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An Approach to the Classification of Potential Reserve Additions of Giant Oil Fields of the World

Open-File Report 2007–1438

U.S. Department of the Interior
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By T.R. Klett and M.E. Tennyson

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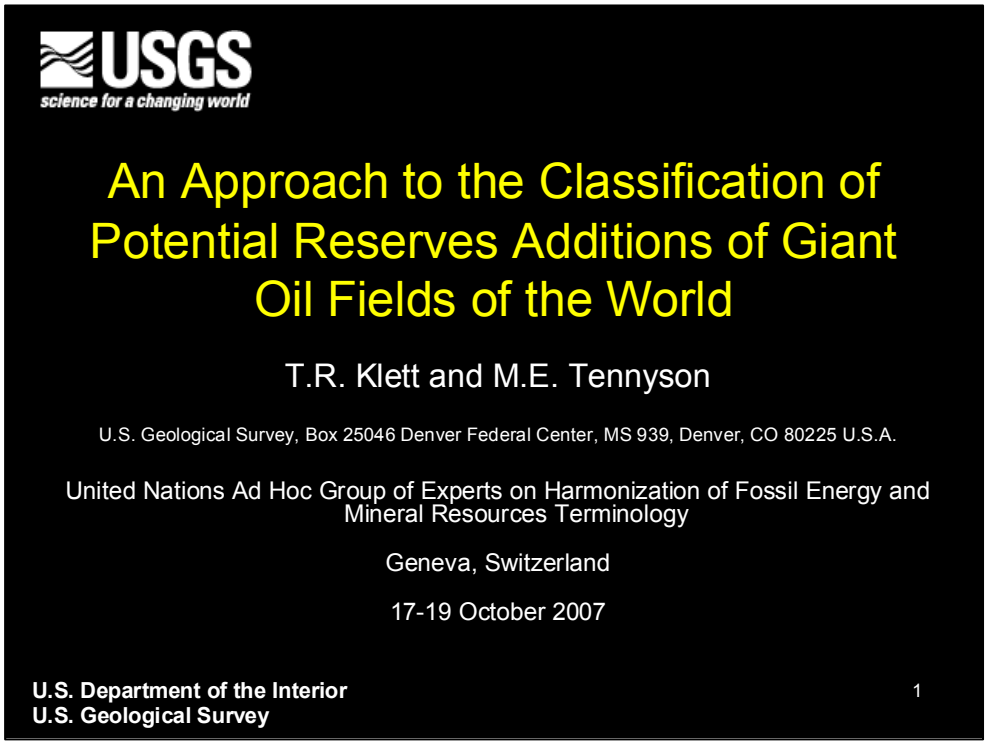
An Approach to the Classification of Potential Reserve Additions of Giant Oil Fields of the World

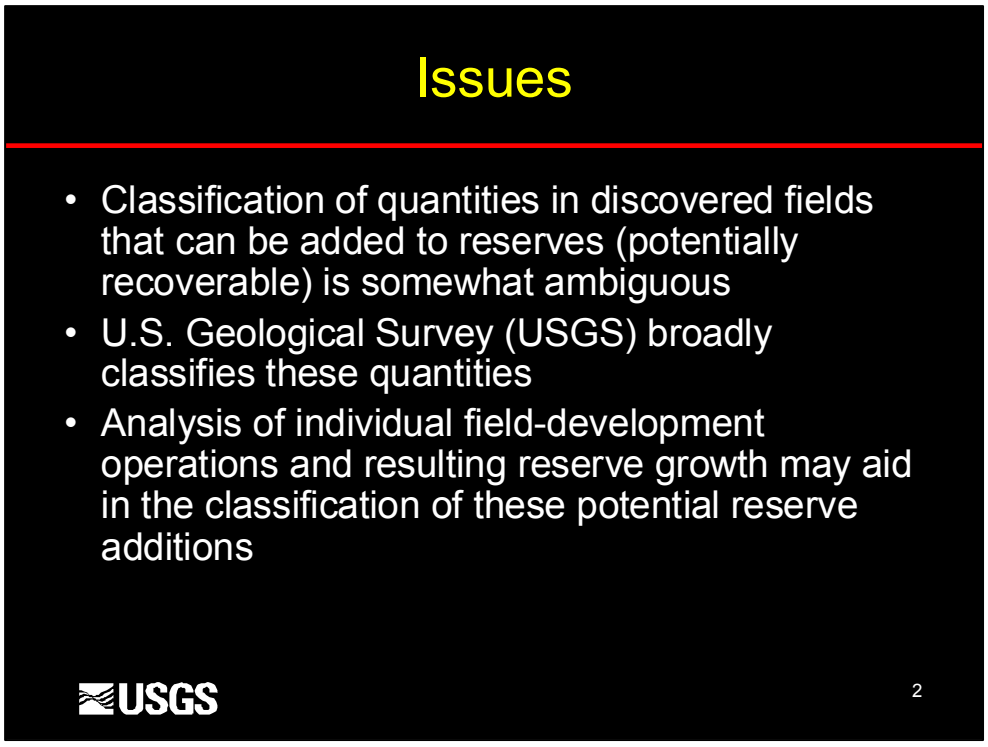
By T.R. Klett and M.E. Tennyson

Foreword

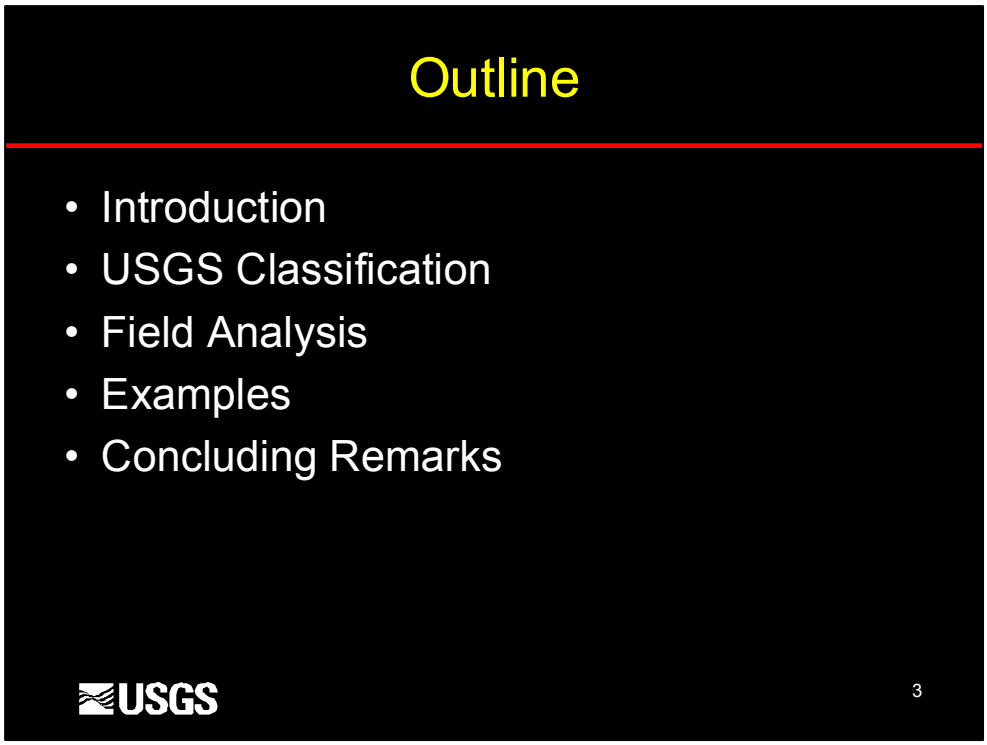
This report contains notes for slides in a presentation given to the Committee on Sustainable Energy and the Ad Hoc Group of Experts on Harmonization of Fossil Energy and Mineral Resources Terminology on 17 October 2007 in Geneva, Switzerland.



Slide 1. This presentation describes the U.S. Geological Survey (USGS) study to characterize and quantify petroleum-reserve additions, and the application of this study to help classify the quantities.



Slide 2. The classification of quantities of petroleum that have the potential to be added to reserves can be ambiguous. The USGS only broadly classifies these quantities. However, analysis of individual field-development operations and resulting reserve growth might aid in the classification of these potential reserve additions.



Slide 3. The presentation starts with a brief introduction, followed by a description of the USGS classification of petroleum quantities. Next, the approach to the field analysis study is described with some examples of reserve additions from actual field operations. Finally, a database of the reserve additions, which might be used for classification purposes, is demonstrated.

- Introduction
- USGS Classification
- Field Analysis
- Examples
- Concluding Remarks

USGS

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Introduction

- U.S. Geological Survey (USGS) estimates petroleum quantities in BOTH
  - ***Undiscovered*** accumulations
    - Easily classified in UNFC system
  - ***Discovered*** accumulations, as reserve growth
    - Somewhat ambiguous in any classification system

USGS

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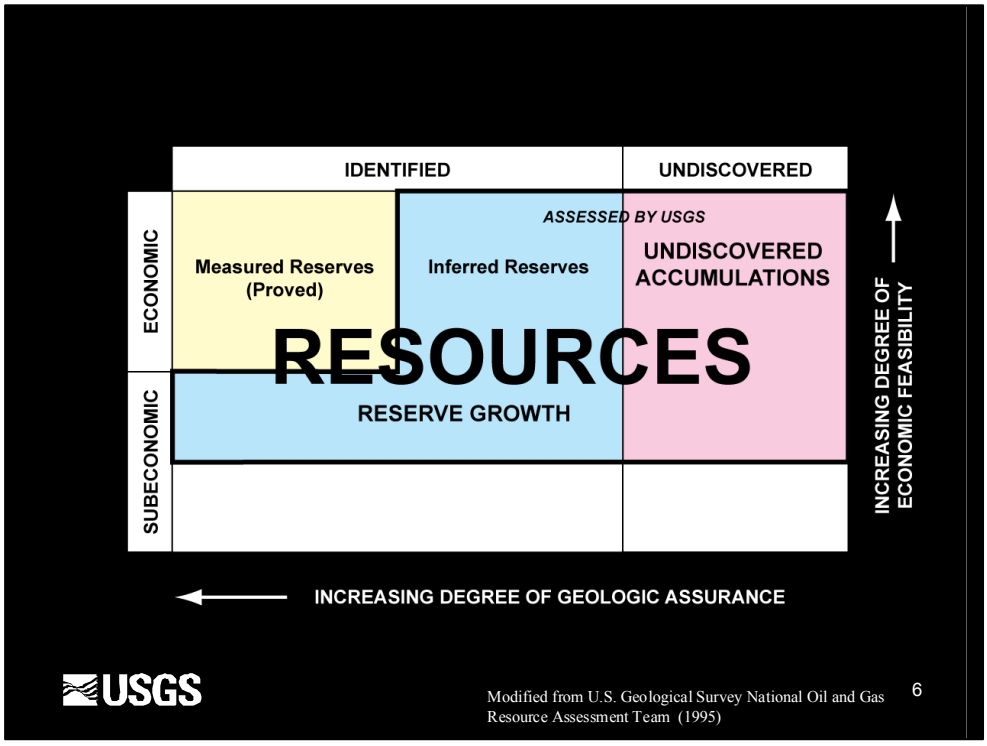
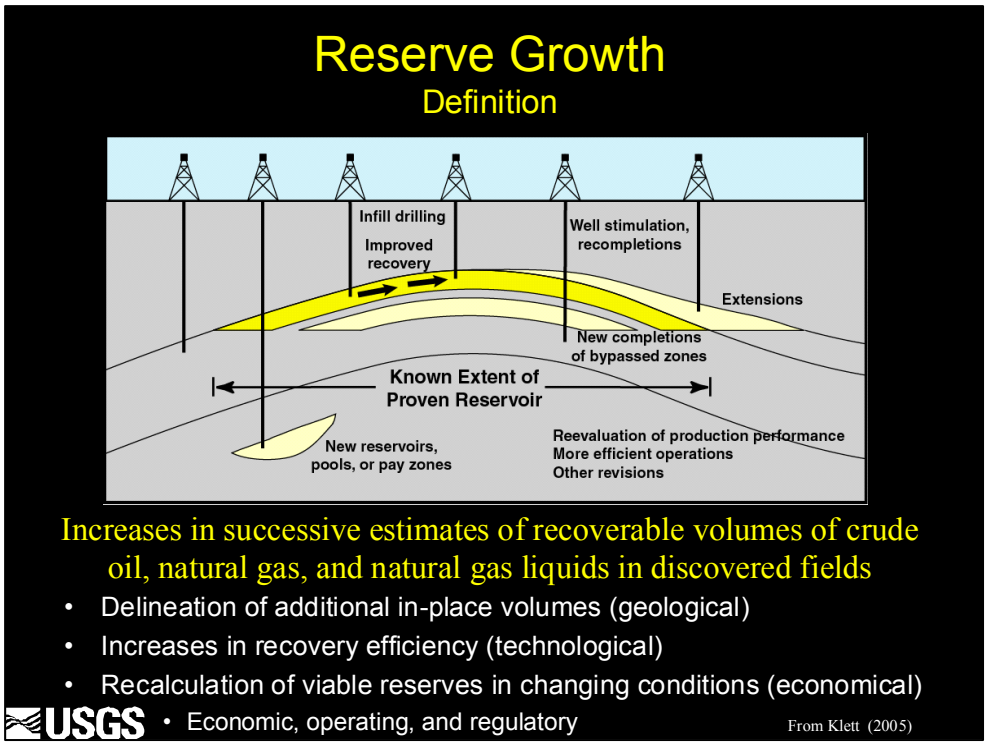
Slides 4 and 5. The USGS estimates petroleum resources in both discovered accumulations, in the form of reserve growth, and in undiscovered accumulations. The term "petroleum" is used as a collective term for crude oil, natural gas, natural gas liquids, and condensates.

Undiscovered resources can be easily classified in the United Nations Framework Classification (UNFC) system. However, resources in discovered accumulations that have the potential to be added to reserves, or recoverable, are not as easily classified. The USGS attributes these additions to reserves as reserve growth and is responsible for estimating these quantities.



Slides 6. The USGS only broadly classifies these quantities. This slide shows the classes that contribute to reserve additions.



Slide 7. Reserve growth is defined as increases in successive estimates of recoverable petroleum quantities in discovered fields. Reserve growth can result from delineation of additional in-place volumes, increases in recovery efficiency, and recalculation of viable reserves in changing economic, operating, and regulatory conditions.

- Introduction
- USGS Classification
- Field Analysis
- Examples
- Concluding Remarks

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USGS Classification

- USGS evaluates and characterizes geologic assurance and economic feasibility, as in the UNFC, during the course of the petroleum-resource assessments
- However, USGS does not have data or a systematic knowledge base of commercial development plans, degree of commitment, and technically feasible projects for the feasibility axis of the UNFC

USGS

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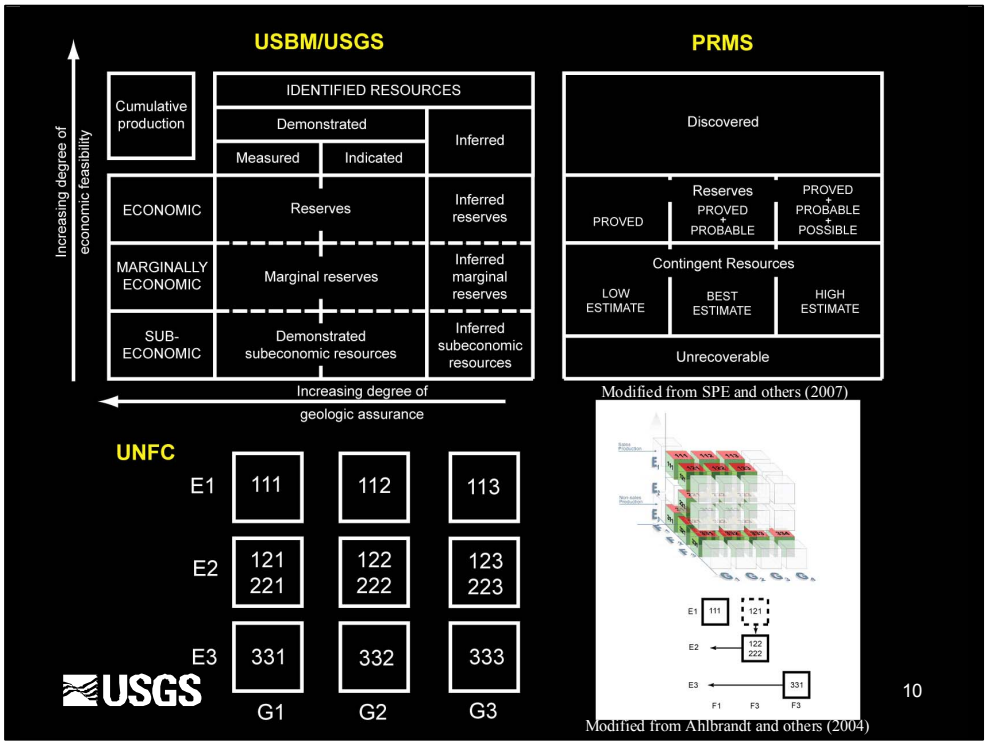
Slides 8 and 9. The USGS evaluates and characterizes geologic assurance and economic feasibility, as provided in the UNFC, during the course of petroleum-resource assessments. However, the USGS does not have data or a systematic knowledge base for using the feasibility axis of the UNFC, nor

does it have access to commercial development plans, degree of commitment, or information on technically feasible projects. The use of the feasibility axis is not required, but is indeed offered in the UNFC. However, the UNFC does allow classes to be grouped or expanded.

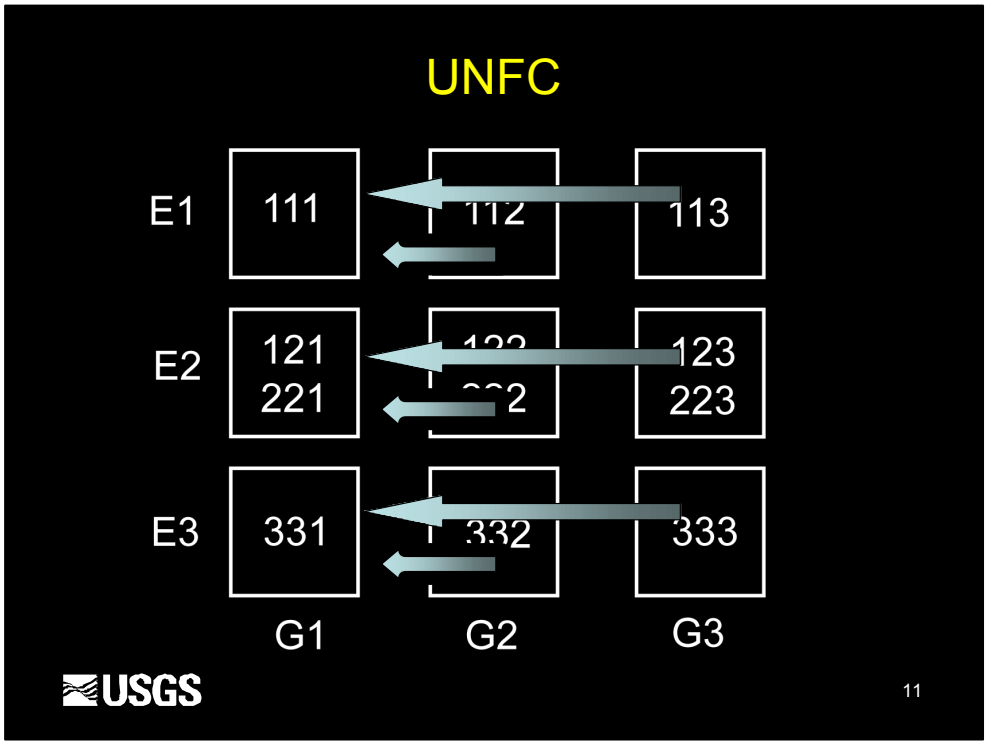


Slide 10. This slide compares three different resource-classification systems. A portion of the McKelvey classification system (U.S. Bureau of Mines and U.S. Geological Survey, 1980) is shown in the upper left, a portion of the Petroleum Resources Management System (PRMS; Society of Petroleum Engineers, World Petroleum Council, American Association of Petroleum Geologists, and Society of Petroleum Evaluation Engineers, 2007) is shown in the upper right, and the UNFC (from Ahlbrandt and others, 2004) is shown below.

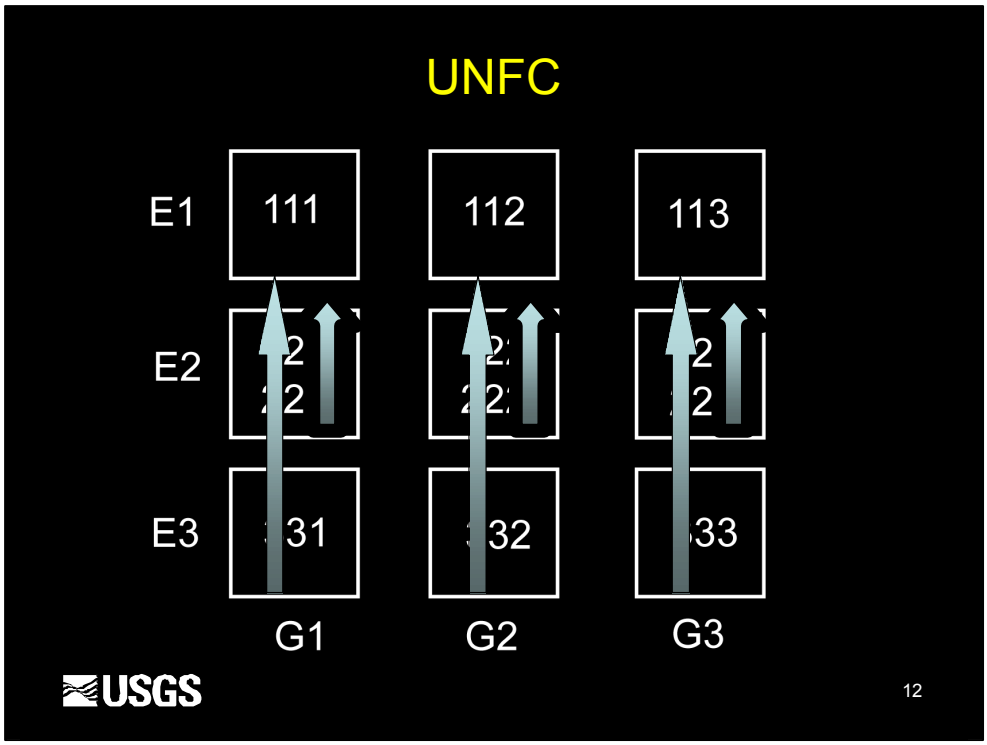
The USGS groups the classes on the feasibility axis (lower right). Once grouped, the UNFC cube becomes a two-dimensional system of economic viability versus geologic knowledge (lower left)—similar to the McKelvey classification system.

Categories in the McKelvey system loosely correspond to those of the PRMS and UNFC. Measured reserves correspond to proved reserves (PRMS) and category 111 (UNFC). Likewise, inferred reserves correspond to proved plus probable plus possible reserves of the PRMS and category 113 of the UNFC.

Classes loosely correspond as well. Reserves correspond to reserves of the PRMS and the three categories of the E1 class of the UNFC. Marginally and subeconomic classes correspond to contingent resources of the PRMS and E2 and E3 classes of the UNFC. Likewise, measured, indicated, and inferred reserves correspond to proved, proved plus probable, and proved plus probable plus possible reserves of the PRMS, respectively. These reserves also correspond to the G1, G2, and G3 classes of the UNFC.



Slide 11. Potential reserve additions are sourced from most of these other reserve and resource classes. These additions might involve increasing geologic knowledge.



Slide 12. Or, these additions might involve increasing economic viability. The path to recovery can be quite complex.

- Introduction
- USGS Classification
- Field Analysis
- Examples
- Concluding Remarks

USGS

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Approach

- Compile and analyze field-history data for large oil and gas fields of the world
  - World's largest oil fields
    - 54 of the 56 oil fields containing = $5X10^9$ barrels of recoverable oil
  - Giant U.S. oil fields
    - = $500X10^6$ barrels of recoverable oil

USGS

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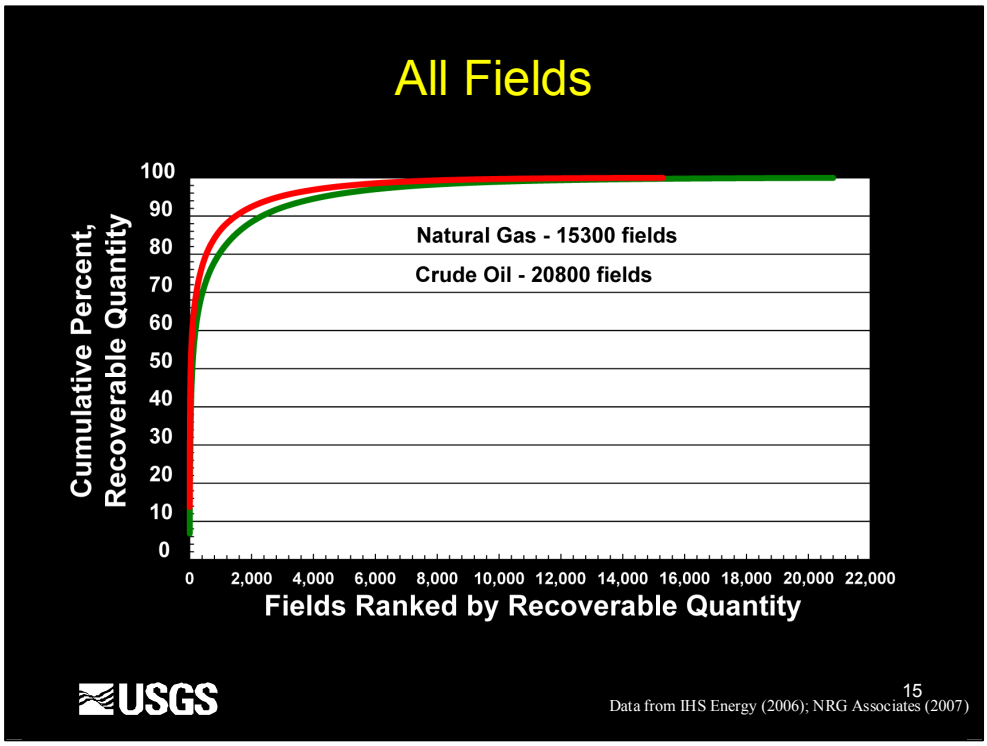
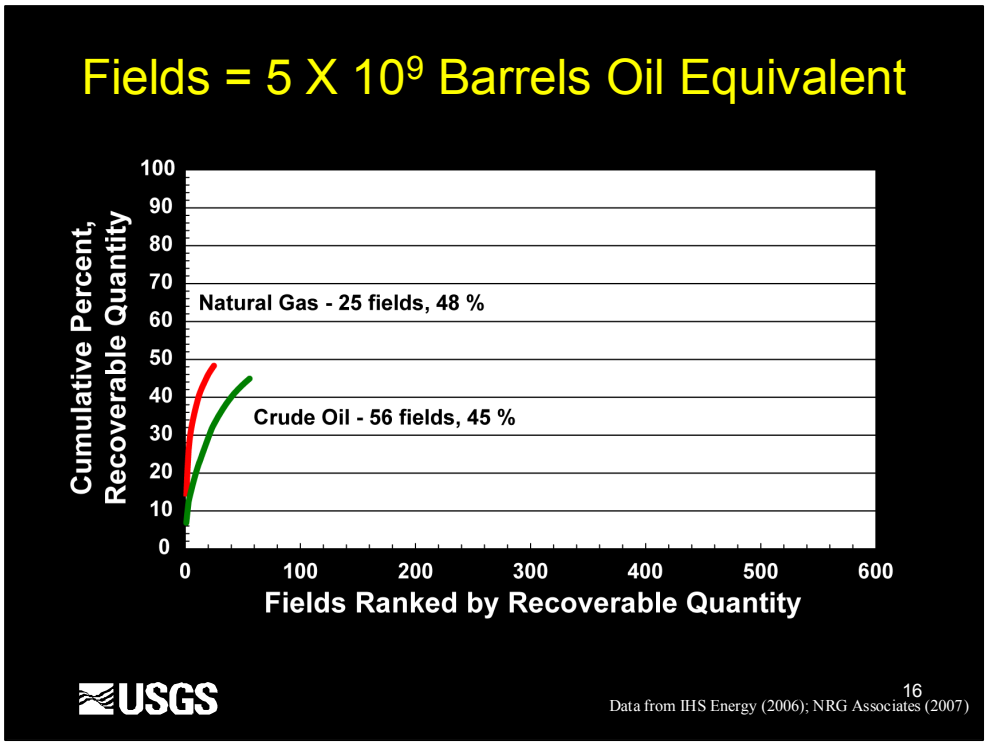
Slides 13. and 14. As a first step to resource classification, one can try to track the paths by examining individual fields. The USGS is compiling and analyzing field-history data for large oil and gas fields of the world, starting with the largest oil fields. So far, 54 of the 56 oil fields containing more than 5

billion barrels of recoverable crude oil were studied. The other two fields are aggregations of many smaller fields and are analyzed at this time.

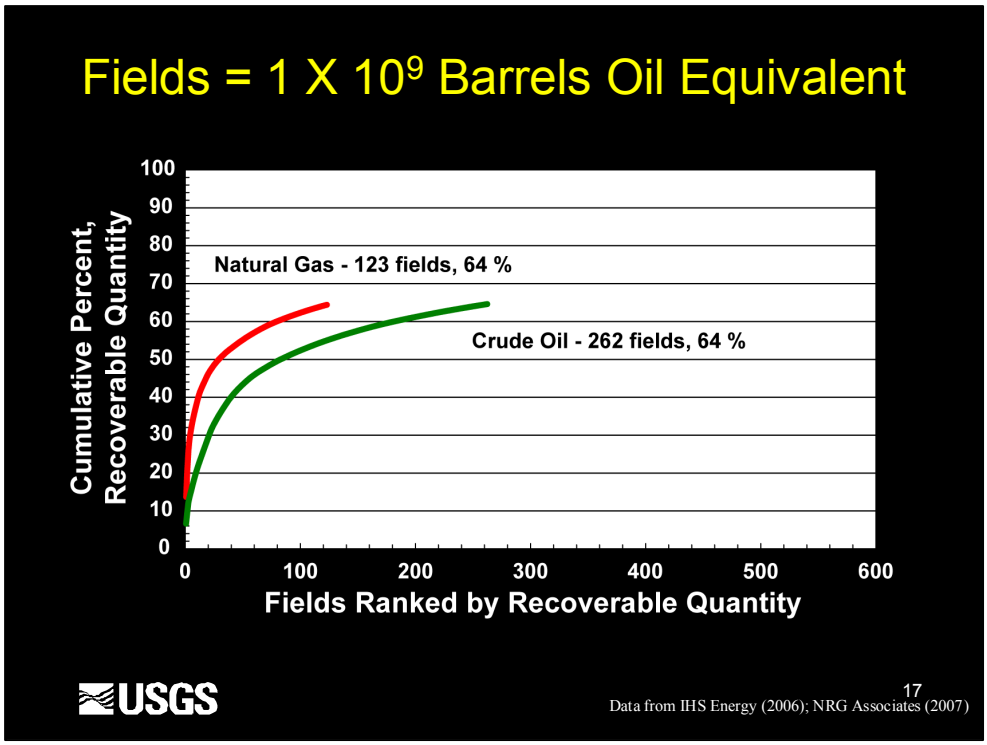
Many U.S. oil fields containing more than 500 million barrels (MMB) of recoverable crude oil, as well as several other smaller oil fields, were also studied.



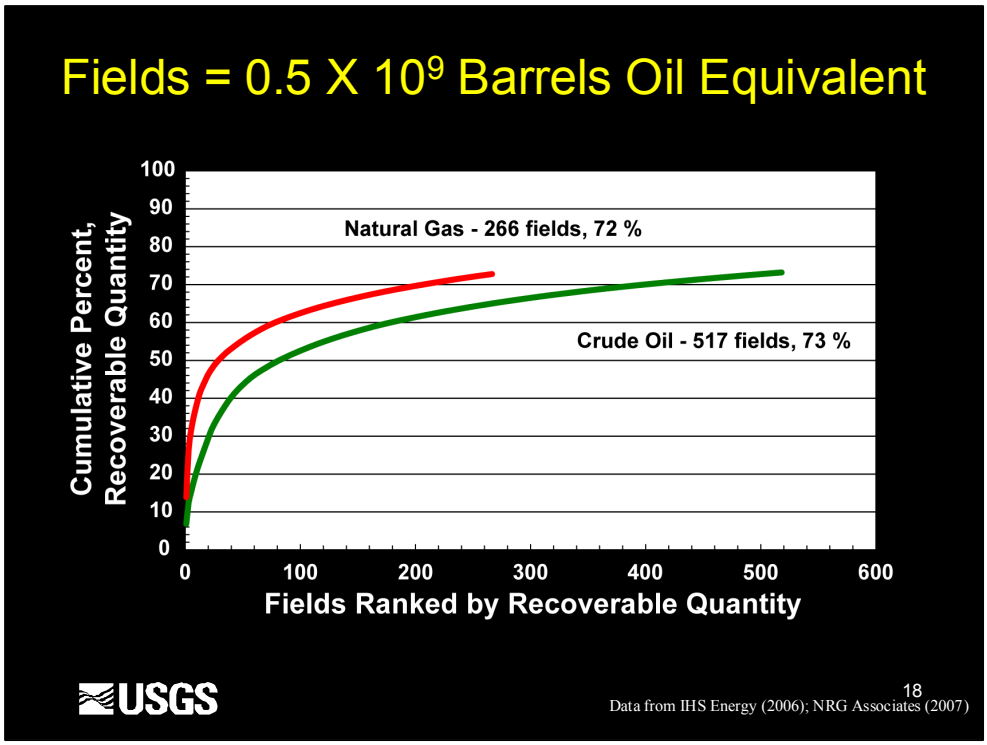
Slide 15. In order to prioritize the fields for this study, the oil and gas fields of the world were ranked by recoverable petroleum quantities. Recoverable quantity is used as a measure of field size. Fields are analyzed in order of decreasing size. This slide shows the rank of the world's fields, except for Canadian fields whereby only 165 fields are represented in this graph. In this and the next three slides, the vertical axis represents the cumulative percent of the world's known recoverable crude oil and natural gas quantities. The horizontal axis represents the fields ranked in order of decreasing recoverable quantity. The red curve represents gas fields (fields containing greater than 20,000 cubic feet of natural gas per barrel of crude oil). The green curve represents oil fields (fields containing less than 20,000 cubic feet of natural gas per barrel of crude oil). Our database contains approximately 15, 300 gas fields and 20,800 oil fields.



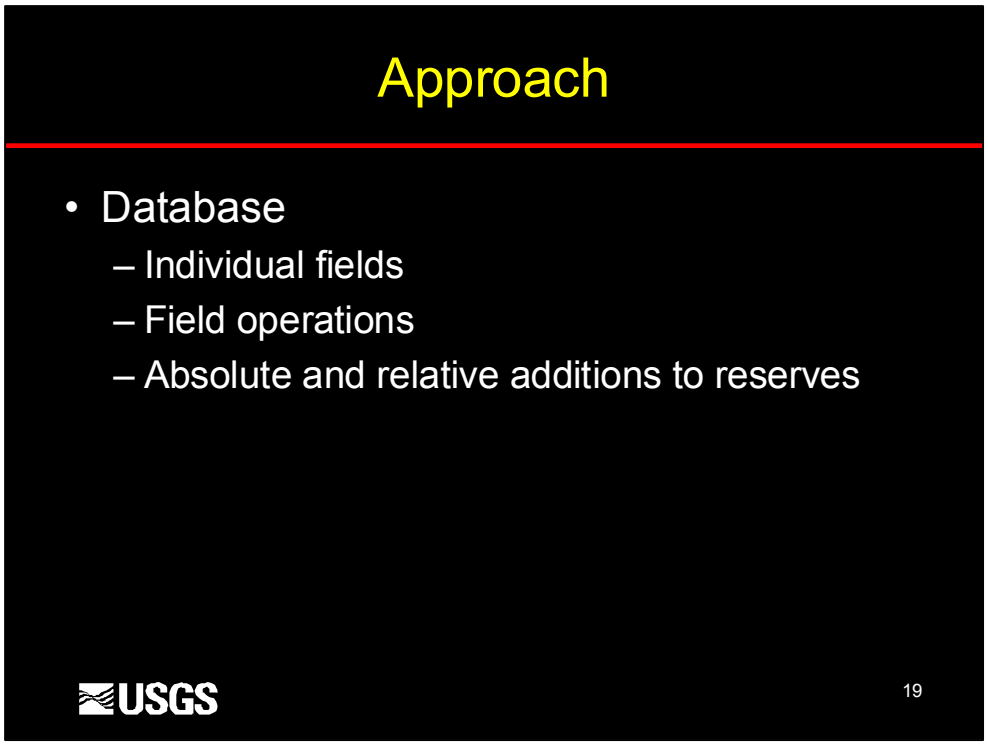
Slide 16. This slide shows the world's fields that contain greater than or equal to 5 billion barrels of crude oil equivalent (BBOE) and thus shows the oil fields we analyzed so far. The slide also shows gas fields of comparable size. The 56 oil fields shown contain approximately 45 percent of the world's known crude oil, and 25 gas fields contain approximately 48 percent of the world's known natural gas.



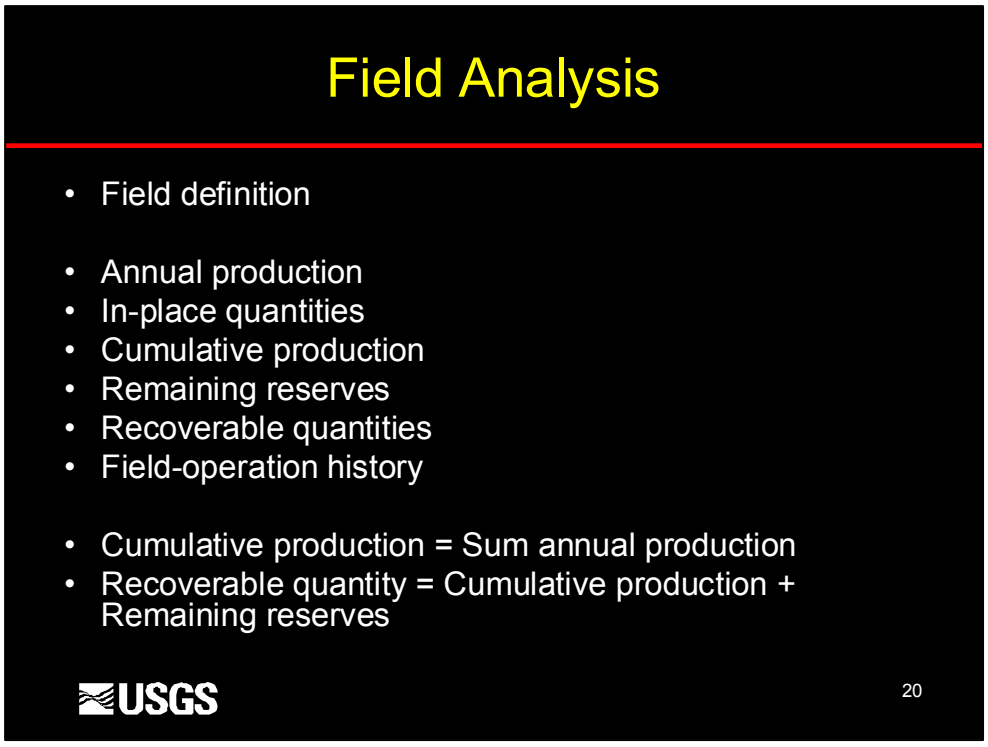
Slide 17. This slide shows fields greater than or equal to 1 BBOE. The next group of fields planned for analysis (another 206 fields) is in this population. Two hundred and sixty-two oil fields contain approximately 64 percent of the world's known crude oil and 123 gas fields contain approximately 64 percent of the world's known natural gas.



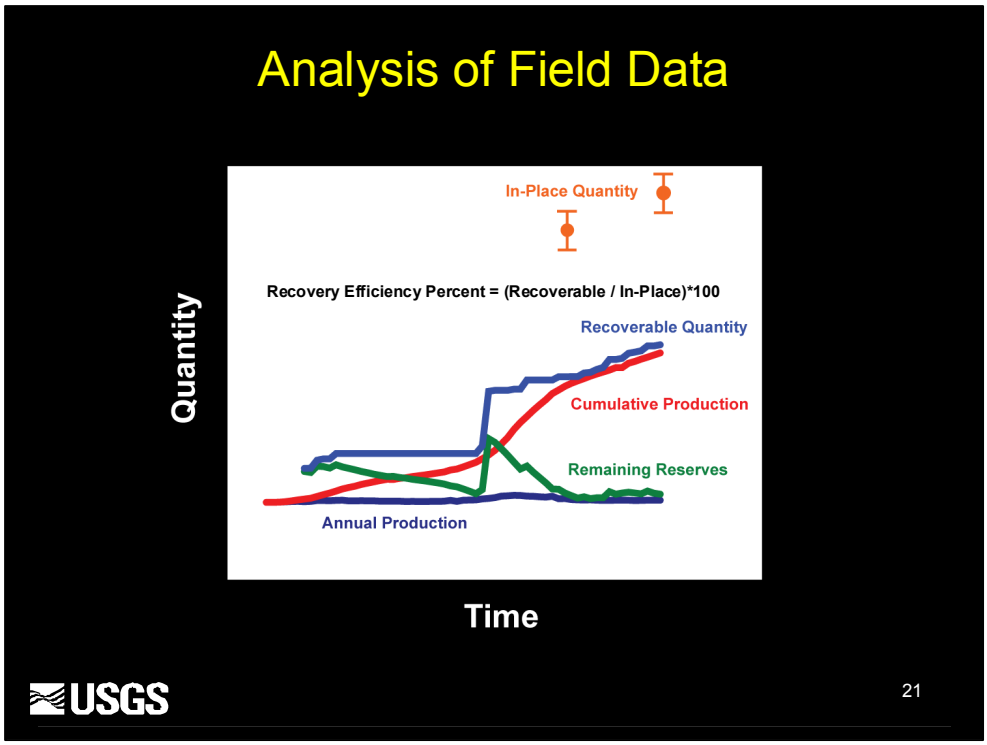
Slide 18. This slide shows fields greater than or equal to 0.5 BBOE—fields considered as giants. To evaluate this population, another 311 oil fields in addition to the 56 fields in the first group and the 206 fields in the second group will be studied. Five hundred and seventeen oil fields and 266 gas fields contain almost three-fourths of the world's known crude oil and natural gas.

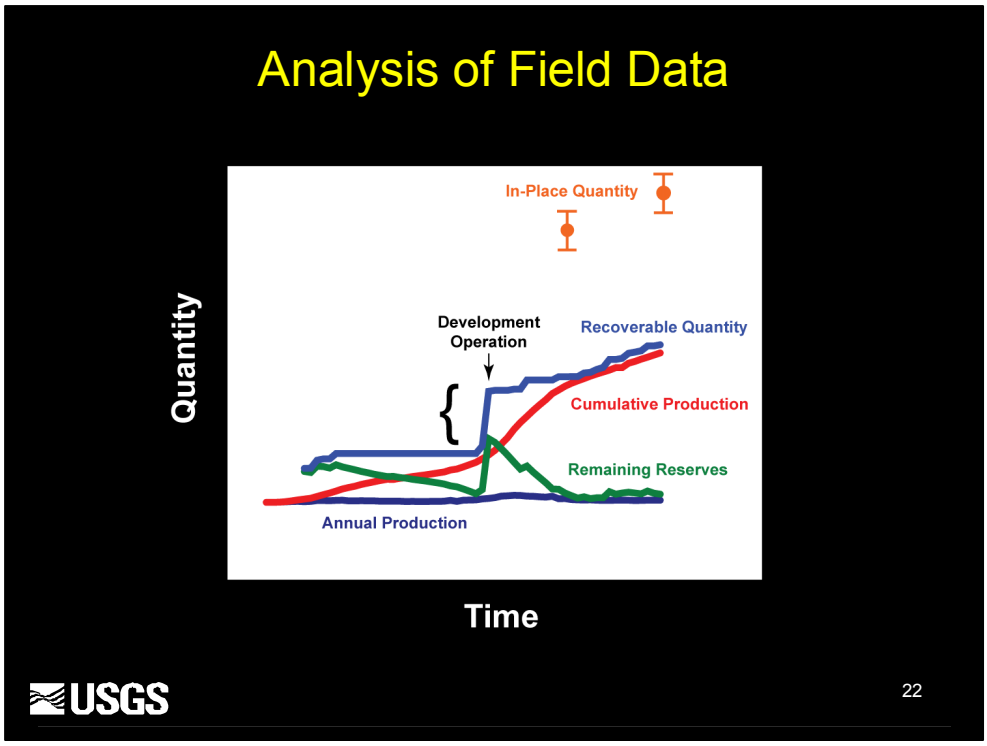


Slide 19. A database can be constructed of individual fields with field operations and associated reserve additions, as both absolute and relative quantities. Data for this study are obtained by analyzing historic estimates of production and reserves and relating these estimates to field operations.



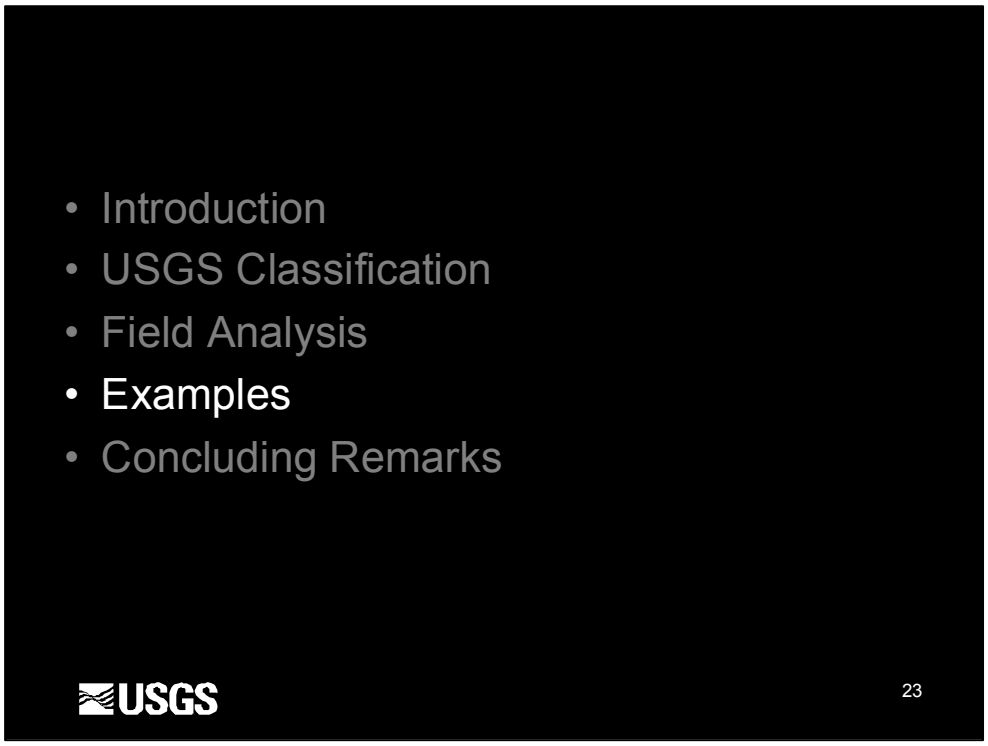
Slide 20. Production and reserve quantities are from published reports and proprietary commercial databases. These quantities include (1) annual production, (2) in-place quantities, (3) cumulative production, (4) remaining reserves, (5) recoverable quantities, and (6) field-operation history. Some quantities can be calculated from others, such as cumulative production, which is a summation of annual production. Also, recoverable quantities can be calculated by adding cumulative production and remaining reserves.

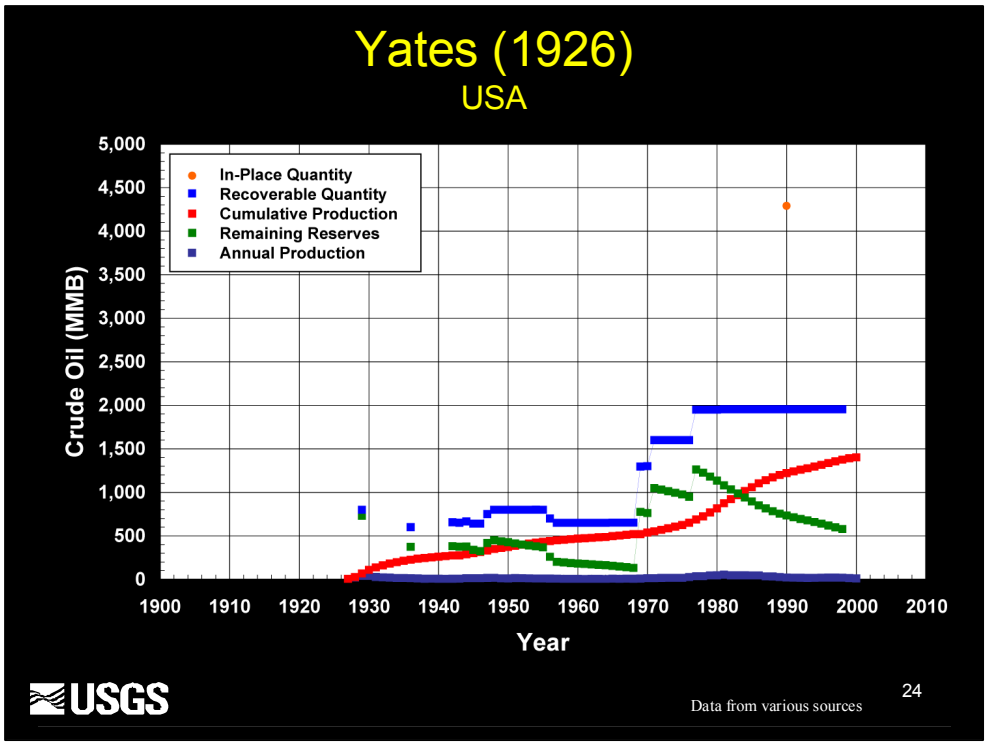


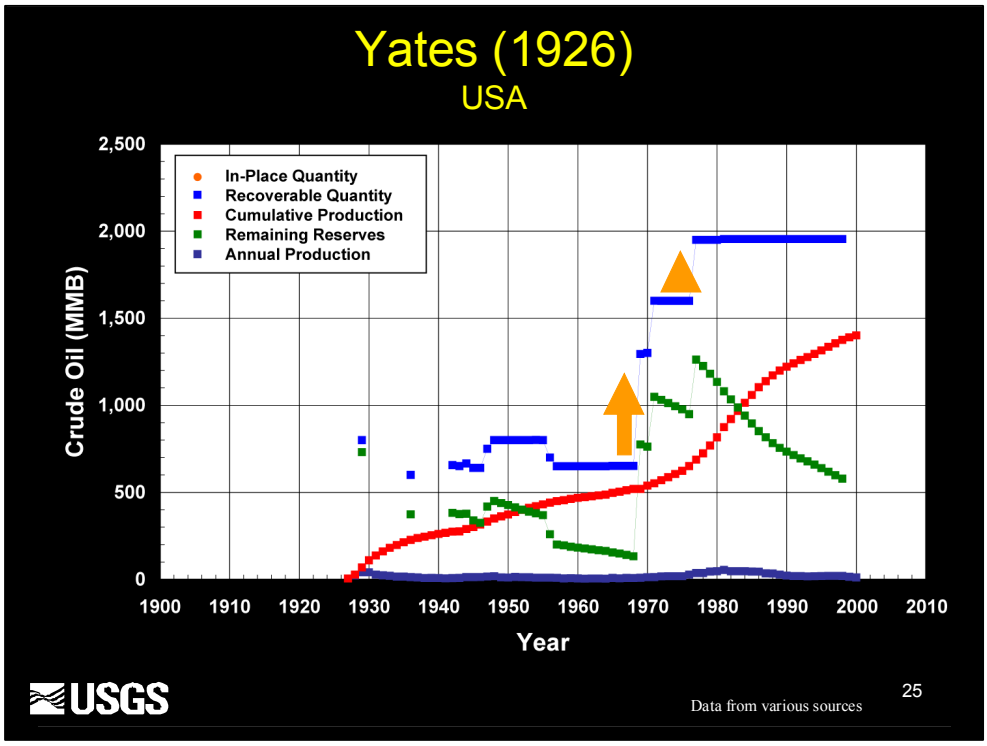


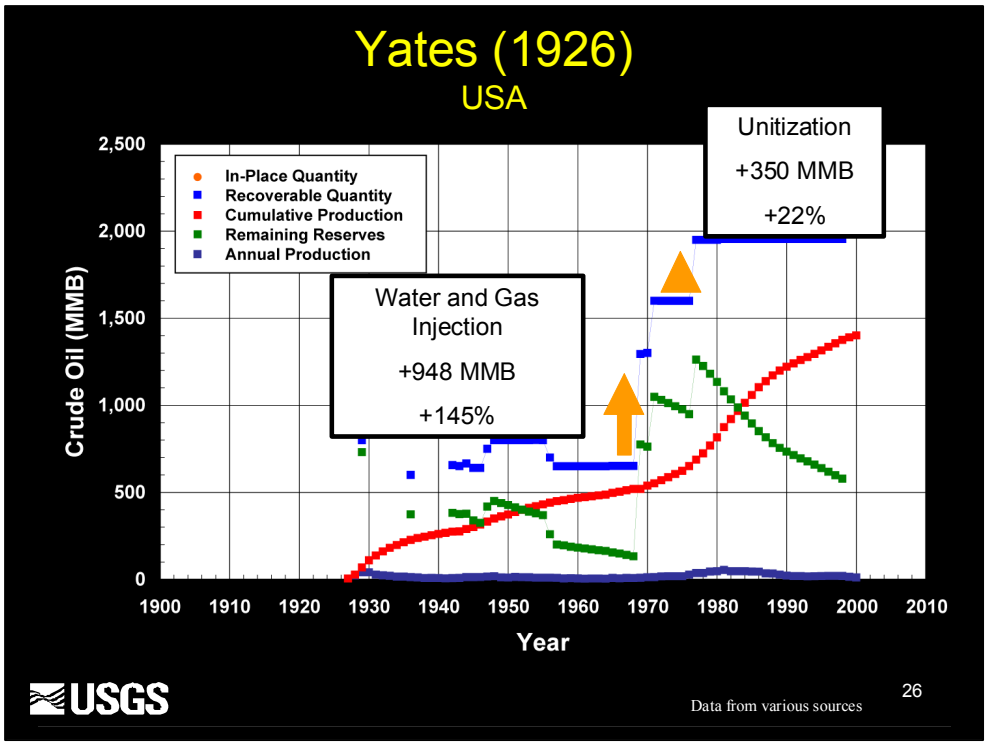
Slides 21 and 22. When plotted by time, a set of curves is generated that characterize field-development history. Data are obtained by simply measuring increases in recoverable quantities and remaining reserves, and relating these increases to an operation.

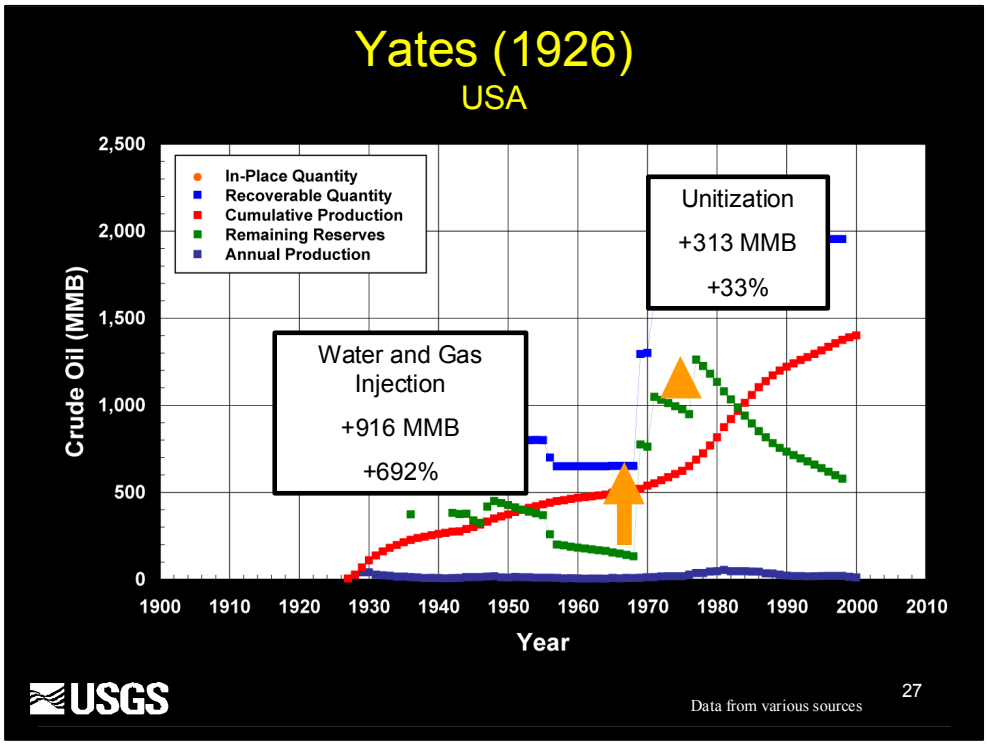
The concept of reserve growth occurs between the recoverable and in-place quantities. Recoverable quantities are used as the reference for reserve growth because reserves are components of recoverable quantities.




Yates (1926)
USA
In-Place Quantity
Recoverable Quantity
Cumulative Production
Remaining Reserves
Annual Production
Crude Oil (MMB)
5,000
4,500
4,000
3,500
3,000
2,500
2,000
1,500
1,000
500
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
USGS
Data from various sources
24


Yates (1926)
USA
In-Place Quantity
Recoverable Quantity
Cumulative Production
Remaining Reserves
Annual Production
Crude Oil (MMB)
2,500
2,000
1,500
1,000
500
0
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
Year
USGS
Data from various sources
25





Slides 23 through 27. The next several slides show an example of field-history analysis. The field-development history of the giant Yates oil field of western Texas is shown. This field was discovered in 1926. Raw data are shown to illustrate the complexity of field histories and inconsistencies

among different data sources, for example, published and commercial data. Not all increases in recoverable quantities can be related to field operations.

Annual production, cumulative production, remaining reserves, recoverable quantities, and in-place quantities are plotted. When in-place quantities are removed, the remaining quantities can be replotted at a larger scale to show more detail. Several increases in recoverable quantities and remaining reserves can be seen. Two of these increases can be related to the implementation of field-development operations. These are water and gas injection in the late 1960s and unitization in the mid-1970s. Recoverable crude oil increased by 948 MMB (145 percent) and 350 MMB (22 percent), respectively. Likewise, remaining crude oil reserves increased by 916 MMB (692 percent) and 313 MMB (33 percent), respectively. Similar observations are made on other large oil fields of the world.

Field	Years	Operation	Increase (MMB)	Increase (percent)
Marun (1964)	1986-1987	Gas injection	300	2
Umm Shaif (1958)	1993-1996	Gas injection	620	11
Zuluf (1965)	1992-1993	Capacity expansion	3360	32
Marjan (1967)	1991-1992	Capacity expansion	1774	80
Priobskoye (1982)	1992-1993	Water injection	3025	4033
Rumaila (1953)	1996-2001	Water injection	1800	8
Yates (1926)	1968-1971	Water and gas inj.	948	145
Wasson (1936)	1969-1971	In-fill drilling	830	128
Wasson (1936)	1983-1985	Carbon dioxide inj.	250	12
Slaughter-L (1936)	1975-1977	Carbon dioxide inj.	293	26

Slide 28. Data from these field analyses are tabulated and various statistics can be calculated, such as the range and mean of increases in recoverable quantities. For example, statistics can be obtained on the relative increases of gas injection versus water injection, or gas injection during the 1980s versus the 1990s.

- Introduction
- USGS Classification
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Classification of Quantities

- Quantities are assets

- Infill or development drilling – G2 and/or G3?
- Extensions and new reservoirs – E2 or E3?
- Improved recovery operations (floods, recompletions) – Combination of categories?

- USGS does not have data to answer these questions at this point in time

USGS

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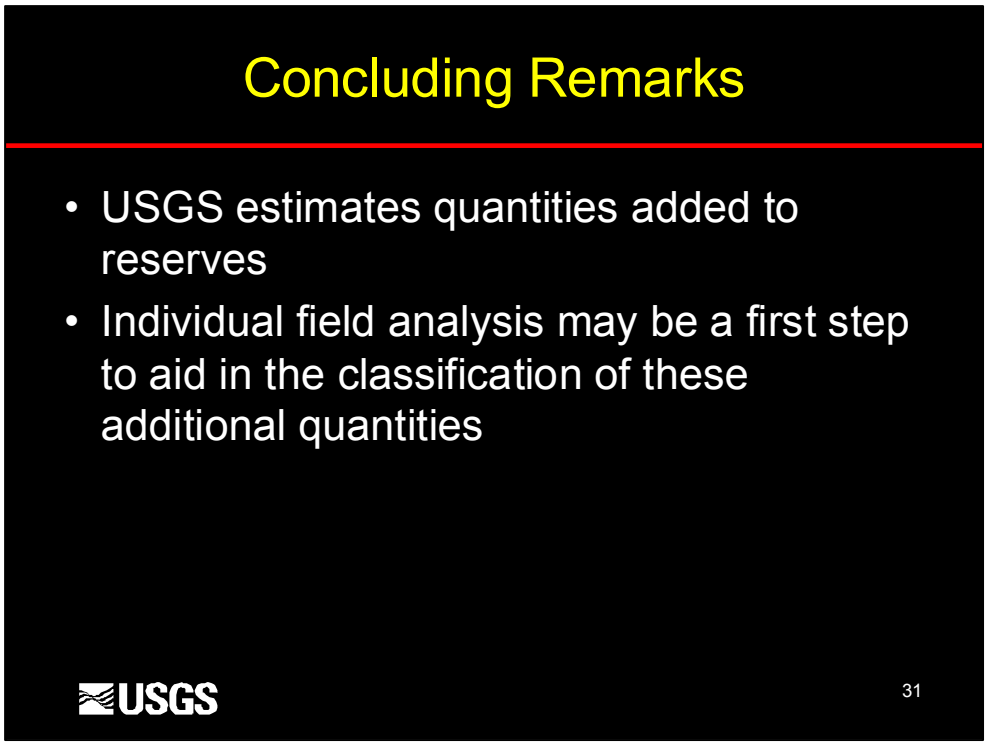
Slides 29 and 30. The volumes of petroleum that contribute to reserve additions or increases in recoverable quantities are assets. But how should these quantities be classified? Given enough information, one might presume that quantities added by infill or development drilling are from the

G2 and G3 classes (112 and 113 categories of the UNFC or possible and probable reserves of the PRMS). Likewise, one might presume that quantities added by extensions and new reservoirs are from the E2 and E3 classes (221, 222, 223, 311, 312, 313, 321, 322, and 323 categories of the UNFC or contingent resources of the PRMS). Also, one might presume that added recoverable quantities by improved recovery operations (floods, recompletions) are from a combination of the other reserve and resource categories and classes.



Slide 31. Although the USGS only broadly classifies the sources of potential reserve additions, it is responsible for estimating these quantities. Relating increases in reserve and recoverable quantities to field operations might be a first step to aid in the classification of these additional quantities.

Slide 32. Thank you for your interest.

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