THE END OF THE FIRST HALF OF THE AGE OF OIL

C.J.Campbell
aspotwo@eircom.net

I-SUMMARY

Petroleum geologists know that oil and gas were formed but rarely in time and place in the Earth's long geological history, which means that that they are finite resources, subject to depletion. Since production has to mirror earlier discovery, the fact that oil discovery has been in relentless decline for forty years means that the onset of the corresponding decline of production is now imminent. In short, the End of the First Half of the Age of Oil arrives. It lasted 150 years, stimulating the rapid expansion of industry, transport, trade and agriculture, fuelled by cheap oil-based energy. As a result, the population was able to multiply six-fold exactly in parallel with oil. In addition, this epoch saw the growth of financial capital, largely in the form of debt and usury in a system that relied on confidence in tomorrow's expansion to act as collateral for today's debt. The Second Half of the Age of Oil, which now dawns, will see the decline of oil, followed by gas, and all that depends upon it. It speaks of the End of Economics as currently understood and practiced.

Peak Oil would be entirely self-evident were reliable information on reserves and production available to the public. There is accordingly an urgent need to lift the veils of confusion and obfuscation delivered by vested interests, many with political agendas, so that governments and the people at large may plan and prepare to meet the new conditions as imposed by Nature. There is much at stake.

II-ORIGIN OF OIL AND GAS

In earlier years, petroleum geologists had only a limited knowledge of the origins of oil and gas, although dark-coloured clays with petroliferous indications were identified as good candidates.

A geochemical breakthrough in the 1980s resolved the uncertainties. It became possible to link the oil in a well with the rock in which it was formed. That in turn allowed the environment of deposition to be accurately determined. Furthermore, laboratory experiments identified the chemical reactions that converted the organic material into oil and gas, as well as the temperature controls.

In short, this research showed that oil is derived from algae and similar micro-organisms, whereas gas comes both from plant remains and ordinary oil that has been overheated by excessive burial. It transpires that the bulk of the World's oil results from just two brief epochs of extreme global warming, 90 and 150 million years, when the algae proliferated. Much was preserved in stagnant rifts which formed as the continents moved apart.

Once formed, the oil and gas began to migrate upwards to zones of lesser pressure. In some cases, it simply dissipated. In others, it encountered a porous and permeable carrier-bed, such as a sandstone, though which it could move, largely under the influence of buoyancy. Where the carrier led to the surface, much of the oil and gas escaped leaving behind a degraded residue. The tar-belts of Canada and Venezuela are examples. Where folded or faulted, the carrier-bed provided traps in which the oil and gas accumulated. Only some of them were large enough to support oilfields.

In such a trap, the carrier-bed acts as a reservoir for the oil and gas which displaces the water that hitherto filled the pore-space between the individual grains of rock. The quality of reservoir ranges widely from, for example, a pure sandstone with plenty of pore-space to one in which the spaces are clogged by fire-grained material. It may be variously thick and homogenous; thin; or made up of alternating beds of different composition. It is worth stressing that, on average, only about 35% percent of the oil in a reservoir is producible, the rest being held immovable by capillary forces or physical constrictions in the rock.

Lastly, the reservoir needs to be capped by an impermeable layer, such as clay or rock-salt, to prevent the oil and gas escaping. No seal has perfect integrity: much oil, and even more gas, has escaped over geological time.

These few words describe the essence of the matter: the details are much more complex.

III–FINDING AND PRODUCING OIL

The first step to finding oil was to secure the rights to do so. The United States is almost unique in that the landowner held the mineral rights, which he was able to lease to oil companies. Elsewhere, governments normally own the rights, and let concessions for a given duration under stated terms.

When an onshore area was opened to exploration, geologists moved in to try to identify the source-rocks, the reservoirs and the structural traps. Many of the World's prolific provinces were found in this way, using technology no more advanced than the hammer, the hand lens and the notebook.

Later, came seismic surveys by which to scan structure far beneath the surface, both onshore and offshore. Energy was released at the surface by an explosive charge or in other ways. The time taken for the echoes to return from the interfaces of deeply buried strata was recorded, making it possible to determine their depth and configuration.

The final step was to move in with a rig and drill so-called *wildcat* wells to test prospects identified as having the right combination of geological conditions. Such wells were commonly drilled to depths of 2000-3000 m, providing a wealth of information from the examination of cuttings and cores. Sondes were lowered down the boreholes to measure electrical and radioactive properties, making it possible to identify any oil-bearing zones.

It was rare for the first *wildcat* in a new area to succeed, but the information it provided refined the geological assessment leading to other prospects. Gradually the possibilities were investigated until a moment-of-truth was reached either by a discovery or by the realisation that the area lacked the essential geology, in which case it remained forever barren. Normally, the larger fields were found first, being too large to miss. When a promising discovery was made, responsibility passed from the explorers to the engineers, charged with developing and implementing an efficient scheme of production, maximizing profit against investment. Huge investments were at stake offshore and in remote areas, so it made good sense for the engineers to be very cautious and work on a step-by-step basis. Normally, they drilled several appraisal wells to delineate the field before making the major investments. It was an expensive undertaking with the *wildcat* alone often costing $10 to 20 million.

There is no reason to describe the production process in detail, which needless to say employed very advanced technology. The first wells were located to tap the reservoir at its thickest, in order to give a high flow rate. As the oil was extracted, the underlying water table rose, meaning that progressively less and less of the oil-bearing reservoir was tapped by the wells. It is easy to understand why production rises to a peak or plateau, as new wells are added, but eventually declines.

Before leaving this topic, it is worth stressing that there is a certain polarity about oil that distinguishes from coal and other minerals. A coal deposit may cover a wide area, but is mined only where the seams are thick and accessible. Thus, if prices rise or costs fall, lower concentrations become viable. Oil by contrast is either there in profitable abundance, or not there at all. Furthermore, it flows from the ground under its own pressure in a manner very different from digging up coal with a pick and shovel. This gave the industry a certain "boom or bust" character that permeated many aspects of the business.

IV-CATEGORIES OF OIL AND GAS

The foregoing is no more than a general description. Considered in greater detail, we may note that there are many different categories of oil and gas, each having its own costs, characteristics and depletion profile. Some were cheap, easy and fast to produce, whereas others were the precise opposite.

Before coming to the measurement of reserves and the estimates of what is left to find, it is

important to be very clear about what to measure. The terms *Conventional* and *Non-Conventional*, have been in wide use, but the boundary lacks a standard definition. To avoid confusion, it is better to introduce a new term, *Regular Conventional Oil (and Gas)*, and define it to exclude the following categories:

- Oil from coal and "shale"
- Bitumen
- Extra-Heavy Oil
- Heavy Oil (10-17.5^{o} API)
- Deepwater Oil and Gas (>500m)
- Polar Oil and Gas
- Natural Gas Liquids from gas plants
- Coalbed methane, "tight gas" etc.

Regular Conventional Oil, as so defined, has contributed most to-date and will dominate all supply far into the future. It accordingly determines the peak of all production, which is the critical subject to address, being much more relevant than final exhaustion. The other categories will be important after peak by ameliorating the decline, but have a minimal impact on peak itself

V-THE DISCOVERY TREND

The foregoing account has made it clear that oil and gas are finite resources formed in the geological past. It follows that they are subject to depletion. Given their central role in the modern economy, it is important to determine the status of depletion, which involves the measurement and dating of discovery. It sounds simple but is anything but that.

The Total Discovery for a country at any point in time is the sum of past production and the estimated future production from known fields, termed *Reserves*. The process of measurement commences with the explorers who had to evaluate the size of their prospects before drilling. The initial *wildcat* and the succeeding appraisal wells, together with the performance of the production wells themselves gradually improved the estimates. The full size of a field became fairly evident early in its life. So, in strictly technical terms, no particular difficulty should be faced in determining the status of depletion for a field, a country, a region or eventually the World as a whole.

The problems arise from the reporting practices, which need to be explained. The reporting by oil companies followed the following general path. The explorers estimated the size of a prospect before drilling, but normally found themselves under pressure to exaggerate in order to secure the funds from distant boardrooms exposed to many alternative investment opportunities. Their estimates, whatever they were, remained confidential. When a discovery was made, the engineers moved on a step by step basis reporting the reserves of each phase as it was committed. Such estimates did enter the public domain through Stock Exchange and host-government reporting procedures.

The Stock Exchanges rules had their origins in the early days of the United States, with its unique ownership arrangements whereby different parts of the same field were commonly developed by different owners. The reserves were financial assets, against which money could be borrowed. The Securities and Exchange Commission (SEC) very properly moved to impose strict rules to prevent fraud, recognising two main *Reserve* categories: *Proved Producing*, being the estimated future production of current wells; and *Proved Undeveloped*, being the estimated future production from projected infill wells, to be located between the existing ones, before they had actually been drilled. The commerciality of the reserves was barely in question in the environment of the United States with its ready market. In short, the rules were designed to prevent exaggerated claims, but were lenient on under-reporting, deemed financial prudence.

The same procedures were adopted outside the United States although the circumstances were rather different, being subject to more commercial uncertainty. In practice, the major companies reported just as much as they needed to deliver a satisfactory financial result, building up for themselves a useful stock of unreported reserves which could be used to cover any temporary setback in their worldwide operations. The practice reduced tax in many circumstances, and the resulting upward revisions of reported reserves provided a comforting image of steady, well-managed growth. No particular trick or conspiracy is

implied: it was just good pragmatic management.

However, the stock of unreported reserves has been substantially drawn down over the past decade, leading several of the major companies to acquire their needed financial reserve base by merger rather than exploration. It is noteworthy that Shell, which did not made significant acquisitions, was finally forced to downgrade its reserves, causing a financial furore that cost the Chairman his job.

The major oil companies lost their primary sources of supply through expropriation. Mexico was the first to do so in 1938, followed in turn by Iran in 1951, and Kuwait, Venezuela, Iraq and Saudi Arabia during the 1970s. These moves led the companies to step up exploration and production elsewhere, leaving these governments with the difficult job of balancing supply with demand to support price, which led to the formation of OPEC.

The OPEC countries started by reporting the conservative reserve estimates inherited from the oil companies. They had to allocate supply amongst themselves under a quota system to provide stable prices. In 1985, Kuwait added 50% to its reported reserves, although nothing particular had changed in the oil fields. In fact it reported a figure close to the total discovered, not its remaining reserves. Three years later, several of the other OPEC countries had to retaliate to protect their quota. Abu Dhabi, Iran and Iraq matched the Kuwait number of 92 Gb within narrow limits, while Venezuela doubled its reported reserves from 25 to 56 Gb. Saudi Arabia was the last to move but increased its reported reserves from 170 to 258 Gb in 1990, adopting Kuwait's practice of reporting Original, not Remaining Reserves. The numbers have barely changed since, despite production, confirming that they are largely arbitrary. It may have made good sense from a quota standpoint to have a relatively fixed number, avoiding difficult renegotiation.

The foregoing discussion shows how public data are grossly unreliable, explaining why so many analysts lacking direct industry experience have been misled by the apparent growth in published reserves, which they attribute to technology and investment when in fact it was nothing more than a reporting artefact. The oil companies could have been more forthright in explaining the position, but their directors had a fiduciary duty to make money for their shareholders by any means open to them, provided they observed the Stock Exchange rules. Especial credit therefore goes to ExxonMobil, which did publish valid information based on sound estimates, with revisions properly backdated to the original discovery[1].

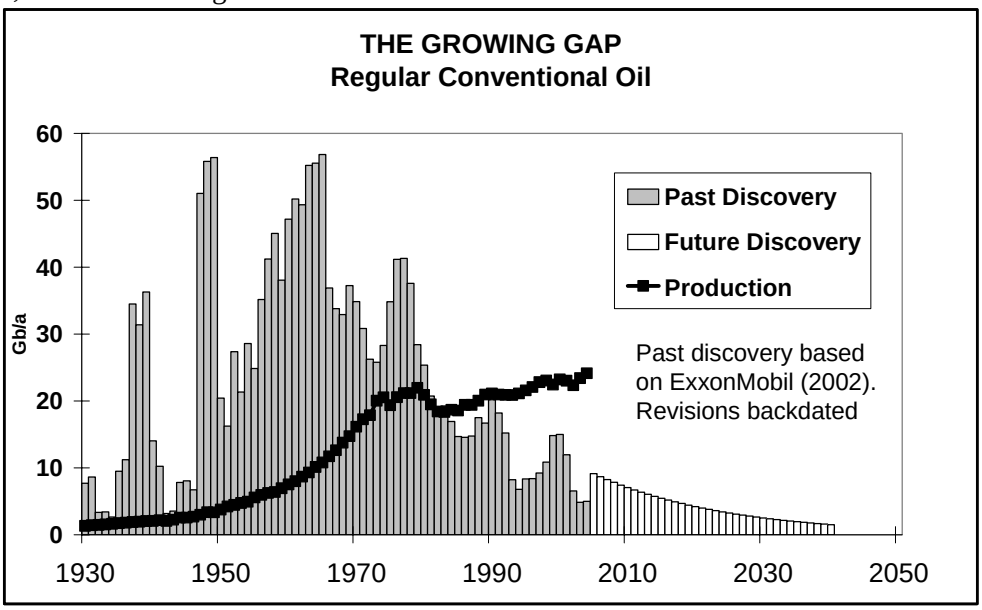

Fig.1 Discovery of Regular Oil (based on Exxon Mobil

Figure 1 is immensely important showing that discovery has been in relentless decline for forty years. It has been in decline despite a worldwide search, always aimed at the biggest and best prospects; despite all the many advances in technology and knowledge; and despite a favourable economic regime whereby most of the cost was offset against taxable income. There is accordingly no good reason to expect the downward trend to change direction. The indicated total discovery of *Regular Conventional Oil* to-date is about 1700 Gb (billion barrels), which by extrapolation of the downward trend suggests that about 150 Gb is yet-to-find. Summing the two, means that about 1850 Gb will have been produced when production ends, commonly termed *Ultimate Recovery*[2].

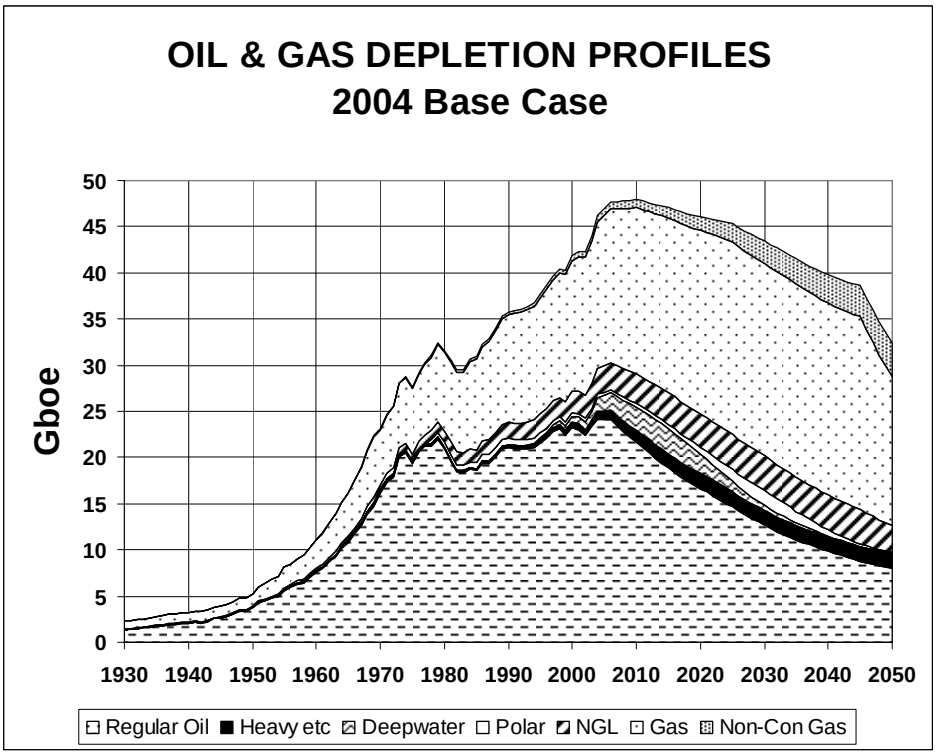

Figure 2. Depletion Profile of Oil and Gas

VI- THE STATUS OF DEPLETION

The production of an individual well is normally constant at a high rate for the first few years of its life being deliberately choked back to drain the reservoir efficiently and match the installed facilities, but eventually it declines to exhaustion.

The production of an onshore field normally rises rapidly as new wells are drilled and then gradually declines as the new wells fail to offset the natural decline of the old ones and as the locations for new wells are used up. Offshore, production normally follows a longer plateau to optimise the installed facilities, followed by a steeper decline.

The production of a country with an unfettered commercial environment and a large population of fields tends to be symmetrical, with peak production coming when about half the *Ultimate Recovery* has been consumed. Some countries may have more than one cycle, reflecting for example an early onshore effort, followed by a move offshore. Ideally, it is desirable to consider natural domains, termed *Petroleum Systems*, as national boundaries sometimes throw up anomalous production patterns.

Production in the OPEC countries was artificially constrained, having a large impact on the world profile, which has not therefore followed the classic symmetrical profile.

Figure 2 is a compilation of the depletion profiles of *Regular Conventional Oil* in some 65 countries, to which has been added a preliminary assessment the other categories of

oil and gas. It is not possible here to review all the details, but so far as *Regular Conventional Oil* is concerned, we may note that as many as 46 countries out of the 65 are already in decline, in the sense that they produce less today than they have at some point in the past, some having been in decline for several years. In addition, we may note that the World as a whole has now produced 945 Gb, almost exactly half the estimated *Ultimate Recovery of Regular Conventional*. In short, the evidence indicates that it is now very close the midpoint of depletion, which generally equates with peak production.

The date of peak production attracts much interest and speculation, but it is not in itself a particularly important matter. As demonstrated in Figure 2 it is not a high isolated peak but rather the high point between gentle slopes. Relatively minor changes in the input assumptions as well as political events, especially in the Middle East or Russia, could delay it by a few years. But in general terms, it is now evident that the First Half of the Age of Oil comes to an end.

VII - THE FIRST HALF OF THE AGE OF OIL

The First Half of the Age of Oil lasted 150 years since the early wells were drilled in Pennsylvania and on the shores of the Caspian.

The Stone and Bronze Ages had ended as Mankind turned to iron and steel for better tools and weapons. At first, firewood, and coal collected from beaches and outcrops was used for smelting, before mines were dug for this precious fuel. But the coal mines were subject to flooding when deepened to the water tables, which led to the development of steam driven pumps. They in turn prompted the development of the steam engine to power industry and locomotives, being used to transport goods to distant markets. In short, these steps marked the birth of the *Industrial Revolution*, primarily in Britain and Germany, some 200 years ago.

Then around 1880 an enterprising German engineer, by the name of Nicholas Otto, had the idea of injecting the fuel directly into the cylinder of the steam pump, inventing what was termed the Internal Combustion Engine. At first, it used carburetted benzene made from coal, but soon turned to petroleum refined from crude oil, for which it developed an unquenchable thirst. The Oil Age had dawned.

Some 300 million people inhabited the Planet at the time of Christ. Primitive yet sustainable agriculture had allowed their number to increase to about one billion by the dawn of the Oil Age. The population then expanded six-fold exactly in parallel with oil production.

Evidently, the new oil-based energy led to a rapid expansion of industry, transport, trade and agriculture, providing the food to support the increased population. In addition, it saw the rapid increase in Financial Capital in a system whereby banks lent money in excess of what was on deposit and charged interest of it, creating money out of thin air. The system was based on a confidence that tomorrow's expansion, driven largely by cheap oil-based energy, was collateral for to-day's debt. World trade expanded under the dominion of world currencies: first, the pound sterling, and later, the US dollar. In fact, it transpires that the primary benefit of empire was the indirect tribute that flowed home from control of trading currencies. World wars and the current international tensions may well have sprung from issues of trade and currency, both indirectly linked to the supply of cheap oil-based energy that made it all possible.

VII - THE SECOND HALF OF THE AGE OF OIL

Despite remarkable progress and technological achievements, the 20th Century was marked by conflicts of unparalleled magnitude dominated by two world wars followed by the so-called Cold War as two power blocs glared at each other across a divided world. Nevertheless, hopes were widely held that a World of stability, prosperity and natural justice could somehow be created through international co-operation. The closing years of the last Century saw much interest being expressed in co-operation to meet a challenge arising from fears that man-made emissions were adversely affecting the climate.

The 21st Century has now dawned with inauspicious acts of violence and unjustified military interventions. The prosperity deriving

primarily from control of the Financial System has been most uneven, which has in turn triggered rising pressures for migration. Yet, these tensions have arisen while world oil and gas supply, which had made the economic progress possible, were still flowing at a high rate.

Those days are now numbered as oil production peaks, followed a few years later by gas. The World accordingly faces a discontinuity of unprecedented magnitude, undermining the very fabric of society and economic wellbeing. In short, the decline of oil, as imposed by Nature, removes the confidence that tomorrow's expansion provides collateral for to-day's debt, which spells the collapse of the present Financial System. It may well usher in a Second Great Depression. The Financial Community begins to become aware of the situation but is ill-prepared for the consequences. Oil prices have soared over the past few months as capacity limits are breached without recourse, but they may well collapse again, if demand falls from deepening recession. Ironically, that might inhibit the move to much needed renewable energies and *Non-conventional oil*, which become viable only under high oil prices.

Oil supply will fall at less than 3% a year, which is a shallow decline that in itself does not necessarily spell crisis. It is rather the growing perception that it is a relentless decline without reprieve that may cause panic and extreme reaction. This possibly explains why organisations, such as the International Energy Agency, have been so hesitant to reveal the true position, couching their pronouncements in near meaningless scenarios that they themselves admit are far from forecasts.

The primary challenge is to deal with the transition. One simple and straightforward mechanism is for the countries of the world to cut their demand to match world depletion rate. A Depletion Protocol to so achieve is a central proposal to be debated at the ASPO meeting in Lisbon. If implemented, it may prove to be a lasting contribution to Humanity

No doubt, the transition will be a time of great tension and difficult adjustment, with a strong possibility of more resource wars [3].

Furthermore, producing countries are likely to conserve resources for their own use, when they face a deficit in supply, lessening the amount available to world trade.

But as the Century passes, the survivors will come to terms with their new environment. It may herald a new regionalism as world trade declines and people again come to live within their own resources. It might indeed be a time of happiness giving people a new-found respect for themselves, each other and the environment within which Nature has ordained them to live.

VIII - REFERENCES

[1] Longwell H.,2002, *The future of the oil and gas industry: past approaches ,new challenges*; World Energy 5/3 2002

[2] See Campbell C.J., 2004 *The Truth about Oil and the Looming Energy Crisis,* available from Info@eagleoffice.net.

[3] Klare M.T., 2002, *Resource wars : the new landscape of global conflict*; Owl Books. Pp.289