Chapter G

Relative Uncertainty of Conventional Natural Gas Plays in the Gulf Coast Region

By Thaddeus S. Dyman, James W. Schmoker, *and* Christopher J. Schenk

Prepared in cooperation with the U.S. Department of Energy–National Energy Technology Laboratory, the Gas Technology Institute, and Advanced Resources International

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

Contents

Figures

Tables

Relative Uncertainty of Conventional Natural Gas Plays in the Gulf Coast Region

By Thaddeus S. Dyman, James W. Schmoker, *and* Christopher J. Schenk

Introduction

In 1995, the U.S. Geological Survey assessed undiscovered conventional and continuous-type (unconventional) oil and gas resources for 560 plays in 71 U.S. provinces in onshore regions and State offshore waters. This assessment was based on a geologic analysis of plays using probabilistic methodologies. Assessments such as this are inherently dependent on varying degrees of uncertainty associated with a geologic understanding of petroleum provinces and plays and the perceptions and levels of experience of province geologists. Uncertainty in natural gas assessments is the focus of this report.

Uncertainty in petroleum resource estimates can be subdivided into five broad areas:

1. *Compiling geologic and production data at the province level*. Uncertainty may arise from a lack of data concerning the geologic history and production characteristics of the province.

2. *Identifying and describing petroleum plays.* Uncertainty may also be due to limited data on the nature of petroleum plays in each province. The experience and perceptions of the province geologist play an important part in uncertainty associated with the petroleum geology at both province and play levels. Some province geologists tend to identify fewer, large plays, whereas others tend to identify a larger number of smaller plays.

3. *Risking plays.* Hypothetical plays (those plays lacking known production) must be risked for the presence of undiscovered accumulations. Uncertainty is expressed by using a risking structure that incorporates three play attributes: charge, reservoir, and trap, where the probability of occurrence of each of the attributes is expressed as a decimal fraction from zero to one. The product of the three values is the play probability. Uncertainty arises due to the geologist's viewpoint, lying on the continuum from conservative to liberal in risking hypothetical plays.

4. *Estimating the sizes, numbers, and types of undiscovered accumulations.* Numerous techniques are employed to make these estimates including historic field-size analysis, reservoir-simulation modeling, discovery-process modeling, use of analogs, and spatial analysis (U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995). Each of these techniques introduces uncertainty in the resource estimation process.

5. *Aggregating estimates.* To estimate undiscovered resources for provinces, regions, and the Nation, probability distributions representing estimates for plays must be progressively aggregated with geologic dependencies incorporated at each level of aggregation. Aggregating play estimates requires knowledge of geologic dependencies between plays for the three attributes of charge, reservoir, and trap. Uncertainty is introduced when province geologists determine the correlation of each attribute for each set of plays in a province. A high correlation (0.9), a medium correlation (0.5), and a low correlation (0.1) were used in the U.S. Geological Survey 1995 National Oil and Gas Resource Assessment (U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995).

Analysis of these five areas of uncertainty provides insight into how resource assessments are conducted and helps answer important questions, such as the following: Are the play estimates of some province geologists more uncertain than the estimates of others? Can we define quantitative measures that capture uncertainty? Can we rank plays in an assessment based on their relative uncertainty? Can we identify the relative degree of uncertainty in plays with specific geologic and production characteristics?

The purpose of this report is to analyze uncertainty in estimates for undiscovered natural gas resources for the 61 conventional nonassociated gas-bearing plays of the Gulf Coast Region in the U.S. Geological Survey 1995 National Petroleum Assessment. The results of our analysis will help us to better understand the assessment process and to prioritize those Gulf Coast Region gas plays that may need to be reevaluated or reassessed based on new data and perceptions since the completion of the 1995 assessment.

The Gulf Coast Region was important to the U.S. Geological Survey in 1995 because it contains a significant undiscovered conventional gas resource. The region contains a mean estimated resource of 97.6 Tcf (trillion cubic feet) of recoverable conventional gas, which represents nearly 38 percent of the gas resource for U.S. onshore regions and State offshore waters. Only one continuous-type (unconventional) gas play, the Cotton Valley Blanket Sandstones Play of the Louisiana-Mississippi Salt Basins Province (No. 4923) was assessed contributing a mean estimated resource of 6 Tcf of gas (U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995; Gautier and others, 1996).

Many nonassociated gas plays in the Gulf Coast Region are also deep. Dyman and others (1996) identified 44 of 61 total Gulf Coast Region plays as deep (all or portion of play equal to or exceeding 15,000 feet/4,572 m in depth). These deep plays account for a mean resource of 27.4 Tcf of undiscovered conventional technically recoverable nonassociated gas. This estimate is about 10 percent of the entire estimated undiscovered nonassociated gas resource for the U.S. (258.6 Tcf of gas) (U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995). A better understanding of

the geologic characteristics and resource potential of these Gulf Coast Region deep gas plays may lead to a better understanding of deep natural gas resources in general.

This report was funded by the U.S. Department of Energy–National Energy Technology Laboratory (NETL), Morgantown, W.Va. (contract No. DE-AT26-98FT40032), the Gas Research Institute (GRI), Chicago, Ill., through a Cooperative Research and Development Contract with Advanced Resources International, Arlington, Va. (contract No. 50942103366), and the U.S. Geological Survey. We wish to acknowledge the helpful reviews of Vito Nuccio of the U.S. Geological Survey, Denver, Colo., and Vello Kuuskraa, Advanced Resources International, Arlington, Va.

Methodology

We introduce a dimensionless uncertainty coefficient (UC) to compare the relative uncertainty of undiscovered resource volumes of plays. The uncertainty coefficient is defined as

$$UC = (F_5–F_{95}) \ /MEAN$$

where F_5 and F_{95} are fractiles of a probability distribution representing the estimate of undiscovered nonassociated gas for each gas-bearing play, and MEAN represents the mean estimate. F_{95} represents a 19-in-20 chance and F_5 represents a 1-in-20 chance of the occurrence of at least the resource amount identified. Use of the uncertainty coefficient is based on the assumption that the fractile range of the undiscovered resource for each play probability distribution (F_5–F_{95}) incorporates all areas of uncertainty that may be introduced into the assessment process. A large range in probability represents a relatively high level of uncertainty, whereas a small range represents a relatively low level of uncertainty. Two cumulative probability distributions are identified in figure 1. They represent a large and a small range of probabilities (F_5–F_{95}), curves A and B respectively, for estimates of undiscovered technically recoverable conventional resources for two example plays. In order to eliminate the effects of magnitude of the resource for each example play, the range is divided by the mean of the probability distribution to define a dimensionless uncertainty coefficient. A similar coefficient is defined by (F_5–F_{95})/F_{50}, but was not used in this report because for many plays in the USGS 1995 assessment, F_{50}=0. Thus, a ranking of uncertainty coefficients for plays represents a relative ranking of play uncertainty based on use of undiscovered gas resource volumes which can be used for establishing priorities for play reevaluation and for assessment planning activities. The play ranking and uncertainty are based on an interpretation of factual data by geologists and engineers using their best interpretive skills and experience.

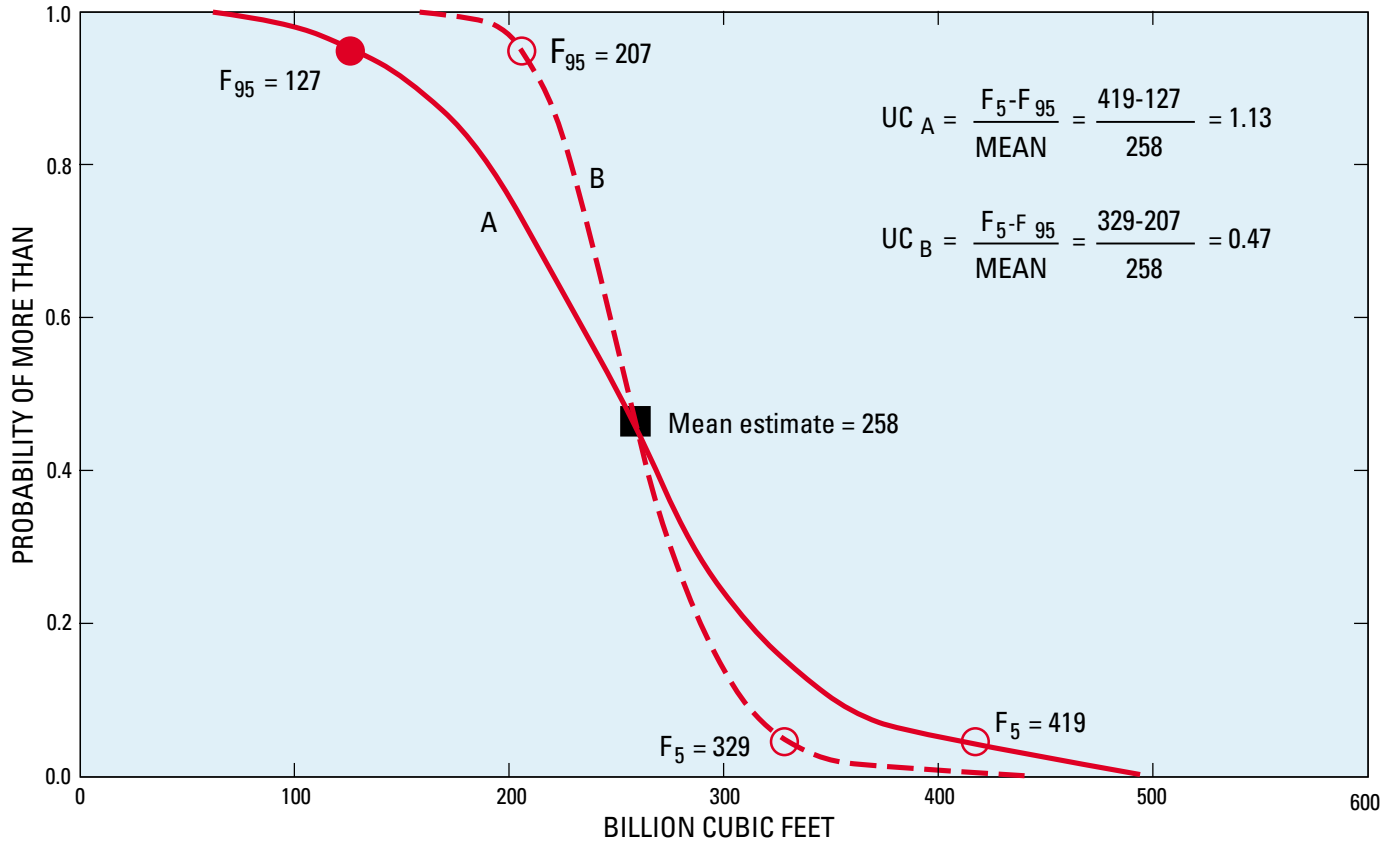

Figure 1. Estimated cumulative probability distributions for undiscovered conventional nonassociated gas resources for two hypothetical plays (A and B) having the same mean and illustrating the difference in range of F_{95} and F_5 fractiles. Uncertainty coefficients (UC) are calculated for each.

Gulf Coast Region Gas Plays

Uncertainty is introduced into the assessment process through the five factors discussed in the Introduction, and it can be compared among plays through the use of uncertainty coefficients. Estimates of undiscovered resource volumes of plays with the highest uncertainty coefficients are relatively *more uncertain* because we know less about these plays than we do about plays with low uncertainty coefficients. Our lack of knowledge may be due to a lack or quality of data and (or) the experience level and perceptions of province geologists responsible for the play assessments. Differences in perception by different province geologists are not an issue for the Gulf Coast Region because all 61 plays were assessed by the same person. (See Schenk and Viger, 1996a, 1996b.)

Natural gas estimates for the 61 gas-bearing conventional plays in the Gulf Coast Region are included in three assessment provinces: Western Gulf (province 47), Louisiana-Mississippi Salt Basins (province 49), and East Texas Basin (province 48). Because many of the plays in provinces 48 and 49 continued across political boundaries with no geologic significance, these provinces were combined for the 1995 National Petroleum Assessment, and plays in both provinces are designated by province 49. Table 1 contains identification, geologic, and resource information for each nonassociated gas-bearing play sorted from high to low uncertainty coefficient. For comparison, table 2 contains summary information for the 20 gas plays with the highest uncertainty coefficient (*most uncertain*) and the 20 plays with the lowest uncertainty coefficient (*most certain*) of the 61 Gulf Coast plays presented in table 1.

The 20 plays with the highest uncertainty coefficients (UC mean=2.81; tables 1 and 2) were analyzed for their geologic characteristics and resource potential. These plays are evenly distributed between the two provinces (47 and combined 49). By contrast, the 20 plays with the lowest uncertainty coefficients (UC mean=1.85; tables 1 and 2) are concentrated in the Western Gulf Province suggesting that our data and knowledge are greater there than for the combined Louisiana-Mississippi Salt Basins and East Texas Basin.

Three hypothetical conventional gas plays were assessed for the Gulf Coast Region. These plays (two Norphlet Formation plays in the Louisiana-Mississippi Salt Basins and East Texas Basin Province (plays 4904 and 4907), and the Jackson Downdip Gas Play in the Western Gulf Province (play 4729)) have high uncertainty coefficients when compared to other Gulf Coast Region gas plays (table 1). As expected, estimates of the undiscovered resource volumes of hypothetical plays are more uncertain because these plays lack known production, and analogs must be used to establish a hypothetical production history.

No relationship was recognized between the dominant reservoir lithology of plays and level of uncertainty. Both the 20 plays with the highest uncertainty coefficients and the 20 plays with the lowest uncertainty coefficients in the Gulf Coast Region are primarily clastic plays. Carbonate plays occur in about equal frequency in both groups.

A relationship exists between the dominant trap type of a play and play uncertainty coefficient. The 20 plays with the highest uncertainty coefficients contain undiscovered accumulations with primarily structurally controlled traps (17 plays; table 2), whereas for the 20 plays with the lowest uncertainty coefficients, only 11 plays are structurally controlled. This contrast is more apparent when all 261 conventional gas-bearing plays in the U.S. are compared (Gautier and others, 1996). For all nonassociated gas-bearing plays in the U.S. as a whole, of the 25 plays with the highest uncertainty coefficients, 12 are structurally controlled, only 2 are stratigraphically controlled, and 11 are mixed structurally and stratigraphically controlled. For the 25 nonassociated gas-bearing plays with the lowest uncertainty coefficients in the U.S., only 3 are structurally controlled, 8 are stratigraphically controlled, and an additional 14 are mixed structurally and stratigraphically controlled plays. A lower uncertainty coefficient may be associated with stratigraphically controlled plays because (1) these plays may be perceived as simpler to understand by province geologists than structurally controlled plays (perceptions), and (or) (2) the difference in uncertainty is simply a reflection of differences in the field-size distribution data used for stratigraphically trapped versus structurally trapped accumulations (data).

The play uncertainty coefficient is also related to volume of undiscovered nonassociated gas in each play (play size). The estimate of the mean undiscovered play size (total mean undiscovered gas resources) for the 20 plays with the lowest uncertainty coefficients is more than twice the mean play size of the 20 plays with the highest uncertainty coefficient (1,356 Bcf versus 641 Bcf). When the middle and bottom third of ranked plays are combined (N=41; table 1), the average play size is 1,294 Bcf, indicating that on the average, large plays are more certain than small plays based on the use of the uncertainty coefficient.

Possible Criteria for Reevaluation of Gulf Coast Gas Plays

A procedure is identified for prioritizing Gulf Coast Region plays for reevaluation from the 1995 U.S. Geological Survey National Petroleum Assessment. The procedure is based on the assumption that plays with the highest uncertainty coefficients and the largest undiscovered nonassociated gas resource estimates (play size) should be reviewed first. The procedure involves selecting plays based on a combination of uncertainty coefficient and mean estimate of undiscovered conventional nonassociated gas. Figure 2 is a plot of uncertainty coefficient versus mean undiscovered nonassociated gas for the 61 gas-bearing plays of the Gulf Coast Region. A minimum uncertainty coefficient of 2.00 and a minimum undiscovered resource of 1 Tcf were arbitrarily chosen for the initial selection process, although other values could also be chosen. An uncertainty coefficient cutoff of 2.00 effectively eliminates the 20 plays with the lowest uncertainty coefficients.

Table 3 contains summary information for the 14 plays meeting these criteria. Together, these plays contain 38 percent of the mean estimated conventional gas resource (37.4 out of 97.6 Tcf) for the entire Gulf Coast Region (U.S. Geological Survey National Oil and Gas Resource Assessment Team,

Table 1. Geologic characteristics and estimated undiscovered nonassociated gas resources for 61 gas-bearing plays in the Gulf Coast Region from the U.S. Geological Survey 1995 National Petroleum Assessment.

[Size, estimated mean size of individual undiscovered accumulations for each play in Bcf (billions of cubic feet); Lith, lithology of dominant reservoir rocks in play; Trap, dominant trap type in play—structure, structural traps; stratigraphic, stratigraphic traps; mixed, mixed structure and stratigraphic traps; Depth, median depth of play in feet; Status, status of play with respect to known production—confirmed, play has at least one known accumulation with production of at least 6 Bcf of nonassociated gas; hypothetical, no known production of 6 Bcf; NA mean, mean estimate of nonassociated gas in play in Bcf; F_{95} res., 95th fractile of the probability distribution for undiscovered conventional resources in play or a 19-in-20 chance of the occurrence of at least the resource amount identified in Bcf; F_5 res., 5th fractile of probability distribution for undiscovered conventional resources in play or a 1-in-20 chance of the occurrence of at least the resource amount identified in Bcf; UC, dimensionless uncertainty coefficient defined by F_5–F_{95}/Mean. Data taken directly from Schenk and Viger (1996a; 1996b)]

No.	Play name	Size	Lith.	Trap	Depth	Status	NA mean	F_{95} res.	F_5 res.	F_{50} res.	UC
4907	Norphlet SE Margin Jackson Dome Flank Deep Gas	42.78	clastic	structure	22000	hypothetical	111.1	0	411.7	7.4	3.71
4904	Norphlet Wiggins - Hancock Arch Gas	35.62	clastic	structure	17000	hypothetical	287	0	961.8	164.6	3.35
4910	Smackover Alabama/Florida Peripheral Fault Zone Oil and Gas	57.48	carbonate	structure	15000	confirmed	639.7	33.7	2107.8	405.1	3.24
4729	Jackson Downdip Gas	66.05	clastic	structure	14000	hypothetical	3053.7	0	9730.4	49.7	3.19
4744	Upper Miocene Fluvial Sandstone Gas and Oil	12.24	clastic	structure	8000	confirmed	99.8	8.3	315.7	46.9	3.08
4721	Upper Wilcox Updip Fluvial Gas	9.17	clastic	structure	5000	confirmed	103.9	9.1	312.9	52.6	2.92
4725	Middle Eocene Sandstones Updip Fluvial Oil and Gas	24.04	clastic	structure	8000	confirmed	303	20.7	888.3	189.7	2.86
4938	Tuscaloosa Stratigraphic Oil and Gas	14.79	clastic	stratigraphic	12000	confirmed	90	9.3	260.7	53.3	2.79
4916	Smackover East Texas - Southern Arkansas Fault Zone Oil and Gas	22.96	carbonate	structure	10000	confirmed	424.4	33.7	1205.6	266.2	2.76
4915	Smackover North Louisiana Gray Sandstone Gas	26.29	clastic	structure	10000	confirmed	245.1	20.7	691.7	151.3	2.74
4931	James Limestone Gas	48.42	carbonate	structure	11000	confirmed	1017	52.4	2832.7	480.5	2.73
4739	Lower Miocene Fluvial Sandstone Oil and Gas	12.24	clastic	structure	8000	confirmed	224.5	22.9	627.2	134.3	2.69
4745	Upper Miocene Deltaic Sandstone Gas and Oil	21.97	clastic	structure	14000	confirmed	253.5	24.2	681.4	172	2.59
4941	Eutaw Southern Salt Basins Gas	46.73	clastic	structure	7000	confirmed	459	44.3	1226.4	314.7	2.58
4924	Cotton Valley Sabine Uplift Gas	55	clastic	structure	10000	confirmed	1080.5	104.6	2863.6	727	2.55
4946	Wilcox N. Louisiana Salt Basin Gas	11.9	clastic	mixed	3000	confirmed	60.1	8.1	161.5	41.1	2.55
4720	Lower Wilcox Downdip Overpressured Gas	46.16	clastic	structure	16000	confirmed	3024	280	7959.8	1931.9	2.54
4730	Vicksburg Updip Gas	9	clastic	structure	7000	confirmed	88.5	11	235	56.7	2.53
4738	Anahuac Sandstone Gas and Oil	30.79	clastic	structure	15000	confirmed	473.2	43.8	1224.8	338.7	2.50
4710	Woodbine South Angelina Flexure Oil and Gas	33.47	clastic	stratigraphic	14000	confirmed	783.5	81.8	2036.1	543.1	2.49
4947	Mobile Bay Miocene Gas	10.3	clastic	stratigraphic	2000	confirmed	180.2	21.9	448.3	129.7	2.37
4922	Cotton Valley Salt Basins Gas	13.16	clastic	mixed	14000	confirmed	407.9	39.4	986.7	238.1	2.32
4929	Sligo/Pettet Salt Basins Gas	15.3	mixed	mixed	11000	confirmed	270.4	29.2	654.6	183.6	2.31
4920	Gilmer Limestone Gas	42.01	carbonate	structure	14000	confirmed	1119	92.7	2675.8	852.9	2.31
4926	Hosston/Travis Peak Salt Basins Gas	35.62	clastic	structure	9000	confirmed	1280.7	118.1	3068.4	892.9	2.30
4937	Tuscaloosa/Woodbine Structural Oil and Gas	16.68	clastic	mixed	9000	confirmed	40.6	7.5	99.9	32.6	2.28
4703	Smackover South Texas Gas	30.79	carbonate	structure	16000	confirmed	1029	120	2448.2	815.3	2.26
4913	Smackover Jackson Dome Deep Gas	52.07	clastic	structure	21000	confirmed	259.8	32.7	613.2	219.7	2.23
4935	Paluxy Downdip Gas	16.68	clastic	structure	10000	confirmed	257.7	32.6	605	211.1	2.22
4705	Lower Cretaceous Carbonate Shelf/Shelf-Edge Gas and Oil	62.99	carbonate	mixed	14000	confirmed	2307.5	227.3	5276.4	1886	2.19
4901	Piercement Salt Dome Flanks Oil and Gas	35.62	mixed	structure	10000	confirmed	651.6	75.4	1493.8	546.7	2.18
4724	Middle Eocene Sandstones Downdip Gas	35.62	clastic	structure	12000	confirmed	1125.3	123	2559.7	902.5	2.17
4709	Tuscaloosa Deep Sandstone Gas	162.18	clastic	mixed	17000	confirmed	6315.3	637.2	14310.3	4782.3	2.17
4927	Travis Peak Sabine Uplift Gas	24.04	clastic	mixed	8000	confirmed	511.6	53.1	1142.3	411.4	2.13
4905	Norphlet Salt Basin Oil and Gas	42.78	clastic	structure	17000	confirmed	240.1	30.1	540.2	213.3	2.12
4912	Smackover Salt Basins Gas and Oil	30.79	carbonate	structure	12000	confirmed	960	106.1	2145.2	713.3	2.12
4727	Yegua Downdip Gas	65.98	clastic	structure	14000	confirmed	5164.2	483.9	11359.7	3713.8	2.11
4736	Frio SE Texas/S. Louisiana Downdip Gas	25.07	clastic	mixed	14000	confirmed	1462.7	159.6	3215.9	1069.7	2.09
4722	Upper Wilcox Shelf-Edge Gas and Oil	48.01	clastic	structure	9000	confirmed	3795.9	313.7	8104.4	2524.8	2.05
4909	Smackover Wiggins - Baldwin Flanks Gas	30.79	carbonate	mixed	16000	confirmed	530.5	71	1155.3	478.1	2.04
4918	Haynesville Salt Basins Gas and Oil	40.65	clastic	structure	14000	confirmed	994.5	126.7	2157	800	2.04
4726	Yegua Updip Fluvial-Deltaic Oil and Gas	24.04	clastic	structure	7000	confirmed	539.6	56.8	1153.4	456.4	2.03
4723	Upper Wilcox Downdip Overpressured Gas	56.71	clastic	structure	16000	confirmed	5709.8	649.1	12061.8	4141.9	2.00

Table 1—Continued. Geologic characteristics and estimated undiscovered nonassociated gas resources for 61 gas-bearing plays in the Gulf Coast Region from the U.S. Geological Survey 1995 National Petroleum Assessment.

[Size, estimated mean size of individual undiscovered accumulations for each play in Bcf (billions of cubic feet); Lith, lithology of dominant reservoir rocks in play; Trap, dominant trap type in play—structure, structural traps; stratigraphic, stratigraphic traps; mixed, mixed structure and stratigraphic traps; Depth, median depth of play in feet; Status, status of play with respect to known production—confirmed, play has at least one known accumulation with production of at least 6 Bcf of nonassociated gas; hypothetical, no known production of 6 Bcf; NA mean, mean estimate of nonassociated gas in play in Bcf; F_{95} res., 95th fractile of the probability distribution for undiscovered conventional resources in play or a 19-in-20 chance of the occurrence of at least the resource amount identified in Bcf; F_5 res., 5th fractile of probability distribution for undiscovered conventional resources in play or a 1-in-20 chance of the occurrence of at least the resource amount identified in Bcf; UC, dimensionless uncertainty coefficient defined by F_5–F_{95}/Mean. Data taken directly from Schenk and Viger (1996a; 1996b)]

No.	Play name	Size	Lith.	Trap	Depth	Status	NA mean	F_{95} res.	F_5 res.	F_{50} res.	UC
4742	Middle Miocene Fluvial Sandstone Gas and Oil	25.07	clastic	structure	10000	confirmed	744.4	86.5	1563	593.1	1.98
4734	Frio Updip Fluvial Gas and Oil	10.3	clastic	mixed	7000	confirmed	219.3	33.8	414.6	194.8	1.98
4704	Cotton Valley Western Gulf Gas and Oil	18.74	clastic	mixed	12000	confirmed	326.6	39.3	681.9	270.9	1.97
4718	Lower Wilcox Lobo Gas	49.16	clastic	structure	9000	confirmed	3187.1	404.8	6576.1	2687.1	1.94
4719	Lower Wilcox Fluvial Oil and Gas	19.1	clastic	mixed	8000	confirmed	563.7	76	1154.2	449.1	1.91
4743	Middle Miocene Deltaic Sandstone Gas and Oil	19.89	clastic	structure	14000	confirmed	345.4	49.2	705.3	285.9	1.90
4732	Frio South Texas Downdip Gas	27.52	clastic	mixed	12000	confirmed	820.9	101	1650.6	618	1.89
4731	Vicksburg Downdip Gas	30.79	clastic	mixed	14000	confirmed	1559.4	144.6	2967.6	948.7	1.81
4930	Pettet Southern Sabine Uplift Gas and Oil	9.62	carbonate	structure	7000	confirmed	151.2	23	295.9	125.5	1.80
4735	Frio SE Texas/S. Louisiana Mid-Dip Gas and Oil	24.04	clastic	structure	12000	confirmed	794.3	83	1515.6	624.6	1.80
4717	Upper Cretaceous Sandstones Downdip Gas	12.05	clastic	mixed	8000	confirmed	242.4	38.4	475.4	234.6	1.80
4933	Glen Rose/Rodessa Salt Basins Gas	23.74	clastic	mixed	10000	confirmed	1068.1	136.9	2049.6	861.4	1.79
4701	Houston Salt Dome Flank Oil and Gas	55	clastic	structure	9000	confirmed	833.5	134.1	1606.8	802.1	1.77
4903	Norphlet Mobile Bay Deep Gas	207.05	clastic	structure	20000	confirmed	5259.6	753.7	9881.4	4889.2	1.74
4737	Hackberry Sandstone Gas and Oil	23.41	clastic	mixed	10000	confirmed	395.8	59.6	744.8	353	1.73
4733	Frio South Texas Mid-Dip Oil and Gas	14.52	clastic	structure	12000	confirmed	517.4	54.8	944.1	345.9	1.72
4741	Lower Miocene Slope and Fan Sandstone Gas	73.3	clastic	mixed	14000	confirmed	2940.4	484.9	5489.4	2895.3	1.70
4740	Lower Miocene Deltaic Sandstone Gas and Oil	27.26	clastic	structure	10000	confirmed	899.4	119.9	1648.1	716.5	1.70

Table 2. Summary data for the 20 nonassociated conventional gas-bearing plays in the Gulf Coast Region with the highest (1) and lowest (2) uncertainty coefficients from the plays in table 1.

(1) 20 plays with highest uncertainty coefficients

Mean UC= 2.82
Province composition: Western Gulf= 10 plays; East Texas Basin and Louisiana-Miss. Salt Basins= 10 plays
Hypothetical plays= 3; confirmed plays= 17
Average median depth= 11,300 ft
Dominant lithology: carbonate plays= 3; clastic plays= 17
Trap type: structure= 17 plays; stratigraphic= 2 plays; mixed trap type= 1 play
Total mean undiscovered nonassociated gas= 12,822 Bcf
Mean undiscovered nonassociated gas/play (*N*=20 plays)= 641 Bcf
Mean undiscovered nonassociated accumulation size= 31.2 Bcf

(2) 20 plays with lowest uncertainty coefficients

Mean UC= 1.85
Province composition: Western Gulf= 17 plays; East Texas Basin and Louisiana-Miss. Salt Basins= 3 plays
Hypothetical plays= 0; confirmed plays= 20
Average median depth= 11,050 ft
Dominant lithology: carbonate plays= 2; clastic plays= 17
Trap type: structure= 11 plays; mixed=9 plays
Total mean undiscovered nonassociated gas (*N*=20 plays)= 27,118 Bcf
Mean undiscovered nonassociated gas/play (*N*=20 plays)= 1,356 Bcf
Mean undiscovered nonassociated accumulation size= 37.3 Bcf

1995). These plays are primarily clastic plays, are structurally trapped, and are associated with a wide range of stratigraphic reservoir units. Only 4 of these 14 plays are part of the 20 plays with the highest uncertainty, suggesting that the volume of undiscovered nonassociated gas resource rather than the uncertainty coefficient may be the most important factor to consider when reevaluating plays.

Ten of the fourteen plays reside in the Western Gulf Province and have a total estimated mean conventional nonassociated gas resource of nearly 33 Tcf, about 33 percent of the resource for the Gulf Coast Region. The mean undiscovered field size for nonassociated gas in these 14 gas-bearing plays is nearly 56 Bcf, which is far more than the mean undiscovered field size for nonassociated gas for all 61 Gulf Coast Region gas-bearing plays together (mean=36.3 Bcf).

These high-priority nonassociated gas plays are also deep. The 10 Western Gulf Province gas-bearing plays have an average median depth of 14,200 feet and an average maximum depth of 20,400 feet (Schenk and Viger, 1996). Only one of the plays, the Upper Wilcox Shelf-Edge Gas and Oil Play (play 4722), has a median depth of less than 10,000 feet (table 3).

Causes of Uncertainty: Examples of Uncertain Plays

Three of the sixty-one Gulf Coast Region nonassociated gas-bearing plays are discussed here as examples to illustrate more clearly the actual causes of uncertainty for each. Detailed play descriptions in Gautier and others (1996) provide information about the geology, production history, and risking process associated with assessing plays in the U.S. Geological Survey 1995 National Petroleum Assessment. Data for the following discussion were taken from Schenk and Viger (1996a, 1996b).

Norphlet Southeast Margin Jackson Dome-Flank Deep Gas (play 4907), East Texas Basin and Louisiana-Mississippi Salt Basins Play (table 1). This hypothetical play occurs in both the East Texas Basin and Louisiana-Mississippi Salt Basins and contains only minor undiscovered nonassociated gas resources (mean undiscovered gas equals 111.1 Bcf), but it has the highest uncertainty coefficient of all nonassociated gas-bearing plays in the Gulf Coast Region (UC=3.71). The volume of undiscovered gas ranges from 0.0 Bcf (F95) to 412 (F5). This play is also one of the deepest plays in the Gulf Coast Region (median depth=22,000 feet). The play was defined on the basis of deep eolian gas reservoirs in the Upper Jurassic Norphlet Formation. Trapping mechanisms are faults associated with deep salt structures. The play was risked for the presence and quality of eolian sandstones (probability equals 0.5; Schenk and Viger, 1996b), particularly in the deeper portions of the play. Adequate reservoir quality is associated with the thermal and diagenetic history of Jackson Dome. Also, the play boundary was poorly understood but drawn where the Norphlet reaches 25,000 feet along the southeast margin of Jackson Dome. The Smackover Jackson Dome Deep Gas Play (play 4913; table 1) was used as a production analog for this play.

Norphlet Wiggins–Hancock Arch Gas (play 4904; table 1). This hypothetical play (UC=3.35) ranges in volume of undiscovered nonassociated gas from 0.0 (F5) to 0.9 Tcf (F95). It was defined on the basis of deep eolian and fluvial gas and condensate reservoirs in the Upper Jurassic Norphlet Formation. Trapping mechanisms are basement faults along the flanks of the Wiggins Arch. The play was risked for the presence and quality of eolian and fluvial sandstone reservoirs forming an apron around the flanks of the arch. The Smackover

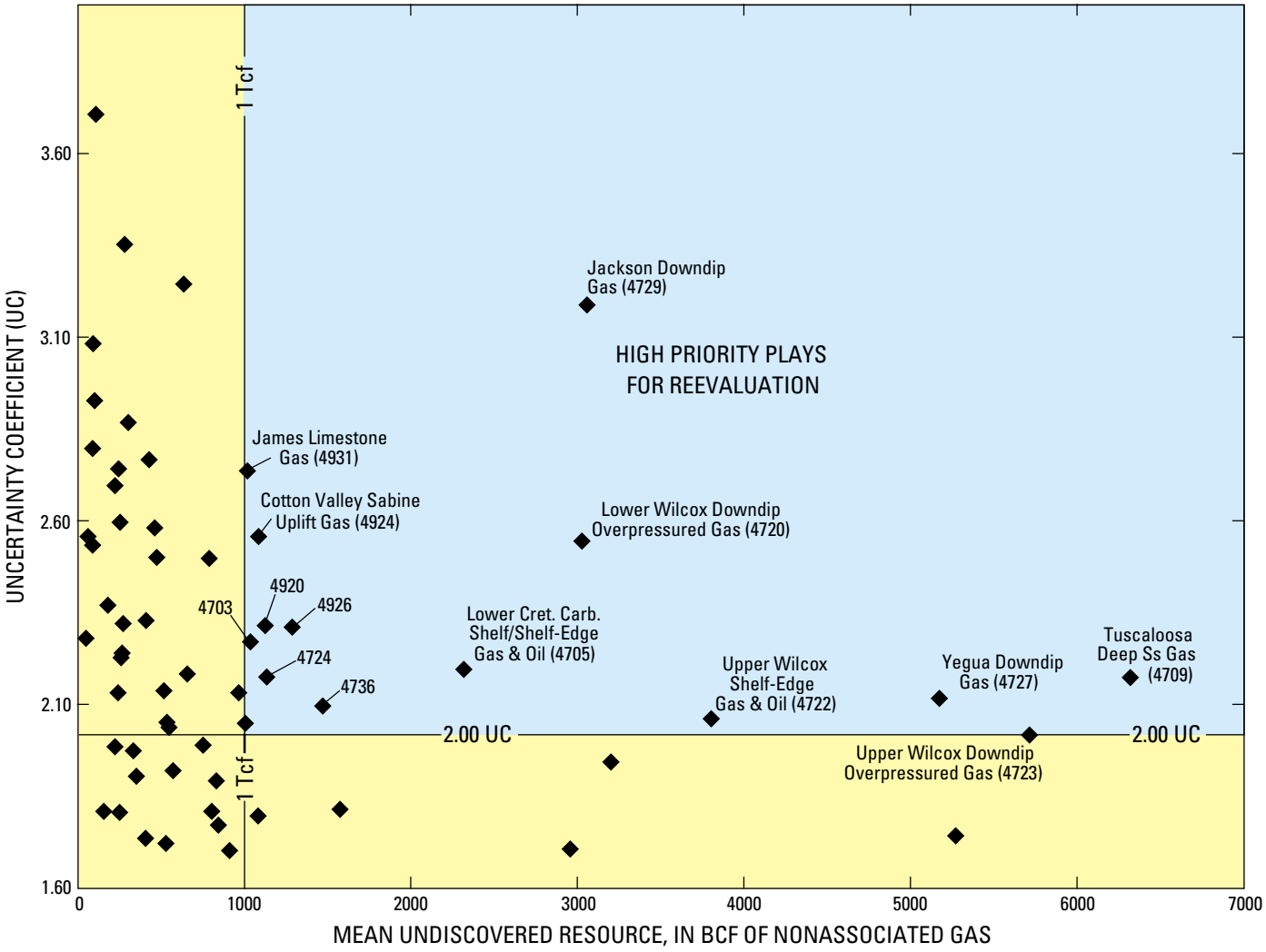

Figure 2. Plot of play uncertainty coefficient (UC, dimensionless) versus mean undiscovered nonassociated gas resource for 61 conventional gas plays in the Gulf Coast Region. Area of possible high-priority plays for reevaluation (in blue) is based on minimum reevaluation criteria of UC=2.00 and mean estimated undiscovered nonassociated gas resource = 1 Tcf. Unnamed plays in high-priority area are: 4703, Smackover South Texas Gas; 4920, Gilmer Limestone Gas; 4926, Hosston/Travis Peak Salt Basins Gas; 4724, Middle Eocene Sandstones Downdip Gas; 4736, Frio Southeast Texas/South Louisiana Downdip Gas.

Wiggins–Baldwin Flanks Gas Play (4909) was used as a production analog for this play.

Tuscaloosa Deep Sandstone Gas Play (play 4709; table 1). This confirmed play has an intermediate uncertainty coefficient (UC=2.17). The volume of undiscovered nonassociated gas ranges from 0.6 Tcf (F_{95}) to 14.3 Tcf (F_5). The play definition was based on the presence of Upper Cretaceous Tuscaloosa Group deltaic sandstone reservoirs in both structural and stratigraphic traps downdip from the Lower Cretaceous shelf margin of southern Louisiana. The updip play boundary was defined by the shelf edge, but the downdip boundary was arbitrarily chosen at 25,000 feet. Although 18 discovered reservoirs were defined for this play in 1995, less was known about the more lightly drilled deeper parts of the play, and uncertainty was based in part on the lack of data on ranges of undiscovered field sizes deeper than about 17,000 feet.

Discussion

New and useful information from the U.S. Geological Survey 1995 National Petroleum Assessment is revealed when data on uncertainty are analyzed.

Play size. Sixteen of the twenty plays with the highest uncertainty coefficients are small with respect to undiscovered play size (<1 Tcf of mean undiscovered gas) (table 1). In the Gulf Coast Region, large uncertainty coefficients are characteristic of small plays. One important constraint in the U.S. Geological Survey 1995 National Petroleum Assessment was that plays could only be defined to the State-Federal water boundary. If play outlines had included Federal Offshore waters in 1995, many geographically small plays such as Norphlet Mobile Bay Deep Gas (4903), Frio South Texas Downdip Gas (4732), Lower

Table 3. Geologic characteristics and estimated undiscovered nonassociated gas resources for 14 gas-bearing plays in the Gulf Coast Region that form a priority list for reevaluation.

[See table 1 for explanation of data]

Play No.	Play name	UC	Estimates of undisc. NA conv. gas				Lithology	Trap	Median depth	Play status	Undiscovered accum. size
			Mean res.	F_{95} res.	F_5 res.	F_{50} res.					
4729	Jackson Downdip Gas	3.19	3053.7	0	9730.4	49.7	clastic	structure	14000	hypothetical	66
4931	James Limestone Gas	2.73	1017	52.4	2832.7	480.5	carbonate	structure	11000	confirmed	48.3
4924	Cotton Valley Sabine Uplift Gas	2.55	1080.5	104.6	2863.6	727	clastic	structure	10000	confirmed	54.8
4720	Lower Wilcox Downdip Overpressured Gas	2.54	3024	280	7959.8	1931.9	clastic	structure	16000	confirmed	46.1
4920	Gilmer Limestone Gas	2.31	1119	92.7	2675.8	852.9	carbonate	structure	14000	confirmed	42
4926	Hosston/Travis Peak Salt Basins Gas	2.30	1280.7	118.1	3068.4	892.9	clastic	structure	12000	confirmed	35.5
4703	Smackover South Texas Gas	2.26	1029	120	2448.2	815.3	carbonate	structure	16000	confirmed	30.7
4705	L. Cretaceous Carbonate Shelf/Shelf-Edge Gas and Oil	2.19	2307.5	227.3	5276.4	1886	carbonate	mixed	14000	confirmed	62.9
4724	Middle Eocene Sandstones Downdip Gas	2.17	1125.3	123	2559.7	902.5	clastic	structure	12000	confirmed	35.5
4709	Tuscaloosa Deep Sandstone Gas	2.17	6315.3	637.2	14310.3	4782.3	clastic	mixed	17000	confirmed	162.1
4727	Yegua Downdip Gas	2.11	5164.2	483.9	11359.7	3713.8	clastic	structure	14000	confirmed	65.9
4736	Frio SE Texas/S. Louisiana Downdip Gas	2.09	1462.7	159.6	3215.9	1069.7	clastic	mixed	14000	confirmed	25
4722	Upper Wilcox Shelf-Edge Gas and Oil	2.05	3795.9	313.7	8104.4	2524.8	clastic	structure	9000	confirmed	47.9
4723	Upper Wilcox Downdip Overpressured Gas	2.00	5709.8	649.1	12061.8	4141.9	clastic	structure	16000	confirmed	56.6
Mean value			2677.5								55.7

Cretaceous Carbonate Shelf/Shelf-Edge Gas and Oil (4705), and possibly others would have increased in size and also in undiscovered resource. Potentially larger plays would undoubtedly have attained a higher uncertainty coefficient due to a lack of data for the more lightly drilled Federal Offshore areas. The same point can be made for lumping and splitting plays within the onshore and State waters of the region. A different province geologist might have defined fewer plays by combining the geologic and production characteristics of some of the 61 plays already defined. These fewer, larger plays would have different uncertainty characteristics.

The size of the undiscovered resource is clearly a more important play parameter for play reevaluation than the level of uncertainty as demonstrated by the data in figure 2. Only 4 of the 14 plays suggested for review in figure 2 reside within the list of 20 plays with the highest uncertainty coefficient. Alternatively, for the Gulf Coast Region as a whole, plays with large uncertainty coefficients tend to be small plays with respect to undiscovered nonassociated gas resource and are considered relatively less important for reevaluation.

Use of analogs for uncertain plays with little or no production. In 1995, the lack of play analogs directly impacted the assessment of hypothetical plays. If the U.S. Geological Survey had access to better exploration/production analogs to identify the sizes and numbers of undiscovered accumulations, uncertainty coefficients could have been reduced, and the magnitude of the play resource might have changed. For future assessments, a procedure to identify and document analogs would benefit the assessment process.

Exploration intensity. Data from this study support the view that uncertainty is directly related to the level of petroleum exploration in a play. The Western Gulf Province contains many large, well-explored and well-understood plays. Even though these plays have low uncertainty coefficients for conventional nonassociated gas (tables 1 and 2), they deserve reevaluation because of their large size and greater impact on the future gas resources of the Nation.

Conventional and Continuous-type plays. In 1995 the U.S. Geological Survey assessed only one continuous-type (unconventional) gas play in the Gulf Coast Region, the Cotton Valley Blanket Sandstones Play (play 4923) of the Louisiana-Mississippi Salt Basins Province and three Austin Chalk continuous oil plays (Austin Chalk Pearsall (play 4747), Austin Chalk Giddings (play 4748), and Austin Chalk Outlying (play 4749)) of the Western Gulf Province, which were estimated to contain some associated gas.

Continuous-type plays contain accumulations that are geographically widespread and generally lack well-defined oil- or gas-water contacts (Schmoker and others, 1995; Schmoker, 1996; U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995). Continuous-type plays were assessed using geologic criteria but a different quantitative method. Hence, the Cotton Valley Blanket Sandstones Play was not compared to conventional plays in this report based on uncertainty. An unresolved issue from the 1995 assessment is the potential continuous nature of some plays previously assessed as conventional. For example, the Cotton Valley Sabine Uplift Gas play (4924) in the Louisiana-Mississippi Salt Basins and East Texas Basin Province is being reevaluated because of its geologic and production characteristics. The Cotton Valley Sabine Uplift Gas Play was identified as one of the 20 nonassociated gas-bearing plays with high uncertainty coefficients in this study (table 1). A reassessment of plays using new data, changing perceptions, and different methods may likely result in substantially different resource estimates.

References Cited

Dyman, T.S., Schmoker, J.W., and Root, D.H., 1996, Assessment of deep conventional and continuous-type (unconventional) natural gas plays in the United States: U.S. Geological Survey Open-File Report 96-529, 30 p.

Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1996, 1995 National assessment of United States oil and gas resources—Results, methodology, and supporting data: U.S. Geological Survey Digital Data Series 30, Release 2.

Schenk, C.J., and Viger, R.J., 1996a, Western Gulf Province (047), *in* Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995 National assessment of United States oil and gas resources—Results, methodology, and supporting data: U.S. Geological Survey Digital Data Series 30, Release 2.

———1996b, East Texas Basin Province (048) and Louisiana-Mississippi Salt Basins Province (049), *in* Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995 National assessment of United States oil and gas resources—Results, methodology, and supporting data: U.S. Geological Survey Digital Data Series 30, Release 2.

Schmoker, J.W., 1996, Method for assessing continuous-type (unconventional) hydrocarbon accumulations, *in* Gautier, D.L., Dolton, G.L., Takahashi, K.I., and Varnes, K.L., eds., 1995 National assessment of United States oil and gas resources—Results, methodology, and supporting data: U.S. Geological Survey Digital Data Series 30, Release 2.

Schmoker, J.W., Crovelli, R.A., and Balay, R.H., 1995, Potential additions to technically recoverable resources for each continuous-type (unconventional) play of the U.S. Geological Survey 1995 National petroleum assessment of oil and gas resources—Graphical and tabular presentations: U.S. Geological Survey Open-File Report 95-75E, 57 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.