Petroleum Systems and Geologic Assessment of Oil and Gas in the San Joaquin Basin Province, California

Chapter 27

Data Sources and Compilation

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Contents

Abstract

Geologic, production, and exploration/discovery-history data are used by the U.S. Geological Survey to aid in the assessment of petroleum resources. These data, as well as the broad knowledge and experience of the assessing geologists, are synthesized to provide, for each assessment unit, geologic and exploration models upon which estimates are made of the number and sizes of undiscovered accumulations for conventional assessment units or number and total recoverable volumes of untested cells for continuous assessment units (input data for resource calculations).

Quantified geologic information and trends in production and exploration/discovery-history data with respect to time and exploration effort provide guides for the estimating parameters of variables recorded on the input-data forms (input data) used to calculate petroleum resources. An Assessment Review Team reviews proposed geologic and exploration models and input data for each assessment unit in formal assessment meetings. The Assessment Review Team maintains the accuracy and consistency of the assessment procedure during the formal assessment meetings.

Introduction

The U.S. Geological Survey (USGS) uses geologic data, petroleum production data, and exploration and discovery histories for preparation of the domestic National Oil and Gas Assessment (NOGA) project. Geologic, production and exploration/discovery-history data are used to estimate parameters of variables recorded on the input-data forms (input data) for undiscovered accumulations in conventional assessment units or untested cells in continuous assessment units used to calculated petroleum resources.

This report describes the sources and compilation of geologic, production, and historical exploration and discovery data used to aid completion of assessment input-data forms, for both conventional and continuous assessment units. Specific geologic data for each assessment unit in NOGA are described in separate sections.

Background

Assessment units are identified to organize the assessment process and serve as the basic area or rock-volume entities for resource appraisal. An assessment unit is a mappable part of a total petroleum system in which discovered and undiscovered oil and gas accumulations constitute a single relatively homogeneous population such that the methodology of resource assessment is applicable (Klett and others, 2000). An assessment unit might equate to a total petroleum

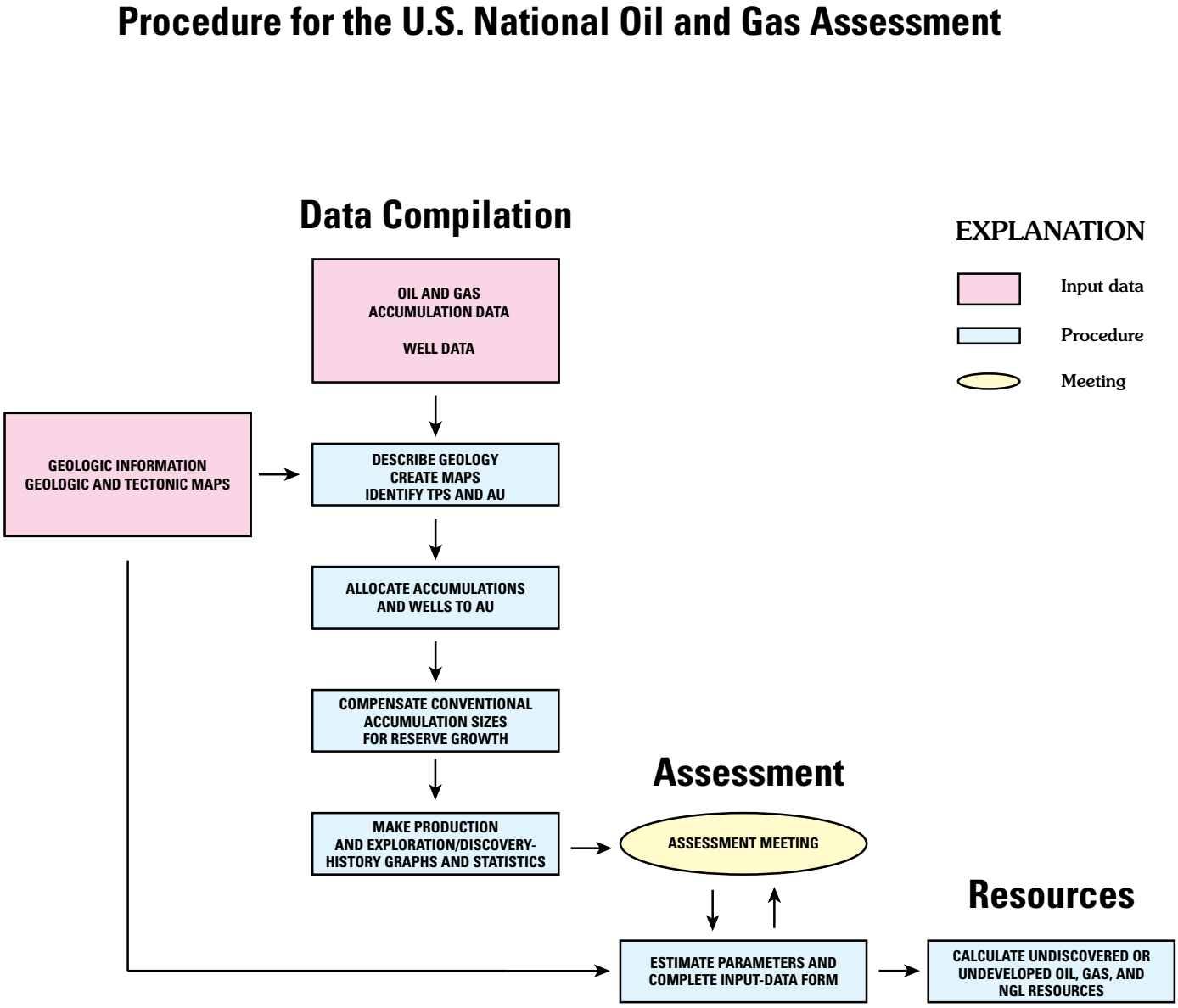

Figure 27.1. Simplified flow diagram of the assessment procedure (modified from Klett and Ahlbrandt, 2000). TPS, total petroleum system; AU, assessment unit; NGL, natural gas liquids.

system, but total petroleum systems may be subdivided into two or more assessment units such that each assessment unit is sufficiently homogeneous in terms of geology, exploration considerations, and risk to assess individually (Klett and others, 2000). An accumulation is composed of one or more pools or reservoirs of petroleum that make up an individual production unit; a field may equate to one or several accumulations.

The terms "conventional" and "continuous" are used to describe both assessment units and accumulations (Gautier and others, 1996). A conventional accumulation is a discrete accumulation, commonly bounded by a down-dip water contact and therefore affected by the buoyancy of petroleum in water (Schmoker, 1996, 1999; Schmoker and Klett, 1999, 2000). A conventional assessment unit consists primarily of conventional accumulations and is assessed by estimating the number and sizes of the undiscovered accumulations. A continuous petroleum accumulation is not significantly affected by hydrodynamic influences, lacks well-defined down-dip water contacts, and is pervasive throughout a large area (Schmoker, 1996, 1999; Schmoker and Klett, 1999, 2000). A continuous assessment unit is assessed by estimating the number and total recoverable volumes of untested cells. Cells are subdivisions or areas within an assessment unit having dimensions related to the drainage areas of wells. Assessment units described as conventional

or continuous primarily contain their respective accumulations.

Data Sources

Geologic data are obtained by assessing geologists from a wide variety of sources including USGS reports and maps, published literature, and operators.

Production data (volumetric and descriptive data such as cumulative production, remaining reserves, total or ultimate recoverable volumes, major producing reservoirs, and petroleum type) and historical data (such as field-discovery dates, well-completion dates, exploration objectives, well depths, and so on) for fields, reservoirs, and wells are derived from commercial databases purchased by the USGS, including (1) PI/Dwights Plus U.S. Production and Well databases (IHS Energy Group, 2003) and (2) NRG Associates, Inc. "Significant Oil and Gas Fields of the United States" (NRG Associates, 2002). Additionally, data are also obtained from proprietary databases provided by the U.S. Department of Energy's Energy Information Administration (EIA). Data from these databases are subject to proprietary constraints, but derivative representations in the form of graphs and summary statistics can be prepared and presented for each assessment unit.

The PI/Dwights Plus U.S. Production database provides production data for wells, leases, or production units (collectively called entities in this database) and the PI/Dwights Plus U.S. Well database provides individual well data (including data for dry holes) that include well identification, locations, and information on penetrated formations (IHS Energy Group, 2003). The NRG Associates, Inc. "Significant Oil and Gas Fields of the United States" database provides production data for fields and reservoirs (NRG Associates, 2002).

The USGS, however, cannot verify the accuracy, completeness, or currency of data that are reported in commercial databases. To supplement commercial databases, additional data are obtained, where available, from operators, State and other Federal agencies, and so on.

Data Compilation

Assessment Procedure

The assessment procedure used for NOGA is shown in figure 27.1. Using geologic information, the geologic province, the total petroleum systems within the province, and assessment units within the total petroleum systems are identified, described, and mapped. Accumulations and wells are then assigned to total petroleum systems and assessment units. Production and exploration/discovery-history data are subsequently compiled and plotted on graphs, and summary statistics of the production data are calculated for each assessment unit. The graphs and statistics serve as guides for estimation of the number and sizes of undiscovered accumulations in conventional assessment units or number and total recoverable volumes of untested cells in continuous assessment units recorded on the input-data form. The geologic, production, and exploration/discovery-history data, graphs, and statistics, as well as the initial estimates of input data, are then presented to a USGS Assessment Review Team for discussion and review. Upon consensus and final approval by the Assessment Review Team, petroleum resources are calculated using the input data.

Assigning Accumulations and Wells to Total Petroleum Systems and Assessment Units

Geology-based digital maps of total petroleum systems and assessment units are created using geographic information systems (GIS). The digital map boundaries are used to assign wells and accumulations to their respective total petroleum systems and assessment units, and these assignments are entered into the databases. Accumulations are assigned to only one total petroleum system and one assessment unit. Wells, however, can be assigned to more than one assessment unit if they penetrate vertically stacked assessment units. Accumulation and well assignments are reviewed to ensure proper assignments, to identify inconsistent data, and to examine the need for minor revisions of assessment-unit boundaries.

Production and exploration/discovery-history data are collected for each assessment unit using accumulation or well assignments. Types of data retrieved are (1) known (sum of cumulative production and remaining reserves) recoverable oil, gas, and natural gas liquids (NGL) volumes of accumulations; (2) discovery dates of accumulations (the year the first reservoir in the accumulation was discovered); (3) monthly production and cumulative production of wells; (4) initial classification and final classification (for example, new-field wildcat, development, producing, abandoned, and so on) of wells; and (5) completion dates of wells.

Production Data

Production data compiled for each conventional accumulation include field name; field discovery year or date of completion of the discovery well; known volumes of oil, gas (nonassociated and associated/dissolved), and NGL; and depth to the top of each reservoir. Production data are compiled for each individual production well in continuous accumulations and include past monthly production of liquids (oil and NGL) and gas (nonassociated and associated/dissolved), from which estimated ultimate recoveries (EURs) are calculated using well decline-curve analysis; the date of first production; and depth to the topmost perforation.

A list of new-field wildcat wells and their completion dates is compiled and organized into the number of wells drilled per year for conventional assessment units. A new-field wildcat well is an exploratory well drilled away from a producing field to test a separate trap. Once organized, the number of wells drilled in a given year is combined with the production data using the discovery dates of the accumulations and the completion dates of the wells.

Similarly, for continuous assessment units, a list of all wells and completion dates is compiled and organized. However, the number of wells drilled in a given year is not combined with production data, but analyzed separately.

Oil and gas accumulations are treated separately. Gas to oil ratios (GOR) are calculated for each conventional accumulation to identify the major commodities (oil or gas), and thus, the type of accumulation. An oil accumulation is defined as having a GOR less than 20,000 cubic feet of gas/barrel of oil whereas a gas accumulation has a GOR equal to 20,000 cubic feet of gas/barrel of oil or greater. Other coproduct ratios (GOR; NGL to gas ratio; and liquids to gas ratio, LGR), based on accumulation-level oil, gas, and NGL volumes, are also calculated to aid in the assessment of those associated resources.

All production data for conventional assessment units are rearranged in terms of oil accumulations and gas accumulations and are sorted by size and discovery date of the accumulations for statistical calculations and plotting. Supplemental data are also compiled to aid in geologic interpretations and the assessment process. These supplemental data represent individual reservoirs within the accumulations and include thickness (net and gross), average porosity, average permeability, temperature, pressure, fluid properties (for example, sulfur content of oil, API gravity of oil, nonhydrocarbon gas contents), trap type, drive type, and well spacing.

Exploration/Discovery-History Data

Examination of the discovery process is one method to aid in the appraisal of petroleum resources in a geology-based assessment model. The discovery process commonly yields consistent trends in historical new-field wildcat-well drilling (exploration effort) and discovery rate reflecting the typical systematic decline in average size of discoveries, or EURs of production wells, as exploration continues (Drew and Schuenemeyer, 1993). These trends can be used to estimate the size distribution of undiscovered accumulations or total recoverable volume distribution of untested cells and to forecast future discovery rates. The distributions of discovered-accumulation sizes or EURs of production wells also provide an indication of the economic truncation of field sizes targeted for exploration (Drew and Schuenemeyer, 1993). Discovery-process analysis, however, is inappropriate for areas that are immature with respect to exploration, discoveries, and new play concepts because systematic trends in exploration effort and discovery size are not yet fully developed.

The procedure used by the USGS in the ongoing domestic petroleum assessments to characterize discovery process in terms of exploration and discovery-history data includes (1) statistically analyzing discovered accumulation sizes, or EURs of production wells, with respect to time; (2) examining plots of the number, sizes, and depths of accumulations discovered through time and with respect to exploration effort; and (3) examining plots of the number of wells drilled through time (new-field wildcat wells for conventional assessment units and all wells for continuous assessment units).

The group of discovered accumulations in a conventional assessment unit, or the group of tested cells in a continuous assessment unit, is divided into three segments with respect to the number of discoveries or tests (the first-third, the second-third, and the third-third). Conventional assessment units containing 2 to 13 accumulations, however, are separated into discovery halves instead of thirds, as are continuous assessment units containing 2 to 13 tested cells. These subgroups are called discovery-history segments and are used to help understand the discovery process (for example, Schuenemeyer and Drew, 1991). Discovery-history segments are used to bin or increment time in terms of exploration maturity in such a way that comparisons of discovery history can be made among assessment units having discoveries at different times. Not only can discovered accumulations or tested cells be analyzed in terms of discovery-history segments, but also, all of the discovered accumulations or tested cells to a certain date may be perceived as constituting one or more segments of a total natural population of which the undiscovered accumulations or untested cells make up the remaining segment(s).

Conventional Assessment Units

Two sets of graphs and statistics are generated for conventional assessment units, one using known accumulation sizes as of the effective date of the assessment and one using accumulation sizes that are adjusted upwards for anticipated reserve growth within the forecast span of the assessment.

Expected reserve growth is considered in evaluation of the sizes of discovered and undiscovered conventional accumulations. To address this subject, a library of reserve-growth functions has been developed by the USGS from proprietary United States reserves data (provided by EIA) to model future changes in accumulation size based on the age of the accumulation and the forecast span of the assessment.

The set of graphs and statistics generated for conventional assessment units includes number and sizes of discovered accumulations with respect to discovery date and exploration effort, exploration effort through time, size distributions of accumulations (both within discovery-history segments and collectively), reservoir depth versus discovery date and exploration effort, coproduct ratios versus reservoir depth, and a histogram of the API gravity. Accumulations containing less than a specified minimum volume of oil or gas (that is, the

smallest accumulation size that is considered in the assessment process) are not included in these graphs or statistics. New-field wildcat wells are used to indicate the exploration effort for finding new accumulations.

Continuous Assessment Units

A set of graphs and statistics similar to that for conventional assessment units is generated for continuous assessment units, but they show the number and total recoverable volume per cell of tested cells rather than sizes and number of discovered accumulations. Tested cells of less than the specified minimum total recoverable volume per cell are not included in these graphs or statistics, and reserve-growth adjustments for cells are not incorporated.

The set of graphs and statistics generated for continuous assessment units includes number of wells drilled through time (all wells as opposed to new-field wildcat wells), probability distributions of the EURs of production wells (both within discovery-history segments and collectively), EUR per production well versus production-start year and number of wells drilled, cumulative EUR per production well versus production-start year and number of wells drilled, cumulative EUR per production well versus depth of the topmost perforation, and GOR versus ranked EUR.

Quantification of Geologic Information

Geologic information is quantified to help estimate the number of undiscovered accumulations in conventional assessment units or the number of untested cell in continuous accumulations. The number of undiscovered fields or untested cells in an assessment unit is generally dependent on the geologic elements and fundamental processes of generation, migration, entrapment, and preservation of petroleum of the total petroleum system, together with the exploration maturity of the assessment unit. Where information is available, prospect counting and analysis of accumulation density are used to refine the estimates of the number of undiscovered fields. Where parts of the assessment unit are unexplored or less explored, the reason for exploration immaturity is examined. Exploration immaturity and heterogeneity may result from poor exploration results and political and physical constraints on exploration, such as extreme water depths or large sand dunes. In addition, incomplete databases can give the impression of exploration heterogeneity. Varying degrees of exploration of different stratigraphic horizons or different trap types within a single assessment are also taken into consideration during the assessment process.

The sizes of undiscovered accumulations or total recoverable volumes of untested cells in an assessment could be estimated using both geologic knowledge and trends observed in discovery-history segments. Distributions of both the number and sizes of undiscovered accumulations or untested cells change through time as an assessment is explored. The largest accumulations or cells are generally found early in the exploration history. Unless a new exploration concept is developed, sizes of discovered accumulations or EURs of production wells tend to decrease through time. Large accumulations or cells can be discovered later in the exploration history, however, if new areas are opened to exploration, or if new exploration concepts are developed. The possibility for new exploration trends, which would not be imbedded in the past discovery history, is therefore considered.

In cases where an assessment unit had little or no discovery information, other assessed areas assumed to be similar in terms of petroleum geology are used as partial analogs. Although assessment units are extremely variable from one another, some may be used as analogs elsewhere. The use of analogs, explicit or implicit, is fundamental to the process of undiscovered resource assessment.

Assessment Meetings

Geologic, production, and exploration/discovery-history data, as well as the broad knowledge and experience of the assessing geologists, are synthesized to provide, for each assessment unit, geologic and exploration models upon which estimates are made of the number and sizes of undiscovered accumulations for conventional assessment units or number and total recoverable volumes of untested cells for continuous assessment units (input data for resource calculations). An Assessment Review Team reviews proposed geologic and exploration models and input data for each assessment unit in formal assessment meetings. The team is made up of senior petroleum geoscientists having years of experience, doctoral degrees, and specialization in various disciplines of geology. The Assessment Review Team is present at each assessment meeting to maintain the accuracy and consistency of the assessment procedure.

At each assessment meeting, the assessing geologists present a description of the assessment-unit geology, including regional setting, structural evolution, source-rock properties, depositional history, and potential petroleum-rich areas, horizons, or plays for future exploration. Each of the estimated parameters on the initial input-data form made by the assessing geologists is then systematically addressed. As the meeting progresses, a digital version of the final input-data form is constructed. Commonly, revisions are made to the initial input data upon analysis of the geologic, exploration, and discovery-history data. Preliminary calculations of undiscovered resources are performed as part of the review process. Upon final consensus of the Assessment Review Team and the assessors, the digital input-data form is saved, printed, and initialed by each of the team members.

The assessment meetings are open only to USGS employees directly involved in the scheduled assessment. Persons from outside the USGS, including USGS-paid contractors, cannot attend these meetings. These rather unusual steps are

taken to ensure that the NOGA project remains fair, honest, and objective. The assessment serves no particular agenda, within or outside of Government, and is not influenced by special interest groups.

Summary

Geologic, production, and exploration/discovery-history data are used by the U.S. Geological Survey (USGS) to aid in the assessment of petroleum resources. These data, as well as the broad knowledge and experience of the assessing geologists, are used to provide, for each assessment unit, geologic and exploration models upon which estimates are made of the number and sizes of undiscovered accumulations for conventional assessment units or number and total recoverable volumes of untested cells for continuous assessment units (input data for resource calculations).

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