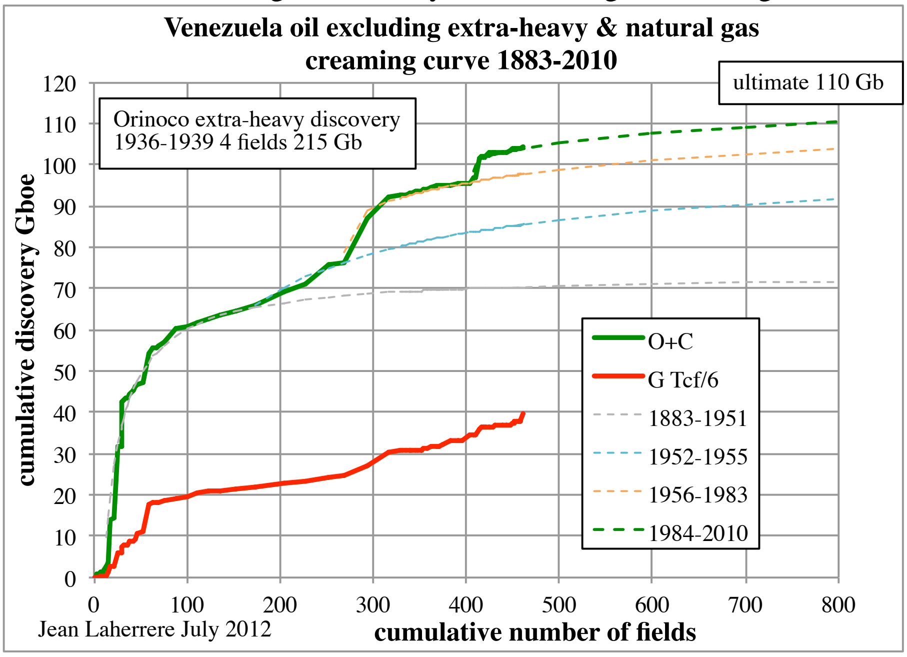
Jean Laherrere 24 July 2012

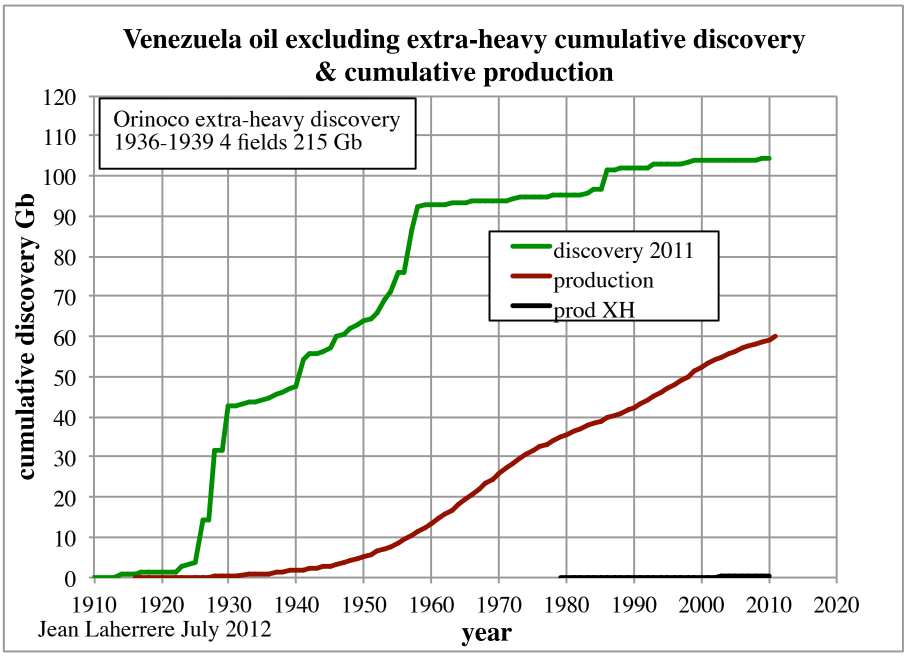
Production of crude less extra-heavy oil in Venezuela

Extra-heavy oil (Orinoco) was discovered between 1936 and 1939 with 4 fields (in fact they are called not field, but area being a continuous-type accumulation) for a total of 215 Gb. Their names were changed from Hamaca, Zuata, Cerro Negro and Machete to now Ayacucho, Junin, Carabobo and Boyaca.

The creaming curve (cumulative discovery versus cumulative number of fields) at end 2010 for crude oil less extra-heavy can be modeled with 4 cycles towards an ultimate of 110 Gb.
Figure 1: Venezuela oil excluding extra-heavy and natural gas creaming curve 1883-2010

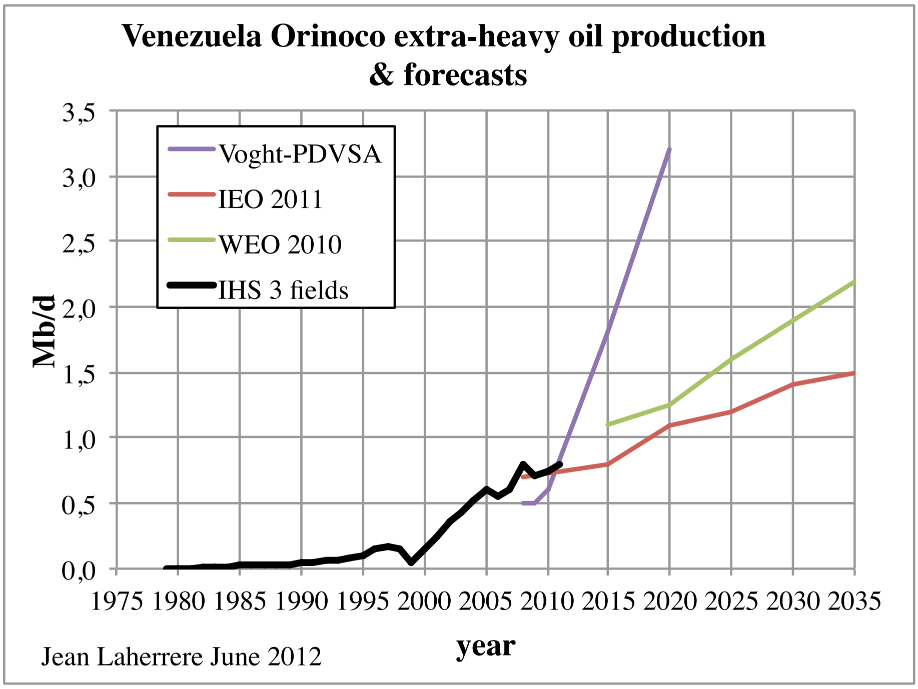


The cumulative discovery of oil excluding extra-heavy versus time is compared to the cumulative production of oil excluding extra-heavy (60 Gb at end 2010), but also the extra-heavy, which looks negligible (0.27 Gb at end 2010). The past production seems difficult to extrapolate towards the ultimate of 110 Gb from reported discovery past discovery.
Figure 2: Venezuela crude excluding extra-heavy oil cumulative discovery " & cumulative production, with also extra-heavy curve



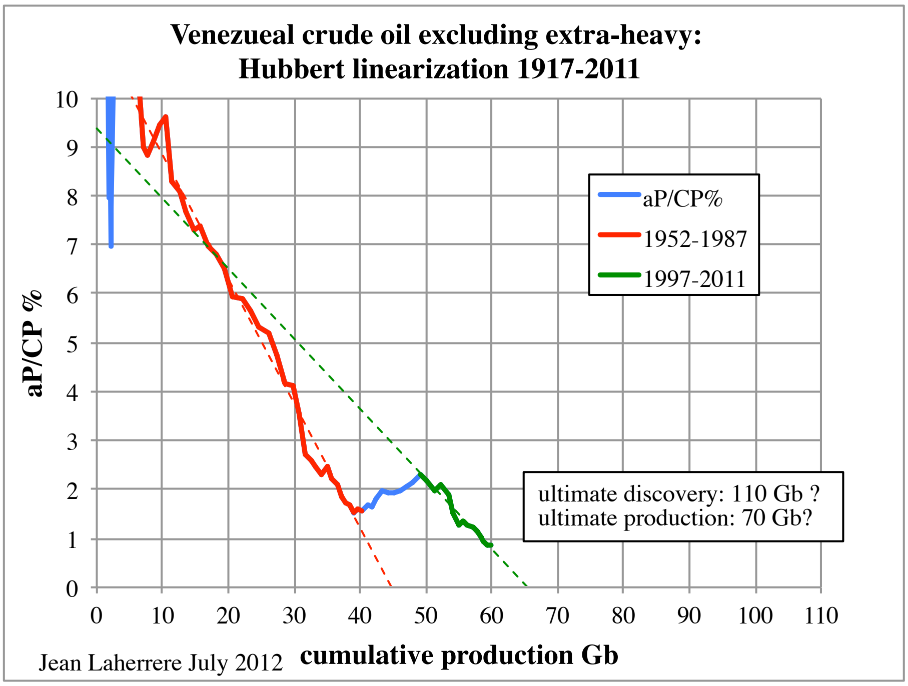
Chavez's nationalization has disturbed the production of extra-heavy oil and the forecast from PDVSA (Voigt) are quite different from EIA/IEO & IEA/WEO:

Figure 3: Venezuela Orinoco extra-heavy oil production & forecasts from PDVSA, EIA/IEO & IEA/WEO

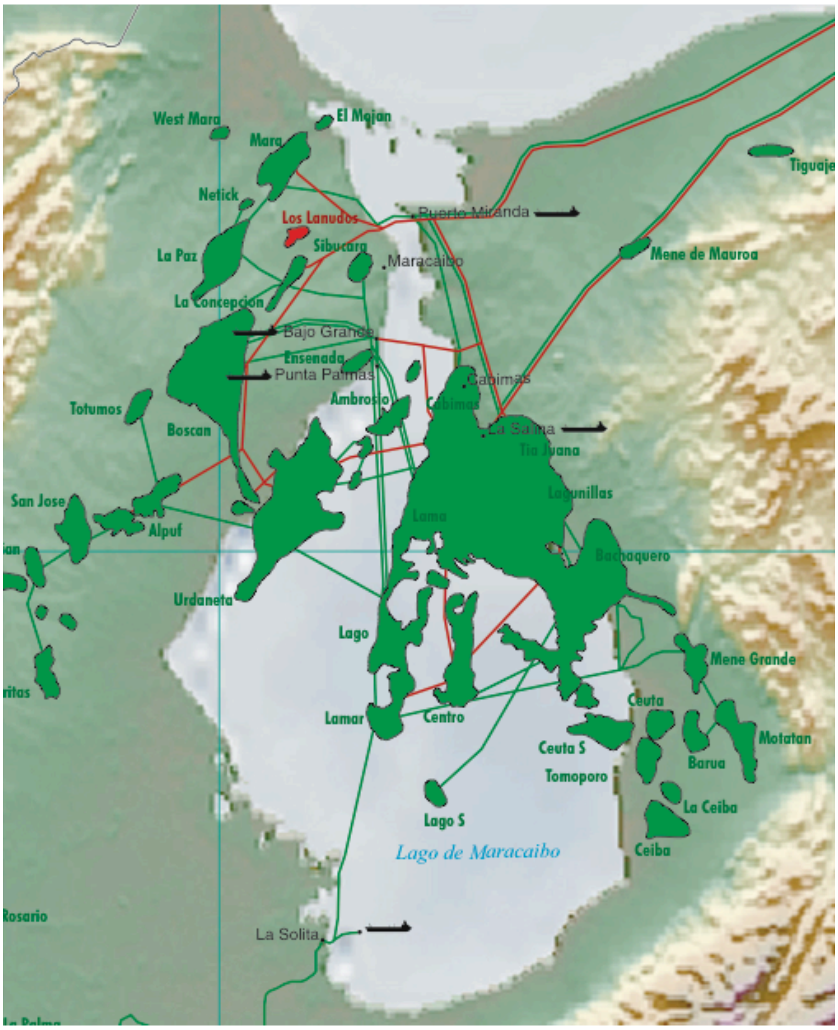


The Hubbert linearization of the past production for crude oil excluding extra-heavy displays several trends: the first from 1952 to 1987 trends towards 45 Gb and the second from 1997 to 2011 trends towards 65 Gb. Oil production Hubbert linearization is not much reliable, but OPEC reserves are not either.

Figure 4: Venezuela oil excluding extra-heavy production: Hubbert linearization 1917-2011

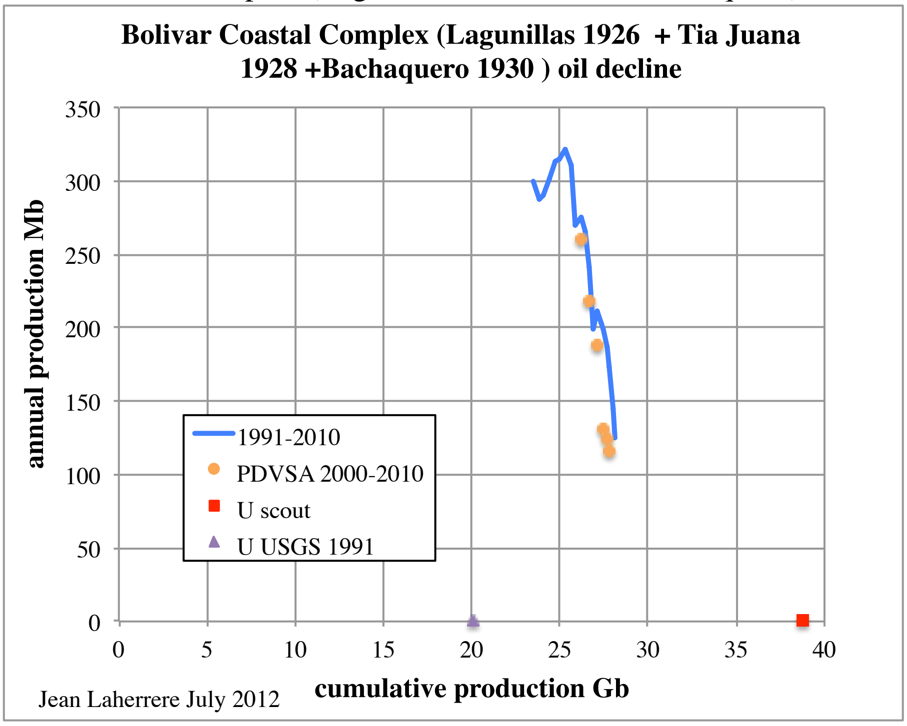


The first problem is the lack of reliable data: PDVSA reports only the production and reserves of their main fields on annual reports (*informe de gestion*) since 2000.
The second problem is that the main part of past production is from the Maracaibo basin (63 Gb discovery and 42 Gb produced) with in particular the supergiant Bolivar Coastal gathering 3 fields: Lagunillas discovered in 1926 U= 10 Gb, Tia Juana discovered in 1928 U= 18 Gb and Bachaquero discovered in 1930 U = 11 Gb.
Trapping is stratigraphic involving unconformities and tar plugging. Few millions year from now and Maracaibo will be like Orinoco!
The following map from the Petroleum Economist Atlas for Maracaibo shows that the fields are connected, leading to confusion with data by field.
Figure 5: Maracaibo oil fields location map



These 3 fields, which the 2P reserves are 39 Gb, have already produced 28 Gb, but the production is on still decline from the known data (1991-2010). These fields were operated by Maraven (backed by Shell people), subsidiary of PDVSA which ceased to exit in 1997.
In AAPG study in geology #25 1984 Roadifer reported giants listed by oil in place and Bolivar Coastal Lagunillas was third with 160 Gb behind Greater Burgan and Ghawar both with 190 Gb.
In 1994 Bolivar Coastal (Laherrere, Perrodon, Demaison 1994) was reported the third largest field with 34.5 Gb ultimate and 25 Gb for cumulative production.
In AAPG 2005 (Horn) the Bolivar Coastal Complex was reported with ultimate of 28.8 Gb with Tia Juana 13.4 Gb, Bachaquero 9 Gb and Lagunillas 6.4 Gb.
But production data from other sources (Maraven, OGJ) could report chaotic values because confusion between the complex and the connected fields (Cabimas 1917, Lama 1957, Ceuta 1957, even Mene Grande 1914). The density of the fields also varies, but Bolivar Coastal is heavy (Tia Juna 17.9°API OGJ 1990 and 25°API OGJ 2001, Bachaquero & Lagunillas 22°API).
The Bolivar Coastal complex oil production data is only complete since 1991 but with cumulative production, which allows to plot the oil decline versus cumulative production. The decline since 1997 (peak at 322 Mb) is very sharp, too sharp to be due only to below ground constraints. 1997 is the end of the previous operator Maraven and the fight between Chavez and PDVSA staff must be one reason for sharp decline.
The production from Tertiary sandstones is heavy, at fairly shallow depth (1000 m), needing steam injection, expensive investments and competent engineers.

Figure 6: Bolivar Coastal Complex (Lagunillas +Tia Juana + Bachaquero) oil decline



A straight extrapolation could lead to an ultimate of 30 Gb or 8 Gb less than estimated, but the decline of production could come from above ground constraints with PDVSA.

The first concession in Venezuela was in 1865 and 14 companies were operating when in 1976 the nationalization reduced the number to four companies associated with the Venezuelan national company CVP and PDVSA backed by international companies: Lagoven (Exxon) Maraven (Shell), Meneven (Gulf) & Corpoven. In 1997 all these subsidiaries were taken over by PDVSA, but with different departments.

The Maracaibo operations is run by PDVSA/Zulia

One of the early above ground problems was subsidence of the surface because of production. The large production has caused a subsidence of the surface of several meters since the start of production: "Subsidence Due to Fluid Withdrawal" G.V. Chilingar et al editors 1995
http://books.google.fr/books?id=q3hBXavOfYwC&pg=PA347&lpg=PA347&dq=Bachaquero+Bolivar+Lagunillas+Tia+Juana+oil+production&source=bl&ots=hvKTQqdpvB&sig=rzoHf-DP4Tjk_wV-jRumDKYUaR8&hl=fr

Figure 7: Bolivar Coastal Complex surface subsidence for Bachaquero & Lagunillas

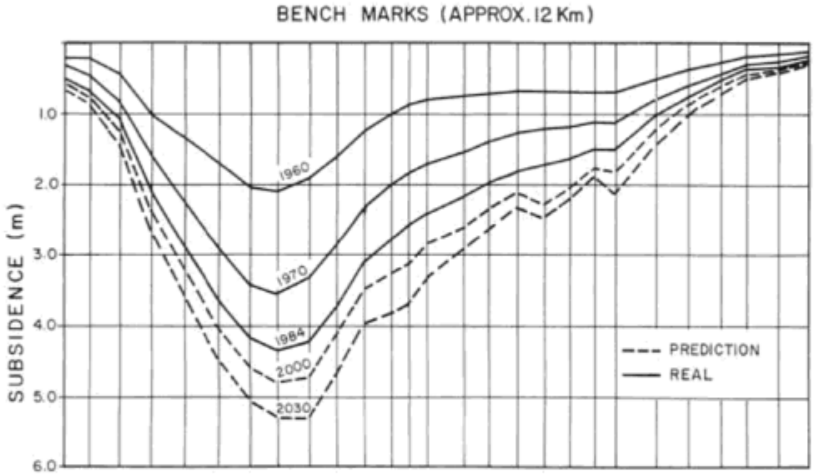


Fig. 7-6. Subsidence history and prediction along the Bachaquero dike.

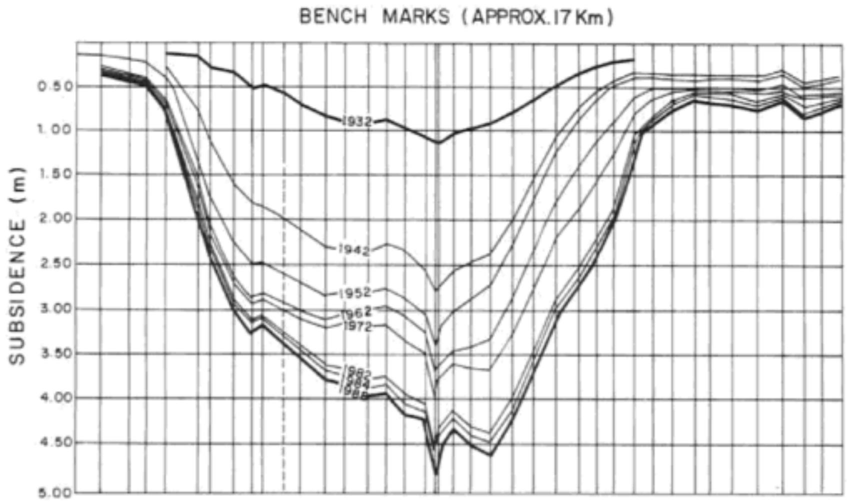


Fig. 7-7. Subsidence history along the Lagunillas dike.

Figure 8: Bolivar Coastal Complex surface subsidence map

350 A. FINOL AND Z.A. SANCEVIC

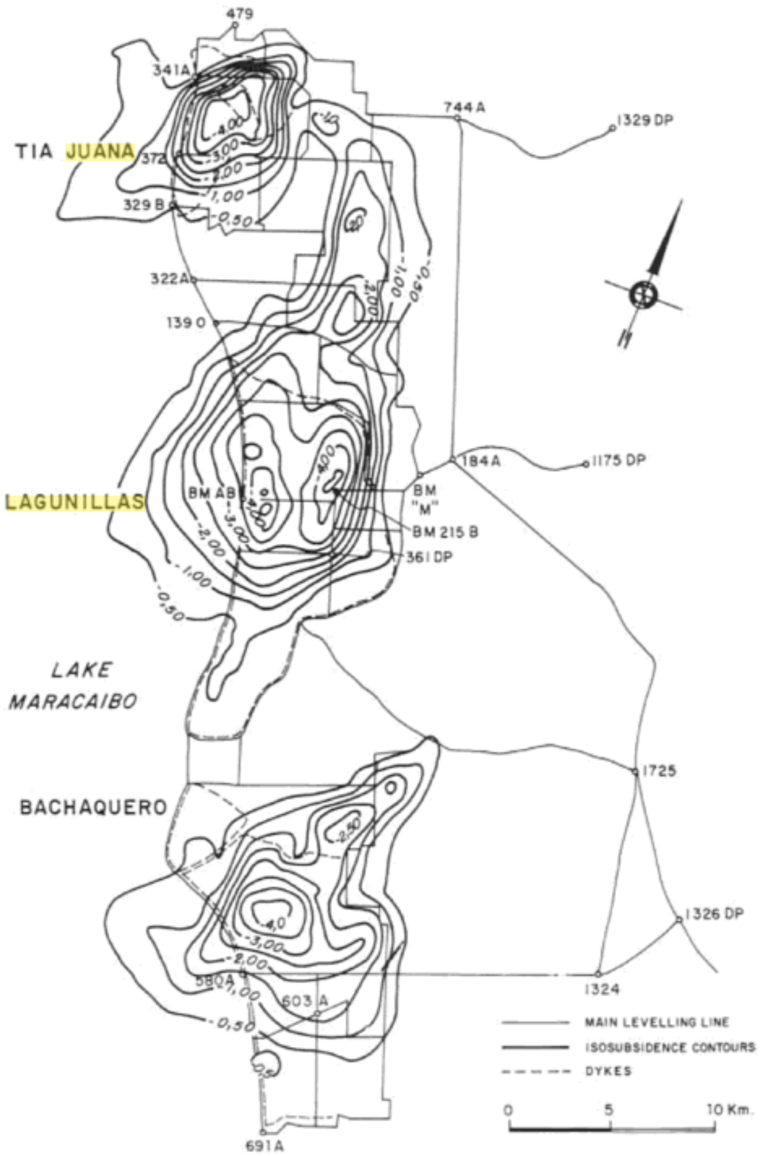


Fig. 7-8. Main levelling network and subsidence contours, 1986.

The 1991 USGS report 39 http://pubs.usgs.gov/cp/39/report.pdf has a map showing the connection between fields

Figure 9: Bolivar Coastal Complex map from USGS 1991

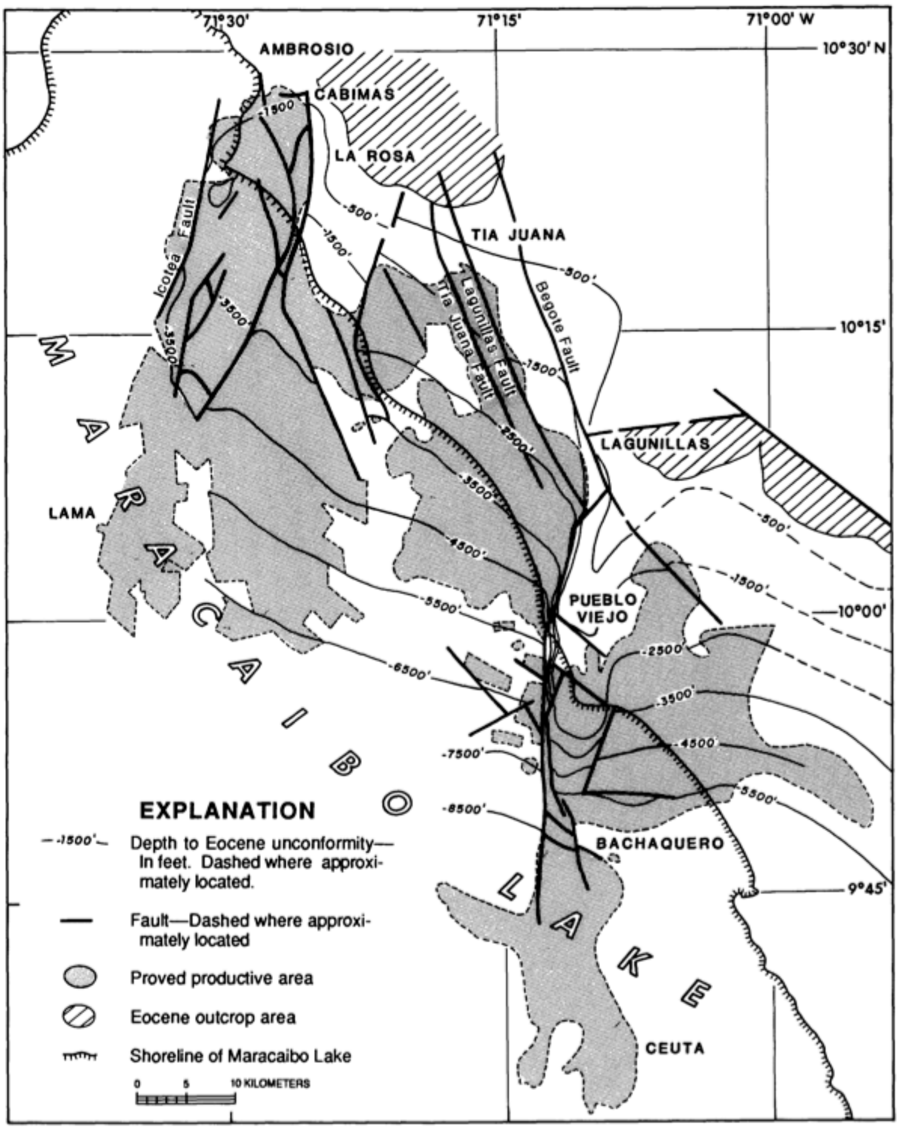


Figure 7.—Giant Bolivar Coastal Field (shaded), estimated ultimate recovery of 35,000 million barrels of oil, Maracaibo Basin, Venezuela.
Figura 7.—El Campo Costero de Bolivar, un campo gigante petrólero con una recuperación última estimada de 35.000 millones de barriles, Cuenca de Maracaibo, Venezuela.

and also the cumulative production and ultimates:
Figure 10: South America: Giant fields ultimates and cumulative production from USGS 1991

Table 10.—*Giant oil and gas fields (estimated ultimate recovery of more than 500 MMB and (or) 3 TCF)*

Tabla 10.—*Campos gigante de petróleo y gas (recuperación final estimada mayor de 500 millones de barriles y (o) 3 trillones de pies cúbicos de gas)*

[MMB, million barrels; TCF, trillion cubic feet; —, no data. See figures 3 and 4 for location of selected basins and fields]

				Major reservoir				Cumulative production (as of 12-31-87)		Estimated ultimate recovery	
Field name	Country	Basin	Year discovered	Age	Lithology	Average depth (Ft)	Type of trap	MMB	TCF	MMB	TCF
South Flank Group	Argentina	San Jorge	1946	Jurassic/ Cretaceous	Sandstone	1600-8500	Fault block	680	—	816	530
North Flank Group	Argentina	San Jorge	1907	Cretaceous/ Tertiary	Sandstone	2000-10,500	Fault block	568	—	842	79
Loma de la Lata (Upper)	Argentina	Neuquen	1977	Cretaceous	Limestone	5200-7200	Stratigraphic, structural	30	—	500	—
Loma de la Lata (Lower)	Argentina	Neuquen	1977	Jurassic	Sandstone	6200-8200	Stratigraphic, structural	—	0.6	—	12
Punta Bardas/ Vacas Muerta	Argentina	Cuyo	1961	Triassic/ Cretaceous	Sandstone	7200-8000	Anticline	338	—	500	—
La Cira-Infantas	Colombia	Middle Magdalena	1925	Cretaceous/ Tertiary	Sandstone	3250	Anticline	459	—	520	—
Caño Limón	Colombia	Arauca	1983	Cretaceous/ Tertiary	Sandstone	7500-8200	Fault block	108	—	1000	—
Shushufindi	Ecuador	Oriente	1969	Cretaceous	Sandstone	7500-8900	Anticline	495	—	1350	—
Sacha	Ecuador	Oriente	1969	Cretaceous	Sandstone	7800-9300	Anticline	338	—	743	—
Amistad	Ecuador	Progreso	1970	Tertiary(?)	Sandstone	—	Anticline	—	—	—	3
La Brea - Parinas	Peru	Talara	1869	Tertiary	Sandstone conglomerate	5500	Fault blocks	539	—	592	—
San Martin	Peru	Ucayali	1984	Cretaceous	Sandstone	12,800	Anticline	—	—	—	3
Cashiriari	Peru	Ucayali	1986	Cretaceous	Sandstone	8800	Anticline	—	—	—	8
Fyzabad Group	Trinidad	South Basin	1913	Tertiary	Sandstone	3000-8000	Stratigraphic, structural	630	—	850	—
Soldado	Trinidad	South Basin	1954	Tertiary	Sandstone	4000-8000	Stratigraphic, structural	463	—	600	—
East Coast	Trinidad	S.E. Coast	1961	Tertiary	Sandstone	5000-11,000	Stratigraphic, structural	555	—	700	—
Galeota Group	Trinidad	Galeota	1968	Tertiary	Sandstone	8000-14,000	Stratigraphic, structural	—	5.0	—	7
North Coast Group	Trinidad	W. Tobago	1971	Tertiary	Sandstone	11,000	Stratigraphic, structural	—	nil	—	3
Tia Juana	Venezuela	Maracaibo	1928	Tertiary	Sandstone	3500	Stratigraphic fault	10,360	—	15,050	—
Bachaqero	Venezuela	Maracaibo	1930	Tertiary	Sandstone	3450	Stratigraphic fault	6264	—	9367	—
Lagunillas	Venezuela	Maracaibo	1926	Tertiary	Sandstone	3000	Stratigraphic fault	3462	—	5220	—
Lama	Venezuela	Maracaibo	1957	Cretaceous/ Tertiary	Sandstone	10,000	Stratigraphic fault	2140	—	2850	—
Ceuta	Venezuela	Maracaibo	1956	Cretaceous/ Tertiary	Sandstone	—	Stratigraphic fault	505	—	1239	—
Cabimas	Venezuela	Maracaibo	1917	Tertiary	Sandstone	2200	Stratigraphic fault	489	—	515	—
Boscán	Venezuela	Maracaibo	1946	Tertiary	Sandstone	8800	Anticline, stratigraphic	729	—	2471	—
Urdaneta	Venezuela	Maracaibo	1956	Cretaceous/ Tertiary	Sandstone	10,000	Anticline, stratigraphic	122	—	2058	—
Centro	Venezuela	Maracaibo	1957	Cretaceous/ Tertiary	Sandstone	10,000	Anticline, stratigraphic	777	—	1702	—
Lamar	Venezuela	Maracaibo	1958	Cretaceous/ Tertiary	Sandstone	12,500	Anticline, stratigraphic	1095	—	1594	—
La Paz	Venezuela	Maracaibo	1925	Cretaceous/ Tertiary	Sandstone	11,400	Faulted anticline	857	—	1042	—
Mene Grande	Venezuela	Maracaibo	1914	Tertiary	Sandstone	8000	Faulted anticline	637	—	686	—
Santa Rosa	Venezuela	Oriental	1941	Tertiary	Sandstone	10,600	Faulted anticline	390	—	697	—
Mata	Venezuela	Oriental	1954	Tertiary	Sandstone	9500	Faulted monocline	469	—	648	—
Guara	Venezuela	Oriental	1946	Tertiary	Sandstone	7800	Faulted monocline	424	—	606	—
Oficina	Venezuela	Oriental	1917	Tertiary	Sandstone	6900	Fault block	384	—	525	—
Cerro Negro	Venezuela	Orinoco	1979	Tertiary	Sandstone	—	Stratigraphic	20	—	11,183	—
San Diego	Venezuela	Orinoco	—	—	—	—	—	—	—	4557	—
Iguana	Venezuela	Orinoco	—	—	—	—	—	—	—	4176	—
Jobo	Venezuela	Orinoco	1956	—	—	—	—	267	—	1453	—
Morichal	Venezuela	Orinoco	1958	—	—	3300	—	169	—	946	—
Santa Clara	Venezuela	Orinoco	—	—	—	—	—	—	—	913	—
Quiriquire	Venezuela	Oriental	1928	Cretaceous/ Tertiary	Sandstone	7000	Stratigraphic	760	—	885	—
Uverito	Venezuela	Orinoco	1981	Tertiary	Sandstone	—	—	1	—	854	—
Bare	Venezuela	Orinoco	—	—	Sandstone	—	—	8	—	763	—
Sur	Venezuela	Orinoco	—	Cretaceous/ Tertiary	Sandstone	14,000	Stratigraphic	—	—	602	—
Melones	Venezuela	Orinoco	1934	Tertiary	Sandstone	5200	Faulted monocline	114	—	600	—
Arecuna	Venezuela	Orinoco	—	—	Sandstone	—	—	—	—	567	—
El Furrial	Venezuela	Oriental	1985	Tertiary	Sandstone	—	Fault block	8	—	529	—
El Placer	Venezuela	Oriental	1984	Tertiary	Sandstone	—	Stratigraphic	—	0.3	—	5

Lagunillas cumulative production (end 1990?) is only 3.4 Gb when it is 11.2 Gb for OGJ 1991 (obviously wrong by 5 Gb) and 2.1 Gb from Maraven 1997

http://www.worldenergy.org/documents/congresspapers/P001165.pdf

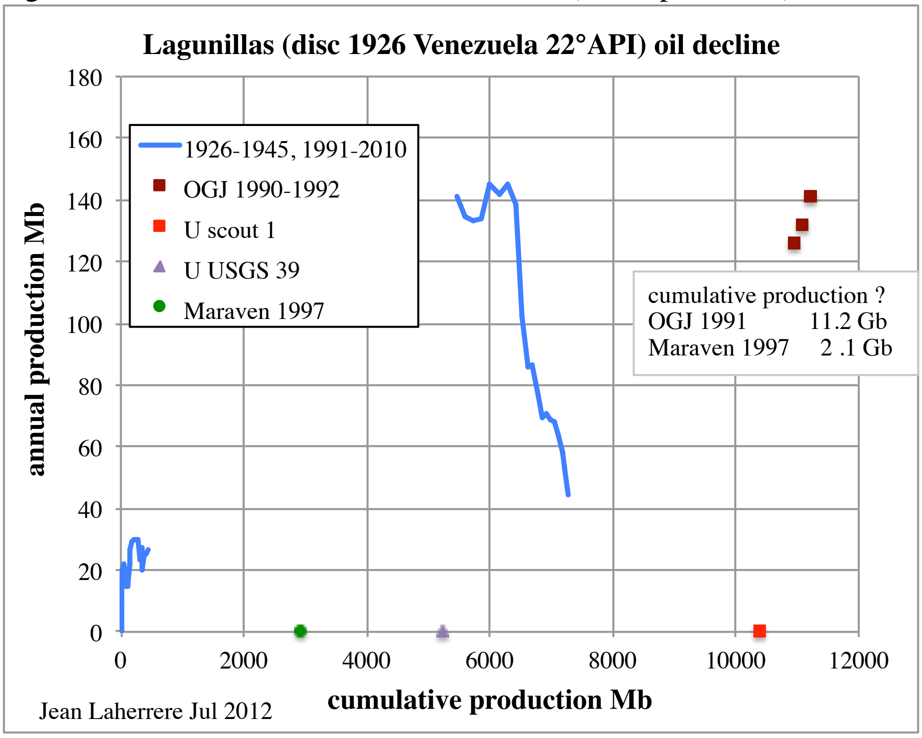
Maraven ultimate at 2.9 Gb is wrong!
Figure 11: Maracaibo fields reserves & cumulative production from Maraven 1997

Table 3 Cases Of Emblematic Fields In The Maracaibo Basin (Western Region Of The Country) That Have Produced More Than 50% Of Their Recoverable Reserves (Mb)

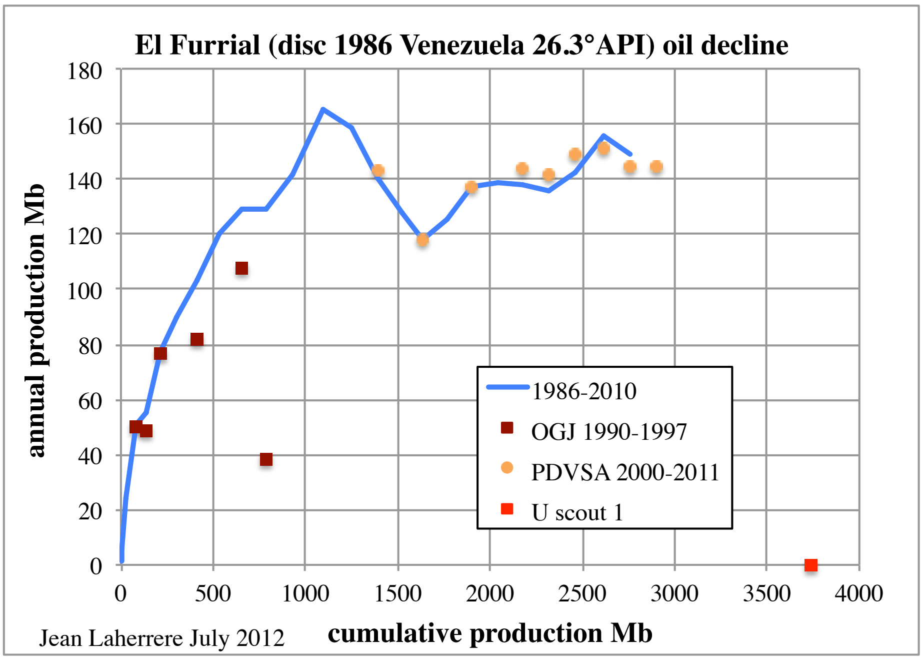
FIELD	RECOVERABLE RESERVES	CUMULATIVE PRODUCTION	% PRODUCED	REMAINING RESERVES
Bachaquero (1930)	2,172.476	1,691.712	77.9	480.764
Cabimas (La Rosa 1917)	391.844	364.783	93.1	27.061
La Concepción (1925)	188.927	146.194	77.4	42.733
La Paz (1923)	1,045.132	885.713	84.7	159.419
Lagunillas (1926)	2.918.529	2.108.065	72.2	810.464
Mene Grande (1914)	755.135	657.660	87.1	97.475
Tía Juana (1928)	2,392.787	1,775.431	74.2	617.356
Totals	9,864.830	7,629.558	77.3	2,235.272

Source: Maraven S.A. Reserves Annual Report, 1997 & Author calculations

Figure 12: Lagunillas oil decline from different sources (incomplete data)

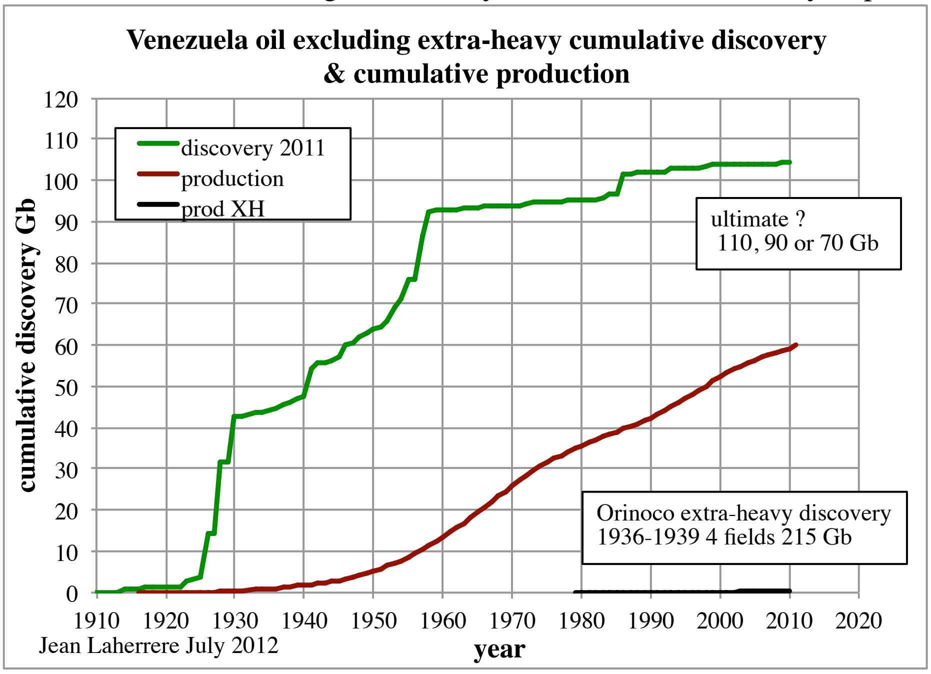


Another check on the field oil reserves data is with the El Furrial field discovered in 1986 with ultimate reported at 3.7 Gb with fairly production data (except for OGJ 1997) with a cumulative production at 2.8 Gb at end 2010. The present production (run by PDVSA/Monogas) is on a plateau since 1998 and the ultimate looks reasonable. The oil decline is yet-to-come and the comparison with the Bolivar Coastal Complex shows that decline is not only due to PDVSA staff decline!
Figure 13: El Furrial oil decline 1986-2011



The Venezuela crude excluding extra-heavy oil discovery leads to a 110 Gb ultimate, being too high compared to the present cumulative production, but future production depends also on the investments, the economy and the policy of the country.

Figure 14: Venezuela crude excluding extra-heavy oil cumulative discovery & production

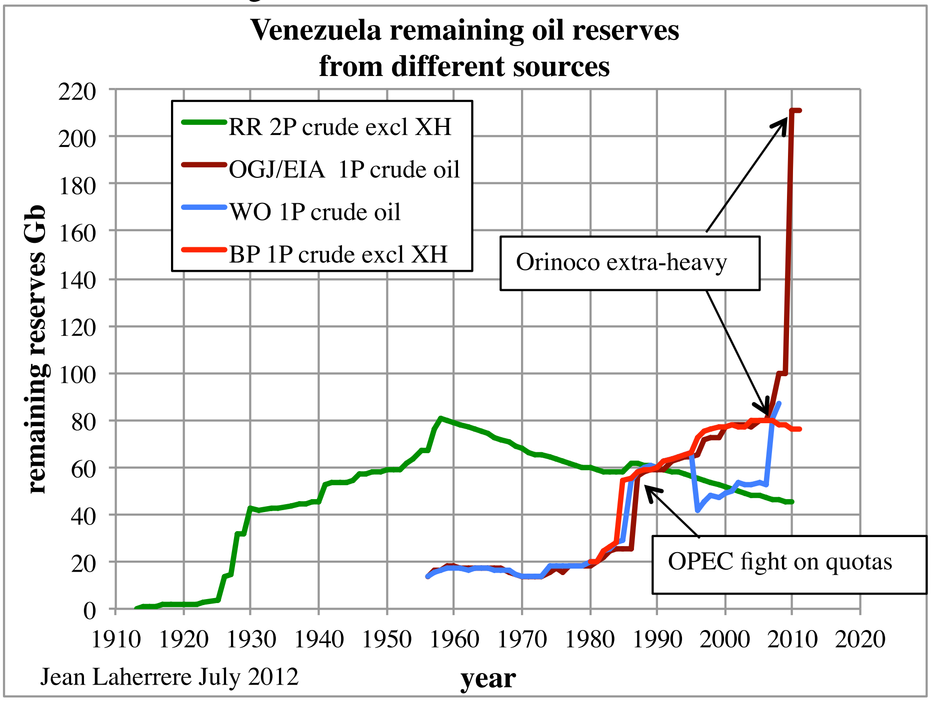


The discrepancy between the extrapolation of discovery and production is hard to solve. The comparison of the reserves estimates by different sources does not help.

The remaining reserves are reported as proved by OGJ (recopied by USDOE/EIA) after an enquiry upon the national agencies, by World Oil magazine (stopped in 2009) and BP (reporting Orinoco separately) and they differ completely with the 2P from scout database. There is a first political rise in 1986 with the OPEC fight on quotas (based on oil reserves) started by Kuwait large reserves increase.

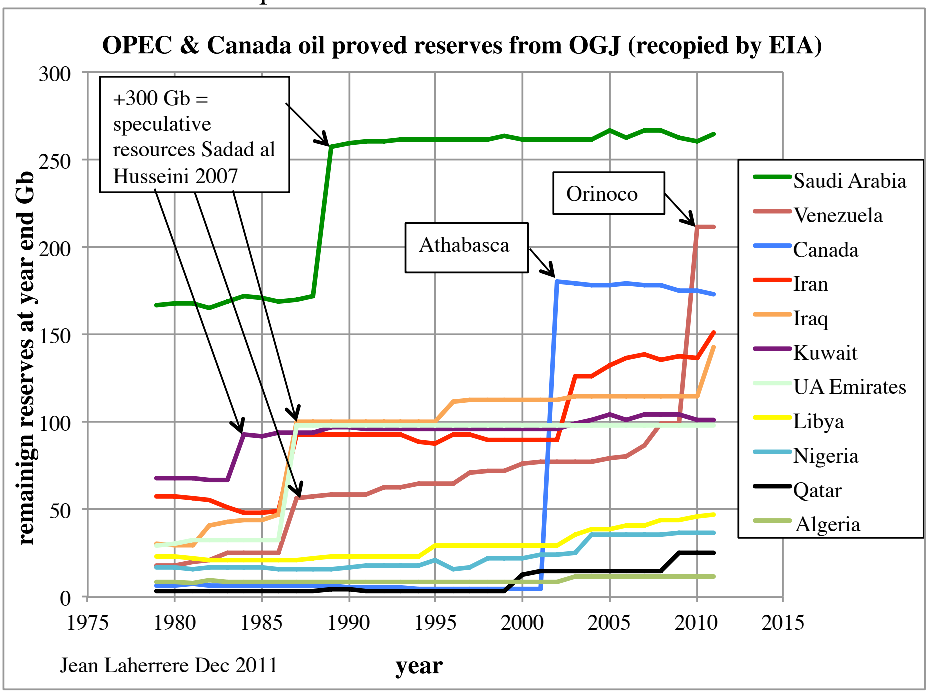
It is strange to see that Venezuela proved reserves increases sharply when oil production decreases sharply! But maybe not if it is political!

Figure 15: Venezuela remaining oil reserves from different sources



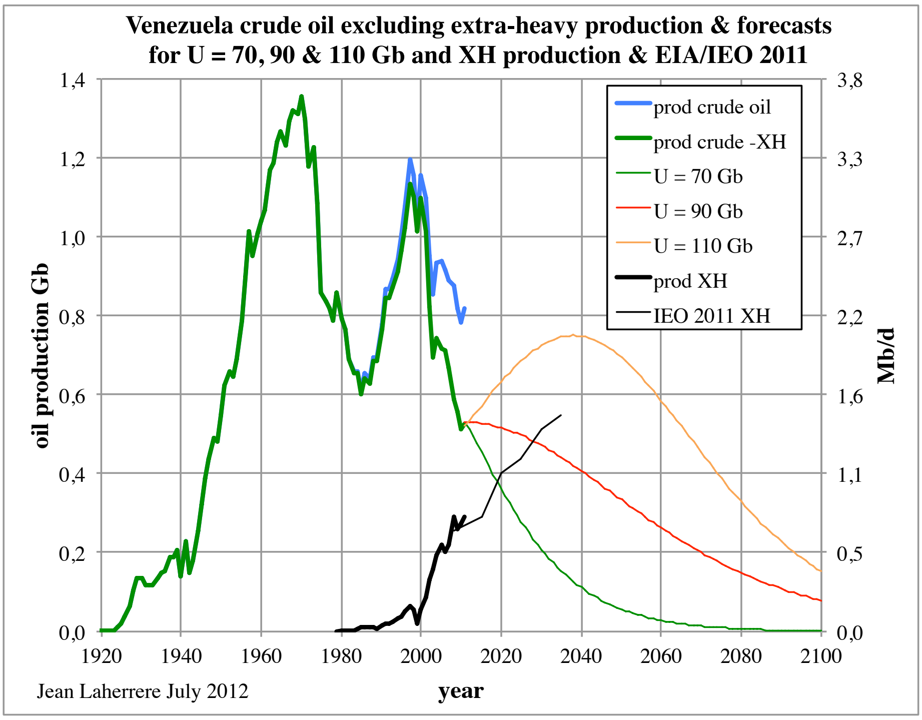
Venezuela proved reserves increases sharply in 2010 by including extra-heavy oil is late compared to Canada increase in 2002, when before OGJ was reporting only conventional oil.

Figure 16: OPEC & Canada oil proved reserves from OGJ



To conclude, it is hard to choose an ultimate for Venezuela crude oil **excluding extra-heavy**, so the best is to use 70 Gb, 90 Gb and 110 Gb

Figure 17: Venezuela crude excluding extra-heavy oil annual production & forecasts, with also extra-heavy production



The 110 Gb ultimate seems too high, needing a huge effort to improve the recovery on the heavy oil fields. The 90 Gb ultimate seems the most likely.

The potential of Venezuela crude excluding extra-heavy oil production, which is on a steep decline since 1997, is such that the decline can be slowed down or even reversed if PDVSA recovers competence, investment and international partners.

Better transparency in the data is also necessary.