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PETROLEUM RESOURCE ASSESSMENT METHODS IN NORTH AMERICA

by

D.J. FORMAN

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SUMMARY

Late in 1977, the author visited various government and private organisations in Canada and the United States of America, primarily to investigate methods of estimating undiscovered hydrocarbons that may be used in Australia. Secondary objectives were to assess the availability of data used in preparing the estimates, and the uses that are made of the estimates.

The main conclusion is that the type of data available on a national basis dictates the method used for preparing national estimates of undiscovered resources, which in turn determines the reliability of the assessment.

The prospect-by-prospect method is the most reliable, but it can only be used where geological and geophysical data, including proprietary company data, are available. It is used in the Resource Management and Conservation Branch of the Department of Energy, Mines and Resources in Canada and by the Conservation Division of the United States Geological Survey primarily for land management decisions, and as such does not make a major contribution to national estimates of undiscovered resources in either country. This has been the prime method used at the Bureau of Mineral Resources (BMR) to assess Australia's undiscovered petroleum resources since 1976.

For national assessments the Geological Survey of Canada has recently developed a play method that uses the same principles and the same types of data as the prospect-by-prospect method. It is faster though somewhat less reliable than the prospect-by-prospect method. Its application depends upon access to much of the confidential data held by the Federal, Provincial, or State resource management and conservation agencies. This method is applicable in Australia and could be used to accelerate progress of the present assessment. The necessary computer program to use the method was developed at BMR early in 1978.

If little information is available, the volumetric method may be the best alternative. The United States Geological Survey relies heavily on variations of this method, even for maturely explored areas, because much of the information that has been gathered and would be required for more reliable methods is not available to the assessors. The approach is at best inadequate and at worst invalid because there appears to be no valid scientific basis for some of the assumptions made. Official estimates of undiscovered resour-

ces in the USA obtained this way may be optimistic and as the method has also been used to prepare world estimates these may also be optimistic. Methodology and yield data were obtained for use in inadequately explored Australian basins, but the Petroleum Assessment Section of BMR regards this as the method of last resort.

The available data on petroleum exploration and production in the United States and part of Canada may be best suited to the application of statistical methods, such as those employed by M. King Hubbert, formerly of the United States Geological Survey. The status of this method is controversial in North America, and it has only very limited applicability in Australia.

In general, petroleum resource assessment information is used for long-term national energy planning, for petroleum leasing decisions, and for international boundary deliberations. For national energy planning, it is important to know not only how much oil or gas remains to be discovered but also when and at what price it will be available. The Department of Energy, Mines and Resources in Canada has completed a draft paper on the cost of developing new Canadian resources, and a similar study is planned in the United States of America.

INTRODUCTION

Various government and private organisations were visited in Calgary, Ottawa, Reston, and Denver, primarily to investigate methods of estimating undiscovered hydrocarbons. Secondary objectives were to see how the estimates are used in policy determination, land use, and leasing and to assess the availability of data on basin yield and field size distribution.

While each of the organisations visited contributed new ideas and special expertise in the various fields of interest, only a part of the information obtained is applicable or desirable for adoption under Australian conditions. In particular, the play method used by the Geological Survey of Canada to assess undiscovered petroleum resources is applicable in Australia, and BMR has now developed a computer program that will allow us to use their method. The Department of Energy, Mines and Resources in Canada has developed a method of assessing the economics of undiscovered resources that provides information on the future cost and availability of petroleum resources.

Overall, Canada and the United States of America both commenced an urgent assessment of undiscovered petroleum resources in the early 1970s as a result of political initiatives. Both countries are now preparing an economic assessment of these resources to answer the basic question of how much oil and gas will become available, when, and at what price. The Canadians appear to be leading in this assessment.

METHODS OF ESTIMATING UNDISCOVERED PETROLEUM RESOURCES

Most of the organisations visited contributed special expertise in the methods of estimating how much oil and gas remains to be discovered, but only a part of this information can be adapted into new systems in Australia. The reasons are that: (1) through original research, literature search, correspondence, and discussion with visiting experts we had already developed a considerable expertise at BMR and had already developed the prospect-by-prospect method; (2) some methods are not applicable in Australia and others may be invalid.

The main value of the visit lay in the exposure to a broader range of methods and in understanding the conditions of data availability that dictated their development. The opportunity to hold in-depth discussions on

the strengths and weaknesses of the methods was also valuable.

Although a number of methods were discussed, including a number of individual variations, the methods used in North America belong to four basic types:

The prospect-by-prospect method, which we have also developed at BMR, is used to assess the potential of offshore areas to assist in land management decisions. It is used in the Resource Management and Conservation Branch of the Department of Energy, Mines and Resources in Canada and by the Conservation Division of the United States Geological Survey.

The play method is used extensively by the Geological Survey of Canada's Institute of Sedimentary and Petroleum Geology to assess the nations undiscovered oil and gas resources.

The volumetric method was used in earlier Canadian studies and is used extensively by various organisations to assess the undiscovered oil and gas resources of the United States. It is used by the Resource Appraisal Group of the United States Geological Survey, by the Potential Gas Committee, and by two consultants visited, one of whom applied the method in Australia in 1973. The American Association of Petroleum Geologists is planning to use the method.

Various statistical methods are used in Canada and the United States. They depend upon projecting past exploration and production results into the future.

Of these methods, the prospect-by-prospect method was developed at BMR before the overseas visit, a variation of the Canadian play method has been developed at BMR since the overseas visit, and a variation of the volumetric method has been applied to the assessment of one area, offshore from Queensland. The statistical methods are generally not applicable in Australia. I am concerned, however, that the volumetric method, particularly the variation that is used for productive areas and that appears to be most extensively used in the United States, could be invalid. Because of this and because the method has been widely used in other countries to prepare estimates of undiscovered hydrocarbons, it deserves further mention.

THE VOLUMETRIC METHOD FOR PRODUCTIVE FORMATIONS

The Potential Gas Committee gives the following description of the procedure for estimating undiscovered hydrocarbons (part of Probable and Possible Potential Supply, in their terminology):

- (a) Within a productive province or sub-province estimate the volume of
 - (1) productive gas-bearing rock, and
 - (2) potential gas-bearing rock:
 - (a) associated with existing fields for estimating Probable Potential Supply, and
 - (b) associated with productive formations for estimating Possible Potential Supply
- (b) Add cumulative production and proved reserves to obtain the total volume of ultimately recoverable gas for the adequately explored portion of the productive gas-bearing rocks.
- (c) Divide this figure by the volume of adequately explored productive gas-bearing rocks to obtain the ultimately recoverable gas per unit volume of productive rocks.
- (d) Adjust the unit volume figure for variations in geological and reservoir conditions in the Probable and Possible gas-bearing rocks.
- (e) Using these adjusted figures:
 - (1) Estimate Probable Potential Supply in extensions and new pools associated with existing fields.
 - (2) Estimate Possible Potential Supply by applying these adjusted figures to the wildcat traps and structures estimated to be present in the inadequately tested portion of the province of sub-province.

The key problems in this method are in procedures (c) and (d). The problem in procedure (c) is to determine which area has been adequately explored and which area is inadequately explored. In practice, one well for two square miles is regarded as adequately drilled by the USGS Resource Appraisal Group. 1-12 wells per 24 square miles is regarded as inadequately drilled and a well density of less than one well per 24 square miles is regarded as unexplored. However, the areas of 'inadequate' or 'zero' drilling (according to the Petroleum Information data available) are probably covered by geophysics (which data are not available to the Group) and there is probably a reason for the comparatively low drilling density in these areas.

The problem in procedure (d) is to find any valid basis on which to adjust the yield-per-unit-volume figure in the adequately explored area to a yield figure that may apply in the undrilled and inadequately drilled areas. Despite considerable investigation and questioning I was unable to find any scientific basis for this part of the procedure and therefore conclude that it is probably invalid.

It is my opinion that the best type of readily available data in the United States are statistical and that, until this situation changes, efforts to apply geological methods (valid or invalid) will be extremely difficult. Hence the controversial estimates of M. King Hubbert, derived by statistical methods, may be as good as any in that country. However, Hubbert's estimate is on the low side compared with other estimates. This supports my own suspicion that estimates prepared by the Resource Appraisal Group of the USGS are too high.

Certain implications arise from the belief that the method most commonly in use in the United States of America is invalid and that estimates derived that way may be too high. It follows that, because many oil companies in the United States use this procedure to estimate the resources of foreign countries, world estimates of undiscovered petroleum may also be too high. This speculation was supported by Mr Frank Rickwood of British Petroleum in his principal address to the Australian Petroleum Exploration Association Conference in 1978. He said:

"Statistical calculations of world reserves of oil based on volume of marine sediments have proved a failure".

"We in BP have been more pessimistic than most over the years regarding the world's oil reserves and I believe this is because traditionally we have been involved in the Middle East in large fields and have seen the significance of large fields. In recent years though more and more people are coming to this view".

If more and more people do come to this view we should see a progressive lowering of estimates of the world's undiscovered oil from a generally accepted figure of about 1200 billion barrels towards the 300 billion barrels that BP estimates will be found between now and the year 2000.

CONCLUSIONS AND RECOMMENDATIONS

Preparation of a reliable independent government assessment of undiscovered oil and gas resources in the United States and to some extent in Canada is hindered by lack of access by the assessors to data that have already been gathered. The problem is accentuated by the large number of States and Provinces, the vast amount of data potentially available, and the need for its reorganisation before it can be effectively used. A similar problem exists in Australia regarding access by the Commonwealth to onshore petroleum exploration and reservoir engineering data held by State governments. However, under the provisions of the former Petroleum Search Subsidy Act, a large proportion of these data is already held by the Commonwealth, and there are prospects for co-operative arrangements with the States or private companies regarding most of the remainder. Compared to the United States or Canada, Australia is therefore in a fortunate position and, provided access to all data is arranged and maintained, should be able to produce an assessment of undiscovered petroleum resources based mainly on the more reliable prospect-by-prospect and play methods for which the methodology has already been developed. Actual performance of this task in an acceptable time frame will, however, require an increase in staff levels within the Petroleum Assessment Section of BMR, and this remains the primary problem.

The following recommendations are made:

- . Australia's undiscovered oil and gas resources should be assessed as far as possible by the prospect-by-prospect or play methods.
- . The assessment work being done by BMR staff should be accelerated by provision of more staff.
- . The assessment should be expanded to include consideration of the availability and cost of the undiscovered petroleum.
- . Special machinery should be established to ensure that all necessary data are available to BMR. Where State governments are not prepared to release onshore data to the Commonwealth they should be encouraged to prepare their own assessments in co-operation with BMR. Co-ordination, standardisation, and facilitation of Commonwealth/State co-operation in assessing petroleum resources should be arranged through the Australian Minerals and Energy Council.

APPENDIX

CANADA

The following government organisations were visited:

- . Geological Survey of Canada - Institute of Sedimentary and Petroleum Geology - Calgary 21/10/77 to 14/11/77
- . Department of Energy, Mines and Resources - Ottawa 15/11/77
- . National Energy Board - 16/11/77
- . Department of Indian and Northern Affairs - Ottawa 16/11/77

INSTITUTE OF SEDIMENTARY AND PETROLEUM GEOLOGY (ISPG)

The 1975-76 annual report of the Department of Energy, Mines and Resources states:

"The efforts of the Government to deal with the energy crisis and to provide for adequate energy supplies over the long term have placed new tasks before the Geological Survey. One such task is an estimate of Canada's resources of oil and gas, the main burden of which falls on the Geological Survey's Institute of Sedimentary and Petroleum Geology at Calgary".

Estimation of undiscovered petroleum resources is carried out in the Energy Subdivision of the Institute. The Energy Subdivision is the equivalent of a Branch at BMR and it contains only one Section, the Petroleum Resources Section. Within the Section there are effectively two subsections: one which prepares the estimates of undiscovered resources; and another which carries out the necessary research on source rocks and their maturity.

Source rock and thermal maturity

Work carried out includes organic geochemistry, clay mineralogy, vitrinite reflectance, spore, pollen, and conodont coloration, gas analysis, and organic microscopy. Staff consist of two organic geochemists, one clay mineralogist, and seven technologists (three of which have BSc or MSc

degrees).

Routine work includes gas analysis of canned samples provided by companies and microscopic inspection of kerogen, followed where necessary by more detailed work. The group carries out research into the origin of hydrocarbons and provides data necessary for assessment of undiscovered resources.

Assessment of undiscovered resources

Basic data are compiled and interpreted by resource geology units consisting of petroleum geologists supported by expertise in applied geochemistry and geophysics, in close co-operation with the staff of the resource management agencies of the Federal government. Data in the public domain as well as data provided to government by the petroleum industry in compliance with Canada Oil and Gas Land regulations are used in the analyses. Final estimates of hydrocarbon potential are prepared by an interdepartmental group called the Geological Potential Subcommittee, consisting of geologists from the Departments of Energy, Mines and Resources, and Indian and Northern Affairs, who meet several times throughout the year in working sessions to systematically examine exploration plays region by region. This subcommittee along with two others dealing with reserves and economics of supply report to a steering committee made up of the Senior Assistant Deputy Minister, the Assistant Deputy Minister Energy, and Assistant Deputy Minister Science and Technology of Energy, Mines and Resources; and the Assistant Deputy Minister Northern Affairs, of Indian and Northern Affairs. The main purpose of the committees is to ensure that basic data are made available to the resource geology units.

Staff in the resource geology unit at the ISPG consist of several geophysicists, four geologists, and three or four technicians including a computer programmer. There is at least one other resource geology unit responsible for the east coast.

DEPARTMENT OF ENERGY, MINES AND RESOURCES Resource Management and Conservation Branch

The Branch is responsible for administration of the Canada Oil and Gas Land Regulations in all federal lands south of 60° latitude.

The Resource Geology Division (within the Branch) has three subdivisions: one concerned with engineering, one with geological potential,

and one with the day-to-day management of operations. The group responsible for geological potential assesses prospects or groups of prospects within title areas, mainly to assist in land management decisions. However, the information is also made available for national assessments through the Geological Potential Subcommittee.

The Petroleum Resources Division has completed a draft paper on the cost of developing new Canadian petroleum resources - including conventional oil and gas, oil sands, and petroleum available by tertiary recovery. They believe that the cost of importing offshore oil may be prohibitively high. They must therefore be more fully aware at what point the exploitation of their own resources becomes economic. Data from the ISPG and the Geological Potential Subcommittee are a prerequisite for assessing the cost of developing undiscovered conventional petroleum resources. A recent publication prepared by the Department is "An energy policy for Canada".

My overall impression of the Department of Energy, Mines and Resources was that it has a strong orientation towards resource and economic assessment.

NATIONAL ENERGY BOARD

The National Energy Board has both regulatory and advisory functions. The regulatory function is to advise on exports of natural gas and oil. Advisory functions cover a large range within the petroleum field, such as pipelines and electricity generation.

The Reserves Division is responsible for compilation of national estimates of identified petroleum resources, mainly proved and probable reserves. About 20 reservoir engineers and engineering geologists are employed in this work. A second division is concerned with estimating the deliverability of reserves to markets over time and a third division estimates the demand for petroleum. These data are generally fed to the Board itself in relation to rather specific problems. The Board is empowered to hold meetings and call evidence on any aspect that they care to investigate. The Board also publishes information on Canadian oil and gas supply and requirements.

DEPARTMENT OF INDIAN AND NORTHERN AFFAIRS

The Department is responsible for oil and gas exploration in the Territories north of 60° - an area of 2½ million square kilometres.

A geologist and a geophysicist are responsible for each of the four districts into which the area is divided. Apart from checking the quality of the data received, the group is occasionally required to interpret geophysical surveys and is responsible for maintaining an overall assessment of each district. Results of these assessments are fed into the Geological Potential Subcommittee. Statements of expenditure are checked, and approved statements are forwarded to the lands section, which keeps track of the manner in which the terms and conditions of tenure are being met. After five years the data are microfilmed and sold to the public, and originals of reports are available for examination.

New legislation is being prepared for a proposed Petroleum and Natural Gas Act and new Canada Oil and Gas Regulations. The regulations are complicated by the need to make special provision for PetroCanada and special conditions for a Canadian participation rate in the event of significant discoveries.

UNITED STATES OF AMERICA

The following organisations and private persons were visited:

United States Geological Survey - Reston	17/11/77-19/11/77
United States Geological Survey - Denver	20/11/77-16/12/77
H.K. Van Poolen and Associates Inc. - Denver	23/11/77
Harry C. Kent, Director, Potential Gas Agency	1/12/77
John D. Haun, Colorado School of Mines	5/12/77
John M. Parker, Petroleum Resource Estimation Project	5/12/77
E.G. Griffith, Argonaut Oil and Gas	7/12/77

UNITED STATES GEOLOGICAL SURVEY - RESTON, VIRGINIA

Geologic Division

The Geologic Division is responsible for energy resources, mineral resources, marine geology, environmental geology, international geology,

earthquake studies, and geochemistry and geophysics. Much of the work of the division is carried out from regional offices.

Office of Energy Resources

The office has separate Branches for oil and gas, coal, chemical resources, and uranium and thorium. The Branch of Oil and Gas Resources has 84 full-time staff (71 professional), and 27 part-time staff (10 professional). Of these staff 17 are located in Reston, and 69 are located at Denver.

Offshore petroleum resources are studied by two groups: an Atlantic and Gulf of Mexico geology group in Reston and a Pacific and Arctic geology group in Menlo Park.

The Atlantic and Gulf of Mexico Group comprises research scientists from the office of marine geology operating from Woods Hole, Corpus Christi, and Reston. Officers of the Branch of Oil and Gas Resources are also incorporated into the program and they use the publicly available non-proprietary data gathered by the USGS research vessels to prepare reports on the structure, stratigraphy, and petroleum potential of the region. Quantitative assessment is carried out by the Resource Appraisal Group in Denver (see later sections).

Office of Marine Geology

As mentioned above, the office has a Pacific-Arctic group and an Atlantic-Gulf of Mexico group. Area study teams within each group are responsible for geological studies (called resource assessment) and environmental and hazard studies. Other teams are responsible for topical research studies.

Office of International Geology

A major task of this office is co-ordination of the Circum Pacific Maps Project. Perhaps the main purpose of this project is to provide international analogue data for petroleum resource assessment.

Conservation Division

The Conservation Division has three major missions:

- . Classification of public lands according to their mineral content and their value for water-power and water-storage purposes.
- . Evaluation of mineral tracts that are subject to competitive leasing.
- . Supervision and regulation of exploration, development, and production of minerals on Federal, Indian, and Outer Continental Shelf Lands authorized by lease, license, and prospecting permits, including the collection of royalties and certain rentals. Leases are issued by the Bureau of Land Management, but the operating regulations are implemented and enforced by the Geological Survey.

A considerable amount of work is carried out in preparation of environmental impact statements and geological hazards information, determination of minimum bid value for title areas, and in determining the safety of offshore structures.

Assessment and valuation of title areas is carried out in the Statistical and Economic Analysis Section.

Overall the missions and organization of the USGS are designed to satisfy critical issues of national significance such as: identification and assessment of potential energy and mineral resources, appraisal of the magnitude and quality of water resources, reduction of hazards from earthquakes and other geologic processes, and supervision of lease operations on Federal lands.

UNITED STATES GEOLOGICAL SURVEY, BRANCH OF OIL AND GAS RESOURCES - DENVER,
COLORADO

The program of the Branch of Oil and Gas Resources is divided loosely into three areas: regional petroleum geology, topical petroleum geology, and resource analysis.

Regional petroleum geology

The Branch is studying the natural gas resources in low-permeability (tight) reservoirs in the Rocky Mountains region. This program is part of

the ERDA Western Gas Sands Project. The work involves: stratigraphic and structural studies; geochemical studies; reservoir property studies; clay mineralogy studies; drilling for core samples; data acquisition and processing; borehole gravity surveys, and resource appraisal. Another study is of gas resources in the Devonian black shales of Virginia. As mentioned earlier, the Branch carries out other regional petroleum studies in Reston and Menlo Park.

Topical petroleum geology

Research is carried out into petroleum-forming processes, reservoir rocks and sedimentary processes, structural traps, seismic stratigraphy, geochemical prospecting, and measurement of gravity in boreholes. Research into oil-forming processes includes analysis of potential source rocks using pyrolysis equipment, gas chromatographs, and a mass spectrometer. The origin and characteristics of modern aeolian sandstones are being studied with a view to better prediction of reservoir conditions in ancient rocks. Diagenesis of sandstones and carbonates (including chalk) is being studied in order to better predict changes of porosity with depth.

Resource analysis

Data available include microfilms of well and log data for the entire United States. Data on reserves are obtained mainly from the American Petroleum Institute (API) and the American Gas Association (AGA) and partly from the Bureau of Mines, which has recently begun its own assessment of identified resources.

Using data from these sources the Resource Appraisal Group is making an assessment of undiscovered resources in the Permian basin of West Texas and in the Gulf of Mexico by a variation of the Volumetric method.

There are 18 staff in the group including at least ten professional officers, a cartographer, a librarian, and two secretaries.

Another system called "Accelerated National Oil and Gas Resource Appraisal (ANOGRE)" was also in use at Denver until about 1975, but has been discontinued because of doubts as to its validity.

H.K. VAN POOLLEN AND ASSOCIATES INC. - DENVER

H.K. Van Poolen and Associates are an internationally recognised firm of petroleum consultants. They have no special system of their own for estimating undiscovered petroleum resources but they mentioned a commercially available system from Garret Computing Systems of Dallas, Texas. In particular, program GREAT can be used to estimate the resources and economics of a single prospect. They prepared an assessment of the undiscovered petroleum resources of the Amadeus Basin of central Australia by the prospect-by-prospect method for the former Petroleum and Minerals Authority.

HARRY C. KENT, DIRECTOR, POTENTIAL GAS AGENCY

The Potential Gas Committee (PGC) comprises volunteer members from the natural gas industry, government agencies, and academic institutions who are concerned with natural gas resources. The Committee functions independently, but its criteria and methods are supervised by the Potential Gas Agency of the Colorado School of Mines. The Potential Gas Agency is supported by the American Gas Association, a lobby group like the Australian Petroleum Exploration Association. The Agency therefore is industry sponsored and has the responsibilities of ensuring the co-ordination and reliability of assessments by industry of undiscovered gas resources and of publishing the results. (Annual estimates of proved reserves of natural gas in the United States are prepared by the Committee on Natural Gas Reserves of the American Gas Association).

The resource assessment work of the PGC is carried out by eleven area work committees whose personnel use data and methodology which are partly confidential. Because the basis for the assessment is partly confidential a check is maintained by asking two groups in each area work committee to prepare an assessment.

JOHN D. HAUN, COLORADO SCHOOL OF MINES

Dr Haun is Professor of Geology at the Colorado School of Mines and a consultant geologist with Barlow & Haun Inc., and was editor of the American Association of Petroleum Geologists Special Studies No. 1 - "Methods of estimating the volumes of undiscovered hydrocarbons".

Because the Potential Gas Committee reports do not contain the geological or statistical data on which their estimates are based they cannot be verified in the usual scientific manner. His work, with that of other authors, is an attempt to develop verifiable data on which a reasonable estimate of the potential gas resources of the Rocky Mountains region can be based. His methods of estimating the discovered hydrocarbons are similar to those publicly disclosed by the Potential Gas Committee and also to those in use by the Resource Appraisal Group of the USGS.

JOHN M. PARKER, PETROLEUM RESOURCE ESTIMATION PROJECT (PREP)

John M. Parker is a consultant geologist employed by the American Association of Petroleum Geologists (AAPG) to develop a proposal that the AAPG prepare a quantitative assessment of the undiscovered oil and gas resources of the United States. A steering committee, a definitions committee, a methods committee, and an appraisals committee have been active. Mr Parker is chairman of the regional appraisals committee which will apply the methods, provided federal funding is obtained for the project.

It is planned to use the methods adopted by the USGS Resource Appraisal Group and the Potential Gas Committee, but it is expected that the methods will evolve as they are used.

E.G. GRIFFITH, ARGONAUT OIL AND GAS

Mr Griffith was vice president of the consulting firm Merrill, Ogle, Babson & Wallis Inc., which prepared an assessment of Australia's gas potential for the Southern California Gas Company in 1973. He provided a confidential copy of their report, which basically uses the volumetric method. Undiscovered gas resources estimated as a result of this study are much higher than those presently accepted by BMR.