Chapter 17

U.S. Geological Survey Assessment Concepts for Continuous Petroleum Accumulations

Click here to return to
Volume Title Page

By James W. Schmoker

Chapter 17 *of*

Petroleum Systems and Geologic Assessment of Oil and Gas in the Uinta-Piceance Province, Utah and Colorado

By USGS Uinta-Piceance Assessment Team

U.S. Geological Survey Digital Data Series DDS–69–B

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
Gale A. Norton, Secretary

U.S. Geological Survey
Charles G. Groat, Director

Version 1.0 2003

For sale by U.S. Geological Survey, Information Services
Box 25286, Denver Federal Center
Denver, CO 80225

Published in the Central Region, Denver, Colorado
Manuscript approved for publication July 24, 2002

ISBN=0-607-99359-6

Contents

Figures

U.S. Geological Survey Assessment Concepts for Continuous Petroleum Accumulations

By James W. Schmoker

Abstract

Continuous petroleum accumulations are those oil or gas accumulations that have large spatial dimensions and indistinctly defined boundaries, and which exist more or less independently of the water column. This report describes the fundamental concepts supporting the U.S. Geological Survey FORSPAN model for resource assessments of continuous accumulations.

FORSPAN provides a strategy for estimating volumes of petroleum having the potential to be added to reserves in a 30-year forecast span. A continuous accumulation is envisioned as a collection of petroleum-charged cells. Cell-level production data, from the accumulation being assessed or an analog accumulation, are the foundation for forecasts of potential additions to reserves. In effect, production data are used to empirically provide the product of petroleum-in-place and recovery factor.

Introduction

The U.S. Geological Survey (USGS) periodically conducts assessments of the recoverable oil and natural gas resources of areas within the United States and also in other regions of the world. The purpose of these assessments is to develop geology-based, well-documented estimates of quantities of petroleum having the potential to be added to reserves within some future time frame. For the National Oil and Gas Assessment (NOGA) series begun by the USGS in 2000, the future time frame—the forecast span—is 30 years.

In recent years, the USGS has distinguished between conventional and continuous petroleum accumulations for purposes of resource assessment (Gautier and others, 1995; U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995; U.S. Geological Survey World Energy Assessment Team, 2000). Briefly stated, conventional accumulations are described in terms of discrete fields or pools localized in structural or stratigraphic traps by the buoyancy of oil or gas in water. In contrast, continuous accumulations are petroleum accumulations (oil or gas) that have large spatial dimensions and indistinctly defined boundaries, and which exist more or less independently of the water column (Schmoker, 1995). Conventional accumulations "float," bubble-like, in water; continuous accumulations do not. Because of their fundamental geologic dissimilarities, the USGS assesses conventional and continuous accumulations using different resource-assessment models and methods.

The primary purpose of this report is to describe the fundamental concepts supporting USGS resource assessments of continuous accumulations. The basic assessment model, called the "FORSPAN" model, was first documented by Schmoker (1999) and has an antecedent in the approach used to assess continuous accumulations in the USGS 1995 National Assessment of United States Oil and Gas Resources (Gautier and others, 1995; Schmoker, 1995). FORSPAN is the model used to assess potential additions to reserves in continuous accumulations as part of the ongoing NOGA series of domestic petroleum assessments.

Computer programs are used in conjunction with FORSPAN to calculate resource estimates. However, assessment results are controlled by geology-based and engineering-based input parameters, as opposed to computer-generated projections of historical statistical trends.

Geologic Nature of Continuous Accumulations

Continuous petroleum accumulations form a geologically diverse group that includes coalbed methane, "tight" gas, basin-center gas, oil and gas in fractured shale and chalk, gas hydrates, and shallow biogenic gas. Despite their obvious differences, these various petroleum deposits are linked together as continuous accumulations by two key geologic characteristics: (1) they consist of large volumes of rock pervasively charged with oil or gas, and (2) they do not depend upon the buoyancy of oil or gas in water for their existence.

Because of these two geologic properties, continuous accumulations cannot be assessed in terms of the sizes and numbers of discrete entities delineated by down-dip water contacts, as are conventional fields. The so-called fields that are sometimes named within a continuous accumulation are not fields in the traditional sense, but rather are only generally defined areas within the continuous accumulation that have relatively better production characteristics (sweet spots).

The commonly applied term "unconventional" is not used here as a synonym for continuous. Continuous accumulations are defined by a rather narrow set of geologic characteristics, whereas unconventional accumulations form a broader and more subjective category. Accumulations have been characterized as unconventional according to such widely varying standards as arbitrary matrix-permeability limits, special regulatory status, the need for unusual (at the time) engineering techniques, or difficulty of physical access (for example, polar regions or deep water). Many "unconventional" accumulation types are not unconventional in terms of resource assessment and do not require special assessment models and methods.

Studies emphasizing the geology and production characteristics of continuous oil accumulations and continuous gas accumulations have been published by Schmoker (1996) and Schmoker and others (1996a), respectively. Common geologic characteristics of a continuous accumulation include occurrence down dip from water-saturated rocks, lack of obvious trap and seal, pervasive oil or gas charge, large areal extent, low matrix permeability, abnormal pressure (either high or low), and close association with source rocks. Common production characteristics include a large in-place petroleum volume, low recovery factor, absence of truly dry holes, dependence on fracture permeability, and sweet spots within the accumulation that have generally better production characteristics but where individual wells still have serendipitous "hit or miss" production characteristics.

Continuous accumulations commonly contain little moveable water in the rock matrix but can produce copious volumes of water from fractures or cleats. Somewhat paradoxically, an interval of improved reservoir quality within a regional-scale continuous accumulation, such as a sandstone having good porosity and matrix permeability, can be undesirable because of high moveable-water content.

Although virtually all wells drilled into a continuous accumulation encounter a petroleum-charged reservoir, it is very possible to drill wells that are economic failures. Therein lies the primary reason that many known continuous accumulations in the United States are developed only locally and have not yet contributed to U.S. oil and gas supplies at levels that might be expected based on their large in-place volumes.

Petroleum Volumes Assessed

Scope of Assessed Resources

The estimated in-place volumes of petroleum in many continuous accumulations are large to extremely large, extending into the hundreds and even thousands of trillion cubic feet for gas, and into the tens and hundreds of billion barrels for oil. The ultimate resource base is enormous. However, in order for USGS resource assessments to be of near-term relevance to the society that funds them, the assessment scope needs to be constrained from that of crustal abundance to resources that might be recoverable in the foreseeable future. Such constraint is supplied by limiting assessments of continuous accumulations to those quantities of oil and gas having the potential to be added to reserves within some specified forecast span (Schmoker, 1999).

Forecast span is the number of years that a resource assessment looks into the future. A forecast span of 30 years—approximately one generation—was used by the USGS in the World Petroleum Assessment 2000 (U.S. Geological Survey World Energy Assessment Team, 2000), and a 30-year forecast span has also been adopted for the current NOGA series begun in 2000. Given the numerous unforeseen developments of the past few decades that have significantly affected the petroleum industry and the possibility for surprises of similar magnitude in the future, 30 years appears to be approaching the limits of a realistic forecast span.

A particular forecast span should not be interpreted too literally. An algorithm does not exist for calculating potential additions to reserves in the next 30 years, as opposed to the next 29 or 31 years, for example. It is more appropriate to equate a forecast span to the idea of a societally relevant resource inventory.

The 30-year forecast span imposes limits upon the potential additions to reserves assessed in continuous accumulations:

- Entire groups or classes of continuous accumulations are excluded from assessment consideration if they are not considered to be practicable in the time frame of 30 years. An example to illustrate the point might be gas hydrates in Antarctica.
- Portions of continuous accumulations are excluded from assessment consideration if the untested area of a continuous accumulation that has potential to contribute to reserves in the next 30 years is thought to be less than the untested area that might ultimately contribute to reserves. For example, the area of a continuous accumulation considered to have potential in a 30-year time frame might be limited to known sweet spots and their postulated extensions.

Categorizing the Assessed Resources of Continuous Accumulations

In the terminology of recent USGS petroleum resource assessments, undiscovered resources are those postulated to exist outside of known fields, whereas reserve growth (which is synonymous with field growth) describes resources added to known fields as they are further developed and produced (Attanasi and Root, 1994; U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995; U.S. Geological Survey World Energy Assessment Team, 2000). However, in the case of continuous accumulations, the distinction between undiscovered resources and reserve-growth resources is not well defined.

The existence, location, and production characteristics of continuous accumulations that already have appreciable development are well known, implying that the assessment of such accumulations is basically an exercise in estimating reserve growth. On the other hand, even the existence of some assessed continuous accumulations is not certain. Such accumulations are only postulated to be present, and their assessment therefore equates to estimating undiscovered resources. Estimates of resources within sparsely developed continuous accumulations fall somewhere between these two end points.

A further complication is that continuous accumulations are sometimes overlain by conventional fields. As an example, the fractured-shale continuous oil accumulation in the Bakken Formation (Mississippian-Devonian), Williston Basin, North Dakota, is overlain by a number of relatively small conventional oil fields in Mississippian carbonate rocks. In theory, reserves developed in the Bakken continuous accumulation could therefore be attributed to reserve growth of an overlying conventional field by the process of new pool discoveries, although this would make little geologic, engineering, or economic sense.

In an effort to reduce confusion between undiscovered resources and reserve-growth resources in continuous accumulations, and also to avoid introducing a new term that would not be a part of existing resource-classification schemes, assessed resources in continuous accumulations are referred to here simply as potential additions to reserves.

Resource-Assessment Approach

Overview

Two basic assessment approaches have been employed by the USGS and others for continuous accumulations. The first approach is based on estimates of volumes of oil or gas in-place. A volumetric estimate of total in-place petroleum can be combined with a recovery factor for the accumulation to narrow the assessment scope from a treatment of crustal abundance to a prediction of potential additions to reserves within a forecast span. The combining of overall recovery factor and total petroleum in-place to obtain a resource estimate for a continuous accumulation is analogous to the familiar idea of recovering a percentage of the petroleum in-place from a conventional field or pool. Although the total oil or gas in-place of a continuous accumulation can be quantitatively appraised from geologic considerations, the estimation of an overall recovery factor must sometimes be quite qualitative.

The second assessment approach is based on the production performance of continuous petroleum reservoirs, as empirically shown by wells. In this method, estimates of in-place oil or gas volumes are not developed. Instead, production data are the foundation for forecasts of potential additions to reserves within a given time span. Such reservoir-performance assessment models are particularly well suited to continuous accumulations that are already partially developed. The wells themselves serve as comprehensive analog computers that evaluate and weight all relevant reservoir parameters. Lacking sufficient drilling and production data, the assessor must draw upon information from analog accumulations.

The assessment model for continuous accumulations used in the USGS 1995 National Assessment (Gautier and others, 1995; Schmoker, 1995) and the revised USGS model (FORSPAN) discussed here are both *reservoir-performance* models. The use of reservoir-performance models for domestic assessments takes full advantage of the development activity that is occurring in many U.S. continuous accumulations. Examples of previous assessments of continuous accumulations based on reservoir-performance methods can be found in National Petroleum Council (1992), Gautier and others (1995), Schmoker (1996), Schmoker and others (1996a, b), and Kuuskraa and others (1998).

Petroleum-Charged Cells

In USGS reservoir-performance assessment models, the petroleum of a continuous accumulation is regarded as residing in cells. A cell is a volume within a continuous accumulation having areal dimensions related to the drainage area (which is not necessarily the current spacing) of wells and extending vertically through the strata to be assessed. From this point of view, a continuous accumulation consists of a collection of petroleum-containing cells (fig. 1), virtually all of which are capable of producing some oil and gas, but which may

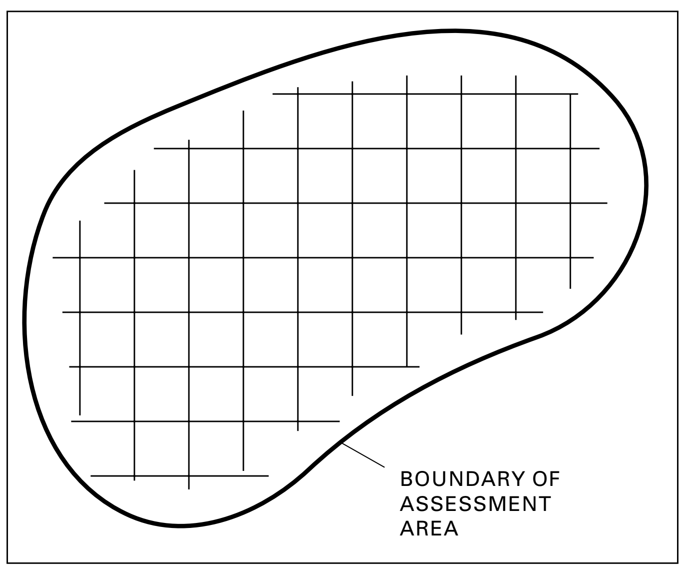


Figure 1. Sketch indicating that a continuous accumulation is made up of petroleum-charged cells. All cells are capable of producing some oil or gas, but production characteristics vary greatly. (Modified from Schmoker, 1995.)

vary significantly in their production (and thus economic) characteristics.

Cells can be divided into three resource-assessment categories (fig. 2): (1) cells already tested by drilling, (2) untested cells, and (3) untested cells having potential to contribute to reserves in the time span of the forecast. For simplicity, the cells of each category are depicted as areally contiguous in figure 2, but this is rarely the actual case. Only cells of the third category (those untested cells having potential for additions to reserves within the forecast span) contribute directly to the resource assessment.

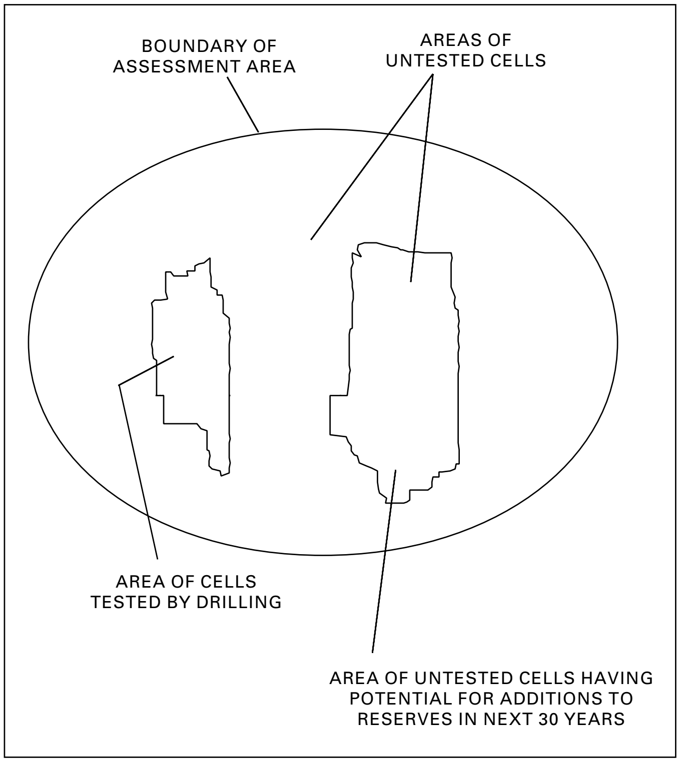


Figure 2. Depiction of three resource-assessment categories for petroleum-charged cells of a continuous accumulation. In this example, forecast span of resource assessment is 30 years. (Modified from Schmoker, 1999.)

In many cases, most of the untested cells having potential for additions to reserves within 30 years will be localized in areas (sweet spots) where production characteristics are relatively favorable. One or more sweet spots may already be known to exist. An important component of the assessment is to postulate, on the basis of geologic understanding and principles of petroleum engineering, the presence or absence of additional sweet spots.

Assessment Procedure

The uncertainties associated with the variables required for an assessment of a continuous accumulation are considerable, leading to a substantial range of possible input values. Many of the variables that make up the set of input data are therefore represented by probability distributions rather than by single (point) values. Resource forecasts derived from these input data are also represented by probability distributions.

The probability distributions for some input variables show the uncertainty of a fixed but unknown value, whereas other probability distributions represent input variables that have a naturally occurring range of values. The F_{100} (minimum), F_{50} (median), and F_0 (maximum) fractiles are the input parameters estimated for all variables represented by probability distributions.

To begin an assessment of potential additions to reserves using the USGS FORSPAN reservoir-performance model, a continuous accumulation is apportioned (if necessary) into more homogeneous sub-units. For the NOGA series, these sub-units are divisions of total petroleum systems, termed assessment units. Assessment units are considered and assessed individually, as outlined by the flow diagram of figure 3.

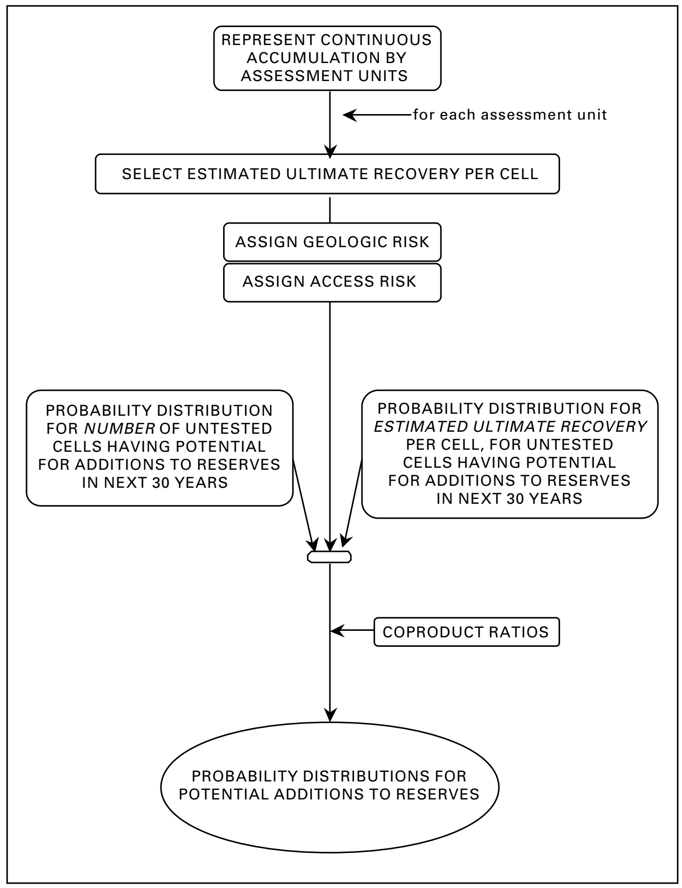


Figure 3. Key steps of current USGS cell-based, reservoir-performance assessment model (FORSPAN) for continuous oil and gas accumulations. (Modified from Schmoker, 1999.)

The essence of the assessment procedure is as follows:

- A minimum estimated ultimate recovery (EUR) of oil (for an oil-prone assessment unit) or gas (for a gas-prone assessment unit) per cell is chosen for the assessment unit. Petroleum in cells expected to have an EUR less than the minimum is not considered to be a significant resource within the 30-year forecast span, and is excluded from the assessment.

- Probabilities for the occurrence of adequate charge, adequate rocks, and adequate timing for at least one untested cell having the minimum EUR or greater are assigned to the assessment unit; this defines the ge logic risk. The probability that necessary petroleum related activities will be possible in the next 30 years, at least somewhere in the assessment unit, is also assigned; this defines the access risk.
- The number of untested cells within an assessment unit having potential to contribute to reserves within 30 years is estimated. This probability distribution results from the combination of probability distributions for (1) the total assessment-unit area, (2) the area per cell of untested cells having potential for additions to reserves in the next 30 years, (3) the percentage of the total assessment-unit area that is untested, and (4) the pe centage of the untested area that has potential for add tions to reserves in the forecast span of 30 years.
- A probability distribution is established for EUR of oil (for an oil-prone assessment unit) or gas (for a gas prone assessment unit) per untested cell having potential for additions to reserves in the next 30 years. This distribution is based on reservoir-performance data from the assessment unit under consideration and (or) an analog area.
- For oil-prone assessment units, ratios of gas/oil and natural gas liquids/gas are estimated. For gas-prone assessment units, the ratio of total liquids/gas is estimated. These ratios are used to assess the coproducts associated with oil in oil accumulations and gas in gas accumulations.
- The combination of geologic and access probabilities, number of untested cells having potential, EUR per untested cell having potential, and coproduct ratios yields probability distributions for potential additions to reserves of oil, gas, and coproducts in the assessment unit.

An important aspect of this assessment procedure is that historical production and development patterns serve only as a starting point for the assessment forecast. With past production performance as a point of reference, input parameters can be chosen to reflect perceived impacts of future change, such as improved technologies and newly developed geologic and engineering concepts. Input parameters can also be chosen so that historical data representing early-discovered sweet spots are not projected to be characteristic of all future development.

Allocation Percentages and Ancillary Data

Two additional data elements are also recorded at the assessment-unit level. The first element consists of percentages necessary to allocate assessed potential additions to reserves to various land entities of interest within the assessment unit. Such land entities could, for example, be surface and mineral ownerships, special use categories of State or Federal lands, or ecological zones. Percentages can also be entered to allocate assessed petroleum volumes to the offshore portion of each entity, if applicable.

The second additional data element establishes a modest set of ancillary information useful for economic and environmental analyses of assessment results. These data do not contribute directly to assessment calculations. Ancillary data for untested cells in continuous oil accumulations are estimates of API gravity of oil, sulfur content of oil, drilling depth, and water depth (if applicable). Ancillary data for untested cells in continuous gas accumulations are estimates of inert-gas content, carbon dioxide content, hydrogen sulfide content, drilling depth, and water depth.

Comparison to USGS 1995 National Assessment

Evolving Assessment Concepts

Through the years, the methods and procedures used in USGS petroleum assessments have not remained static but have evolved as databases, computers, and geologic knowledge have advanced, and as the need for resource forecasts of more short term relevance has increased.

A major change in assessment procedures occurred in the USGS 1995 National Assessment of United States Oil and Gas Resources (Gautier and others, 1995), in that continuous accumulations were defined and quantitatively assessed for the first time. The assessment concepts for continuous accumulations described in this report are changed somewhat from those of the 1995 National Assessment, in response to experience gained. However, the cell-based, reservoir-performance model of the 1995 National Assessment continues to be at the core of the present methodology.

Differences Between 1995 and Present Assessment Models

This section describes four of the more important conceptual differences between the 1995 and the present assessment models for continuous accumulations.

Plays Versus Assessment Units

The 1995 National Assessment used the play as the basic level of assessment. Plays are established primarily according to similarities of the *rocks* in which petroleum occurs. In contrast, the National Oil and Gas Assessment (NOGA) series begun by the USGS in 2000 uses subdivisions of the total petroleum system—termed assessment units—as the basic level of assessment. A total petroleum system consists of all genetically related petroleum generated by a pod or closely related pods of mature source rocks. Particular emphasis is placed on similarities of the *fluids* of petroleum accumulations. Assessment units are therefore more closely associated with the generation and migration of petroleum than are plays.

The choice of play versus assessment unit probably does not result in significant systematic differences in the assessed resources of continuous accumulations. However, the total petroleum system and its assessment units provide a more comprehensive and unifying framework for studying oil and gas accumulations.

Technically Recoverable Resources Versus Potential Additions to Reserves

In the 1995 National Assessment, the fundamental petroleum quantity assessed was technically recoverable resources. These were defined as resources producible using current recovery technology but without reference to economic profitability (U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995).

However, given the sophistication of current petroleum-related technology, essentially all of the moveable oil or gas in almost any accumulation that can be envisioned has become recoverable from a purely technical standpoint. In the FORSPAN resource-assessment model for continuous accumulations, more restrictive conditions are imposed, to the extent that assessed petroleum volumes must not only be technically recoverable but must also have the potential to be added to reserves.

Unlimited Versus 30-Year Time Frame

In the 1995 National Assessment, continuous accumulations were assessed without regard for the time span that might be required to realize the assessed volumes. Because the forecast span was unlimited, the question of "when?" was not addressed. In contrast, a finite forecast span is a central tenet of the FORSPAN assessment model. This forecast span equals 30 years for the NOGA series, which is a more restrictive condition than an unlimited time span.

Because of the unlimited time span of the 1995 National Assessment, all plays were considered accessible for petroleum-related activities; no political or technological barrier should be expected to last forever. In a 30-year time frame, however, access to a particular area for petroleum-related activities (for example, Yellowstone National Park) might not be certain. FORSPAN therefore includes a probability for adequate access, at least somewhere in the assessment unit, during the forecast span.

Randomly Distributed Versus Clustered Production Characteristics

A fundamental concept embedded in the 1995 assessment model for continuous accumulations was that those untested cells that have favorable production characteristics would be randomly distributed throughout a play. The drilling of each cell is therefore an independent experiment, and all untested cells would have to be drilled in order to identify those having favorable production characteristics. Because of the unlimited forecast span of the 1995 National Assessment, it was assumed that all untested cells could eventually be drilled. A success ratio (fraction of successful wells) was established to impose the constraint that some untested cells of a play would not be viable.

During the past several years, the geologic nature of continuous accumulations has become better understood. In consequence, the concept of randomly distributed reservoir properties in a continuous accumulation has been replaced, in FORSPAN, by the hypothesis that untested cells having favorable production characteristics will tend to be clustered together (areally correlated), in sweet spots. Once found, sweet spots could be developed more efficiently than a random-drilling model would predict. Similarly, untested cells having unfavorable production characteristics will also tend to be clustered. Such "non-sweet spots" could be identified by geologic and geophysical means, or by drilling a limited number of wells, and then avoided. Instead of a success ratio, the percentage of the untested area of an assessment unit that has the potential to contribute to reserves in the next 30 years is estimated. Although the present model (clustering of favorable and of unfavorable cells) is not necessarily more restrictive than the 1995 model (random distribution of favorable and of unfavorable cells) in terms of assessed resources, much different economics and land-use patterns are implied.

Summary

This report focuses on the specialized concepts required for assessment of continuous oil and gas accumulations. A continuous accumulation is essentially a single large field that does not owe its existence directly to the buoyancy of petroleum in water. As such, continuous accumulations cannot be represented and assessed in terms of the sizes and numbers of individual, countable fields or pools that are delineated by down-dip water contacts. Continuous accumulations form a geologically diverse group that includes coalbed methane, "tight" gas, basin-center gas, oil and gas in fractured shale and chalk, shallow biogenic gas, and gas hydrates.

The USGS model described here for assessing continuous petroleum accumulations is called the FORSPAN model. FORSPAN provides a strategy for estimating volumes of petroleum having the potential to be added to reserves in a 30-year forecast span, and is being used by the USGS in the

National Oil and Gas Assessment (NOGA) series begun in 2000.

FORSPAN is a cell-based, reservoir-performance model. In this model, a continuous accumulation is envisioned as a collection of petroleum-charged cells. All cells are capable of producing some oil or gas, but production characteristics of cells vary greatly. Cell-level production data are the foundation for forecasts of potential additions to reserves within 30 years. The wells themselves act as comprehensive analog computers that evaluate and weight all relevant reservoir parameters, empirically "calculating" the product of petroleum-in-place and recovery factor. The use of a reservoir-performance assessment model takes full advantage of the development activity that is occurring in many continuous accumulations in the United States.

To begin an assessment using the FORSPAN model, a continuous accumulation is apportioned (if necessary) into more homogeneous sub-units, termed assessment units, which are then assessed individually. A minimum estimated ultimate recovery (EUR) of oil or gas per cell is chosen for the assessment unit, and geologic risk and access risk are assigned. Estimates in the form of three fractiles (F_{100}, F_{50}, and F_0) are developed for the number and the EUR of untested cells of the assessment unit having potential to contribute to reserves within 30 years. Coproduct ratios are also estimated. The combination of these variables yields probability distributions for potential additions to reserves of oil, gas, and coproducts in the assessment unit. These assessed petroleum volumes can be allocated to various land entities of interest within the assessment unit, according to percentages specified by the assessor.

The concepts described herein have evolved somewhat from those used to assess continuous accumulations in the USGS 1995 National Assessment of United States Oil and Gas Resources (Gautier and others, 1995), although a cell-based, reservoir-performance model is at the core of both. Four of the more important conceptual changes embedded in the current NOGA series are (1) use of the total petroleum system (of which assessment units are a subdivision) instead of plays, (2) estimation of potential additions to reserves instead of technically recoverable resources, (3) use of a 30-year forecast span instead of an unlimited assessment time frame, and (4) incorporation of the hypothesis that untested cells having more favorable production characteristics are clustered together instead of being randomly distributed.

References Cited

Attanasi, E.D., and Root, D.H., 1994, The enigma of oil and gas field growth: American Association of Petroleum Geologists Bulletin, v. 78, no. 3, p. 321–332.

Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995, 1995 National assessment of United States oil and gas resources—Results, methodology, and supporting data: U.S. Geological Survey Digital Data Series DDS–30, 1 CD-ROM.

Kuuskraa, V.A., Schmoker, J.W., Koperna, George, and Quinn, J.C., 1998, Barnett Shale rising star in Fort Worth Basin: Oil & Gas Journal, v. 96, no. 21 (May 25), p. 67–76.

National Petroleum Council, 1992, The potential for natural gas in the United States—Source and supply (Volume II): Washington, D.C., National Petroleum Council, 501 p.

Schmoker, J.W., 1995, Method for assessing continuous-type (unconventional) hydrocarbon accumulations, *in* Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995, 1995 National assessment of United States oil and gas resources—Results, methodology, and supporting data: U.S. Geological Survey Digital Data Series DDS–30, 1 CD-ROM.

———1996, A resource evaluation of the Bakken Formation (Upper Devonian and Lower Mississippian) continuous oil accumulation, Williston Basin, North Dakota and Montana: The Mountain Geologist, v. 33, no. 1, p. 1–10.

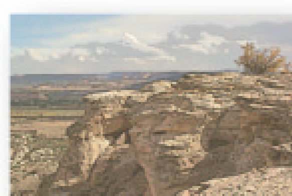
———1999, U.S. Geological Survey assessment model for continuous (unconventional) oil and gas accumulations—The "FORSPAN" model: U.S. Geological Survey Bulletin 2168, 9 p. [Available only on-line at URL http://geology.cr.usgs.gov/pub/bulletins/b2168/]

Schmoker, J.W., Fouch, T.D., and Charpentier, R.R., 1996a, Gas in the Uinta Basin, Utah—Resources in continuous accumulations: The Mountain Geologist, v. 33, no. 4, p. 95–104.

Schmoker, J.W., Quinn, J.C., Crovelli, R.A., Nuccio, V.F., and Hester, T.C., 1996b, Production characteristics and resource assessment of the Barnett Shale continuous (unconventional) gas accumulation, Fort Worth Basin, Texas: U.S. Geological Survey Open-File Report 96–254, 20 p.

U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995, 1995 National Assessment of United States oil and gas resources: U.S. Geological Survey Circular 1118, 20 p.

U.S. Geological Survey World Energy Assessment Team, 2000, U.S. Geological Survey World Petroleum Assessment 2000—Description and results: U.S. Geological Survey Digital Data Series DDS–60, 4 CD-ROMs.



***Click here to return to* Volume Title Page**