A New Modelling Method for Evaluating Undiscovered Resources of World Conventional Oil

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In this note, a new modelling method is introduced for evaluating the general magnitude of the world's remaining resources of undiscovered conventional oil. This is accomplished by examining the consistency that should exist among values for the cumulative and current production, the reserves, and both the historical and present rates of discovery. In the nomenclature normally employed, oil production is derived from the exploitation of reserves either directly, or from the rather short-term inventories characteristic of the industry with the exception of the minor withdrawals made from time-to-time from strategic storage arrangements of one kind or another around the world. Reserves are thus considered to be discovered resources available for working under the economic and technical conditions relevant to the time. It follows that the total oil discovered to date is the sum of the cumulative production plus the established reserves: this information (however uncertain) is normally published at the end of each successive year. The discovery rate may be thought of as the speed at which undiscovered resources are converted to reserves. This information should be coherent in the sense these numbers should be internally self-consistent because oil cannot be produced that has not yet been discovered. Therefore the integrated discovery rate over the time the industry has existed to a given date should equal the sum of the cumulative production and the reserves. As geological understanding increases and with the experience gained with time, in a maturing industry the future discoveries should become related more coherently with the discoveries of the past. In this note, it is assumed that a smooth mathematical relationship of some kind will emerge with time that will be a reasonably accurate predictor of the conversion of the world's remaining oil resources into reserves. With the many uncertainties and the limited (and sometimes doubtful) information available, there seems to be little merit in assuming complex relationships for this mathematical linkage. For this reason, a simple exponential function is chosen here to represent the decline in the discovery rate to be expected as less oil remains to be discovered. In essence, the discovery rate at any future year in the mature period of the industry is assumed to be broadly proportional to the amount of oil remaining to be discovered at that time. It is then possible to make an estimate of the oil remaining to be discovered given that some degree of self-consistency exists among such factors as the cumulative production, the established reserves, and the present and historical rates of discovery.

Two pieces of information have become available in the last few years that provide the opportunity to check the internal consistency of these estimates. The first is an estimate of the rate of discovery of world conventional oil first published in a document issued by the ExxonMobil Company. This data has been widely used and annotated by others, particularly as the basis for a graph published monthly in the Newsletter of the Association for the Study of Peak Oil and Gas (ASPO) [1]. This graph, which appears in this note as the background of Figure 2, illustrates both the decline in the rate of discovery and the increasing regularity of this decline over time. This increasing predictability strongly suggests this data can be used, at least in later years, as the basis for modelling. The ASPO Graph was employed to estimate the rate of discovery at the end of 2005 at 7.3 gigabarrels per year (GB/Y) and is denoted the CC Case in the text and graphs. At the time of writing, 2005 was the most recent statistical year available in the *BP Statistical Review of World Energy*.

A second estimate of the world discovery rate has been prepared by the IHS Energy consultancy for the proprietary use of its clients. This information has now become public by third party reference, such as by Skrebowski, with a value of 11 GB/Year applicable to year-end 2005.[2] The calculations based on this value appearing in the text and graphs below are referred to as the IHS Case.

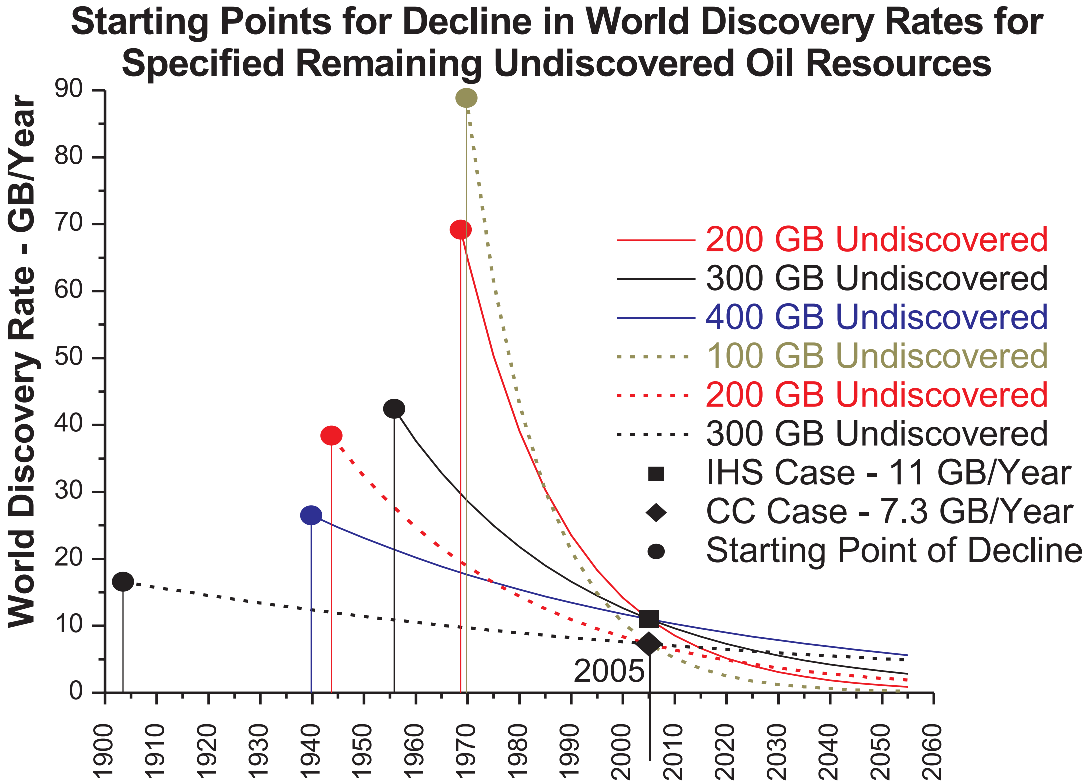

Figure 1

Methodology

A simple exponential equation of the following form was employed:

$$f = Ce^{kt}$$

where f is the discovery rate of world conventional oil in GB/Year, C is a constant, and t is the time measured from zero in years.

The exponential modifier, k, a negative term, is first evaluated for each of the six cases by assuming that t = 0 at 2005. This function is then integrated from t = 0 to t = 55 (rather than infinity) on the grounds that the discovery rate after fifty years, that is after t = 55, would not be sufficiently important numerically in view of other errors and approximations to justify the extra complexity of dealing with an asymptotic approach to the horizontal axis. The constant C, which is the discovery rate at t = 0, is equal to 11 GB/Y in the 3 IHS Cases and 7.3 in the 3 CC Cases respectively. These two values were considered to cover the likely range of possibilities for a rolling average value of the discovery rate in 2005. Given these assumptions, the value of k can be determined by setting the integral equal to the quantity of conventional oil remaining expected to be found in each case: 200, 300 and 400 GB were assumed to be found in the three IHS Cases and 100, 200 and 300 GB in the 3 CC Cases.

Having established the value of k for the 6 cases, the initial decline point for the six cases was then determined by computing the time before 2005 to a theoretical starting point. The integral of the function from the 0 at an unknown date to t - the time to reach 2005 - was set equal to the sum of the cumulative production to date plus the reserves divided by two. The value for the world reserves was taken from the *BP Statistical Review of World Energy* to the end of 2005 after making a minor deduction for

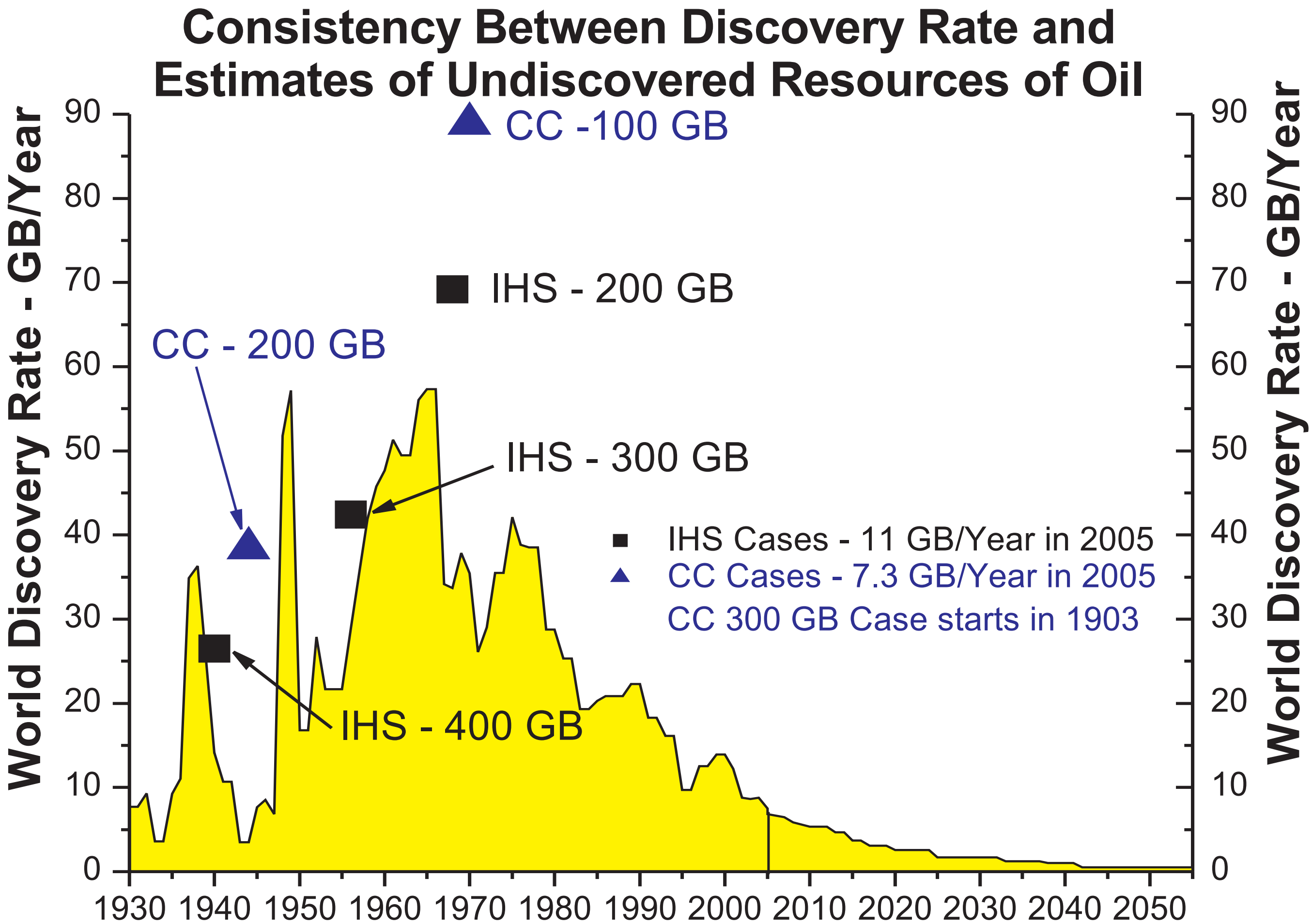

Figure 2

the non-conventional oil sands of Alberta. The basis for the distinction between conventional and non-conventional oil employed by this author appears in a recent reference.[3] The cumulative production to 2005 was taken from the Skrebowski correspondence because both parties in that controversy accepted 1,079 GB.[2] The cumulative production and the adjusted reserves totalled 2300 GB which represents the oil discovered until the end of 2005.

The quantity of oil discovered each year must have started at zero at the start of the oil era, followed by an erratic increase depending upon the discovery process to some maximum rate before beginning a decline to its present value. The back extrapolation of the declining portion of the exponential discovery curve may be assumed to originate at some maximum theoretical point and this is assumed to occur when half the quantity of oil discovered to date was found. This timing of this event is not sure and it could have occurred during the period when from 60/40 to 40/60 of the already discovered oil was found. This is the greatest uncertainty in this calculation.

The integral of the exponential discovery function from 0 to t is set equal to one half the oil produced to date or 1150 GB. In the following equation this integral relationship is divided by the value of the function itself that equals numerically either 11 GB/Y or 7.3 GB/Y at time t (2005). It is then possible to determine a value for t, the time from the theoretical maximum discovery rate from 0 at (2005 – t) to 2005, for each of the six cases. A value for the constant C, the theoretical maximum discovery rate, may then be determined since k and t are now known. The results of the calculation may be checked by integrating each of the six functions from their respective t = 0 points to t + 50. The value of this integral should equal half the oil discovered to 2005 plus the assumed undiscovered oil for each case.

$$\frac{\int_0^t f dt}{f} = \frac{C\int_0^t e^{kt}\, dt}{Ce^{kt}} = \frac{1150}{11 / or / 7.3}$$

The results of the six cases are plotted in Figure 1. The three IHS Cases must pass through 11 GB/Y and the three CC Cases through 7.1 GB/Y in 2005. The six starting theoretical starting points for the curves have been identified with round symbols. The coordinates for the start of five curves were then replotted in Figure 2; the coordinates of the sixth case – CC - 300 – was off-scale as its theoretical start was as early as 1903. These points appear against a backdrop of the history of world oil discovery derived from presentations by the ExxonMobil Company and plotted by Colin J. Campbell in the *Newsletter* of the Association for the Study of Peak Oil and Gas. (Exact values should not be read from this section of Figure 2 as it was necessary to greatly expand a small graph to obtain the year-by-year measurements needed to replot it - an inherently inaccurate process.) The plots of the starting points of the five combine the time and the maximum average rate of discovery for each case. Simple inspection reveals that the only plausible cases for any degree of consistency between the discovery rate on the one hand, and the cumulative production to date and present reserves on the other, are IHS – 300, IHS – 400 and CC - 200 GB.

It may be concluded from this study that the undiscovered resources of conventional oil remaining to be found are in the range of 200 – 400 GB. This range can be compared with the estimate published by ASPO [1] for the remaining ‘regular’ oil of 131 GB and the 758 GB defined as ‘exploration potential’ by Cambridge Energy Research Associates of the U.S.A.[2]

Summary and Conclusions

Most descriptive characteristics of the world oil supply system become more regular and predictable with the passage of years to maturity. Advantage is taken of this observed behaviour to predict the remaining undiscovered resources of conventional oil by in effect taking a ‘back-bearing’ into the more erratic earlier period but one for which data is available. Various plausible values for the as yet undiscovered resources were assumed which permitted the related theoretical starting points for the discovery decline curves to be at least estimated, if only crudely. The decline of the rate of discovery was assumed to follow a simple exponential curve in which the rate of fall is proportional at any time to the oil remaining to be found. This calculation was conducted in such a way that known values for the sum of the cumulative production and the reported reserves (which together constituted the oil discovered to date) were evaluated along with two values for the rate of discovery for the year 2005 in a self-consistent way. The theoretical starting points for decline in each case were then compared with the historical discovery record.

The two values for the discovery rate in 2005 were taken as 11 GB/Year for the IHS Cases and 7.3 GB/Year for the CC Cases. These are assumed to cover the possible range at the present time. The remaining undiscovered resources were assumed from experience to be 200, 300 and 400 GB for the IHS Case and 100, 200, and 300 GB for the CC Case. Only the 300 and 400 GB IHS Cases and the single 200 GB CC Case resulted in plausible values for their theoretical starting points. For the other Cases, either the timing or the initial production values (or both) at the theoretical peak of the discovery rate caused their rejection. Based upon this method of assessment, it is concluded that as of the end of 2005, the undiscovered resources of conventional oil for the World are likely between 200 and 400 GB.

References

1. Graph appearing in the *Newsletter* of the Association for the Study of Peak Oil and Gas (ASPO). Editor: Dr. Colin J. Campbell. Published monthly and downloadable from the Web in .pdf format at www.aspo-ireland.ie.

2. C Skrebowski. Letter to Peter M. Jackson of Cambridge Energy Research Associates published by the Oil Depletion Analysis Centre (ODAC), London, in December 2006 at its Web Site. (www.odac-info.org)

3. J.H. Walsh, *Energy Elements – A Retrospective from Past Papers*, March 2007. Web: pages.ca.inter.net/~jhwalsh/energyelements10pages.pdf.

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