

Status of North Ghawar

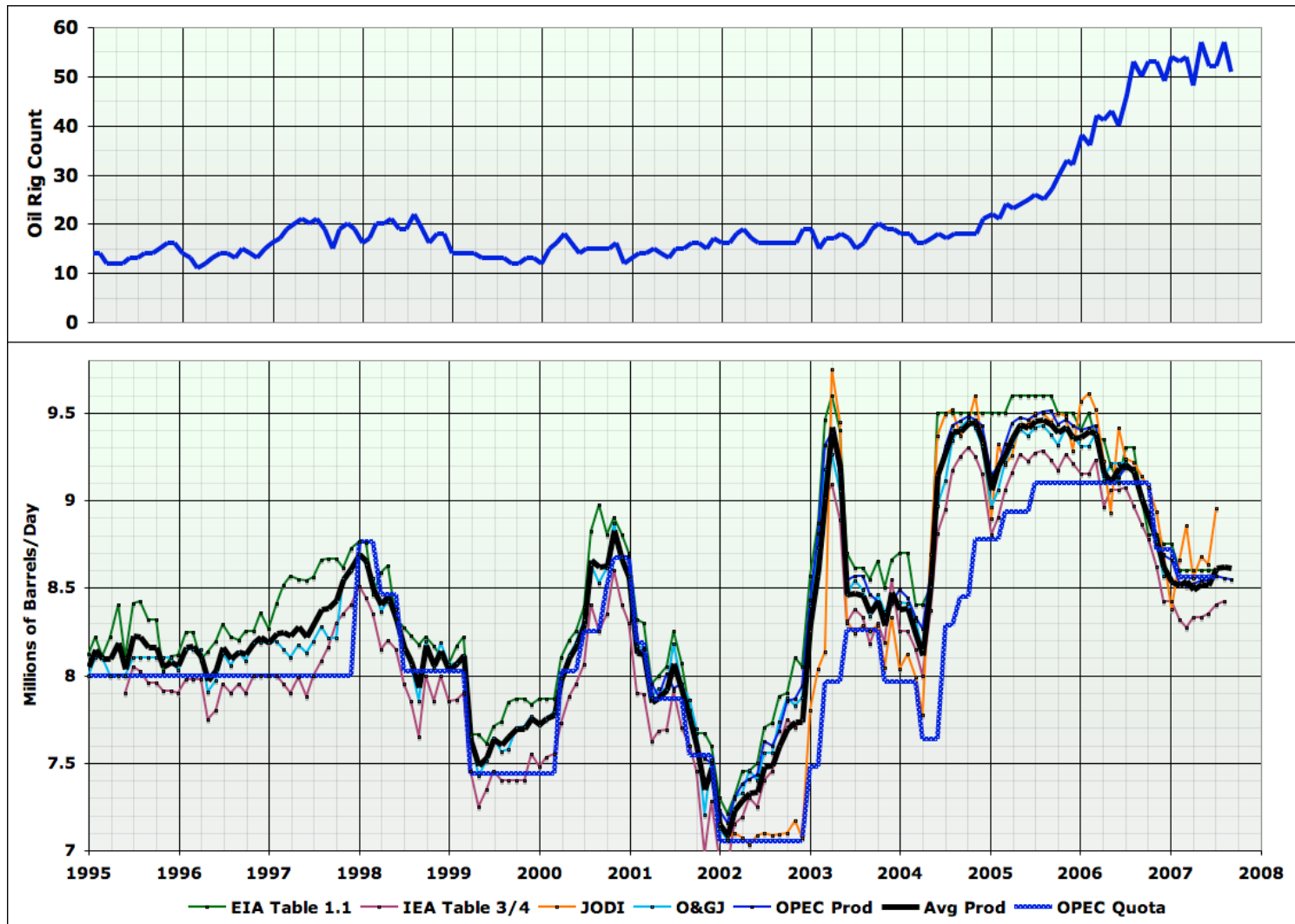
Stuart Staniford, Invicta Consulting

(joint work with Euan Mearns, Isotopic Ltd)

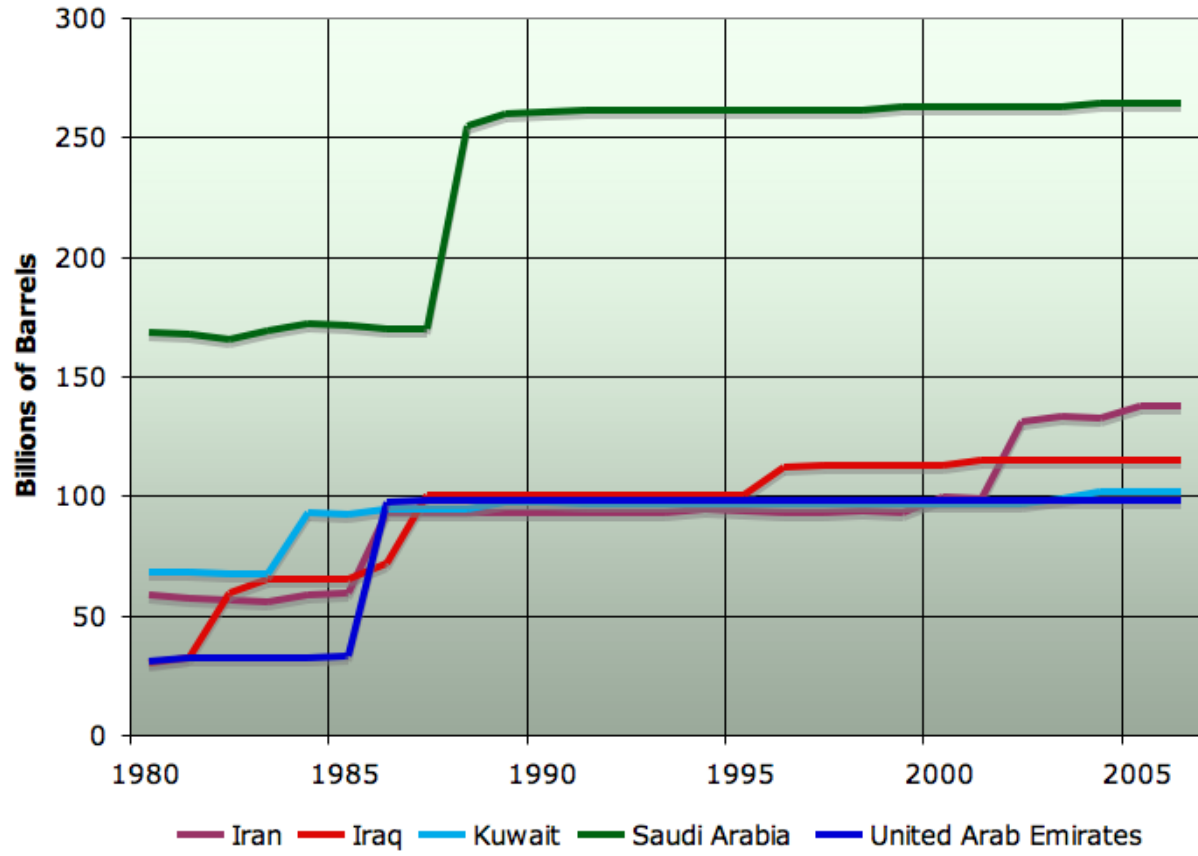
[The Oil Drum](#)

October 17th, 2007

Does this...

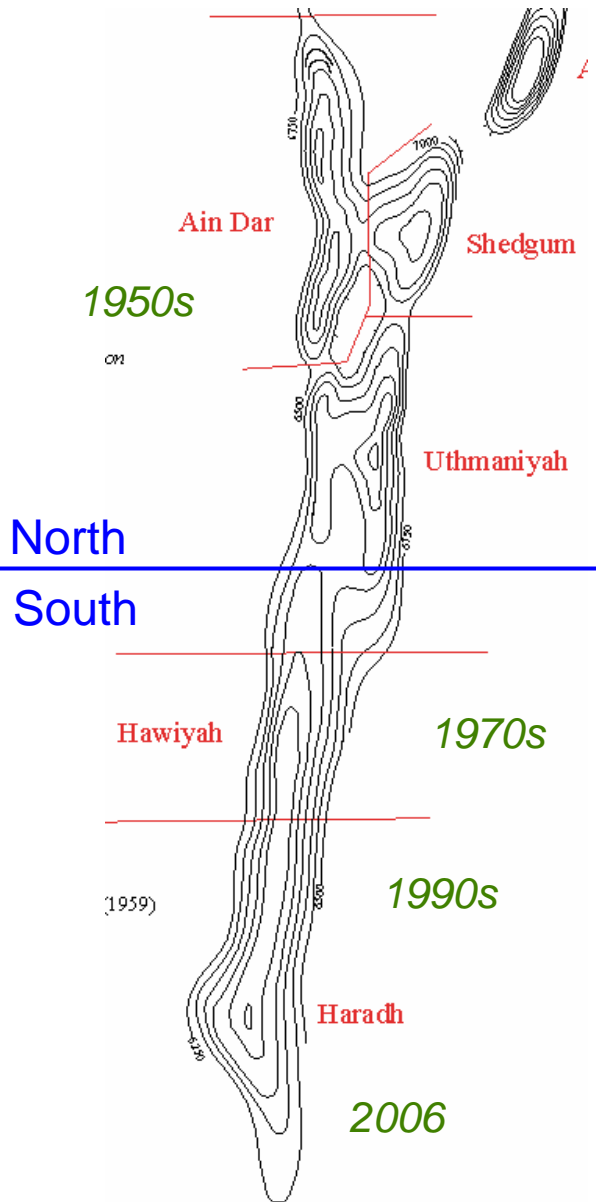


Have anything to do with this?



Source: BP

Ghawar



- World's biggest oilfield
 - By far
- 5 mbpd (at least to 2003)
 - 6% of global supply
- Over half of Saudi production
 - About a third of original reserves
- 225 km x 25 km
- Large technical literature
 - Dozens of papers

Calculating Original Reserve

- Reserve is a product of five factors
 - The area
 - Average net pay thickness
 - Average porosity
 - Oil saturation change in pore volume
 - Starts out mostly oil with some water
 - Ends up mostly water with some oil
 - Formation volume factor

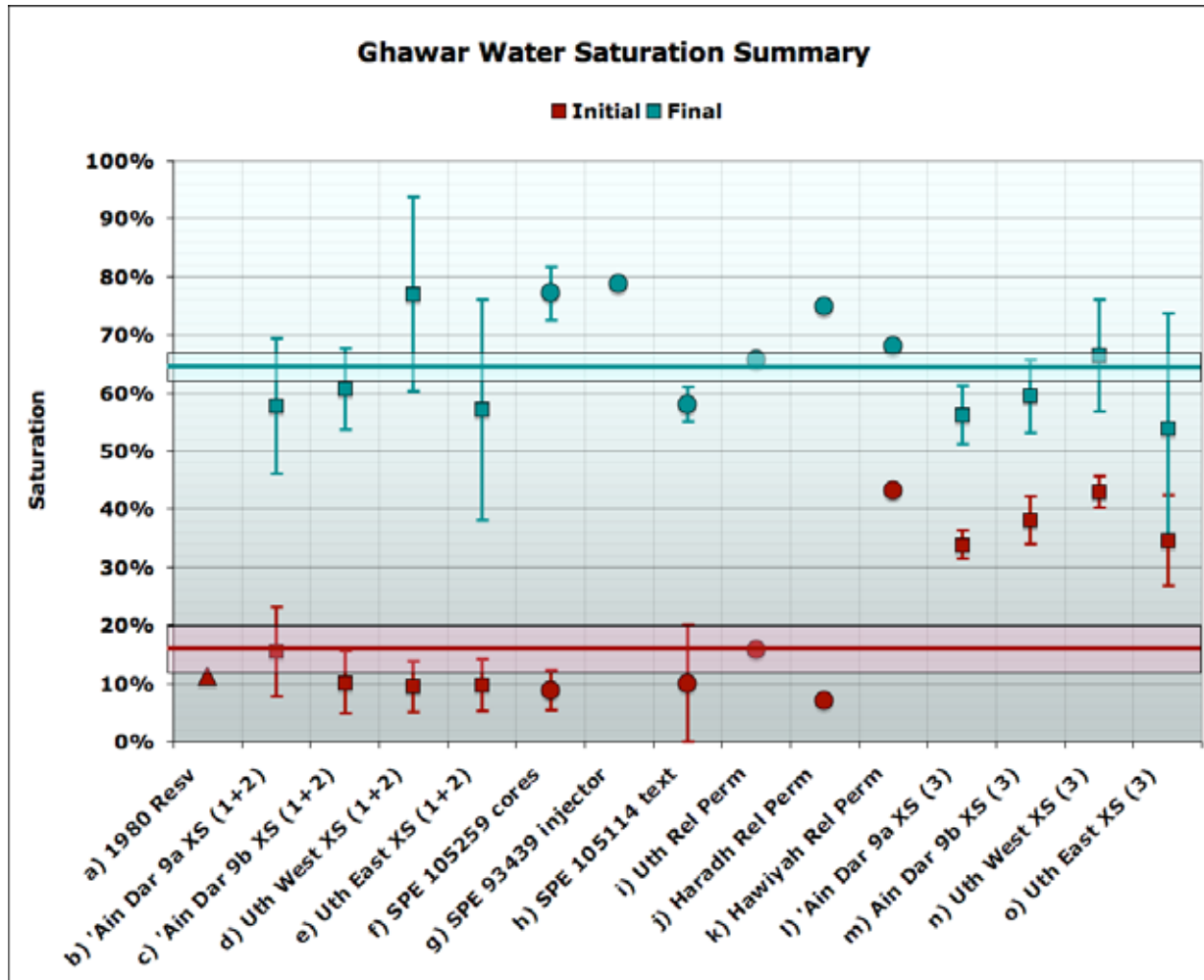
1980 Aramco Table

- Has porosity, net pay, and formation volume factor for major fields as of 1980

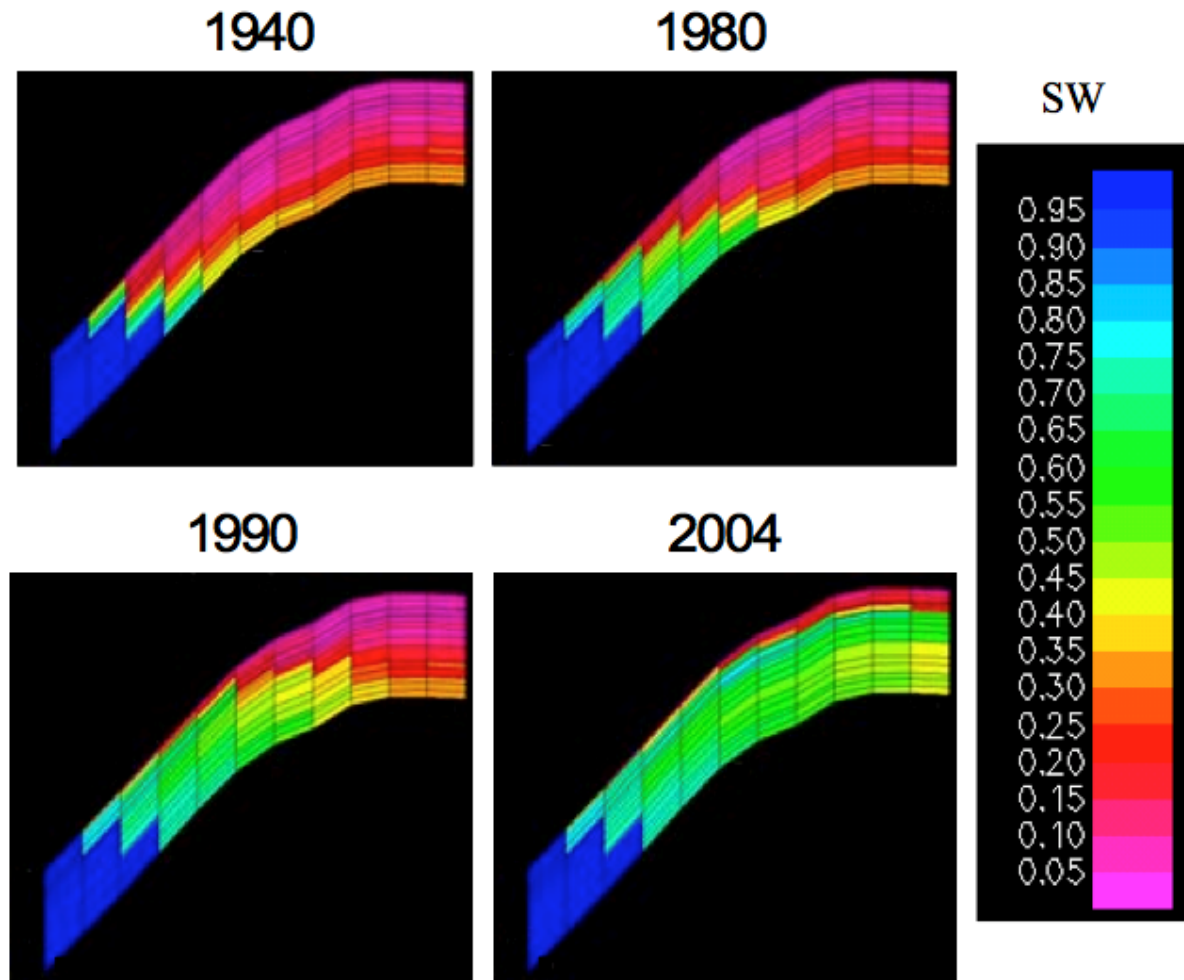
| FIELD NAME | RESERVOIR NAME | RESERVOIR DATA | | | | FLUID DATA | | | | | |
|-------------|----------------|----------------------------|-----------------|-----------------------------|---------------|------------|-------------------|---------------------------------|-------------------------|---|------------------|
| | | ORIGINAL OIL-WATER CONTACT | AVG. NET THICK. | ORIGINAL PRESSURE AND DATUM | | AVG. TEMP. | ORIG. SAT. PRESS. | ORIGINAL SOLUTION GAS-OIL RATIO | ORIG. FORM. VOL. FACTOR | VISCOSITY ORIGINAL RESERVOIR CONDITIONS | STOCK TANK GRAV. |
| | | (feet subsea) | (feet) | (psig) | (feet subsea) | (°F) | (psia) | (SCF/STB) | (RB/STB) | (centipoise) | (deg. API) |
| ABQAIQ | Arab-C | 6,242 | 30 | 2,934 | 5,900 | 215 | 593 | 130 | 1,142 | 2.12 | 28 |
| | Arab-D | 7,112/7,210* | 227 | 3,395 | 6,500 | 215 | 2,560 | 860 | 1,528 | 0.36 | 37 |
| | Hanifa | 6,946 | 280 | 3,485 | 6,800 | 220 | 2,196 | 737 | 1,434 | 0.47 | 37 |
| ABU HADRIYA | Arab-A | 8,704 | 29 | 4,208 | 8,500 | 215 | 218 | 57 | 1,081 | 1.70 | 34 |
| | Arab-B | 8,704 | 23 | 4,208 | 8,500 | 215 | 218 | 57 | 1,081 | 1.70 | 34 |
| | Arab-C | 8,679 | 80 | 4,235 | 8,500 | 218 | 218 | 57 | 1,063 | 1.70 | 28 |
| | Hanifa | 9,185 | 64 | 4,517 | 9,140 | 227 | 287 | 110 | 1,091 | 1.80 | 32 |
| | Hadriya | 10,140 | 100 | 4,843 | 9,720 | 240 | 790 | 260 | 1,190 | 0.75 | 35 |
| Fadhili | 10,096/10,103* | 60 | 5,019 | 9,857 | 240 | 2,550 | 875 | 1,315 | 0.62 | 36 | |
| ABU JIFAN | Arab-D | 3,472 | 113 | 1,918 | 3,270 | 130 | 570 | 253 | 1,176 | 2.06 | 32 |
| ABU SA'FAH | Arab-C | 6,409 | 98 | N.D. | 6,325 | 188 | 230 | 34 | 1,065 | 12.10 | 19 |
| | Arab-D | 6,685 | 310 | 3,250 | 6,535 | 189 | 325 | 74 | 1,082 | 2.50 | 30 |
| BAKR | U. Jubaila | 9,292 | 45 | 4,573 | 9,250 | 218 | 223 | 60 | 1,083 | 2.62 | 30 |
| | L. Jubaila | 9,444/9,453* | 107 | 4,597 | 9,350 | 218 | N.D. | 60 | 1,150 | 2.60 | 30 |
| | Hanifa | 9,470 | 14 | 4,662 | 9,456 | 218 | N.D. | 100 | 1,150 | 2.80 | 31 |
| BERRI | Arab-A | 7,458 | 44. | 3,627 | 7,390 | 218 | 411 | 150 | 1,143 | 1.06/1.40 | 36/33 |
| | Arab-B | 7,478 | 46 | 3,635 | 7,300 | 218 | 411 | 139 | 1,133 | 1.19/1.82 | 35/32 |
| | Arab-C | 7,418/7,437* | 98 | 3,624 | 7,300 | 220 | 423 | 150 | 1,141 | 1.87 | 32 |
| | Arab-D | 7,420 | 100 | 3,700 | 7,450 | 220 | 462 | 136 | 1,130 | N.D. | 31 |
| | Hanifa | 7,979/8,212* | 220 | 3,980 | 8,000 | 220 | 1,920 | 659 | 1,400 | 0.50 | 39 |
| Hadriya | 8,730 | 148 | 4,250 | 8,500 | 230 | 2,280 | 805 | 1,500 | 0.42 | 38 | |
| Fadhili | 9,132 | 71 | 4,390 | 8,700 | 240 | 3,015 | 1,206 | 1,674 | 0.29 | 41 | |
| DAMMAM | Arab-A & B | 4,650 | 78 | 2,258 | 4,550 | 204 | 2,169 | 370 | 1,228 | 0.79 | 35 |
| | Arab-C | 4,650 | 100 | 2,258 | 4,550 | 206 | 2,190 | 370 | 1,228 | 0.81 | 35 |
| | Arab-D | 4,650 | 160 | 2,258 | 4,550 | 206 | 2,219 | 353 | 1,219 | 0.94 | 35 |
| DHIB | Dhib | 10,149#/10,204# | 109 | 5,013 | 10,118 | 225# | 290 | 79 | 1,091 | 1.79 | 31 |

Still need saturation change and area (from map)...

Saturation Change

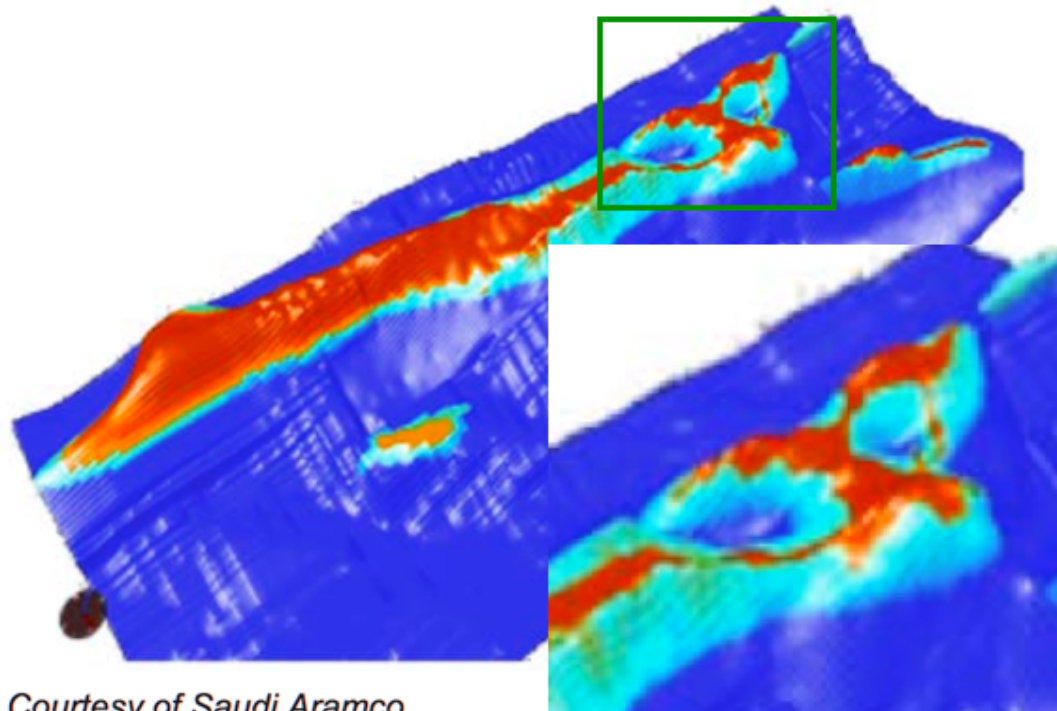


Saturation Evidence Example

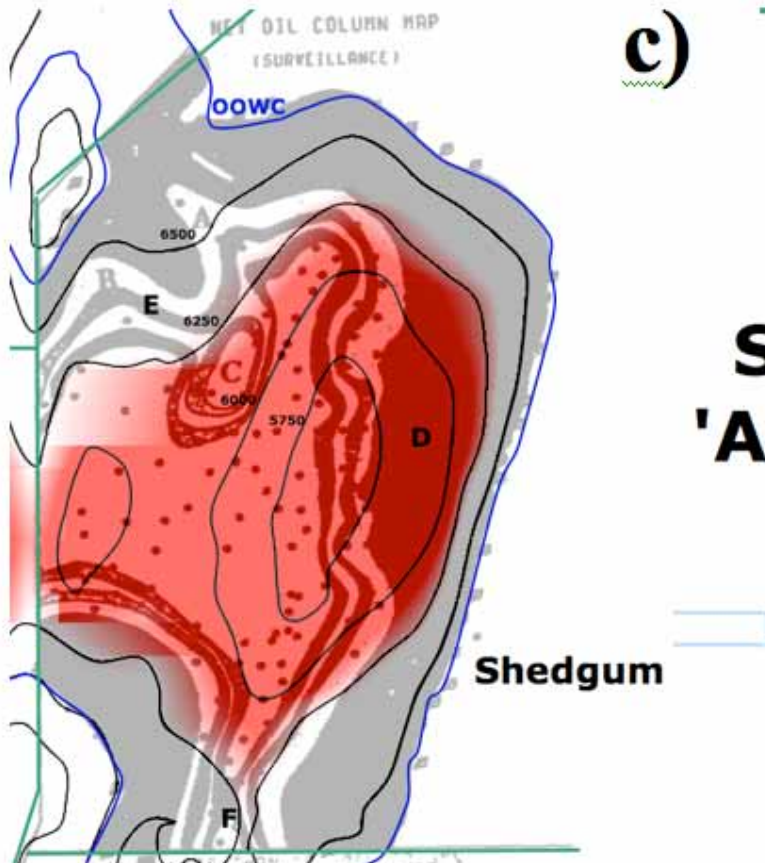


Supercluster picture

Ghawar Field Oil Saturation Plot



Oil layer map evidence



c)

South
'Ain Dar

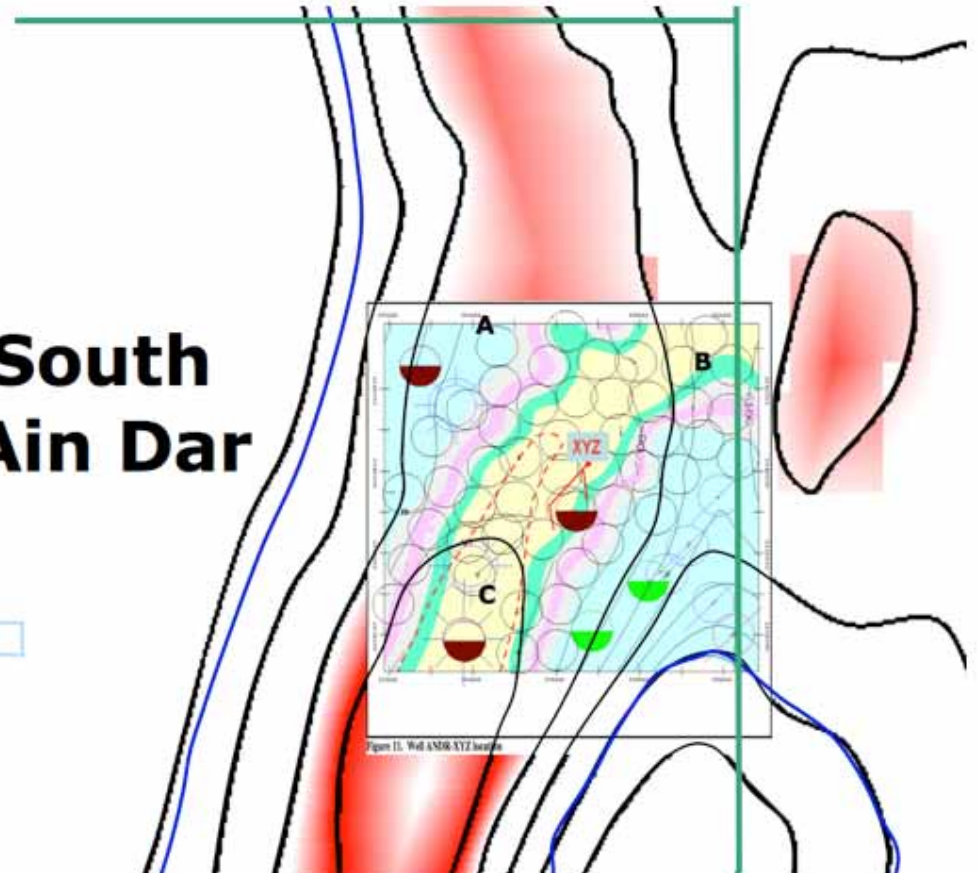
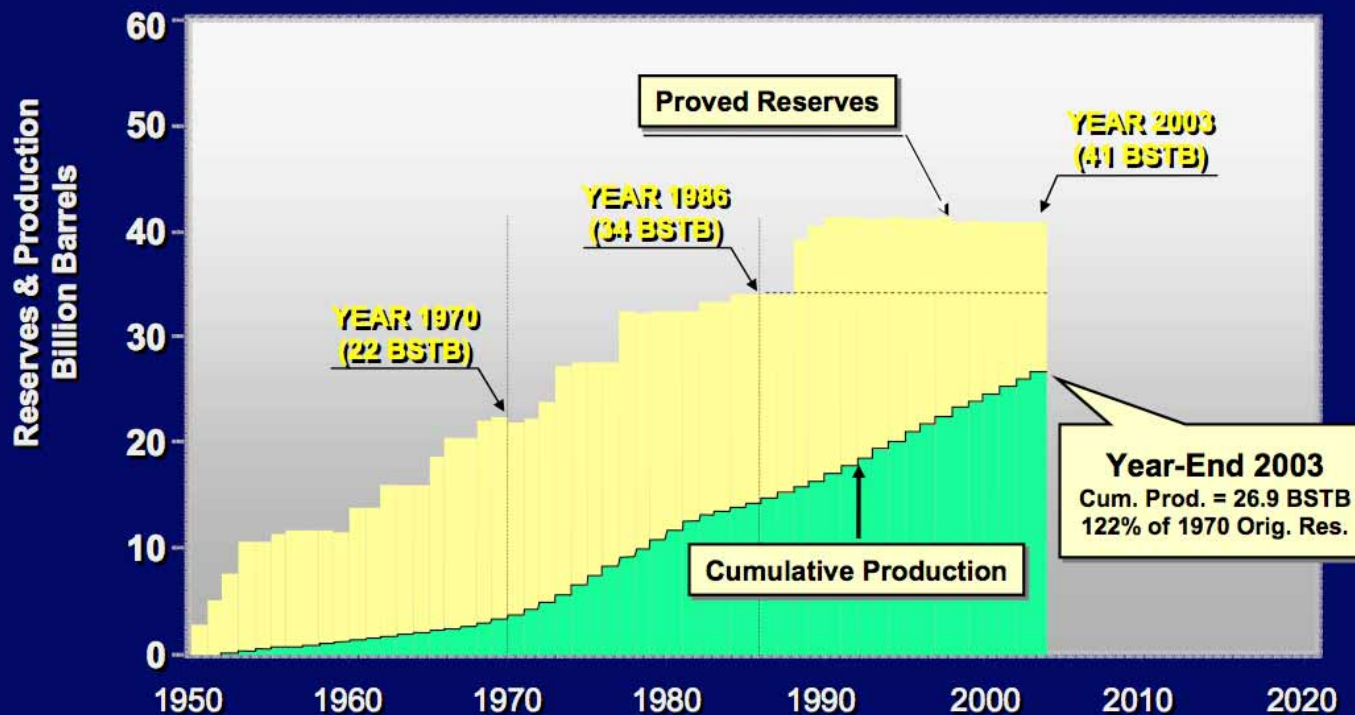


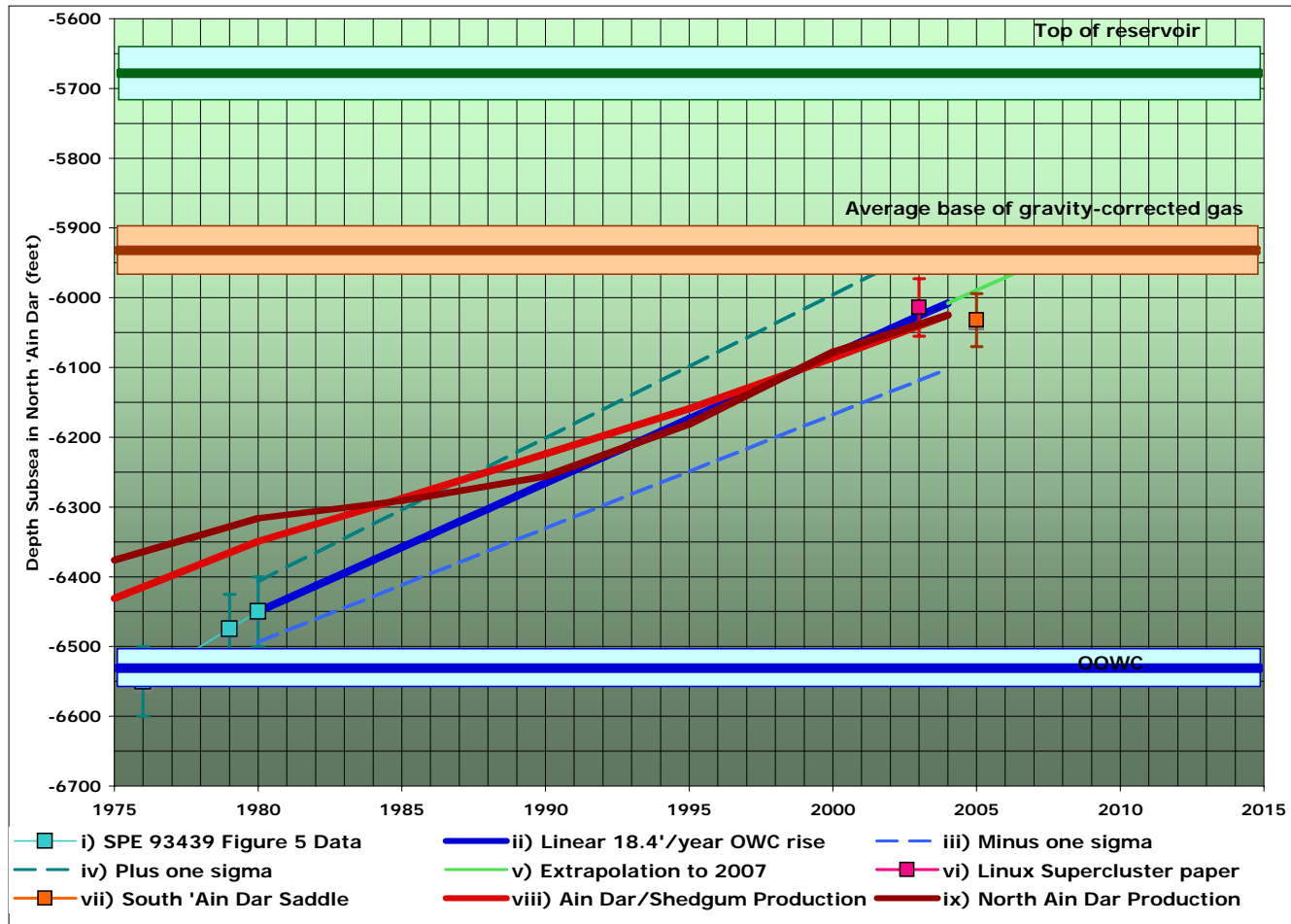
Figure 11. Well AMRAYZ section

Cumulative Production

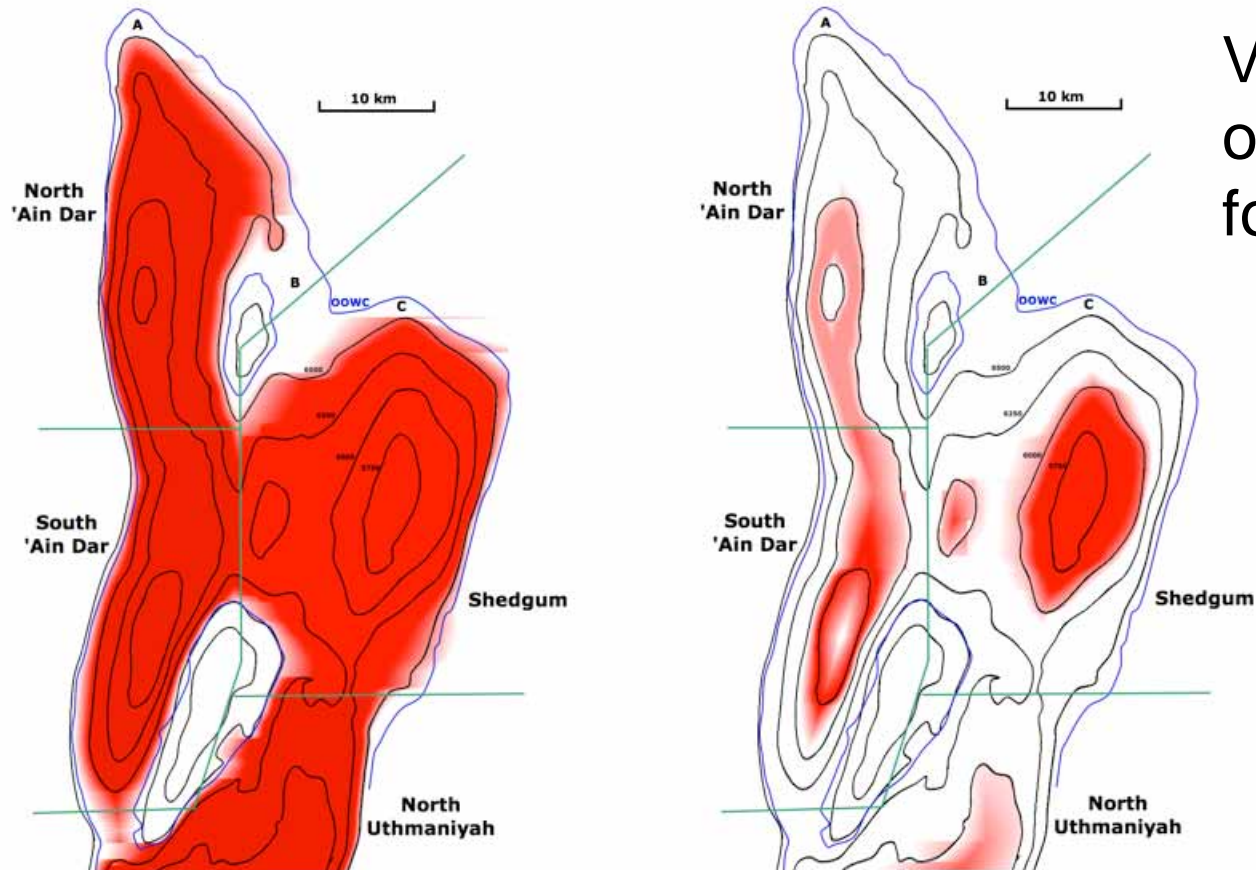
Reserves Appreciation 'Ain Dar Shedgum /Arab D



'Ain Dar/Shedgum OWC height



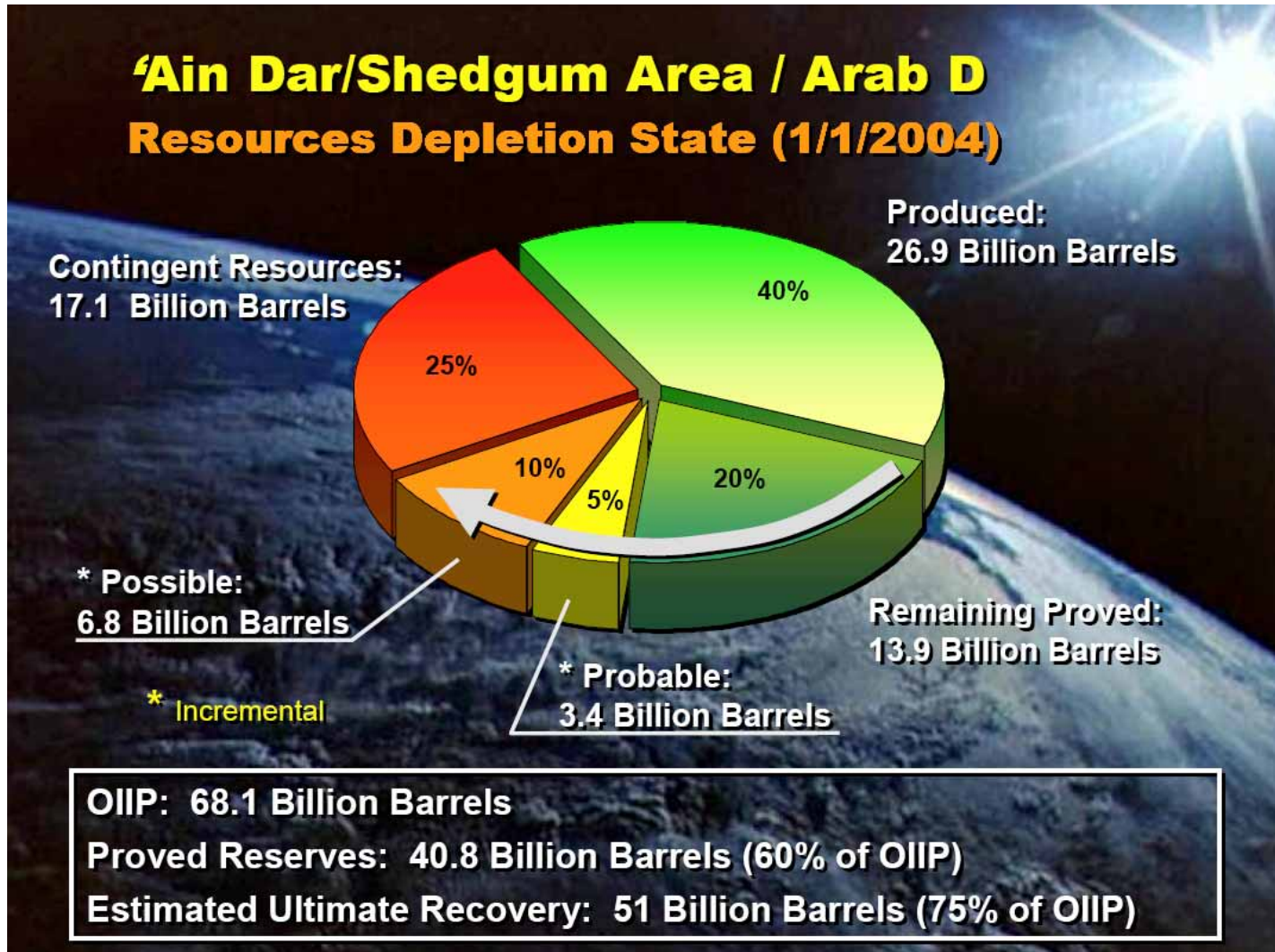
'Ain Dar/Shedgum



Vertical
offset 511'
for 2004

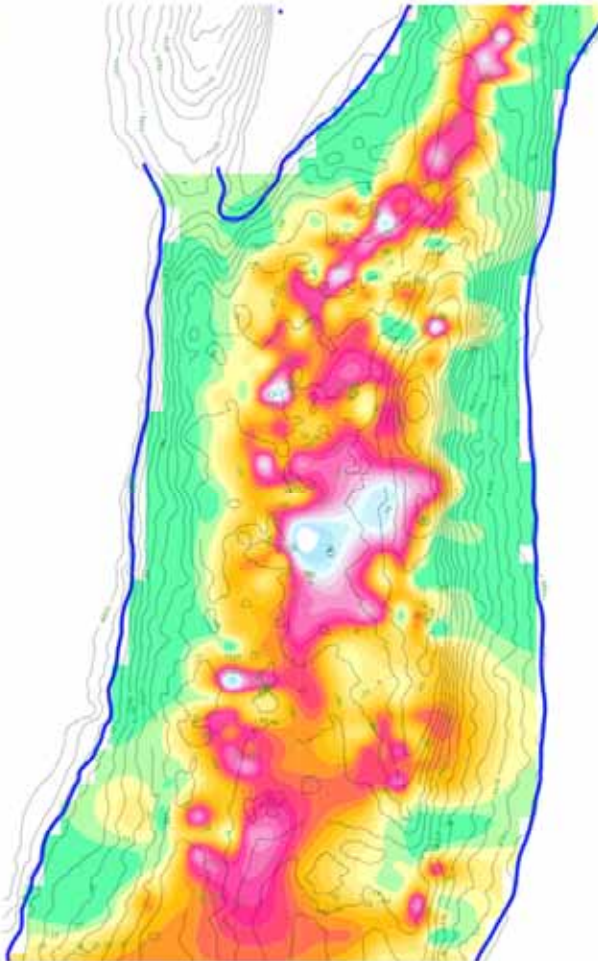
With no OOIP growth, we get 54 ± 4 gb (versus 68.1 gb)
That turns out to not be enough oil to make analysis consistent

'Ain Dar/Shedgum - official

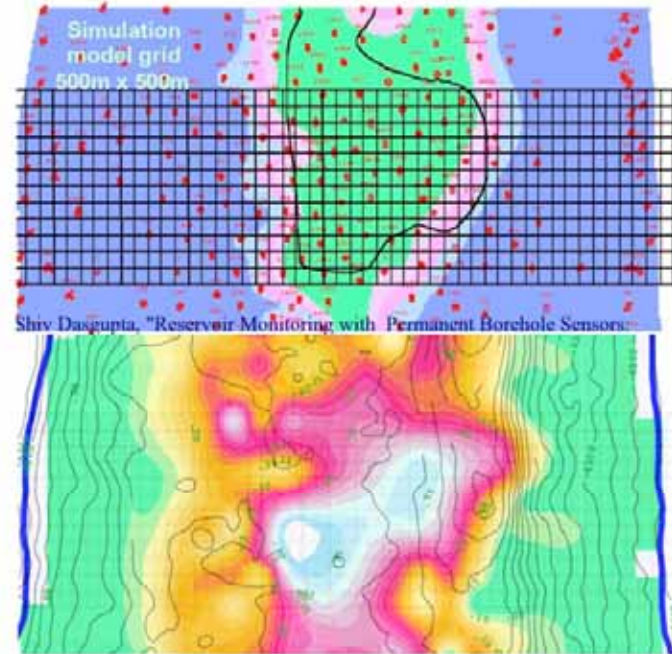


North Uthmaniyah

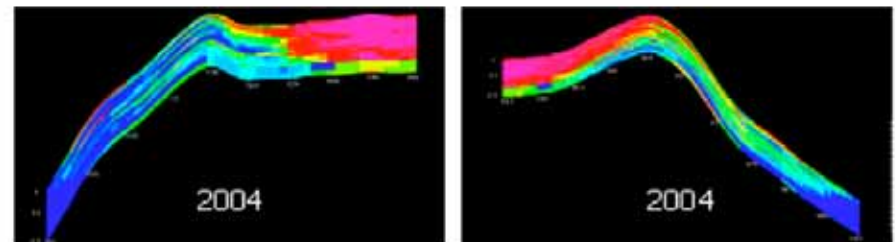
a)



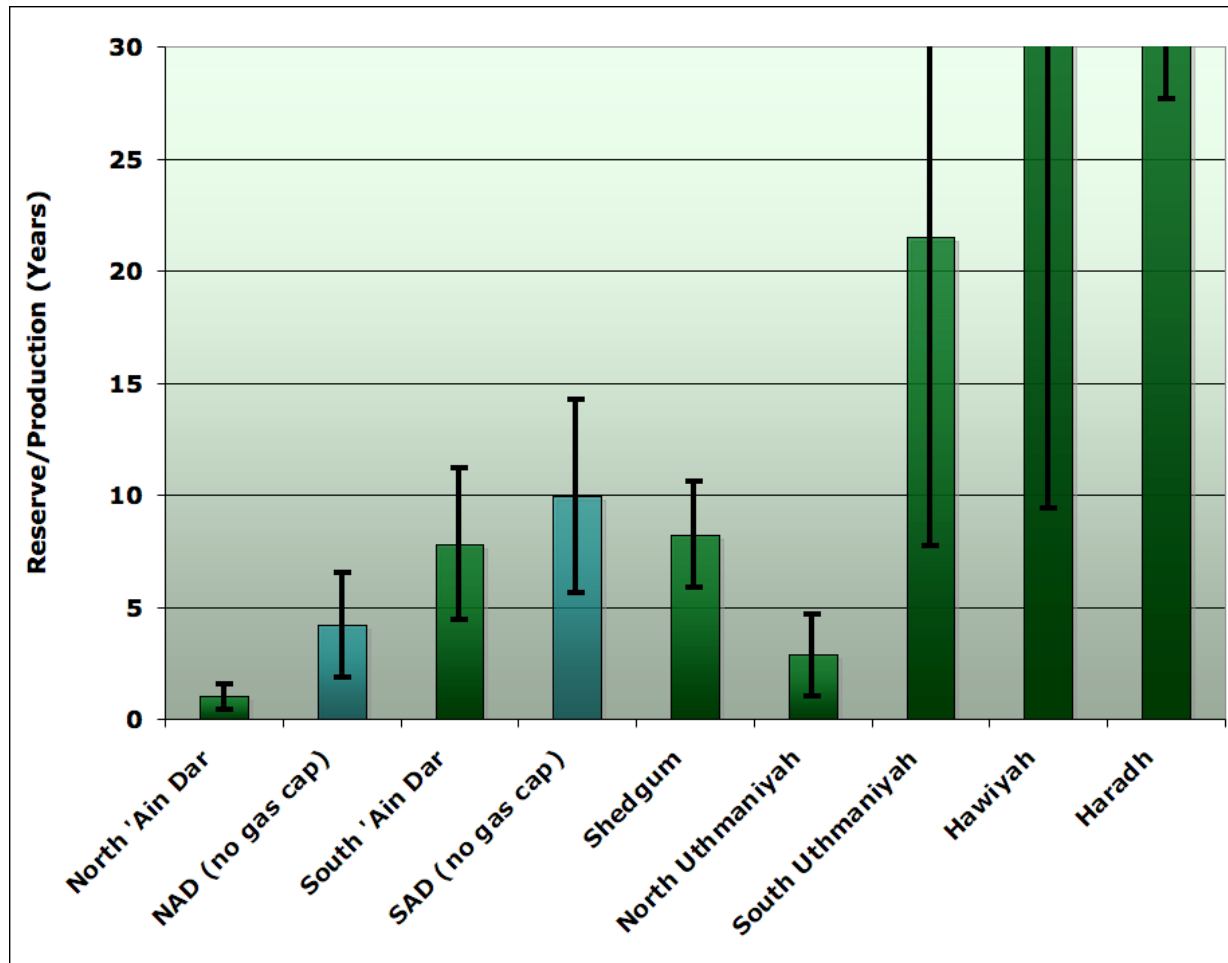
b)



c)

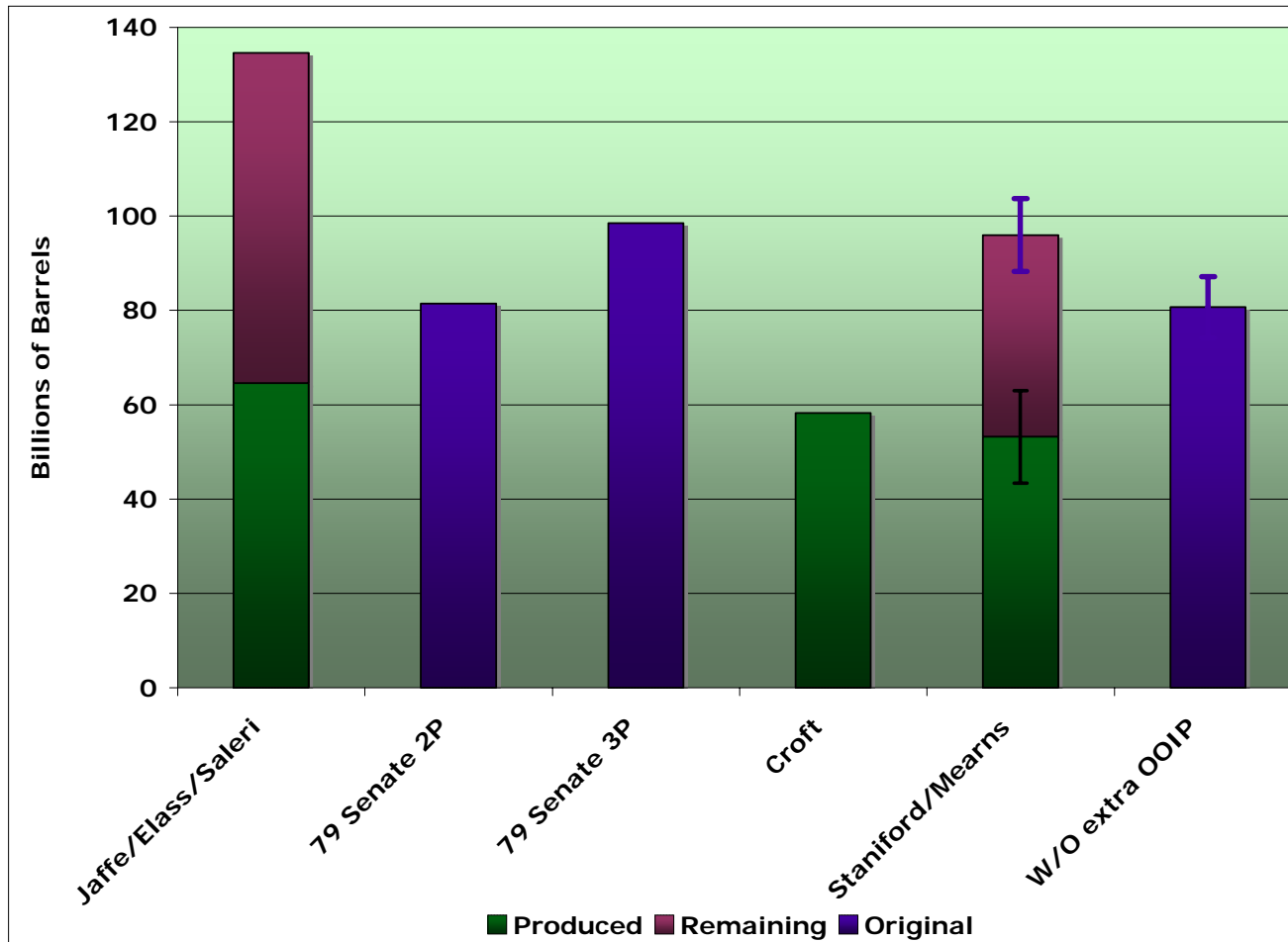


Impact on Production



“Reserve” is 2P exclusive of tertiary recovery

Ghawar Overall Comparison



What does this say about KSA

- Evidence for over-aggressive recovery claims
 - We estimate 52% versus 60-75% Aramco claims
- No evidence of any other factual distortion in technical papers/presentations
- Support for OOIP growth in ADS
- They say 700gb OOIP in total KSA
- Laherrere median recovery (giant fields): 40%
 - Gives 280gb EUR for KSA
 - With very large error bars
- 120gb cumulative production to date
 - Lot left (160gb), even if less than the 260gb they say.

Key Takeaways

- North Ghawar is heavily depleted
- May be impacting production now, certainly will be soon
- KSA reserve claims here are very likely overstated
- South Ghawar can produce for decades
- KSA as a whole probably has a lot of oil left.
 - Rough expectation is several more decades at production levels similar to recently.
 - Quite a lot of uncertainty
 - Then kaput.

2007 Houston World Oil Conference

Proceedings



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