The Oil Drum
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Tech Talk - Extracting the Attic Oil From Abqaiq

Posted by Heading Out on April 15, 2012 - 7:40am
Topic: Supply/Production
Tags: abqaiq, berri, crude oil production, laterals, mrc, saudi arabia [list all tags]

Current figures suggest that world liquid fuels production is running at around 90 mbd, of which roughly 74 mbd is crude. A reasonable estimate of the annual decline in existing well production lies at around 5%, so that each year new sources of oil must be brought on line to generate 5% of 74 mbd (3.7 mbd) to cover these declines. In addition to that need, if world oil markets continue to grow as expected, then an additional roughly 1 mbd of new production will have to be added this year to meet the growth in demand. (China imported 5.95 mbd in February, and though this dropped to 5.55 mbd in March, this is still up 8.7% on March last year.) This state of affairs does not include the fall-out from political actions, such as the embargo on Iranian oil, which imposes additional demands on the rest of the global suppliers of crude by taking that production out of the market. As Econbrowser has just noted, the countries that are potentially capable of upping production to meet the size of the total additional demand likely foreseeable this year seem singularly limited to a kingdom whose initials are KSA.

There is no doubt that Saudi Arabia has considerable oil assets, though I have noted in the past that they tend to use the total discovered oil volume as their reserve, without discounting the amount that they have already produced. Rather, the question that will increasingly arise in the future is whether the country can continue to produce at the same rate, or – if they are to meet the claimed 12.5 mbd of achievable production - to be able to achieve a rate that is 25% higher than current levels. Not that the amount available from some older fields is not of some concern. Consider this plot that came from Aramco in 2004, when Mahmound Abdul Baqi and Nansen Saleri debated Matt Simmons at CSIS. And remember that production has continued from those fields in the eight years since.

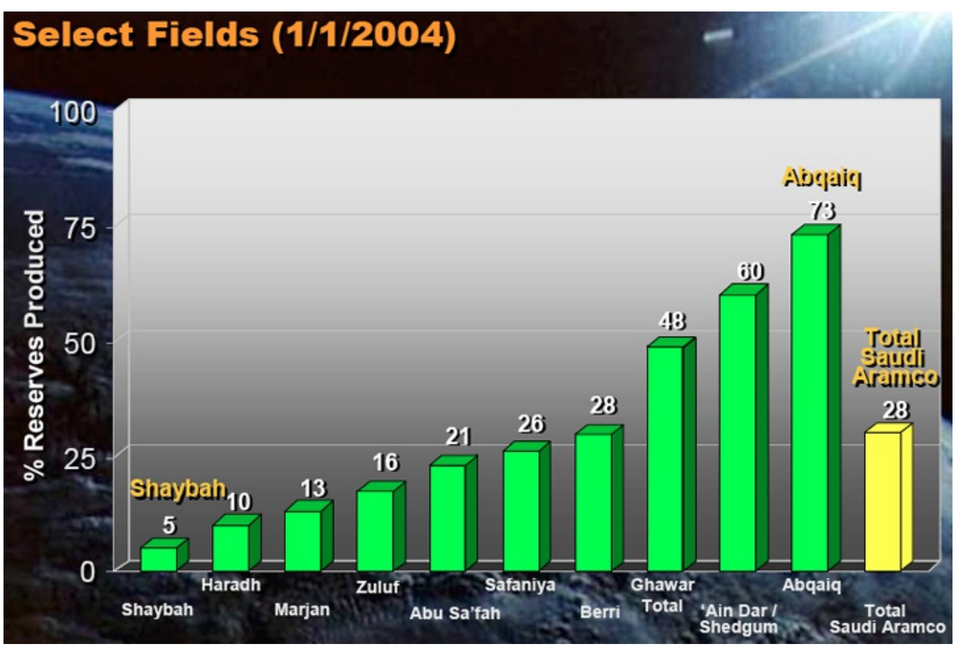

Figure 1. Extent of Proved Reserves Depletion in Select Fields (Baqi and Saleri, 2004)

In the post last week (and my apologies to Glenn Morton for unintentionally confusing him with Greg Croft at the beginning of that piece) I pointed out that there are a significant number of rock layers under the surface in the country that contain oil. Now not all of them do this very consistently, but as the example with Abqaiq showed, as the original oil reservoir becomes depleted, so other rock layers can be tapped to produce in their turn.

However, the story with Abqaiq shows the difficulty in being able to sustain production as fields reach the end of their life, and the increasing costs that must be incurred to do so.

In the early life of the field, wells are vertical, relatively inexpensive, and produced for decades. Now it is only advances in technology that allow production to remain at high levels. The original vertical wells have been sidetracked so that a horizontal section is established in the top 10 ft of the reservoir.

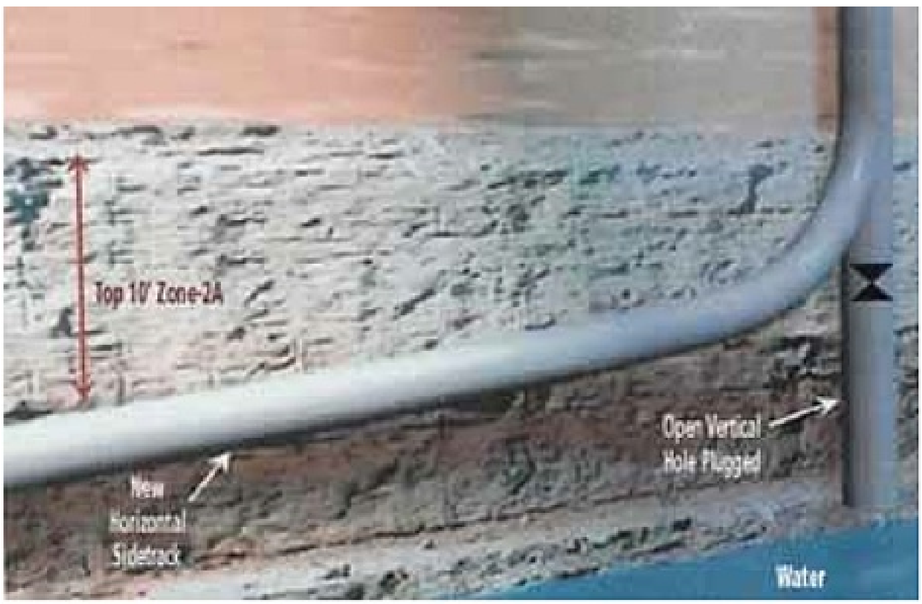

Figure 2. Initial sidetrack from an original vertical well in Abqaiq (Abduldayem et al)

However, to reduce costs and improve production (which stalls at a certain level as an individual horizontal well gets longer) Aramco has changed to the use of Maximum Reservoir Contact wells (MRC). These initially started out as a series of laterals drilled out from the main horizontal well, so that although the distance from the vertical remained quite short for each segment, the overall exposure of the well to the formation could reach, in this case, some 12 km.

Figure 3. Initial MRC pattern of laterals used at Shaybah (Baqi and Saleri, 2004)

However, with the laterals laid out in this manner alone, the entire layout become vulnerable if there is premature water breakthrough in any of the laterals. The initial test at Abqaiq, for example, watered out in six months. A second test with five laterals to give a total reservoir contact of 6.9 km produced initially at 19,000 bd and lasted for two years.

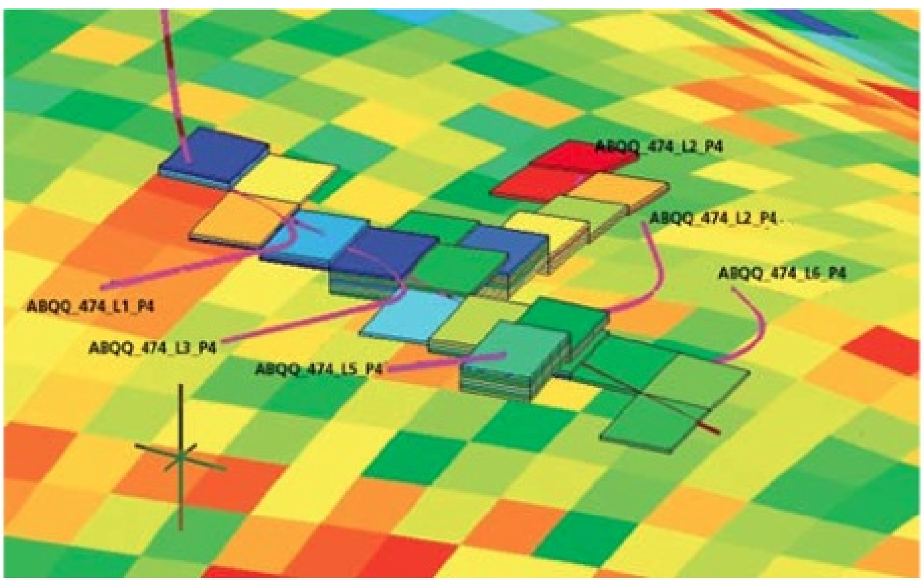

Figure 4. First MRC well at Abqaiq. The different colors in the squares show changes in the rock characteristics (Sung et al)

To prevent water penetration into individual lateral from having a fatal result on the whole well, a series of small valves was interposed at the entry to each lateral, so that it could be bypassed if flooded, without impacting the rest of the well.

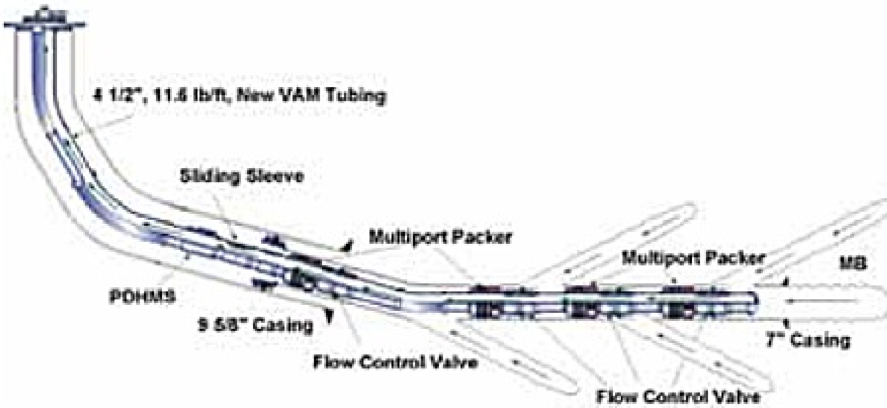

Figure 5. Flow control of laterals at Abqaiq ([Abduldayem et al](#))

The life of each well is limited, as I noted last time, since these technologies were introduced as the water flood reached levels close to the top of the reservoir, and the remaining oil (sometimes referred to as 'Attic" oil) is thinner in depth and underlain by varying heights of water column.

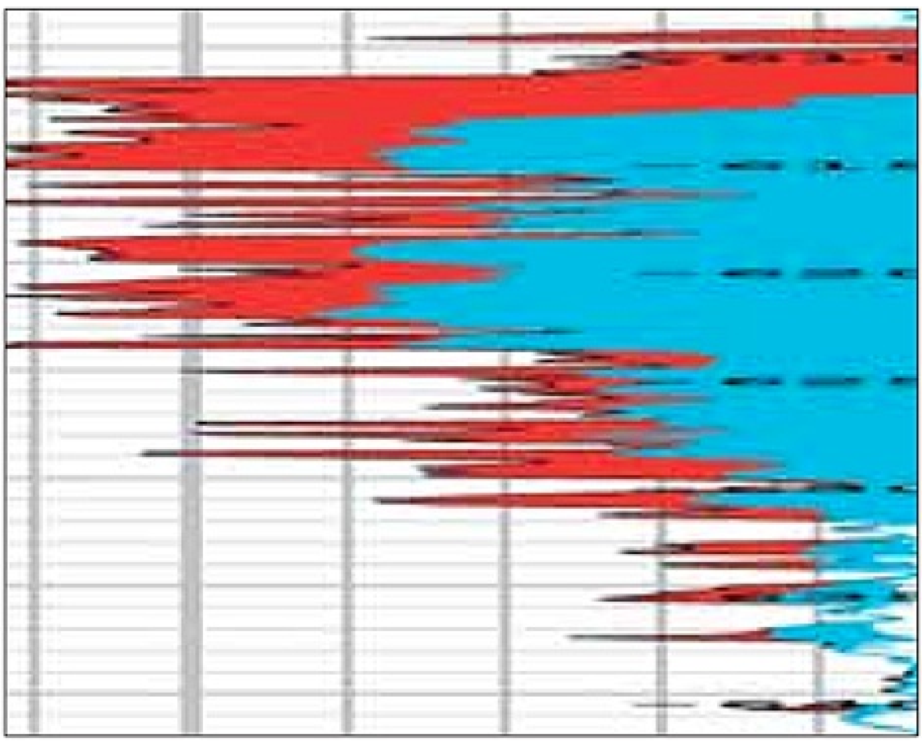

Figure 6. Saturation log over the full height of the original oil in the main reservoir at Abqaiq taken in 2007. The red intervals on the logs indicate oil saturation while the blue sections indicate water-bearing intervals. ([Lyngra et al](#))

Simplistically, the above figure, which is a log of the well's relative fluid content as a function of depth from the top of the reservoir down, shows that while water (blue) is present in much of the lower segment of the reservoir, there is still a significant amount of oil (red) in the section of the reservoir flooded with the water.

By 2008, some 30% of the field production was coming from these attic wells, with 71% of that coming from 15 medium radius horizontals, 1 MRC well and 15 MRC wells with smart completions. In 2009, the program had 98 km of reservoir contact. ([Lyngra et al](#)). The more recent innovation has been to switch to a segmented slim smart completion product (SSC) with a more sophisticated valving system.

> The SSC system consists of three major components:
> 1. Downhole hydraulic flow control valves: Three downhole valves were run. These valves provide the necessary controls to choke/shut-in laterals.
>
> 2. Permanent downhole pressure and temperature gauges: These provide important real-time data used for optimization of the well production. After production start up, individual lateral production tests are performed to determine the Productivity Index (PI) and reservoir pressure for each lateral. This information is used with flow modeling software to determine the optimum flow control setting for each valve to achieve the desired rate from each lateral.
>
> 3. Open hole packers: These are utilized to hydraulically isolate and compartmentalize the three laterals. The packer is a hydraulically set, open hole packer with a high expansion solid rubber element capable of setting and sealing in washouts up to 2½” higher than the run- in Outer Diameter (OD) of the completion string. The packers were set in anhydrite sections to ensure complete isolation from the other laterals. The proposed packer depths were confirmed suitable by the four-arm caliper log at gauge hole intervals.

The advantage of the SSC completion is that with valves down the laterals, it can be divided into segments and thus water inflow in one section of the lateral does not shut down the whole lateral.

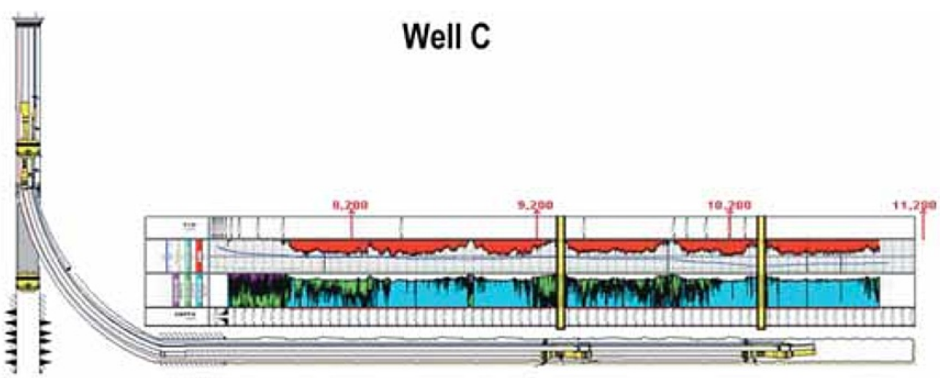

Figure 7. SSC completion valve layout in well C with packer locations shown in yellow – ([Lyngra et al](#))

[Lyngra et al](#) note that for best success, the laterals should be located in the 3-10 ft thick upper lobe of the attic oil zone, with entry being through side-tracks from wells otherwise defined as dead. Life of the wells will still, however, remain limited due to the fact that this is the last remaining trapped oil now being recovered from Abqaiq, and then it will be over. Some of the initial wells watered out within six months.

But the technology has proved beneficial already in extending the life of not only Abqaiq, but also of the reservoirs in the nearby Berri field. Back in 2004, Baqi and Saleri noted that this field had the highest depletion rate of the major fields in the kingdom.

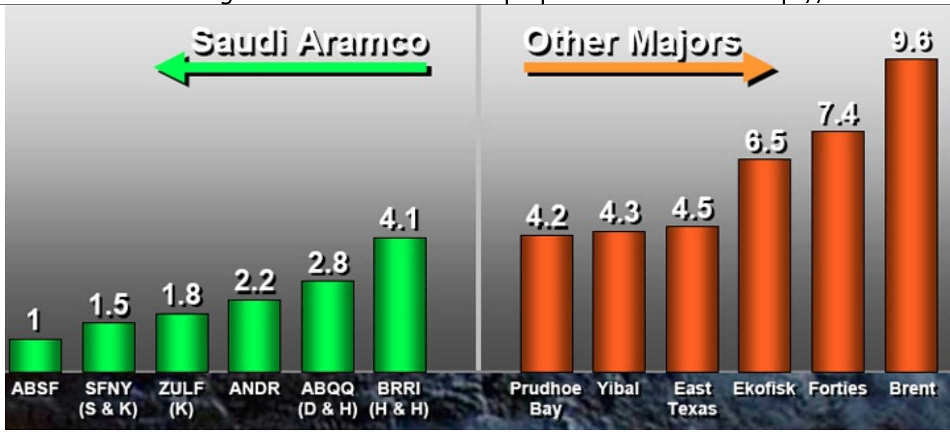

Figure 8. Depletion rates for different fields in KSA when compared with other major fields. The rate is given as a percentage of the original proven reserves in the field (Baqi and Saleri, 2004)

Note that these rates were reported in 2004, and that the fields have shrunk a little in size over the past eight years. So, at a relatively constant draw-down of the oil, the amount that is removed becomes an increasingly large fraction of that remaining, and the lifetime of the wells and now the field, shrinks accordingly.

As I just commented, it is the evolution of this technology which has provided new life to Berri, but given the length of this post already, I will postpone that discussion until next time.

P.S. Although the representations of the wells shown above are relatively straight and have a smooth path, the reality is not quite that simple. Sung et al have shown the reality of the first five-lateral MRC well paths in their paper.

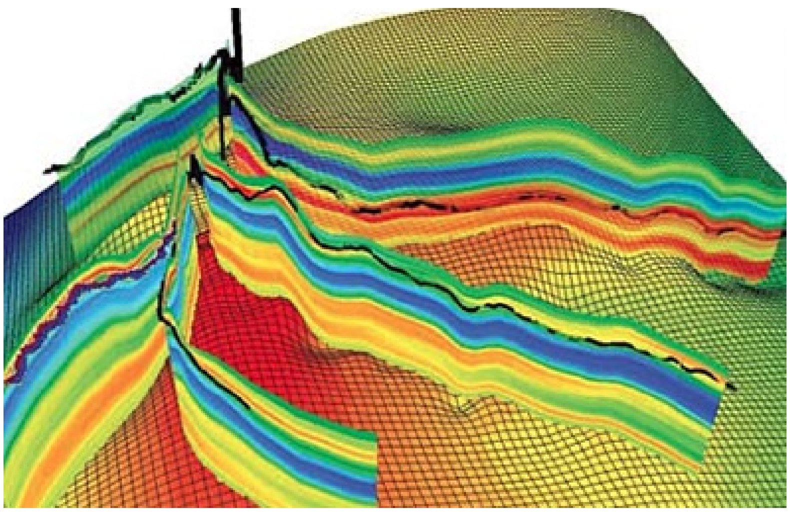

Figure 9. The actual lateral paths from the Abqaiq well, shown using a GeoMorph model (Sung et al).