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by

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CROP CIRCLES IN THE DESERT: THE STRANGE CONTROVERSY OVER SAUDI OIL PRODUCTION

Michael C. Lynch*

Ever since its rich reserves were discovered more than a half-century ago, Saudi Arabia has pumped the oil needed to keep pace with rising needs, being the mainstay of the global energy markets.

But the country's oil fields now are in decline, prompting industry and government officials to raise serious questions about whether the kingdom will be able to satisfy the world's thirst for oil in coming years.[1]

On February 24, 2004, the day the article cited above appeared, an intriguing debate took place at the Center for Strategic and International Studies (CSIS) in Washington, D.C. between Matthew Simmons and two executives of Saudi Aramco, Mahmoud Abdul Baqi and Nansen Saleri, concerning the technical situation in the Saudi oil fields. This marked the beginning of an unusual campaign to convince the world, or some subset thereof, that trouble is looming in the Saudi oil fields, with one speaker going so far as to say (in another venue) that skeptics are like those who believed "peace is at hand" in the 1930s.[2]

Whether these arguments are intended to bolster the political view that the United States cannot rely on Saudi oil to buttress the global economy, validate forecasts of an ever-booming oil service sector, or support an ideological belief in "peak oil," they have been disseminated widely and are being promoted by some who should know better.[3]

The basic arguments are straightforward: (1) Saudi oil is vital for the world; (2) most of it comes from a few fields; (3) these fields are old and the Saudis have not been finding new oil, because they have none; (4) Saudi reserve numbers are suspect and appear to be exaggerated; (5) Saudi fields are experiencing increasing technical difficulties; (6) the fields have been produced in such a way that they will soon experience a collapse in production; (7) this will augur a peak in world oil output and/or severe economic consequences for the planet; and (8) we are not prepared and/or there is little or nothing to be done about it.

There have been other arguments made that might be seen to support these views but in actuality do not. The Centre for Global Energy Studies was described as saying that raising capacity would be "tricky," but a careful reading shows the analyst merely said, "that would depend on domestic politics and the ability to raise capital for investments."[4] This, of course, is true everywhere and not evidence of a peak or geological constraints on supply.

Similarly, articles by former Saudi Aramco executive Saddad al-Husseini are seen by some as confirming a pessimistic view of Saudi problems but, in fact, he refutes them.[5] And while he challenges the notion that the Saudis would *choose* to raise production to 20 million barrels per day (mbd), he is discussing the *policy question* of whether or not the Saudis would want to raise output; he is quite optimistic about their resources and technical capabilities.[6]

Another major problem in discussing this entire issue is that for over a year, no major published works have appeared. There have been a number of short articles in the Association for the Study of Peak Oil & Gas (ASPO) newsletter[7] and publications on the web as well as a few short, general papers and Powerpoint presentations by Matthew Simmons.[8] This in itself is cause for skepticism.

Further, many of the concerns consist of unattributed comments and/or rumors (massive buys of electric submersible pumps, remaining fields are "dogs," etc.), which are hardly conclusive. Now, with the publication of Simmons' book, *Twilight in the Desert*, it is possible to see if there is any fire to go with the smoke.[9]

This paper will review the primary work that has appeared to date and demonstrate that the bulk of these arguments are either irrelevant or incorrect, based primarily upon poor analysis. The first section will discuss the various miscellaneous alarms; the second will deal with the controversy over Saudi reserves and resource estimates. Then, the technical problems some authors perceive will be described, followed by claims that there is a lack of preparedness to deal with potential difficulties. Finally, the existing evidence will be analyzed to see how well it conforms to the problems being trumpeted.

Miscellaneous Acorns: The Sky Is Falling

Many of the authors warning about "peak oil" have no expertise in either the oil or mineral industries[10] or in the specialized practice of forecasting.[11] Although there appears to be a large body of publications, the bulk of what is being written consists of nothing more than anecdotes and quotations from the works of others.

What is noteworthy about this body of work is that it has been wrong repeatedly; the theories underlying it have been demonstrated false and largely abandoned by their proponents; and much of the research is shown to rely on unproven assertions. Rather than extensive research, simplistic extrapolation of historical curves is used, even though the method is not based on sound theory and clearly does not provide reliable projections.[12]

Back Off—I'm a Scientist: A favored tactic is to include technical information, implying the writer has a technical background that serves to intimidate many readers, including those in the general press.[13] Being trained as a political scientist, I would hardly argue that "lay" experts cannot understand technical issues. However, it is telling that the great bulk of these articles appear in non-refereed journals or solely on the Internet. Indeed, basing much of his argument on having read technical journals, Simmons has twice appeared before large audiences dominated by petroleum engineers[14] and not mentioned them. At the Offshore Technology Conference (OTC), he made no substantive remarks, but chose to be entertaining; his remarks to the Society of Petroleum Engineers (SPE) did not address his work on Saudi Arabia.[15]

What If…:

What if the Ghawar IS dying? With the death of Ghawar will undoubtedly come the deaths of humans. Many humans, it would seem, the result of probably unavoidable wars for the last remaining oil to the much-predicted pandemics and mass starvation.[16]

Amazingly, the primary argument of both Haynes' "Ghawar Is Dying" and much of the work by Simmons boils down to "what if" problems occur. Speculation about the potential damage from the problems is discussed with little or no description of the impact of this damage, that is, what new investment would be needed, how much would oil production decline, etc. And, of course, observers—such as the press or policy makers—ask the same question: what if the alarmists are correct? The consequences would be severe, which is why their warnings are thought to deserve attention.

Not to argue that even the wildest claims deserve a hearing, but there are two clear responses. Warnings first should be judged on their *apparent validity* and *probability of occurring*. Arguably, the South African government has ignored the first test, thinking "what if those who don't believe HIV causes AIDS are right?" But the preponderance of medical evidence suggests they are not, and the South African public is paying the price. Similarly, the second test is clear if you say, "What if a meteor struck the Saudi oil fields?" It is well established that large meteors sometimes strike the Earth, and Ghawar is the largest oil field in the world; therefore, it is the most likely to be struck by a meteor. Yet no one proposes preparing for such a possibility because it is clearly of a very low probability.

More specific examples can be found when Simmons essentially asks: what if the Saudis overproduce their fields, what if they cause the pressure to drop to the bubble point, and what if the Saudis develop the southern part of Ghawar in the same manner as the northern part?[17] The only hint of an answer is when he suggests that reaching the bubble point would leave the oil "inert" (which is actually incorrect). Similarly, he fears that a well penetrating a fault or fracture would soon die but has already discussed the Saudis' efforts to pinpoint the faults and avoid them.[18] Because Simmons notes the extensive modeling and analysis of the fields undertaken by the Saudis, his concern that they will drill blindly without regard for local geology seems contradictory.

"For every action, there is an equal and opposite reaction."—Newton's Third Law: The other side of the coin is that there is a very clear answer to the "what if" question and not the one proffered by Haynes nor the technical challenge Simmons sees. In response to the question, "what if" problems grow: more investment will be needed. "What if" wells water out: more will be drilled. "What if" Ghawar declines: capacity will have to be added elsewhere. Since fields are already declining all over the world, and somewhere on the order of 5 mbd to 6 mbd annually are being added currently, why would offsetting the decline of a 5-mbd field be considered threatening?

The Need for Saudi Oil:

> *But a senior intelligence official, who insisted on remaining anonymous because he was not permitted to speak publicly on the issue, said that the Saudi plans to increase production by nearly 14% in the next four years were not enough to meet global demand. Even the Energy Information Administration recently scaled back its expectations of how much more oil the Saudis could pump in 20 years.*[19]

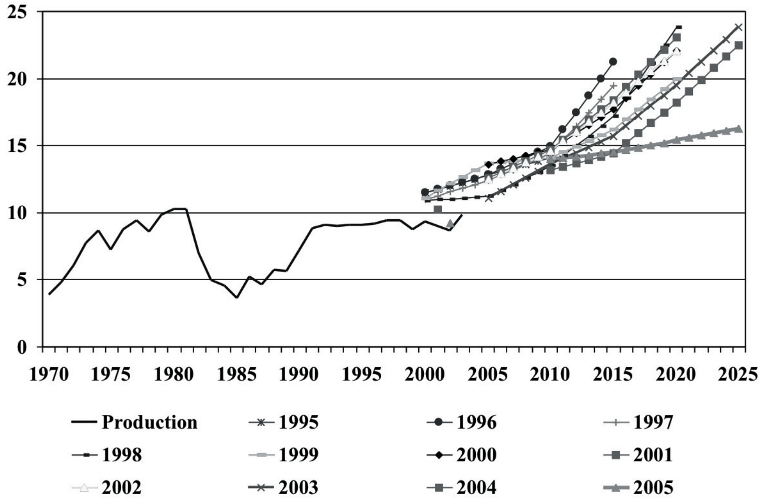
One of the factors confusing this debate is actually an entirely separate issue, that of the long-term need for Saudi production. Numerous authors recently have derided the projections that the world will need over 20 mbd of oil from Saudi Arabia at some point in the future, perhaps in the next two decades. Even authors like al-Husseini, who are optimistic in a technical sense about Saudi resources, are sharply critical of the assumption that the Saudis will actually proceed with such plans. It is uncertain whether they will or not, but it is important to note that projections of this sort have been made for many years and have yet to prove true.[20] Even as demand from the Organization of the Petroleum Exporting Countries (OPEC) was collapsing in the early 1980s, many analysts incorrectly asserted that it would turn around in the near term and that all future incremental growth in supply had to come from the Middle East. The International Energy Agency's (IEA's) 1982 *World Energy Outlook* is just one of many such projections.

Figure 1 shows such an example: the U.S. Department of Energy's assumption of Saudi capacity as it evolved over time. Reading it either right to left or top to bottom shows that past estimates of the need for Saudi oil have been far overestimated. Even ignoring the latest estimate, the tendency has been for repeated downward (or rightward) revisions. The reality is that for over a quarter-century, nearly all world oil market forecasts have been *too pessimistic* about the ability of the industry to meet demand without relying on massive increases in Arabian Gulf and particularly Saudi production, e.g., the projected need for Saudi oil in 2015 has dropped by a third since the 1996 forecast.

Myths and Fallacies: A number of comments made by various writers are egregiously in error and can be addressed quickly. For example, the *age of a field* is largely irrelevant to its production potential.[21] Ghawar at 50 produces 5 mbd and is showing no signs of difficulties. Yibal in Oman suffered a production collapse at a young age, and even large, well-managed fields like Forties in the United Kingdom and Prudhoe Bay in Alaska began their decline in their first decade. The geology and geography of the field and the decisions of the managers and engineers determine the production profile, not the "age." Fields do not become "tired."

The argument that Saudi Arabia is *thoroughly explored* and no giant fields could possibly remain is puzzling and appears based more on an

Figure 1
The Evolution of U.S. Department of Energy Projections of Needed Saudi Oil Production, 1970-2025 (in million barrels per day)



Source: U.S. Department of Energy (DOE), *International Energy Outlook* (Washington, D.C.: DOE, various editions).

assumption. Few exploratory wells have been drilled in Saudi Arabia in recent decades as existing fields have been more then adequate to provide necessary oil (and capacity). And much of the country's petroleum prospective territory has had only a few wells drilled, although it is not thought to be as petroliferous as the Eastern Province. When Saleri pointed this out to him at the CSIS talk in 2004, Simmons stated that he was referring to seismic work, not drilling. Surprisingly, Simmons' 2005 book reverts to a reference to "intense exploratory drilling,"[22] even though the number of wells drilled in Saudi Arabia in 2005 was expected to be about the same as in the state of Alabama.[23]

Shocked to Find Gambling at This Casino! A major element supporting the belief in looming problems is the tendency toward technical ignorance. Many writers are not experts in the oil field, so they tend to be surprised by very normal events. Campbell has "discovered" that reported OPEC proved reserves are government data and not highly reliable. (Few economists would be surprised to learn that government data are imprecise and sometimes unreliable.)

But we have the odd case of a journalist reporting:

> *The hairs on the back of my neck stood up. Ghawar's water injections were hardly news, but a 30% water cut, if true, was startling. Most new oilfields produce almost pure oil or oil mixed with natural gas—with little water."*[24]

This may sound alarming to the non-specialist or less-than-careful reader, but the actual wording and implications are clear. The reporter is unfamiliar with the oil industry and was startled to discover a standard bit of information. A 30% water cut is nothing unusual; it is startling only to someone ignorant of reservoir operations.

True, new oil fields often produce pure oil or oil and gas, but Ghawar is hardly new, so the comparison is invalid. That Roberts does not notice this is odd. That he did not check its meaning is stranger.[25] It is estimated that the global average water cut is 75%, meaning that Ghawar, far from being threatened, is *performing well above average*. (This is a good example of how providing numbers without context can be misleading but it also demonstrates poor scholarship.)

More astonishingly, there is the statement from Simmons: "I had never heard the term 'fuzzy logic' before. Hearing the Aramco manager's comment was one of the little events that tipped my thinking about the Saudi Arabian Oil Miracle towards skepticism."[26] Nowhere does he explain why his ignorance of a commonly employed programming method made him suspicious. As Jarrell notes, "Fuzzy logic is a valuable analytical tool and has proved to be very useful in expert systems, artificial intelligence and other applications for reservoir scientists and engineers."[27] It was actually developed in the 1960s. For his part, Peter Maass remarks, "What could be fuzzy about an oil reservoir?"[28] And Simmons elsewhere notes, "it would be natural to assume that most, if not all, of the great field's important reservoir properties were now thoroughly understood."[29] Geologists would no doubt be stunned to hear that theirs is thought to be an exact science without unanswered questions, even for a well-studied oil field.

Eyes Wide Shut: Another puzzling matter is Simmons' reference to "The 1970's Cover-Up,"[30] where he notes two government documents. His book discusses a 1978 General Accounting Office report[31] as well as the 1979 *New York Times* story by Hersh, "the only report ever to make its way into print on the findings from a 1974 U.S. Senate closed investigation following the 1973 Oil Shock."[32] How secret was this information? According to Simmons, the 1974 report was available from the Library of Congress and the 1979 Senate report was in the University of Houston Library.[33] He states that "none of this explosive data ever got into the public domain."[34] He also mentions that "the media never reported on these important hearings,"[35] although earlier he cited Hersh's 1979 *New York Times* story.[36] In fact, a summary was published as a supplement in *Petroleum Intelligence Weekly.*[37] So the information Simmons considers "secret" or unnoticed has appeared in the *New York Times*, been published as government documents, and is available in public libraries. The SPE papers are not only available on the web for a nominal fee but have been presented before audiences of, presumably, thousands of petroleum engineers.

Perverse Logic—Big Fields: In a number of instances, the inference drawn from events is presented in a manner that is not really logical. For example, much is made of the fact that Saudi Arabia has not found many large fields recently and that most of their oil comes from a few very large fields (notably Ghawar). The implication is that other fields either do not exist or are not large enough to be significant.[38] But it would be much more persuasive to argue the Saudis have such an abundance of unexploited oil fields that they would be wasting money by continuing to explore.

The reality is that a large portion of the resource for any given basin lies in its smaller fields, making up in numbers what they lack in size. This has been shown repeatedly and is clear from the most basic data. Indeed, this is basic geological theory—that field size in a given basin follows a sharply declining curve after the biggest fields, with a long tail. Simmons refers to the French Petroleum Institute (IFP) characterization of this as one King, a Queen (or two or three), perhaps five or ten Earls or Lords, and the rest are commoners or peasants.[39]

This is true, for instance, in the case of the United Kingdom, where the Forties and Brent fields are head and shoulders above the others, and the bulk of large fields (producing in 2001) actually were only a fraction of their size, with only nine fields above 500 million barrels (figure 2). Similar results can be seen in other provinces.

In every instance, *a large portion of any given resource is located in the smaller fields*. Table 1 compares several areas where data are available to show that even using the U.S. Geological Survey (USGS) estimate of ultimate recoverable reserves (URR), Ghawar represents a much greater proportion of the estimated recoverable resource base than those in a number of other large basins. Of course, the regions observed are not single petroleum basins, but neither is Saudi Arabia. Still, despite the imprecision, the order or magnitude of evidence suggests clearly that Saudi Arabia should have much more undiscovered oil and implies that even the USGS's estimate of 370 billion barrels is likely to be conservative.[40]

Why High Tech? Another concern of Simmons is the Saudi reliance on the most modern technology in the fields (such as maximum reservoir contact or MRC wells) in the fields, suggesting it is necessitated by extraordinary technical problems. Baqi and Saleri replied, logically, that the better technologies were used because they lowered costs, while others have suggested it reflects a tendency towards gold plating by the engineers, which would not be surprising in a state mineral enterprise with ready access to capital.[41] And Simmons himself notes that costs were cut by the application of horizontal drilling but then does not draw the connection between the choice of high technology and the desire to lower costs.[42]

Reserves and Resources

A lot has been made of the unreliability of OPEC reserves in general and Saudi reserves in particular, especially the upward revisions that occurred in the late 1980s—a time when the organization considered employing a standard formula for quota-setting that would use reserves

Figure 2
British Giant Fields by Size (in million barrels)

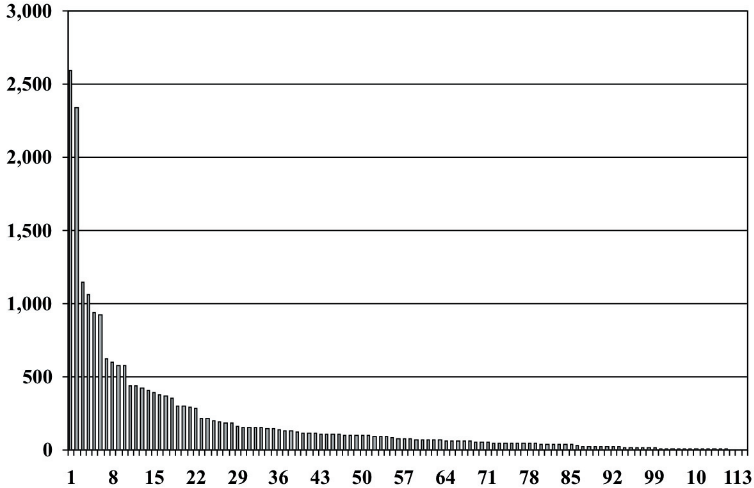


Table 1
Relative Size of Largest Field

Region	Largest Field	Fields (%)	Observed Large Known Oil (%)	% URR[a]
California	Wilmington	12.7	9.5	n.a.
Texas	East Texas	17.5	11.6	n.a.
Norway	Statfjord	13.3	14.3	10.0
United Kingdom	Forties	11.6	11.3	8.9
Saudi Arabia	Ghawar		50.0	37.8
Russia	Samotlor		12.4	9.2

[a]URR=ultimate recoverable reserves.

Sources: Known oil (cumulative and proved reserves) and URR from U.S. Geological Survey (USGS), World Petroleum Assessment Team, *World Petroleum Assessment* (USGS, 2000); California and Texas from *Oil & Gas Journal*; Norway from Norwegian Petroleum Directorate, *Facts: The Norwegian Petroleum Sector* (Oslo, 2005).

as one factor. (Contrary to the claims of some Hubbert disciples, this was never implemented.) But this says little about *resources*, particularly in an area that has seen little drilling.

Certainly, the published reserve estimates are not as reliable as they once were, but this does not mean they are exaggerated in every case. As Campbell himself acknowledged in discussing the 1980s' Middle East upward revision, "it is less easy to determine if in reality the new numbers were overstated or whether the old numbers were understated…."[43] IHS Energy, often praised by Campbell and Laherrere for its superior information, has stated that its estimates are close to the Saudis' own.[44] That they are slightly higher can be explained because the Saudis are using proved reserves and IHS Energy reports 2P, i.e., proved plus probable (table 2).

Campbell recently has come up with an interesting alternative explanation for the 1988 revision and the relatively flat level since then, namely, that what are called current proved reserves actually represent original reserves, i.e., cumulative production plus current reserves.[45] His evidence for this consists of nothing more than the fact that the resulting numbers would be approximately similar, that Saudis increased their reported reserves in 1987 suspiciously, and their numbers do not change much over time. The alternative explanation, that the company only conducts minimal exploration intended to replace production, is not given any notice.

Numerology: A more detailed look at Campbell's assertions about Saudi oil is telling of the manner in which he approaches research. In February 2004 at the CSIS, Baqi and Saleri commented that Saudi Arabia could produce at a plateau of 10 mbd to 15 mbd for 50 years, which would consume 68% of their proved and probable reserves.[46] Campbell's response:

> *This sounds utterly implausible. The statement of using 68% of Proved & Probable Reserves sounds as if it really means 68% of Proved & Probable oil-in-place. Also, claiming static production until 2054, which is an odd date to select, sounds suspiciously like a Reserve to Production Ratio of 50. It simply divides remaining reserves by current production, ignoring natural depletion.*[47]

From there, he calculates that 50 years of production at current levels of 3.1 billion barrels per year would be 155 billion barrels. Adding this to past production of 97 billion barrels yields 252 billion barrels, which he notes is suspiciously close to official proved reserves of 260. From this, he assumes that the official reserves figure includes past production, even though the Saudis have published precise figures showing past production, current reserves, and oil-in-place (which he ignores). Instead, by *assuming* that 68% is the recovery factor, Campbell calculates that oil-in-place is 370 billion barrels. Then, stating that a more reasonable recovery factor is 50%, he argues that there are really only 88 billion barrels of remaining conventional oil. This would mean that *the Saudis should be past peak* under the traditional Hubbert-style model, and thus experiencing declining production.

This is an astonishing performance, almost high-school level. First, the Saudis clearly state their discovered oil-in-place is 700 billion barrels. Second, the 50-year figure refers to a planning horizon, known as a "round number," and is not "suspicious" in the least. The 68% figure is quite clear cut, meant to represent exactly what the Saudis said it was—the proportion of proved and probable reserves produced under the scenario described. There is no justification to modify it from the stated proportion of reserves recovered by 2054 to a recovery factor (proportion of oil-in-place that can be extracted). Simply put, his entire calculation selectively ignores the published data.

Table 2
Estimates of Saudi Oil Resources (in billion barrels)

Source[a]	Cumulative Production	Proved Reserves	Undis-covered	Ultimate Re-coverable Reserves
OGJ		**259**		
ASPO 2002	**91.2**	**194.4**	**14.3**	**300**
IHS Energy		**294**		
Saudi Aramco		**260**		
USGS		**283**	**87**	**370.6**

[a]OGJ=*Oil & Gas Journal*; ASPO 2002=Association for the Study of Peak Oil & Gas, *ASPO Statistical Review of Oil and Gas*, Proceedings of the 1st International Workshop on Oil Depletion, Uppsala, Sweden, May 23-25, 2002, eds. K. Aleklett and C. Campbell, at http://www.isv.uu.se/iwood2002; USGS=U.S. Geological Survey (USGS), World Petroleum Assessment Team, *World Petroleum Assessment* (USGS, 2000); IHS=Philip Stark and Ken Chew, "Global Oil and Gas Resources—The View from the Bottom Up," May 5, 2004, available at http://energy.ihs.com/Resource-Center/Presentations/regional.htm.

But the Saudi oil fields are a special case. They are controlled by a sovereign government that treats much of the geological information as secret because of the quota politics dynamics of the Organization of the Petroleum Exporting Countries. This means that even meager scraps of information or insight can gain extra notoriety, almost without regard for how valid or relevant they are.

The Numerology of Field Size: Simmons notes that the Saudi fields were estimated by Aramco in 1975 (when four U.S. majors owned it) to contain 108 billion barrels of oil and frets, "If these estimates were 'correct,' the end is in sight."[48] Such a statement is revealing about Simmons' entire message: the conditionality ("if") suggests he is uncertain, but the implication is severe, while the unstated assumption that fields have not grown in three decades defies industry practice.

In fact, whether the estimates were correct is irrelevant; reserves estimates are not resource estimates but reflect rather the companies' estimates of the oil that is developed and available with a high degree of confidence *at that particular point in time*. It hardly would be surprising that 25-year old estimates would be relatively low compared to current ones; indeed, the reverse would be astonishing.

This is part and parcel of the larger argument made by Simmons and some of the other oil resource pessimists, namely, that the reserve growth phenomenon is mythical, especially outside the United States. This is an *assertion* that has been repeated on many occasions but with no corroborating evidence, a point that has been made by numerous authors including this one.[49] There is a rich literature describing reserve growth around the world, with many fields doubling, tripling, or more in size.[50]

Evidence to refute this concern can be inferred from data provided by Simmons. He lauds the estimates of the concession holders in 1975, when Ghawar was estimated to have 46 billion barrels of remaining reserves and having produced 15.5 billion barrels.[51] Yet to this date, Ghawar has produced 55 billion barrels or 90% of the earlier estimate, far past the midpoint when Simmons claims output should decline. And he himself remarks that most of the field has not been drilled.[52] Also, every other reference to Ghawar's size is substantially above that made by the majors in 1975, which suggests their estimates were conservative relative to the current reserves (table 3).

Morton is less precise but no less certain, stating that "for someone like me who has spent a lifetime in the oil industry trebling the recovery factor is a fantasy we all wish we could do. But no one has ever figured out how."[53] This statement calls a normal event a fantasy and confuses the terms "recovery factor" with "reserves." Although it is unusual for the recovery factor (the percentage of oil-in-place that is extracted) to triple, it is not unheard of, though mostly for heavy oil. But reserve growth actually includes increases in oil-in-place as well as the recovery factor; recovery factor growth is not limiting. Given that larger fields are generally found to have the highest growth rate (and Ghawar's status is by far the world's largest), it seems only reasonable that it might have nearly tripled in size. What cannot be explained is Morton's comment that "no one has ever figured out how." Even casual perusal of existing data shows this.[54]

Technical Arguments

"200+ Technical Papers Do Not Exaggerate. Paper trail of challenges/problems has exponentially grown….Viewed as a whole, the papers create a forensic pathology of Saudi Arabia's oil system."[55] The idea that the Saudis are facing a peak due to reservoir problems comes from Simmons' analysis of over 200 technical papers published by the SPE. Although he makes frequent reference to these problems when addressing general audiences, he did not mention these particular issues when speaking to the SPE in 2004, the audience most capable of assessing their validity, which raises suspicions about his faith in his own analysis.[56]

The Threat from New Technologies: One of Simmons' major unexplained assertions is the consistent argument that new technology is about to cause a collapse in oil-field production, especially in the giant oil fields. Beginning in 2001-2002, in a study entitled "The World's Giant Oilfields," he argued that (a) most of the world's oil comes from a small number of fields and (b) they had all been at a plateau for an extended period but were about to see production collapses.[57] In his 2005 book, he attributes this specifically to "super-straws that quickly extracted the targeted oil and then led to decline rates steeper than the industry had ever seen."[58]

The evidence for this is difficult to ascertain from his writing but appears to come from the behavior of the Yibal field in Oman (which he cites as the prime, indeed, only example). Otherwise, he shows graphically the decline rate in eight of the world's giant or super-giant oil fields as evidence, except that two of them are Russian—where Soviet engineering practices are known to have been atrocious—and most of the rest do not appear to be in abnormal decline. Six of them actually began their decline

Table 3
Estimates of Saudi Field Size (in billion barrels)

Field	Simmons (1976)	Nehring (1978)	IHS Energy (2004)	Laherrere (2005)	Wood Mackenzie (2004)
Ghawar	**61.5**	**83**	**147**	**115**	**131**
Safaniya	**18**	**22.5**	**55**	**54**	**25**
Abqaiq	**9.5**	**12.5**	**19**	**11**	**16**
Berri	**7.3**	**12**	**18**	**11**	**8.3**
Shaybah			**22**	**18**	**14**

Sources: M. R. Simmons, *Twilight in the Desert* (Hoboken, NJ: John Wiley, 2005) for the General Accounting Office report with data from the then-U.S. partners of Aramco; IHS Energy and Wood Mackenzie from J. Laherrere, "Forecasting Production from Discovery," Association for the Study of Peak Oil & Gas, Lisbon, May 2005; Richard Nehring, *World Petroleum Availability 1980-2000* (Washington, DC: Office of Technology Assessment, 1980).

over 20 years ago, before super-straw technology was employed, so citing them as evidence is fallacious. As figure 3 shows, the Forties field decline (Simmons' example of the threat to the oil market) was severe, not only predating the technologies he describes and not resulting in a decline in overall U.K. production. Indeed, none of these claims finds support in the general literature, except for "peak oil" zealots who enthusiastically embrace them but do not provide any actual evidence to show either the degree of decline or the impact on overall production.

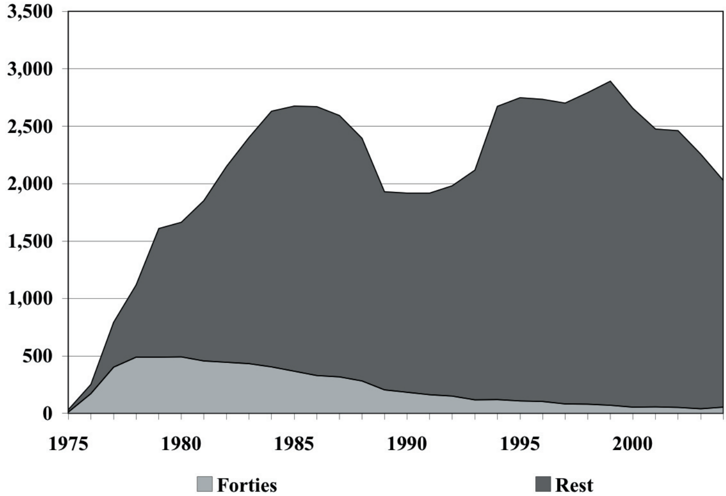
Field Damage from Overproduction: Considerable space is devoted to three separate reports from the 1970s: a 1974 Senate hearing, a 1978 report by the General Accounting Office (a Congressional agency), and an April 1979 Senate staff report.[59] In general, these three reports indicated that Saudi oil fields were being overproduced in the early 1970s and their ability to raise output was questionable.

Simmons argues that this danger is not past, accepting that the Saudi fields appear to have been overproduced in the past, but also arguing that they are likely to be so again, causing (a) rising water cuts and well abandonment and (b) field pressure dropping to the "bubble point," resulting in the oil becoming inert. As Simmons puts it:

> *What Twilight In The Desert Means*
>
> *Pressurized oil fields all have "rate sensitivity" to how they are drained. / The higher the production, the faster high reservoir pressures end. / Once pressure falls to "bubble point," gas bubbles to top of the field and pressure falls faster. / Once dew point is reached, remainder of oil is "inert" or "left behind." /* **Saudi Arabia is over producing its key fields.**[60]

In actuality, the oil does not become inert or left behind, although it is often desirable to repressurize a field. This is consistent with Saudi claims that they invested heavily in water injection in the 1970s. The 1979 Senate report claims the fields had reached the "bubble point," yet production subsequently rose substantially; the Saudis' claim appears vindicated.

Figure 3
U.K. Production: The Role of Forties (in thousand barrels/day)



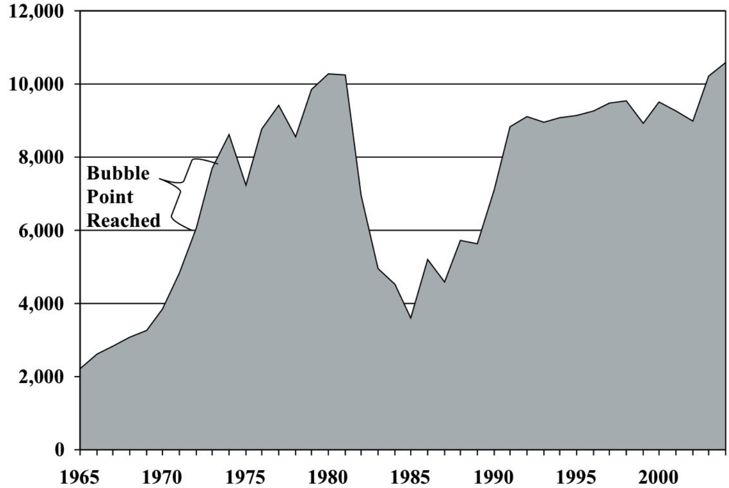
As Simmons himself notes, "Never in the long history of oil had a single country ramped up its oil output so rapidly."[61]

Simmons also mentions that Ghawar's water cut seems to have stabilized at 33%, some 7% higher than in 1993.[62] Of course, elsewhere he notes that the global water cut is 75%,[63] implying that Ghawar is in much better shape than most of the world's production, although he does not connect the two.

Evidence to the Contrary: There is no detailed discussion in Simmons' book of what happens after the bubble point is reached. In fact, while undesirable, it is not catastrophic and can be offset through additional drilling and investment. The best evidence of this comes from Saudi production behavior after the bubble point was reached in the early 1970s (per the 1979 Senate report). Saudi output continued to rise until the market collapsed in the mid-1980s. Simmons implies that the fields needed the rest, but there is no evidence to support this (figure 4). Jarrell corrects the misrepresentation by noting:

> *For example, Twilight implies the "dew point" is the pressure at which a well stops flowing or producing. In fact, dew point is a thermodynamic state of pressure and temperature such that for a gas at a given temperature, lowering the pressure below the dew point will cause natural gas liquids to condense from the gas. As another example, Twilight indicates that reservoir pressure will 'fade away' as a water flood matures. Rather, a key purpose of a water flood is pressure maintenance. The abandonment pressure typically is the water flood operating pressure. Furthermore, water injection does not erase the possibility of having secondary recovery, as Twilight states. It is secondary recovery.*[64]

Figure 4
Saudi Production Post-Bubble Point, 1965-2004 (in thousand barrels/day)



Simmons himself offers a cautionary note: "As events played out, the concerns raised by these early warnings that Saudi Arabia might be doing serious damage to the great oil reservoirs of Ghawar, Abqaiq, Berri, and Safaniya by producing at these high rates would prove to be exaggerated."[65] Yet he does not heed his own implicit caution.

The Dog That Didn't Bark: Although Simmons includes an Appendix, referred to as supporting data, it is largely general data about Saudi oil that does not, in any way, indicate water cut is growing, that the company is spending excessively to control technical problems, that a peak is near, or, indeed, any of his arguments. As Robert Skinner has noted, "Observation is not analysis," but all too often this work is filled with observations masquerading as analysis.[66]

Interestingly, there are significant amounts of data available about Saudi oil not even mentioned here (but which will be covered below). Nor does Simmons cite a text on reservoir engineering to explain the implications of the problems he is describing, merely, saying "soon the oil remaining underground becomes inert and ceases to flow. It can then be pumped out, but the pumping process also brings out far more water and gas that crowd out the oil."[67]

Here There Be Monsters

Even should there be little credence for the various technical arguments, the "what if" issue always remains. Simmons rephrases this by saying that there is "no Act 2" or follow up in Saudi Arabia to the Ghawar field, and there is "no plan B" globally to respond to a drop in Saudi output. As before, however, this reflects a combination of ignorance of oil industry operations and blindness to actual developments, where the Malthusians predict that we are about to sail off the edge: of population sustainability, petroleum production, etc.

Act 2—Saudi Oil Exits Stage Right: Simmons correctly notes (but does not reference the extensive scientific literature) that oil basins typically have only one or two large fields, followed by smaller fields in greater numbers; the other Saudi fields are, indeed, smaller than Ghawar. However, it is a huge leap to conclude that none of the other fields could play a significant role in offsetting a Saudi output decline.

This is an extension of the old canard "only giant fields matter," heard since at least the 1970s and repeatedly invalidated by actual experience. Because the industry naturally prefers to find larger fields, there is a bias in discovery towards them. (Even random drilling would discover larger fields first.) Only when the larger fields have all been found does the industry start to exploit smaller ones.[68] The dominance of larger fields is thus an artifact of rational behavior by the industry, not evidence that smaller fields are incapable of providing significant amounts of oil.

The experience in the British North Sea is illustrative. Just as with Ghawar, Simmons has described the Forties field as "the gold standard," the biggest, most prolific field in the basin, and points to its decline as cause for alarm. What he conveniently overlooks is that the Forties field began its decline in 1981, and yet British output did not drop despite virtually no major new discoveries for decades.[69] The last giant field (above 1 billion barrels in reserves) was found in 1975. Indeed, Adelman and Lynch pointed out that 20% of U.K. oil production in 1995 was from fields that had originally been too small to be produced, but due to a combination of ongoing infrastructure development (easier access to pipelines) and technology improvements (subsea templates), they had become viable.[70]

Campbell applied the same flawed logic in his 1991 book, arguing there was no likelihood of major new discoveries in the U.K. North Sea and only large fields mattered; thus, production would be falling by 11% annually.[71] This led him to forecast that output would drop to 352,000 barrels per day (b/d) by 2004, when the actual level was 2.029 mbd. As seen in figure 3, this proved quite incorrect; indeed, many smaller fields offset the decline in the "King" field, Forties.

The concept that there is no Act 2 thus is seen as myth. If the Saudis are still relying on only four fields for the bulk of their production, then they are at a very immature point in the exploitation of their total resource. If anything, they are still in Act 1, Scene 1, of what should be at least a three-act play. To believe otherwise would mean that Saudi Arabia does not conform to both petroleum geology theory and the experience of every other producing province in the world.

Plan B: From Outer Space? Related to this is the comment that the world has no "plan B" to cope with a drop-off in Saudi production, i.e, the collapse that Simmons predicts with his "super-straw" theory. The implication is that the global community should have teams of drillers on high alert, waiting to be rushed off somewhere. Again, this is part of the "what if" argument, where one has to ask why there is no plan B to deal with a meteor striking the Saudi oil fields.

This shows yet another example of poor research and numbers taken out of context. The threat being discussed is of depletion that would cause a production loss on the order of 500,000 b/d per year, at the outside, which sounds large unless you realize global capacity additions are about 5 mbd to 6 mbd, most of which goes to offset depletion. In short, even in the most dire scenario—for which there is no evidence—the impact would be only marginally noticeable.

Figure 5 compares the amount of capacity added annually since 1990, broken down into additional capacity and replacement for depletion, with the amount that would be needed over a similar time period should production in Ghawar begin to decline by 10% per year. *The increment reflects the annual net change in production. Depletion offset is calculated using the depletion rate (production divided by reserves).*

Although the additional amount from OPEC and the former Soviet Union (FSU) is a less straightforward calculation (both have seen production changes without capacity changes), the net increment there is on the order of 2 mbd. In other words, offsetting a 10% decline in Ghawar output would mean that the industry would have to add about 10% to its annual gross capacity additions. So, the argument from Simmons is that we require a plan to prepare for something that seems neither likely to occur nor difficult to deal with.

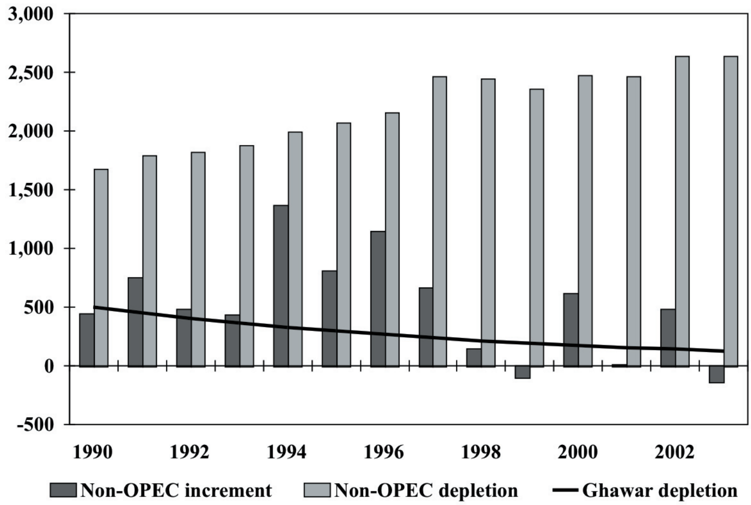
Evaluation: Ultimately, then, all the evidence purporting to show a near-term peak in Saudi oil production is discredited. It falls into patterns of irrelevant observations that are purported to be significant, assumptions of causality without considering alternative explanations, misrepresentation of data, numbers taken out of context, and so forth. The entire approach of presenting data clearly is not useful, and the reader is left to wonder at the habit of not making simple conclusions or noting contradictions between various data and arguments.

In order to make his case, Simmons and the others would need to (a) show the problems the Saudis are having and how they are changing, (b) compare them to other fields and show they are more severe, (c) demonstrate that the problems' resolution is expensive relative to the price of oil, and (d) provide indicators of resource maturity. None of this is done. While much useful data are not available, or not in a useful form, there actually is quite a bit of information about Saudi resource activity, none of which has been presented by any of the "alarmist" analysts. The next section tries to correct this.

Hard Data: The Ultimate Test

As part of his implication that Saudi data could not be trusted, Simmons derided the idea that Saudi Arabia had 2 mbd of surplus capacity during

Figure 5
Non-OPEC Global Capacity Additions, 1990-2003[a]
(in thousand barrels/day)



[a]OPEC = Organization of the Petroleum Exporting Countries.

his February 2004 presentation, commenting that he had not seen it on an (unofficial) visit there ("where could 'shut-in capacity' hide?").[72] Of course, other producers have found that idle capacity is not always readily available nor as large as estimated.[73] Since his comments, however, Saudi output rose by 1.5 mbd, and capacity is estimated to have risen by 0.8 mbd (figure 6).[74] This is an extraordinary performance, one that suggests either it is exceptionally easy to produce oil in Saudi Arabia or that Saudi capacity numbers were reasonably accurate.

Beyond that, the industry has not questioned the Saudi contention of having mothballed a number of fields in favor of lower-cost production. Saudi Aramco has announced plans to raise production capacity to 11.8 mbd in the next two years and has provided details on the specific projects involved; as table 4 shows, contracting has begun with billions of dollars already committed. The implication of Simmons' contention that Saudi oil is near a peak and these fields cannot contribute the capacity claimed is that Saudi Aramco is spending a fortune on Potemkin villages, trying to drive the price of oil down even as their output is about to peak. Apparently, they do have a "plan B."

Saudi Resource Maturity—Actual Evidence: For all the talk of Saudi secrecy, data exist that should have been provided by Simmons to support his case; neither he nor any other "alarmist" has done so. The actual data included are irrelevant, out of context, or are static, not showing any actual

Figure 6
Recent Saudi Production, January 2003-2006 (in thousand barrels/day)

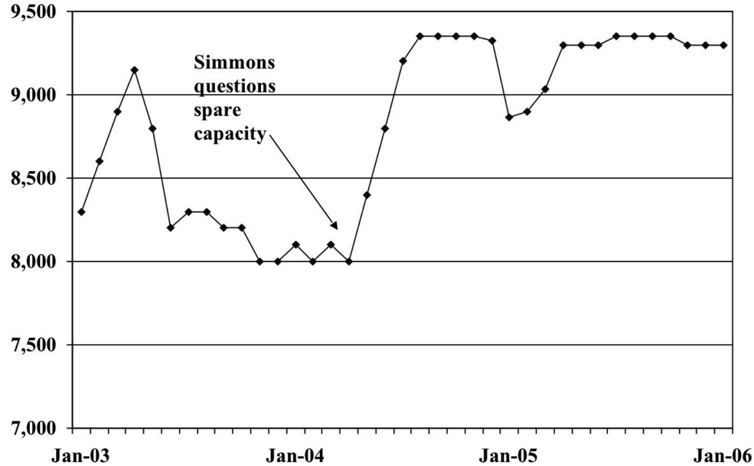


Table 4
Saudi Capacity Addition Plans (in thousand barrels/day)

Field Name	Capacity	Status	Target Date
Haradh	300	Phase 3	2006
Shaybah	300	Expansion	2008
Khursaniyah	500	Expansion	2007
Khurais	1,200	Mothballed	2009
Nuayyim	100	New field	n.a.
Total	2,400		

Source: *International Oil Daily*, April 14, 2005.

trends. This is surprising because a significant amount of evidence exists about the status of Saudi resources. This includes the Saudis' recent output and investment plans, current supply economics, the geology of existing fields, and the level of maturity.

Historical production behavior is one valuable sign. Despite the claims that reserves are inadequate, surplus capacity is not available, and the fields are "tired," on three occasions the Saudis have raised output rapidly in response to supply disruptions. In 1979-1980, in 1990, and again in 2003, the Saudis increased production far beyond what any other producer has ever accomplished in a short period of time.

But other physical and economic data also are highly indicative of the status of the Saudi resource. For economists, rising costs are usually the surest indicator of resource maturity, that the resource base is being strained and depletion is having an effect. Measuring upstream costs is made difficult by many factors, including joint products, imprecise reserve data, and a host of others.[75] However, approximations can and have been made for Saudi Arabia by a number of sources, shown in table 5. And as Adelman shows in the Appendix, the costs of the current expansion are quite low, far below that of most areas in the world with the possible exception of Iraq. There is little question that Saudi oil is among the cheapest in the world.

Geological data are no less convincing. For one thing, despite the Simmons claim that Saudi Arabia has been extensively explored, *its drilling density is approximately 14 wells per 1,000 square miles of prospective area versus about 900 for the United States in 1970, the year U.S. output peaked* (table 6). While not proof that any particular level of oil is undiscovered, it is strongly suggestive. Indeed, even the USGS suggests there is an additional 30 billion to 160 billion barrels to be discovered, an amount that is conservative given implicit assumptions about infrastructure, etc. (The USGS estimates that a larger proportion of Saudi oil has been found than of U.S. oil, partly reflecting the estimated resource base of the deepwater Gulf of Mexico and the greater economic viability of smaller fields in the United States.) Although these numbers are somewhat approximate, especially for undiscovered oil and Saudi wells drilled*, the indicators are of such large orders of magnitude as to be uncontestable*.

Further, the data for well productivity are much better established, with decades of relatively (if not completely) reliable statistics. The *Oil & Gas Journal* for many years has published estimates of the number of wells operating; figure 7 shows the Saudi data at five-year intervals (log scale) compared to other regions. Not only has Saudi well productivity not declined significantly over four decades, it remains far above any other region.

Rig data also are indicative. As figure 8 shows, the number of drilling rigs in Saudi Arabia is not very different from what it was three decades ago. The increase seen in the last 20 years reflects rising production and the need to offset depletion, plus the recent expansion program. And note that the U.S. industry is currently employing 1,400 rigs, more than 40 times as many as Saudi Arabia.[76]

Thus, in order to believe the thesis that Saudi oil output is near a peak, it is necessary to believe that production costs will soar and productivity decline *in a manner never seen before*, contradicting both resource economics and industry experience. Incremental change is the norm, particularly when dealing with large numbers, and the possibility that costs could become prohibitive in the short term due to depletion is essentially absurd.

The Last Refuge: In late 2005, Simmons seems to have moderated his alarms and retreated to a call for better data on Saudi (and global) oil. Specifically, he has asked that field and well data be released by every nation so that the world will have a better idea of the true situation. The

Table 5
Estimates of Saudi Production Costs

Source	Date	$/Barrel	$/Daily Barrel
Adelman	1968	$0.41	
CGES	1993	$3.25	$4,936
Stauffer	1994	$1.21	
CERA	2001	$3.96	
IEA	2001	$1.85	
Appert	2003	$1.026-$5.11	
Baqi	2004	<$3	
Adelman	2005	$2.11	$3,211

Source: Michael C. Lynch, "The Economics of Oil and Gas Supply," forthcoming 2006; datafiles available with the author.

Table 6
U.S. and Saudi Arabian Resource Maturity (in billion barrels)

	United States	Saudi Arabia
Discovered oil	279	284
Undiscovered oil	83	87
% Discovered	77.1%	76.5%
Prospective area (square miles)	2,534	560
Wells drilled	2,270,000	8,000
Drilling density	896	14

Sources: U.S. Geological Survey (USGS), World Petroleum Assessment Team, *World Petroleum Assessment* (USGS, 2000); *World Oil*; *Energy Statistics Sourcebook* (Tulsa, OK: PennWell Publishing, various years); Gustavo Rodrigues Elizarraras, "Crisis in the Oil Industry: Retracing Our Steps," *OPEC Bulletin*, February 1988.

Saudis have rejected this as an infringement on their sovereignty; the primary supporters of this suggestion have been consumers, not producers.

Aside from a suspicion that this is intended to set a condition that cannot be met and thus leave Simmons' arguments unrefuted, it should be noted such data will not necessarily yield valuable results. As Lynch noted, successful oil supply models are virtually non-existent, even for the United States and Canada, where large quantities of data, both field and well, are available.[77] Production in the North Sea rarely has been forecast well, even for a few years into the future.

Indeed, there is a perfect example of what can be done given access to well data. Simmons describes a detailed analysis performed using Texas natural gas well data, arguing, "Logically, it is hard to see why this survey of 16% of the US gas supply would not be a rough proxy for what

Figure 7
Per Well Productivity, 1963-2003 (in barrels/day/well)

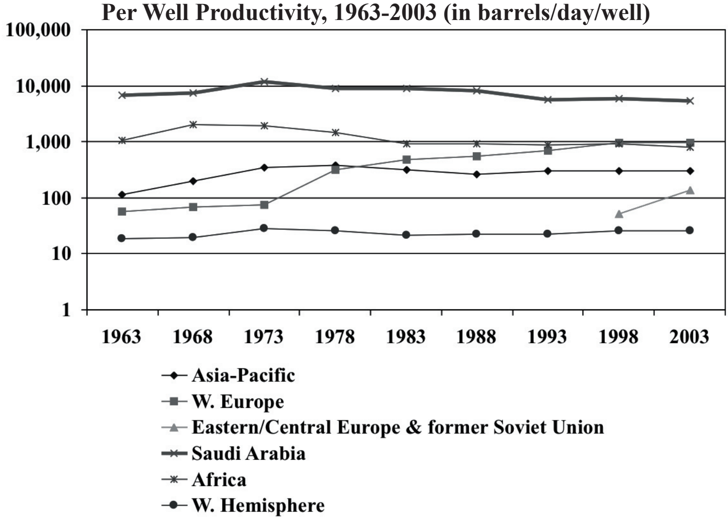
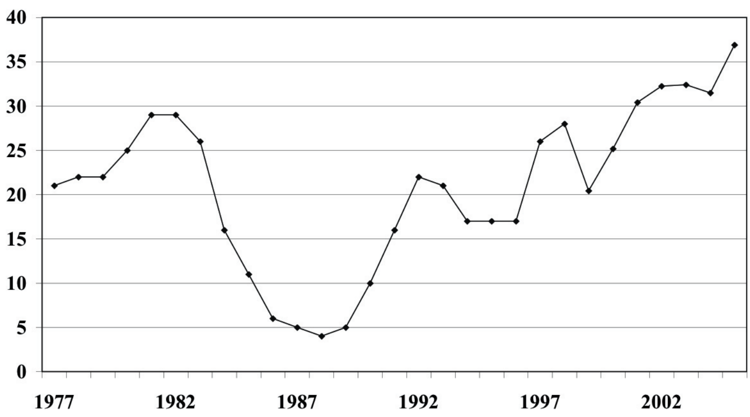


Figure 8
Saudi Arabia: Rigs Active, 1977-2005



is likely to happen to gas supply for the entire country."[78] Using this, he notes,

> *The fact that 75% of Texas counties suffered declines of 15% during a historical drilling boom illustrated that a statewide drop of this magnitude or more could be realistic. Handicapping the odds of such an event is impossible.*[79]

In fact, Texas natural gas production has not been dropping at all (figure 9). Beyond that, Simmons concluded that "a decline in gas supply as little as 1% to 3% now seems almost impossible, once the full impact of a drilling collapse is finally felt. I think the U.S. will be fortunate if the decline is only 10%. It could be far higher."[80]

While declines of that magnitude might occur in a small producing area, in a large producing nation like the United States such would be extremely unlikely. And, in fact, natural gas production in the United States has declined only slightly, mostly due to hurricane damage (figure 10).

Clearly, the problem here is one of taking a snapshot of a dynamic system, not recognizing the various offsetting variables, and making simplistic assumptions. As in the case of Saudi Arabia, Simmons presents observations and draws conclusions without really connecting the two, with the resulting failure.

The simple truth is that more data always allow for improved analysis but do not allow one to predict (a) field discovery, (b) new basin discovery, or (c) investment patterns; as such, their value is somewhat limited. Even in countries like the United States and Canada, where investment, drilling, and reserve data are very high quality, or the United Kingdom and Norway, where the number of fields is very limited, the many attempts to project oil supply have nearly all failed, and rather abysmally.

Summary: It is hard to characterize the discussion about Saudi oil resources as scientific in nature. Much of the technical information cited is either irrelevant (provided without explanation of its meaning) or wrong. Many of the arguments involve perverted logic and are often refuted by information provided by the "alarmists" themselves, particularly in the case of Simmons. The omission of publicly available information raises questions about the sincerity of the work.

The actual evidence presented by the Simmons work suggests that (a) the Saudis are at the beginning of their resource curve, (b) they are developing their fields in a very careful manner, and (c) they have faced and overcome numerous technical challenges. Nowhere is there anything to support his conclusions that their production is going to peak, and historical evidence refutes this hypothesis quite clearly.

> *It is also interesting to realize that these 12 papers, each dealing with various technical problems in Saudi Arabian oilfields, were presented at a prominent industry forum to an audience of technical experts assembled from all over the world, and not a single question was raised about the overall capability of Saudi Arabia as an oil supply.*[81]

Schermer has a simple test of any hypothesis: consider which is more likely, the hypothesis put forth or its opposite?[82] In this case, we are being asked to believe whether it is more likely that a Harvard M.B.A. with no technical background has correctly perceived an extraordinary conclusion from engineering papers, contradicting all other data and observed reality as well as the vast majority of expert opinion, or whether he simply got it wrong. The evidence in this paper shows that what he has said, which can be tested, is demonstrably wrong.

Figure 9
Texas Natural Gas Production, 1989-2004 (in billion cubic feet)

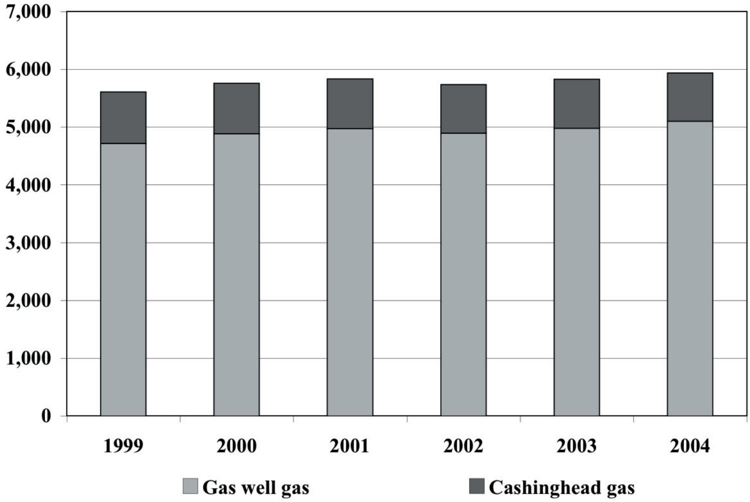
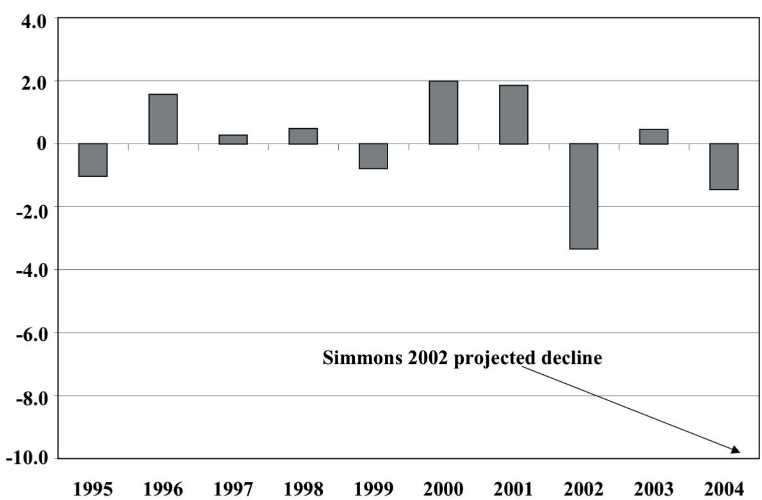


Figure 10
Annual Change in U.S. Gas Marketed Production, 1995, 2005 (in percent)



Sources: U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review* and M. R. Simmons, "Unlocking the Natural Gas Riddle," White paper, May 1, 2002, p. 30, available at http://www.simmonsco-intl.com/Research.aspx?Type=MMSpeechArchives.

Overall, the arguments made by the various "alarmists" resemble a cable television special on crop circles, where only evidence conforming to the zealots' beliefs is presented—most of it unquestioningly—even where it is illogical, meaningless, or simply incorrect. What is needed is greater critical thinking on the part of the audience on both crop circles and Saudi peak-oil warnings.

NOTES

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[1]Jeff Gerth, "Forecast of Rising Energy Demand Challenges Tired Saudi Fields," *New York Times*, February 24, 2004.

[2]Matthew R. Simmons, "The Peak Oil Debate: Crisis or Comedy?," Society of Petroleum Engineers Annual Technical Conferences, September 22, 2004. (Hereafter cited as Simmons, *SPE 2004*). For the presentations of Baqi and Saleri to the February 24, 2004 meeting at the Center for Strategic and International Studies, Washington, D.C. (hereafter cites as *CSIS Meeting*), see Mahmoud Abdul Baqi, "Fifty-Year Crude Oil Supply Scenarios: Saudi Aramco's Perspective," available at http://www.saudi-us-relations.org/energy/Saudi-energy-abdul-baqi.html, and Nansen Saleri, "Future of Global Oil Supply: Saudi Arabia," available at http://www.saudi-us-relations.org/energy/Saudi-energy-saleri.html.

[3]Some have suggested that those making these arguments are neo-conservatives, but I know of no evidence to suggest anything is at work other than self-interest and/or a Malthusian bias. This is not to say the arguments have not been embraced by stock brokers, neo-conservatives, environmentalists, and others, for whatever reason.

[4]"Oil Output will Depend on Investment, not Reserves," *Financial Express*, January 13, 2006.

[5]For the misinterpretations, see Lian Halligan, "Oil Supplies Overestimated," Channel 4 (United Kingdom), October 26, 2004, available at www.peakoil.net/channel4.htms and Saddad al-Husseini, "Rebutting the Critics: Saudi Arabia's Oil Reserves, Production Practices Ensure Its Cornerstone Role in Future oil supply," *Oil & Gas Journal*, April 6, 2006.

[6]Saddad al-Husseini, "Why Higher Oil Prices Are Inevitable This Year, Rest of Decade," *Oil & Gas Journal*, August 2, 2004.

[7]Association for the Study of Peak Oil & Gas (ASPO), available at http://www.asponews.org/.

[8]Available at http://www.simmonsco-intl.com/. (Hereafter cited as Simmons, *Web site*.)

[9]Matthew R. Simmons, *Twilight in the Desert* (Hoboken, NJ: John Wiley & Sons, 2005). (Hereafter cited as Simmons, *Twilight*.)

[10]R. W. Bentley, "Global oil & gas depletion: an overview," *Energy Policy*, 2002; Paul Roberts, *The End of Oil: On the Edge of a Perilous New World* (Boston: Houghton Mifflin, 2004); David Goodstein, *Out of Gas: The End of the Age of Oil* (New York: W. W. Norton, 2004); Stephen and Donna Leeb, *The Oil Factor: Protect Yourself—and Profit—from the Coming Energy Crisis* (New York: Warner Books, 2005).

[11]Kenneth S. Deffeyes, *Hubbert's Peak: The Impending World Oil Shortage* (Princeton, NJ: Princeton University Press, 2002); Richard Duncan and Walter Yongquist, "The World Petroleum Life-Cycle," presented to the Petroleum Technology Transfer Council, Los Angeles, October 22, 1998; Jean Laherrere, "Modelling Future Liquids Production from Extrapolation of the Past and from Ultimates," delivered to the International Workshop on Oil Depletion, Uppsala, Sweden, May 23, 2002.

[12]Michael C. Lynch, "The New Pessimism about Petroleum Resources: Debunking the Hubbert Model (and Hubbert Modelers)," *Minerals and Energy,* vol. 18, no. 1 (2003), provides an extensive critique of this body of work.

[13]The most entertaining example is Morton's inclusion of a quote from Deffeyes: "A small part of the reservoir was dolomite, but most of it turned out to be a fecal-pellet limestone. I had to go home that evening and explain to my family that the reservoir rock in the world's biggest oil field was made of shit." G. R. Morton, "Trouble in the World's Largest Oil Field—Ghawar," web published at http://home.entouch.net/dmd/ghawar.htm. Perhaps the most amusing aspect of this is that Morton's writings appear to be limited to a publication he refers to as "PCSF," which is actually *Perspectives on Science and Christian Faith*, published by the American Scientific Affiliation, a group that has not staked out a position on the evolution vs. creationism debate and so is uncertain as to the existence of dinosaurs.

[14]The OTC and SPE conferences, both in Houston in 2004.

[15]The debate at the SPE can be viewed at http://spe.org/spe/jsp/basic/0,,1104_1573_2980165,00.html, while Simmons' PowerPoint presentations can be seen at Simmons, *Web site.*

[16]Chip Haynes, "Ghawar is Dying," August 2001, at http://www.newcolonist.com/ghawar.html.

[17]Simmons, *Web site*, “Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy,” Boston Council on Foreign Relations, PowerPoint presentation, April 12, 2005.

[18]Simmons, *Twilight,* p. 176.

[19]Jeff Gerth, “Doubts Raised on Saudi Vow for More Oil,” *New York Times*, October 25, 2005.

[20]“Bias and Theoretical Error in Long-Term Oil Market Forecasting,” in *Advances in the Economics of Energy and Natural Resources*, ed. John R. Moroney (Greenwich, CT: JAI Press, 1994).

[21]Simmons, *Web site*, “The Saudi Arabian Oil Miracle,” Center for Strategic and International Studies, Washington, D.C., February 24, 2004. (Hereafter cited as *Web site, CSIS*.)

[22]Simmons, *Twilight*, p. 73.

[23]*World Oil*, February 2005.

[24]Paul Roberts, op. cit., p. 2.

[25]An Internet search using Google and the terms “petroleum water cut SPE” yields a SPE distinguished lecturer abstract with the 75% figure. Andrew K. Wojtanowicz, “Downhole Water Separation,” Los Angeles SPE forum, November 14, 2003, abstract at http://laspe.org/petrotech/petrooct03.html.

[26]Simmons, *Twilight*, p. 330.

[27]Jim Jarrell, “Another Day in the Desert: A Response to the Book “Twilight in the Desert,” *Geopolitics of Energy*, October 2005.

[28]Peter Maass, “The Breaking Point,” *New York Times Magazine*, August 21, 2005, p. 32.

[29]Simmons, *Twilight*, p. 159.

[30]Simmons, *Web site*, “Twilight in the Desert: The Coming Saudi Oil Shock and the World Economy,” PowerPoint presentation, Boston Committee on Foreign Relations, April 12, 2005, slide 20.

[31]Simmons, *Twilight*, p. 70.

[32]Ibid., p. 50.

[33]Ibid., pp. 380 and 378.

[34]Ibid., p. 380.

[35]Ibid. p. 382.

[36]Ibid., p. 50.

[37]*Petroleum Intelligence Weekly*, Supplement, April 23, 1979.

[38]The anonymous advisor to the *ASPO Newsletter* writes that these fields are “dogs,” which is both imprecise and rather bizarre given the

desperation many foreign oil companies have shown to gain access to the oil upstream in Saudi Arabia. *ASPO Newsletter,* October 2004, p. 11.

[39]Simmons, *Twilight*, p. 127. There is a broad literature on this subject, of which Simmons and the Hubbert modelers appear to be unaware. See Gordon Kaufmann in *Energy Resources in an Uncertain Future*, eds. M. A. Adelman, John C. Houghton, Gordon M. Kaufman, and Martin B. Zimmerman (Cambridge, MA.: Ballinger, 1983), for a summary discussion and Gordon Kaufmann, "Statistical Issues in the Assessment of Undiscovered Oil and Gas Resources," *The Energy Journal*, January 1993, for an updated review. Thomas Ahlbrandt and T. R. Klett, "Comparison of Methods Used to Estimate Conventional Undiscovered Petroleum Resources: World Examples," *Natural Resources Research*, September 2005, also provides a summary of the many methods employed and compares their results in one province. Emil D. Attanasi and Phillip A. Freeman, "Size-Frequency Analysis of Petroleum Accumulations in Selected United States Plays: Potential Analogues for Frontier Areas," USGS Open-File Report 2004-1299, demonstrate this for many U. S. basins.

[40]Saudi Oil Minister Naimi has been quoted as saying that the country would revise its reserves estimates up by about 200 billion barrels, which would support this view. James Cordahi, "Saudi Arabia, Exxon Say Oil Will Last for Decades," *Bloomberg*, September 27, 2005.

[41]*CSIS Meeting*; Mahmoud Abdul Baqi, op. cit; Nansen Saleri, op. cit.

[42]Simmons, *Twilight*, p. 317.

[43]Colin Campbell, *The Coming Oil Crisis* (Perly, Switzerland: Petroconsultants, in association Multi-Science Publishing Co. Ltd., 1997).

[44]Philip Stark and Ken Chew, "Global Oil and Gas Resources—The View from the Bottom Up," May 5, 2004, available at http://energy.ihs.com/Resource-Center/Presentations/regional.htm.

[45]*ASPO Newsletter*, April 2004.

[46]*CSIS Meeting*; Mahmoud Abdul Baqi, op. cit.; Nansen Saleri, op. cit.

[47]*ASPO Newsletter*, April 2004, p. 3. Emphasis in the original.

[48]Simmons, *Web site*, "Saudi Arabian Oil: A Glass Half Full or Half Empty," Hudson Institute, July 9, 2004, slide 22.

[49]See Michael C. Lynch, "The New Pessimism about Petroleum Resources: Debunking the Hubbert Model (and Hubbert Modelers)"; Philip Stark and Ken Chew, op. cit.; Thomas Ahlbrandt and T. R. Klett, op. cit.

[50]Tone Sem and Denny Ellerman, "North Sea Reserve Appreciation, Production and Depletion," MIT CEEPR Working paper 1999-011, October 1999, p. 22, available at http://web.mit.edu/ceepr/www/99011.pdf;

David F. Morehouse, "The Intricate Puzzle of Reserves Growth," *Natural Gas Monthly*, July 1997, p. xvi; Philip Stark and Ken Chew, op. cit.; G. C. Watkins, "Characteristics of North Sea Reserve Appreciation," December 2000, MIT CEEPR Working paper 2000-008, December 2000, available at http://web.mit.edu/ceepr/www/2000-008.pdf.

[51]Simmons, *Twilight*, p. 72.

[52]Ibid., p. 157.

[53]G. R. Morton, op. cit.

[54]U.S. data are limited by the fact that most large fields were discovered before recording keeping was extensive. The British and Norwegians publish field data and they show extensive growth, with occasional tripling in size.

[55]Simmons, *Web site*, "Twilight in the Desert: The Fading of Saudi Arabia's Oil,:" Hudson Institute, September 9, 2004, slide 30.

[56]Simmons, *SPE 2004.*

[57]Simmons, *Web site*, "The World's Giant Oilfields," White paper, January 9, 2002.

[58]Simmons, *Twilight*, p. 116.

[59]Ibid., pp. 50-52, 70-74, and 76-77.

[60]Simmons, "Twilight in the Desert," Boston Committee on Foreign Relations, April 12, 2005, slide 21. Emphasis in original.

[61]Simmons, *Twilight*, p. 49.

[62]Ibid., p. 153.

[63]Ibid., p. 138.

[64]Jim Jarrell, op. cit., p. 9.

[65]Simmons, *Twilight*, pp. 51-52.

[66]Personal comment, 2006.

[67]Simmons, *Twilight*, p. 51.

[68]This is primarily to a given basin, but the actual decisions also are affected by infrastructure, field depth, water depth, political access, etc., a plethora of factors besides just field size.

[69]This was pointed out to Simmons directly at the OTC in May 2004.

[70]M. A. Adelman and Michael C. Lynch, "Fixed View of Petroleum Resources Creates Undue Pessimism," *Oil & Gas Journal*, April 7, 1997.

[71]C. J. Campbell, *The Golden Century of Oil 1950-2050*: *The Depletion of a Resource* (Dordrecht, The Netherlands: Kluwer Academic Publishers, 1991).

[72]Simmons, *Web site*, *CSIS*, slide 14.

[73]In 1967, during the first Arab oil embargo, Texas was estimated to have 3.5 mbd of spare capacity but, when called upon to utilize it, found that both the amount and the availability were greatly exaggerated.

[74]Estimates are from *Oil Market Intelligence*, published by the Energy Intelligence Group, New York, which is the primary source used by the industry for these date.

[75]Michael C. Lynch, “Forecasting Oil Supply: Theory and Practice,” *Quarterly Review of Economics and Finance*, July 2002.

[76]The ratio for oil-directed rigs is approximately 200/15.

[77]Michael C. Lynch, “The Analysis and Forecasting of Petroleum Supply: Sources of Error and Bias,” in *Energy Watchers VII*, ed. Dorothea H. El Mallakh (Boulder, Colorado: International Research Center for Energy and Economic Development, 1996) and “Forecasting Oil Supply: Theory and Practice,” *Quarterly Review of Economics and Finance*, July 2002.

[78]Simmons, *Web site*, “Unlocking the Natural Gas Riddle,” White paper, May 1, 2002, p. 29.

[79]Ibid.

[80]Ibid., p. 30.

[81]Simmons, *Twilight*, p. 315.

[82]Michael Schermer, *Why People Believe Weird Things: Pseudoscience, Superstition, and Other Confusions of Our Time* (New York: Henry Holt & Company, 1997).

Appendix
Saudi Arabian Production Costs
Prepared for this paper by M. A. Adelman

In any large field, variations in rocks and fluids are to be expected. Usually, wells should be drilled around the periphery of the field, following the oil-water contact as then known. There is a tradeoff: new wells might be drilled higher, hence fewer, but less efficient in sweeping the periphery of the field. Either way, as the field grows in area and liquid/gas content, the engineers learn more about it, by hard work observing and calculating. To assume the fluid volume as lower because the engineers are working (and publishing their papers) to learn more about the field would be a very curious lesson to draw. For a famous (or notorious) example, see Matthew Simmons’ book, *Twilight in the Desert*.

According to *Petroleum Intelligence Weekly* (July 18 2005, p. 7), Saudi Arabia plans to spend $11.2 billion on development drilling over the five-year period 2007-2010. We add one-third, to estimate total development expenditures at $14.9 billion. The decline rate is assumed at 4%. Total oil produced over five years is five times 10 million barrels daily (mbd); the aggregate loss made good by development is 2 mbd. To this we must add the new net capacity, from 10 mbd to 12.5 mbd. Hence, total new capacity installed is 2 mbd + 2.5 mbd = 4.5 mbd. Total development investment is then $3,310 per daily barrel or $9.07 per annual barrel.

Current expenditures, weighted and discounted, amount to 8%. The annual decline is 4%. The usual discount rate for 2005 is about 13%; we add half as much to allow for discovery effort. The annual rate of return is then 32% (.08+.04+.20). The cost of the barrel is $9.07x.032=$2.90 per barrel at post-2005 prices. Our estimate is too high because it includes natural gas, but we have as yet no basis for separating it out.