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 gestión*) 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 Juana 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.
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=q3hBXav0fYWc&pg=PA347&lpg=PA347&dq=Bachaquero+Bolivar+Lagunillas+Tia+Juana+oil+production&source=bl&ots=hvKTQqdpvB&sig=rzOHzfDP4Tjk_wV-jRumDKYUaR8&hl=fr

Figure 7: Bolivar Coastal Complex surface subsidence for Bachaquero & Lagunillas
Figure 8: Bolivar Coastal Complex surface subsidence map

Figure 9: Bolivar Coastal Complex map from USGS 1991.
and also the cumulative production and ultimates:

Figure 10: South America: Giant fields ultimates and cumulative production from USGS 1991
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>
<thead>
<tr>
<th>FIELD</th>
<th>RECOVERABLE RESERVES</th>
<th>CUMULATIVE PRODUCTION</th>
<th>% PRODUCED</th>
<th>REMAINING RESERVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beca (1930)</td>
<td>2,172,476</td>
<td>1,691,712</td>
<td>77.9</td>
<td>480,764</td>
</tr>
<tr>
<td>Campana (1917)</td>
<td>381,844</td>
<td>384,783</td>
<td>93.1</td>
<td>27,061</td>
</tr>
<tr>
<td>La Concepcion (1925)</td>
<td>188,927</td>
<td>146,194</td>
<td>77.4</td>
<td>42,733</td>
</tr>
<tr>
<td>La Paz (1923)</td>
<td>1,045,132</td>
<td>655,713</td>
<td>84.7</td>
<td>159,419</td>
</tr>
<tr>
<td>Lagunillas (1926)</td>
<td>2,918,829</td>
<td>2,188,065</td>
<td>72.2</td>
<td>810,464</td>
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<tr>
<td>Mene Grande (1914)</td>
<td>755,135</td>
<td>697,690</td>
<td>87.1</td>
<td>97,475</td>
</tr>
<tr>
<td>Tia Juana (1929)</td>
<td>2,392,787</td>
<td>1,775,431</td>
<td>74.2</td>
<td>617,356</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>9,864,830</td>
<td>7,629,658</td>
<td>77.3</td>
<td>2,235,272</td>
</tr>
</tbody>
</table>

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.