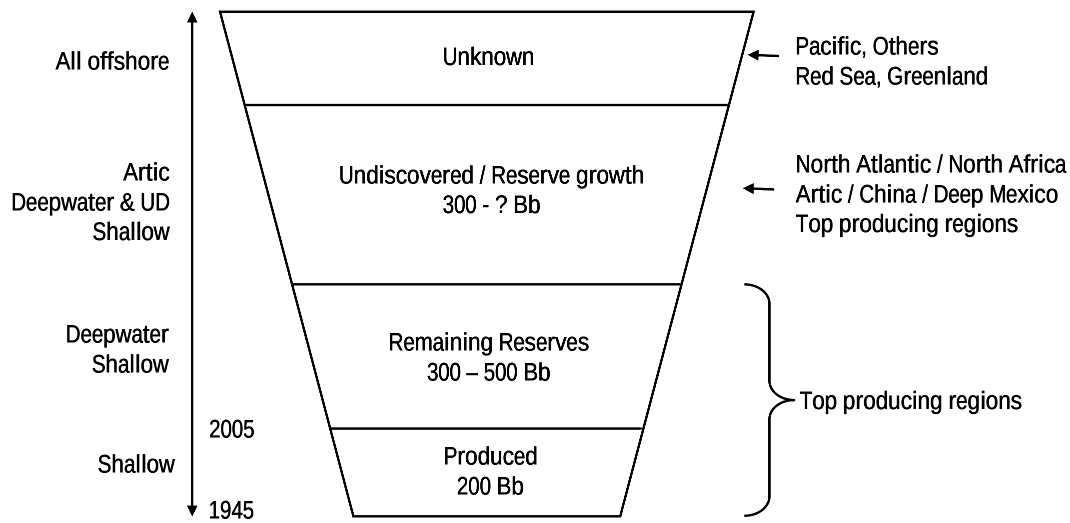


Figure 9: Global offshore production outlook, kb/d