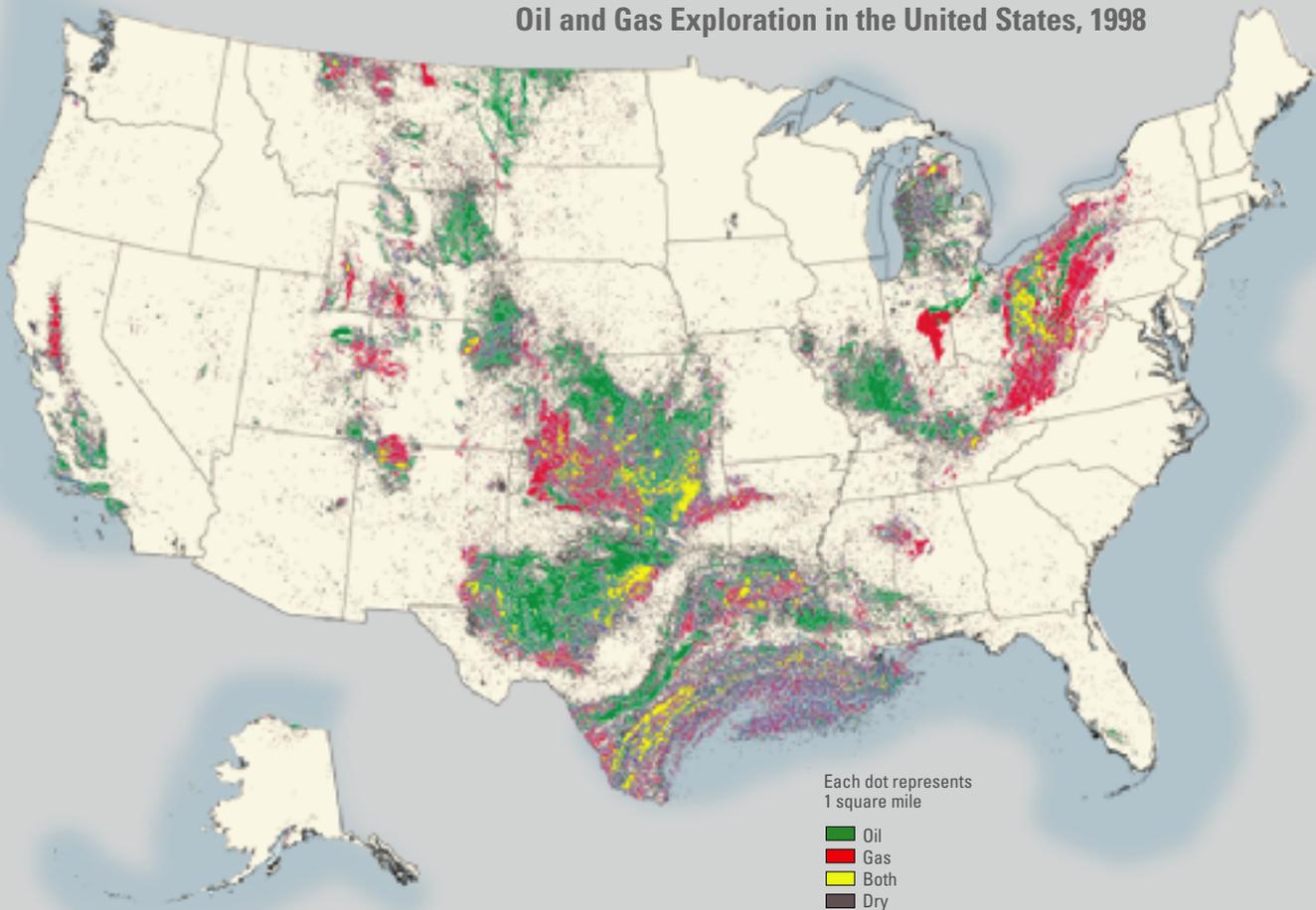


Changing Perceptions of United States Natural-Gas Resources as Shown by Successive U.S. Department of the Interior Assessments

Chapter B of
Geologic, Engineering, and Assessment Studies of Reserve Growth

U.S. Geological Survey Bulletin 2172-B

Oil and Gas Exploration in the United States, 1998



Cover. This map represents historical oil and gas exploration and production data for the conterminous United States. It was derived from data used in U.S. Geological Survey Geologic Investigations Series I-2582.* The map was compiled using Petroleum Information Corporation's (currently IHS Corporation) database of more than 2.2 million wells drilled in the U.S. as of June 1993. The area of the U.S. was subdivided into 1 mi² grid cells for which oil and gas well completion data were available. Each colored symbol represents a 1 mi² cell (to scale) for which exploration has occurred. Each cell is identified by color as follows: red, a gas-producing cell; green, an oil-producing cell; yellow, an oil- and gas-producing cell; gray, a cell that has been explored through drilling, but no production has been reported. Mast and others (1998) gives details on map construction.

*Mast, R.F., Root, D.H., Williams, L.P., Beeman, W.R., and Barnett, D.L., 1998, Areas of historical oil and gas exploration and production in the conterminous United States: U.S. Geological Survey Geologic Investigations Series I-2582, one sheet.

Changing Perceptions of United States Natural-Gas Resources as Shown by Successive U.S. Department of the Interior Assessments

By James W. Schmoker and Thaddeus S. Dyman

Chapter B of

Geologic, Engineering, and Assessment Studies of Reserve Growth

Edited by T.S. Dyman, J.W. Schmoker, and Mahendra Verma

U.S. Geological Survey Bulletin 2172–B

U.S. Department of the Interior

Gale A. Norton, Secretary

U.S. Geological Survey

Charles G. Groat, Director

Version 1.0, 2001

This publication is only available online at:
<http://geology.cr.usgs.gov/pub/bulletins/b2172-b/>

Manuscript approved for publication March 29, 2001

Published in the Central Region, Denver, Colorado

Photocomposition by Carol Quesenberry

Edited by L.M. Carter

Any use of trade, product, or firm names in this publication
is for descriptive purposes only and does not
imply endorsement by the U.S. Government

Contents

Abstract.....	1
Introduction	1
U.S. Total Gas Endowment.....	1
Gas in Undiscovered Conventional Fields.....	1
Reserve Growth	2
Conventional Fields	2
Continuous Accumulations.....	3
Percentage of Gas in the Offshore	3
Overview	4
References Cited.....	4

Figures

1-3. Histograms showing:	
1. Successive estimates of United States total technically recoverable gas endowment (cumulative production plus remaining resources)	2
2. Successive estimates (mean) of United States technically recoverable gas in undiscovered conventional fields.....	3
3. Successive estimates of United States future reserve growth of gas in known conventional fields.....	4
4. Pie diagram showing percent (by volume) of estimated United States technically recoverable gas resources in offshore and onshore as of January 1, 1994, remaining resources and total endowment	5
5. Graph showing successive estimates of percent (by volume) of United States technically recoverable gas in the offshore for future reserve growth in known conventional fields, and undiscovered conventional resources	6

Tables

1. Summary of recent U.S. Department of the Interior assessments of technically recoverable United States natural gas resources, showing volumes of gas	7
2. Summary of recent U.S. Department of the Interior assessments of technically recoverable United States natural gas resources, showing percentages of gas (by volume) in the offshore.....	8

Changing Perceptions of United States Natural Gas Resources as Shown by Successive U.S. Department of the Interior Assessments

By James W. Schmoker and Thaddeus S. Dyman

Abstract

Trends in four successive estimates of United States technically recoverable natural gas resources are examined in this report. The effective dates of these assessments were January 1 of 1975, 1980, 1987, and 1994.

The 1994 estimate of the U.S. total gas endowment increased significantly over the previous three estimates, indicating that the technically recoverable endowment of gas is not an absolute volume, but rather is a quantity that can increase through time in response to advances in technology and in geologic understanding. Much of this increase was in the category of reserve growth. Reserve growth refers to additions to the estimated ultimate recovery of fields that typically occur as discovered fields are developed and produced. The potential for U.S. reserve growth, rather than being rapidly used up, appears to be sustainable for many years by intensive engineering efforts coupled with improving technology. Potential additions to reserves in continuous (unconventional) accumulations also represent a type of reserve growth, and were estimated (for the first time) in the 1994 assessment at 358 trillion cubic feet of gas. This resource category provides a significant new contribution to the estimated U.S. total gas endowment.

Introduction

The U.S. Department of the Interior (DOI) periodically conducts geology-based assessments of the oil and natural gas resources of the United States. Four such systematic petroleum assessments have been completed since 1975 (Miller and others, 1975; Dolton and others, 1981; Mast and others, 1989; Gautier and others, 1995, together with Minerals Management Service, 1996). For the first and second assessments, the U.S. Geological Survey (USGS) was responsible for the entire United States. For the third and fourth assessments, the USGS was responsible for onshore areas and State waters of the United States, and the Minerals Management Service (MMS) was responsible for the Federal Offshore.

This report considers the natural gas components of these assessments. Because a core of procedures and tenets was retained from one assessment to the next, changes through time in perceptions of the U.S. gas resource base can be attributed in large part to evolving technology and improved scientific understanding.

In this report, the four successive estimates of the Nation's technically recoverable natural gas resources are summarized in tables 1 and 2. Trends in the successive gas-resource estimates are examined, with a view toward better understanding the U.S. gas resource base in the context of the next few decades.

U.S. Total Gas Endowment

The first three DOI estimates of the U.S. endowment of technically recoverable total gas (cumulative production plus remaining resources, which are the sum of proved reserves, reserve growth, undiscovered conventional resources, and potential additions to reserves in continuous (unconventional) accumulations) were 1,404, 1,542, and 1,403 trillion cubic feet of gas (tcf), respectively (fig. 1). Note that these three studies did not specifically include continuous gas resources as a separate resource-assessment category.

The differences among these first three estimates are regarded as relatively minor, given the uncertainties associated with long-range petroleum assessments. Thus, the DOI assessments prepared during the 1970's and 1980's suggest a more or less fixed U.S. total gas endowment of 1,400 to 1,500 tcf, of which almost one-half had been produced by 1987 (table 1).

Against this background, the 1994 estimate of the U.S. total gas endowment increased significantly to 2,230 tcf (fig. 1). This increase is interpreted here as indicative of a growing realization that the technically recoverable endowment of total gas is not an absolute volume, but rather is a quantity that can increase through time in response to advances in technology and in geologic understanding. This point is illustrated by the fact that continuous accumulations were assessed as a separate resource category by the USGS in their 1994 assessment of U.S. onshore areas and State waters (Gautier and others, 1995).

Continuous accumulations are defined as deposits that are not localized by the buoyancy of gas in water; they lack well-defined down-dip water contacts and thus include such diverse types of gas accumulations as tight gas, coal-bed gas, gas in shales and chinks, and basin-center gas (U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995). In contrast, conventional fields are considered to be discrete, countable deposits floating bubble-like in water, and delineated by down-dip water contacts.

Gas in Undiscovered Conventional Fields

The four successive DOI assessments of technically recoverable gas in U.S. undiscovered conventional fields range from 399 to 594 tcf (fig. 2). No systematic variation in these estimates is apparent. In view of the large uncertainties associated with any forecast of undiscovered petroleum resources, the four DOI assessments are interpreted here as being in general agreement and indicating that roughly 500 tcf of gas remains to be discovered in conventional fields (fig. 2). The large increase in

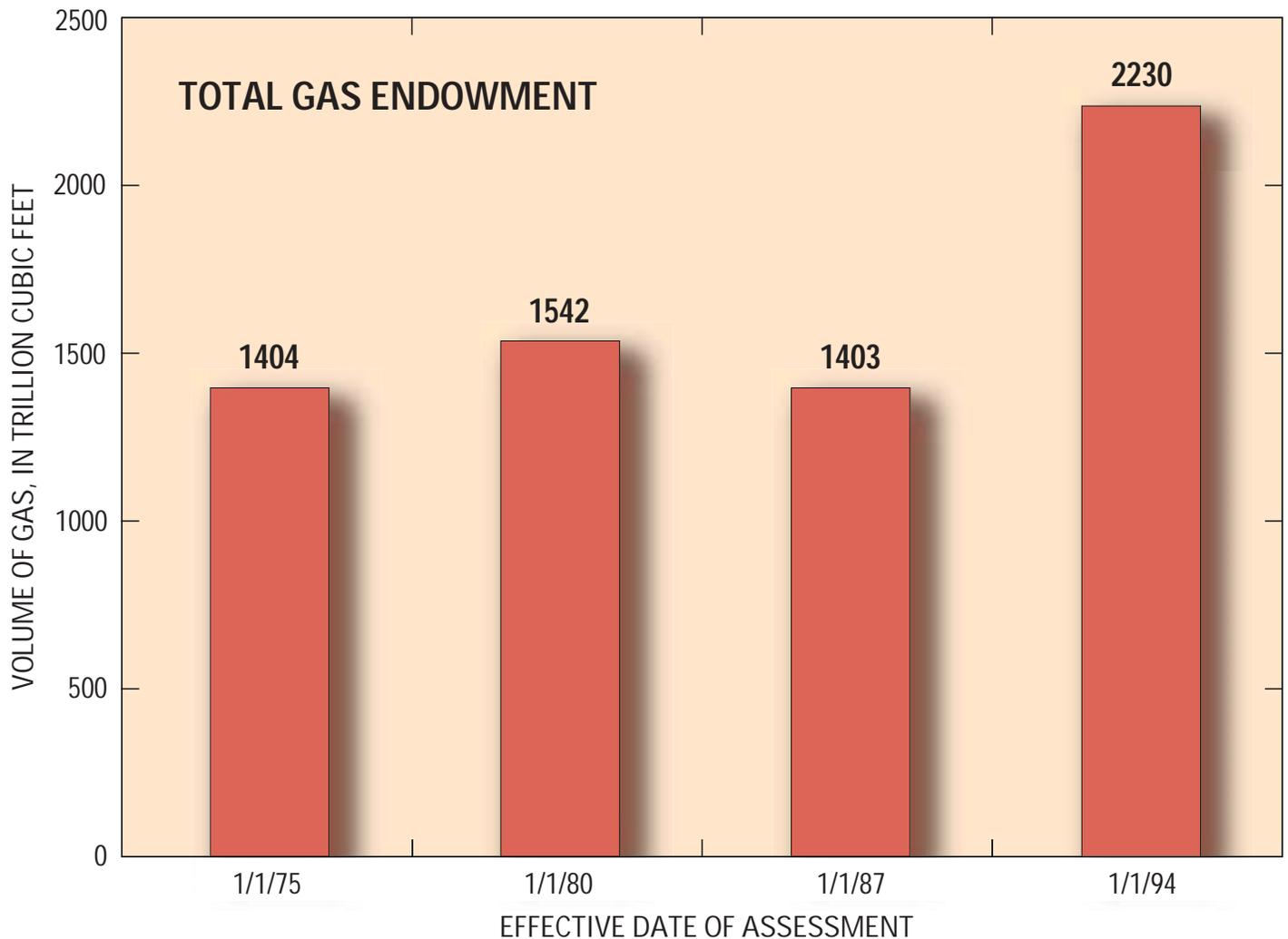


Figure 1. Successive estimates of United States total technically recoverable gas endowment (cumulative production plus remaining resources). Data are from table 1.

the 1994 estimate of the U.S. total gas endowment, noted in the previous section (fig. 1), is not the result of abruptly heightened optimism regarding the sizes or numbers of undiscovered conventional gas fields.

Imbedded in the observation that the volume of undiscovered conventional gas remained approximately constant through four assessments spanning two decades is the implication that the U.S. inventory of undiscovered conventional gas is being replenished. In order to maintain a constant volume of undiscovered gas over a period of time, fields removed from the undiscovered category by drilling must be replaced by new exploration plays and prospects, and (or) estimated sizes of remaining undiscovered fields must be increased.

Reserve Growth

Conventional Fields

The term “reserve growth,” which is synonymous with “field growth,” refers to the increases in estimated ultimate

recovery that typically occur as discovered fields are developed and produced. Successive DOI estimates of the future reserve growth of gas in U.S. known (discovered) conventional fields are shown in category 3 of table 1.

The first three reserve-growth estimates decreased from 202 tcf to 178 tcf to 99 tcf, successively (fig. 3). These declining estimates are consistent with the idea of an ongoing transfer of gas resources out of the category of future reserve growth and into the category of proved reserves, with little replenishment of the initial reserve-growth volume.

In the fourth assessment, however, estimated U.S. future reserve growth of gas in conventional fields increased by a factor of 3.6, from 99 tcf to 361 tcf. This considerably more optimistic outlook for reserve growth of conventional fields (fig. 3) accounts for almost one-third of the increase in the 1994 forecast of U.S. total gas endowment (fig. 1). The 1994 reserve-growth estimate appears to incorporate a paradigm shift, in which the reserve-growth potential of U.S. discovered conventional fields is not necessarily rapidly used up, but rather can be partially sustained for many years by intensive engineering efforts coupled with advancing technology.

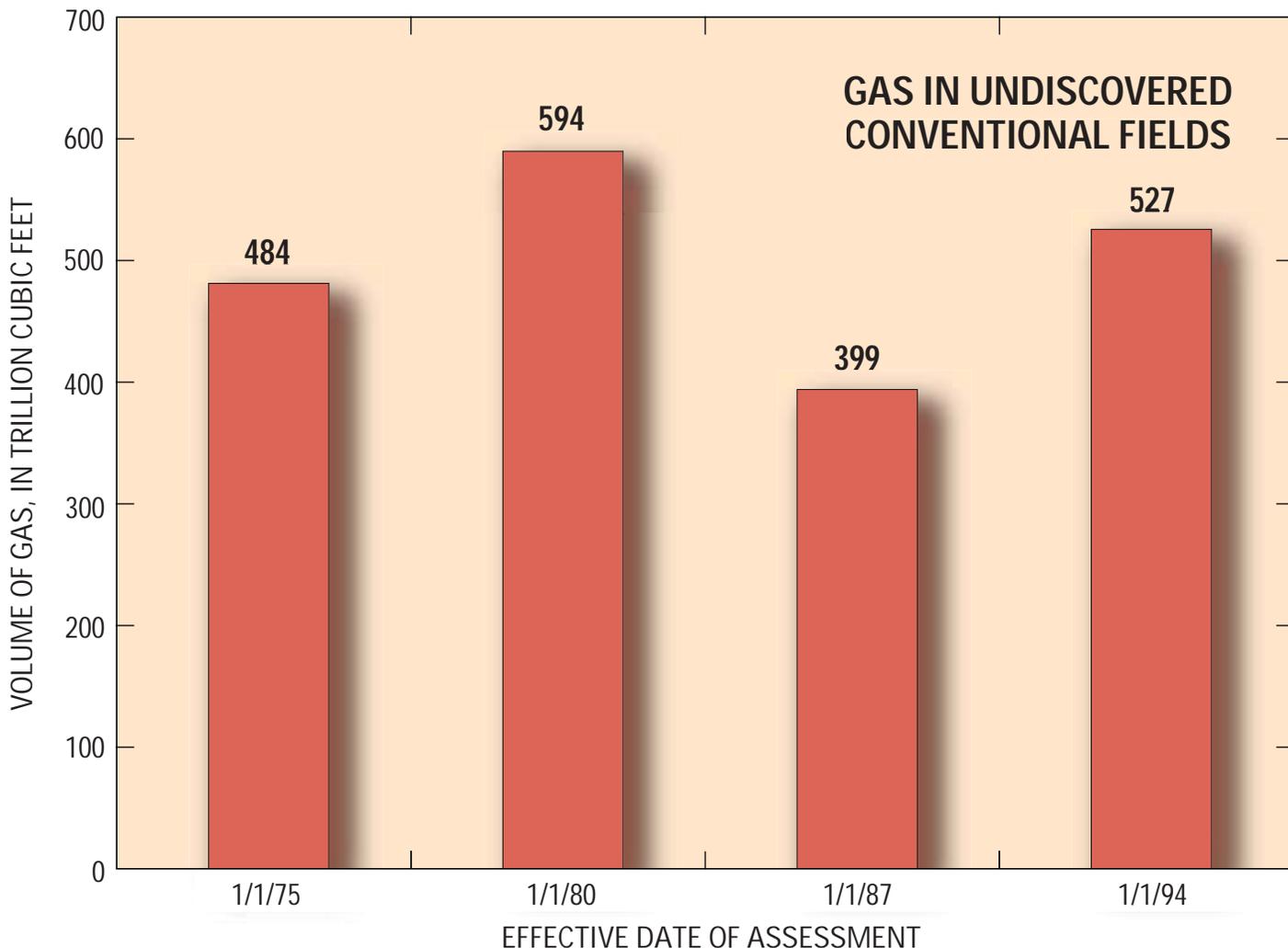


Figure 2. Successive estimates (mean) of United States technically recoverable gas in undiscovered conventional fields. Data are from table 1.

Continuous Accumulations

The existence and location of most of the continuous gas accumulations assessed in 1994 were known. The resource estimate of 358 tcfg made in 1994 for this category (table 1) thus does not represent “undiscovered” gas in the sense of undiscovered conventional accumulations, nor is it exactly the same as “reserve growth” of discovered conventional fields. Because of this blurring of resource categories, future resources in continuous accumulations are termed “potential additions to reserves” in table 1.

The systematic development of a continuous accumulation is similar in concept to the infill drilling of an areally large conventional field. Because of this analog, it is reasonable to think of the potential additions to reserves in continuous accumulations as representing a type of reserve growth.

This idea is incorporated into figure 3, which combines the estimates made in 1994 for future reserve growth in known conventional fields (361 tcfg) and for potential additions to reserves in continuous accumulations (358 tcfg) into a single reserve-growth column totaling 719 tcfg. Considered in this

manner, continuous gas accumulations in onshore areas of the United States were seen in the 1994 assessment as contributing significantly to U.S. future reserve growth; their estimated contribution approximately equals that of the reserve growth of conventional fields.

Percentage of Gas in the Offshore

The conditions, requirements, and economics for petroleum-related activities vary substantially between offshore and onshore areas of the United States. For these reasons, the offshore components of the four recent DOI assessments of U.S. natural gas resources are of interest and are shown in table 2 as percentages (by volume) of U.S. totals.

As of January 1, 1994, 24 percent of remaining U.S. gas resources and 20 percent of the U.S. total gas endowment were estimated to reside in offshore accumulations (fig. 4). These percentages were much the same in each of the three previous assessments (categories 6 and 7 of table 2).

Counterbalancing trends are evident in two of the components that make up the category of remaining gas resources (by

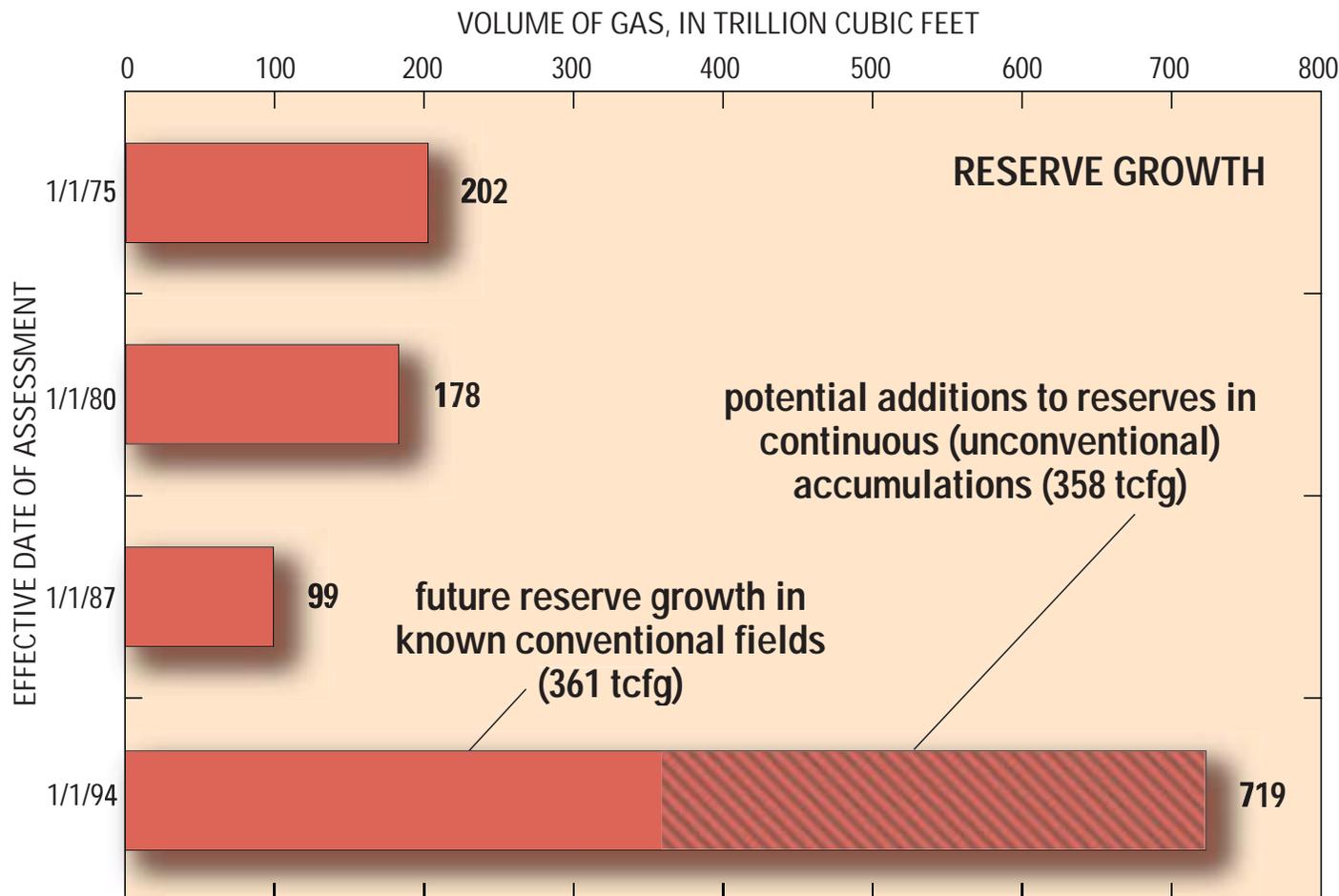


Figure 3. Successive estimates of United States future reserve growth of gas in known conventional fields. Potential additions to reserves in continuous accumulations also represent a type of reserve growth. Data are from table 1.

percent) in the offshore (fig. 5). The estimated percent of undiscovered conventional U.S. gas resources in offshore accumulations increased systematically from 22 percent to 51 percent in the four successive assessments, whereas the estimated percent of U.S. future reserve growth of gas in discovered conventional offshore fields decreased from 34 percent in the first assessment to 6 percent in 1987 and 11 percent in 1994 (fig. 5). In other words, the remaining U.S. potential for undiscovered gas is increasingly in the offshore, whereas the remaining potential for reserve growth is increasingly onshore. Both trends indicate that the exploration maturity of onshore gas provinces of the United States was increasing relative to the offshore during the time period spanned by these assessments.

Overview

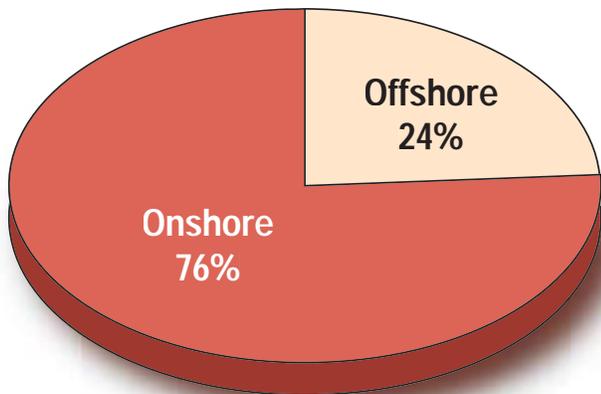
Each of the four successive Department of the Interior petroleum-resource assessments examined here presents a numerical hypothesis for the U.S. natural gas resource base as comprehended at a particular point in time. As technology and scientific understanding evolved, these numerical hypotheses

changed (tables 1 and 2). In the future, the continuing advancement of technology and improvement in scientific understanding will call for further periodic assessments of U.S. gas resources.

References Cited

- Dolton, G.L., Carlson, K.H., Charpentier, R.R., Coury, A.B., Crovelli, R.A., Frezon, S.E., Khan, A.S., Lister, J.H., McMullin, R.H., Pike, R.S., Powers, R.B., Scott, E.W., and Varnes, K.L., 1981, Estimates of undiscovered recoverable conventional resources of oil and gas in the United States: U.S. Geological Survey Circular 860, 87 p.
- 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].
- Mast, R.F., Dolton, G.L., Crovelli, R.A., Root, D.H., Attanasi, E.D., Martin, P.E., Cooke, L.W., Carpenter, G.B., Pecora, W.C., and Rose, M.B., 1989, Estimates of undiscovered conventional oil and gas resources in the United States—A part of the Nation's energy endowment: United States Geological Survey and Minerals Management Service, 44 p.

A. REMAINING GAS RESOURCES



Miller, B.M., Thomsen, H.L., Dolton, G.L., Coury, A.B., Hendricks, T.A., Lennartz, F.E., Powers, R.B., Sable, E.G., and Varnes, K.L., 1975, Geological estimates of undiscovered recoverable oil and gas resources in the United States: U.S. Geological Survey Circular 725, 78 p.

Minerals Management Service, 1996, An assessment of the undiscovered hydrocarbon potential of the Nation's Outer Continental Shelf: OCS Report MMS 96-0034, 40 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.

B. TOTAL GAS ENDOWMENT

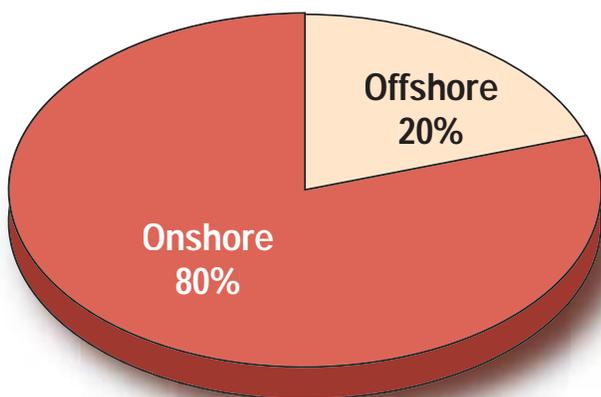


Figure 4. Percent (by volume) of estimated United States technically recoverable gas resources in offshore and onshore areas as of January 1, 1994. *A*, Remaining resources. *B*, Total endowment. Figure is derived from data of table 2.

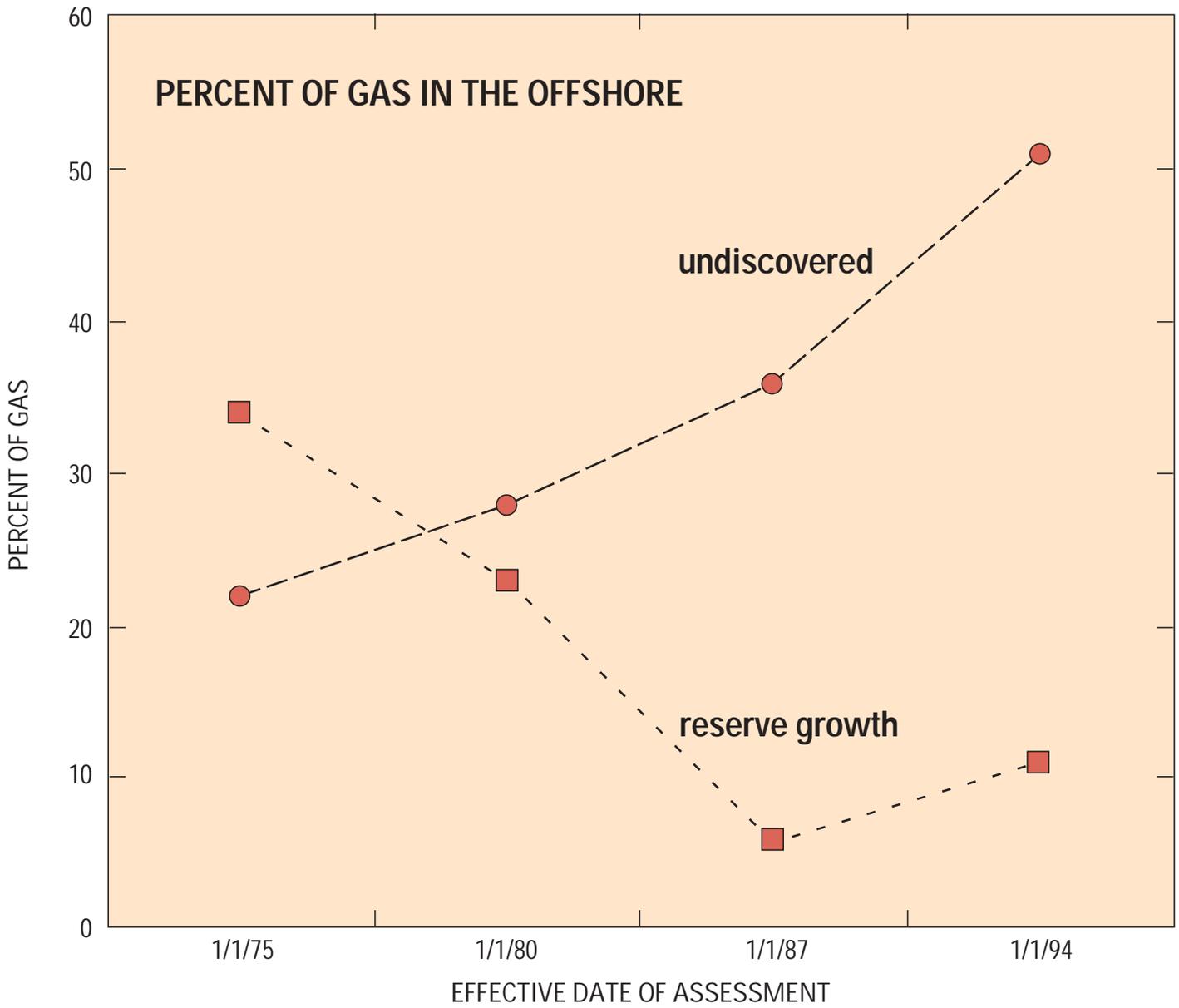


Figure 5. Successive estimates of percent (by volume) of United States technically recoverable gas in the offshore, for (1) future reserve growth in known conventional fields, and (2) undiscovered conventional resources. Data are from table 2.

Table 1. Summary of recent U.S. Department of the Interior assessments of technically recoverable United States natural gas resources, showing volumes of gas.

[Data from Miller and others, 1975; Dolton and others, 1981; Mast and others, 1989; Gautier and others, 1995; Minerals Management Service, 1996. NA, not assessed; tcfg, trillion cubic feet of gas; conv. res., conventional resources. Effective dates of the fourth assessment are 1/1/94 for onshore areas and State waters, and 1/1/95 for the Federal Offshore; for simplicity, the earlier date is used in this report]

Category	Volume of U.S. gas (tcfg) Effective date of assessment			
	1/1/75	1/1/80	1/1/87	1/1/94
1. Cumulative production	481	578	698	818
2. Proved reserves	237	192	207	166
3. Future reserve growth in known conv. fields	202	178	99	361
4. Undiscovered conv. res. (mean)	484	594	399	527
5. Potential additions to reserves in continuous (unconventional) accumulations, including coal-bed gas (mean)	NA	NA	NA	358
6. Yet-to-be produced resources (categories 2 through 5)	923	964	705	1,412
7. U.S. total endowment (categories 1 through 5)	1,404	1,542	1,403	2,230

Table 2. Summary of recent U.S. Department of the Interior assessments of technically recoverable United States natural gas resources, showing percentages of gas (by volume) in the offshore.

[Data from Miller and others, 1975; Dolton and others, 1981; Mast and others, 1989; Gautier and others, 1995; Minerals Management Service, 1996. Percentages are calculated from data provided in cited sources; conv. res., conventional resources. Effective dates of the fourth assessment are 1/1/94 for onshore areas and State waters, and 1/1/95 for the Federal Offshore; for simplicity, the earlier date is used in this report. For the first two assessments, the offshore includes both State and Federal waters; for the third and fourth assessments, the offshore includes only Federal waters]

Category	Percent of U.S. gas (by volume) in the offshore			
	Effective date of assessment			
	1/1/75	1/1/80	1/1/87	1/1/94
1. Cumulative production	7	10	11	14
2. Proved reserves	15	20	24	19
3. Future reserve growth in known conv. fields	34	23	6	11
4. Undiscovered conv. res. (mean)	22	28	36	51
5. Potential additions to reserves in continuous (unconventional) accumulations, including coal-bed gas (mean)	(continuous accumulations not yet assessed in offshore)			
6. Yet-to-be produced resources (categories 2 through 5)	23	26	28	24
7. U.S. total endowment (categories 1 through 5)	17	20	20	20