Estimates of Oil Reserves

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This document for the IIASA site gathers many graphs and a long text for those who want to get technical data on many countries and explanations, but only a part will be shown during my presentation.

My apologies for my broken English

Introduction

The western world lives in a culture of belief in growth and everyone hopes to see their children having better lives than they had, but for the first time we are not sure. Everyone would like to see the growth continue and hates to speak about decline.

Politicians promise that growth will solve the present problems on welfare, retirement and they would dearly love to see the reserves of oil, which fuels the economy, grow.

As the French writer Antoine de Saint Exupery wrote: "we do no inherit from our parents, we borrow from our children"

There are two schools on reserves but also much the confusion between reserves and resources.

The views of so-called "Pessimists" (mainly retired geologists or retired CEO (Bernabe 1998, Bowlin 1999) are compared with those of so-called "Optimists" (mainly economists Aldeman, Lynch, or governmental agencies DOE, IEA, EU)

The Pessimists have access to technical data when the Optimists have access to political or financial data.

Reporting data on oil production or oil reserves is a political act. The SEC, to satisfy bankers and shareholders, obliges the oil companies listed on the US stock market to report only Proved Reserves and to omit Probable Reserves that are reported in the rest of the world. This poor practice of reporting only Proved Reserves led to a strong reserve growth, as 90% of the annual reserves oil addition come from revisions of old fields, showing that the assessment of the fields was poorly reported. This reserve growth of conventional oil reserves is wrongly attributed to technological progress. Technical data, on which development decisions are taken, exist but they are confidential. There are database companies (or "scout" data as a scout is someone sent to get information without revealing his source), selling technical data, but these databases are very expensive.

Reporting of reserves is poor, but reporting on production is not much better as the 10$/b of early 1999 seems to be mainly due to the « missing barrels » of IEA overestimating the supply and underestimating the demand (end of Asiatic crisis), giving a false impression of oil abundance (Simmons 2000).

Recovery factor is assumed to depend mainly upon oil price, when it depends mainly on the geology and physics of the reservoir.

The Optimists believe that technology (as Santa Claus) will solve all the problems, but they do not want to listen to technicians who say that technology has limits.

The Greek philosopher Esopus said that the tongue was the best tool (when saying words of love or poetry) and the worst tool (when shouting hate or murder).

The oil industry uses also the best and the worst technology. The best technology is in seismic, logging, producing. The worst technology is in defining units, measuring, reporting and communicating about oil. The oil industry is not alone. The $125 million Mars spacecraft was lost because NASA navigators mistakenly thought a contractor used metric measurements. The contractor had used English units, and the probe burned up in the Martian atmosphere on Sept. 23, 1999. The computer industry was not very bright in letting the Y2K bug to occur, but the worst was that there was no bug at all, even for the countries, which did not bother to correct it. The last US presidential elections with obsolete punched cards and poor machines are a bad image of modern technology. The blackouts of California confirm this poor image.

The importance of oil was recently denied in front of the emergence of Internet or the huge increase of GPD (manipulated to show growth). But the new economy has been badly damaged by the last oil shock.

Published data are unreliable and the image of the oil industry given by different actors confusing. As an uncertain estimate has to be given within a range and not by one single number, the ways of describing the oil industry would show their strengths and also their weaknesses. I claim to be a oil explorer as a geologist-geophysicist who has participated in finding many oil fields including some giants ones (the first one being Hassi Messaoud (Algeria 10 Gb) and the last one Cusiana (Colombia 0.7 Gb), but I drilled a lot of dry holes. It is only by recognising the errors that progress can be made (the "trial and error" approach in mathematics when a solution is not available). Claiming that an author is wrong because he was wrong once is denying progress. Only persevering in obsolete practice should be reprimanded.

1 What oil?

There is a lack of definitions and consensus as everyone wants to be free to say what he wants. People are very conservative and reluctant to change, keeping obsolete units and terms.

1.1 What product?

Oil could be crude oil (2000 World 65 Mb/d, but 68 Mb/d with lease condensate) or petroleum (76 Mb/d), which includes the condensate (from separator on wellhead), natural gas liquids (NGL from gas processing plants), synthetic oil, refinery processing gains, other oils and stock withdrawal.

NGL could include or not the condensate, in the US lease condensate is included with the oil, but in OPEC the oil quotas exclude condensate.

The world's oil supply is given for 1998 to 2000 as in Mb/d:

	WO	CGES	DOE oil+NGL	BP	DOE oil	OGJ	OPEC
1998	75.4	75.3	73.6	73.4	67	66.2	65.5
1999	74.1	74		71.9	65.7	64.7	64
2000	76.7	76.7			68.2	67.1	

Sources: World Oil, Oil & Gas Journal, BP Review, USDOE/EIA, OPEC Bulletin, Centre for Global Energy Studies

In addition to the petroleum gathered from production plants as crude oil, condensate, natural gas liquids, synthetic oil, there are also the liquids from the refinery reported as of the processing gains, being about 1.7 Mb/d/ But the supply is also different from the demand as there is petroleum coming from stocks withdrawal which varies about plus or minus 1.5 Mb/d.

CGES	1998	1999	2000
Processing gains	1.6	1.7	1.7
Supply less demand	1.5	-1.2	0.4

This explains the discrepancy of about 3 Mb/d which can be found in the values of the petroleum production from different sources, in addition of the 6 Mb/d coming from gas liquids.

For 1998 the US production of NGL is reported in EIA ar98 as 833 Mb and in EIA aer99 (Natural Gas Plant Liquids Production) as 642 Mb, which is a difference of 30%

In the US, the importance of the NGL (24%) and the processing gain (12%) versus the domestic production has to be noted.

US supply for 1999	Mb/d	%	% domestic
crude & condensate	5.88	30	76
NGL	1.85	9	24
total liquids production	7.73	40	100
imports	9.91	51	128
processing gain	0.89	5	12
withdrawal	0.3	2	4
alcohol	0.38	2	5
others	0.31	2	4
total supply	19.52	100	253

Oil and gas could be conventional or unconventional (or non-conventional).

Conventional covers usually primary and secondary recovery for porous and permeable reservoir, identified water contact and oil characteristic (light and medium gravity and not viscous oil).

Unconventional covers unusual reservoir characteristics, enhanced oil recovery (tertiary recovery), extra heavy oils (heavier than water), tarsands (defined by viscosity over 10 000 cP), tight reservoir, coalbed methane, geopressured aquifers, methane hydrates, oil shales (in fact mainly immature source-rock which should be classified as coal). Some include deepwater (vary from author from 200 m to 1000 m), ultradeepwater (over 2000 m), Arctic.

USGS define unconventional as continuous type accumulations where there is no defined water contact.

Oil supply differs from demand by the change in stocks

EIA STEO Aug 2000	1999	2000
Demand world Mb/d	74.8	75.8
Supply world Mb/d	73.9	76.6

The inventory of supply and demand is neither easy to come by nor reliable. The International Energy Agency (IEA) in Paris is generally regarded as the best source, but many errors have occurred. The exceptional low price of 10$/b in 1998 was due to the mistaken decision to increase OPEC quotas in the face of the Asian recession and a serious over-estimation of the supply (300 to 600 Mb) by the IEA (the “missing barrels”: Simmons 2000).

1.2 Measures?

1.2.1 Volume or weight or energy

Oil could be measured as volume (measurements of flow in a pipe or in a container) or as weight. In fact if one is chosen, the density has to be given too (it varies with time), as it is impossible to convert one into the other with accuracy without knowing its density. To compare energy, oil equivalence is often used but also the energy (or calorific or work) unit in Btu (British thermal unit) or Joule (work, energy and heat unit). Btu is very small unit (the heat in a wooden head match) and Joule is about one thousand times larger and corresponds to the work of moving one water litre by 10 cm, 1 Btu = 1005.06 J. Btu is banished from the EU since the end of 1979.

Oil could be given either in gallons, barrel, cubic meter, ton, exajoule (EJ= 10E18 J), Btu (quad= quadrillion Btu ≈ EJ)

In UK and France, oil and condensate (in fact NGL) are given in ton, but in Norway oil, and condensate are in cubic meter (as Canada) but NGL in ton, in US oil and condensate in barrel (condensate could be in barrel oil equivalent different from the measured volume). WEA in gigaton and exajoule, IEA& WEC in gigaton.

The oil density varies between 740 and 1030 kg/m^3 (60°API to 6°API) and could be expressed in barrel per ton. But what is published is often contradictory.

OPEC statistics - Conversion factors for Crude oil in barrel per ton

By country	1995	1996	1997	1998	1999
Algeria	7.7741	7.7741	7.7741	7.9448	7.9448
Indonesia	7.7600	7.7600	7.7600	7.2338	7.2338
IR Iran	7.3145	7.3145	7.3145	7.2957	7.2840
Iraq	7.4530	7.4530	7.4530	7.4127	7.4127
Kuwait	7.2622	7.2460	7.2460	7.246	7.2580
SP Libyan AJ	7.5876	7.5876	7.5876	7.5584	7.5584
Nigeria	7.3540	7.3540	7.3540	7.4114	7.4114
Qatar	7.6058	7.6058	7.6058	7.5898	7.6180
Saudi Arabia	7.3229	7.3229	7.3229	7.2843	7.2845
United Arab Emirates	7.5964	7.5964	7.5964	7.5875	7.5532
Venezuela	6.9337	6.9488	6.9580	7.3104	7.1210
Average OPEC	7.3661	7.3671	7.3718	7.3677	7.3464

It shows a false or virtual accuracy and political change (no change and sudden jumps)

But BP Review gives both barrels and tons, and the corresponding density is different, as for example Saudi Arabia is not 7.3 b/t but 7.6 b/t, Algeria is not 7.9 but 8.7.

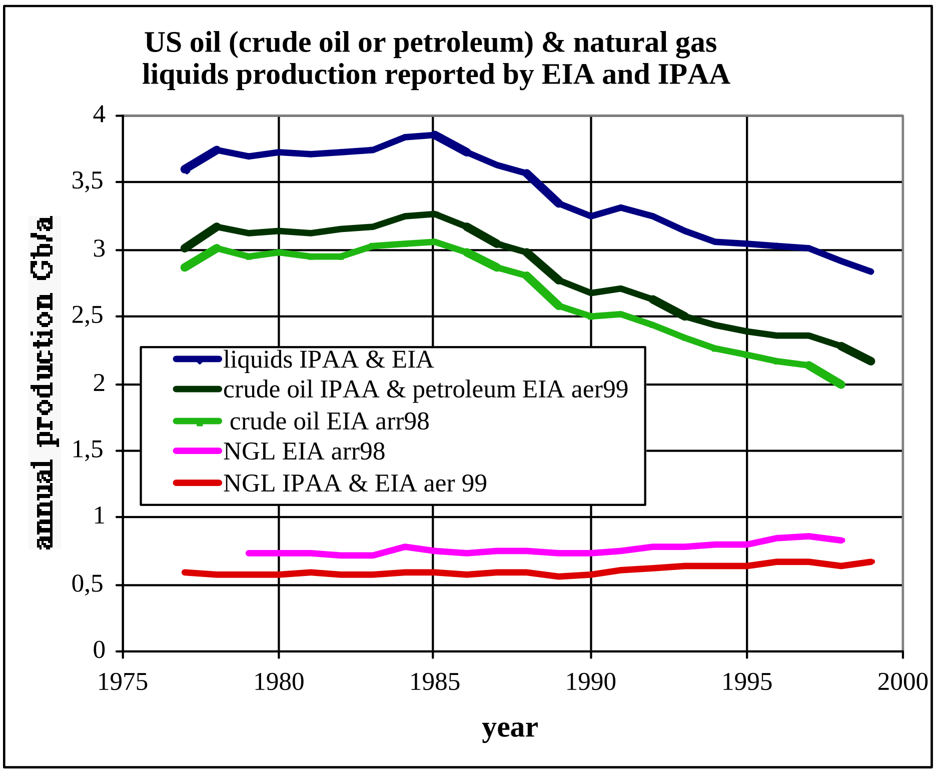
BP Statistical Review 2000			
Oil: Production 1999	Mt	Mb	b/t
USA	354.7	2832	8
Canada	120.3	947	7.9
Mexico	166.1	1221	7.4
Total North America	641.1	5001	7.8
Argentina	42.7	310	7.3
Brazil	56.3	407	7.2
Colombia	42.5	307	7.2
Ecuador	19.5	139	7.1
Peru	5.5	40	7.3
Trinidad & Tobago	6.6	49	7.5
Venezuela	160.5	1141	7.1
Other S. & C. America	6.6	49	7.5
Total S. & C. America	340.2	2442	7.2
Denmark	14.5	110	7.6
Italy	5.6	40	7.2
Norway	149.1	1166	7.8
Romania	6.4	47	7.4
United Kingdom	137.1	1057	7.7

Other Europe	16.7	126	7.5
Total Europe	329.4	2546	7.7
Azerbaijan	13.8	102	7.4
Kazakhstan	30	230	7.7
Russian Federation	304.8	2256	7.4
Turkmenistan	7.4	55	7.4
Uzbekistan	8.1	69	8.6
Other Former Soviet Union	6	47	7.9
Total Former Soviet Union	370	2759	7.5
Iran	175.2	1296	7.4
Iraq	125.5	942	7.5
Kuwait	99.3	739	7.4
Oman	45.2	332	7.3
Qatar	33.4	261	7.8
Saudi Arabia	411.8	3137	7.6
Syria	29	204	7
United Arab Emirates	111.4	914	8.2
Yemen	18.8	144	7.7
Other Middle East	2.3	18	7.9
Total Middle East	1052	7988	7.6
Algeria	56.5	489	8.7
Angola	38.5	285	7.4
Cameroon	4.8	35	7.2
Rep. of Congo (Brazzaville)	14.6	108	7.4
Egypt	41.4	305	7.4
Equatorial Guinea	4.5	37	8.1
Gabon	17	124	7.3
Libya	68	520	7.6
Nigeria	99.9	741	7.4
Tunisia	4	31	7.8
Other Africa	5.9	44	7.4
Total Africa	355	2717	7.7
Australia	24.5	210	8.6
Brunei	8.9	66	7.4
China	159.3	1166	7.3
India	36.2	283	7.8
Indonesia	68.2	527	7.7
Malaysia	36.6	297	8.1
Papua New Guinea	4.5	35	7.7
Thailand	4.9	46	9.3
Vietnam	14.6	106	7.3
Other Asia Pacific	6.6	51	7.7
Total Asia Pacific	364.5	2787	7.6
TOTAL WORLD	3452.2	26240	7.6
Of which: OECD	989.1	7712	7.8
OPEC	1409.9	10705	7.6
Non-OPEC‡	1672.3	12771	7.6

*Includes crude oil, shale oil, oil sands and NGLs (natural gas liquids – the liquid content of natural gas where this is recovered separately). Excludes liquid fuels from other sources such as coal derivatives.

In the US, the data from USDOE/EIA or IPAA (Independent Producers American Association)

Figure 1:



1.2.2 Unit

The US government adopted the metric system in 1866 to be rid of the British system but the US people do not like to follow that the government says and they preferred to stick to old practices (as many French still use old francs (100 times larger), obsolete for now 40 years). The US is the only country in the world with Burma and Liberia to not use the International system of units (known as SI or metric system) (http://www.sc.edu/library/pubserv/reserve/bras/metric.html). Most of the US system of measurements is the same as that for the UK. The biggest differences to be noted are in capacity, which has both liquid and dry measures as well as being based on a different standard - the US liquid gallon is smaller than the UK gallon. Even as late as the middle of the 20th century there were some differences in UK and US measures which were nominally the same. The UK inch measured 2.539 98 cm while the US inch was 2.540 005 cm. Both were standardised at 2.54 cm only in July 1959.

-Barrel: it is not an official unit for oil!

In a Handbook of chemistry and physics, there are about 18 different definitions of barrels.

By weight, a barrel of flour is 196 lbs., of beef and pork, 200 lbs.

By volume

In US 1 barrel liquid = 31,5 gallons = 119.237 litres

1 barrel oil = 42 gallons = 158.983 litters

In UK 1 imperial gallon = 1.2009 US gallon

1 barrel oil = 34.97 UK gallons

1 barrel beer = 36 UK gallons

The first barrels were in wood at about $1.75 to $2.00 in 1861 being much more valuable than its contents. The size was from 30 (as for whale oil) to 50 US gallons. But the volume was settled at 42 gallons.

-Why 42 gallons? = The Weekly Register, an Oil City newspaper of late August 1866. « We, all producers of crude petroleum on Oil creek, mutually agree and bind ourselves that from this date we will sell no crude by the barrel or package, but by the gallon only. An allowance of two gallons will be made on the gauge of each and every 40 gallons in favour of the buyer. »

It showed already the lack of accuracy in measuring oil. This 5% bonus was to compensate for bad measures or as a promotion (as 13 by dozen).

The Petroleum Producers Association finally adopted the 42 gallon oil barrel in 1872. Peckham, reported to the Census Bureau in 1880 report and passed on in 1882 to the U.S. Geological Survey, U.S. Bureau of Mines and other agencies unto today.

But this unit is not an official US unit and federal agencies are obliged to add after barrel (42 US gallons)

1.2.3 Abbreviations

-Barrel: meaning of bbl?

Barrel is written by many as bbl, but also bl, b, but bw for water, bc for condensate, bo for oil and boe for oil equivalent. In all my papers I write b, Mb (megabarrel) Gb (gigabarrel), as boe I use also Gb/a where a is the SI symbol for year as « annum »

Most of oilmen use bbl without knowing what it means and why double b? The first b is for blue but there is disagreement of the meaning of this colour:

-colour of Standard of California to distinguish their barrels from other companies

-to identify the right barrel of 42 gallons within the range of 30 to 50 gallon barrels

-to identify the crude oil in blue barrel when the refined product was in red barrels (rbl)

But this practice is more than a century old and there is not one wooden barrel in any museum. Why to keep this obsolete abbreviation and this obsolete barrel when claiming that modern technology rules the oil industry

-Billion of cubic meter or cubic kilometer?

If the US is guilty by using this obsolete barrel, Europe is also guilty by writing billion (10^9 as with the SI billion is 10^{12}) of cubic meter as Gm^3, which is in fact a cubic gigameter, as km^2 is a square kilometer.

A cubic gigameter is 10^{27} m^3, about one million times the earth volume. In fact a billion of cubic meter is a cubic kilometer. But to order to write with the same symbol a billion of cubic meter and billion of ton (Gt), 10^9 m^3 could be written $G.m^3$

For those who write 10^9 m^3 = Gm^3 it means that km^2 is equals to 10^3 m^2 or 0.1 hectare!

1.2.4 Prefix

However the metric system (called SI International system of units is compulsory for federal agencies since 1993) the oil industry use M and MM for thousand and million when in the SI M is for million and G for billion. In the US newspapers there are many ads for computers and none is confused for MB (megabyte) for RAM memory and GB (gigabyte) for hard disk memory. Everyone has spoken about the Y2K (and not Y2M) bug, which by the way was a fake as the countries, which did not care to correct it, did not find it. The Mars climate explorer probe was lost because Nasa sent the instruction for thrust in newtons (SI) when Lockheed has built the probe to be in pounds.

1.2.5 Equivalence: 1MWh=0.2 toe or 0.08 toe?

The problem is that different energies can be compared as the necessary input (called primary energy) or as the resulting output (consumed energy). Heat can be in some cases the goal, but in other cases a nuisance that you have to be rid of. As most of electric plants have an efficiency of about 40%, the electric energy can be taken by some countries (and the WEC) as 1 MWh = 0.08 toe (ton oil equivalent) and by others (as France) as 1 MWh= 0.22 toe the definition of toe is about 42 GJ and as 1 MWh= 3.6 GJ = 3.6/42= 0.08 toe, but to produce 1 MWh of electricity 60 % of the oil energy is lost and 2.5 more oil or 0.08*2.5 =0.22 toe are needed.

In the WEC (World Energy Council) 2000 "Energy for tomorrow's world- acting now!" it is written page 175 after the table of conversion factors and energy equivalents: ""In this Statement the conversion convention is the same as that used in the previous report, namely that the generation of electricity from hydro (large and small scale), nuclear, and other renewables (wind, solar, geothermal, oceanic but excluding modern biomass), has a thermal efficiency of 38.46%. This convention, together with the use of the actual efficiencies (based on the low heating value) for plants using oil or oil products, natural gas or solid fuels (coal, lignite and biomass), guarantees a good comparability of primary energy. However, for the record, WEC has now adopted in all of its recent publications the new conversion convention used by the IEA. New renewables and hydro are assumed to have a 100% efficiency conversion, except for geothermal (10% efficiency). For nuclear plants (excluding breeders) the theoretical efficiency is 33%. For the sake of continuity with the previous report, these new conventions are not used in the Statement.""

In other words, what WEC did in the past is wrong, but for the sake of continuity WEC continue to do so. It is obvious that world's energy assessments are unreliable. Furthermore some primary energy assessments include the non-commercial biomass (for some countries over 40% of the consumption, but very hard to assess), when some others do not (it is simpler). In the BP Review 2000 the world's primary energy consumption (excluding biomass) for 1998 is given as 8 516.8 Mtoe (what accuracy!!), when the WEC gives 10 400 Mtoe (notice the round figures as they know that the accuracy is poor). This is typical of the discrepancy in energy. It is as manipulated as the GDP (with the hedonic factor)

2 Reports: what is published could be different from technical results!

2.1 Political versus technical data

Publishing data (usually single number by item) on a country or a company is a political act as it depends upon their image the author wants to give. Within the range of uncertainty he will choose the one which fits his goal, high if he wants to look big (quotas, DCQ (daily contractual quantity), stock market), low if he wants to look small (taxation).

The published data by Oil & Gas Journal (OGJ) is the basis of mainly other database as BP Review. The values come from an enquiry upon the national companies and agencies, but as it is published one or two weeks before the end of the year and the estimates are supposed to be for the end of the year, any serious national agency does not yet know the result as they need few weeks or months to do properly the work. It is why many countries do not reply and they are reported as no change as if the new discoveries during the year have compensated the production. For the last two studies published by OGJ,

OGJ Dec20, 1999	end	1999	change from 1998		change %	
	O Gb	G Tcf	O Gb	G Tcf	O	G
78 countries	659	4309	0	0	0	0
27 countries	357	836	-18,2	1,3	-4,9	0,2
total	1016	5146	-18,2	1,3	-1,8	0,03
OGJ Dec18, 2000	end	2000	change from 1999		change %	
	O Gb	G Tcf	O Gb	G Tcf	O	G
81 countries	586	4025	0	0	0	0
24 countries	442	1253	12,4	133	2,9	11,9
total	1028	5278	12,4	133	1,2	2,6

For the last result as end of 2000, a large majority of countries (for oil 77% in number and 57% in reserves) show no change: it is a joke! And OGJ does not correct these values later on, when World Oil (WO) waits six months to issue its values and corrects it the following year.

The problem is that to follow the US practice (for me a very poor practice to follow SEC rules to please the bankers) the reserves are reported as proved, neglecting the probable reserves when in the rest of the world gives proven plus probable. In particular in UK DTI gives a full range of values.

C.1 Estimated oil reserves on United Kingdom Continental Shelf

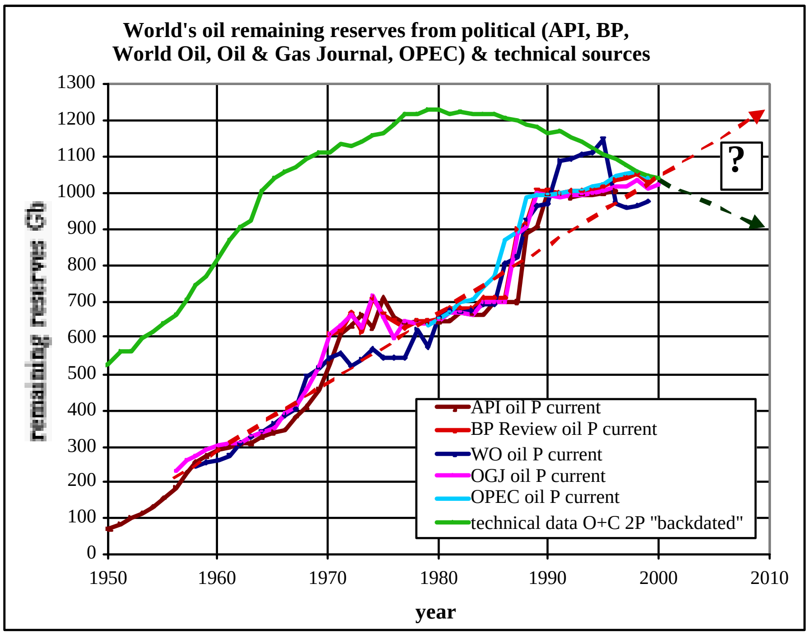
As at 31 December 1999	Million tonnes Oil reserves			
Initial recoverable oil reserves in present discoveries	Proven	Probable	Proven plus Probable	Possible
Fields in production or under development	3110	300	3410	350
Other significant discoveries not yet fully appraised	-	155	155	190
Total initial reserves in present discoveries	3110	455	3565	545

As the offshore UK cumulative production at end of 1999 is 2283 Mt (17.5 Gb), it means that the remaining offshore reserves are proven 827 Mt (6.2 Gb) and proven plus probable (2P) 1282 Mt (9.6 Gb). The difference in remaining reserves is about 50% between the conservative proven and the more realistic proven plus probable! OGJ reports 5.1 Gb for all UK.

In Norway the NPD reports one of the best classification for reserves and resources with 10 classes, but reserves are only for developed or approved development fields with only one value (mean) for each field, all other discoveries hold only resources. At end of 1999 the oil reserves were 3508 M.m3 with 2006 already produced (1502 M.m3 remaining = 9.5 Gb), and the resources are 173 M.m3 (1.1 Gb) in fields and 396 M.m3 (2.5 Gb) in discoveries. OGJ reports 10.8 Gb.

So between the use of proved reserves for most of reported reserves and the political reports from OPEC companies, it is obvious in the following graph that there are two kinds of figures. The political ones reported by OGJ, WO, BP Review, API (American Petroleum Institute), OPEC and the technical ones existing only in confidential database for the world. The technical values of past discoveries have to be « mean » value (close to the proven + probable) and using present estimates, it means that the present estimates have to be backdated to the year of discovery. The technical values shown in the following figure is a compilation of several sources, that I have corrected them to be homogenous in proven+probable and backdated to the real discovery year (South Pars in Iran, extension of North Field in Qatar was recorded discovered in 1991 when since 1971 this extension was known to everyone)

Figure 2:

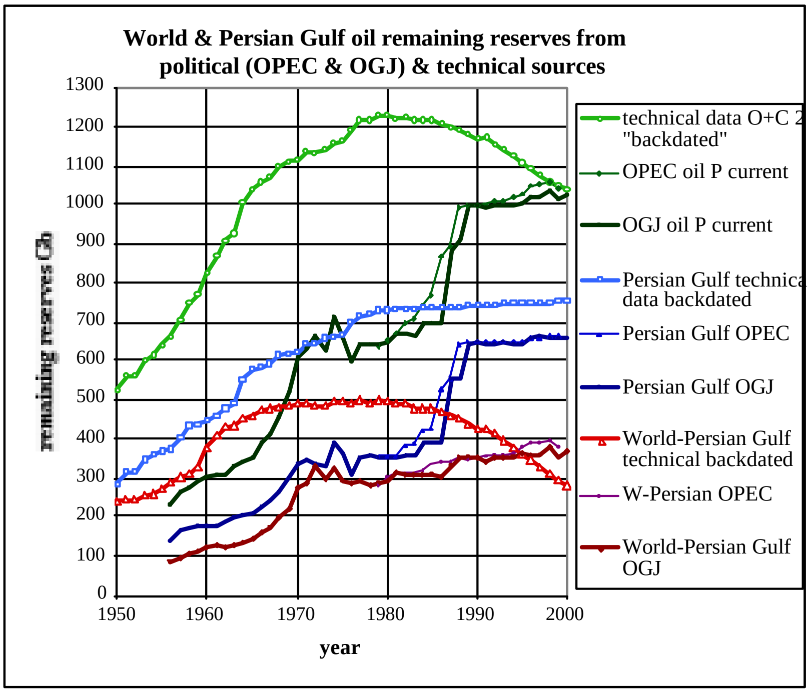


The world's remaining reserves as given by the political sources shows first a huge jump around 1986 when the OPEC quotas started to be effective to share the market between the swing producers. These swing producers, Saudi Arabia, Kuwait, Iran, Iraq, Abu Dhabi increased their reserves as Venezuela by more than 300 Gb from 1985 and 1990 without any significant discoveries to justify those increases. Since 1950 the trend is a continuous rise even if it is by levels. By contrast, the technical reserves (2P+ proven+probable) shows a peak around 1980 and a continuous decline since.

From the published data, the economists could expect at least 1200 Gb as remaining reserves in 2010, when from the technical data the realists could expect only 900 Gb.

The breakdown into the Persian Gulf (swing producers) and the rest of the world (non-swingers or producing at full capacity) in the following graph shows that the Persian Gulf remaining reserves are levelling since 1980 on technical data and increasing sharply around 1987 on political data. For the rest of the world, the remaining reserves decrease since 1980 with a steeper decline on the last decade on technical data and slightly rising since 1970 on political data.

Figure 3:



The technical data are usually confidential as they belongs to the owner of the concession, but operators on federal lands are obliged to release their data after a certain time. In the US Gulf of Mexico OCS (outer continental shelf) the USDOI MMS (Mineral Management Services) publishes the detail of the near 1000 fields. It is a mine of interesting and modern data, but unfortunately MMS does not bother to check the data, as in a significant percentage of fields, some year the cumulative production decreases as if it is possible to have a negative annual production!

The USDOE/EIA (Energy Information Agency) is the best place in the world to get detailed, homogeneous and on long period data on energy for the US but also worldwide. I thank them as I use them very often.

2.2 False accuracy

Most of readers believe that a data with many decimals should be right. In the oil industry as accuracy on global data is around 10%, any author giving more than 3 significant digits shows that he is incompetent in assessing accuracy and in probability. Usually when more than 3 decimal digits are used, it is likely that the first digit is wrong.

For proved remaining oil reserves at end of 1999

Oil & Gas Journal 1 016 041.221 Mb

World Oil 978 868.2 Mb

BP Review 1 033.8 Gb

Furthermore this world total is supposed to be proved reserves (probability of 90% following SPE/WPC rules) and the sum of the country proved reserves is not the world proved reserves. It is unlikely that this conservative value will occur in every country. The sum is underestimating the world proved reserves, as it is incorrect to aggregate them, only the sum of country (or field) « mean » reserves represents the « mean » reserves of the world (or a basin).

It is ridiculous to see ultimates, which are largely uncertain, given as 3003 Gb for the USGS. In this matter a maximum of two significant digits should be given as 3 Tb. In the franc to euro conversion on January 1st 2002 the rate 1 euro = 6,55957 FF is also ridiculous, as centime does not exist in France (only 5 c), the 3 last decimals concern virtual money!

The UN announced that the world's population has reached 6 billions on Oct..12, 1999, but the world's population is known with an accuracy of about 150 million -the accuracy of census is reported 0.5% in France, 2% in China and 20% in Nigeria (in 1990 the UN estimated Nigeria at 122 M when the census gave 88 M!)-

In summary, any conclusion based on the political data is unreliable and only conclusions from the technical data have to be considered.

3 Assessments

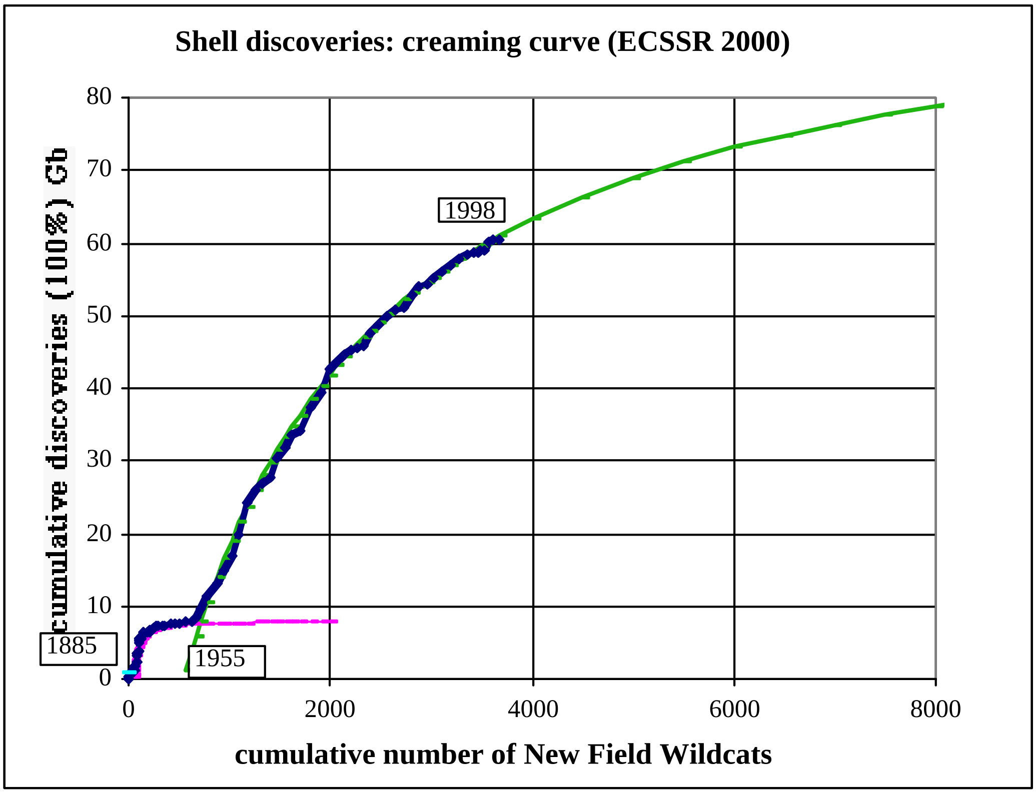
3.1 Creaming curves: cumulative discoveries in volume versus cumulative number of new field wildcats.

The most efficient way to consider the result of past exploration in a country or in a oil basin is to plot the cumulative discoveries (in number and volume) versus exploration activity as versus time reflects the stop and go of the exploration. UKOOA used it in 1997 to assess the UK offshore ultimate.

Shell was the first company to introduce the concept of creaming curve. It is interesting to display the cumulative discoveries made by Shell (at 100%, as there are often partners) versus the cumulative number of new field wildcats (NFW). As the definition of exploratory wells varies with country and include many appraisal wells it is necessary to consider only the new field wildcats much better defined and more representative of the search for new discoveries.

Most of creaming curves display the typical diminishing return (decreasing slope) of most mineral exploration. The large fields are found first as they cover huge areas and could be found by luck (as East Texas oilfield) and as the largest structures are drilled first. The simplest model is a hyperbola curve. But most of times the efficiency changes with technology and new basins and the plot displays several hyperbolas as shown by the Shell creaming curve.

Figure 4:



From 1885 (first discovery) to 1955 (over 600 NFW and 8.5 Gb discovered) the discoveries follows an small hyperbola with an asymptote of 9 Gb, but new techniques (CDP seismics and digital recording which were a much larger progress than 3D)) and new areas started a much more efficient new cycle which follows a near perfect hyperbola with an asymptote of 100 Gb. But the asymptote takes a long time to be approached and in 1998 after 3700 NFW (and more than 110 years) and 60 Gb discovered, the model shows that doubling the present number of NFW will bring only an addition of 20 Gb compared at 60 Gb in the past.

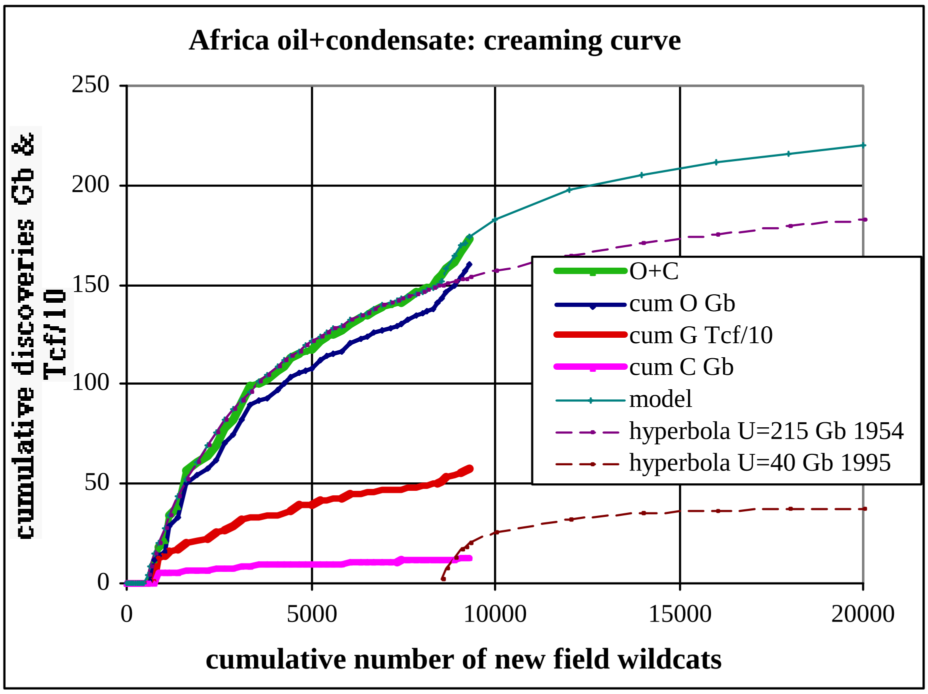
It is dangerous to take an asymptote as an ultimate. The ultimate should correspond to the end of oil production, it means no more than a century as when production declines drastically, exploration is stopped even if there are still marginal fields to be discovered. It is wise to speak of an ultimate covering the production until 2050 or 2100 at the most, but not beyond.

Creaming curves are an efficient way to assess the ultimate of a Petroleum System (defined by the source-rock which generates the oil concentrated in the fields) when combined interactively with a size-rank fractal display model with a parabola (Laherrere 1996, 1999).

The creaming curves for oil+condensate of the 6 continents (Africa, Asia, Europe, FSU, Middle East, Latin America) are a quick way to asses the potential of the world outside US + Canada.

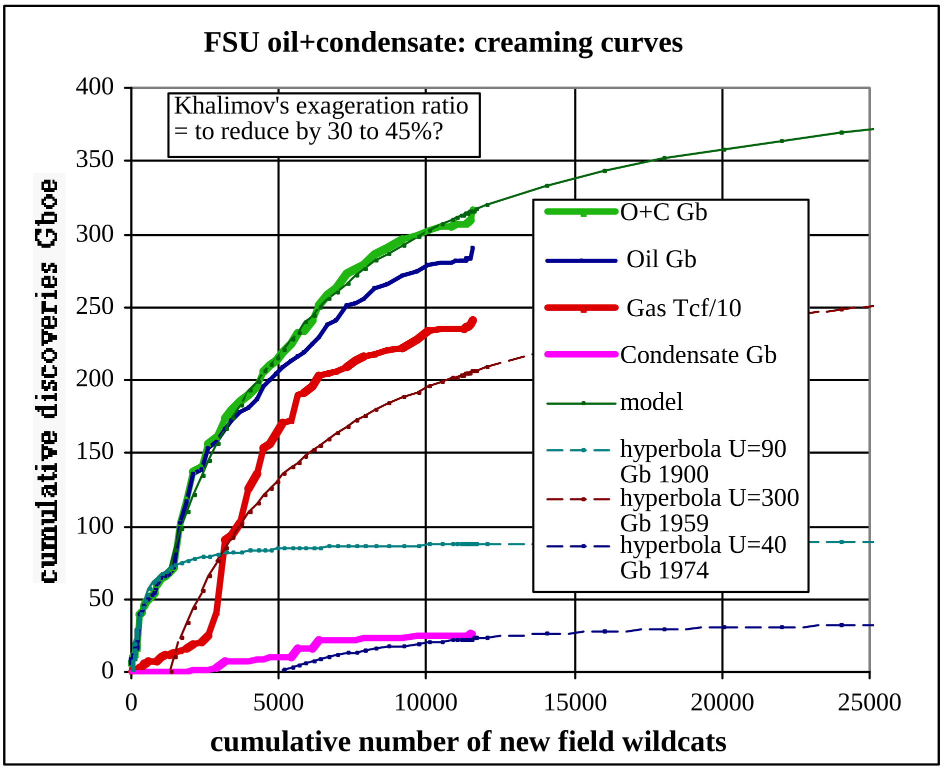
Africa creaming curve for oil + condensate displays two hyperbolic curves as a new curve occurs around 1995 with the deepwater and the Saharan new Berkine play. In 2000 with about 9000 NFW 170 Gb have been found and 220 Gb could be expected when 20 000 NFW are drilled.

Figure 5:



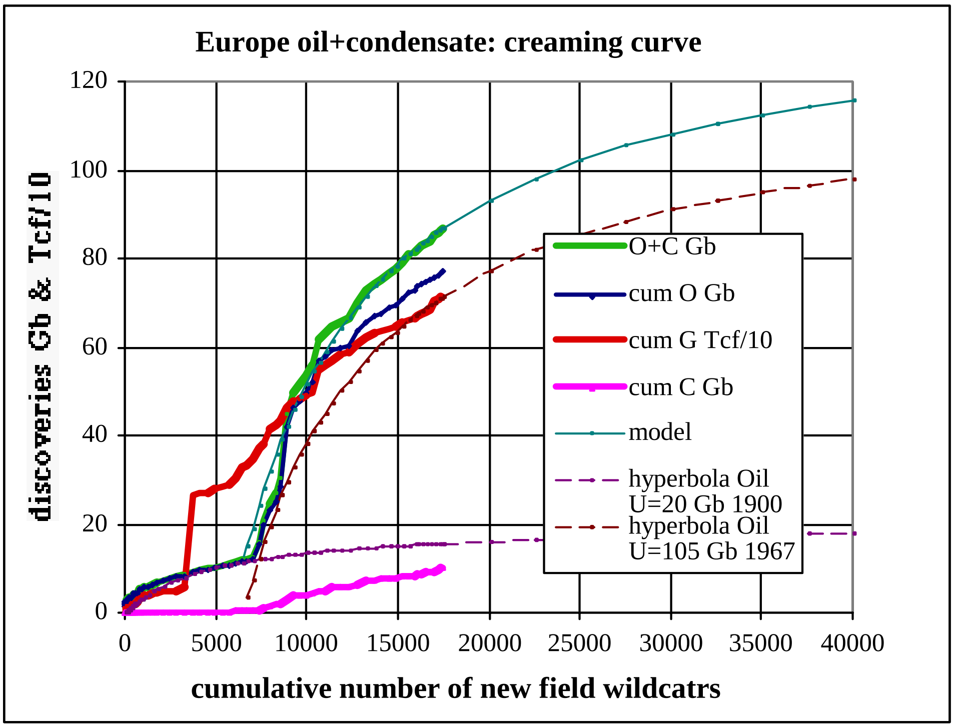
For FSU the creaming curve can be modelled with three hyperbolas, the second one starting in 1959 and the third one in 1974. In 2000 with 12 000 NFW 310 has been found and with 25000 NFW, 370 Gb could be expected. But we will see later the FSU reserves, which have been estimated with a Russian classification (presented by Khalimov in 1979 WPC), are now described by the same Khalimov (1993) as grossly exaggerated.

Figure 6:



Europe creaming curve can be modelled with two hyperbolas, the second one starting in 1967 with the offshore exploration.

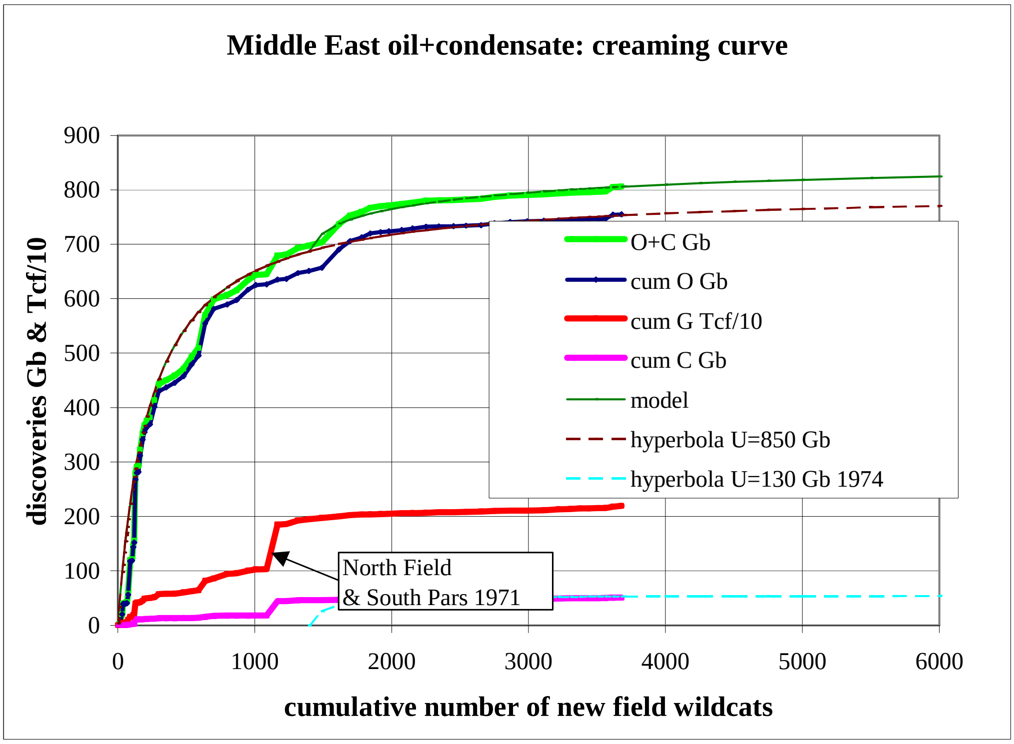
Figure 7:



In 2000 with 17 500 NFW, 87 Gb has been found and with 35 000 NFW 115 Gb could be expected.

In Middle East creaming curve could be modelled with two hyperbolas, the last one starting in 1974. In 2000 with 3700 NFW 800 Gb has been found and with 6000 NFW 820 Gb could be expected. We believe that the potential for undiscovered natural gas is much higher than for oil.

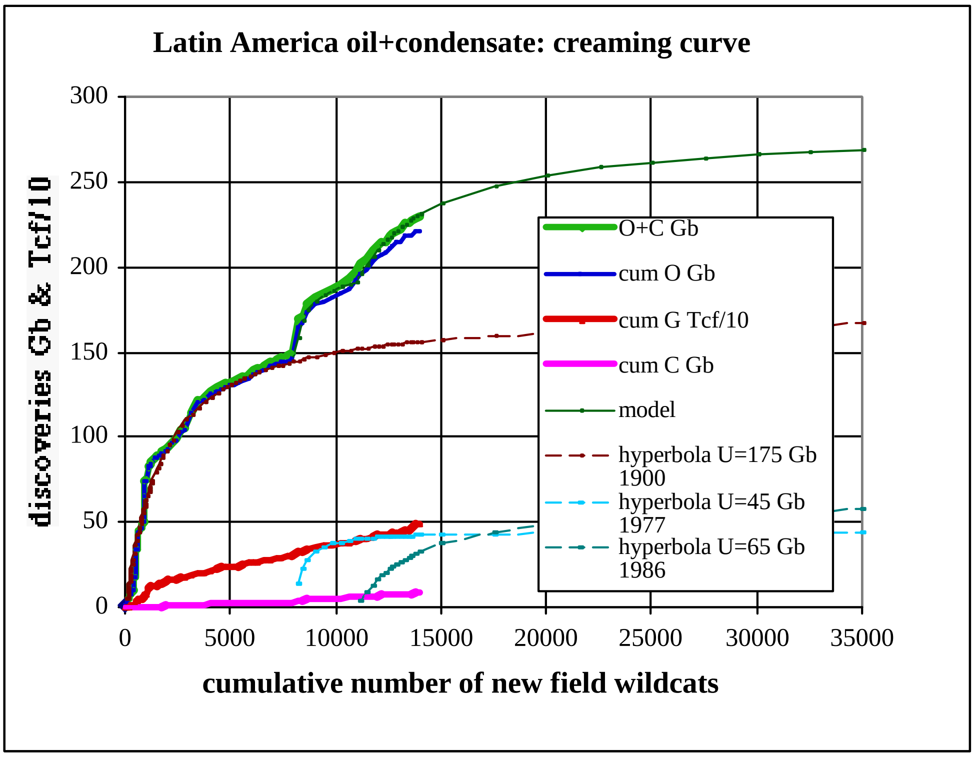
Figure 8:



For Latin American three hyperbolas are needed, starting in 1900, 1977 and 1986.

In 2000 with 14 000 NFW 230 Gb have been found and with 35 000 NFW 270 Gb could be expected.

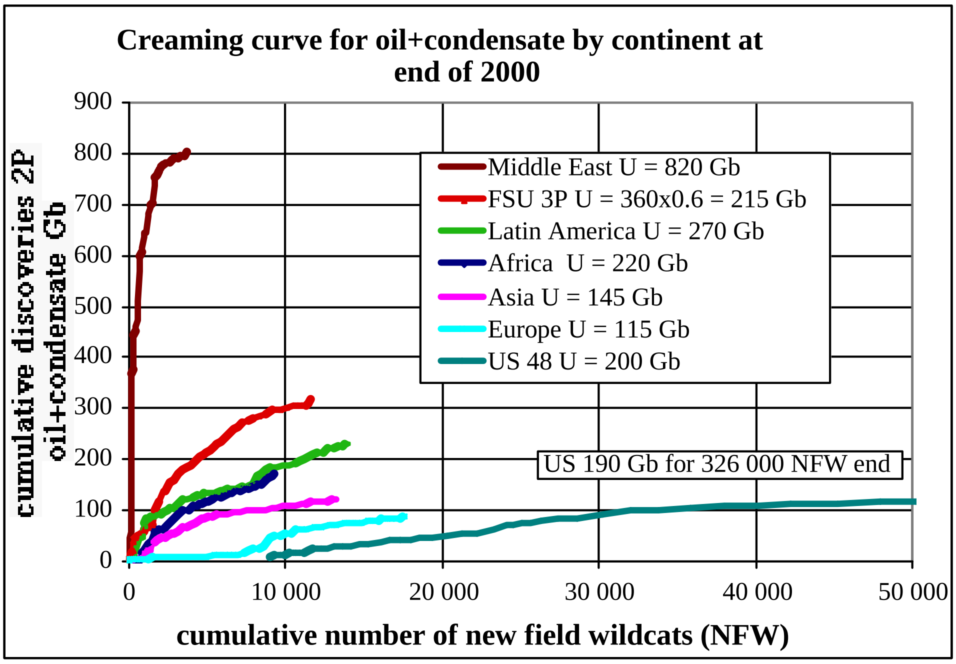
Figure 9:



The creaming curve of the US needs to use proven+probable (or "mean") values and not the published proved values. A USDOE/EIA report 90-534 gives the annual discovery estimated in 1988 (this later estimate is much better than the current estimate), to obtain a "mean" value, we use the reserve growth model of MMS (ultimate recovery is 4.5 times the estimate at discovery year) to grow these values (up to 1988) and the new discoveries of annual reports (from 1989 to 1999). The US curve can be modelled with one hyperbola. In 2000 with 330 000 NFW 190 Gb have been found and doubling the number will reach only a little over 200 Gb.

The plot of the creaming curve of the 6 continents plus the US shows a huge difference between the Middle East and the rest, between the cluster with FSU, Latin America, Africa and Asia and Europe and the very flat curve of the US.

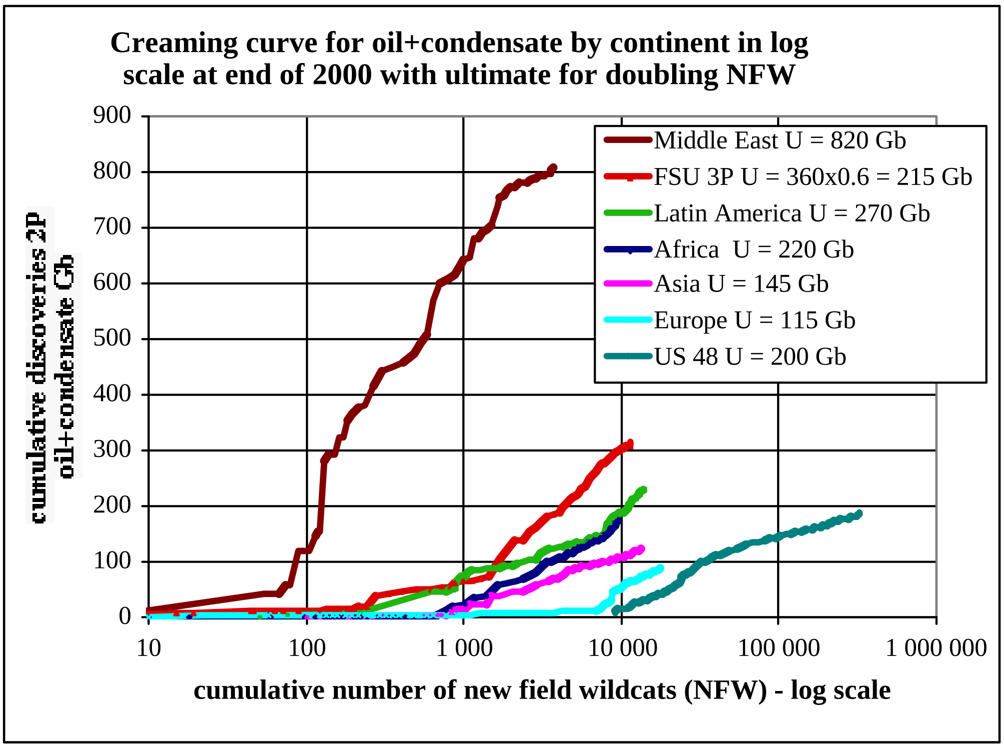
Figure 10:



The same graph with the cumulative number of NFW in log scale shows better this huge range and in the legend there is the ultimate of each continent for doubling the number of NFW.

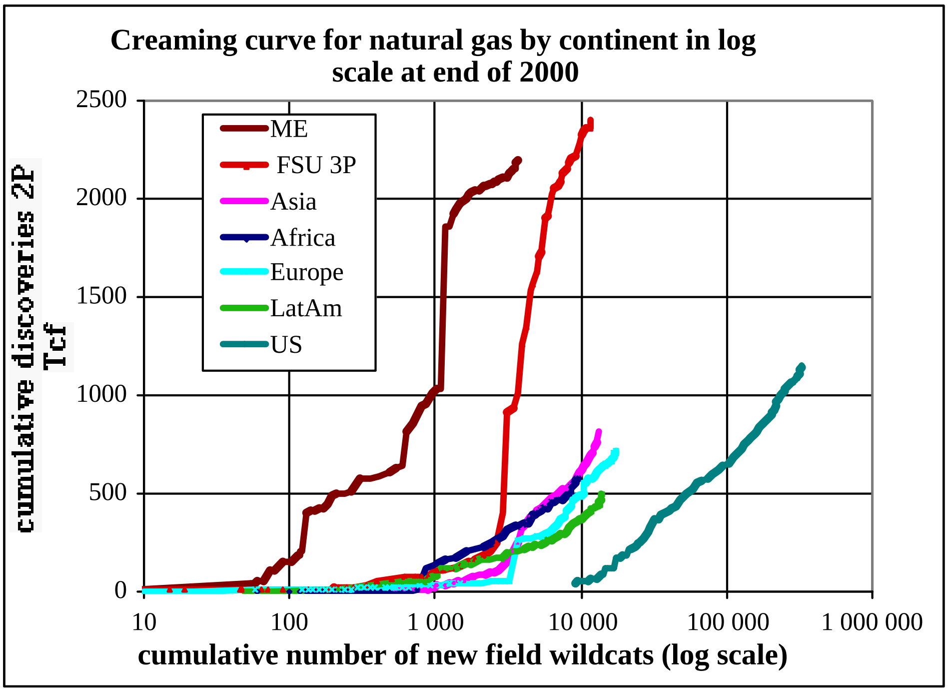
continent	ultimate O+C Gb
Middle East	820
Latin America	270
US +Canada	250
Africa	220
FSU	215
Asia	145
Europe	115
World	2000

Figure 11:



It is interesting to see the same display (log scale for NFW) for natural gas.

Figure 12:



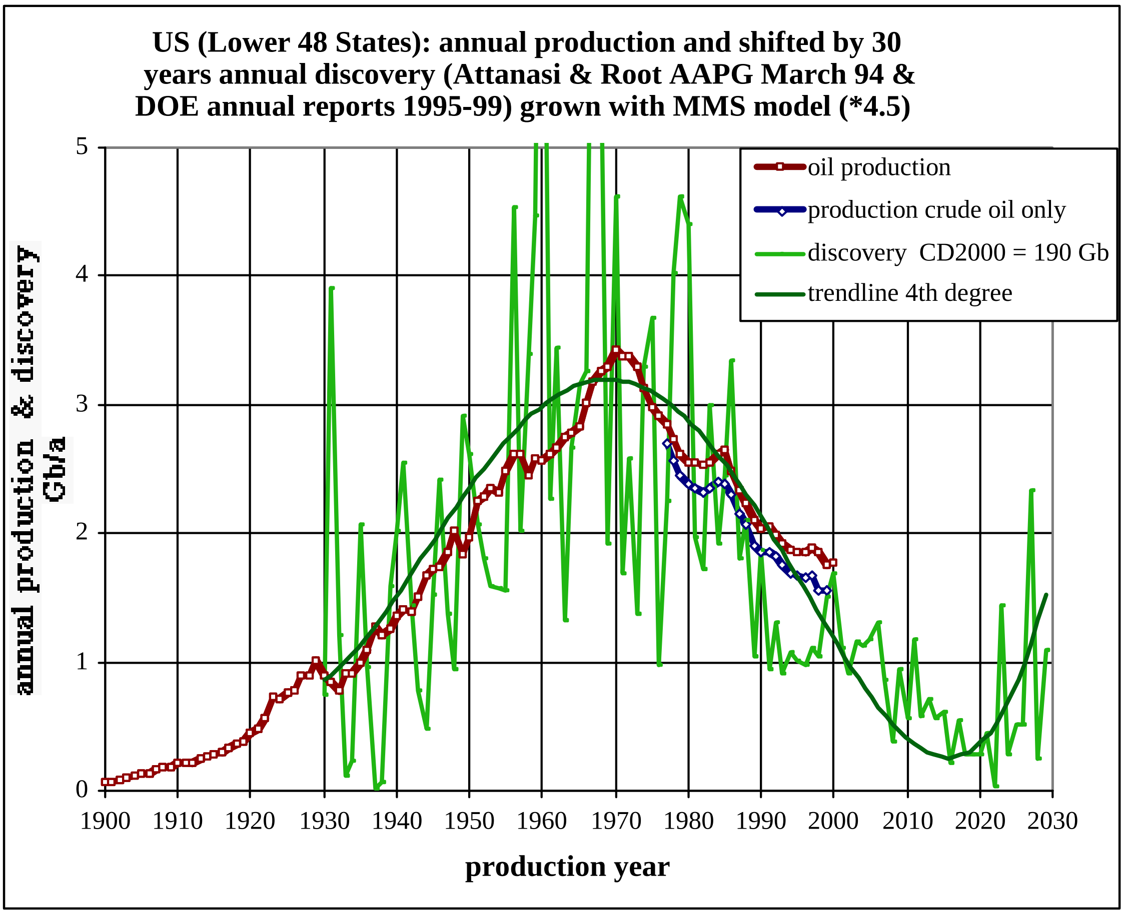
The Middle East competes with FSU to be the richest gas area. Asia, Europe, Africa and Latin America are similar and the US is far away wit a similar slope

3.2 Correlation annual discovery and annual production:

Few people outside the oil business realise that to produce oil, you have to find it first. King Hubbert was the geologist-geophysicist who introduced the hydrodynamic concept for trapping hydrocarbons, but also the production cycle (bell-shaped) following the discovery cycle with a certain lag. He was considered as a fool when in 1956 he forecasted that the US oil production would peak in 1970. About the same time, the USGS opposed a US oil ultimate of 590 Gb against Hubbert 200 Gb.

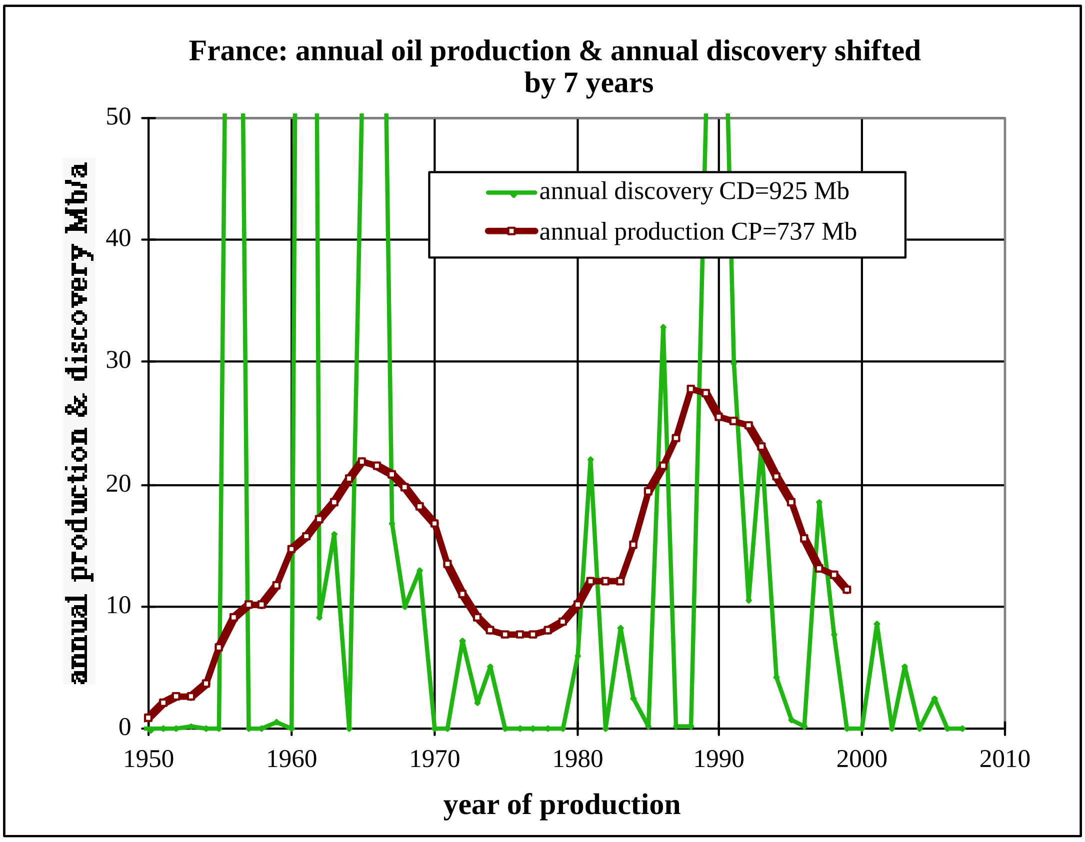
Using my file of proven+probable discovery (Attanasi & Root AAPG March 94 (from USDOE 90-534) + annual EIA reports) grown with MMS reserve growth model the US Lower 48 states annual discovery is correlated with the annual production. The fit in time for the global shape is found for a shift of 30 years and it is amazing to see that the 4th degree trendline of the shifted discovery is very close to the annual production. It is not necessary to draw any Hubbert model (derivative of the logistic curve or a Gauss (normal) curve); the shifted part of the discovery plot gives a forecast for the next 30 years. The part corresponding to the last 5 years shows a rise, due in part by the deepwater discoveries but mainly by the MMS multiplier that is too high as deepwater discoveries are much better estimated than in the past for shallow water. In the chapter later on reserve growth, we will try to demonstrate it.

Figure 13:



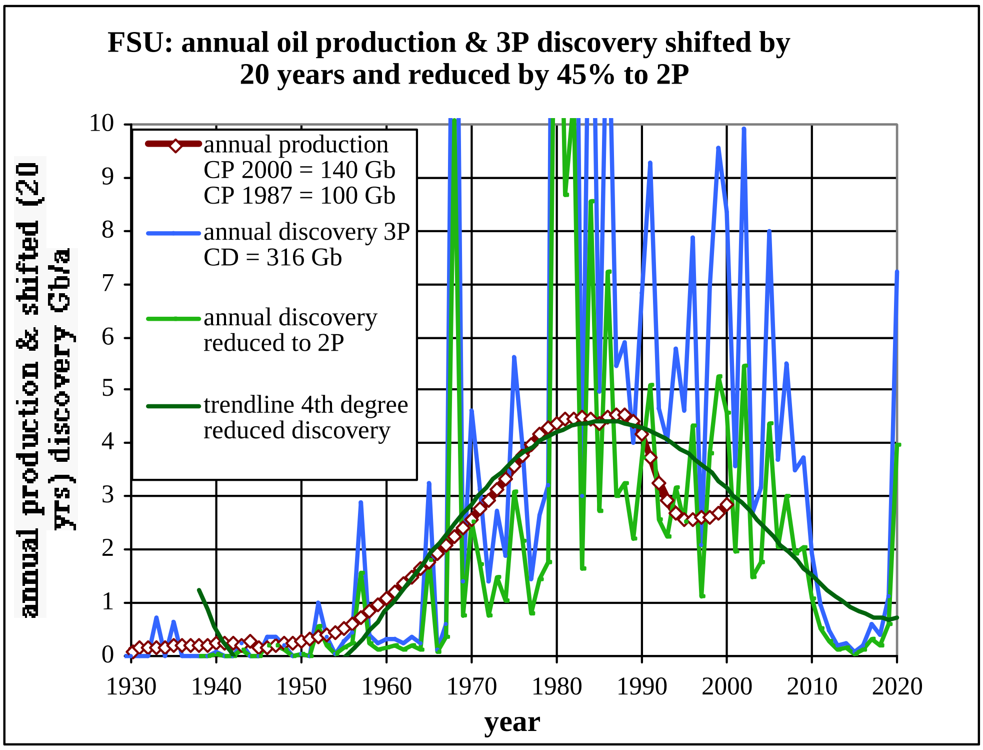
Most of the times annual discovery displays several cycles, in the US there is a different cycle with Alaska. France is a good example of two cycles (as UK or Netherlands), but the shift is much shorter than in US, it is around 7 years. In fact it is about 10 years for the first cycle and 5 years for the second cycle. The low value period in time (15 years) between the two cycles is about the same in discovery and production.

Figure 14:



FSU being as the US 48 a large country with many oil basins has an annual discovery pattern as a bell-shaped curve. The fit in time between the annual discovery and annual production is about 20 years but the 4th degree trendline of discovery does not fit with the production curve. But the Russian classification corresponds to proven +probable+possible (or 3P) as reserve estimates were made using the maximum theoretical recovery factor, neglecting economy and technology, as quoted by Khalimov (1993). The fit is good when the 3P annual discovery is reduced by 45% from 1950 to 1990 to correspond to 2P values. During 1990 to 2000 the breakdown of the FSU has disturbed the fit. But now the present production is in line with the discovery.

Figure 15:

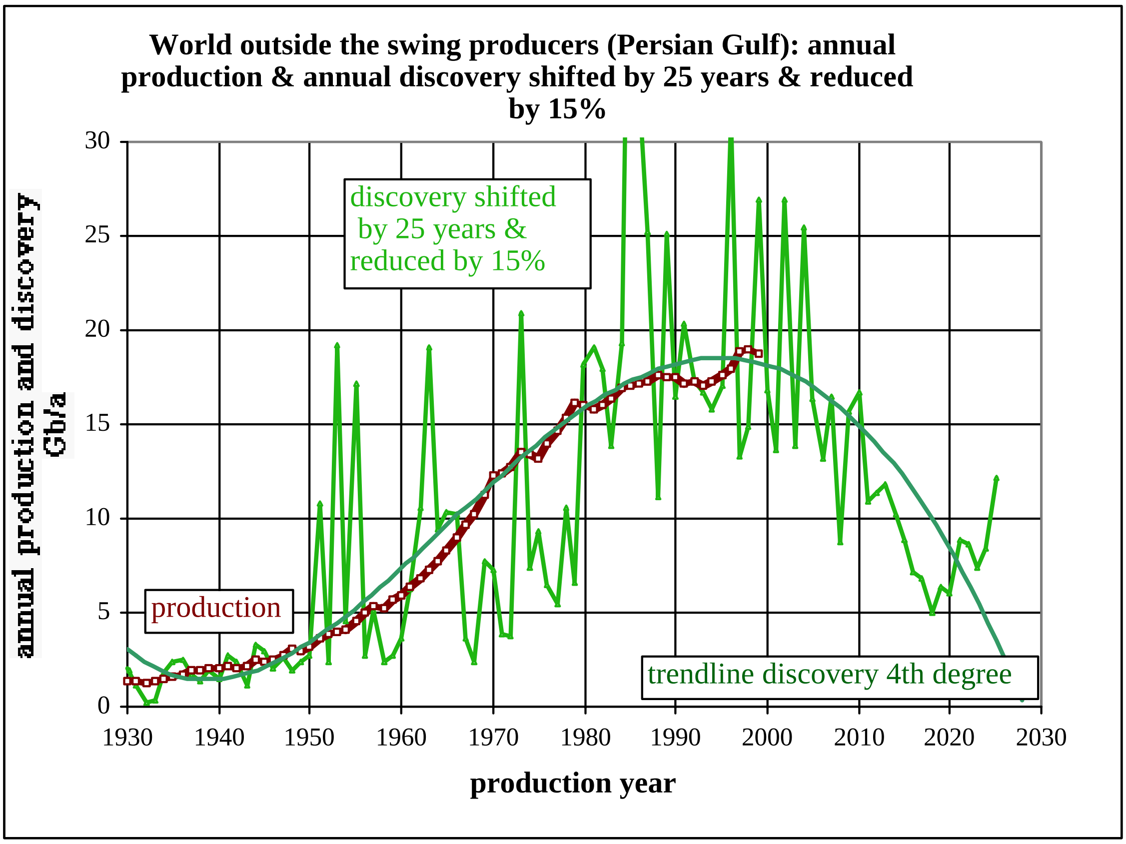


The correlation between discovery and production is reliable only in countries where production is not constrained by politics, so it could not apply to the Persian Gulf countries.

The correlation for the world outside the Persian Gulf between discovery and production is more difficult as the production has not yet peaked in contrary to the previous examples.

But correlating only the rising slope gives a shift of about 25 years and to get a fit in Gb/a it is necessary to reduce the discovery value by 15% (to take care of the overestimated FSU and others). This display shows clearly that the non-swingers countries are going to peak soon and that the drop from now to 2020 could be around 8 Gb/a or 20 Mb/d. A drastic drop difficult to be filled by the Persian Gulf.

Figure 16:

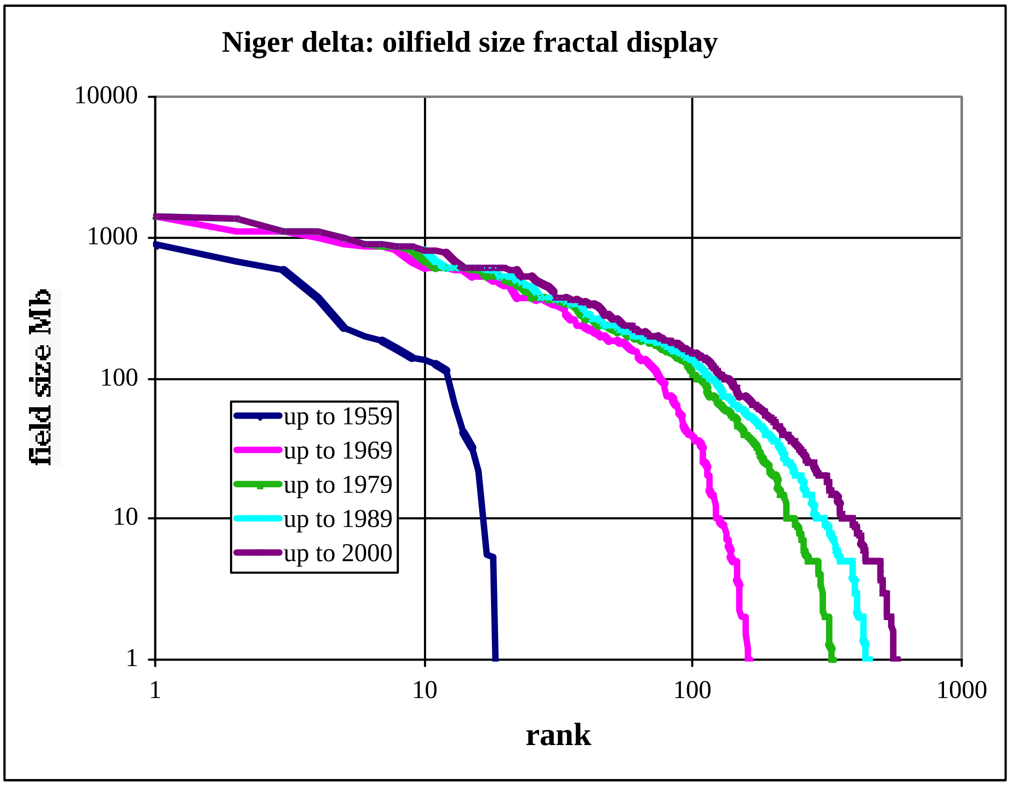


The WEC 2000 “Energy for tomorrow’s world –Acting Now » has already shown (page 80 & 81) my graphs of US and world outside the swing producers discovery-production, but the above graphs are updated to 2001.

3.3 Parabolic fractal display:

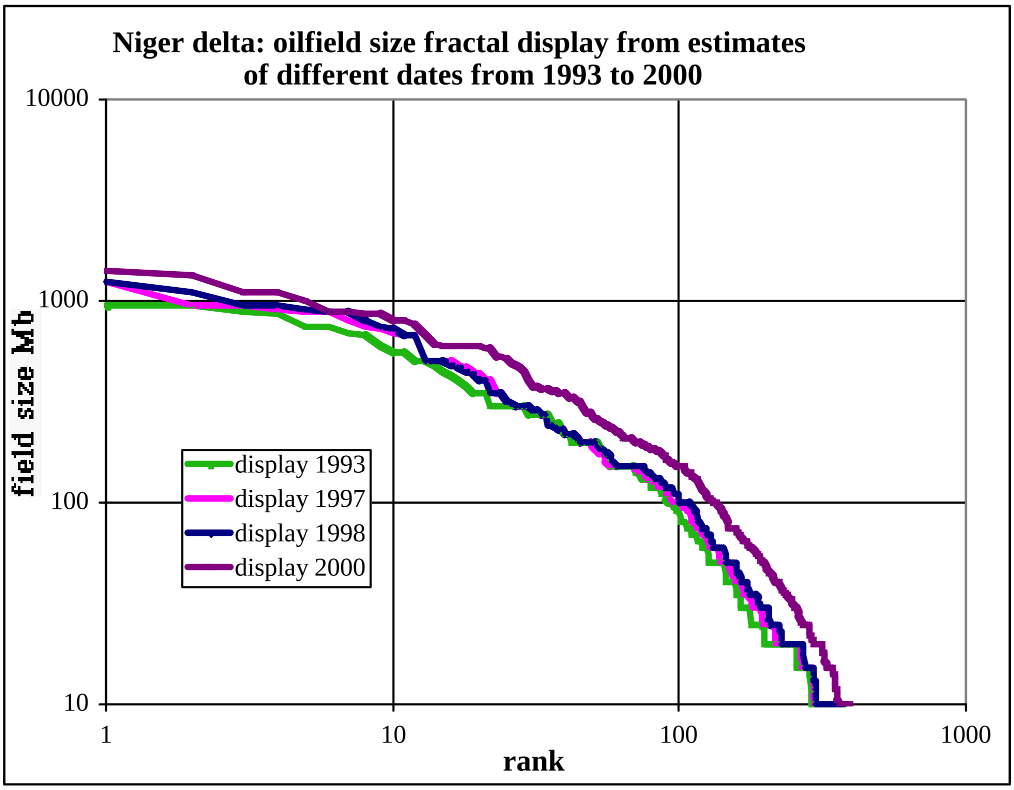
One of the best displays is the fractal distribution of field size-rank in a log-log format. When the distribution is natural as it is in a Petroleum System the fractal displays follow a curve (and not a straight line (or power law) as claimed by Mandelbrot) (Laherrere 1996, 1999). This parabolic fractal is found for urban agglomerations, earthquake (the Ritcher-Gutenberg, power law, is a rough approximation), galaxies, species, . A fractal distribution corresponds to auto-similarity, quite frequent in nature, but as auto-similarity is not perfect, the fractal is not linear, but curved.

Figure 17:



The parabolic fractal display of the Niger delta Petroleum System has just shifted in parallel from 1993 to 2000. Revisions and new discoveries do not change the distribution, it increases globally the reserves.

Figure 18:



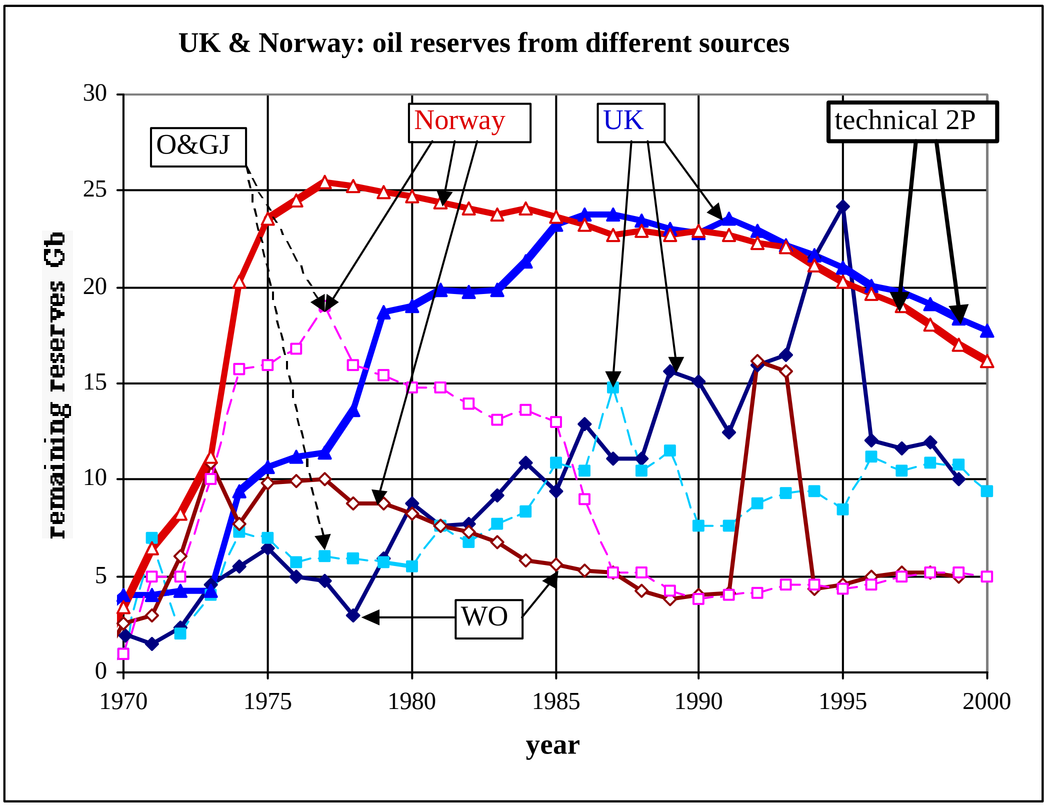
4 Examples of reserve & production data from countries

It is interesting to study few countries to see the problems and what to expect from these countries. Examples of field oil decline (annual production versus cumulative production) are shown to see the difference between scout value and decline estimate (the value of the estimate varies from questionable to good with the quality of the slope).

4.1 North Sea: UK & Norway

The reported political values for the remaining reserves of UK and Norway are a mess as it can be seen on the figure 19. The technical values show a similar value for both countries since the last 15 years, being 17 Gb (2P) in 2000 and it is not surprising that the production are now similar about 3 Mb/d when the value from OGJ and WO gives 5 Gb for UK (they take the low range) and 10 Gb for Norway (there is only the mean value for developed fields).

Figure 19:

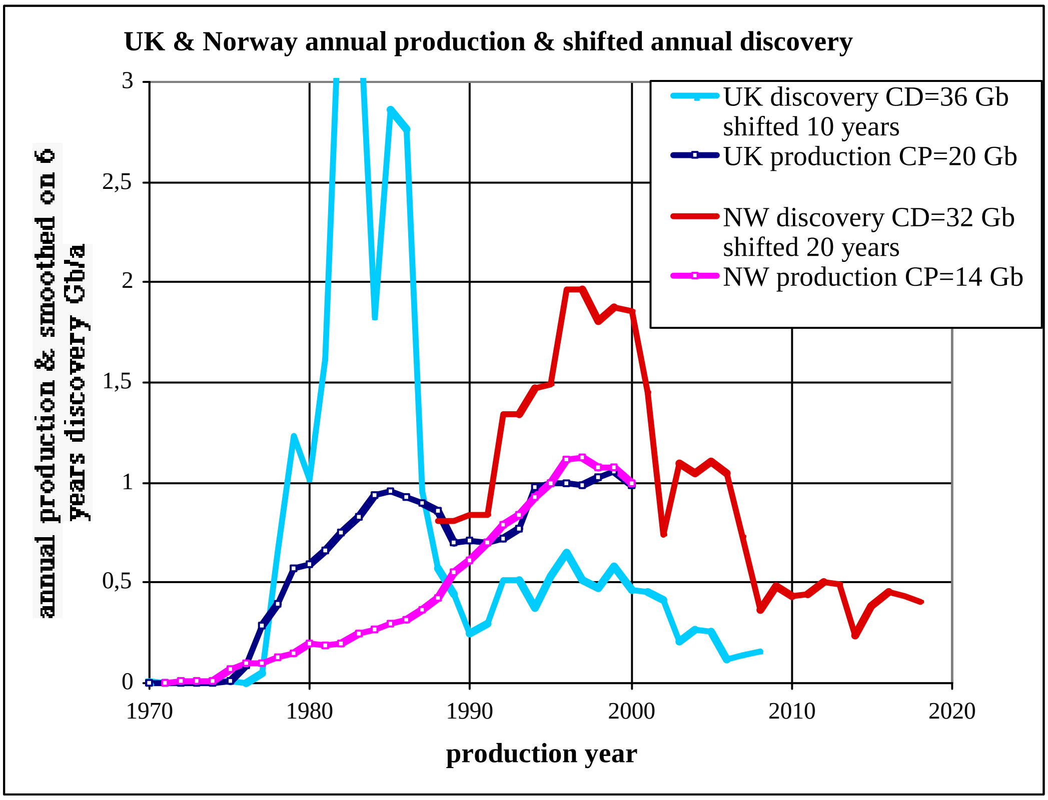


Looking at the status of the UK and Norway, the proven+probable values for oil +condensate and the number of oilfields are as follows:

Status 2001	UK	UK	UK	UK	NW	NW	NW	NW
	O+C Gb	nb	% Gb	% nb	O+C Gb	nb	% Gb	% nb
developed	31,7	276	89	52	26,3	64	83	33
undeveloped	3,9	254	11	48	5,3	128	17	67
Total	35,6	530	100	100	31,6	192	100	100

In UK only 52% of the discoveries are developed representing 89% of the reserves. In Norway, only 33% of the discoveries are developed representing 83% of the reserves.

Figure 20:



The oil decline of Forties is easy to extrapolate. The Brown Book agrees with the decline.

Figure 21:

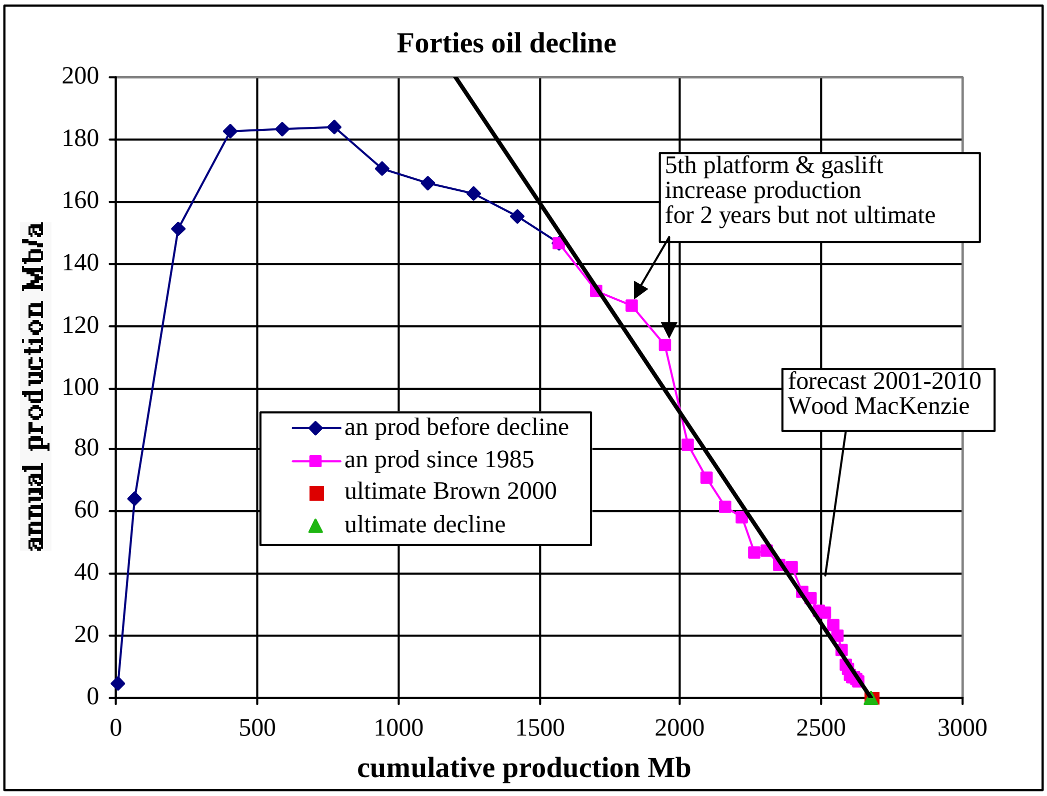
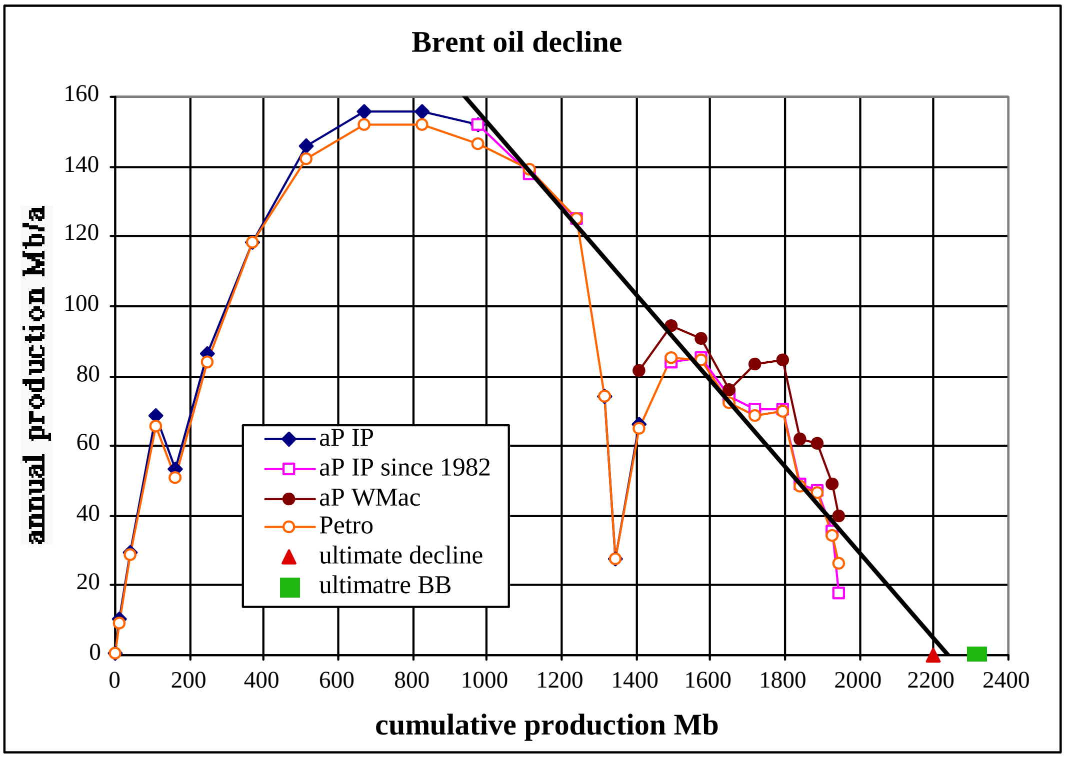


Figure 22:



Brent oilfield decline estimate is not as easy as data varies from sources and production was stopped for repairs. The ultimate could be smaller.

4.2 Venezuela

Venezuela has a low reserves where operated by the international companies (not to appear too rich) and there is a lot of heavy oil. The Orinoco extra-heavy oils are not yet included in the oil reserves (reserves correspond to developed field).

Figure 23:

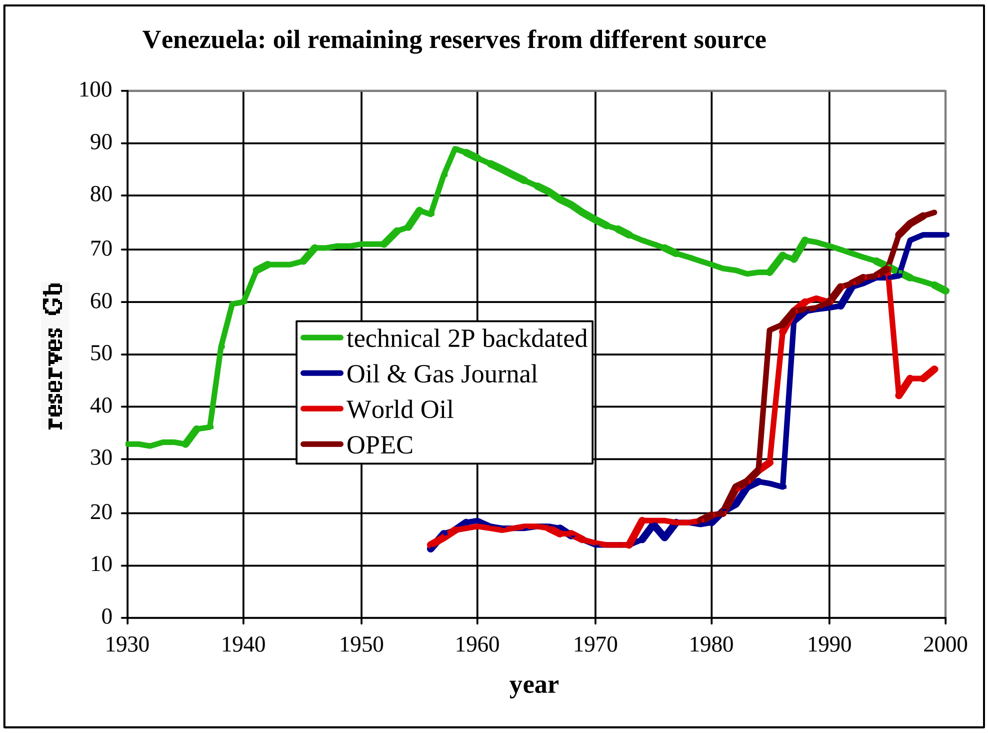
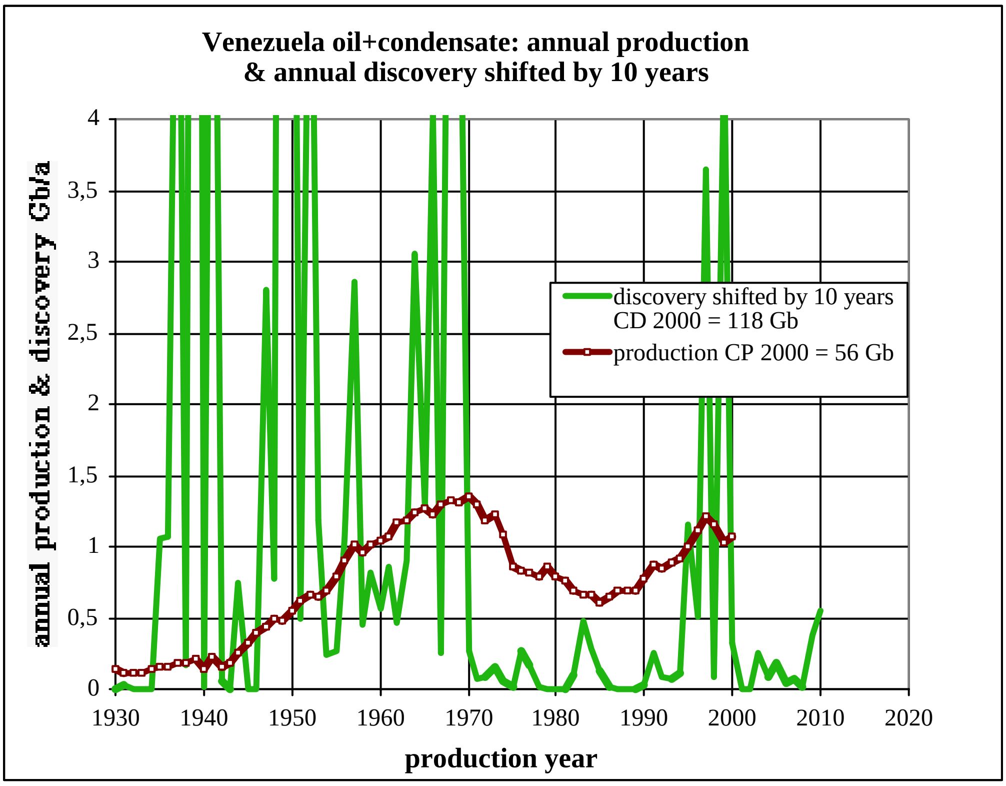


Figure 24:



4.3 Mexico

Interesting case of large negative growth (20 Gb) from World Oil and OGJ (after the Mexican financial crisis is solved) in 1998, as the reserves were overestimated.

Figure 25:

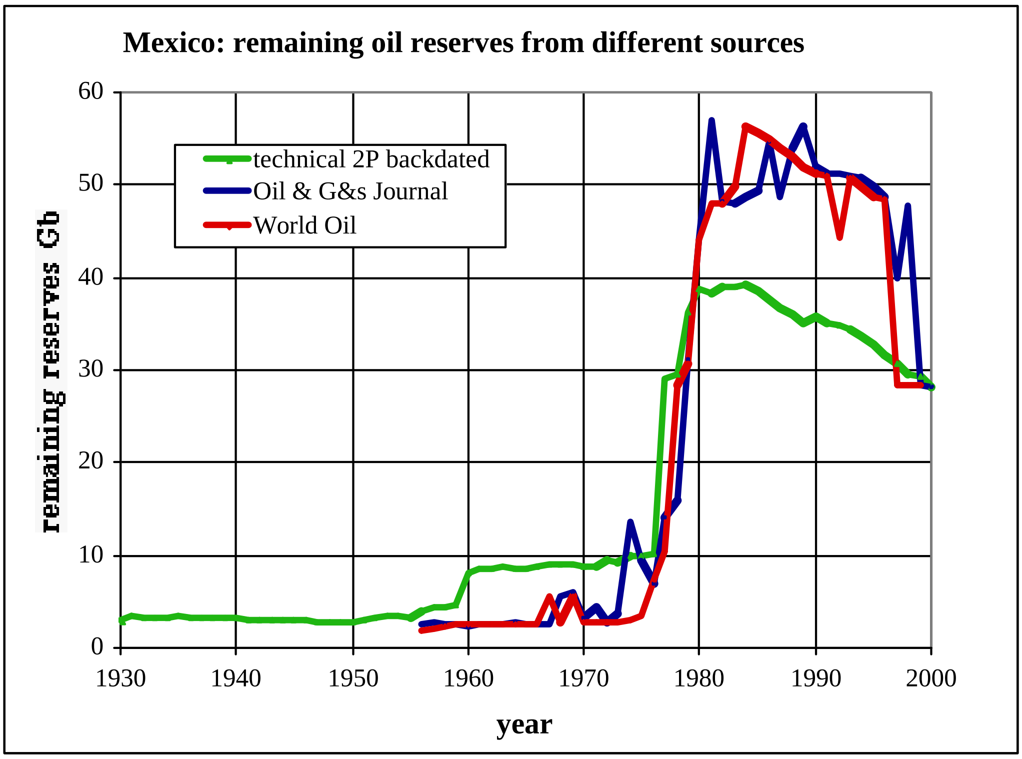
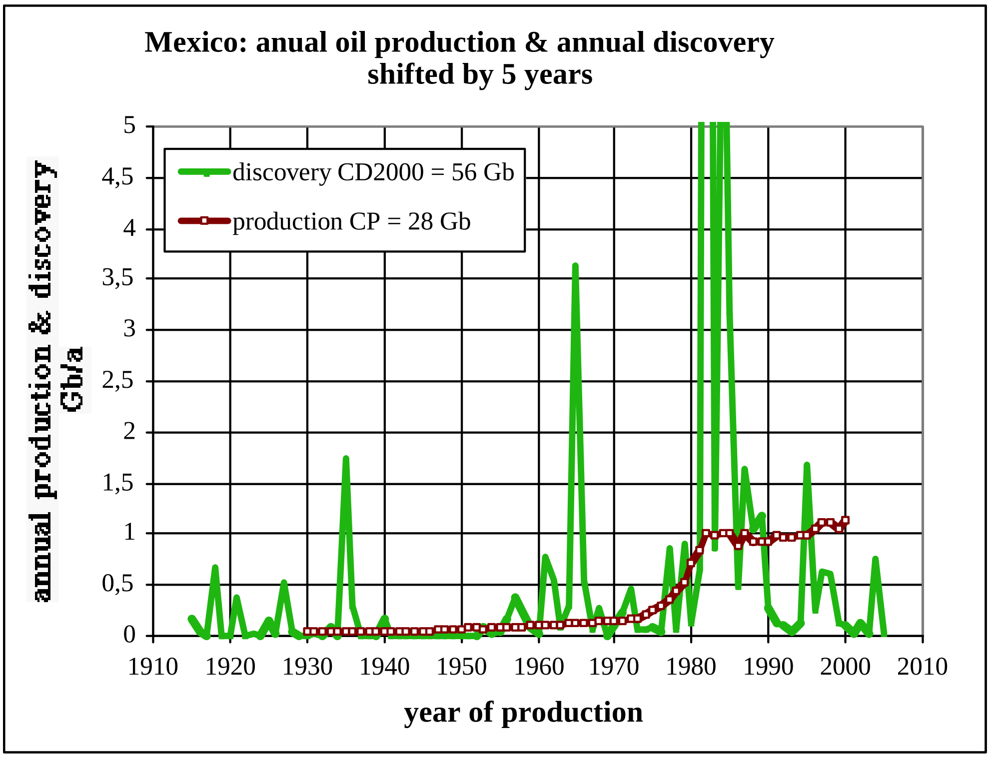


Figure 26:



The largest field Cantarell is not yet on decline with EOR investments. But most other fields are on decline.

Figure 27:

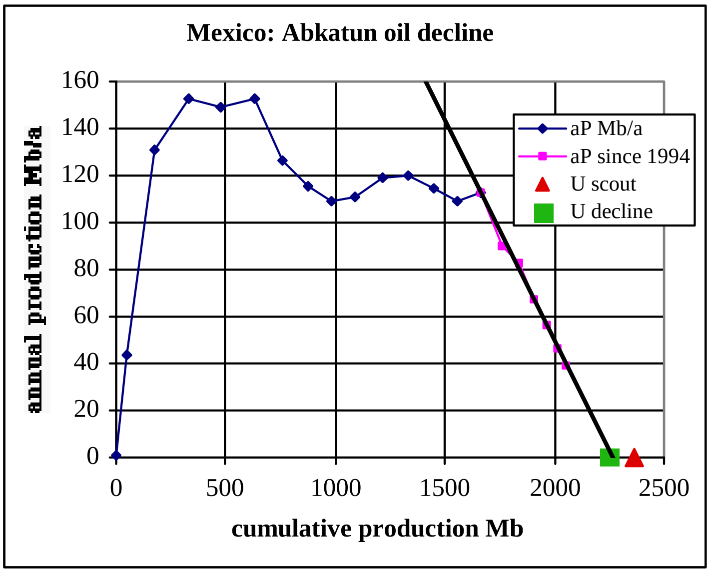


Figure 28:

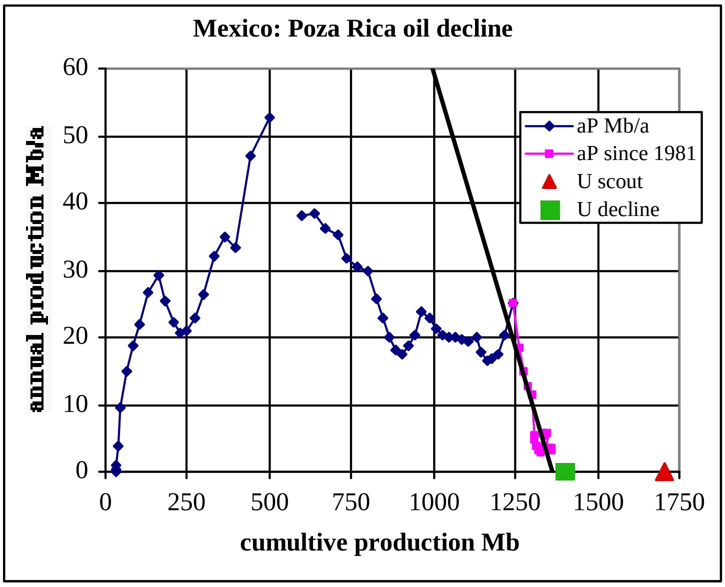
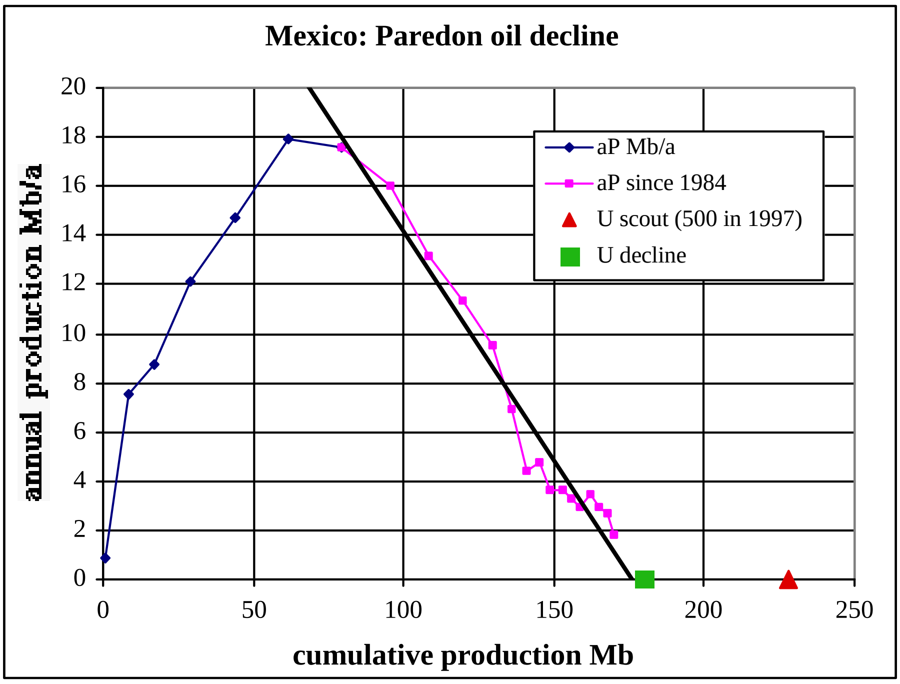


Figure 29:



4.4 Colombia

The exploration went through several cycles because of geology but also civil wars. The last large discovery was overestimated when discovered (press release by Triton for the stock market at 3 Gb when it was estimated 1.5 Gb by BP and 1 Gb by Total).

Figure 30:

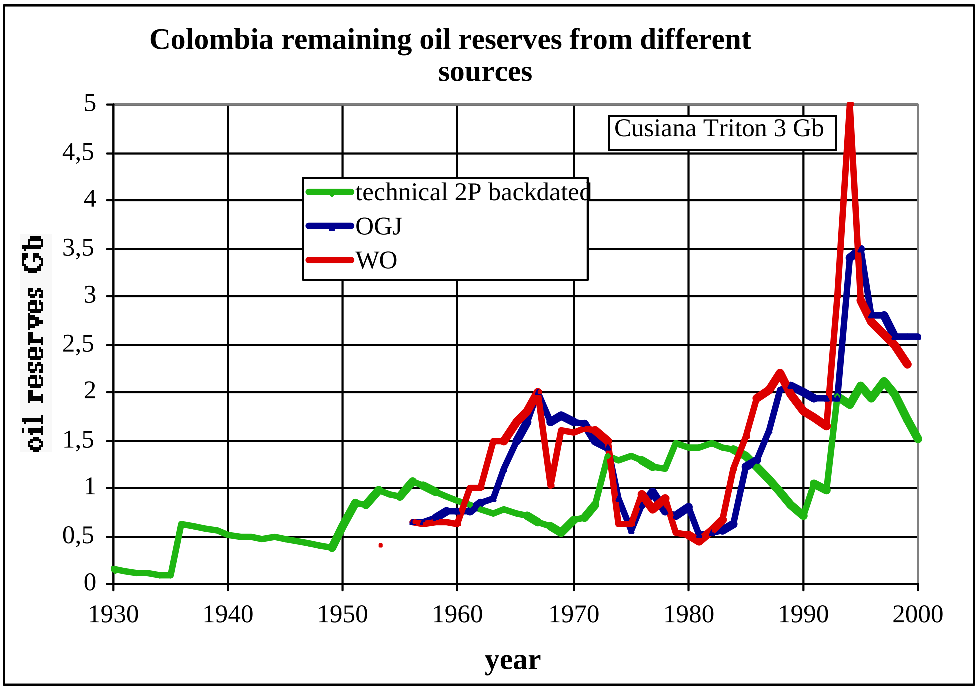
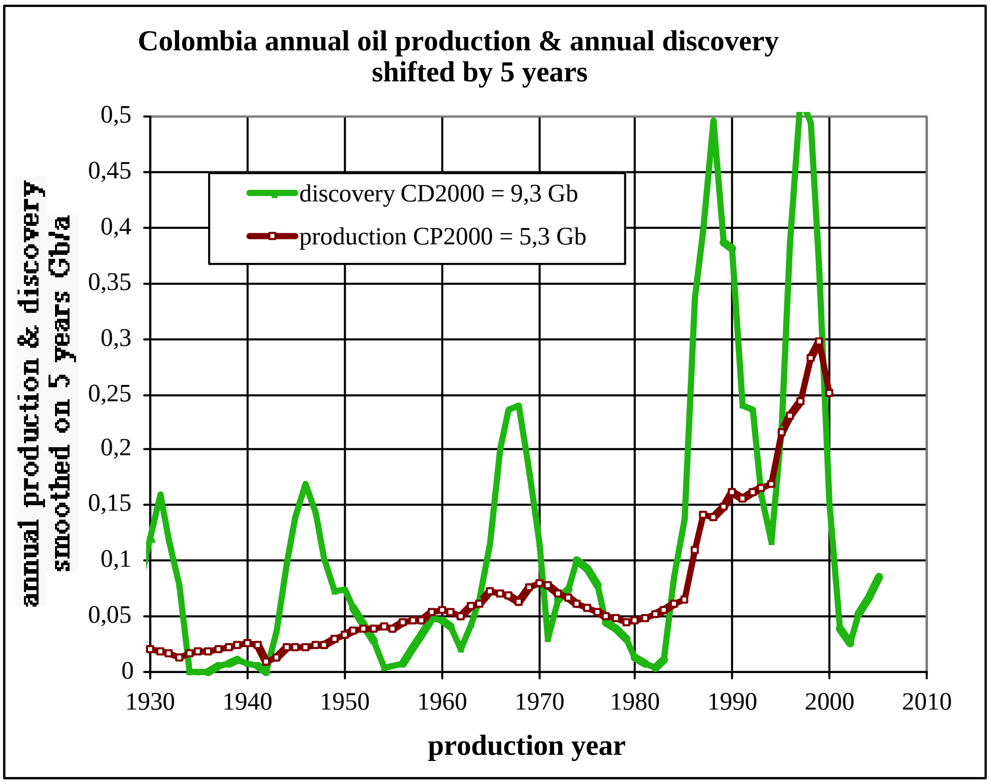


Figure 31:



The Cusiana field has started to decline (last year) and the estimate is now about 700 Mb, when the “scout” value is 950 Mb (but 1625 Mb last year).

Figure 32:

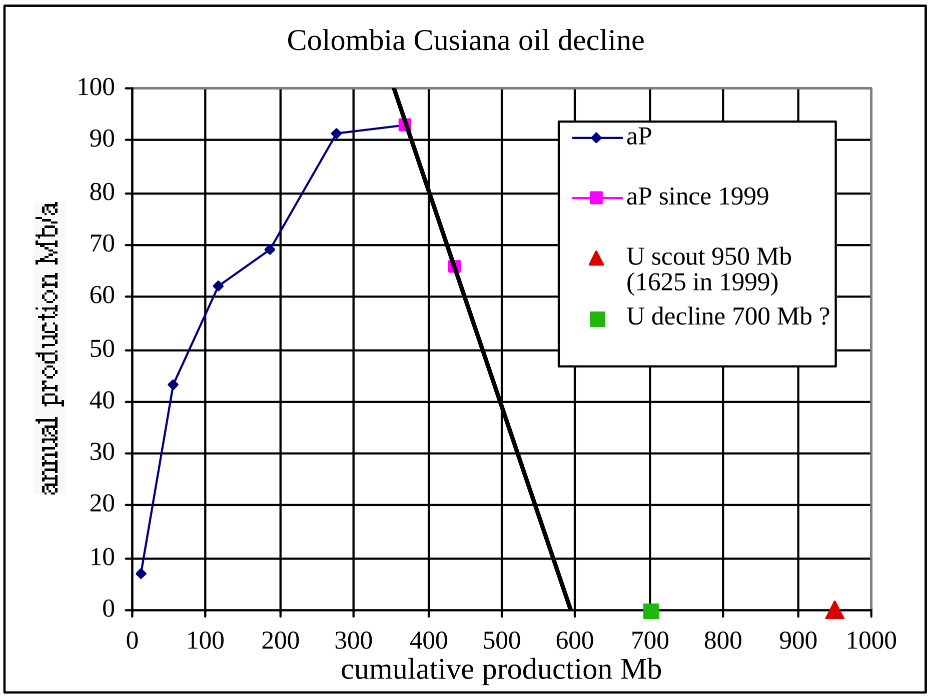


Figure 33:

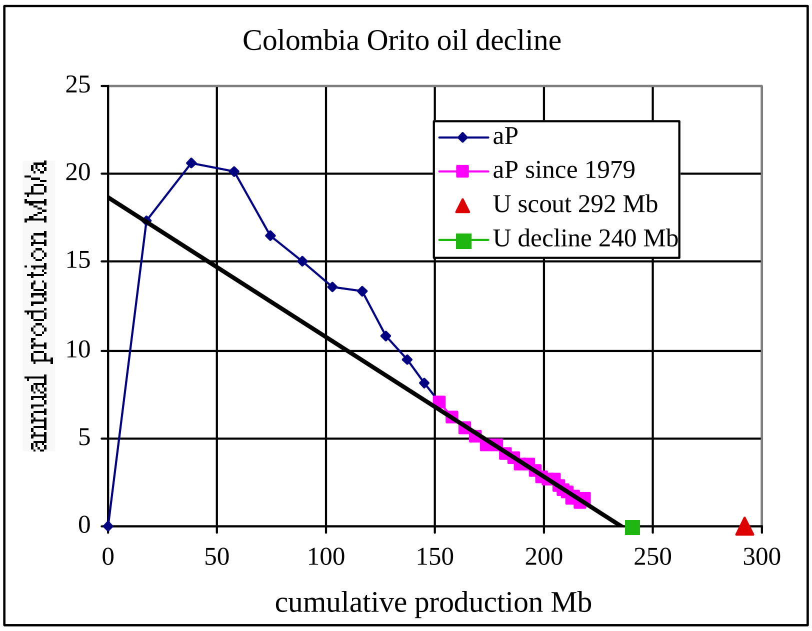
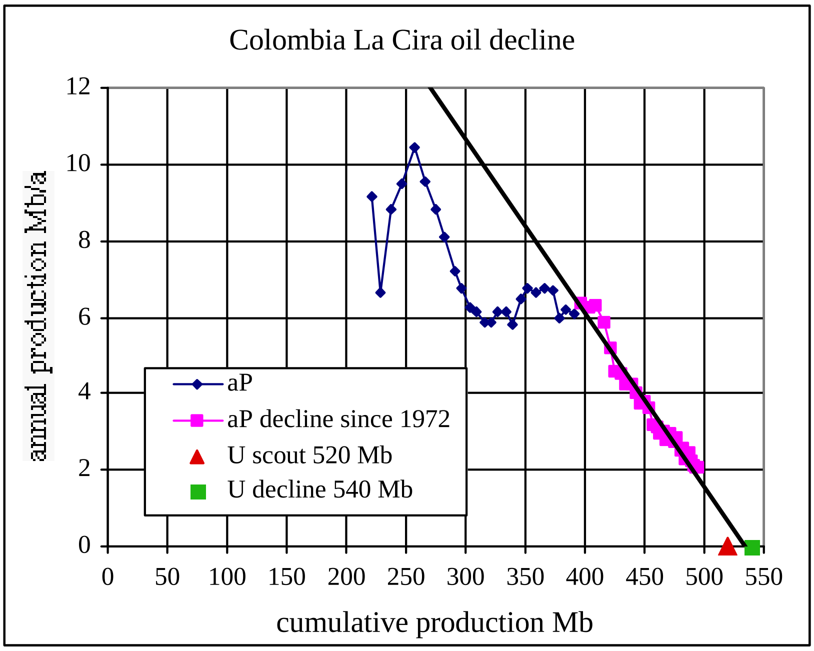


Figure 34:



4.5 Nigeria

Nigeria has also disturbed exploration because civil war. The data are poor.

Figure 35:

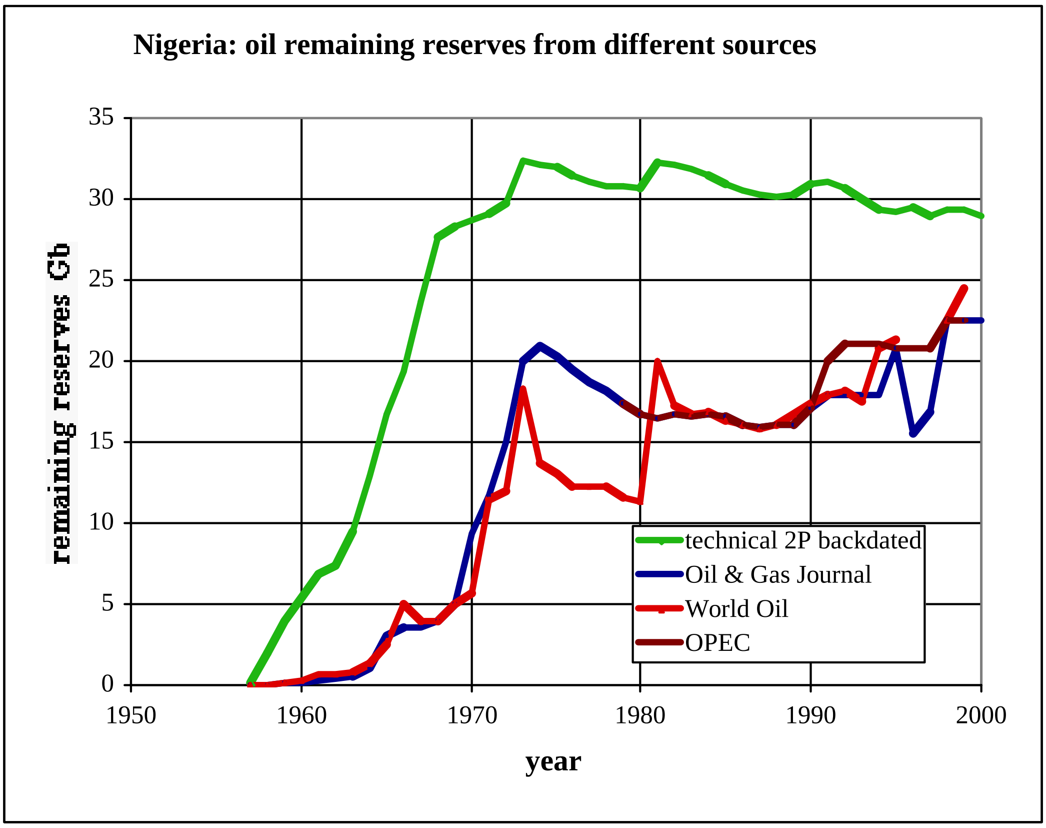


Figure 36:

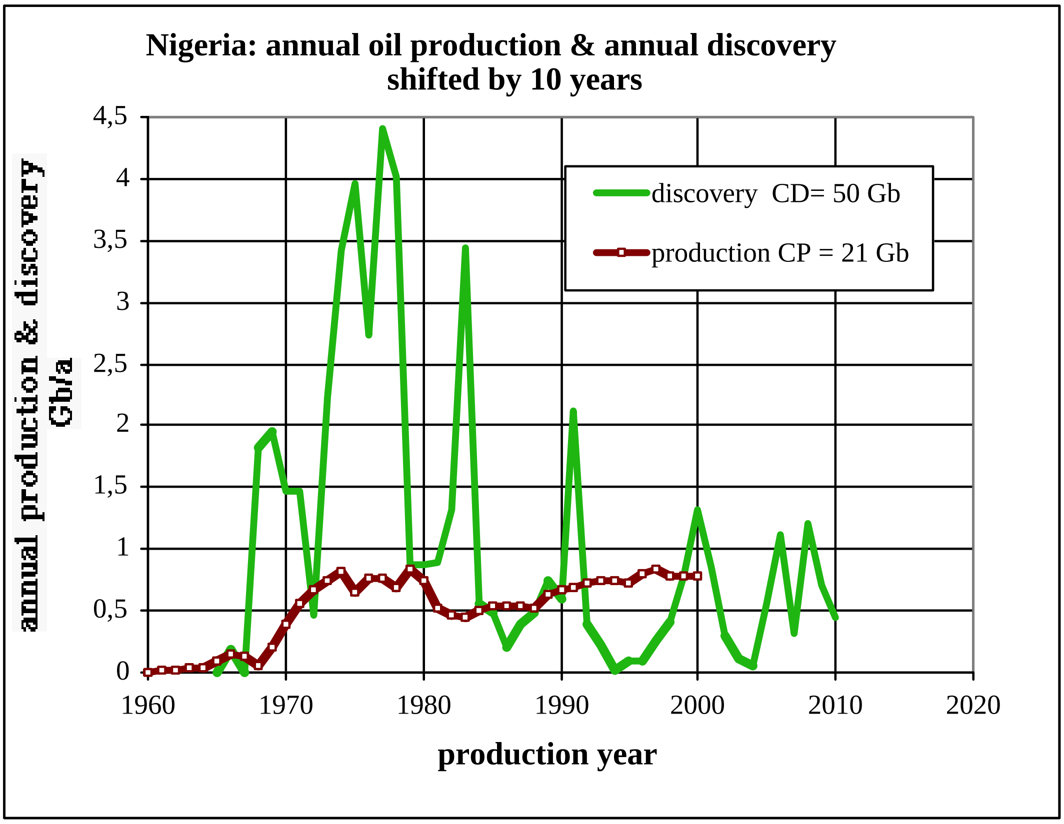
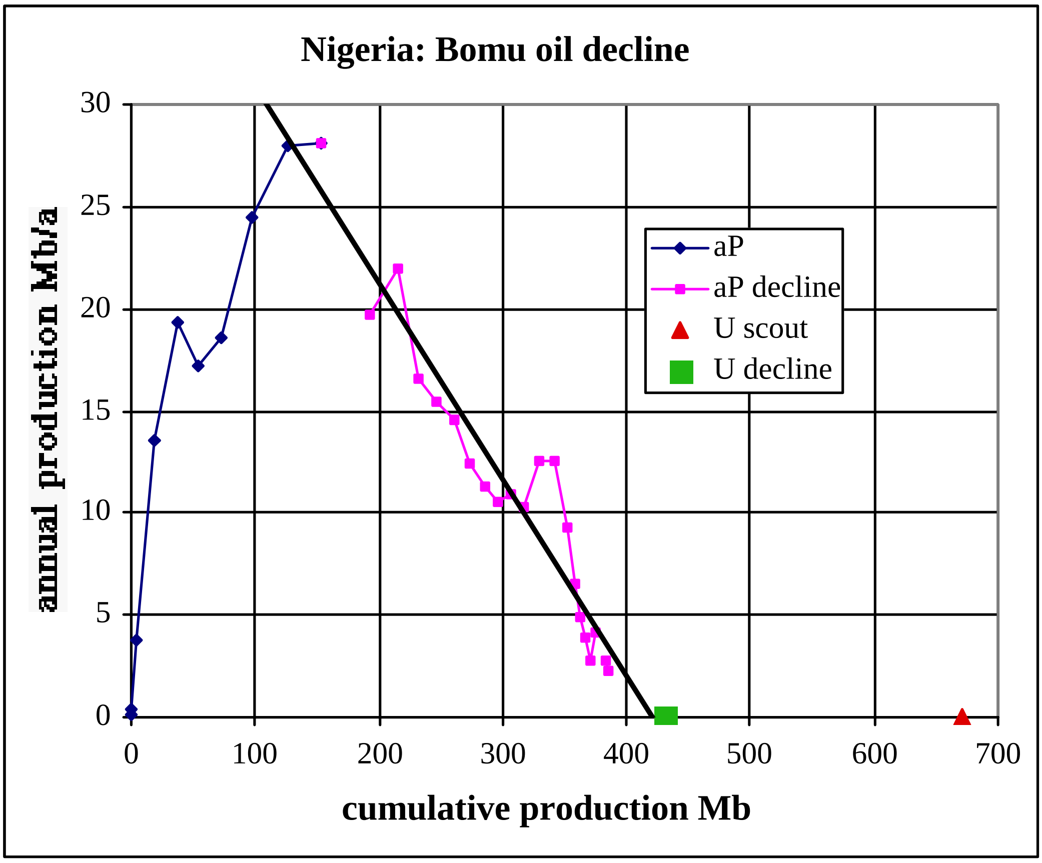


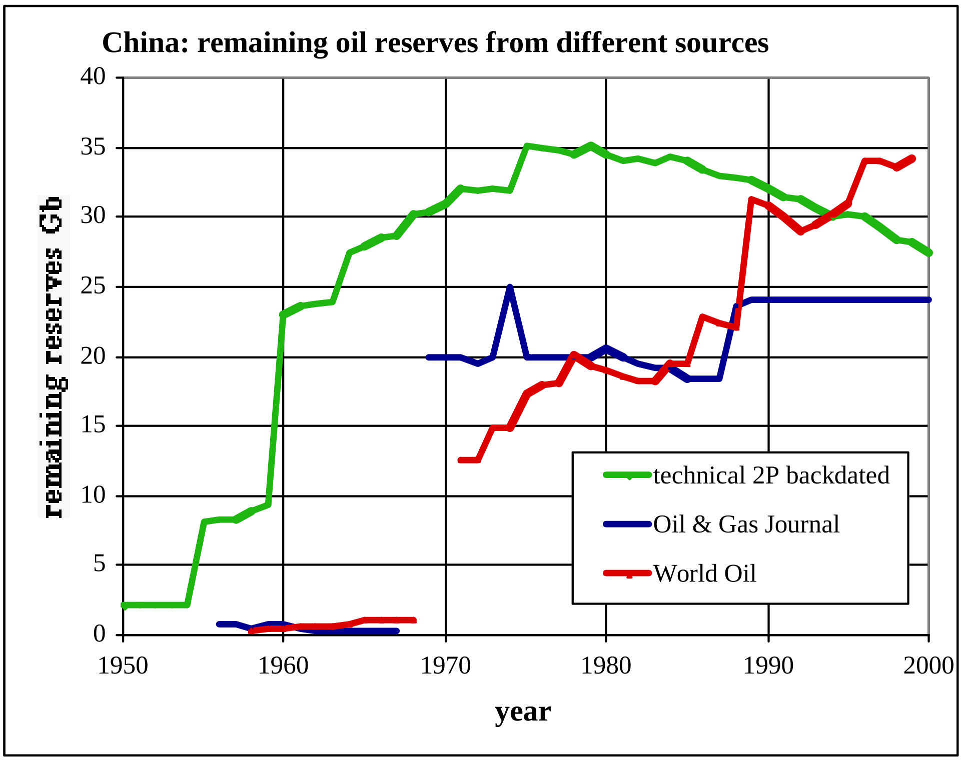
Figure 37:



4.6 China

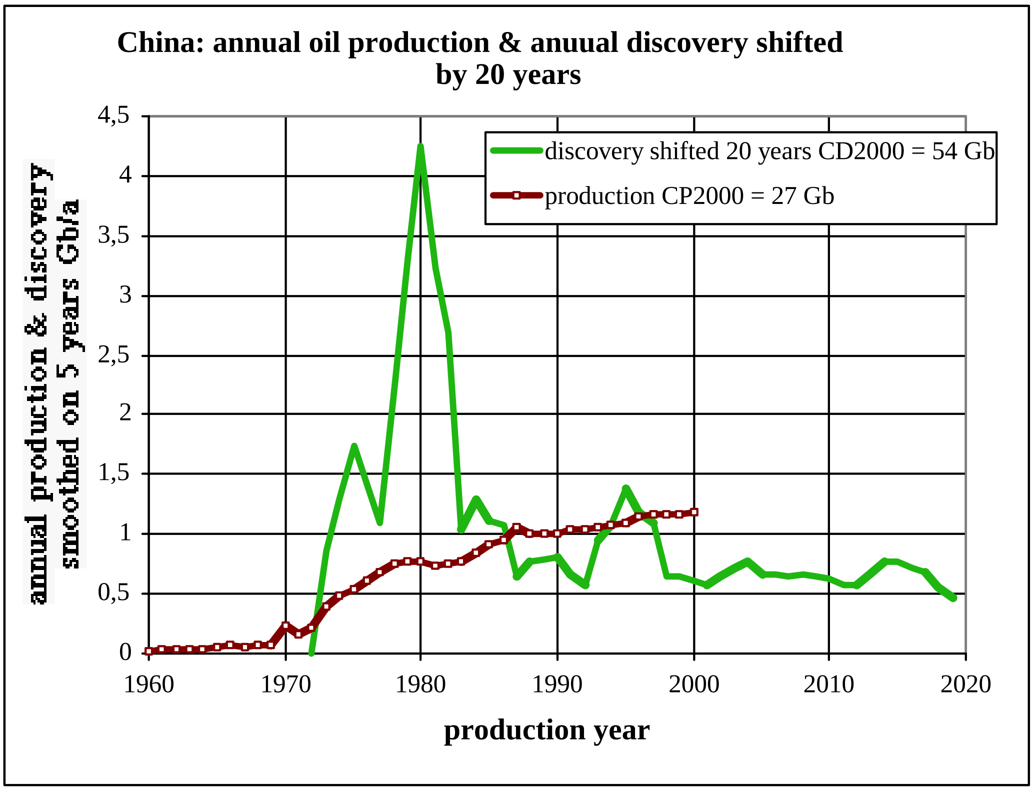
Data are not very good and fields are grouped.

Figure 38:



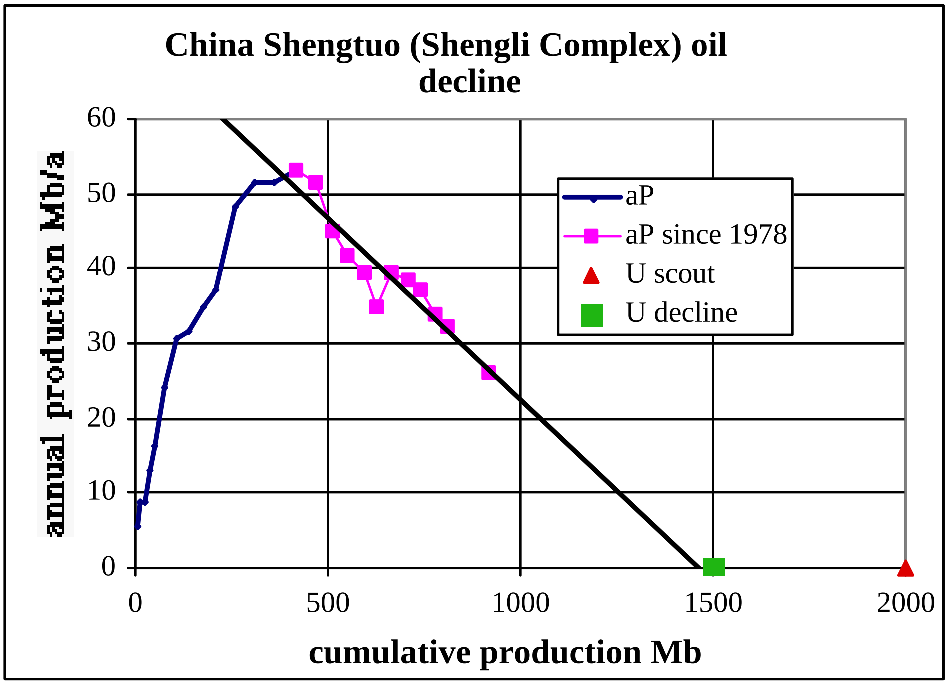
The largest oilfield Daqing is very large with a large town to produce it with over 20 000 wells for 1 Mb/d.

Figure 39:



Shengli is the second largest field. It was covered with simple 3D in 1966 using abacus and many geophysicists, when the first commercial 3D was carried out in US only in 1972, when computer power was available.

Figure 40:

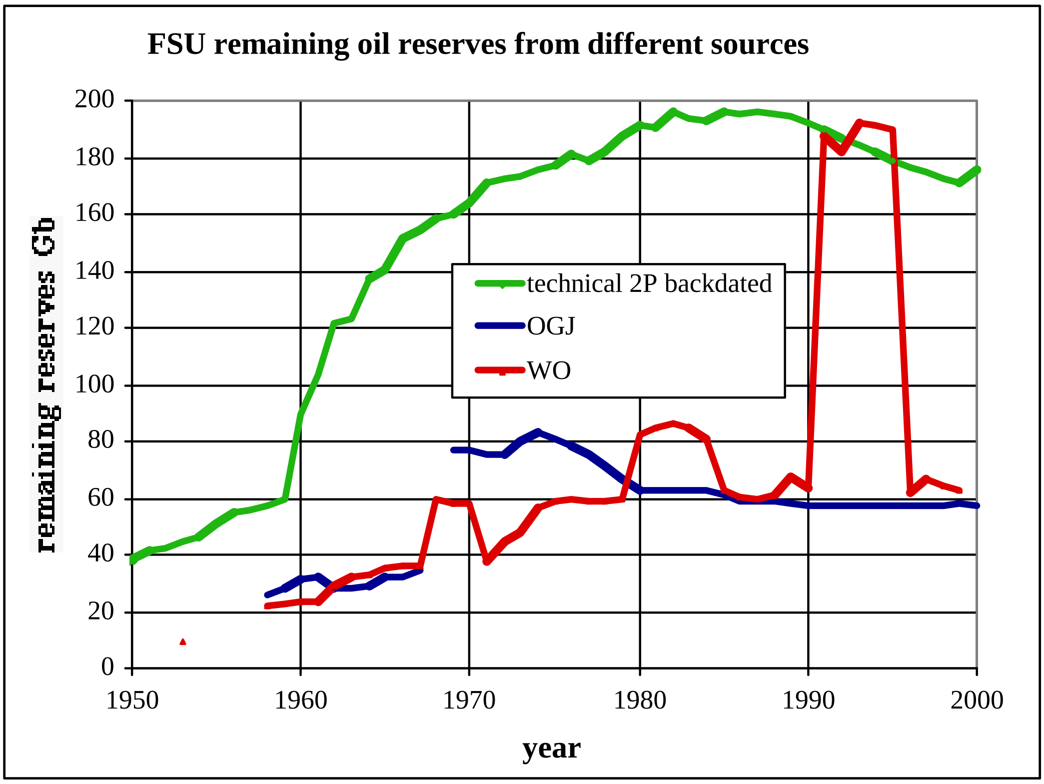


4.7 FSU

USSR Deputy Oil Minister Khalimow (& Feigin) presented the Russian classification of reserves at the 1979 WPC in Bucharest as a well-conceived approach. But in 1993 (AAPG 77/9), Khalimow qualified this classification by stating: "The resource base [of the former Soviet Union] appeared to be strongly exaggerated due to inclusion of reserves and resources that are neither reliable nor technologically nor economically viable". USSR reserves were estimated based upon theoretical maximum recovery, neglecting economic considerations. The sum of the so-called A+B+C1 reserves were in fact close to proved + probable + possible reserves, (or 3P). Gochenour (1997) compares the A+B+C1 reserves of five Russian companies (the two largest being Lukoil & Yukos), with total reserves of 49.4 Gb, to the definition of reserves in the U.S. (P90 reserves following SPE/WPC rules). The P90 estimates give reserves of 26.4 Gb, which are only 53% of the Russian estimate. Gochenour wrote that a formal draft proposal was submitted to the government in 1995 by the State Reserves Committee to amend the reserve classification.

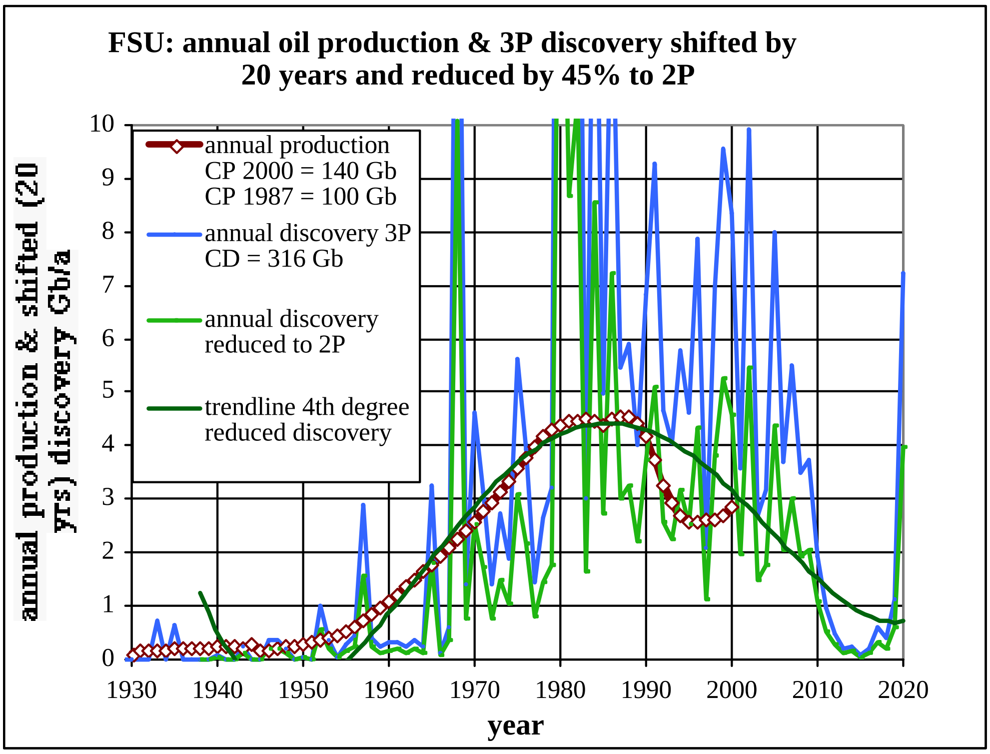
The remaining reserves from different sources shows that World Oil tried in 1991 to 1995 to include probable in their reserves but they dropped it and returned to the so-called proved reserves as OGJ. The 3P technical reserves show a peak around 1985 and on 2000 the discovery of Kashagan.

Figure 41:



The fit of the peak of 3P annual discovery to the annual production peak shows a shift of about 20 years, but it is necessary to reduce the annual discovery by 45% to get a fit to the level of annual production. This reduction is in line with Khalimov's statement.

Figure 42:



The check on the real estimate of reserves from decline production is done on the two largest oilfields, Samotlor and Romaskhino showing clearly the overestimation of the Russian system. Samotlor is reported having original reserves at 28 Gb when the decline indicates less than 20 Gb (a decrease of 30% on original reserves but 80% on remaining reserves). Romaskhino is reported at 17.5 Gb when decline gives 16 Gb (a decrease of 10% on original reserves and 60% on remaining reserves), confirming Gochenour article.

Figure 43:

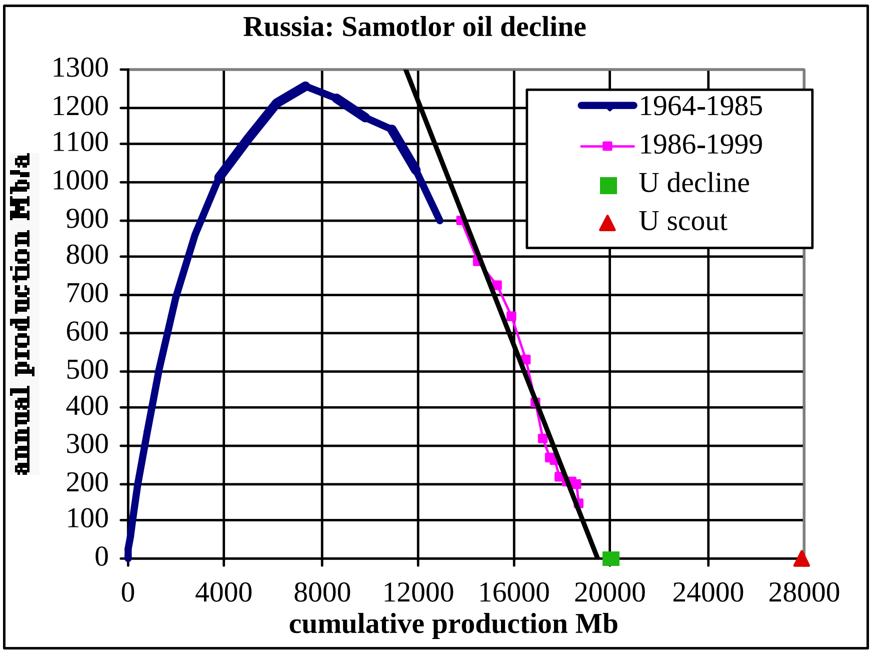
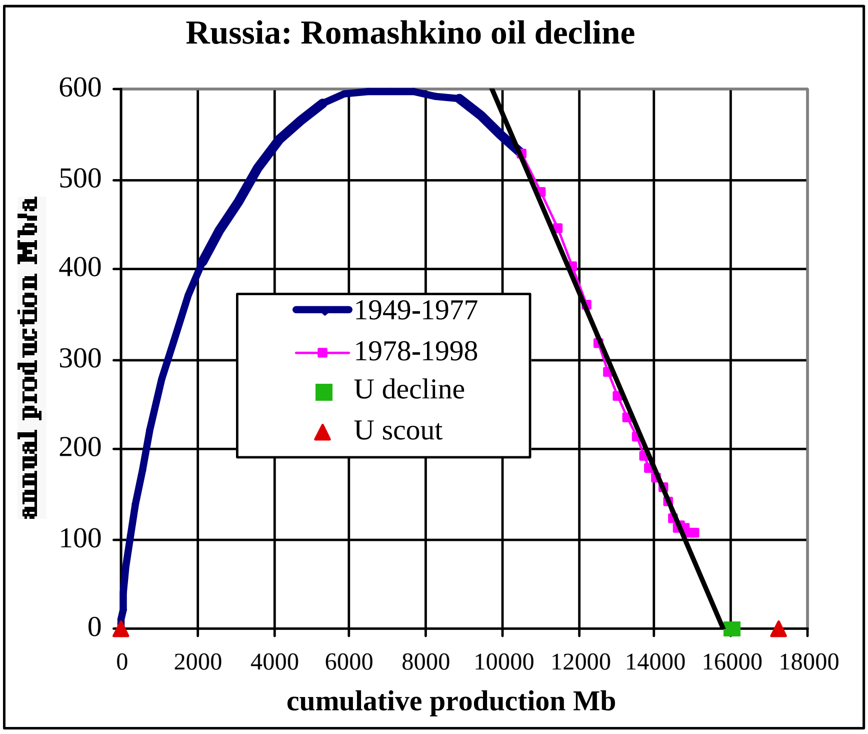


Figure 44:



4.8 Oman

Oman is an interesting country as most of oil exploration and production was conducted by PDO, in fact Shell, which has run Oman as the best school for its engineers. Shell is the most important enterprise of the country and Shell manager was as important as the oil minister. I went to Oman (as partner) and I learned a lot from Shell operations. Oil is produced even in Infracambrian formations.

Figure 45:

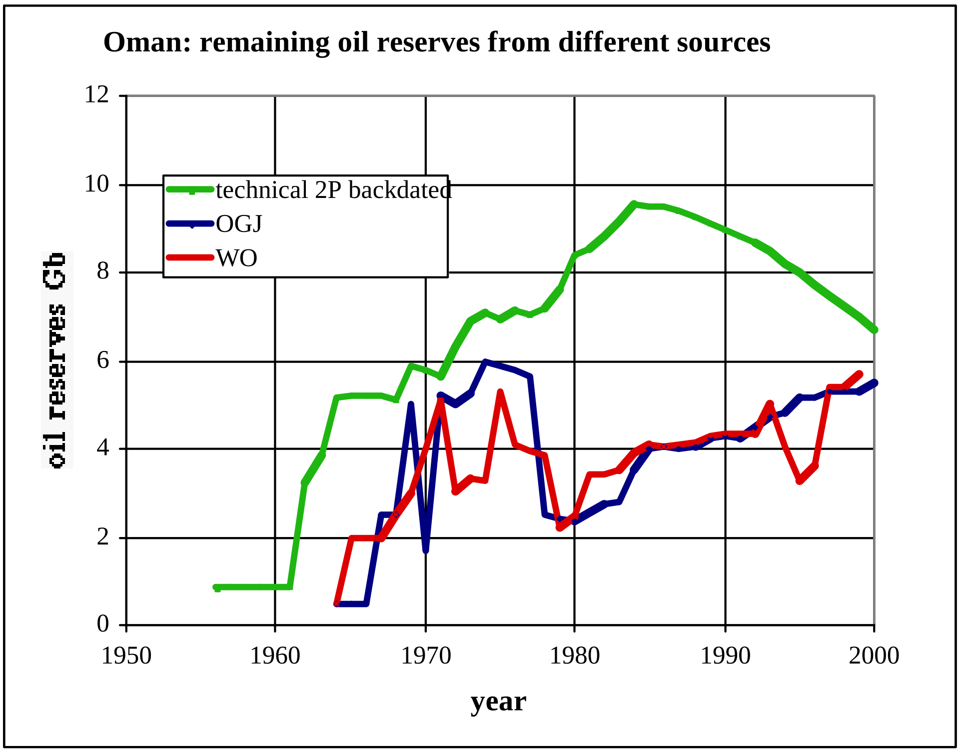
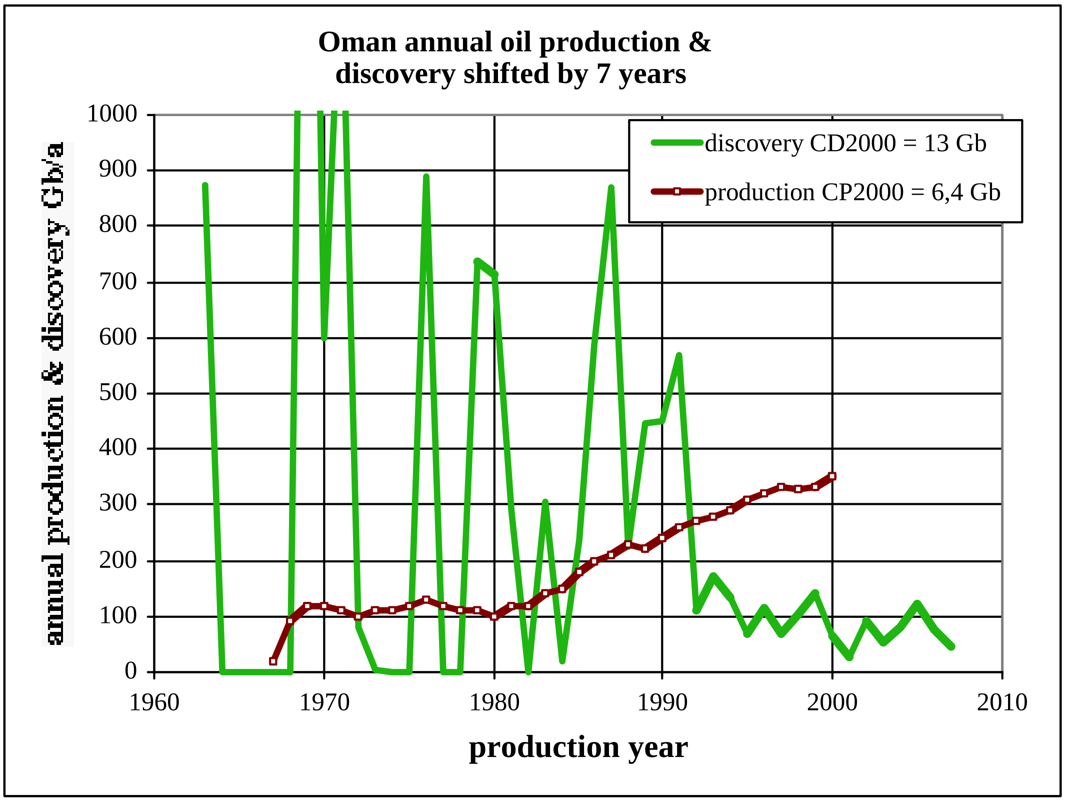
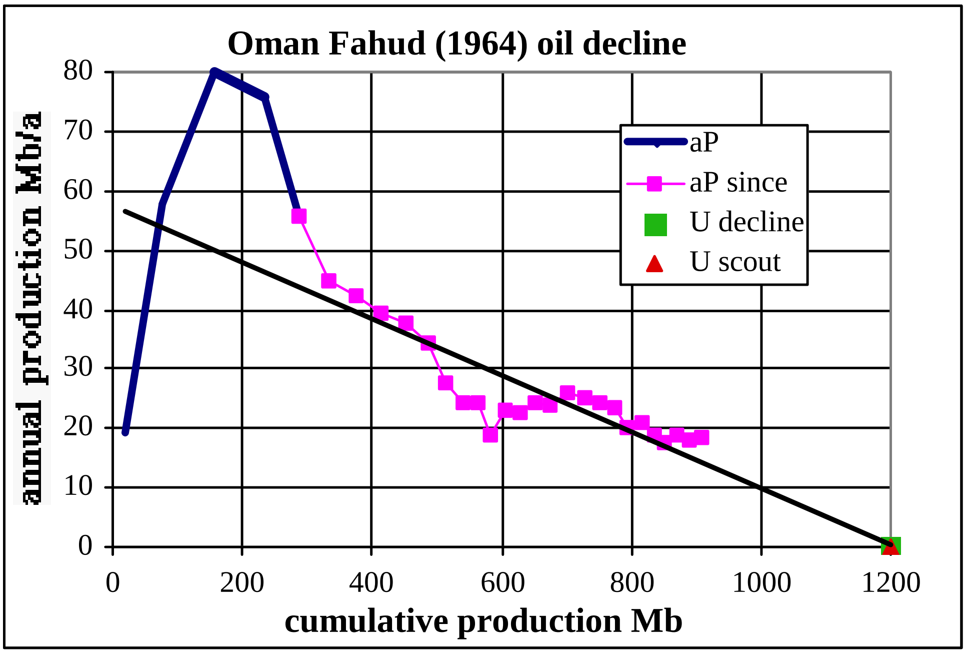


Figure 46:



The Fahud field discovered in 1964 is interesting, as it is located 200 meter from a dry hole drilled in 1957 by the IPC consortium that decided to drop exploration except Shell (and Gulbenkian).

Figure 47:



4.9 Angola

Angola has three exploration cycles: onshore in the 60s, offshore shallow in the 80s and deepwater at the end of the 90s.

Figure 48:

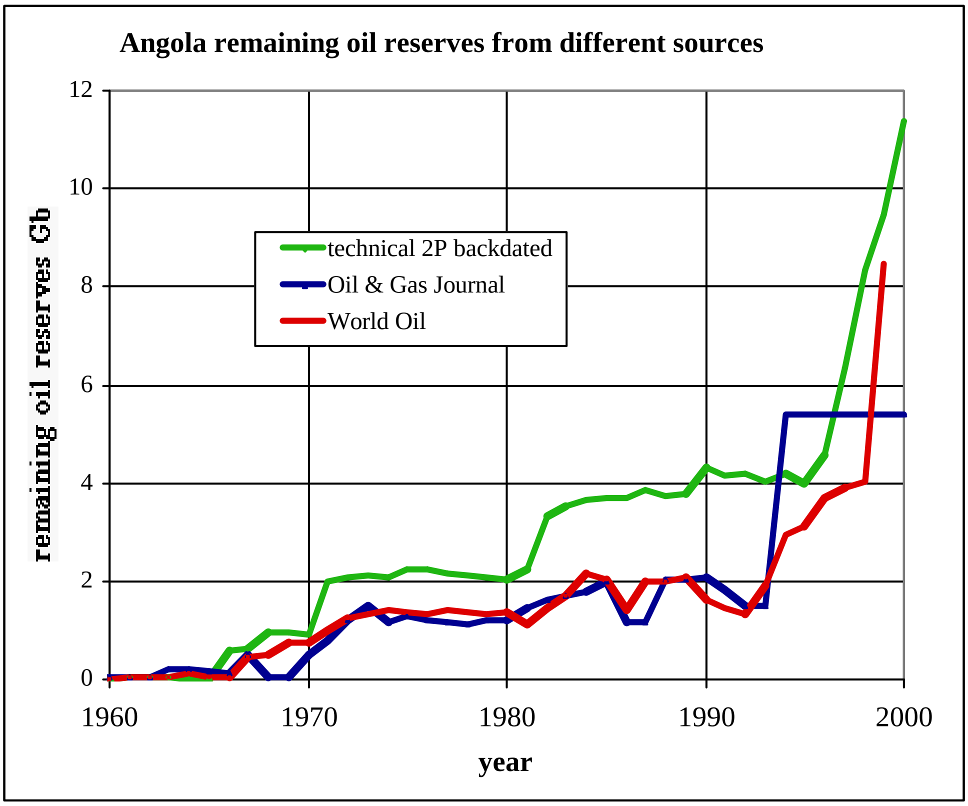


Figure 49:

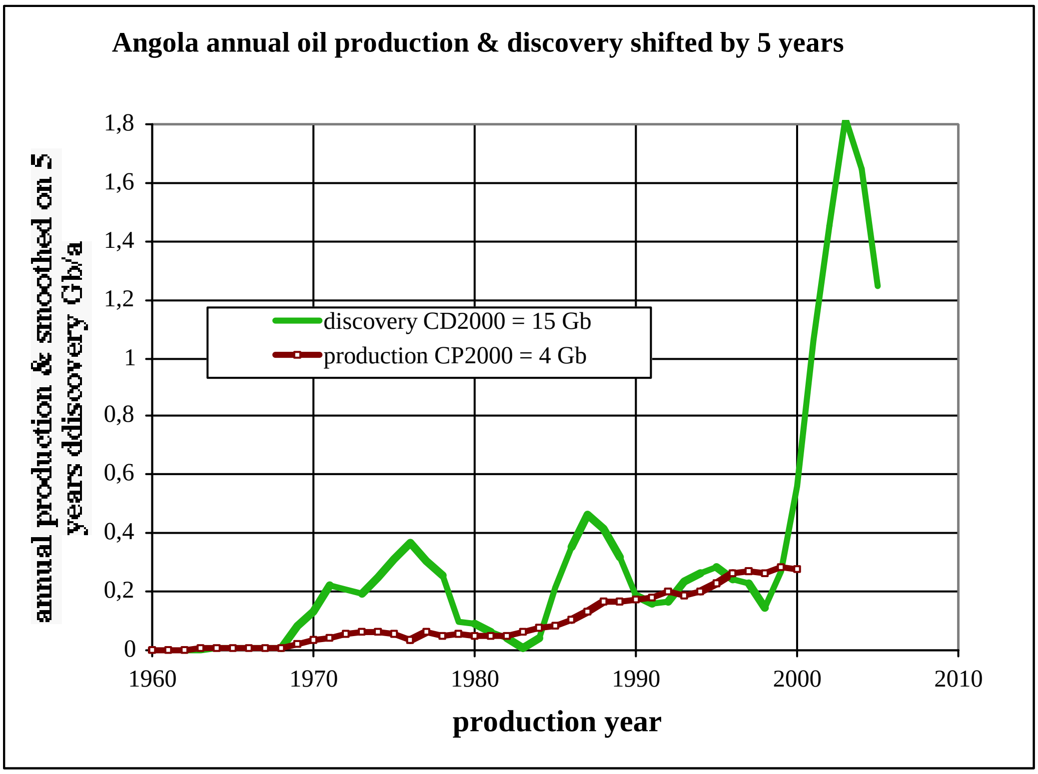
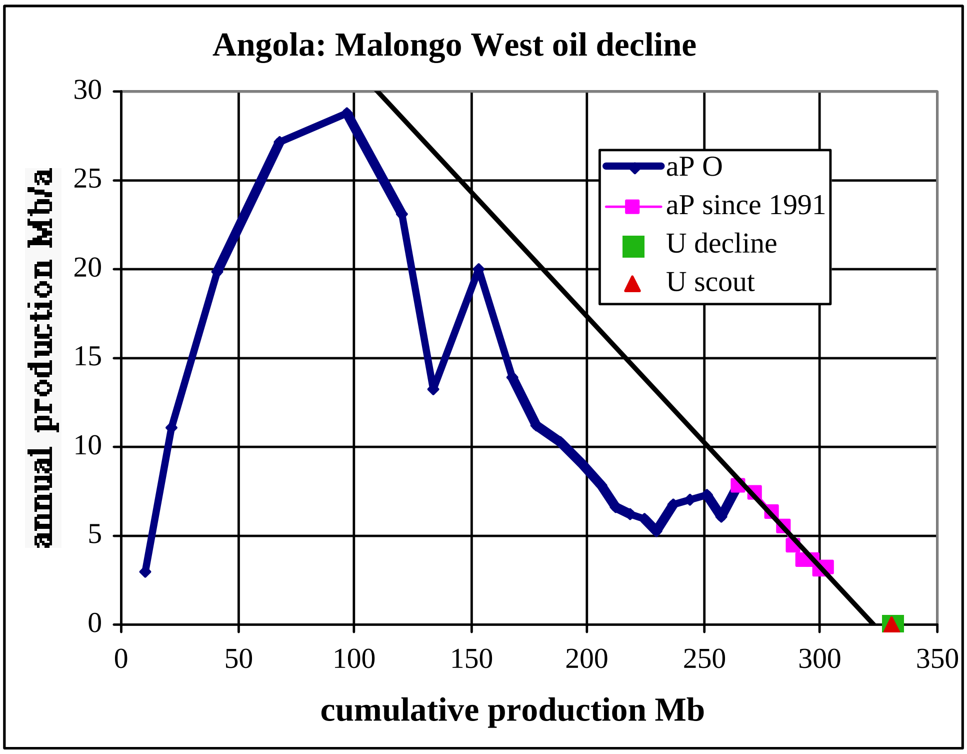


Figure 50:



4.10 Algeria

Two supergiants were found (I participated in the discovery) in the 50s Hassi Messaoud (10 Gb) and Hassi R'Mel (100 Tcf), but a new cycle reappears in the 90s in the Berkine area. It has to be noticed that around 1970 (because of the Russian influence?), reserves were boosted to high values reported by OGJ to drop quickly back to normal.

Figure 51:

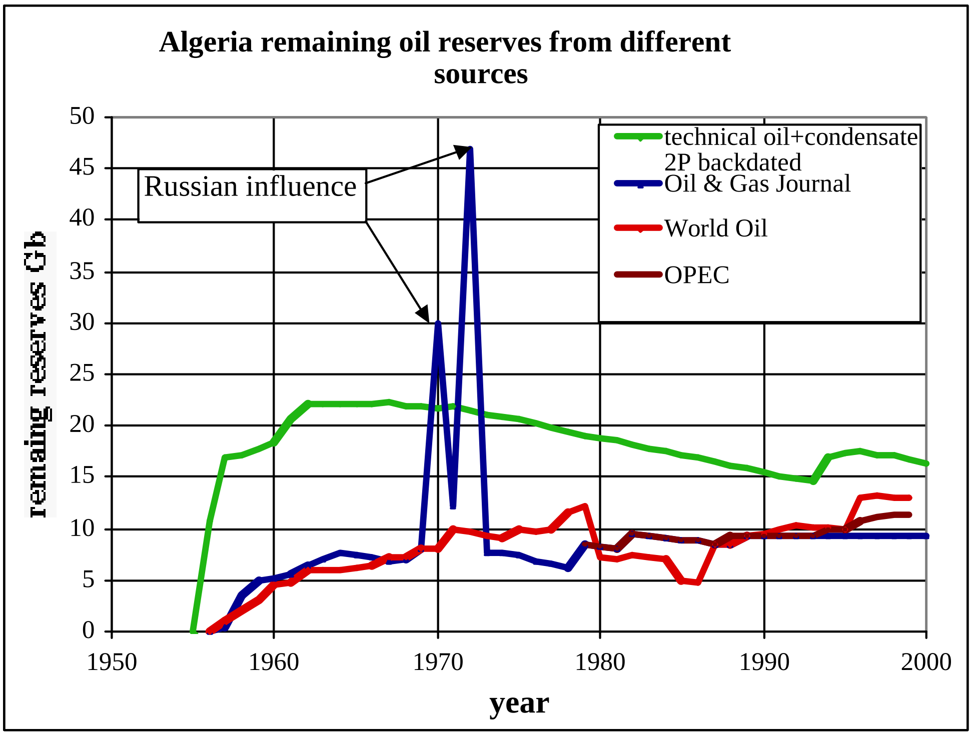
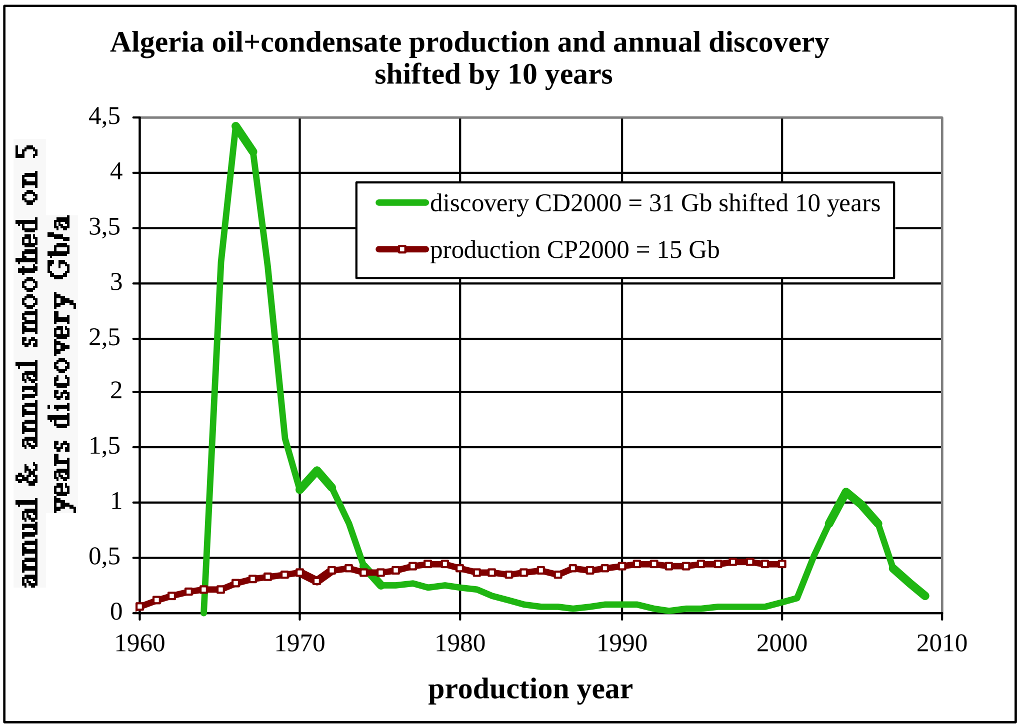
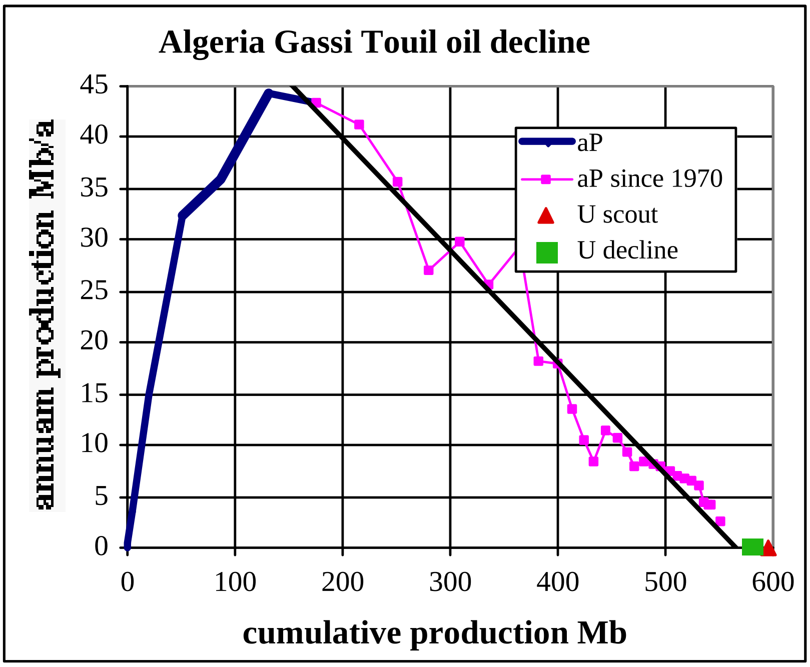


Figure 52:



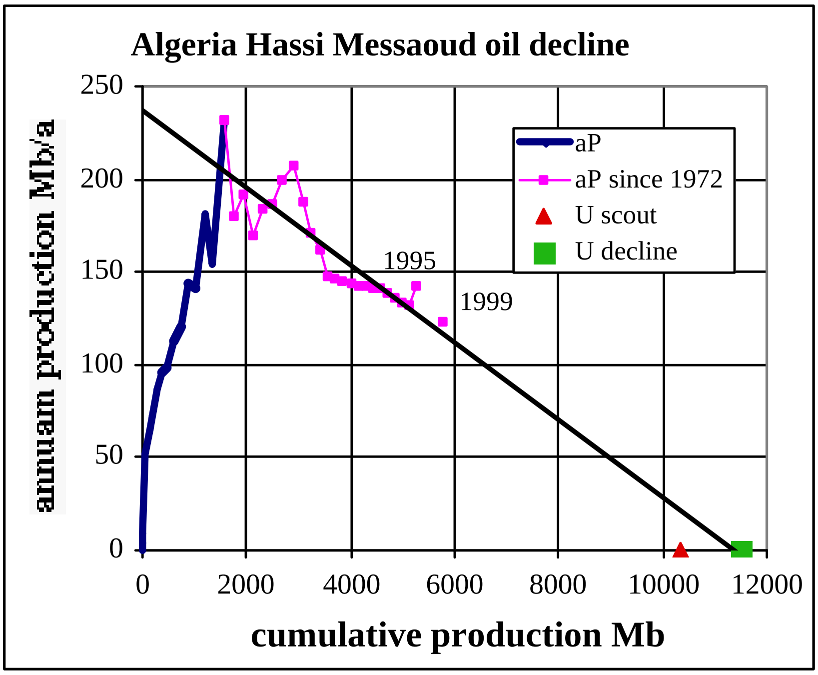
Gassi Touil was famous in 1961 because of a blow out with a flame of 200 m high, I saw it the day before it was extinguished

Figure 53:



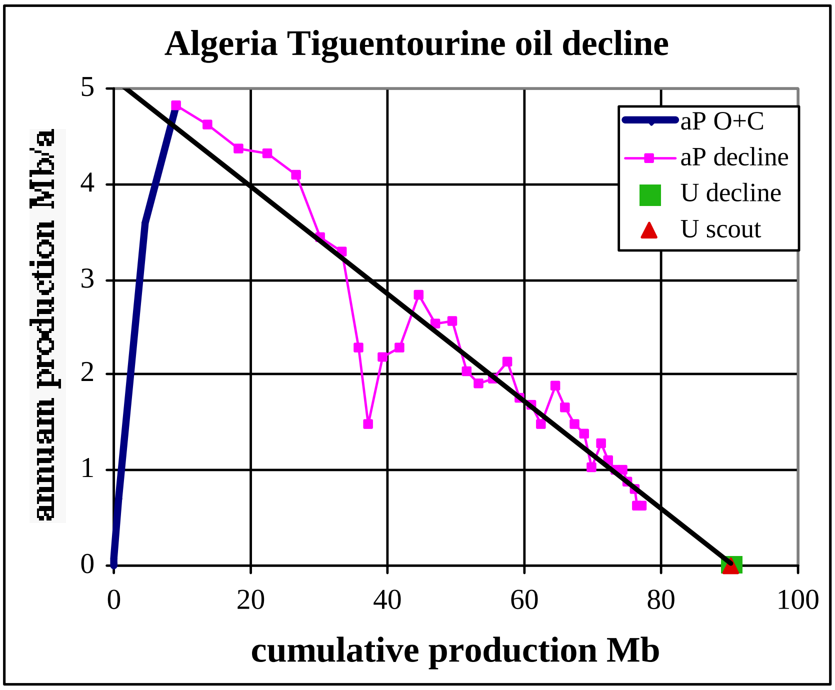
Hassi Messaoud is the largest oilfield of Africa, it could be classified as unconventional as it is produced using EOR with miscible gas. The decline since 1972 is not well confirmed as there are up and down and data are missing for few years, with a strange value in 1995. The decline ultimate (11.5 Gb) looks higher than the scout ultimate

Figure 54:



Older field as Tiguentourine shows better decline, in agreement with the scout value.

Figure 55



5 Reserve growth

Reserve growth is the most important problem in assessing the future production.

Statistically reserve growth occurs because the reserves are badly estimated. If they were estimated with a probabilistic approach using a wide range of minimum, mean, maximum, statistically the mean reserves of a country is the sum of the mean reserves of each - which is not the case for Proved Reserves - and there should not be any global growth in the day of reckoning at the end of production of the country, despite huge variation in detail between estimated value and real value of every field.

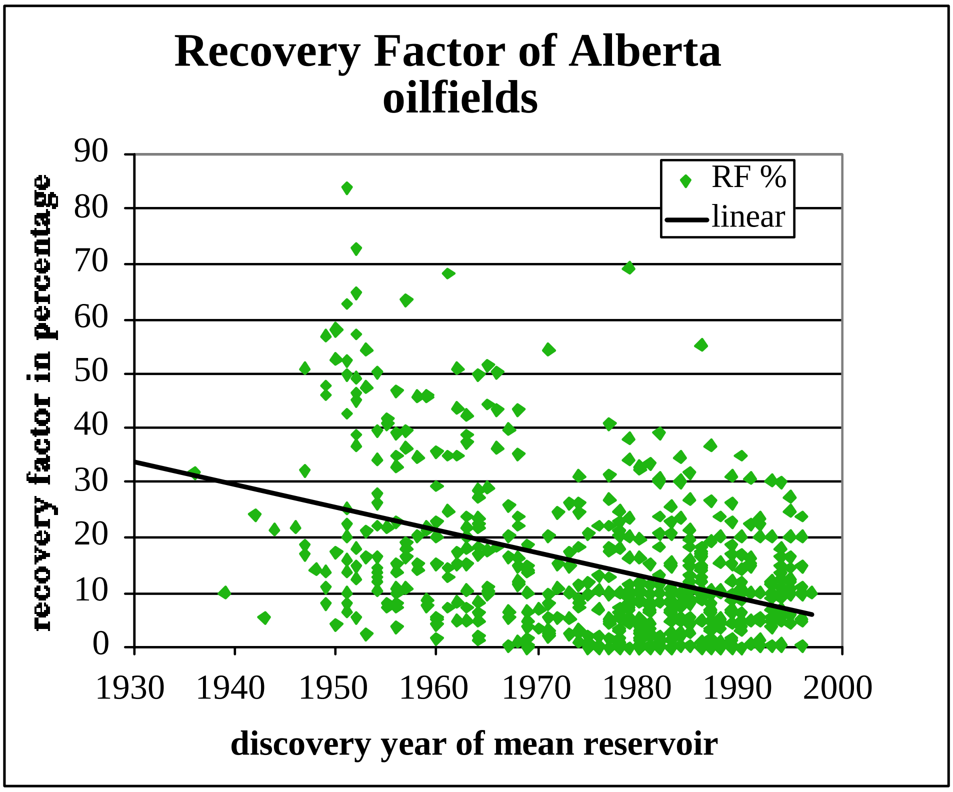
At the present time, it is claimed that there is reserve growth in the evolution of the reserves, but in fact the extent of reserve growth can be measured only when the fields have been depleted and abandoned. On still producing fields, cases of reserve growth are publicised whereas little is said about reserve decrease. The huge increase during the second half of the 1980s by the OPEC countries was political (quotas) and the decrease in 1999 of 20 Gb by Mexico was done after the financial crisis was solved (previously large reserves were needed to guarantee the loan from the US and IMF and before Nafta agreement signed)

Reserve growth is claimed to come from higher recovery factor thanks to technology progress and increase in oil price. Is it true?

5.1 Recovery factor (RF)

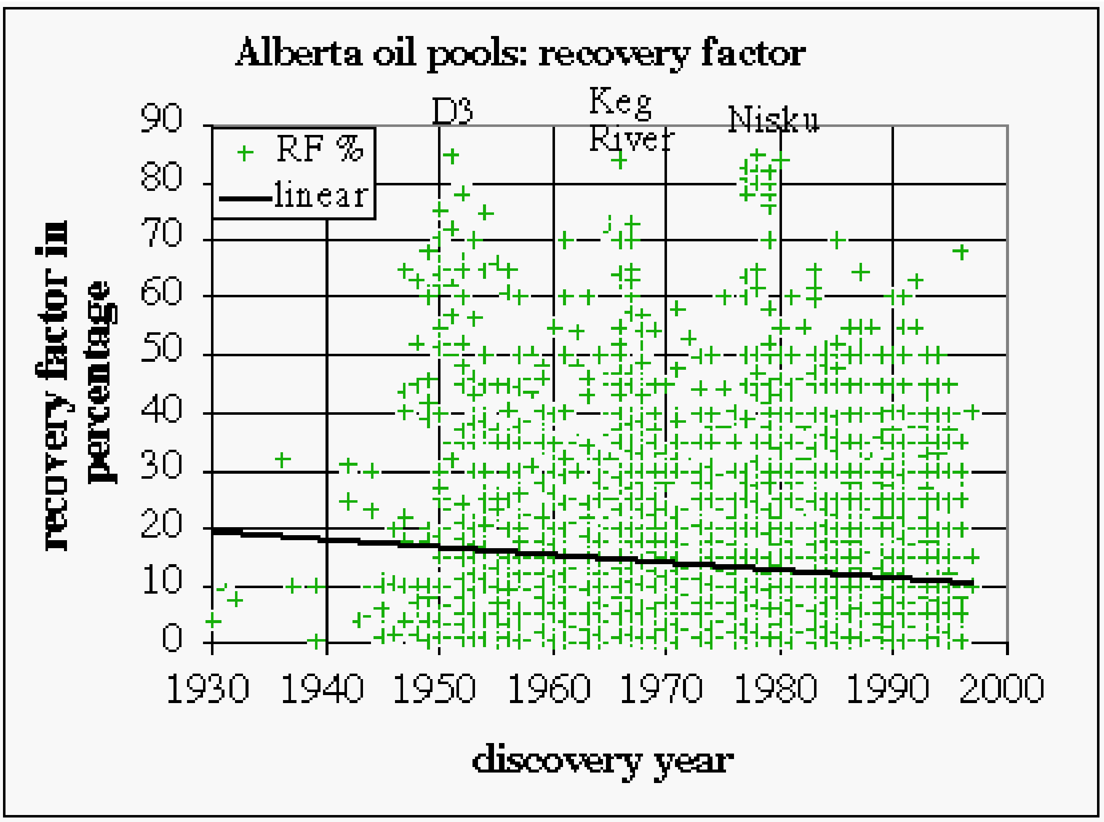
People believe that the recovery factor is a function of the technology level when it is mainly due to geology, to the quality of the reservoir and not the quality of the production scheme or the present technology. It is obvious in Canada that the RF varies with time not with technology but with the different types of reefs found when exploration moves to a new area and new play.

Figure 56:



The RF is more precise at the pool level:

Figure 57:

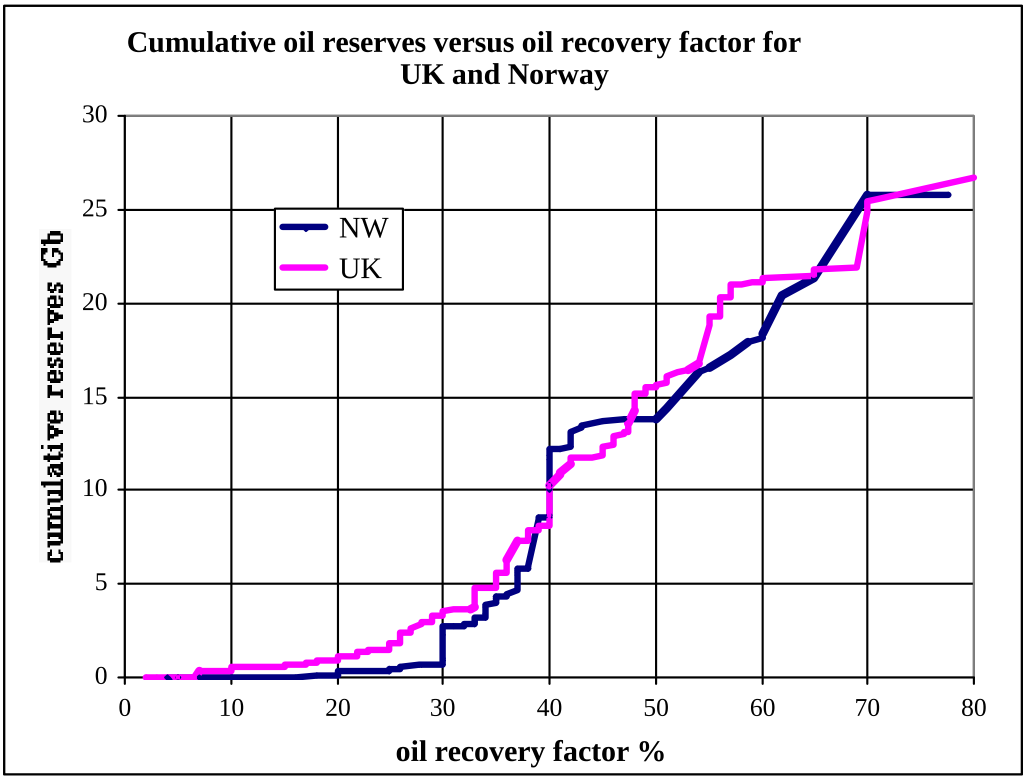


It is known that for poor reservoirs (fractured tight reservoir) the RF is about 3% and for very high porous and permeable reservoir (as a reef) it is about 80%.

5.2 Geology mainly

In the North Sea the distribution of cumulative discoveries versus RF shows an almost identical curve between UK and Norway. As most of the reserves comes from North Sea and since the boundaries is at the middle of distance, having identical distribution the reserves are evenly spread in the North Sea, the largest being close to the centre (Viking grabens). It is funny to think the limit between the two nations were settled using the middle distance, giving half of the reserves to each countries. Another rule could have been chosen as the deepest waters, giving nothing to Norway, as the country is only basement and the deepest water line stays in the basement. It could be said that it is unfair to give a sedimentary offshore to a country with a basement onshore and offshore up to the deepest waters.

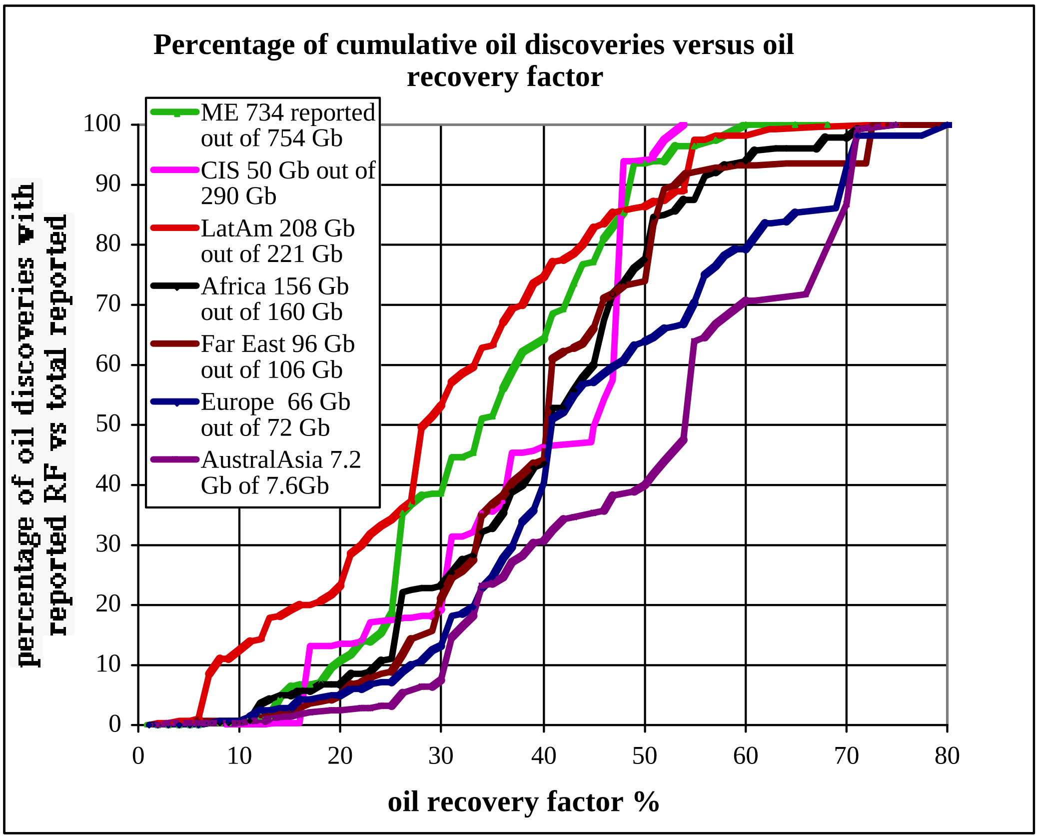
Figure 58:



RF varies from 20% to 40% (5%-95%) with the median reserves around 45%. Norway has decided in 1999 to take 50% as the goal for average oil reserves.

The distribution by continent on figure shows different pattern for the percentage of reserve versus RF. The best one is for Australiasia and the worst for Latin America.

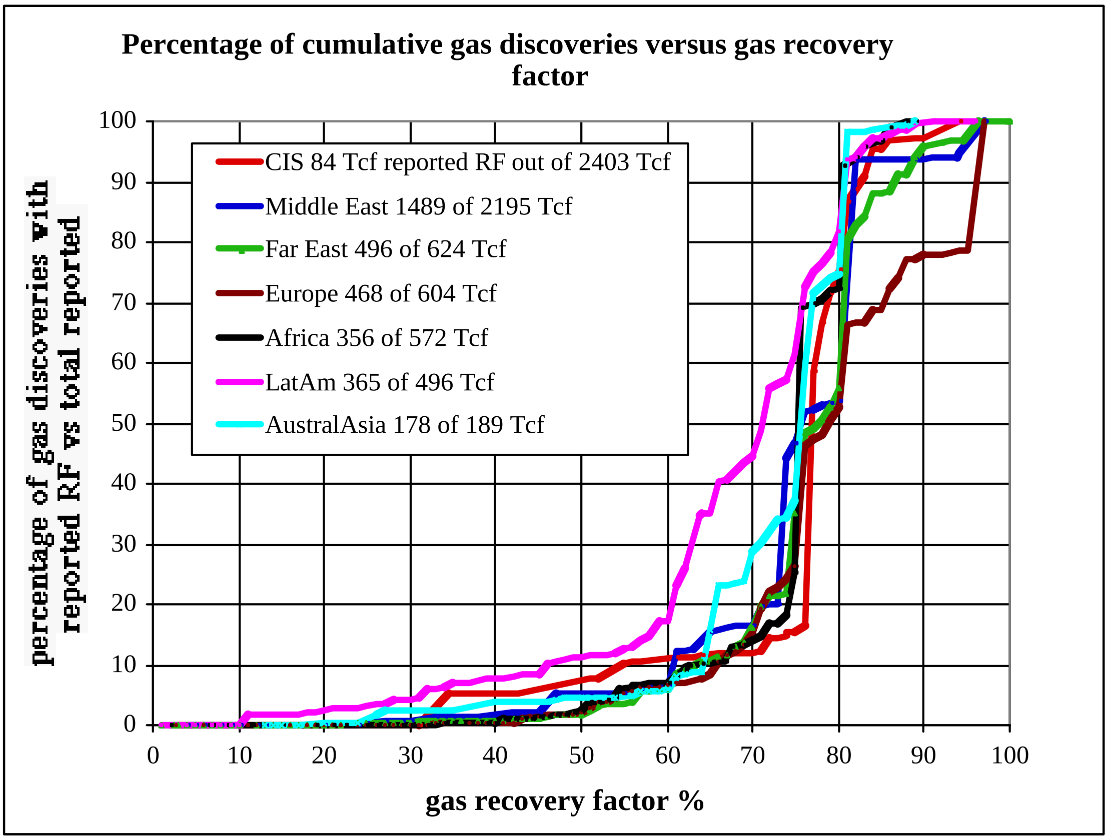
Figure 59:



The median point 550% of the reserves is at 30% for Latin America, 33% for Middle East, 40% for Africa, Far East and Europe, 45% for CIS and 55% for AustralAsia.

The same graph for gas recovery factor (range RF 50%-90%) shows a median point at 70% for Latin America, 75% for the rest. (Norway has chosen 75% as its goal average).

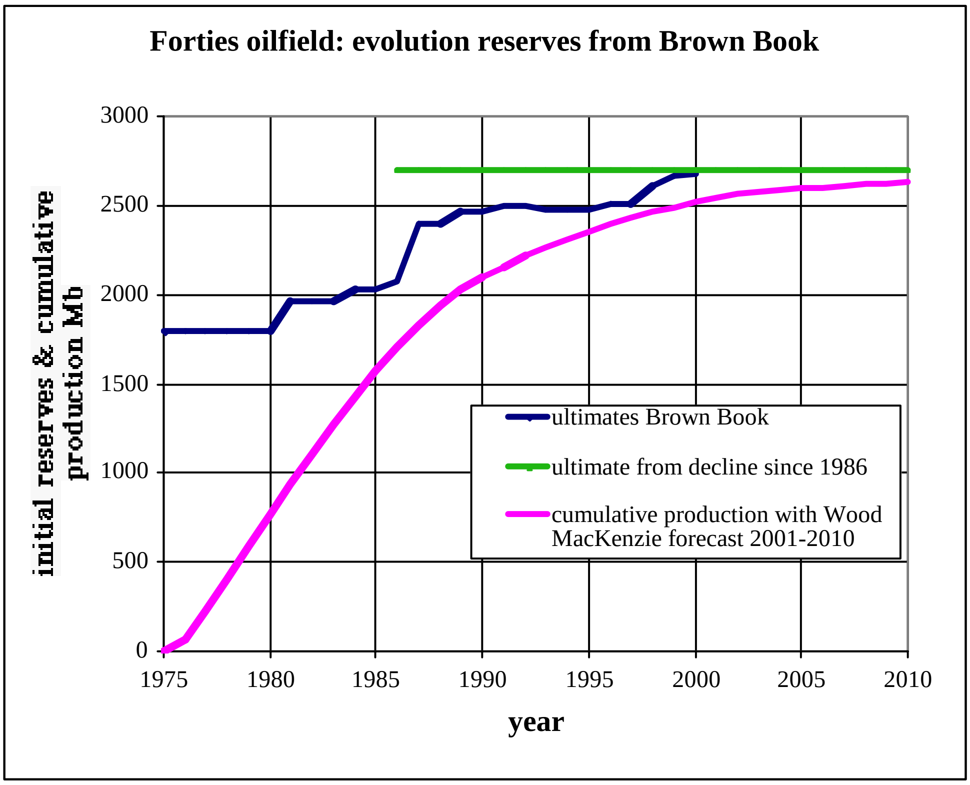
Figure 60:



The main impact of technology progress on conventional fields is to produce cheaper, faster but not more.

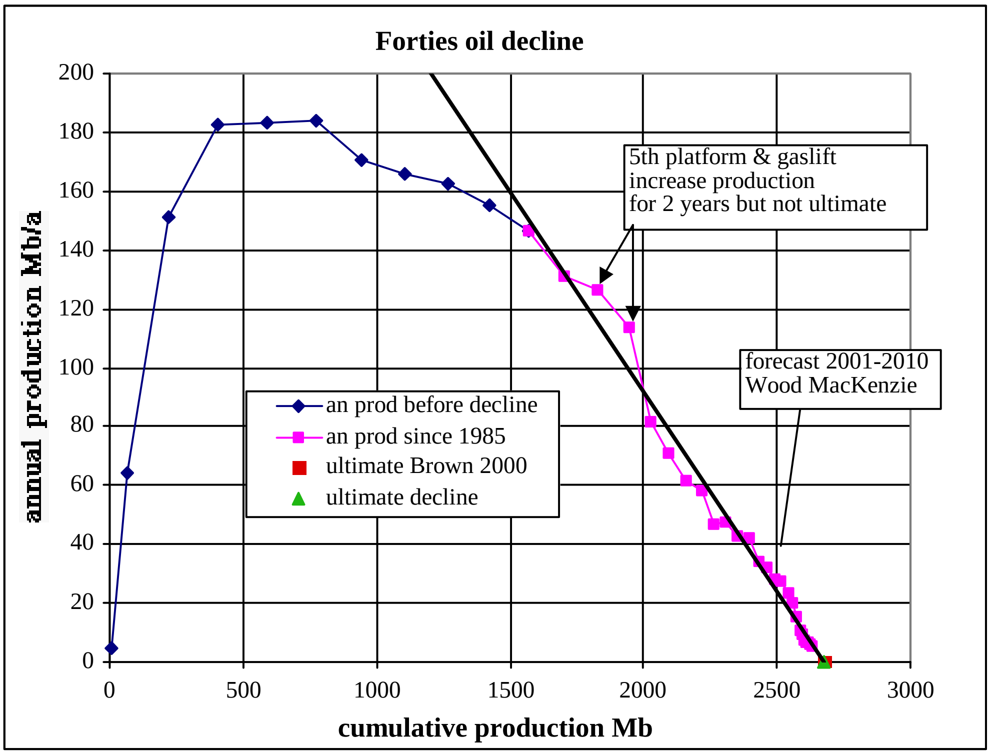
The best example is the giant oilfield of Forties in North Sea. The operator announced that the reserves would increase thanks to a fifth platform with gas injection in 1985. The annual production in 1986 & 1987 were larger than the past decline but in 1988 the production went back to the past decline on the same ultimate as before. The estimates from the Brown Book (DTI) do not give the best values that can be assessed from the technical data.

Figure 61:



From the decline graph annual production versus cumulative production it is obvious that the ultimate was established as earlier than 1986 at 2.7 Gb but the operator waited until 1997 to report this value.

Figure 62:



The reported ultimate for Thistle varies up and down from 1980 to 1996, when the ultimate could be correctly estimated at 410 Mb since 1983.

Figure 63:

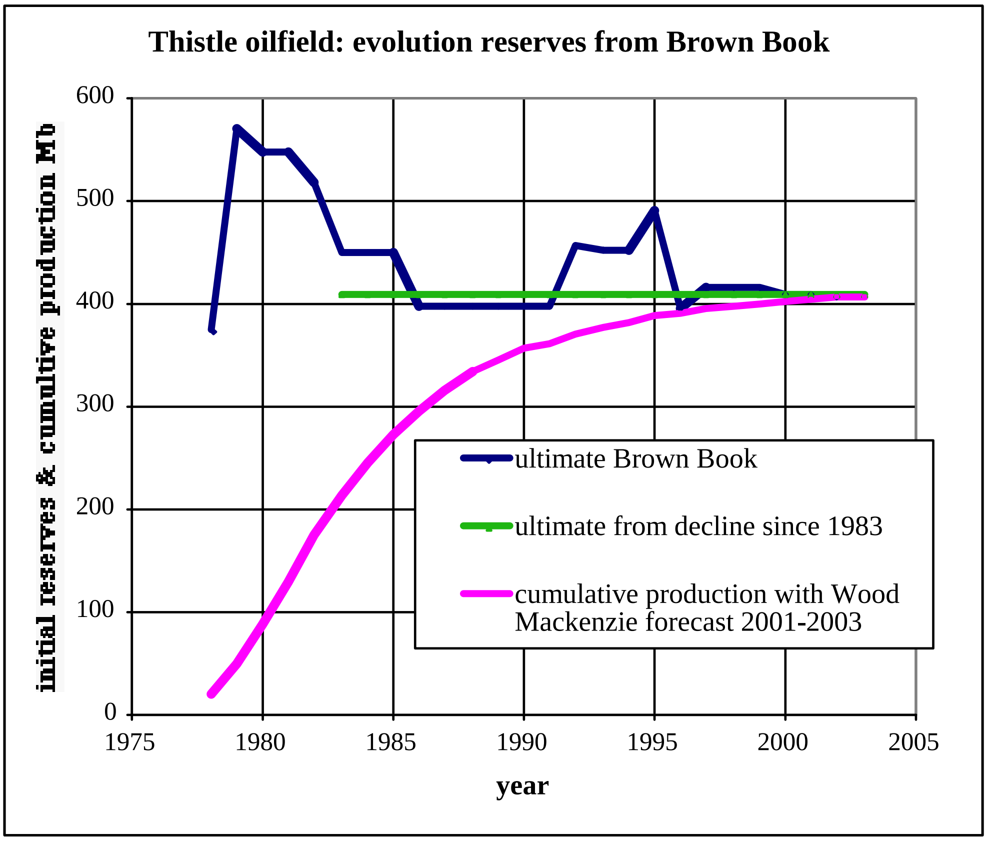
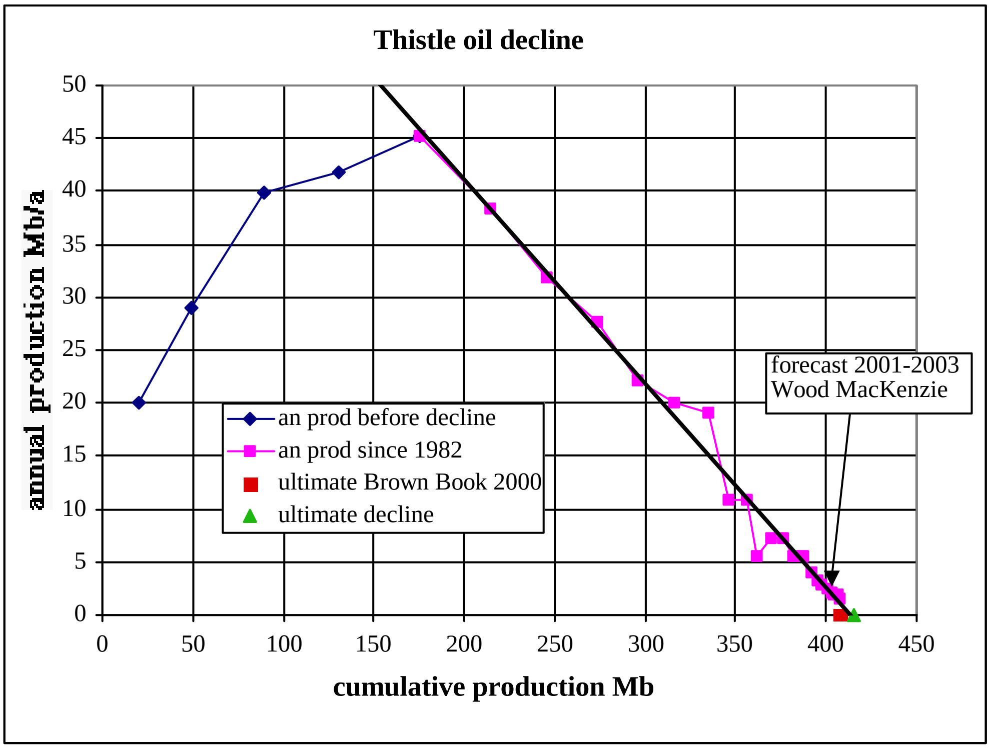


Figure 64:

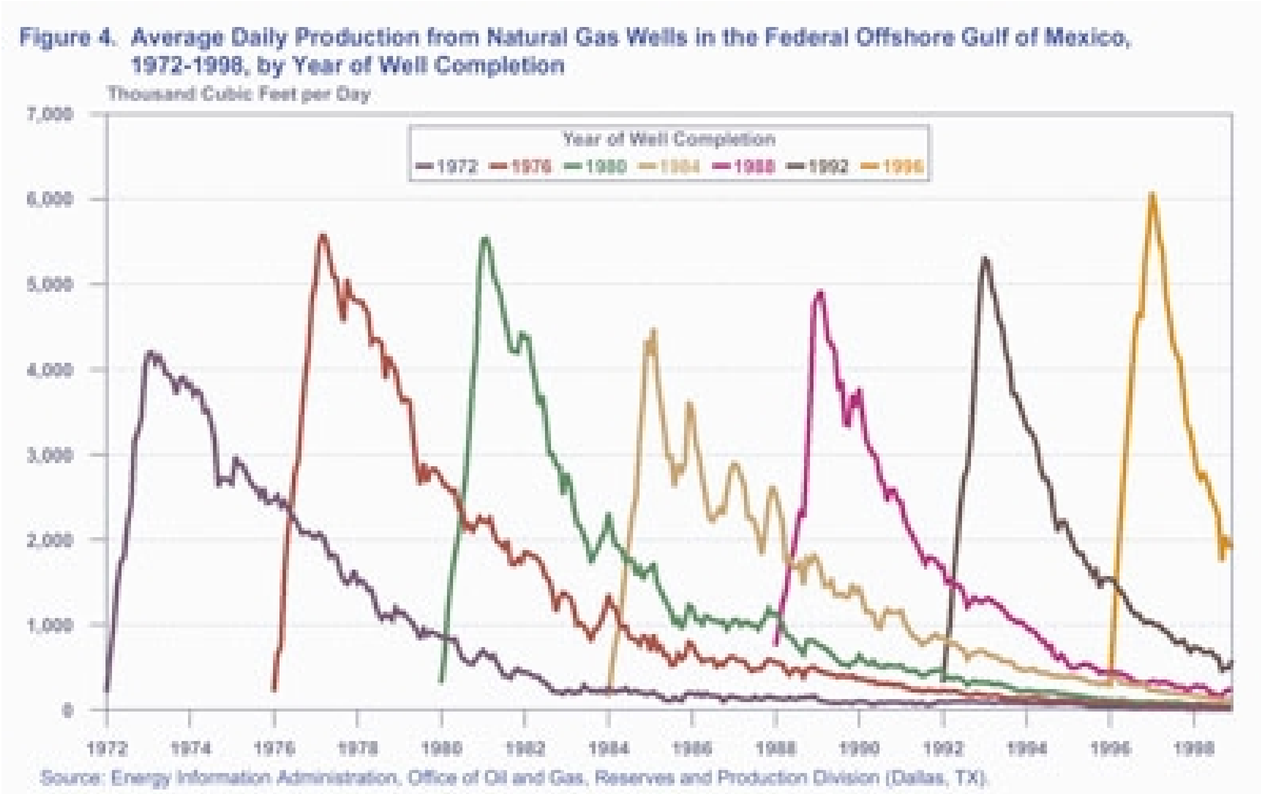


5.3 Technology: impact on reserves: conventional little, unconventional large

Conventional:

Technology on conventional fields has for main impact to produce cheaper and faster. The big improvement is in depletion rate of the producing wells, as it has increased from about 10%/a to 50%/a. The increase in depletion rate is higher for gaswells as shown in this graph for the GOM. From an USGS study on accelerated depletion.

Figure 65: Daily production from gaswells in GOM OCS from 1972 to 1996 (every 4 years)



As shown for Forties oilfield decline, technology progress (gas flooding) allows to produce faster but does not increase the reserves.

Unconventional

In contrast to conventional fields, technology progress is a « must » in unconventional fields to increase the reserves.

Orinoco heavy oils in Venezuela are now produced without steam but with cold production thanks to horizontal wells with pumps just above the reservoir.

But geology is much more important than technology and the best results from the Orinocco plants will be found at the best geological places where the reservoirs are continuous, porous and permeable.

5.4 Oil price impact

Most economists confuse resources and reserves and believe that an oil price increase will increase the amount of reserves. Outside the US stripper wells, oil price has a little impact on the production rate that depends upon the reservoir characteristics and the surface equipment. The oil price has an effect on the decision to drill or not marginal prospects, but not on the production except for infilled wells and stripper wells which are classified as unconventional oil. Usually high oil prices correspond to a decrease in success ratio, as poor prospects are drilled.

Most of the misunderstanding on this point comes that the economists treat oil and gas fields as mineral deposits as coal, copper, gold or uranium. The production of a mine depends of the economical cut-off and the low concentrated ores are treated as wastes. When the price of the mineral increases the low-grade ores are considered as new reserves. In case of oil, oil is liquid and it is produced directly without needing any concentration plant (water is simply eliminated), it is even better for gas. An oilfield is already concentrated deposit and does not need to be concentrated further, it is drilled, capped and when flowing it is only necessary to open the tap to produce it.

Furthermore economists consider only the money involved, omitting to look at the "net energy" or the energy return on invested energy. The net energy can be negative as it is often for the ethanol from corns.

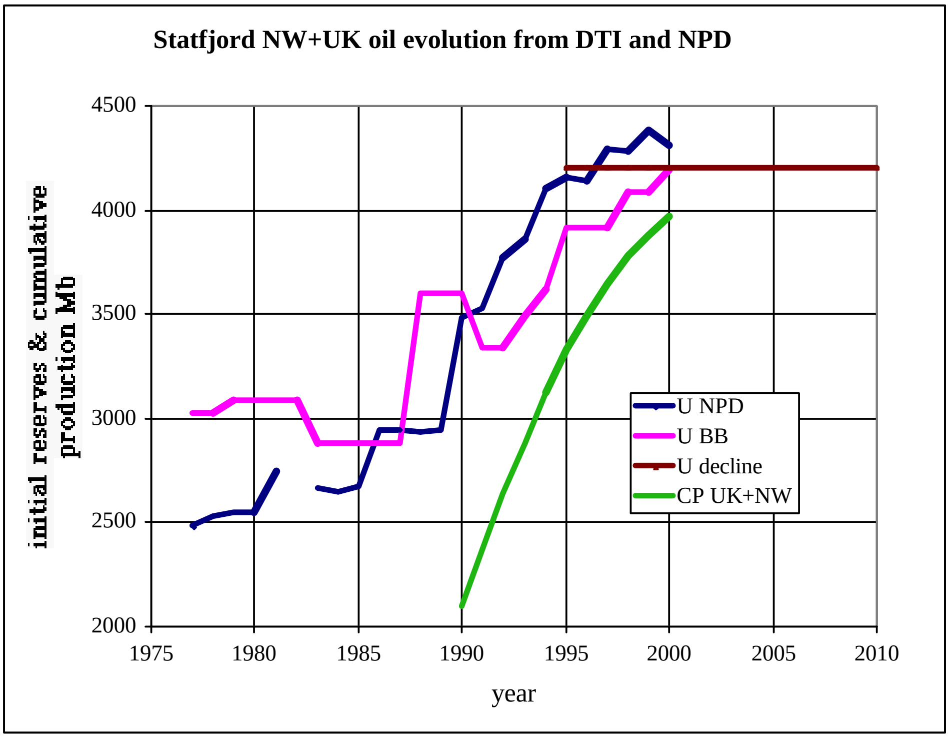
5.5 Difference between old fields and new fields

Reserve growth analysis has to be performed using data on modern discoveries in order to properly extrapolate estimated reserves to the future. Most of the reserve growth in the Lower 48 states comes from Californian heavy oilfields found a century ago, with the Midway-Sunset oil field shown to be the best example of reserve growth by Schmoker USGS 2000 FS 119-00. The Minerals Management Service (MMS) has elaborated a model for the Gulf of Mexico (GOM) and their reserve growth curve is only about half of the Lower 48 reserve growth function used for the world outside the US in the USGS 2000 assessment. The 1999 Annual Report by the US DOE/EIA gives positive reserve additions for the federal GOM (Louisiana) of 693 Mb and negative revisions of 730 Mb. They also report 2 Mb for adjustments, 55 Mb for extensions, 238 Mb for new field discoveries and 77 Mb for new reservoirs in old fields, 376 Mb for production and proved reserves went from 2483 Mb in 1998 to 2442 Mb in 1999. For this area, the negative revisions were larger than the positive revisions in 1999 (in 1998 they were about the same) which means that reserve growth could be about zero for the GOM where 78% of the oil was discovered before 1980.

5.6 Poor and contradictory data

When the same field is shared by two countries as Statjford oilfield, the estimates from the two national agencies differ much more than the reported growth from one source. In 1998 the ultimate was estimated at 4386 Mb (4 significant digits what accuracy!) by NPD and 4088 Mb by the Brown Book but in fact the decline estimate gives 4200 Mb since 1995.

Figure 66:



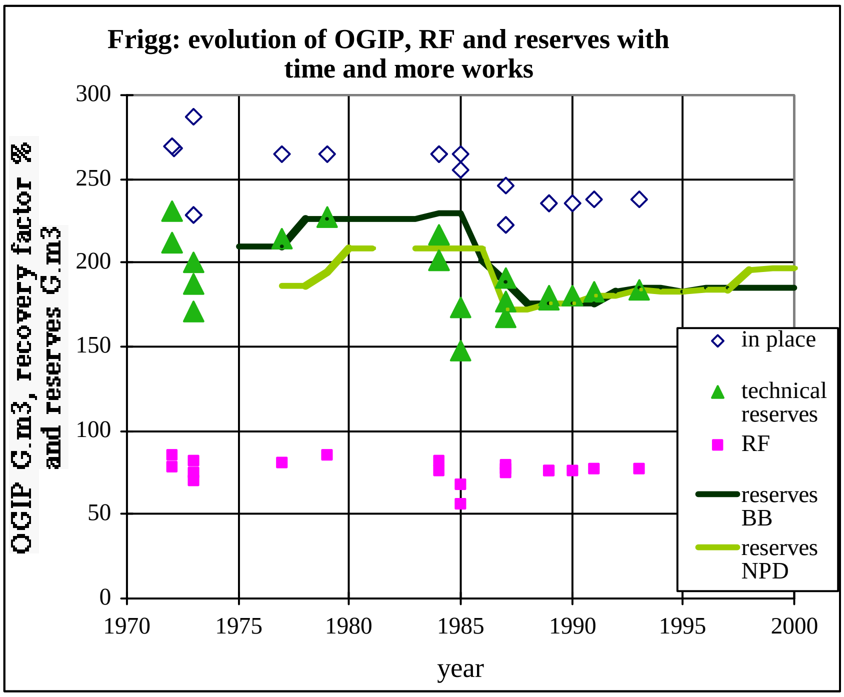
But getting two different sets of annual production data disturbs the assessment as shown be the two different declines from the data from Petroconsultants or from Wood Mackenzie. The difference could be NGL or bad conversion from weight to volume as oil is reported in Mt in UK and M.m3 in Norway.

The problem is not reserve growth but poor reporting first of the data and second of the decline value.

Reserve growth could be established only when the trend is stronger than the normal uncertainty of the measures.

In the case of the Frigg gasfield (again at the bounder, shared by UK and Norway), Torheim 1996 gives the range of the technical data

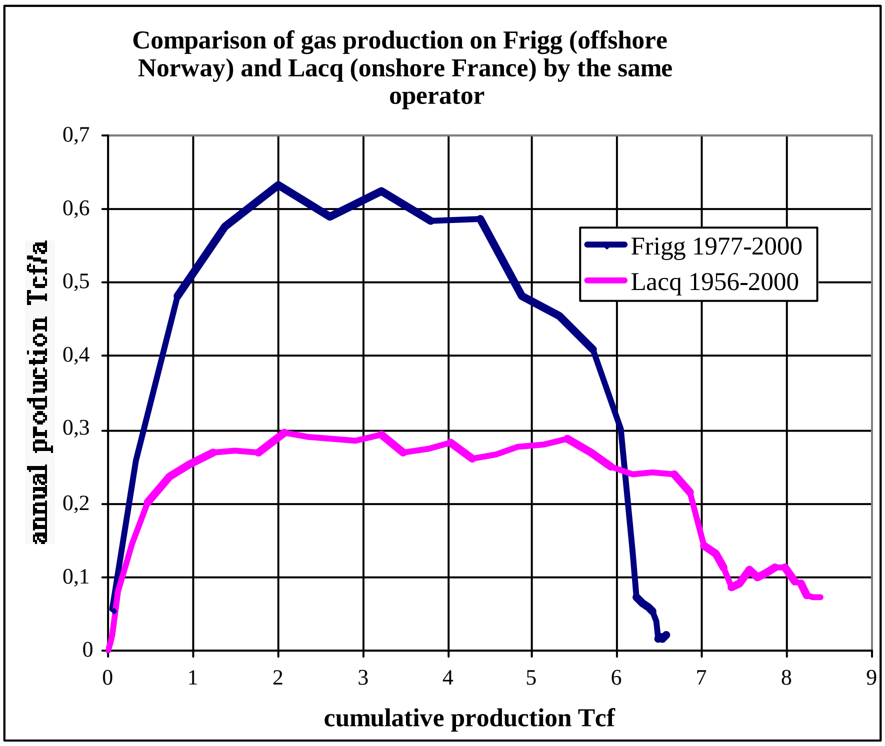
Figure 67:



In 1975 the reserve range was between 165 and 230 G.m3. The highest value was officially reported in order to get the highest DCQ (daily contractual quantity) giving the highest profit. The gas in place varies as the reserves as the RF stays around 75%, except for one study.

The comparison of the depletion of Frigg offshore UK-NW and Lacq onshore France is striking as they were depleted by the same operator (Elf) but Frigg in 20 years (plateau over 5.5 Tcf/a from 1980 to 1985) and Lacq in 50 years (plateau over 0.2 Tcf/a from 1961 to 1985). However because of high H2S in Lacq gas the capacity of the plant to extract the sulphur was a constraint for this field

Figure 68:

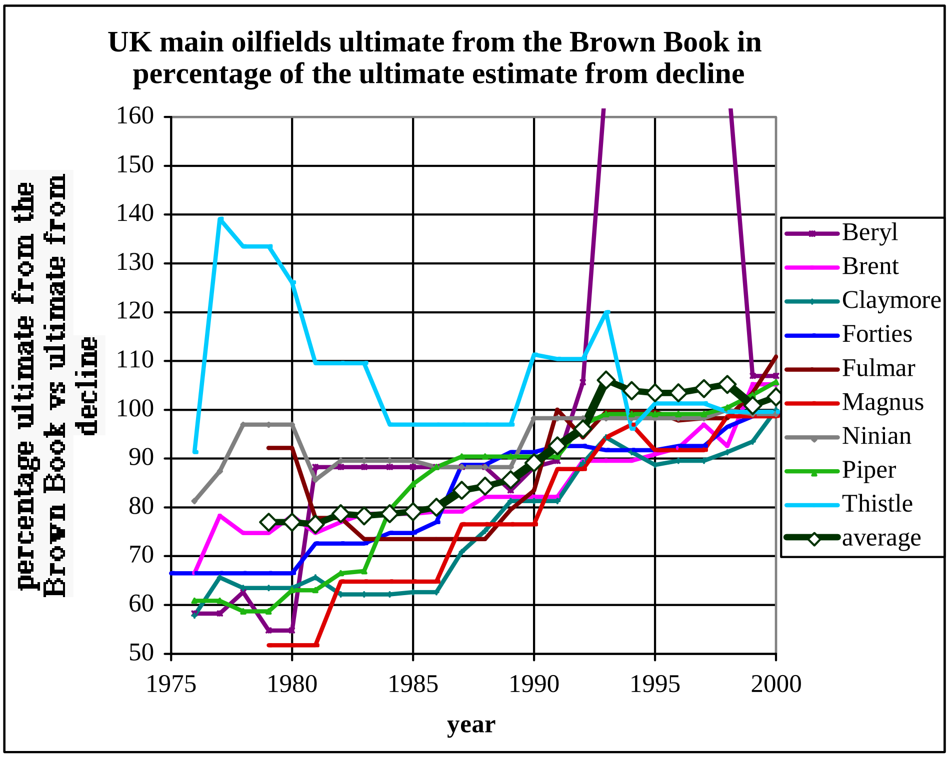


Reserve growth for the world outside the US will provide positive growth in some countries but negative growth in others (as was the case for the 20 Gb Mexican decrease, OGJ December 1999). The global result is likely to be negative, but at the most nil, in contrary to USGS 2000 assumption.

5.7 Examples from the UK on estimates reported in the Brown Book

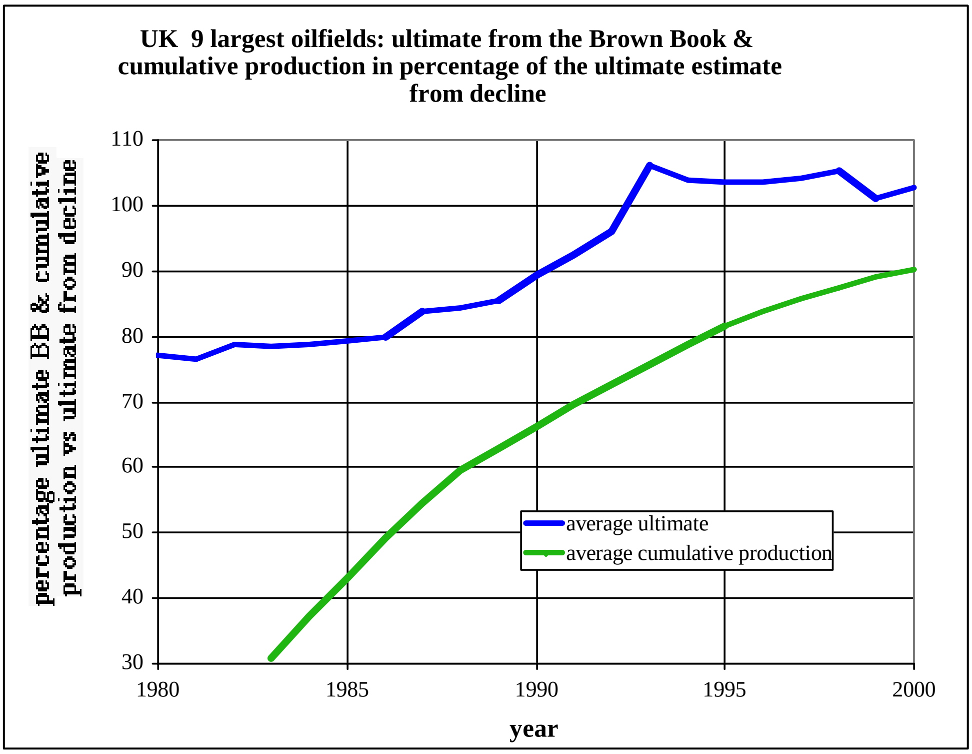
The evolution with time of reserve estimates for 9 major UK oilfields from the Brown Book is displayed as a percentage of the real value estimated from the decline of each field. Most of fields behave similarly except Beryl that went through an exceptional increase to be 170% overestimated.

Figure 69:



It shows that the average went into a growth from 1980 to 1993 but it was already overestimated since 1993 and in 2000 it is still 2% overestimated. The reserve growth started when over 50% of the ultimate was produced and flattened when 75% was produced. Now 90% has been produced.

Figure 70:

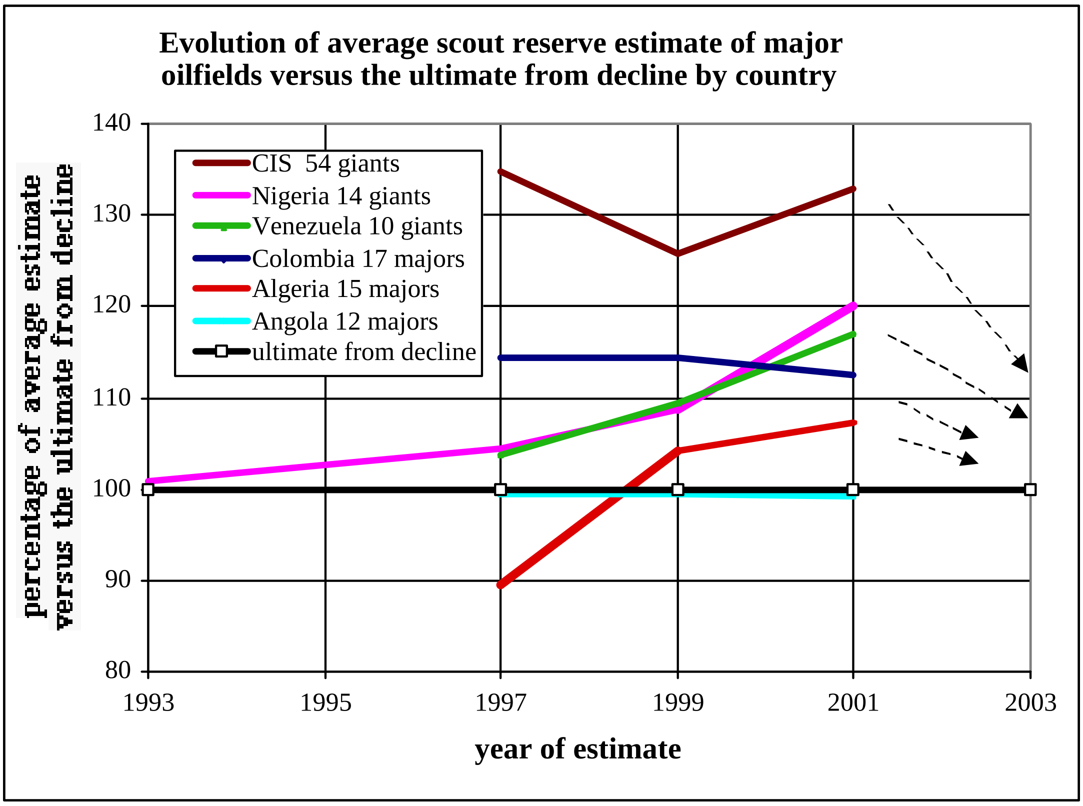


5.8 Evolution of average "scout" reserve estimate of major oilfields in 6 different countries.

The annual production data from major oilfields in FSU, Venezuela, Colombia, Nigeria, Algeria, Angola were used, despite some missing years, to estimate the decline ultimate when the decline was fair enough to extrapolate to the end of production.

The evolution of the percentage of the reported "scout" value to the decline ultimate was averaged by country and displays on figure 71. Except Angola, all other countries show overestimation and in most the overestimation still continue to grow. There will be hard landings!

Figure 71:



All these examples prove that reserve growth is often positive but also often negative. The global result is still uncertain but likely negative. The first thing is to improve the estimate and reporting of reserves.

In conclusion, reserve growth occurs from bad reporting practice, as for example in reporting only proved reserves. Furthermore the USGS practice to evaluate the reserve growth as a multiplier of the estimate of the year of discovery is misleading, as this estimate is premature, still incomplete. In the past it was considered that 5 years were needed to get a reliable value.

But when reserves are estimated as the mean value, reserve growth still exists as only good news are reported and bad news (and marginal discoveries) are either hidden or put outside to be delivered later on. It was not hidden in FSU (Khalimov statement) but ignored as oil companies are looking for hunting grounds and they are described FSU as plentiful to attract investments.

6 Reserves & Resources

The study of hydrocarbons generated in Petroleum Systems where elaborated studies with Rock-Eval analysis were carried out, is to be found in our 1994 report « Undiscovered petroleum potential ». It shows that the oil concentrated in oilfields represents less than 1% of the oil generated. It means that there is a huge discrepancy between the oil in the sediments and the oil concentrated in oilfields that will be produced. If reserves are badly defined, it is even worse for resources that can be the oil in place in fields, the undiscovered, and the ultimate.

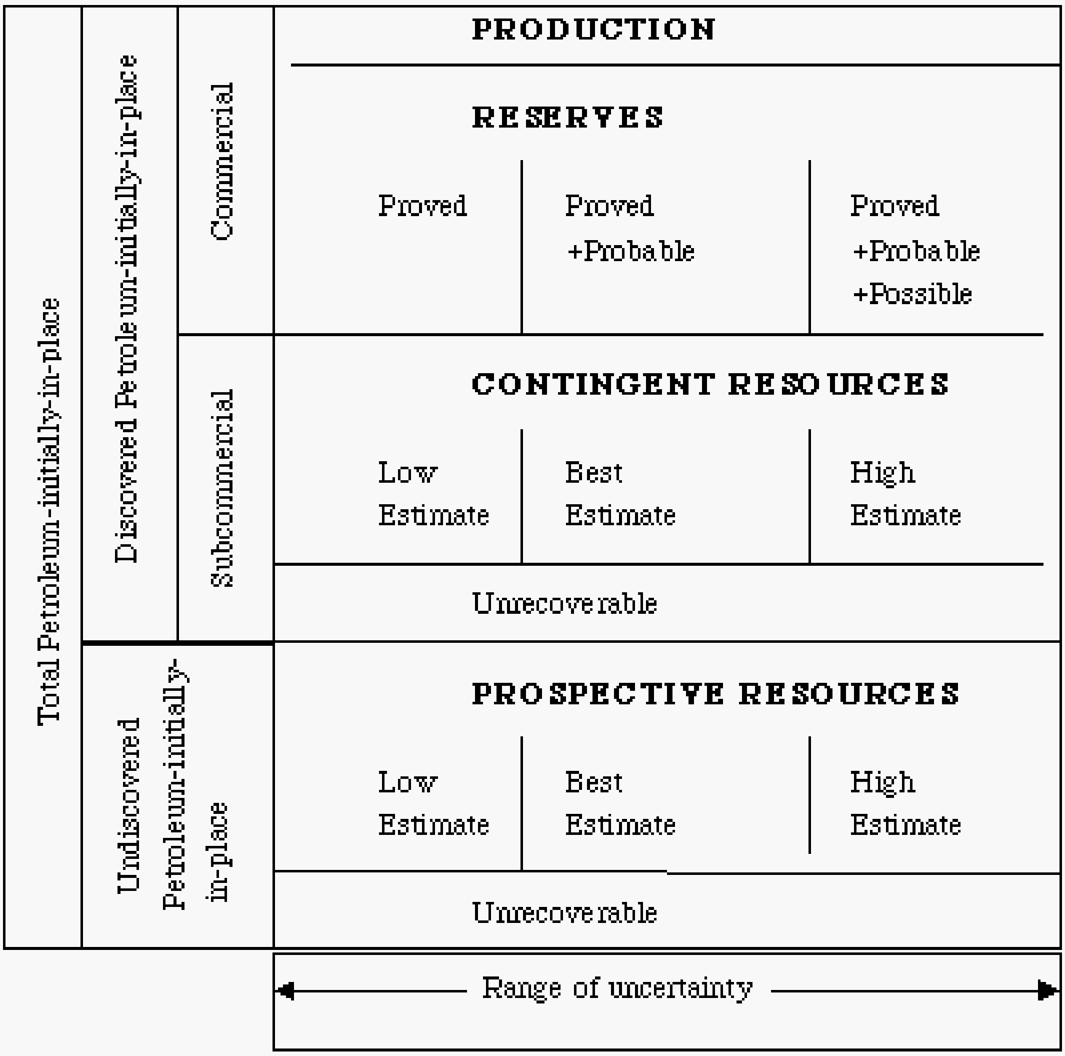
The confusion between reserves and resources is the main problem when discussing the matter with economists. When oil (or coal) is no more produced in a basin the reserves are nil, but there are still oil (or coal) in the ground, and there are still resources.

Some use wrongly recoverable reserves but it is a pleonasm as reserves are what are recovered

The use of resources should be restricted to future production in addition to the known reserves coming from either known fields or undiscovered fields, as indicated in the new SPE/WPC/AAPG definitions.

Resource classification system from SPE/WPC/AAPG

Figure 1: Resource classification system



Approved by the Board of Directors SPE, the Executive Board WPC and the Executive Committee AAPG Feb 2000

About 90% of reserve additions are revisions of past estimates because probable reserves are ignored. Good practices should lead to statistically neutral revisions. In the rest of the world, such as the North Sea, reserves are reported as proven + probable. Development of a large offshore platform only occurs after several appraisal wells have determined that the proven + probable reserves are sufficient to justify a profitable development. Proven reserves are inadequate for such an analysis. A. Martinez (head of the SPE/WPC/AAPG reserve task force) has approached the SEC to accept proved + probable instead of proved reserves. In Russia, use of reliable reserve data will lead to negative reserve growth from 3P to 2P.

7 Ultimates

World ultimates have been assessed by aggregating regional studies, in the past using the volume of sedimentary basins and analogy with other producing basins, later extrapolating creaming curves or sizes distribution of mature basins. It was done by country, or by tectonic basins, or lately by genetic basins (Petroleum System). It was mainly done by the major companies, but they stopped when they reduced staff and when the results started to look sad. Now it is left to governmental agencies (as the USGS) or contractors (as Robertson) or to retired oil geologists concerned about the future of their grandchildren.

7.1 Retired oil geologists group

Our ultimate estimate involves more than seven years of study by four retired exploration geologists: Alain Perrodon, who was the first to introduce the term Petroleum System, Gerard Demaison, who quantified generation of a Petroleum System, Colin Campbell and myself.

We are also in very close contact with two famous US retired geologists: Walter Youngquist (Geodestinies 1996) and Buzz Ivanhoe (Hubbert Centre at the Colorado School of Mines).

The four reports totalling 1250 pages from 1994 to 1998 are:

-Laherrère, J.H. A.Perrodon, and G.Demaison 1994 " Undiscovered Petroleum Potential"; Petroconsultants Report 383p March

-Laherrère J.H., A.Perrodon, and C.J.Campbell 1996 "The world's gas potential" Petroconsultants Report July, 200p, CD-ROM

-C.J.Campbell C.J.& J Laherrère 1995."The world's oil supply -1930-2050", Petroconsultants Report 650p, CD-ROM

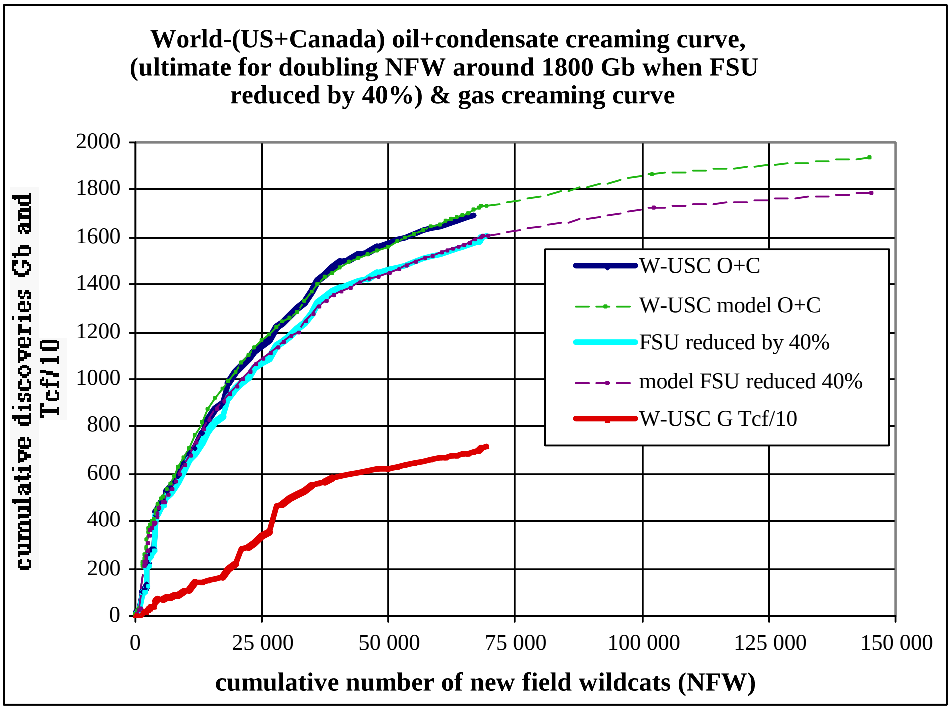
-Perrodon A., J.H. Laherrère and C.J.Campbell 1998 "The world's non-conventional oil and gas"; Petroleum Economist March report 113p

Our ultimate is as follows:

Perrodon et al 1998	mini	mean	maxi
Conventional oil	1 700	1 800	2 200
Conventional gas liquids	200	250	400
Non-conventional liquids	300	700	1 500
Ultimate liquids Gb	2 300	2 750	4 000
Conventional gas	8 500	10 000	13 000
Non-conventional gas	1 000	2 500	8 000
Ultimate gas Tcf	10 000	12 500	20 000

Our ultimate of 2000 Gb for oil +condensate estimated in 1998 is confirmed (+/- 10%) by the update with 2001 data of the creaming curve giving 1800 Gb for the world outside US & Canada and with an ultimate for US & Canada of 250 Gb.

Figure 72:

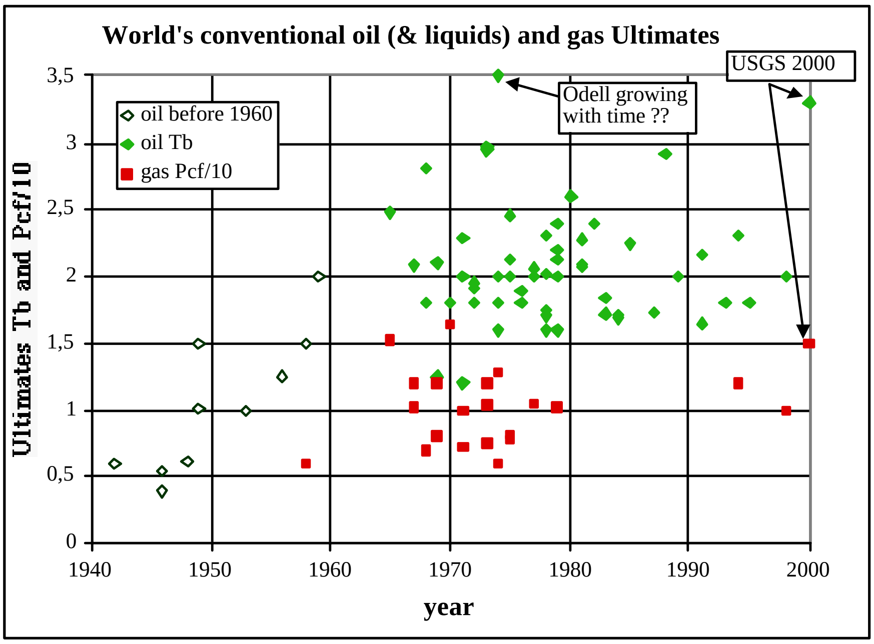


Our estimate is also in line with most of the estimates made over the past 60 years

7.2 Evolution of ultimates

The record of published ultimate estimates since 1940 is plotted on figure 75 and the average around 2 Tb for liquids (conventional) and 10 Pcf for conventional gas levelling since 1965.

Figure 73: Past estimates of conventional oil ultimate



Relying on the evolution of heterogeneous values to get the ultimate of ultimate (Odell & Rosing) 1974) has no geological meaning and is little more than a mathematical game! Let us return to the basic data and to the geologists who have carried out the assessments in detail.

P-R Bauquis (Journee de l'Energie Paris Mai 18, 2001): "There is practically no increase in the estimate of conventional oil ultimate from 1973 to 2000."

7.3 USGS world assessment 2000

This study was a good project to define first all the Petroleum Systems of the world with the help of the major oil companies and to draw good maps, but the results were poor because the oil companies did not participate in the assessment, preferring to keep their knowledge and ideas confidential since they were competing with each other for the prime areas. It was left to a single USGS geologist to assess each individual basin (in the past it was done with Delphi inquiries involving many geologists). It was done without the benefit of seismic coverage and well data. Most of the estimates were made by academic geologists with little oil exploration practice. The database for reserves by field was 1995 & 1996 was out of date for a 2000 assessment and it was also inconsistent, with Proved reserves being used for the US and Canada (P) and Proved & Probable reserves (2P) being used the rest of the world.

The USGS study is considered by some to be a geological rather than a statistical study. It relies on many Monte Carlo simulations based on poor estimates of undiscovered sizes and numbers. Furthermore the past discovery data is old data (1996) when better-updated data exist.

The only parameters asked to the USGS geologist were to give:

http://greenwood.cr.usgs.gov/pub/bulletins/b2165/B2165.pdf

-*Characteristics of the assessment unit*:

-the minimum size

-number of discovered fields exceeding the minimum size

-median size of discovered oil and gas fields

-probability of geological charge, rocks and timing plus the adequate location for activities

-*Undiscovered oil and gas Fields*

-number of undiscovered fields with minimum, median and maximum

-sizes of undiscovered fields with minimum, median and maximum.

A second page asks for the gas/oil ratio, the density, the sulphur content and the drilling depth and depth of water.

That was all that the geologist has to supply. From this sheet of papers, a lot of time and money were spent running Monte Carlo simulations. Out of the 32 000 pages of this report, apart the geological maps, the main hypothesis on the 105 ranked assessment units for undiscovered oil was only 105 pages. The five largest undiscovered provinces are given as:

Province	undiscovered oil
Mesopotamian Foredeep Basin	61 Gb
West Siberian Basin	55 Gb

East Greenland Rift Basins	47 Gb
Zagros Fold Belt	45 Gb
Niger Delta	40 Gb

7.3.1 East Greenland

The East Greenland is undrilled but non-exclusive seismic surveys are available (but very expensive) as shown in the figure 74. The USGS did not acquire this seismic data, but assume that it will show all the necessary components.

Figure 74:

The USGS assessment gives a 100% geological probability of oil occurrence, but only 70% for access (it is covered most of the time with ice!)

The description of the Petroleum System is reduced to the following guess:

<<USGS PROVINCES: Northeast Greenland Rift Basins (5200) GEOLOGIST: M.E. Henry

TOTAL PETROLEUM SYSTEM: Permian/Upper Jurassic Composite (520001)

ASSESSMENT UNIT: Northeast Greenland Shelf Rift Systems (52000101)

DESCRIPTION: This assessment unit includes the continental margin off eastern and northeastern Greenland and is almost entirely offshore. The eastern boundary extends to the approximate position of the boundary between continental and oceanic crust, the northern boundary separates this province from the Wandell Sea Basin, the southern boundary is placed near lat. 70 N. and the western boundary is drawn to include the nearshore deep sub-basins on the shelf that have been interpreted from geophysical data.

SOURCE ROCKS: The principal source rock for this unit is expected, primarily by analogy with the Norwegian shelf and the Viking Graben of the North Sea, to be Late Jurassic shales of the

Hareelv Formation. Other potential source rocks probably exist in the unit and include, in order of expected importance, the Upper Permian Ravenfjeld Formation, Upper Carboniferous lacustrine shales, the Lower Jurassic Kap Stewart Formation, and other Devonian and Triassic beds.

MATURATION: Little published data exits in the offshore area regarding thermal maturity of these likely sources. Considering the probable depths of the source rocks in the numerous sub-basins that exist on the shelf, which are as deep as 10 km, thermal maturity for petroleum generation must have been reached at least locally in these depressions.

MIGRATION: Because of the nature of structural deformation in this unit lateral migration may be rather limited but vertical migration could have been important.

RESERVOIR ROCKS: Principal reservoir rocks are expected to be sandstones of the Middle Jurassic Vardekløft and Olympen Formations. Other important reservoir units include carbonate build-ups in the Upper Permian and sands of the Lower Jurassic Kap Stewart and Neill Klintner Formations.

TRAPS AND SEALS: The system of fault blocks, rotated generally landward, lead to the expectation that major traps are likely to be found in the uplifted side of the blocks and that faulting will be important in trap formation. Overlying shales will form top seals for many traps.

REFERENCES: -Christiansen, F.G., Dam, G., Piasecki, S., and Stemmerick, L., 1992, A review of Upper Paleozoic and Mesozoic source rocks from onshore East Greenland. -Larsen, H.C., 1990, The east Greenland shelf, -Price, S.P., and Whitham, A.G., 1997, Exhumed hydrocarbon traps in east Greenland–analogs for the Lower-Middle Jurassic play of northwest Europe<<

It is obvious that the USGS has no access to the seismics and that they speculate that traps will be there. Their references (1990, 1992 & 1997) are not up to date!

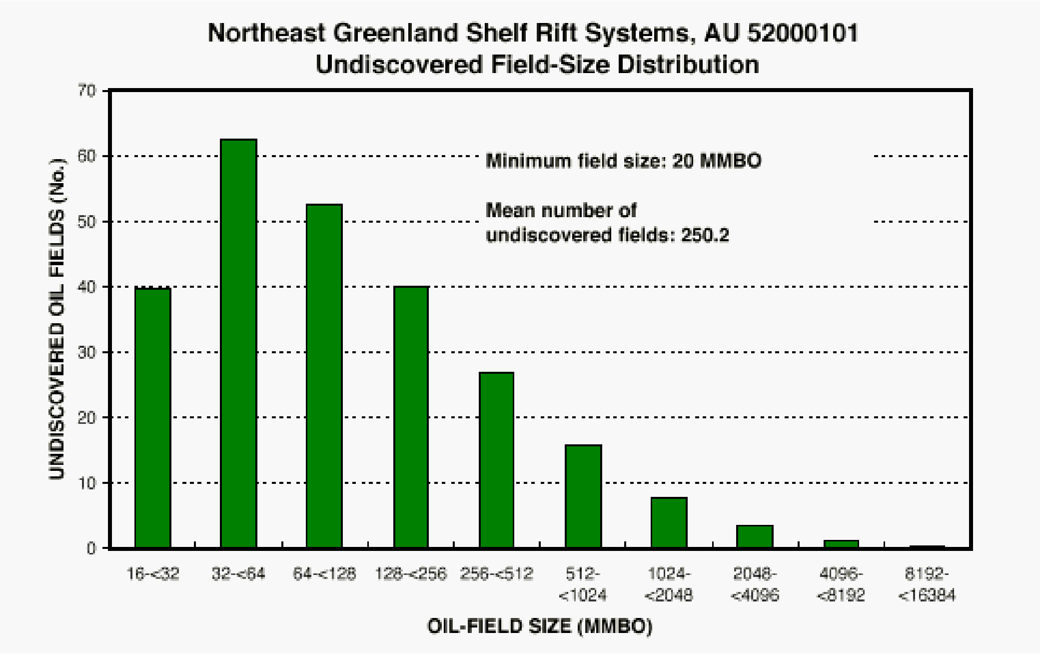
The distribution given by Henry is for oil: for the number, 1-250-500 undiscovered oilfields, for the size, 20-85-12000 Mb, for the gravity: 15-40-55 °API. For gas, the distribution is 1-50-100 in number and 0.12-0.5-20 Tcf in size.

These simple numbers with a huge range show that they come from nowhere, being just pure guesses and wishful thinking!

From this ungeological assessment, Monte Carlo simulation gives a beautiful distribution.

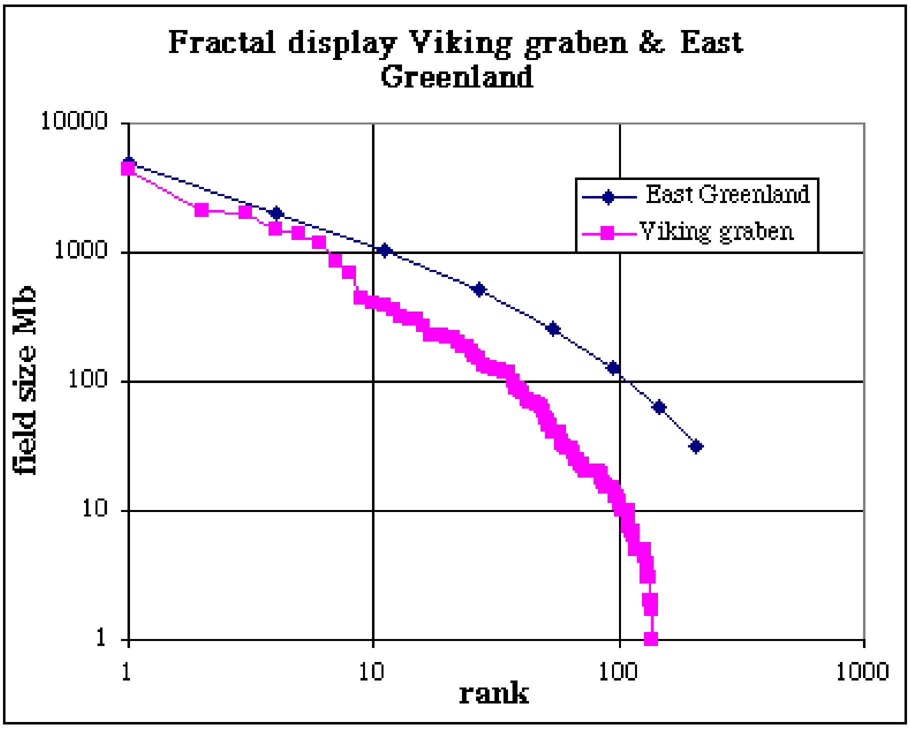
No scientific credence can be given to work of this sort.

Figure 75:



Comparing this assumed oil size distribution on East Greenland to the North Sea (Viking grabens) on a fractal display, shows that the assumed East Greenland is richer than the real North Sea.

Figure 76:



There are less than 40 oilfields larger than 100 Mb in the Viking grabens, whereas East Greenland is assumed to contain about 100 oilfields over 100 Mb (and the probability is supposed to be 100%!)

7.3.2 Lower 48 Reserve growth used worldwide?

Another dream from the USGS 2000 is about reserve growth. It is derived from the bad US practice of reporting, to comply with the SEC rules, only proved reserves when the rest of the world reports proven+probable. Ignoring probable reserves leads to a huge upward revision and 90% of the annual addition come from revisions of old discoveries.

Chuck Masters, the previous director of the studies, had a sound understanding of the position. and his USGS evaluation did not use Proved Reserves but Inferred Reserves (he corrected them to include Probable) and he pointed that the reserve growth is likely to be negligible in comparison of the large number of reported discoveries which are marginal and maybe never developed.

In the chapter of reserve growth in the USGS 2000 study; the authors Schmoker and Klett wrote:

<<<Therefore, patterns of reserve growth for the world as a whole are poorly understood, and the problem of quantitatively estimating world potential reserve growth is formidable. For most areas outside the United States and Canada, however, Attanasi and Root (1993) and Root and Attanasi (1993) concluded that successive field-size estimates were not sufficiently reliable and consistent to develop world-level reserve-growth functions. At the time of the World Petroleum Assessment 2000, available world field-size estimates still appear to be inadequate—in terms of completeness, quality, and internal consistency—to construct a credible world reserve-growth function. . That is to say, the preferred approach outlined above to developing a world reserve-growth function cannot be implemented because of data limitations. Given this conclusion, three reserve-growth options were considered for the World Petroleum Assessment 2000:

-1. Defer the forecasting of world potential reserve growth to some future assessment.

-2. Forecast potential reserve growth for those relatively few areas of the world where field-size estimates are adequate to establish local reserve-growth functions.

-3. Forecast potential reserve growth at the world level by using an analog model that incorporates the reserve-growth experience of the United States. The third option is the one that has been pursued, on the reasoning that, although the resulting preliminary forecast of world potential reserve growth carries much uncertainty, a greater error would be to not consider world-level reserve growth at all.

There are also several reasons why a reserve-growth function based on the Lower 48 states could overestimate world potential reserve growth:

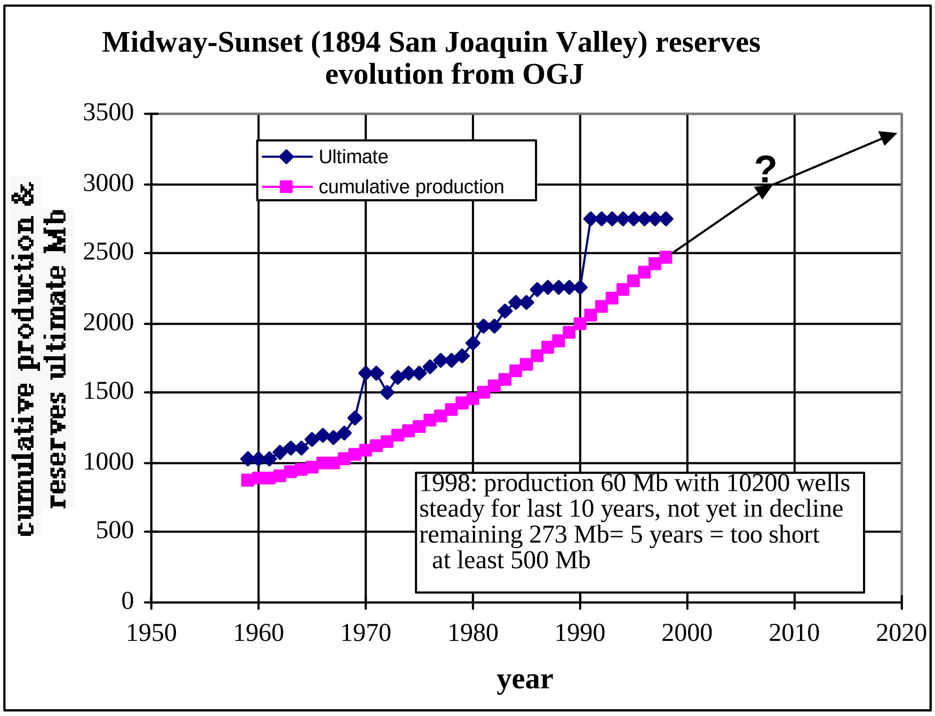
-Engineering criteria for reporting reserves of world oil and gas fields might, in general, be less restrictive than those for the United States, tending to increase known reserves and decrease the potential for reserve growth.

-Reported reserves might be deliberately overstated in some countries, reducing the potential for future reserve growth.

-Large world oil and gas fields might tend to have more substantial development than U.S. fields prior to release of initial field-size estimates, leading to more accurate initial reserves estimates and reducing the potential for future reserve growth. The balance that will ultimately emerge from these and other influences upon world reserve growth relative to U.S. reserve growth is unclear.<<<

Despite admitting that they are unable to give a reserve growth for the world, they use the Lower 48 for the rest of the world. This Lower 48 comes from the evolution of estimates made 50 years ago on onshore old fields at a time when seismic was not routine. And, even worse, they apply such a flawed method of assessment to present deepwater new fields. Schmoker (2000) uses the Midway-Sunset oilfield as the best example of reserve growth. This field was discovered in 1897 and is a heavy oilfield (13°API) classified by many as unconventional field. This field has not yet peaked a century later. It is not the best example to use, as most new fields will not produce for a century before peaking!

Figure 77:



My comments on this report: « Is the USGS 2000 assessment reliable? » was in the WEC

Cyber oil conference of May 2000.

There is only less than 40 oilfields larger than 100 Mb in the Viking grabens when East Greenland is assumed to contain about 100 oilfields over 100 Mb (and the probability is supposed to be 100%!)

7.4 Others:

Robertson Research International Ltd. (RRI)

The world's undiscovered liquids, according to a study by RRI (Fowler 2000), is about 440 Gb, compared to USGS 2000 of 939 Gb, but RRI did not mention any reserve growth when USGS 2000 adds 730 Gb, giving an addition of 1670 Gb for the next thirty. This is 50 Gb/a, which is utterly implausibly being more than three to four times what was discovered annually over the last ten years. If USGS is right, it means that the oil industry is incompetent, or the reverse?

Robertson uses a fractal display to assess the ultimate but mistakenly truncates the largest fields and draws a linear fractal, which is a poor way to assess a curve pattern.

Robertson commented the USGS 2000 report as: << We are surprised at the USGS outcome.<<

Shell International:

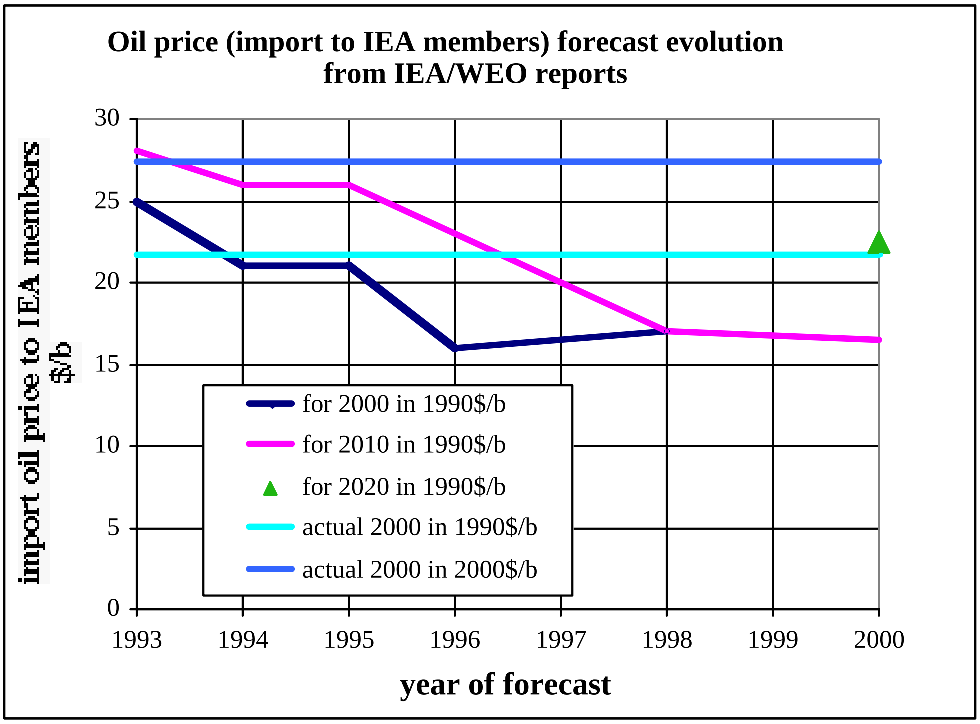
Ged Davis in the BBC "the Money programme" of Nov.8, 2000 « The last oil shock » estimates the undiscovered oil at 250-260 Gb, about one third of USGS estimate and not far from our estimate (200 Gb). He added that the improved recovery would add about the same volume.

8 Forecasts

8.1 Oil price forecasts:

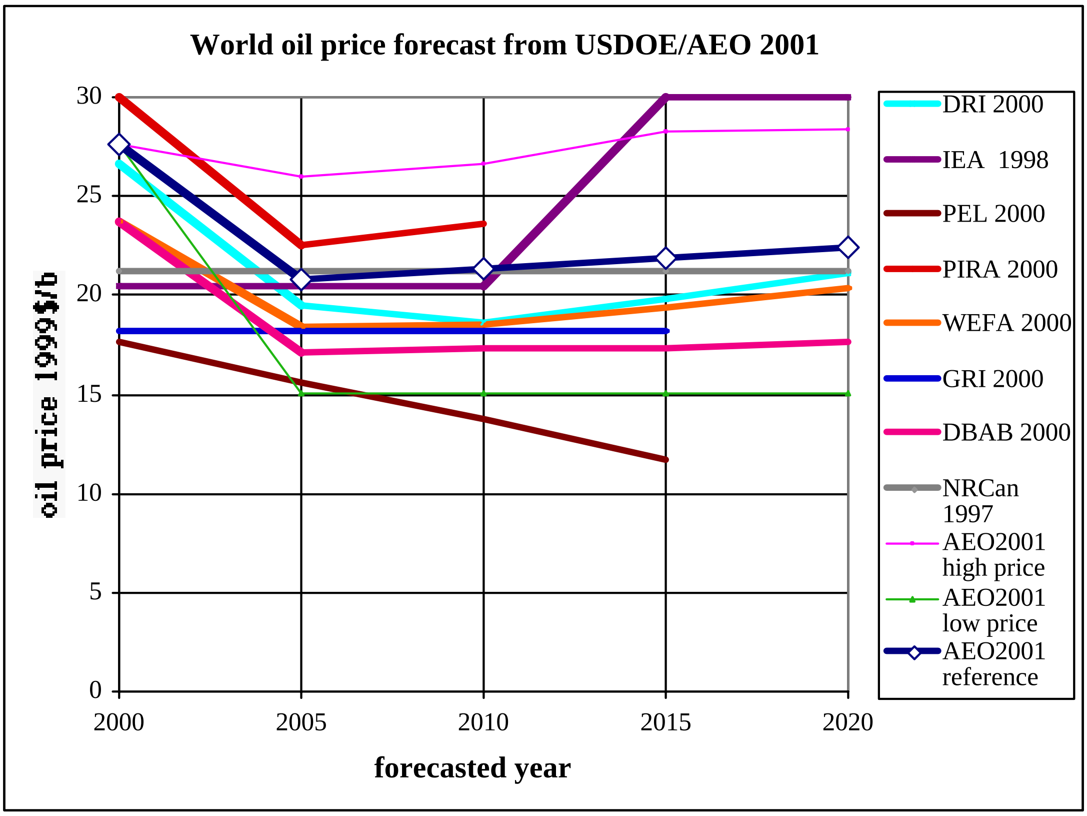
In IEA/WEO 2000 the evolution of the forecast on oil price (imports to IEA members) in 1990$/b for 2000 and for 2010 is given from 1993 to now. The real price on 2000 is lower than the 1993 forecast but higher than the 1996 to 1998 forecasts.

Figure 78:



A comparison of the world oil price forecast in 1999$/b for the next 20 years from different sources is given by the USDOE. For 2010 the range is from 13 to 27 1999$/b with an average of 18 $/b. Everyone can make his own guess as there is no expert in this matter.

Figure 79:



The USDOE oil price forecast in 1999 was an increase from 15 $/b to 20 in 2005 and flat then until 2020. In 2000 they corrected with a spike at 22$/b in 2000 (the price soared to 27$/b) returning to low price in 2001. This year forecast is the 2000 spike will be back to 1999 forecast in 2002. It seems that politics is more used than science and that there is a clear policy to keep the cheap oil forecast as the US way of life is based on cheap oil.

Figure 80:

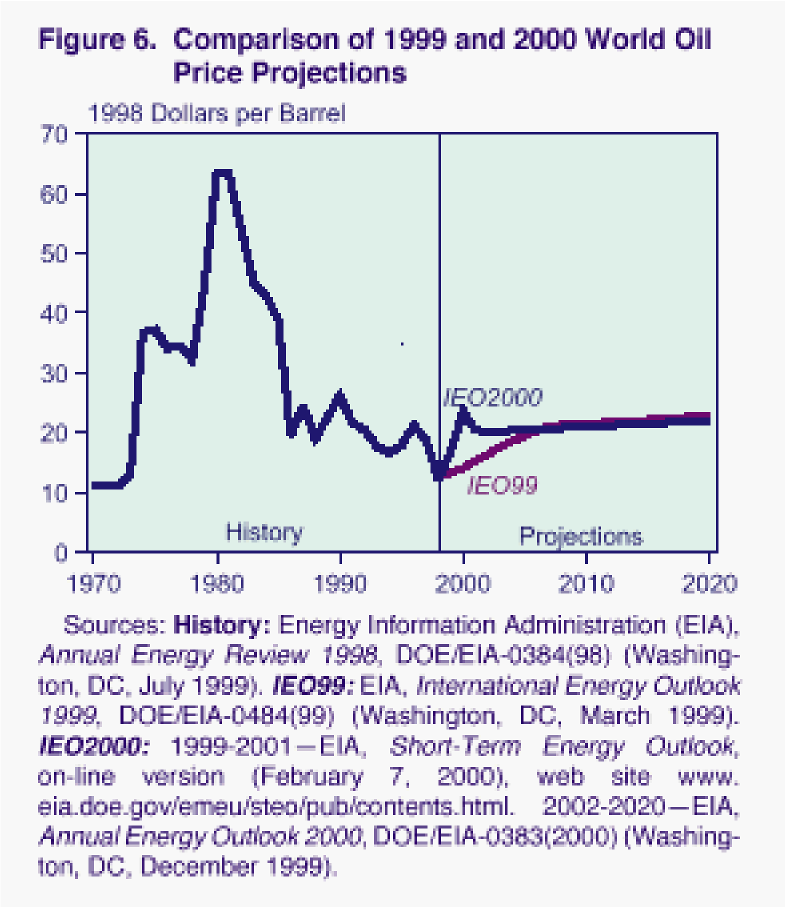
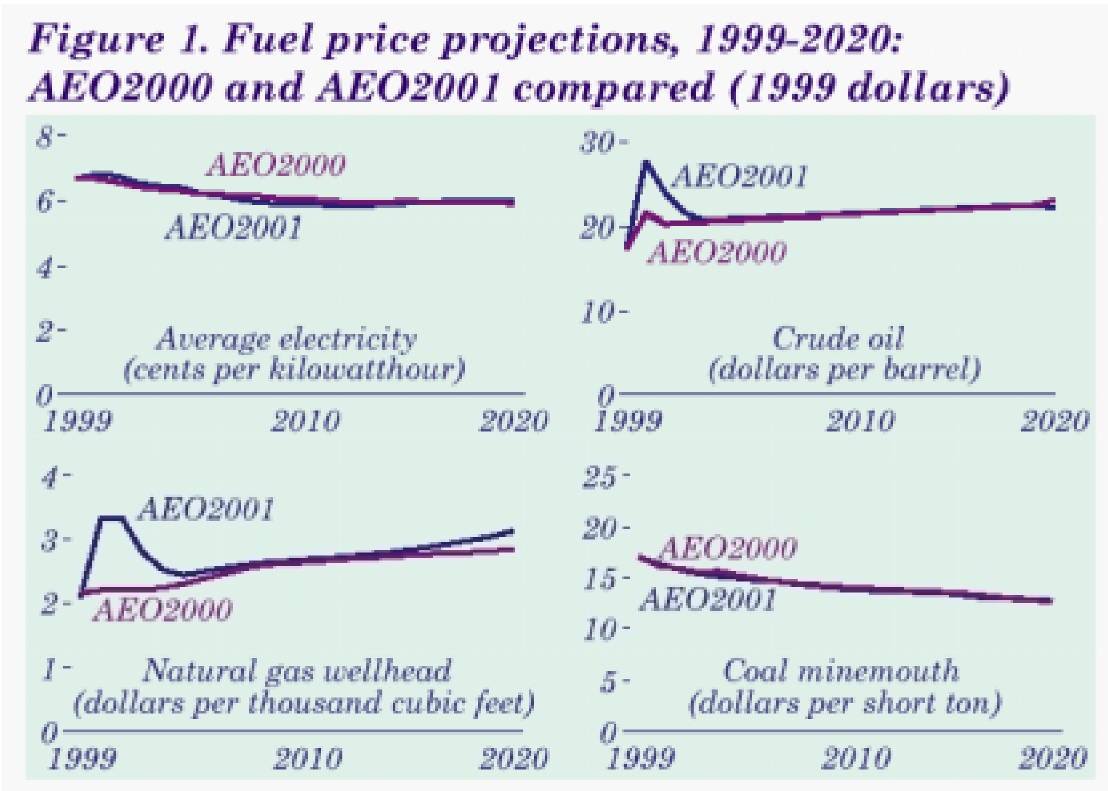


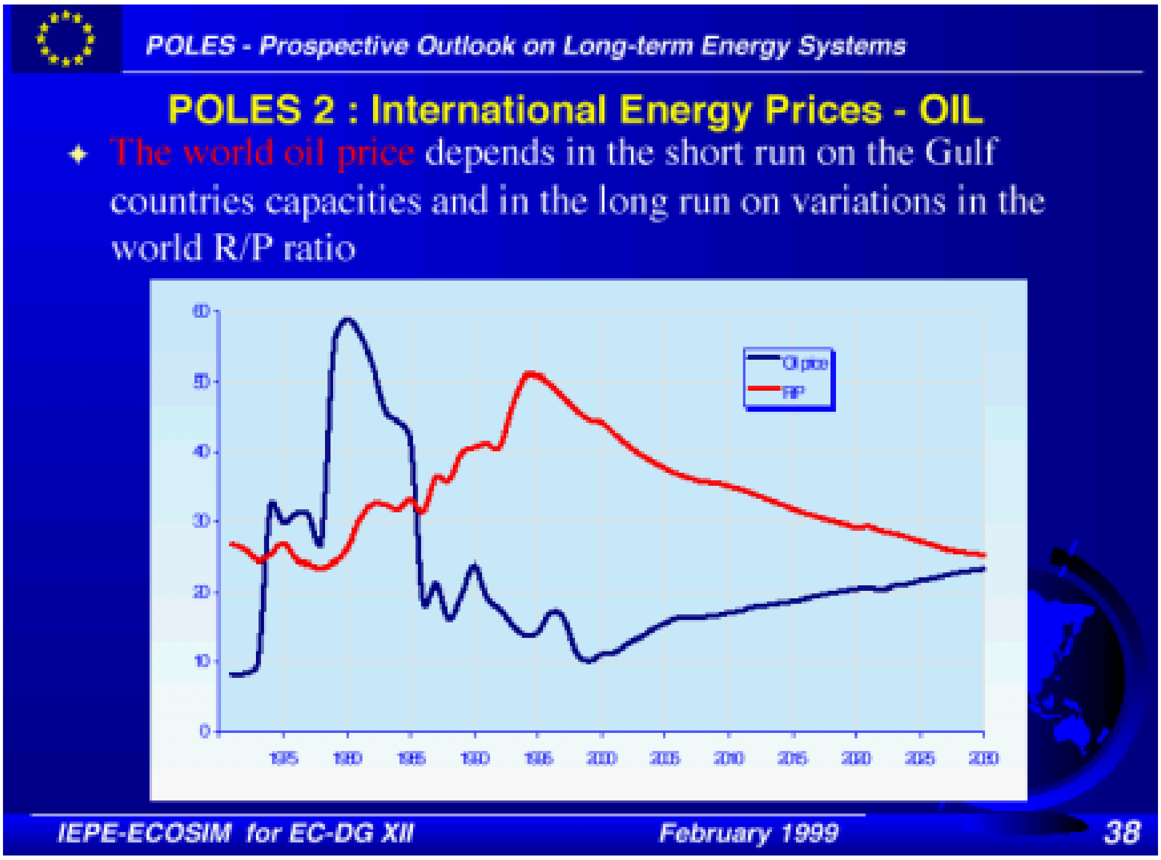
Figure 81:



It is the same policy in the European Union in this graph of February 1999 where the low price of 10$/b was related to the inverse of the world R/P (peaking in 1995) and forecasting only 20$/b around 2010! Ten months later the forecast for 2020 was overtaken!

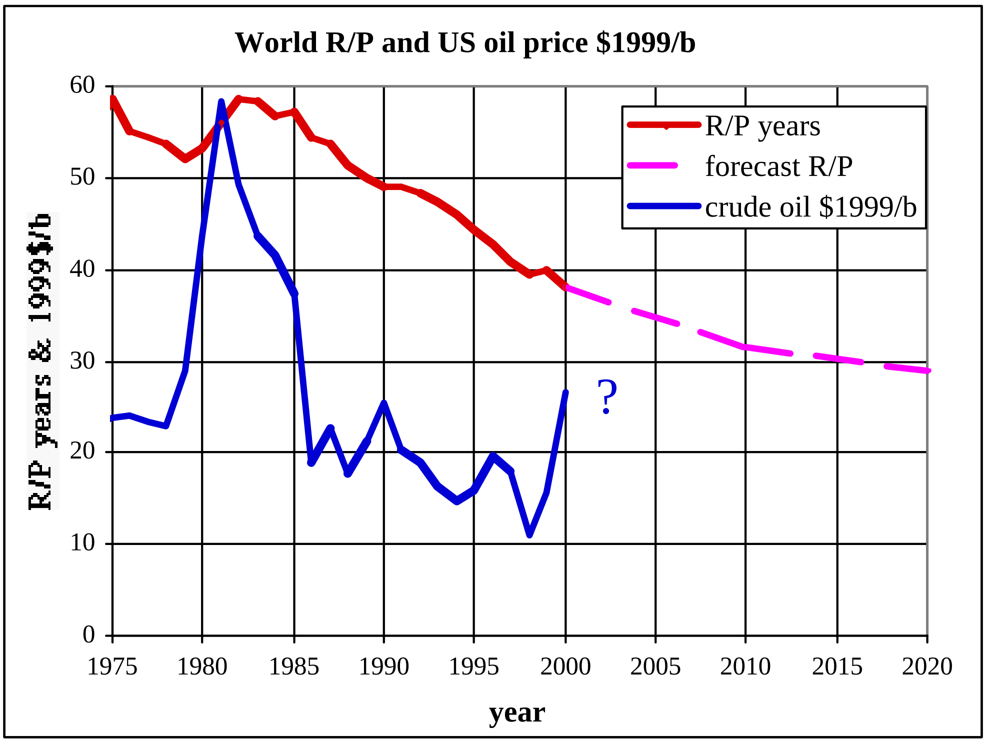
The R/P is the worst ratio to use as for example in the US the R/P has been around 10 years since the last 50 years, crossing the oil shocks and the rise, peak and decline of the US production. When production ends in the US there will still be a R/P of around 10 years as it is the rule of thumb for stripper well producers to assess their reserves by multiplying by 10 the present annual production. Sometimes when the USGS has no data on reserves they use this rule.

Figure 82:



Furthermore R is assumed to be proved reserves, and if mean value is used the ratio is quite different as shown in the next figure. The peak is ten years sooner. The R/P in 1980 was over 50 years and not 25 years as indicated by IEPE.

Figure 83:



While we have to wait many years to check if the forecast in volume is right, the impact on oil price comes much sooner. The consensus between official agencies is that in 2002 the oil price will be lower than the goal of OPEC to get 25$/b. If the average in 2001 is over 25$/b it will indicate that official forecasts are in trouble and if oil price stays at 25$/b in 2002 it will show the failure of the official forecasts. It will not be a surprise as the last oil shock (27$/b in 2000) was not forecasted by any agency or any economist. The only people in 1998 to speak about « The end of cheap oil » was us (Scientific American March 1998) and Franco Bernabe, CEO ENI before retiring, Forbes June 15, 1998 « Cheap oil: enjoy it when it lasts ») and Mike Bowlin CEO ARCO after having sold his company to BP (« last days of the oil age » Feb.1999). Finally in mid 2000 Brown CEO of BP announced that BP now means « Beyond Petroleum ».

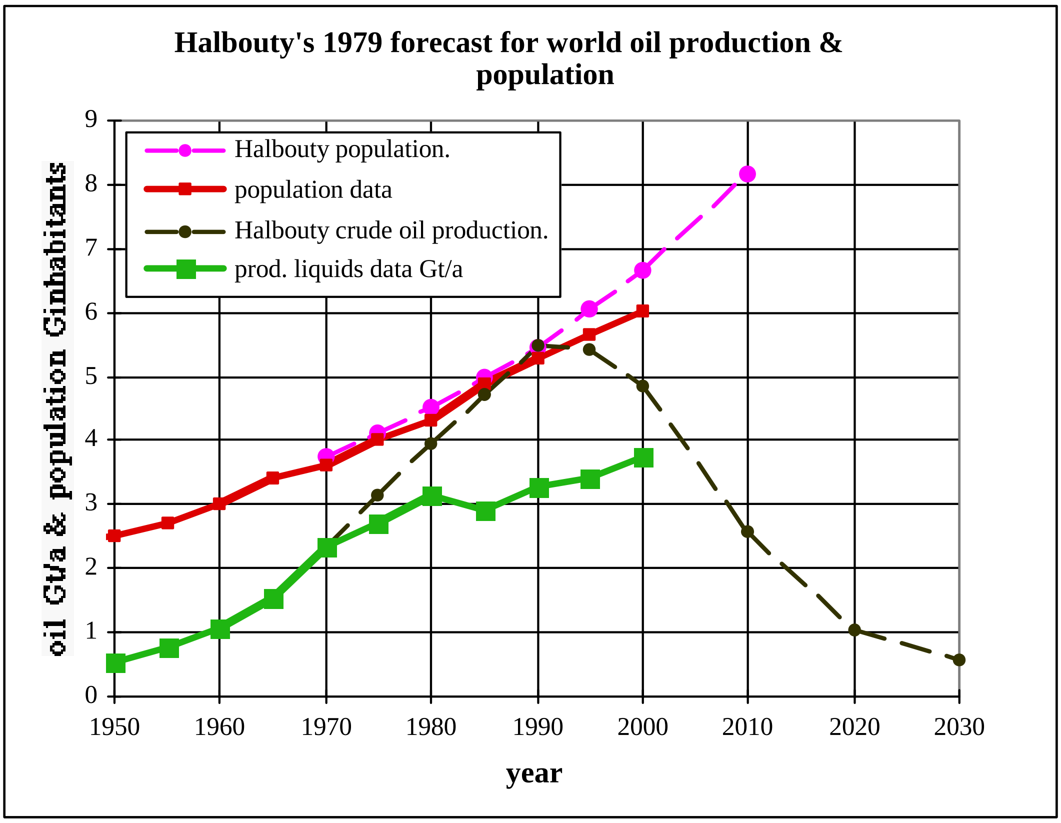
9 Future production

9.1 Past forecast: Halbouty–Moody 1979:

Forecasting future production is difficult because world events may intervene changing the patterns, as happened in 1979.

Moody J.D. and Halbouty M., two well known oilmen, presented forecasts of oil production and population at the World Petroleum Congress of 1979 ("World's ultimate reserves of crude oil"), as shown in Figure 16. They anticipated a production peak of 38 Gb/a in 1990 which was reasonable in resource terms, save that it failed to take into account the effects of the oil shocks of the 1970s which cut demand, such that 1979 production was not surpassed for fifteen years. So far as their population forecast is concerned, they assume exponential growth, which has not been experienced since.

Figure 84:



9.2 USDOE long term forecast

John Wood (2000) from the USDOE/EIA in his long term study was obliged to take into account the USGS study (3003 Gb for conventional ultimate) but he added two of my graphs (from “the end of cheap oil “ (Scientific American 1998) and from “the world’ non-conventional oil and gas” (2000 Gb for conventional plus 750 Gb for unconventional) (Petroleum Economist 1998) to show that he accepted the possibility of alternative interpretations.

Figure 85:

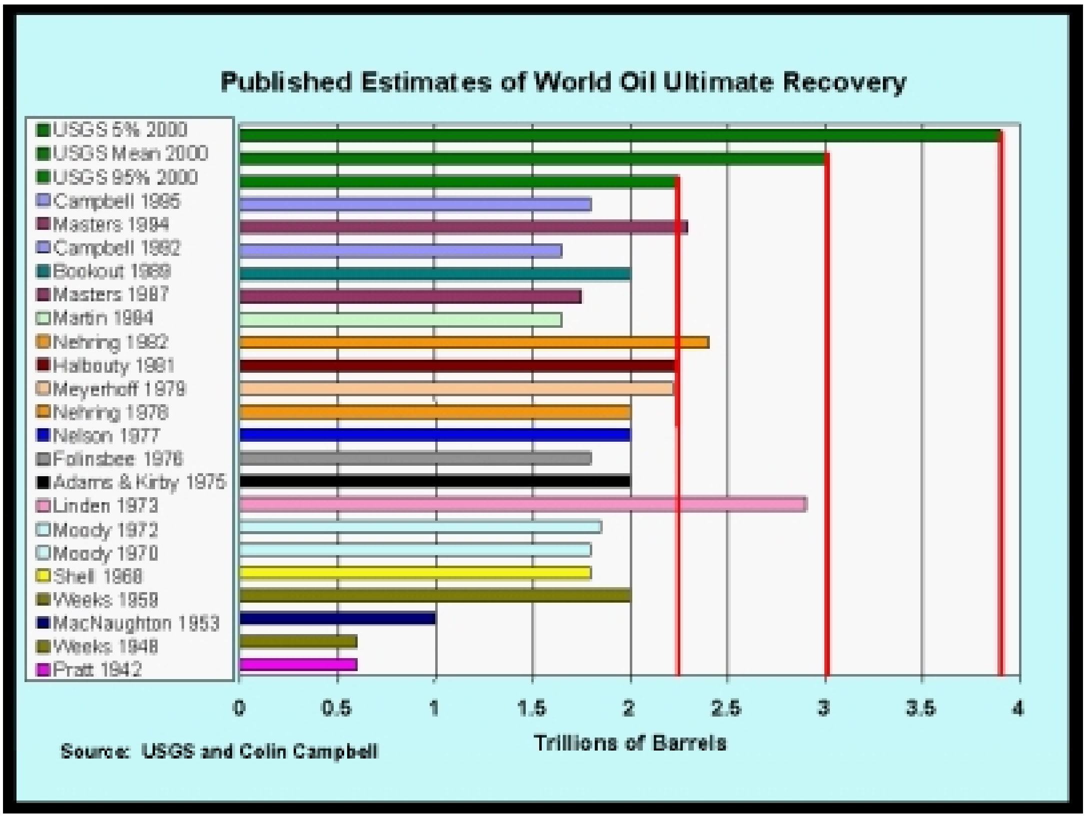


Figure 86:

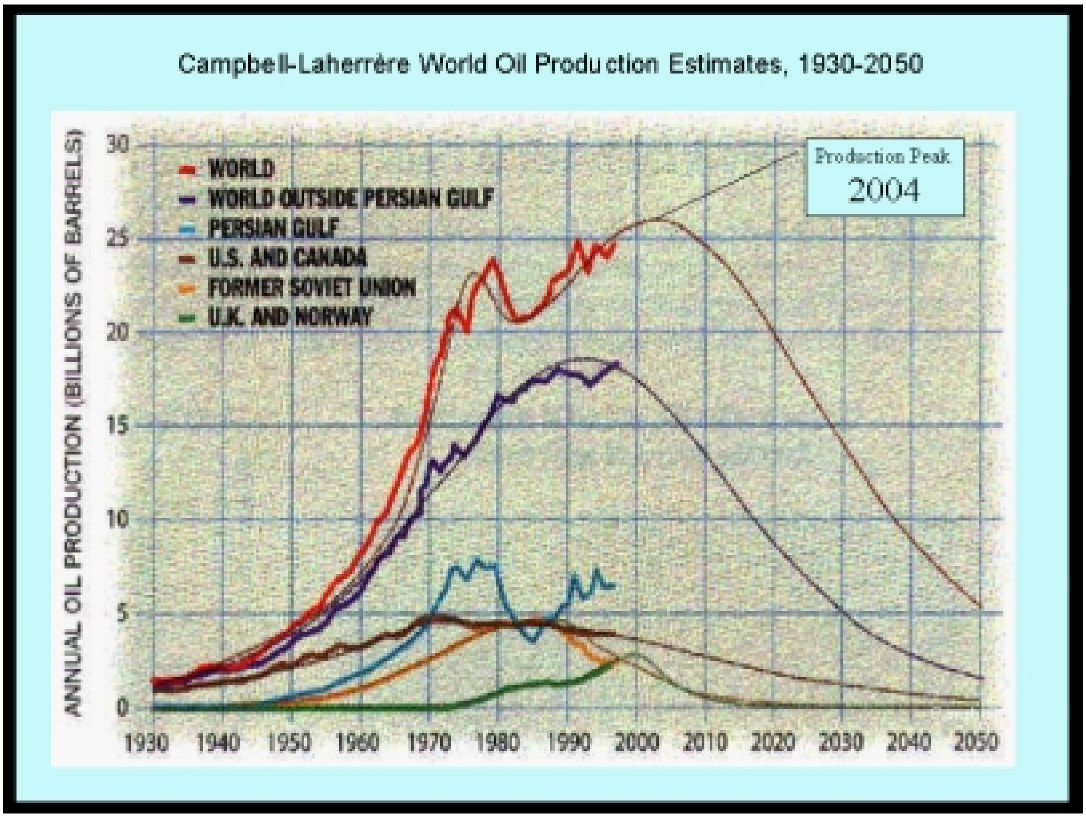
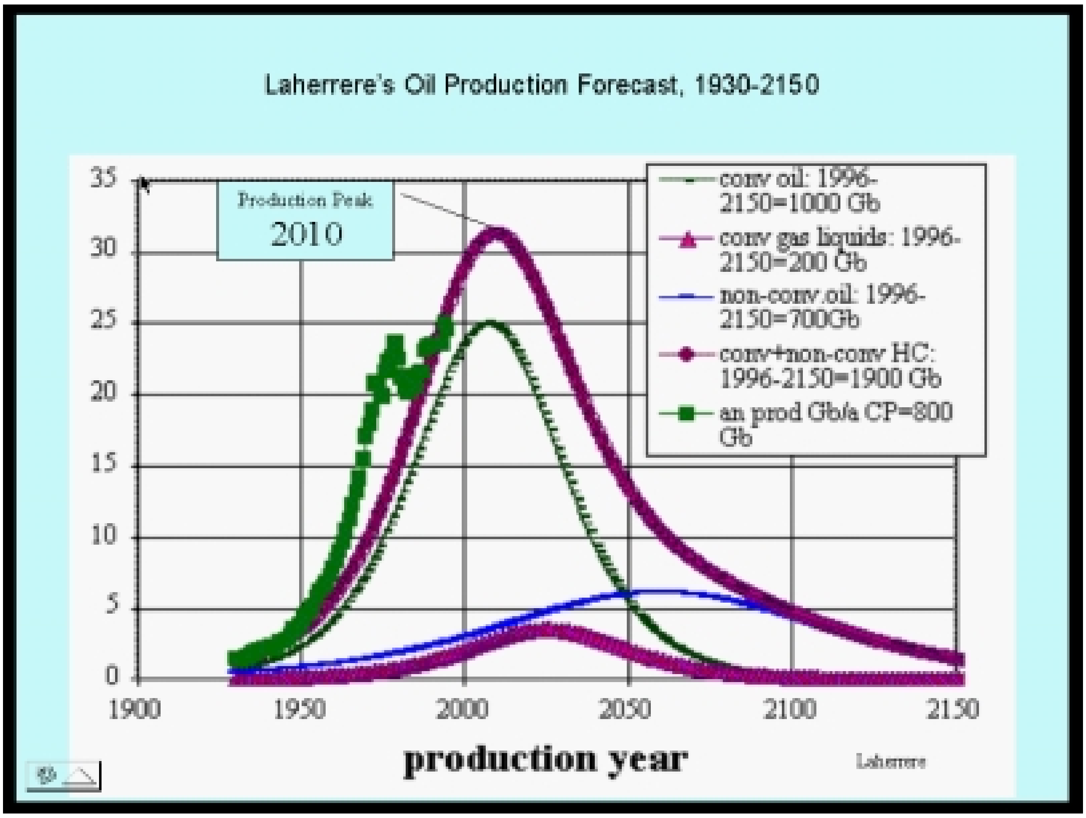
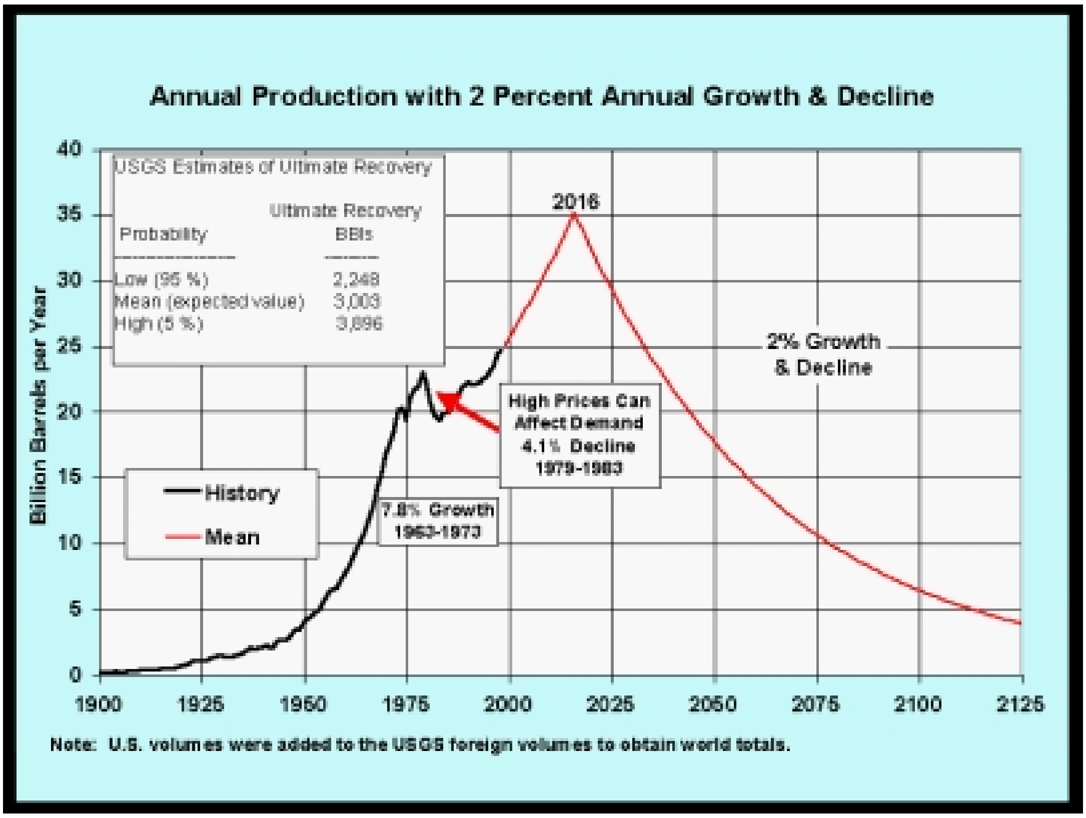


Figure 87:



John Wood forecasts from the USGS ultimates a likely peak in 2016 at 35 Gb/a

Figure 88:

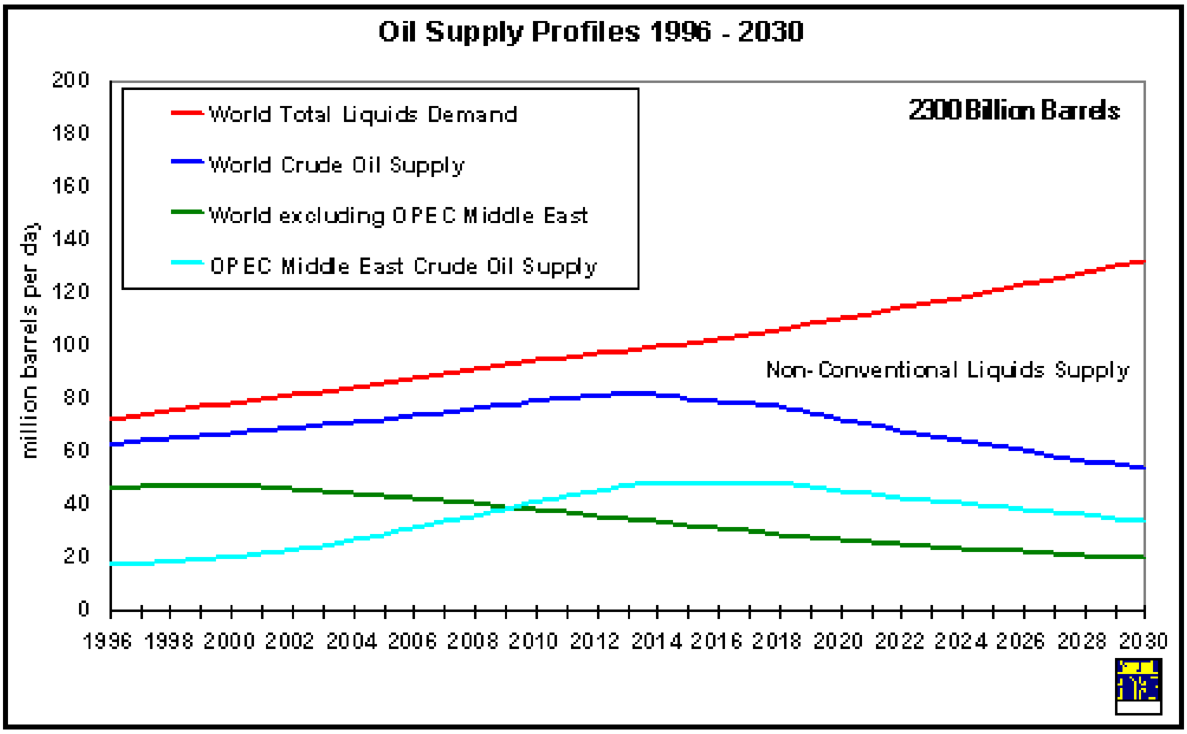


Les Magoon (USGS and author of some chapters of the USGS 2000) felt obliged to give a view different from that of the USGS 2000 and published a poster USGS open file 00-320 "Are we running out of oil?" where he presents our graph from Scientific American.

9.3 IEA 1998 forecast

After an oil conference in Paris on Nov.11, 1997 at which the so-called pessimists (Campbell, Laherrere, Bentley) were asked to confront the so-called optimists (Aldelman, Lynch, Odell, Kenney), the IEA for the G8 Energy Ministers' Meeting in Moscow 31 March 1998 presented the figure 9 of **"World Energy Prospects to 2020"** where the conventional oil peaks around 2013 and the demand for 2020 is met only by producing "unidentified unconventional" oil (Bakhtiari 2001). It is a political way to say that it is very unlikely!

Figure 89:

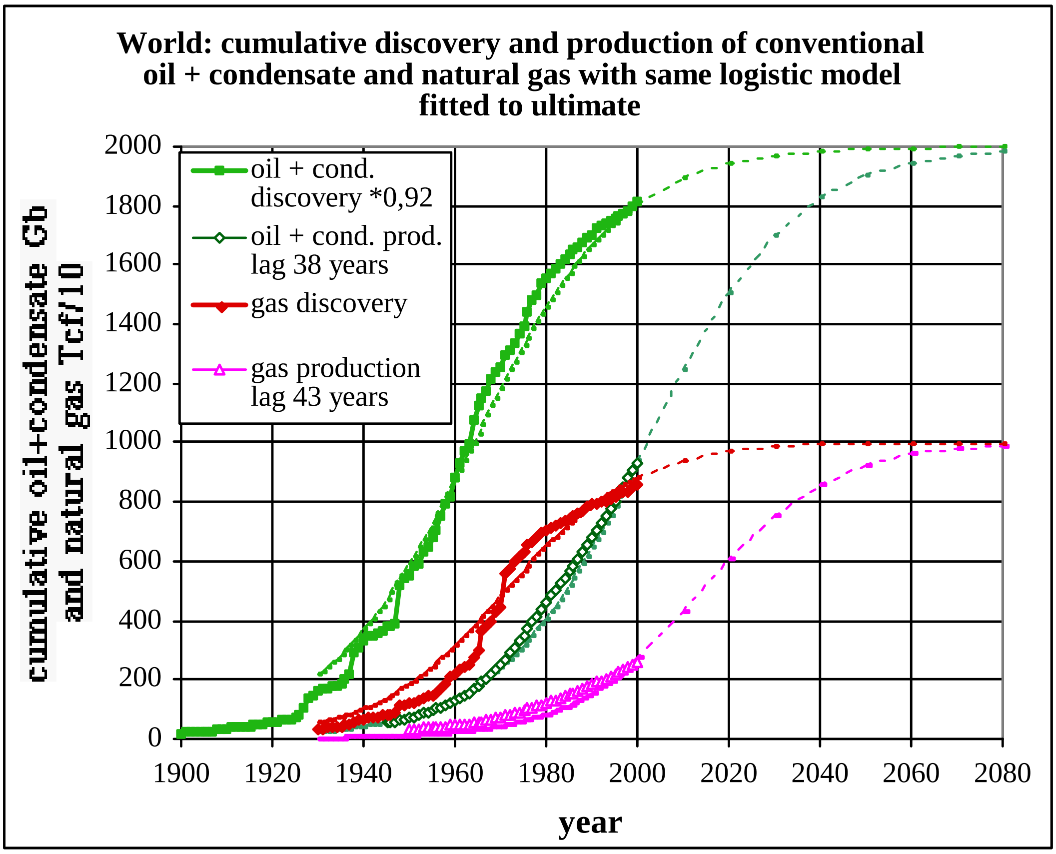


This graph is given in WEO 1998, but the WEO 2000 is much more optimistic (no more peak for conventional) as the IEA long term analysis director has changed!

9.4 My forecast

Using my file of world's (oil+condensate 2P) conventional discoveries and my estimate of 2000 Gb and 10 000 Tcf of conventional ultimates, I drew the cumulative discoveries for oil+condensate and for gas using a logistic model for the future and I applied the same model to the cumulative production as shown in the following figure:

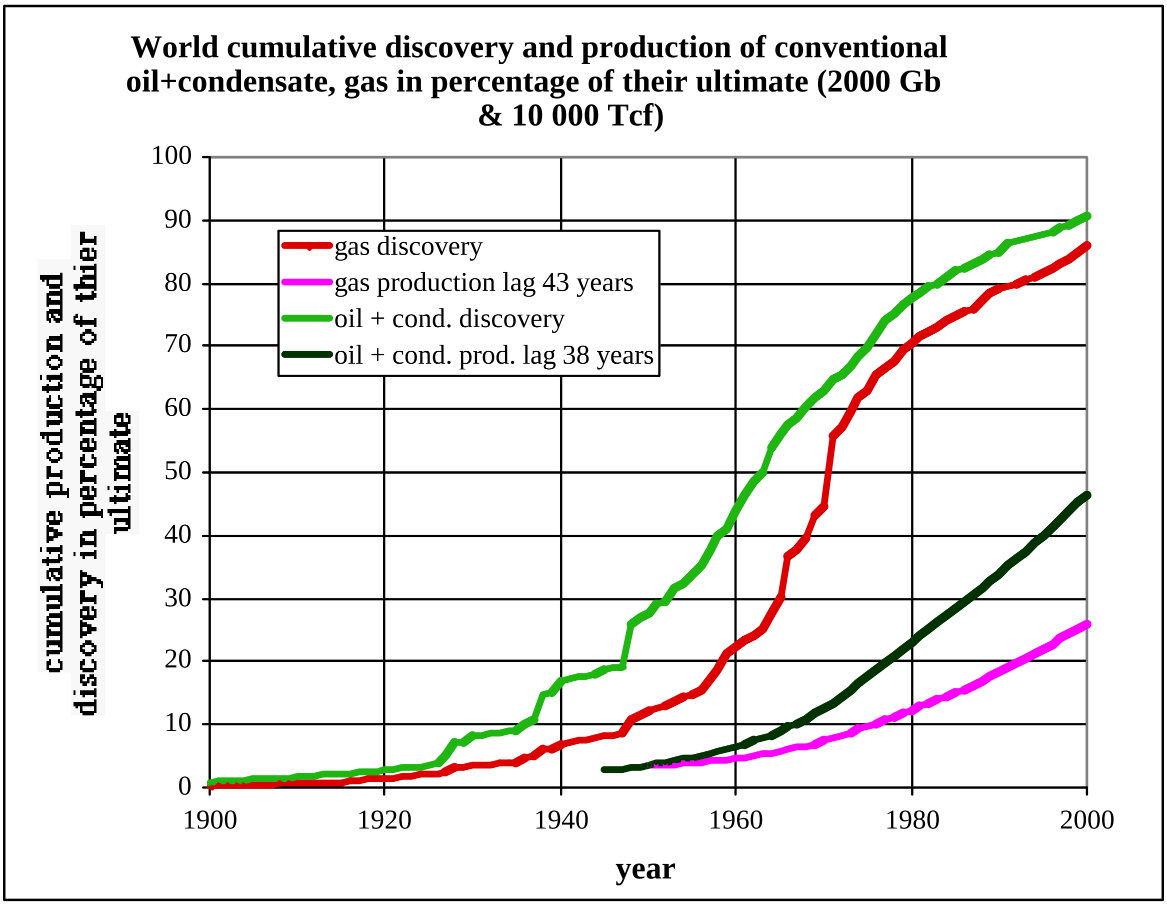
Figure 90:



The shift between discovery and production is 38 years for oil and 43 years for gas.

The next graph is the cumulative discovery and production in percentage of their ultimate: 90% of oil is discovered, 85% of gas is discovered, 45% of oil is produced and 25% of gas is produced.

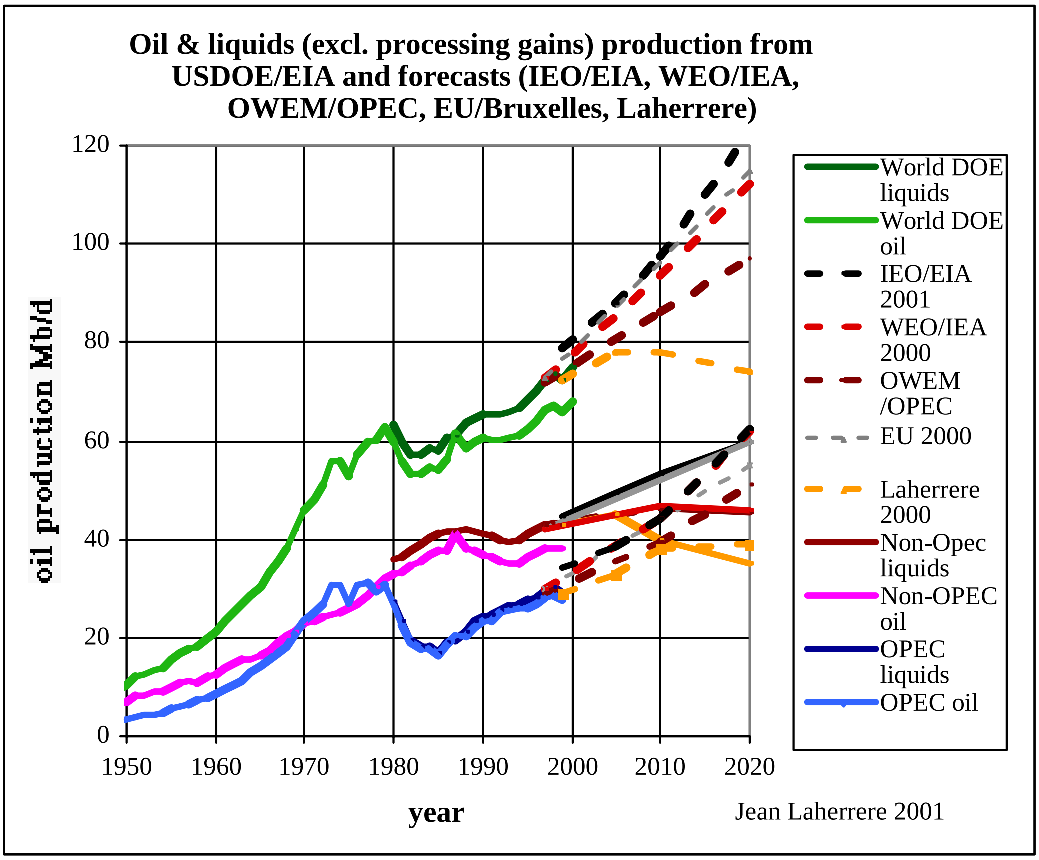
Figure 91:



9.5 Comparison different forecasts

The different forecasts for world's oil production up to 2020 from USDOE/EIA IEO (International Energy Outlook), IEA WEO (World Energy Outlook), OPEC OWEM (OPEC's World Energy Model) and European Union are plotted with the past production from 1950 (usually only the forecast is shown without the past) with my own forecast as given above. The breakdown into OPEC and Non-OPEC is given.

Figure 92:



The four official forecasts show a rising trend without recognising peak and without stating the assessed Ultimate that obviously has to influence the forecast. My forecast, based on geological assessments of ultimates, shows the onset of decline in 2010.

The comparison in detail is disturbed by the fact that IEA exclude the "unconventional" whereas EIA and OPEC do not, as shown in the table.

	WEO/IEA 2000			OWEM/OPEC			IEO/DOE-EIA 2001		
Mb/d	1997	2010	2020	1997	2010	2020	1999	2010	2020
world	74,5	95,8	115	73,4	87,9	99	78,7	97,4	122,4
non-OPEC	42	46,9	46,1	42,9	46,4	45,7	44,5	53,1	60
OPEC	29,8	44,1	61,8	29	39,6	51,2	34,2	44,3	62,4
unconventional	1,3	2,7	4,2	0	0	0	0	0	0
processing gains	1,6	2,2	2,6	1,5	1,9	2,1	0	0	0
world-processing gains	72,9	93,6	112	71,9	86	96,9	78,7	97,4	122,4

In Oil & Gas Journal April 30, 2001 A.M. Bakhtiari & F. Shahbudoghou (National Iranian Oil Co) "IEA, OPEC oil supply forecasts challenged" write "Obviously the IEA's WEO and OPEC's OWEM forecasts for 2010 and 2020 are too optimistic, given the present status of global oil reserves and actual production capacities."

So, those with a technical background and a knowledgeable analyst in the National Iranian Oil Company share our view that the official forecasts are unlikely to be reached.

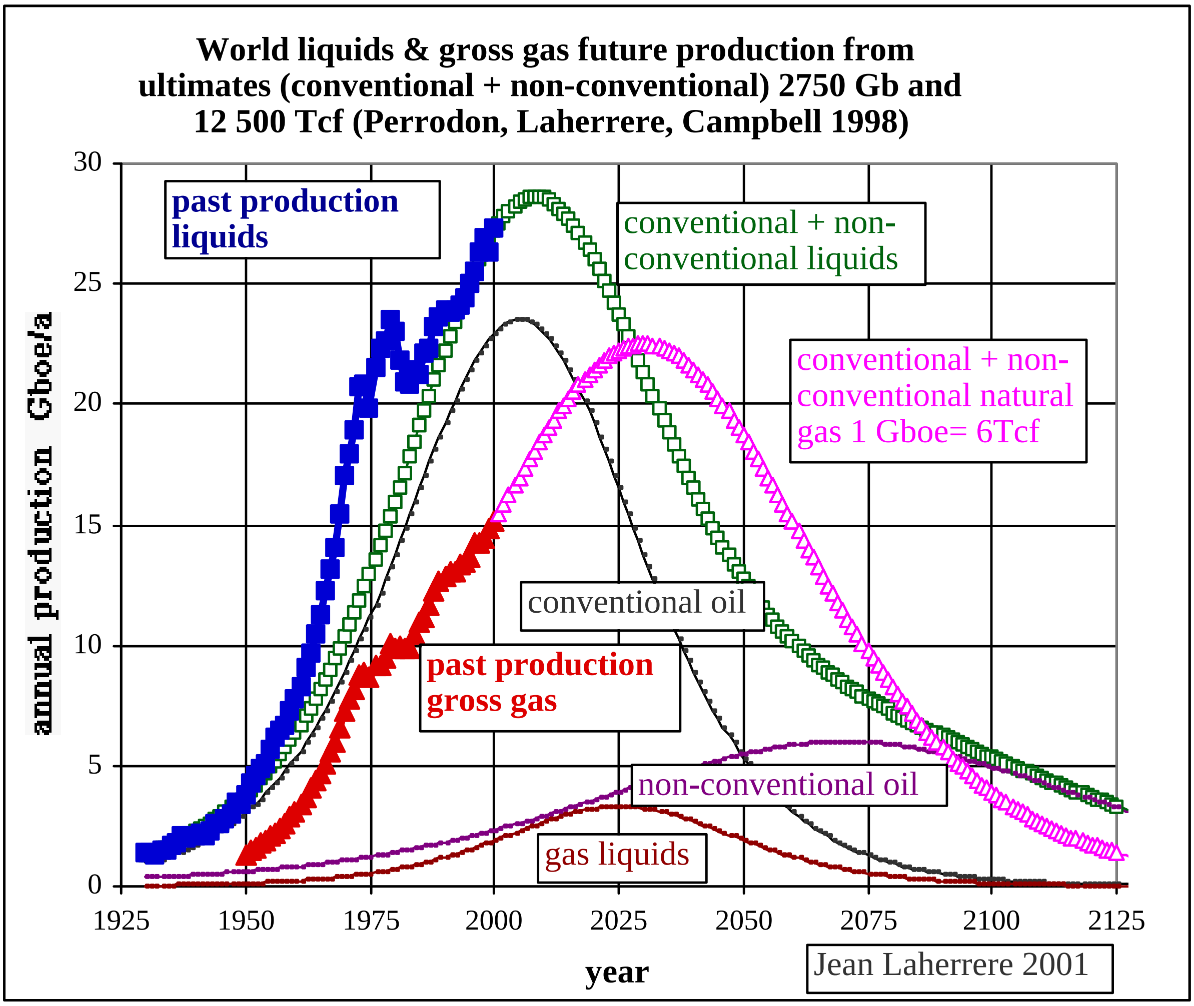
9.6 Global forecast oil &gas conventional and unconventional

In our 1998 World's non-conventional oil and gas study, I plotted a forecast for world liquids (excluding refinery gains) together with detailed of modelling for conventional oil, unconventional oil and gas liquids. The actual record over the last two years data confirms the curve. I also add the gross gas production (the dry production is about 85% of the gross). Mostly, only dry gas production is reported, whereas the remaining reserves are estimated in terms of gross volumes – a further source of confusion.

The indicated peak for liquids (75 Mb/d in 2000) is before 2010 at 28 Gb/a (80 Mb/d)

The peak for gas (90 Tcf/a or 15 Gboe/a in 2000) is in 2030 at 135 Tcf/a or 22.5 Gboe.

Figure 93:

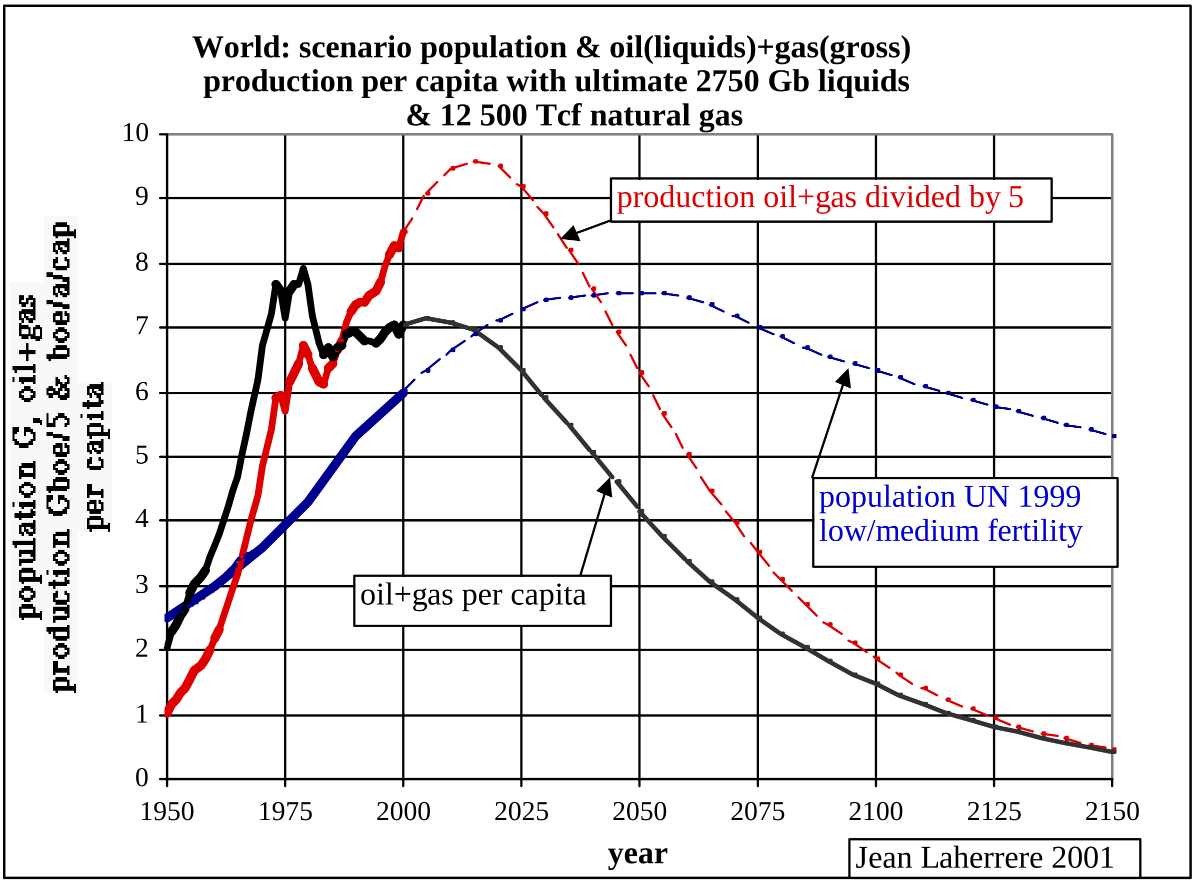


9.7 Global forecast per capita

The global above oil plus gas forecast is plotted in the next graph per capita, using the United Nations 1999 forecast with the low/medium fertility rate. The reference case (medium fertility rate taken as 2.1 to obtain the replacement ratio that gives a steady population) is unrealistic. Every decrease in fertility rate in developed countries did not stop at 2.1, but went down to 1.5 in average, even 1.1 for Spain and Italy. In this scenario, world population peaks in 2050 at less than 8 billion.

The oil+gas consumption per capita peaked at 8 boe/a in 1979, went down to 6.5 in 1985 and is flat at 7 boe/a (or 1 toe/a or 40 GJ) since 1990. It appears therefore that this per capita consumption will stay flat until 2015 and then decline to 4 boe/a in 2050 and 1.5 boe/a (or 0.2 toe/a or 10 GJ) in 2100.

Figure 94:



10 Impact on climate change: IPCC scenarios

The IPCC conclusions are a great concern for everyone, but very few people bother to look at the assumptions behind scenarios. I will not comment on the value of the modelling but as a geologist I wonder how a model can be reliable when half of the carbon released into the atmosphere disappears without knowing where it goes. Forests are assumed to be sink for some and a source for others. The missing carbon has to be explained before modelling could be considered as reliable. It is the same for the Universe, the missing matter (dark matter, unknown what and where, being 90 to 95% of the universe) has to be explained before concluding if it is expanding for perpetual Big Bang or heading for a Big Crunch.

The assumptions of the IPCC 2000 are as follows, compared to the World Energy Assessment (United Nations and World Energy Council)

	IPCC 2000		Emission scenarios				World Energy Assessment		
	A1FI	A1B	A1T	A2	B1	B2	growth A high	growth B middle	growth C ecologically
population	G								
1990	5,3	5,3	5,3	5,3	5,3	5,3	5,3	5,3	5,3
2020	7,6	7,5	7,6	8,2	7,6	7,6			
2050	8,7	8,7	8,7	11,3	8,7	9,3	10,1	10,1	10,1
2100	7,1	7,1	7	15,1	7	10,4	11,7	11,7	11,7
per capita	**per**	**year**							
primary	energy	GJ							
1990	65	65	65	65	65	65	72	72	72
2020	90	90	80	70	80	70			
2050	160	150	140	90	90	90	103	83	60
2100	290	310	290	110	70	130	159	125	75
GDP	k$1990								
1990	4	4	4	4	4	4	4	4	4
2020	7	7	8	5	7	7			
2050	20	20	20	7	15	10	10	7	7
2100	75	75	80	15	50	20	26	17	19
CO2 fossil	fuels	tC							
1990	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1	1,1
2020	1,5	1,6	1,3	1,3	1,3	1,2			
2050	2,7	1,8	1,4	1,5	1,3	1,2	1,2	1,0	0,5
2100	4,3	1,8	0,7	1,9	0,7	1,3	1,1	0,9	0,2
CO2 concentration		ppm							
1990	350	350	350	350	350	350	358	358	358
2020	410	415	410	410	410	405			
2050	565	530	500	530	480	470	460-510	470	460
2100	960	705	570	840	540	610	530-730	590	460

10.1 Population

Whereas IPCC 1995 was high on population, IPCC 2000 is much lower. Most assumptions are 7 billion in 2100 (but one at 15) compared to 12 billion for WEA and 6.5 in the UN low/medium fertility.

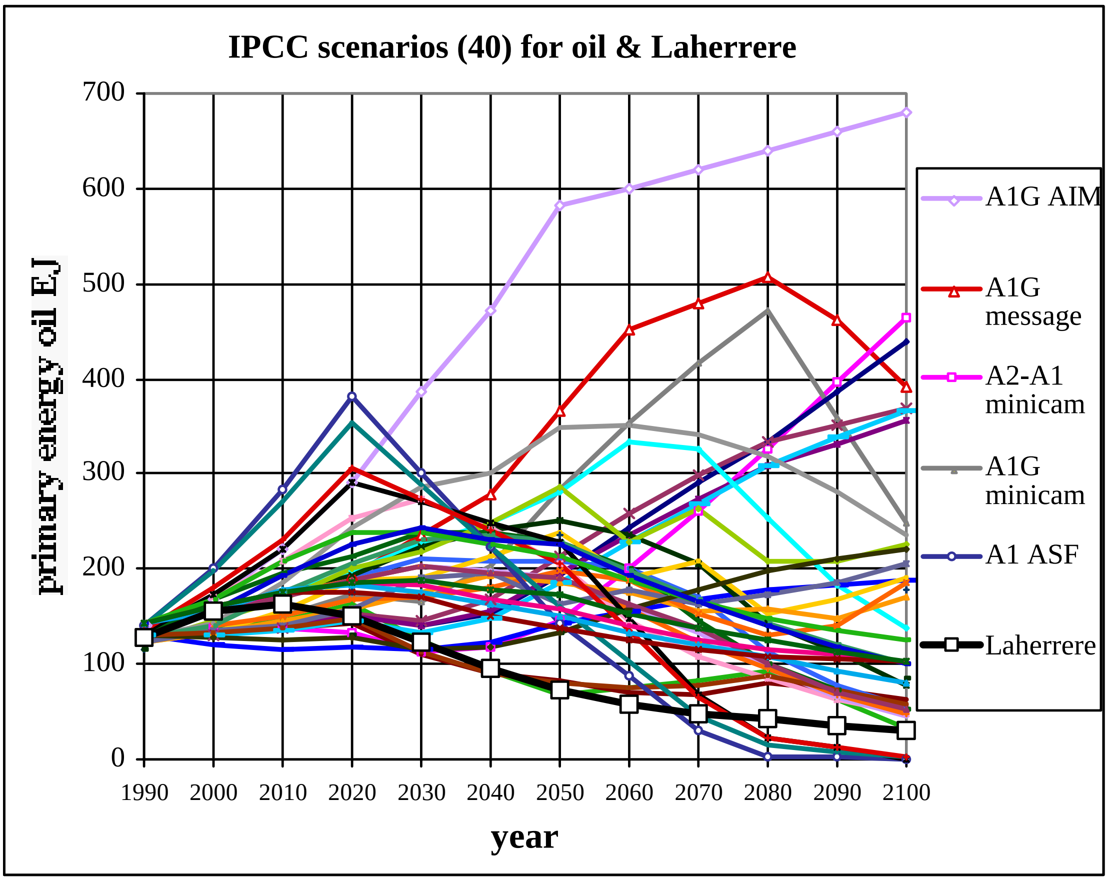
10.2 Primary energy

The primary energy per capita being 65 GJ in 2000 is assumed to be around 300 GJ in case A1 and around 100 BJ in the other scenarios (about the same order for the WEA). In our scenario the energy from oil and gas will be in 2100 around 10 GJ; it means that oil and gas will represents only 10% of the energy consumption. It is unlikely.

10.3 Primary energy for oil and for gas

Out of the 40 scenarios (http://www.grida.no/climate/ipcc/emission/data/allscen.xls) giving the detail of primary energy for oil on the following graph, most of them are out of range with my forecast for liquids based on technical data. Scenarios as AIG AIM or A1G message or A1 ASF (too high too soon) look too far to be realistic.

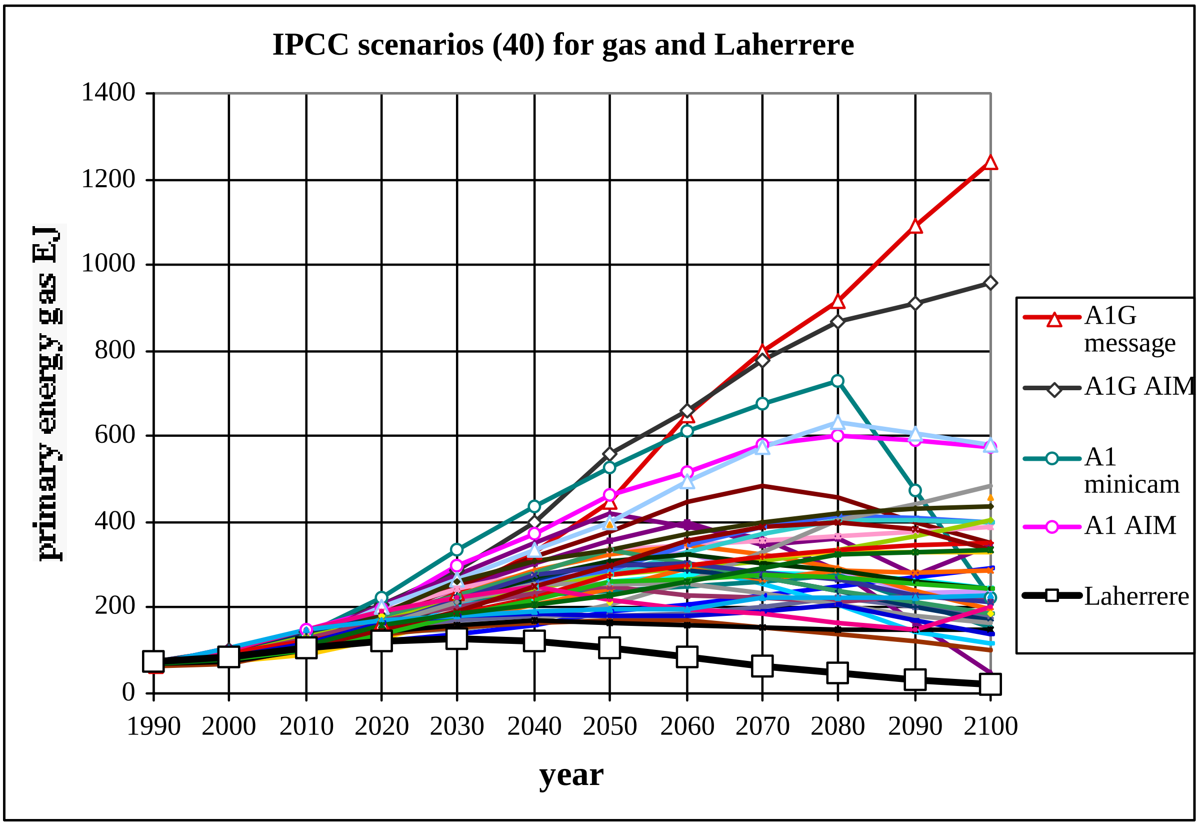
Figure 95:



Most of IPCC scenarios for oil are higher than my scenario for conventional and unconventional liquids, all of them for the period 2030-2060.

For gas, all IPCC scenarios beyond 2020 are higher than my scenario for conventional and unconventional gas!

Figure 96:

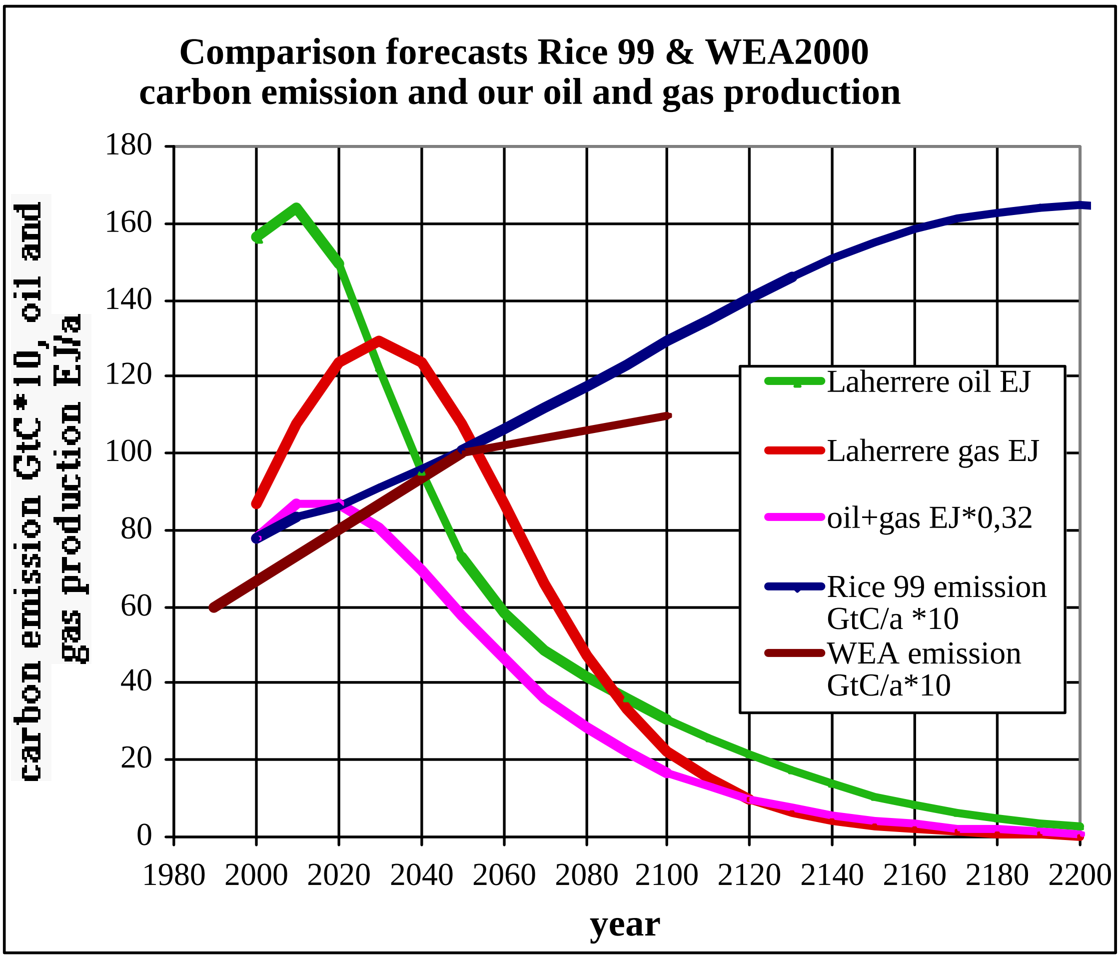


For natural gas, some is pure fantasy as “A1G message” is assumed in 2100 to consume natural gas 14 times as much as in 2000!

It is obvious that the IPCC assumptions for oil and gas are based on the assumption of abundant cheap oil and gas. This concept has to be revised.

The comparison of the Yale University model (RICE 99) of carbon emissions and of WEA 2000 with our forecast on oil and gas production up to 2100 shows also a strong divergence, coal and biomass (the other sources of carbon emission) cannot fill the difference.

Figure 97:



The WEA consumption for the period 1990-2100 in PJ for their 3 cases is compared to our forecast:

PJ=10E15 J		WEA	WEA	WEA
1990-2100	Laherrere	A high growth	B middle growth	C ecolog. growth
oil	9,8	27,6-15,7	15,3	10,9
gas	9,3	18,4-28,7	15,8	12,2-12,9

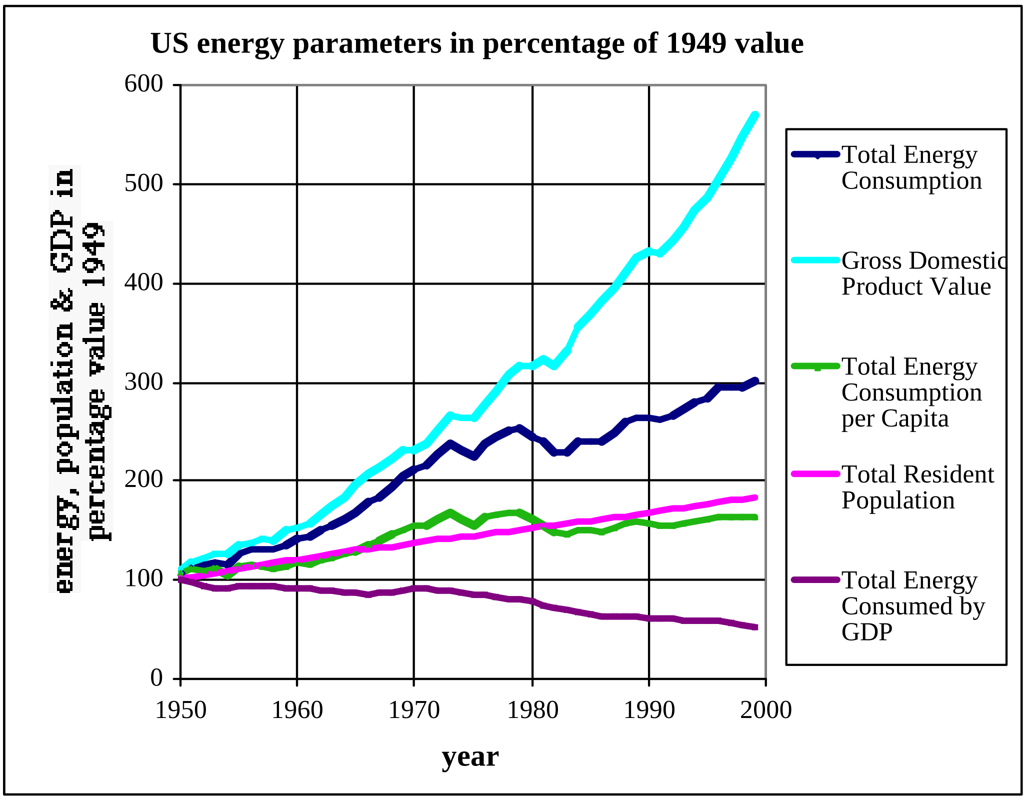
WEA future consumption for the middle case of oil and gas for the next century is 50% above our forecast.

10.4 GDP

In 1990 the world GPD per capita was 4 k1990$, in 2100 the assumption is 75 k1990$ for A1 and about 20 for the other scenarios (as for WEA). It is claimed that “oil” is replaced by “information”. The importance of oil is denied in front of the emergence of Internet or the huge increase of GPD. Anthony Blair, Prime Minister of the United Kingdom at the World Economic Forum Annual Meeting 2000 Friday, January 28, 2000, Davos, Switzerland: "Twenty years on from the oil shock of the 70s, most economists would agree that oil is no longer the most important commodity in the world economy. Now, that commodity is information” Eight months later... Blair sends for the troops, saying: "Troops were put on standby last night to intervene in the deepening fuel crisis as the health service went on emergency alert, supermarkets began rationing food and schools and businesses closed."

In the following graph from 1949 the US relative increase to 2000 is: population 180%, energy consumption 300% and GDP almost 600%.

Figure 98:



It is difficult to see such increase in GPD with little correlation with population and energy since 1973. The US GPD is manipulated using inflation and “hedonic” factor. When computer or software doubles in memory or speed, the productivity is assumed to double and the real investments are doubled too through the “hedonic” factor to get into GPD. There are protests in Germany and UK about US practice: Richebacher (2000) « Had the German statisticians applied the U.S. methods for deflating IT equipment, according to the Bundesbank, real IT investment in Germany in 1998 would have been DM 64 billion, that is, twice as high as reported. In 1999, the difference would have risen to 170%. »

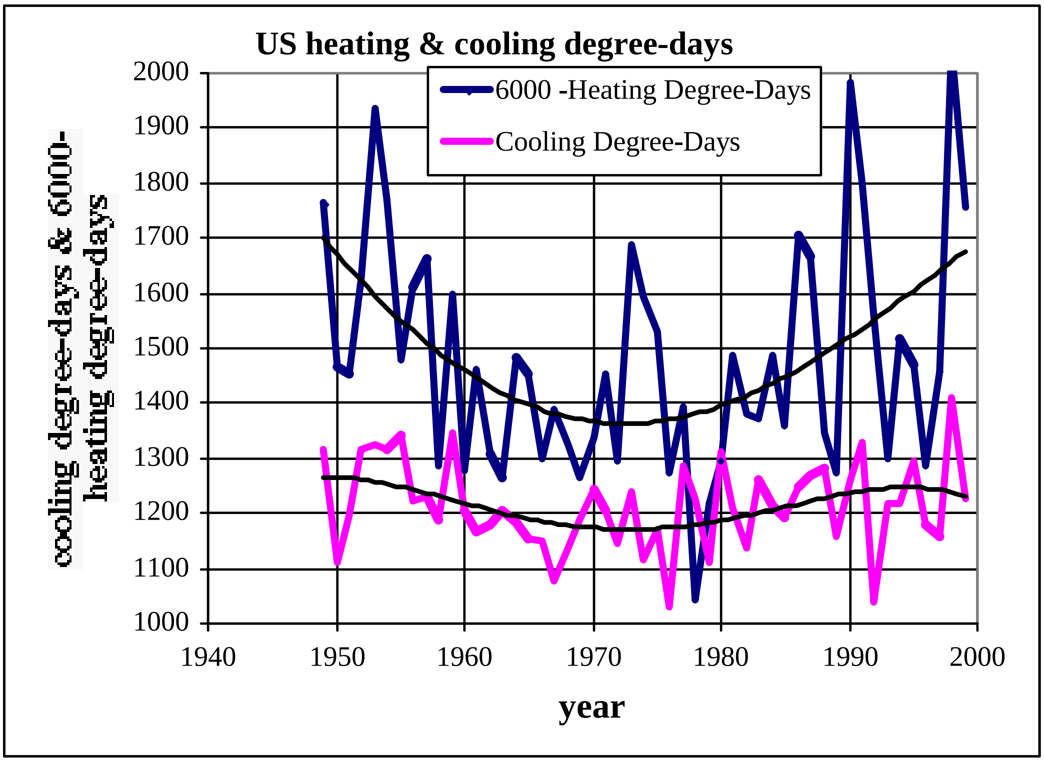
The China GDP is known to be overestimated and the FSU GDP underestimated as a good part of trade has been barter since the FSU break-up.

It is why energetic intensity has to be treated with caution. I prefer not to use it.

10.5 Heating and cooling days: interesting parameter

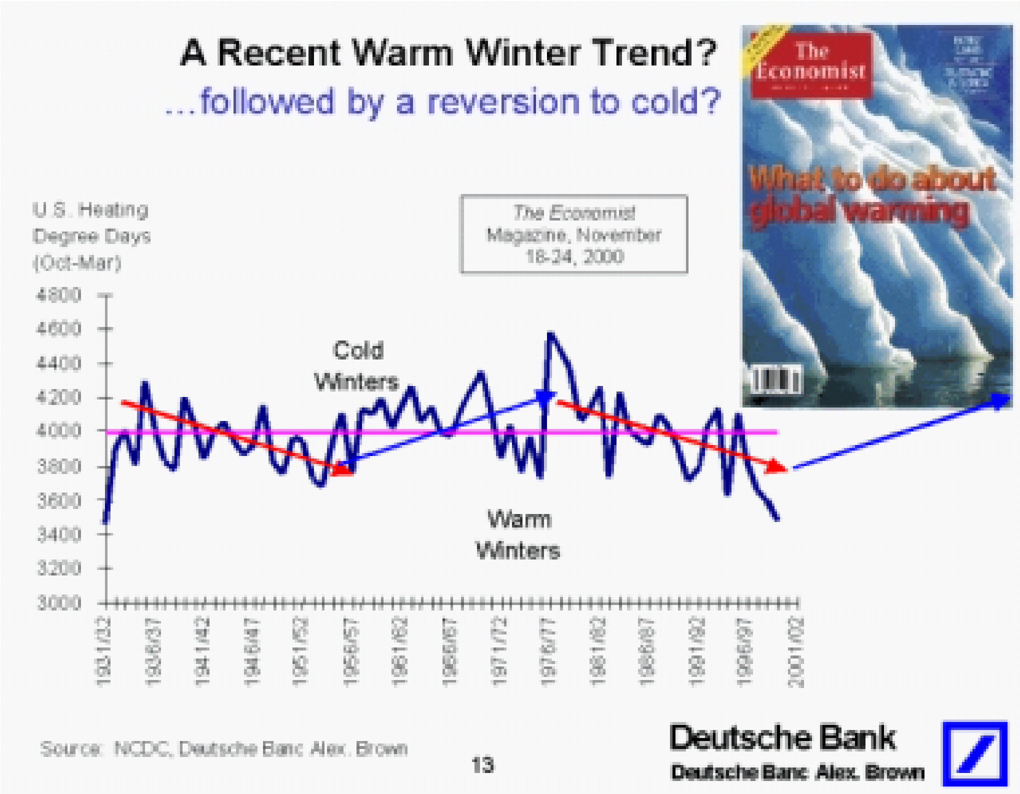
In the energy parameters recorded with care in the US are the heating and cooling days. They show a low around 1970, as it is well known that the global temperature went down from 1940 to 1970. In 1970 the concern was about global cooling and not global warming as it is now.

Figure 99:



Deutsche Bank shows a longer trend from 1930 to 2000 on heating days with three cycles or a cycle of about 23 years (or one solar cycle as the solar period is 11 years but with change polarity). It is in agreement with the Svensmark theory of the impact of cosmic rays from the sun cycles on clouds. Clouds are the most important factor in temperature, more than CO_2.

Figure 100:



Conclusions:

The consuming society thinks it needs growth to be happy. It is understandable therefore that everything is presented in order to give hopes for growth.

The goal of the oil companies is to make profit. They have no obligation to publish data, beyond that legally required of them. They prefer to keep information confidential, partly because it would be useful to competitor, and they prefer to publish what improves their image.

Government agencies follow the policy of every government that promises that tomorrow will be better than today and relies on growth to solve all future problems.

Future oil and gas demand is overestimated because the estimates assume cheap prices and large resources.

There are two or three different and parallel worlds involved in estimating oil reserves. They are sometimes described as pessimists and optimists, but they are neither. One world comprises oil executives who gained the freedom to speak when retired, and had experience and access to confidential technical data. The other world comprises « academic writers » and/or economists, who talk about future miracles of technology (but refusing to listen to technicians) and rely on published data which are mainly political. There are also “theoretical writers” who deal only with theories and wishful thinking. They present ideas as facts, and reject facts as confusing.

The oil industry follows archaic and poor practices in reporting data for both production and reserves because confidentiality, conservatism and fear of the impact on the stock market.

Forecasts cannot be more unreliable than the underlying basic data.

However data on past discoveries and production shows that oil and gas liquids will peak before 2010, and that natural gas will peak around 2030.

The IPCC assumptions on energy up to 2100 are accordingly unrealistic being based on cheap and abundant oil and gas.

Good estimates of oil reserves need good data, which are almost impossible to obtain even where records are in the public domain as in the Federal Gulf of Mexico where the USDOI/MMS data shows unpardonable mistakes.

It is important as a matter of urgency that the oil industry and the governmental agencies start to realise that the main priority now is to improve the world database. Indeed, that was the goal of a recent meeting in Bangkok (April 2-3) between six organisations and 20 producing and consuming countries.

The ideal is to find an organisation, which is apolitical, in which consumers, and producers can trust. I do not see any organisation that complies with the necessary qualities. IIASA could one possibility. IIASA has to show that it can do it.

References:

-Attanasi E.D. & Root D.H. 1994 "The enigma of oil and gas field growth" AAPG 78/3 March, table 1

-Bakhtiari A.M.S., Shahbudaghlou F. 2001 « IEA, OPEC oil supply forecasts challenged » OGJ April 30,

-Bauquis P-R. 2001 “Quelles energies pour un developpement durable” Journees de l’energie au Palais de la decouverte 18 Mai

-Bernabe F. 1998 « Cheap oil: enjoy it while it lasts » Forbes June 15 http://www.forbes.com/asp/redir.asp?/forbes/98/0615/6112084a.htm

-Blair A. 2000 “Special message" World Economic Forum Annual Meeting 2000 Davos, Switzerland http://www.asiamedia.ucla.edu/Davos2000/Speeches/Blair.htm

-Bowlin M. 1999 « last days of oil age have begun » ARCO press release Feb.9 http://www.arco.com/Corporate/news/p020999.htm

-Campbell C.J, Laherrere J.H. 1998 "The end of cheap oil" Scientific American March p80-85

-Gochenour D.T. 1997 “Practical difficulties of valuing Russian oil reserves” SPE 37958

- IEA1998 « World Energy Prospects to 2020 ª G8 Energy Ministers' Meeting in Moscow 31 March http://www.iea.org/g8/world/oilsup.htm (figure 9)

-Khalimov E.M., 1993, "Classification of oil reserves and resources in the Former Soviet Union" AAPG 77/9 Sept p.1636

-Khalimov E.M., M.V.Feign 1979 "The principles of classification and oil resources estimation" WPC Bucharest, Heyden London 1980 p263-268

-Laherrere J.H. , A.Perrodon, C.J.Campbell 1996 “The world’s gas potential” Petroconsultants report July, 200p, CD-ROM

-Laherrere J.H. 1996 “Distributions de type fractal parabolique dans la Nature” Comptes Rendus de l’Academie des Sciences- T.322 -Série IIa n°7-4 Avril p535-541
http://erebus.phys.cwru.edu/phys/courses/p196/cheap/p196eocopg1.gif or
http://www.oilcrisis.com/laherrere/fractal.htm

-Laherrere J.H. 1997 "Evolution of "development lag" and "development ratio"" IEA Oil reserves conference Paris Nov 11 http://dieoff.com/page182.htm or " Development ratio evolves as true measures of exploitation" World Oil Feb 1998 p117-120

- Laherrere J.H. 1999 "Parabolic fractal, creaming curve improve estimate of US Gulf reserves" Offshore Magazine May p113, 114, 177

-Laherrere J.H. 1999 "Reserve growth: technological progress, or bad reporting and bad arithmetic?" Geopolitics of Energy 22/4 April p7-16 http://dieoff.com/page176.htm

-Laherrere J.H. 2000 b "Is the USGS 2000 assessment reliable ? " Cyberconference by the World Energy Council, May 19, Strategic Options http://www.energyresource2000.com

- Laherrere J.H. A.Perrodon, G.Demaison 1994 "Undiscovered Petroleum Potential" Petroconsultants report, 383p

-Magoon L, 2000 "Are we running out of oil?" USGS open file 00-320 http://geopubs.wr.usgs.gov/open-file/of00-320/of00-320.pdf

-Moody J.D. and Halbouty M. 1979 « World's ultimate reserves of crude oil" World Petroleum Congress

-Perrodon A., J.H. Laherrere, C.J.Campbell 1998 "The world's non-conventional oil and gas" Petroleum Economist March report 113p see http://textor.com/cms/dPEWNC.html

-Richebacher K, 2000 "Euro travails" http://www.gold-eagle.com/editorials_00/richebacher100600.html

-Robertson Research International 2000, R.M.Fowler "World conventional hydrocarbon resources: how much remains to be discovered and where is it?" 16th WPC http://www.robresint.com/wpc

-Schmoker 2000 «Reserve growth on estimates of oil and natural gas resources » US DOI USGS fact sheet FS-119-00 http://pubs.usgs.gov/factsheet/fs119-00/fs119-00.pdf

-Simmons M.R. 2000 " Fighting rising demand & rising decline curves: Can the challenge be met? " SPE Asia Pacific Oil & Gas Conference, Yokohama, April 25 http://www.simmonsco-intl.com/web/downloads/spe.pdf

-Torheim E. "Changing perceptions of a gas field during its life cycle: a Frigg field case study" Quantification and prediction of HC resources NPF special publication 6 Elsevier 1996 Proc. NPSociety Dec 93 Stavanger.

-UKOOA (UK Offshore Operators Association) 1997 "Towards 2020 -Future oil and gas production in UK waters -An industry-based study": http://www.ukooa.co.uk/

-USDOE/EIA-0534 1990"US oil and gas reserves by year of field discovery" Aug. "

-USGS 2000: "World petroleum assessment 2000 –description and results" 16th WPC, summary: http://energy.cr.usgs.gov:8080/energy/WorldEnergy/weppdf/sumworld.xls, 4 CD-ROM: USGS DDS-60,

-Wood J. 2000 : "Long term world oil supply (a resource base/production path analysis) " http://www.eia.doe.gov/pub/oil_gas/petroleum/presentations/2000/long_term_supply/LongTermOilSupplyPresentation.ppt

-World Energy Council 2000 "Energy for tomorrow's world –Acting Now"