METHOD FOR ASSESSING CONTINUOUS-TYPE (UNCONVENTIONAL) HYDROCARBON ACCUMULATIONS

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ABSTRACT

A method is described for assessing those unconventional hydrocarbon accumulations that can be defined as continuous-type gas or oil accumulations, not significantly affected by hydrodynamic or hydrostatic influences, for which the standard methodology of the 1995 National Assessment is not appropriate. "Continuous-type" accumulations are essentially large single fields having spatial dimensions equal to or exceeding those of plays, and cannot be represented in terms of discrete, countable units delineated by down-dip hydrocarbon-water contacts (as are conventional fields). Assessment methods based on sizes and numbers of discrete fields in a play are not applicable to continuous-type accumulations.

The central idea of the assessment method is that a continuous-type play can be regarded as a collection of hydrocarbon-containing cells. Geologic risk (play probability) is assigned to each play. The number of untested cells in a play and the fraction of untested cells expected to become productive (success ratio) are estimated. A probability distribution is established for estimated ultimate recovery (EUR) from untested cells of the play expected to become productive. The combination of play probability, success ratio, number of untested cells, and EUR probability distribution yields the potential additions to reserves expected for the play. The in-place hydrocarbon volume is not used in this assessment procedure.

A play of the Mississippian and Devonian Bakken Formation of the Williston basin serves to illustrate the geologic parameters required for the assessment of continuous-type plays.

INTRODUCTION

STATEMENT OF PROBLEM

The unconventional hydrocarbon accumulations addressed by this report are defined as continuous-type gas or oil accumulations, not significantly affected by hydrodynamic or hydrostatic influences, for which the standard methodology of the 1995 National Assessment is not appropriate. The purpose of this report is to describe the geologically based portion of the protocol used in the 1995 National Assessment to assess potential additions to gas and oil reserves from continuous-type accumulations. Computational and economic aspects of the protocol are described in separate chapters.

Continuous-type accumulations are essentially large single fields having spatial dimensions equal to or exceeding those of plays. Continuous-type accumulations cannot be represented in terms of discrete, countable units delineated by down-dip hydrocarbon-water contacts (as are conventional fields). The standard methodology of the 1995 National Assessment is based on sizes and numbers of discrete fields in a play and is therefore inappropriate for continuous-type accumulations.

NATURE OF CONTINUOUS-TYPE ACCUMULATIONS

The concept of a continuous-type hydrocarbon accumulation is based on the geologic setting of the accumulation; the definition does not incorporate criteria that are commonly associated with other types of unconventional accumulations such as low API gravity, low matrix permeability ("tight"), special regulatory status, or need for unusual engineering techniques. For example, a tight-gas accumulation with special regulatory status may or may not be a continuous-type accumulation, for which the resource-assessment method of this report is necessary.

The geologic setting typical of continuous-type accumulations is illustrated by figure 1. Common geologic characteristics of a continuous-type accumulation include occurrence downdip from water-saturated rocks, lack of obvious trap and seal, crosscutting of lithologic boundaries, large areal extent, relatively low matrix permeability, abnormal pressure (high or low), and close association with source rocks. Aspects of hydrocarbon production common to a continuous-type accumulation include large in-place hydrocarbon volume, low recovery factor, and a heterogeneous "hit or miss" character for production rates and ultimate recoveries of wells.

CLASSIFICATION AS UNDISCOVERED OR INFERRED

In the traditional terminology of conventional-resource assessment, undiscovered resources are those that will be found unassociated with known accumulations, whereas inferred resources are those that will be added to known accumulations. However, in the case of continuous-type accumulations, the distinction between undiscovered and inferred resources is somewhat blurred. The locations of continuous-type accumulations are often well known (implying inferred resources), but hydrocarbon estimates may be broadly dependent on geologic knowledge and theory (implying undiscovered resources).

In the context of the 1995 National Assessment, a confirmed continuous-type play is one wherein the accumulation is geologically well constrained and production characteristics are known; potential reserve additions are deemed analogous to inferred resources. In contrast, a hypothetical continuous-type play is one wherein the accumulation is poorly known and geologically speculative, with little control from drilling and production data; potential reserve additions are deemed analogous to undiscovered resources.

TERMINOLOGY

Selected definitions of particular importance to the assessment of continuous-type accumulations are presented here. These definitions should be viewed more as explanationsthan as inflexible technical rules. Each definition refers specifically to continuous-type accumulations.

Cell.- A subdivision of a play with an area or size (mi^2=acres/640) equal to the median spacing as dictated by drainage area expected for wells of the play. Virtually all cells in a continuous-type accumulation are capable of producing some hydrocarbons. For purposes of this discussion, however, a productive cell is one that contains at least one well for which production from the play is formally reported. A nonproductive cell is one that contains one or more wells that evaluated the play, none of which was productive in the play. An untested cell is one that has not been evaluated by a well. The number of untested cells in a play equals the total number of cells minus the number of cells (productive plus nonproductive) that have been evaluated.

Success ratio.- The fraction (0-1.0) of untested cells in a play expected to become productive. The combination of success ratio and number of untested cells yields the number of untested cells in a play expected to become productive.

Estimated ultimate recovery (EUR) probability distribution.- A distribution that serves as a reference model for production from untested cells of a play expected to become productive. The EUR data of the distribution (barrels of oil or millions of cubic feet of gas) should be representative of cells yet to be drilled that are expected to become productive, rather than representative of established production.

Play probability.- The probability (0-1.0) that untested cells of a play can produce a total of at least one million barrels of oil or six billion cubic feet of nonassociated gas.

Because a continuous-type accumulation such as illustrated by figure 1 is almost certain to be capable of producing these minimum volumes, a play probability less than 1.0 reflects the possibility that some geologic factor necessary for the accumulation to exist is inadequate.

PROCEDURE

OVERVIEW

The assessment procedure for continuous-type accumulations is straightforward in concept
(fig. 2). A continuous-type accumulation is partitioned into geologic plays and the plays are analyzed individually. Geologic risk (play probability) is assigned to each play. A play is regarded as a collection of hydrocarbon-containing cells. The number of untested cells in a play and the fraction of untested cells expected to become productive (success ratio) are estimated. A probability distribution is established for estimated ultimate recovery from untested cells of the play expected to become productive. The combination of play probability, success ratio, number of untested cells, and EUR probability distribution yields the potential additions to reserves expected for the play. The in-place hydrocarbon volume is not used in this assessment procedure.

A consequence of basing the assessment method upon production characteristics is that reliance is not placed upon estimates of secondary reservoir parameters such as porosity, permeability, and water saturation. The integrated effect of all these factors is reflected in a well's ultimate recovery.

The assessment method projects production and development patterns of the past into the future. As a result, the assessment is implicitly based upon a continuation of historic trends.

REPRESENT CONTINUOUS-TYPE ACCUMULATION BY PLAYS

The first step of the assessment (fig. 2) is to represent the continuous-type accumulation by a play or plays. For some plays, several geologic models or concepts having different play probabilities, cell sizes, success ratios, and/or EUR probability distributions may be plausible. Rather than attempting to compress such multiple geologic hypotheses into a single resource-calculation stream, more than one geologic scenario is allowed for a play. The probability for each scenario must be specified; the sum of scenario probabilities equals 1.0. The resource-computation model first computes a conditional resource estimate for each scenario, and then combines these outcomes according to probability theory to yield a resource estimate for the play (see chapter by R.A. Crovelli for details).

A play must be sufficiently homogeneous so that each geologic scenario can be reasonably characterized by a single play probability, cell size, success ratio, and EUR probability distribution.

Each play is identified as either a gas play or an oil play. A gas to oil ratio of 20,000 cubic feet of gas per barrel of oil, the same criterion that is used in the 1995 National Assessment for discrete accumulations, separates gas plays from oil plays.

ASSIGN RISK TO PLAY

A play probability is estimated for each play. In conformity with the convention used in the 1995 National Assessment for discrete accumulations, a continuous-type play is not assessed if the play probability is 0.10 or less. In some cases, the data pertaining to a play are so sparse that an effort at quantitative assessment cannot be defended, irrespective of the play probability, and the play is not assessed for that reason. For continuous-type plays not assessed, a play narrative is included in documentation of the 1995 National Assessment.

After assigning risk to a play, the assessment process proceeds along two parallel flow paths. The right branch of figure 2 addresses the number of untested cells in a play expected to become productive, and the left branch addresses the estimated ultimate recovery from those cells.

ESTIMATE NUMBER OF UNTESTED CELLS IN PLAY

For purposes of resource assessment, it is convenient to envision the hydrocarbons of a continuous-type accumulation as residing in cells. A play is then regarded as a collection of cells. The cell area or size is equal to the median spacing, as dictated by drainage area, expected for wells of the play (fig. 3). The total number of cells in a play equals the area of the play (mi^2) divided by the cell size (mi^2).

A cell is characterized as either evaluated or untested (fig. 3). An evaluated cell is either productive or nonproductive. The number of untested cells in a play equals the total number of cells minus the number of evaluated (productive plus nonproductive) cells.

Uncertainties in defining play boundaries and in the number of evaluated cells lead to measurement error in the number of untested cells. This measurement error is recognized by estimating the minimum possible number (100th fractile) and maximum possible number (0th fractile) of untested cells in the play, in addition to the median value (50th fractile).

Realistic consideration of the uncertainties associated with the number of untested cells in a play usually leads to a substantial range between the minimum and maximum possible number of untested cells. The computation program treats the number of untested cells as a frequency distribution, in the form of either a bell-shaped "Crovelli" distribution or a uniform distribution (see chapter by R.A. Crovelli for details). The bell-shaped distribution is smoothly varying, either symmetrical or skewed left or right as the data require, and is fit to the 0th, 50th, and 100th fractiles. The uniform (or rectangular) distribution assigns equal probability to all values between the 0th and 100th fractiles.

ESTIMATE SUCCESS RATIO FOR UNTESTED CELLS OF PLAY

If existing drilling results are thought to be representative of the entire play, success ratio can be estimated as the number of productive cells divided by the number of evaluated (productive plus nonproductive) cells. If existing drilling results are thought to be inappropriate for the remaining cells of the play, or the play is insufficiently drilled for a realistic success ratio to be established, success ratio can be based upon drilling data from an analog play or upon concepts regarding geologic factors controlling production.

Success ratio is treated as a single-valued parameter. The combination of success ratio and number of untested cells yields the number of untested cells in the play expected to become productive. This statistical calculation provides no insight as to which untested cells are expected to become productive.

ESTABLISH ESTIMATED ULTIMATE RECOVERY (EUR) PROBABILITY DISTRIBUTION FOR UNTESTED CELLS OF PLAY EXPECTED TO BECOME PRODUCTIVE

The initial step in generating the EUR probability distribution is to select a sample set of wells representative of the untested cells of the play expected to become productive. If necessary, wells from an analog play can be used. Because the EUR probability distribution provides a reference model for untested cells of the play expected to become productive, rather than for the cells already evaluated, production data considered to be atypical of the remaining cells of the play should not be used.

The next step is to determine EUR values for the wells of the sample set, and to plot them as a probability distribution. The data developed for the 1995 National Assessment suggest that the typical general form of the EUR probability distribution resembles that of a truncated, log-normal function, as illustrated by figure 4.

Seven fractiles of the EUR probability distribution (the 100th, 95th, 75th, 50th, 25th, 5th, and 0th fractiles) are supplied as input to the computation program. The 100th, 50th, and 0th fractiles are the minimum, median, and maximum values of the distribution, respectively.

INTERIM SUMMARY

At this point in the assessment procedure, fundamental data of the assessment are established. The computation program calculates potential reserve additions (the base-case assessment of fig. 2) by combining the play probability, number of untested cells, success ratio, and EUR probability distribution.

In order to calculate co-products in a play (gas in an oil play or liquids in a gas play), the ratio of total gas to oil (cubic feet of gas per barrel of oil) for an oil play, or the ratio of oil and natural-gas liquids to total gas (barrels of liquids per million cubic feet of gas) for a gas play is also input to the computation program.

ANCILLARY DATA FOR PLAY

Selected ancillary data for a play are provided as support for economic analysis. These ancillary data are: 1) the minimum, maximum, and median depths (ft) of untested cells; 2) the fraction (0-1.0) of untested cells expected to be evaluated by wells originally targeted for the play, for a deeper horizon, and for a shallower horizon; 3) the API gravity (degrees) of liquids in the play; 4) the fraction (0-1.0) of the play that carries a "tight" Federal Energy Regulatory Commission (FERC) designation; and 5) the fraction (0-1.0) of new wells in the play expected to be stimulated.

OPERATIONAL ASPECTS

The information required for the assessment of continuous-type accumulations is supplied by earth scientists who are knowledgeable about the petroleum geology of the province under consideration. These regional experts (province geologists) complete a one-page form (fig. 5) for each geologic scenario of a play. These forms are the source of the input data required for the computation program, and also provide selected ancillary information relevant to economic analysis of the play.

To bridge the gap between the one-page data form (fig. 5) and the extended explanation of the assessment method presented here, and to promote procedural uniformity among province geologists, an outline that provides guidelines for completing the data form (Appendix A) is supplied to each assessor.

EXAMPLE - BAKKEN FORMATION OF WILLISTON BASIN

DEFINITION OF BAKKEN PLAYS

Shale members of the Mississippian and Devonian Bakken Formation of the Williston basin are extremely rich in oil-prone, type II kerogen. The Bakken Formation is within the oil-generation window over about 17,000 mi^2 of North Dakota and Montana, where the formation forms a self-sourced, overpressured, continuous-type oil accumulation.

The overall Bakken continuous-type play (fig. 6) is bounded on the north by the Canadian border (a political rather than geologic boundary), on the east, northwest, and west by thermally controlled limits of oil generation, and on the southwest by the Bakken subcrop. However, this entire area cannot be characterized by a single set of play attributes. Consequently, the overall Bakken play is partitioned into three smaller plays (fig. 6). The Bakken Intermediate play furnishes the example used in the following discussion.

Data from the Antelope field (fig. 6) are excluded from the assessment of the Intermediate play on the assumption that similar producing areas do not exist in the play. Bakken production from the so-called Sanish pool of the Antelope-field anticline was established in 1953. The median well has produced about 160,000 barrels of oil (BO), but no analog to the Sanish pool has been found in the intervening 40 years.

DATA FOR ASSESSMENT OF BAKKEN INTERMEDIATE PLAY

Referring to the input-data form of figure 5, the Bakken Intermediate continuous-type play is designated as an oil play because the expected gas to oil ratio of 800 cubic feet of gas per barrel of oil (CF/BO) is less than the cutoff value of 20,000 CF/BO. The expected gas to oil ratio is derived from commercially available well-production data.

Oil production within the Intermediate play is geographically scattered. Production characteristics of large areas of the play are not well defined. Potential reserve additions are a matter of considerable geologic speculation, and are more akin to undiscovered resources than to inferred resources. Therefore, the play is classified as hypothetical.

Only one geologic scenario is ascribed to the play. A bell-shaped (Crovelli) frequency distribution, rather than a uniform distribution, is specified for the number of untested cells. The bell-shaped distribution, which assigns higher probability to the 50th fractile than to the extremes of the distribution, is chosen because the central tendency for the number of untested cells is based upon well constrained maps of Bakken subcrops and thermal maturity.

The play probability of 1.0 reflects certainty on the part of the province geologist that the geologic factors necessary for the play to produce at least one million BO are present.

The cell size of 640 acres (fig. 5) is the median spacing expected for wells of the play assuming development using non-interfering vertical wells. (Looking ahead on the data form, the EUR fractiles must be consistent with this choice of cell size and represent non-interfering vertical wells.)

The mapped area of the Intermediate play is 8,185 mi^2, determined by planimetry, from which it follows that the total number of cells is 8,185. The search of a commercially available well-production data base reveals that 76 of these cells are productive.

The number of nonproductive cells in the Intermediate play does not follow directly from the search of a well-history data base because some wells drilled to deeper horizons did not evaluate the unconventional Bakken reservoir. Using the criteria that deeper wells that actually evaluated the Bakken reservoir were: 1) drilled after 1979, when the continuous nature of the accumulation was more widely recognized, and 2) not productive in a deeper horizon, so that incentive existed to test uphole zones, leads to an estimate that 303 cells of the Bakken Intermediate play have been evaluated and found to be nonproductive.

The median number of untested cells in the play is 7,806, calculated as the difference between the total number of cells (8,185) and the number of evaluated cells (76 + 303).

The estimate of 976 as the minimum possible number of untested cells (fig. 5) is based on the possibility that the Intermediate play as mapped (fig. 6) is too large. As an extreme scenario, the play attributes of figure 5 are assumed to apply only to three separate, relatively small areas
surrounding loci of existing production. These three areas total 1,100 mi^2 and contain 124 evaluated cells.

The estimate of 11,709 as the maximum possible number of untested cells is based on the possibility that the Intermediate play as mapped is too small. As an extreme scenario, the play attributes of figure 5 are assumed to apply to an expanded area, incorporating an additional 4,000 mi^2, and containing 476 evaluated cells. The expanded area extends beyond the overall Bakken play boundary of figure 6 and also displaces part of the Bakken Outlying play.

For the Intermediate play, the historical success ratio is considered to be representative of cells not yet tested (which is not a valid assumption for all continuous-type plays). In this case, the success ratio of 0.20 (fig. 5) is determined as the number of productive cells (76) divided by the number of evaluated cells (76 + 303).

The 100th EUR fractile for the Intermediate play (fig. 5) is somewhat arbitrarily set at zero, a value for which the probability is 100% that the EUR of an untested cell expected to become productive will be higher. The 95th, 75th, 50th, 25th, and 5th fractiles are picked directly from the EUR probability distribution of figure 7. The 0th fractile is estimated as 450,000 BO, even though the largest observed EUR is 300,000 BO. The relatively small sample set of 67 cells (fig. 7) is unlikely to include the maximum-EUR cell of the play.

The ancillary data (fig. 5) provide background information and are useful for economic analysis, but are not used directly in the computation program. Such data derive in large part from the regional expertise of the province geologist.

To complete the example, the principal assessment results for the Intermediate play may be of interest. Using the input data of figure 5, potential additions to reserves for the Bakken Intermediate play are estimated as 70 million BO at the mean, 41 million BO at the 95th fractile, and 111 million BO at the 5th fractile.

Figure 5. Data form for assessment of continuous-type accumulations. As an example, form is completed using Intermediate play of the Mississippian and Devonian Bakken Formation, Williston basin (Figure 6).

1995 NATIONAL ASSESSMENT

DATA FORM FOR ASSESSMENT OF CONTINUOUS-TYPE ACCUMULATIONS

Province Geologist: J.W. Schmoker Province Name, No.: Williston basin, 31

Date: 8/2/94 Play Name, No.: Bakken Intermediate, 3111

(codes in parenthesis, such as III B, refer to Appendix A)

Play type: _ Oil or **_ Gas** (I C) **_ Confirmed** or **_ Hypothetical** (I D)

Geologic scenario (I E): **one geologic model; Crovelli distribution for number of untested cells.**

Play probability (0-1.0) (II A): **1.0** Stop here if play probability does not exceed 0.10 (II B).

Cells (III):**Cell size** (III A1): **640 acres; 1.0 mi^2 (acres/640)**

Area of play (III A2): **8,185 mi^2 Total no. of cells** (III A3): **8,185**

No. of productive cells (III B): **76** **No. of nonproductive cells** (III C): **303**

No. of untested cells (III D): **7,806** **50th fractile**

Minimum possible number of untested cells (III E1): **976** **100th fractile**

Maximum possible number of untested cells (III E2): **11,709** **0th fractile**

Success ratio (0-1.0) (IV): **0.20**

EUR probability distribution (V)*:

Minimum Median Maximum

Fractile:100th (95th) (75th) 50th(25th)(5th)0th

EUR (BO or

MMCF) **__0__** **(_300_)** **(_4,800_)** **_18,000_** **(_59,000)** **(_139,000)** **_450,000**

Data to assess co-products (VI):

_ Oil play - expected GOR: **_800_ CF/BO**

or_ Gas play - expected liquids/gas ratio: **_____ BO/MMCF**

*100th, 50th, 0th fractiles are required. Other fractiles should be supplied if sufficient data are available.

Selected ancillary data (VII):

Depth (ft) of untested cells (VII A): **median_10,500_; minimum__7,500_; maximum 11,100**

Fraction (0-1.0) of untested cells that will bedeeper shallower

tested by wells originally targeted for (VII B): **the play_0.8_; horizon_0.2_; horizon 0**

API gravity of liquids (VII C): **__41__ degrees**

Fraction (0-1.0) of play with "tight" FERC designation (VII D): **__0**

Fraction (0-1.0) of new wells that will be stimulated (VII E): **_0.1**

Appendix A. Guidelines for completing data form for assessment of continuous-type accumulations.

OBJECTIVE

To estimate potential additions to gas and oil reserves in unconventional hydrocarbon accumulations defined as "continuous-type" gas or oil accumulations, not significantly affected by hydrodynamic or hydrostatic influences, for which the standard methodology of the 1995 National Assessment is not appropriate.

SELECTED DEFINITIONS

cell -- a subdivision of a play with an area or size (mi^2=acres/640) equal to the median spacing as dictated by drainage area expected for wells of the play.

play probability -- the probability (0-1.0) that untested cells of a play can produce a total of at least 1 million barrels oil or 6 billion cubic feet non-associated gas.

PROCEDURE

I. Represent continuous-type accumulation by plays.

A. Define a play or plays sufficiently homogeneous so that each geologic scenario can be reasonably characterized by a single play probability, cell size, success ratio, and estimated ultimate recovery (EUR) probability distribution.

B. Map each play.

C. Identify play as either a gas play or an oil play. A cutoff of 20,000 cubic feet gas/barrel oil is used to distinguish gas plays from oil plays.

D. Identify play as hypothetical (poorly known, potential reserve additions classified as undiscovered) or confirmed (well known, potential reserve additions classified as inferred).

E. Supply geologic scenario, which is an alphanumeric descriptor. If play has more than one geologic scenario, a scenario probability must be provided. Specify either a uniform or bell-shaped (Crovelli) frequency distribution for number of untested cells.

II. Assign risk to play.

A. Estimate play probability (see definition).

B. If play probability does not exceed 0.10, or if data are so sparse that a quantitative assessment cannot be defended, the play will not be assessed and following items do not need to be evaluated. A play narrative will be included in documentation of the 1995 National Assessment.

III. Estimate number of untested cells in play.

A. Determine total number of cells.

1. Estimate cell size (see definition), using data from an analog play if necessary.

2. Measure area of play (mi^2).

3. Total number of cells within mapped play boundary = area of play (mi^2)/cell size (mi^2).

B. Count number of productive cells. A productive cell contains at least one well for which production from the play is reported.

C. Count number of nonproductive cells. A nonproductive cell contains one or more wells that evaluated the play, none of which was productive in the play.

D. Calculate number of untested cells. (no. untested cells = no. total cells - no. productive cells - no. nonproductive cells)

E. Estimate error in the number of untested cells due to uncertainties in play boundaries and number of productive and nonproductive cells.

1. What is the minimum possible number of untested cells?

2. What is the maximum possible number of untested cells?

IV. Estimate success ratio for untested cells of play. (Success ratio = fraction (0-1.0) of untested cells expected to become productive.)

A. If existing drilling results are thought to be typical of the play as a whole, success ratio is the number of productive cells divided by the number of evaluated (productive plus nonproductive) cells.

B. If play is insufficiently drilled to establish a realistic success ratio, or existing drilling results do not represent the play as a whole:

1. Estimate success ratio using data from an analog play.

2. Or, estimate success ratio from geologic concepts regarding the play.

Explanatory note -- the combination of success ratio and number of untested cells yields the number of untested cells in the play expected to become productive.

V. Establish estimated ultimate recovery (EUR) probability distribution for untested cells of play expected to become productive. (Units are barrels oil or million cubic feet gas)

A. Select a sample set of wells representative of untested cells of the play expected to become productive. Use wells from an analog play if necessary.

B. Examine production data and determine EUR values for wells of the sample set. The EUR data constitute a reference model for untested cells of the play expected to become productive. Be wary of production data that might be atypical of the untested cells of the play.

C. Based on B (above), establish an EUR probability distribution for untested cells of the play expected to become productive. A sample set of relatively few cells may not include the maximum EUR of the play. The minimum EUR is zero, for which the probability is 100% that a cell's EUR will be higher. Supply the 100th, 95th, 75th, 50th, 25th, 5th, and 0th fractiles.

VI. Information needed to assess co-products.

A. If an oil play, estimate the expected ratio of total gas to oil (GOR) (cubic ft gas/barrel oil).

B. If a gas play, estimate the expected ratio of oil and natural-gas liquids to total gas (barrels liquids/million cubic ft gas).

At this point, fundamental elements of the assessment are established. Potential reserve additions are calculated by combining the play probability, number of untested cells, success ratio, and EUR probability distribution.

VII. Ancillary data for play.

A. Estimate median, minimum, and maximum depths (ft) of untested cells.

B. Estimate fraction (0-1.0) of untested cells expected to be evaluated by wells originally targeted for the play, for a deeper horizon, and for a shallower horizon.

C. Estimate API gravity (degrees) of liquids in the play.

D. Estimate fraction (0-1.0) of the play that carries a "tight" Federal Energy Regulatory Commission (FERC) designation.

E. Estimate fraction (0-1.0) of new wells in the play expected to be stimulated.

FIGURE CAPTIONS

Figure 1 Sketch depicting geologic setting of continuous-type gas and oil accumulations relative to discrete accumulations in structural or stratigraphic traps.

Figure 2 Flow diagram emphasizing geologically based portion of protocol (above wavy line) used to assess continuous-type gas and oil accumulations.

Figure 3 Sketch depicting a continuous-type play as a collection of hydrocarbon-containing cells. Circles represent cells that have been evaluated by wells; evaluated cells are either productive (solid circles) or nonproductive (open circles). Remaining cells are untested.

Figure 4 Illustration, using hypothetical data, of an estimated ultimate recovery (EUR) probability distribution for untested cells of a play expected to become productive. Curve shape is that of a truncated, log-normal function. Horizontal axis is that of standard probability paper.

Figure 5 Data form for assessment of continuous-type accumulations. As an example, form is completed using Intermediate play of the Mississippian and Devonian Bakken Formation, Williston basin (Figure 6).

Figure 6 Map showing overall Bakken Formation continuous-type oil play, Williston basin. Overall play is partitioned into three smaller plays to isolate regions of roughly uniform play attributes.

Figure 7 Estimated ultimate recovery (EUR) probability distribution for untested cells of the Bakken Intermediate play expected to become productive. Each data point is the EUR (barrels oil) of a non-interfering vertical well, calculated from commercially available well-production data using exponential decline-curve analysis. Horizontal axis is that of standard probability paper.

Appendix A. Guidelines for completing data form for assessment of continuous-type accumulations.