Flesh on the bones of Mexican oil production

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Topic: Supply/Production
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Following on from Khebab's posts (**Jan 2007** and **July 2006**) I wanted to put some production geology flesh on the bones of Mexican oil production. The main points I want to make are:

1. Forecast production decline of 14% per annum in Cantarell sounds alarming but it is in fact the result of planned reservoir management.
2. The forecast decline of Cantarell is due in part to the diversion of nitrogen injection from Cantarell to the neighbouring Ku-Maloob-Zaap (KMZ) complex of fields. Production at KMZ is forecast to rise to around 800 MBD and this will partly offset production falls at Cantarell.
3. Cantarell / Mexican production is predominantly heavy crude, and it is postulated that any production declines in Mexico may be met by additoinal production of Saudi Arabian heavy crude forward to 2012.
4. Notwithstanding point 3, Mexican oil production decline means that 4 out of 5 major OECD producers are now in decline (Norway, UK, USA and Mexico), leaving only Canada with growing production and this presents the OECD with a growing problem of energy security.
5. The Hubbert Linearisation (HL) for Mexico reflects reservoir management (gas lift and nitrogen injection) and new field developments but the interpretation remains equivocal. A brief description is given of why Pemex have used gas lift and nitrogen injection to boost production at Cantarell.

Cantarell's loss is Ku-Maloob-Zaap's (KMZ) gain

Much concern has revolved around the Cantarell Field in Mexico that is forecast to decline at **an alarming 14% per annum**. The Cantarell complex (Figure 1) has been a wonder producer for Mexico reaching maximum production of 2.14 million barrels per day (MMBPD) in 2004. This, however, was only acheived by the application of world leading reservoir management methods.

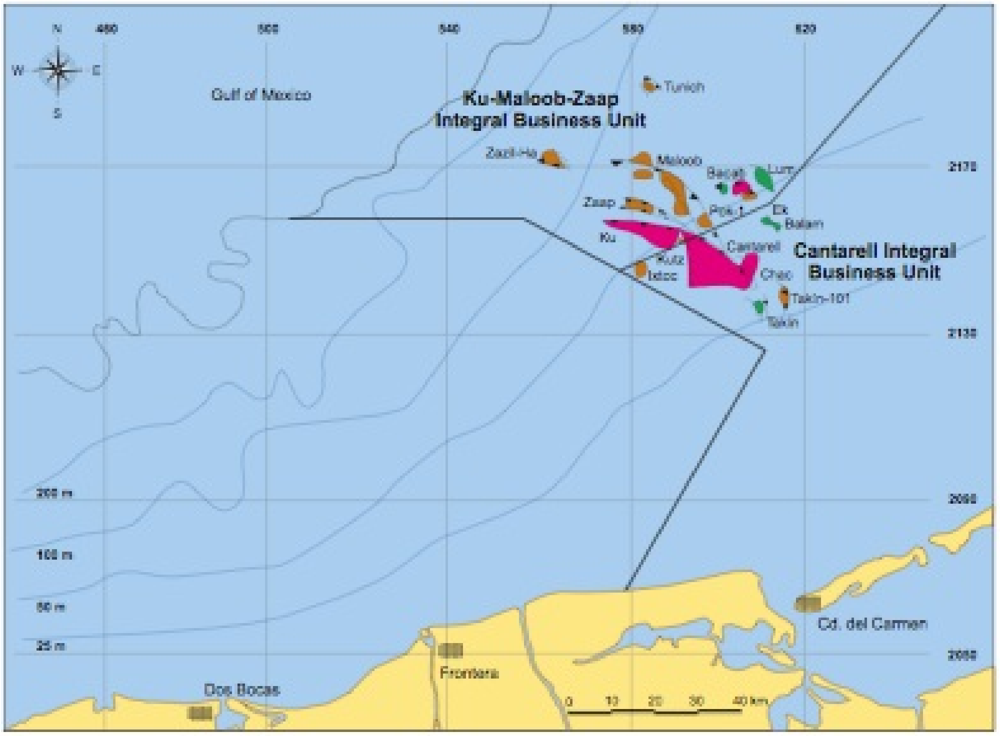

Figure 1. *Map showing the location of the Cantarell and KMZ complexes in the Bay of Campehe (click to enlarge). Map copied from a* ***Pemex report*** *(large pdf).*

Mexico produces heavy crude

72% of the crude oil produced in Mexico is heavy "Maya" with average API gravity of 22 degrees. Light crude has higher API gravity, and for example Brent Blend has API gravity of 38 degrees and Westexas Intermediate 39 degrees.

One of the key differences between light and heavy crude is the **viscosity of the liquid**. Light crude has a viscosity close to that of water, especially at reservoir temperatures. In other words light crude is highly mobile. Heavy crude is more viscous and has mobility more like thin syrup. Heavy crude, therefore, does not move through the reservoir rocks so easily and this can present production problems. Note that the viscosity of crude oil falls with increasing temperature and vice versa.

Gas lift used to increase production rates

Flow rates for heavy crude may be low, depending upon reservoir quality and pressure decline. On Cantarell, flow rates were increased by introducing **gas lift to most wells** in the period 1988 to 1994. **Gas lift** involves injecting natural gas into the oil production stream at the bottom of the oil well. This lowers the density of the oil throughout the whole well and lowering the density reduces the liquid pressure inside the well at its base. This creates a greater pressure difference between the reservoir and the well resulting in higher flow rates.

Nitrogen injection

Maintaining reservoir pressure can also be more problematic with heavy crude as water injection is less applicable. This is because injecting cold water may increase the viscosity of the oil and may result in a very uneven sweep of the reservoir. It is common practice to inject steam into heavy crude reservoirs to overcome some of these problems. In Cantarell, however, it was elected to inject nitrogen gas instead and this lead to the construction of the world's largest nitrogen plant at a cost of $6 billion. Note that it is not possible to simply inject air as the oxygen may set off a number of undesirable chemical and biological reactions in the reservoir.

Nitrogen injection is a form of **miscible gas flood**. The nitrogen helps to boost reservoir pressure and to mobilise the oil. In Canatrell the effects were miraculous with a marked rise in production accompanying nitrogen injection in 2000 (Figure 2). However, the nitrogen has now dones its work and continued injection is likely to damage reservoir productivity. **The decision has now be made, therefore, to divert nitrogen from Cantarell to the neighbouring KMZ complex (Figure 1) where injection is expected to boost production to 800 MBD by 2010**. This will offset more than half of the production decline from Cantarell (Figure 2).

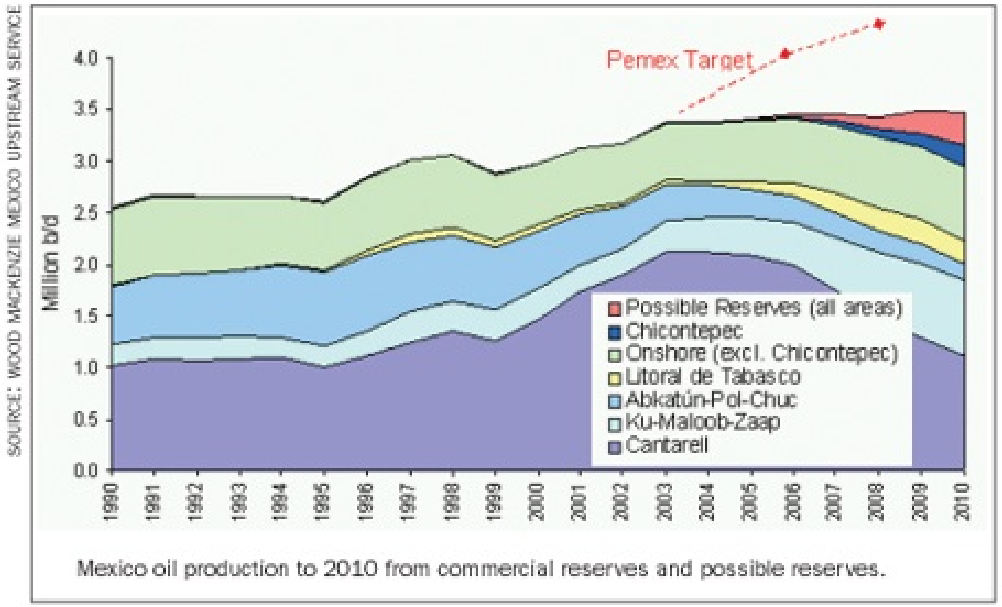

Figure 2. *Mexican oil production past and future, Wood Mackenzie, copied from **here**. Note how production from KMZ is forecast to expand and partly offset the decline in Cantarell.*

Production forecast

Figure 2 shows that Mexican production is not about to go off a cliff edge. The cupboard is not yet bare, and new fields will be developed off the Tabasco coast and on-shore at Chicontepec. I think the "possible reserves" wedge needs to be ignored, and I consider it likely that the picture painted in Figure 2 may be over-optimistic. Furthermore, project delays may result in sharper production decline near term. Dave has discussed logistical problems in the oil industry **"south of the border"**. But the fact remains that KMZ, Tabasco and Chicontepec will partly offset the demise of Cantarell forward to 2010.

With 60% of production forecast to decline at 14% per annum, it seems likely that 2004 will prove to be Mexico's peak production year. The new supplies indicated in Figure 2 are unlikely to plug the gap in my opinion, although, as detailed by **Khebab**, the EIA and IEA see Mexican production rising to over 4 MMBPD by 2010. The question for Mexico, therefore, is how rapidly production declines post-peak. As discussed below, it is still too early for Hubbert to provide this answer and it is only possible to make an educated guess. So my guess is decline will run at around 4% per annum which is appropriate for a mix of offshore and onshore production. **Khebab's** "Low Logistic" based on monthly crude+condensate data also declines at around 4% per annum.

Impact on world crude oil market

With production of 3.7 MMBPD, domestc consumption of 2.1 MMBD, Mexico exported around 1.6 MMBD of predominantly heavy crude in 2006. Much of this was exported to the USA which has refining capacity tuned to refine heavy crude **as discussed by Dave**.

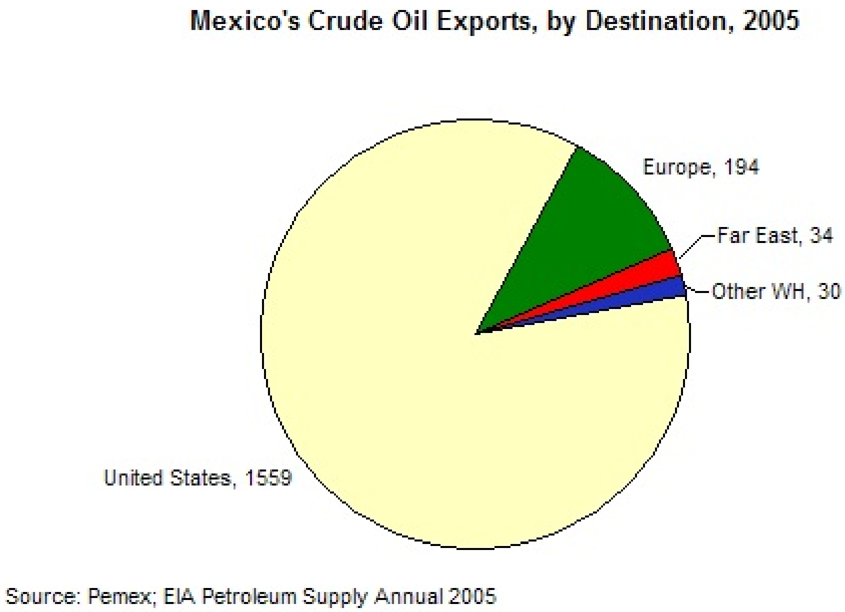

Figure 3. ***[86% of Mexico's oil exports go to the USA.]***

Assuming a 4% decline rate in Mexican production would result in avearge daily production falling from 3.74 MMBPD in 2006 to around 2.93 MMBPD in 2012. This represents a fall of around 800 MBPD by 2012. Whilst not wanting to trivialise this loss of OECD production, my opinion is that much of this lost production of heavy crude may be met by increased production of heavy Saudi Arabian crude from the Safaniya Field. In Twilight in the Desert, Simmons documents possible spare capacity at Safiniya of the order 500 to 1000 MBPD and this should meet falling Mexican production for a few years at least. What I'm trying to say is that falling Mexican production would be more serious if it were light sweet crude production that was lost. One consequnce of this, however, will be loss of conserved Saudi capacity and shrinking spare capacity going forward should be bullish for the oil price.

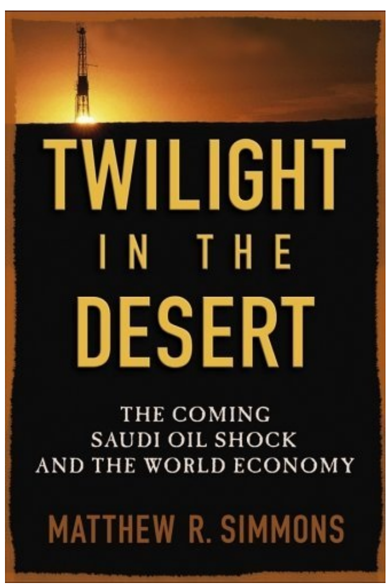

Figure 4. *The Safaniya heavy oil field is described by Matt Simmons on pages 187 to 191.*

Hubbert dog leg

Finally, I want to take a brief look at Hubbert Linearisation (HL) for Mexico. From the work of **Khebab** it was clear to me that there was a dog leg in the HL with a marked change in gradient at around 1995 (Figure 5). Note that in Khebab's more recent work, this dog leg is obscured through use of monthly as opposed to annual production data. I wanted to see what production geology event this might relate to as understanding this is vital to the overall interpretation - the pre 1995 leg points to reserves of 35 Gb whilst the post 1995 leg points to 66 Gb (Figure 5). What event might have added 31 Gb to Mexico's reserves? Or is there some deception at work here? Khebab, however, has noted that the pre 1995 leg has a P/Q value greater than 5% meaning that the production from this period is not sufficiently mature to provide a reliable estimate of URR.

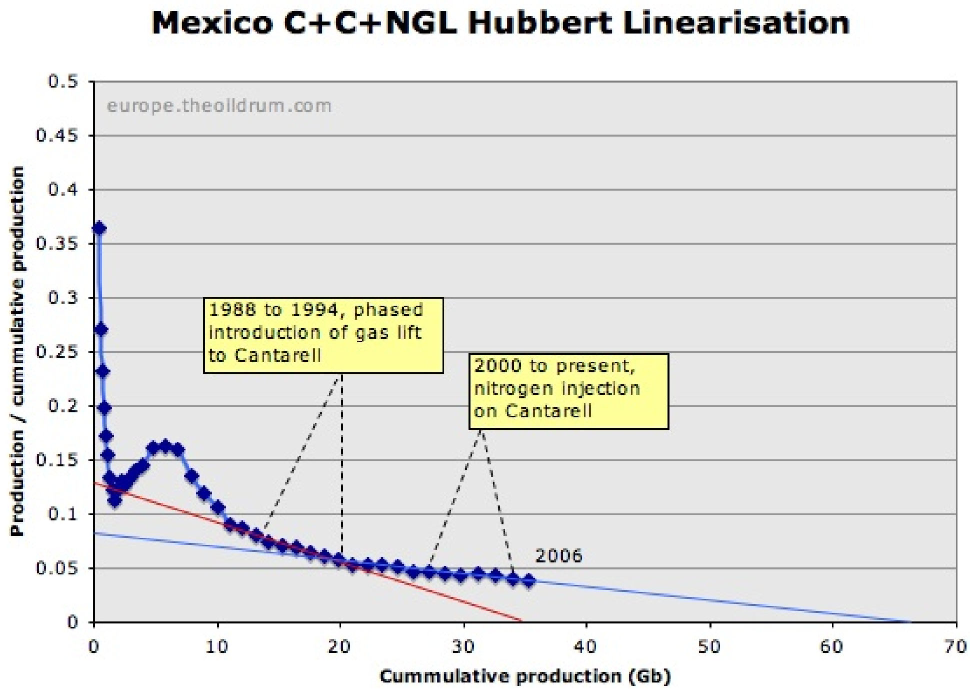

Figure 5. *Hubbert Linearisation for Mexico. Crude+condensate+NGL (C+C+NGL). Data from* ***BP statistical review****.*

Unfortunately, the 1995 dog leg does not correlate with the major resevoir management interventions on Cantarell. The introduction of gas lift (1988 to 1994) pre-dates the dog leg and the introduction of gas injection in 2000 significantly post-dates the dog leg (Figure 5).

However, from Figure 2, it is quite clear that 1995 was a significant year for Cantarell because in this year production began to rise from the 1 MMBPD plateau (1990 to 1995) towards the 2 MMBPD reached in 2003. I can only speculate that new production platforms or new oil export facilities (pipelines) were brought on line in 1995 allowing production at Cantarell to grow significantly over the next 8 years - boosted by gas lift and nitrogen injection infrastructure.

So might this result in adding 31 Gb to Mexican oil reserves? Well the answer is yes and no. Gas lift and nitrogen injection provide higher production rates without necessarily adding to reserves. But on the other hand, nitrogen injection provides greater mobilistion of oil and more efficient sweep of the reservoir which will result in greater ultimate recovery than would have occured without this intervention.

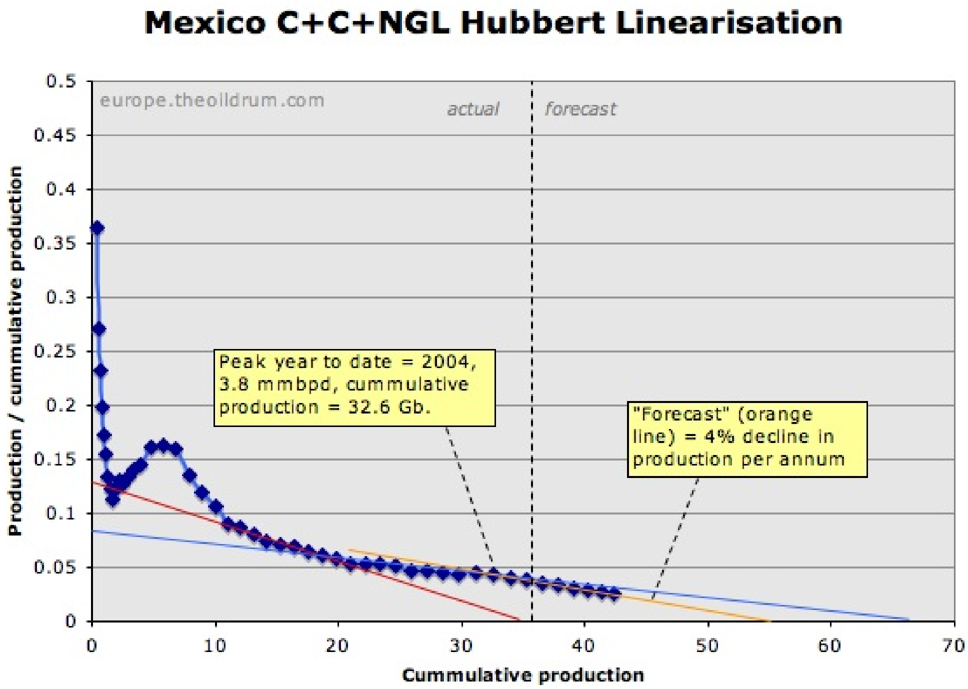

Figure 6. *HL "forecast" assuming 4% decline in Mexican C+C+NGL production from 2006 onwards points to ultimate recoverable reserves of around 55 Gb.*

So the honest answer is that it is too early for HL to say. My best guess is based on assuming 4% annual decline and this points to ultimate recoverable reserves (URR) of 55 Gb, though it has to be said that this figure falls close to several other estimates for Mexican URR as summarised on **Graphoilogy**. But we must also remember that Mexico has a vast unexplored deepwater area that may yield some major discoveries in the years ahead. This will have no impact upon peak oil which I see in 2012 ± 3 years, but deep water Mexican production may have a significant roll to play in keeping the hybrids running post 2020.