Introduction to the 2002 Geologic Assessment of Undiscovered Oil and Gas Resources in the San Juan Basin Province, Exclusive of Paleozoic Rocks

Click here to return to
Volume Title Page

By U.S. Geological Survey San Juan Basin Assessment Team

Chapter 2 of 7

Total Petroleum Systems and Geologic Assessment of Undiscovered Oil and Gas Resources in the San Juan Basin Province, Exclusive of Paleozoic Rocks, New Mexico and Colorado

Compiled by U.S. Geological Survey San Juan Basin Assessment Team

Digital Data Series 69–F

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

U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia 2013

For product and ordering information:
World Wide Web: *http://www.usgs.gov/pubprod*
Telephone: 1-888-ASK-USGS

For more information on the USGS—the Federal source for science about the Earth,
its natural and living resources, natural hazards, and the environment:
World Wide Web: *http://www.usgs.gov*
Telephone: 1-888-ASK-USGS

Suggested citation:
U.S. Geological Survey San Juan Basin Assessment Team, 2013, Introduction to the 2002 geologic assessment of undiscovered oil and gas resources in the San Juan Basin Province, exclusive of Paleozoic rocks, chap. 2 *of* U.S. Geological Survey San Juan Basin Assessment Team, Total petroleum systems and geologic assessment of undiscovered oil and gas resources in the San Juan Basin Province, exclusive of Paleozoic rocks, New Mexico and Colorado: U.S. Geological Survey Digital Data Series 69–F, p. 1–8.

Contents

Figures

Tables

Introduction to the 2002 Geologic Assessment of Undiscovered Oil and Gas Resources in the San Juan Basin Province, Exclusive of Paleozoic Rocks

By U.S. Geological Survey San Juan Basin Assessment Team

Purpose

The U.S Geological Survey (USGS) periodically conducts assessments of undiscovered oil and gas resources in the United States. The purpose of the U.S. Geological Survey National Oil and Gas Assessment is to develop geologically based hypotheses regarding the potential for additions to oil and gas reserves in priority areas of the United States. The last major USGS assessment of oil and gas of the most important oil and gas provinces in the United States was in 1995 (Gautier and others, 1996). Since then a number of individual assessment provinces have been reappraised using new methodology. This was done particularly for those provinces where new information has become available, where new methodology was expected to reveal more insight to provide a better estimate, where additional geologic investigation was needed, or where continuous accumulations were deemed important. The San Juan Basin was reevaluated because of industry exploitation of new hydrocarbon accumulations that were not previously assessed and because of a change in application of assessment methodology to potential undiscovered hydrocarbon accumulations.

Several changes have been made in this study. The methodology is different from that used in 1995 (Schmoker, 2003; Schmoker and Klett, 2003). In this study the total petroleum system (TPS) approach (Magoon and Dow, 1994) is used rather than the play approach. The Chama Basin is not included. The team of scientists studying the basin is different. The 1995 study focused on conventional accumulations, whereas in this 2002 assessment, it was a priority to assess continuous-type accumulations, including coal-bed gas. Consequently we are presenting here an entirely new study and results for the San Juan Basin Province. The results of this 2002 assessment of undiscovered oil and gas resources in the San Juan Basin Province (5022) are presented in this report within the geologic context of individual TPSs and their assessment units (AU) (table 1). Results are reported as the estimated mean of potential additions to reserves as well as for the 95, 50, and 5 percent fractiles.

San Juan Basin Province (5022)

The 2002 San Juan Basin Province (5022) is located in New Mexico and Colorado between lat 35°1′23″ and 37°22′26″ N. and long 106°38′23″ and 109°3′14″ W. (fig. 1). The area assessed, which covers about 16,368 mi^2, is less than that in the 1995 National Oil and Gas Assessment, where the boundary of the total assessed area followed county lines in many places (Huffman, 1996). Additionally, it was determined that potential source beds in the Chama Basin, located adjacent to the northeast part of the San Juan Basin (fig. 1), never reached the thermal maturity level necessary to generate hydrocarbons. Thus, the Chama Basin, which was included in the 1995 assessment of the San Juan Province, was excluded from this 2002 assessment. The San Juan Basin Province includes not only the central basin where the bulk of the hydrocarbon resources are located but also the surrounding structural features, which consist of all or part of the Chaco slope, Four Corners platform, Hogback monocline, Archuleta arch, Zuni uplift, and Nacimiento uplift (fig. 2).

The San Juan Basin is principally a Laramide structural basin that formed between 75 and 35 million years ago, although rocks as old as Cambrian are present in the basin. The basin has a pronounced northwest–southeast structural grain that appears to have controlled sediment geometry and shoreline positions throughout the Phanerozoic (fig. 3), and hence determined the location of oil and gas resources. This structural grain is probably inherited from Precambrian basement blocks that appear to have formed in the early Paleozoic (Stevenson and Baars, 1986, p. 515; Taylor and Huffman, 1998, 2001; Huffman and Taylor, 2002; fig. 2).

Total Petroleum System Approach

The TPS approach incorporates knowledge of the source rocks, reservoir rocks, migration pathways, and time of generation and expulsion of hydrocarbons. Each TPS is characterized by a single hydrocarbon-source-rock interval or a number of source rocks, in which case, it is called a composite TPS. Within a TPS, there may be one or more assessment units

Table 1. San Juan Basin Province, New Mexico and Colorado, 2002 assessment results.

[MMB, million barrels; BCF, billion cubic feet; NGL, natural gas liquids. Results shown are fully risked estimates. For gas fields, all liquids are included under the NGL (natural gas liquids) category. F95 denotes a 95 percent chance of at least the amount tabulated. Other fractiles are defined similarly. Fractiles are additive only under the assumption of perfect positive correlation. Gray shading indicates not applicable or not assessed.]

Total Petroleum Systems (TPS) and Assessment Units (AU)	Field type	Total undiscovered resources											
		Oil (MMB)				Gas (BCF)				NGL (MMB)			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Conventional Oil and Gas Resources													
Fruitland TPS													
Tertiary Conventional Gas AU	Gas					25.76	74.40	152.91	79.98	0.23	0.73	1.83	0.84
Mancos-Menefee Composite TPS													
Mesaverde Updip Conventional Oil	not quantitatively assessed												
Gallup Sandstone Conventional Oil and Gas AU	Oil	0.00	1.98	6.29	2.34	0.00	0.29	0.98	0.35	0.00	0.00	0.01	0.00
Mancos Sandstone Conventional Oil and Gas AU	Oil	5.41	11.33	20.72	11.99	23.34	53.28	106.75	57.57	0.84	2.07	4.52	2.30
Dakota-Greenhorn Conventional Oil and Gas AU	Oil	0.78	2.26	4.73	2.45	2.53	7.49	17.10	8.34	0.02	0.07	0.16	.08
	Gas					5.59	12.63	22.40	13.35	0.22	0.50	0.96	0.53
Todilto TPS													
Entrada Sandstone Conventional Oil	Oil	0.81	2.19	4.18	2.32	1.84	5.15	10.66	5.56	0.07	0.20	0.45	0.22
Total Conventional Resources		**7.00**	**17.76**	**35.92**	**19.10**	**59.06**	**153.24**	**310.80**	**165.15**	**1.38**	**3.57**	**7.93**	**3.97**
Continuous Oil and Gas Resources													
Fruitland TPS													
Pictured Cliffs Continuous Gas	Gas					3,865.41	5,510.68	7,856.23	5,640.25	9.07	15.95	28.06	16.92
Fruitland Fairway Coalbed Gas	Gas					3,081.06	3,937.16	5,031.14	3,981.14	0.00	0.00	0.00	0.00
Basin Fruitland Coalbed Gas	Gas					17,342.26	19,543.12	22,023.27	19,594.74	0.00	0.00	0.00	0.00
Lewis Shale TPS													
Lewis Continuous Gas	Gas					8,315.22	10,105.95	12,282.31	10,177.24	18.08	29.25	47.32	30.53
Mancos-Menefee Composite TPS													
Mesaverde Central-Basin Continuous Gas	Gas					1,053.32	1,305.62	1,618.35	1,316.79	3.44	5.12	7.60	5.27
Mancos Sandstone Continuous Gas	Gas					3,980.80	5,062.07	6,437.03	5,116.37	50.64	73.97	108.04	75.96
Dakota-Greenhorn Continuous Gas	Gas					3,148.66	3,896.17	4,821.14	3,928.98	10.29	15.27	22.66	15.72
Menefee Coalbed Gas	Gas					228.30	569.08	1,418.55	663.94	0.00	0.00	0.00	0.00
Total Continuous Resources						**41,015.03**	**49,929.85**	**61,488.02**	**50,419.45**	**91.52**	**139.56**	**213.68**	**144.40**
Total Undiscovered Oil and Gas Resources		**7.00**	**17.76**	**35.92**	**19.10**	**41,074.09**	**50,083.09**	**61,798.82**	**50,584.60**	**92.90**	**143.13**	**221.61**	**148.37**

Figure 1. Shaded relief map showing the location and boundary of the San Juan Basin Province (5022) (solid red line) assessed in the 2002 National Oil and Gas Assessment (U.S. Geological Survey Assessment Team, 2002); green line circumscribes the Chama Basin.

each of which is defined as a mappable volume of rock that encompasses both discovered and undiscovered accumulations that share similar geologic traits. Additionally, each TPS is characterized by a time of maximum generation and expulsion of hydrocarbons, which is defined by the depositional and thermal history of the basin. For a basin containing multiple TPSs, especially those closely related in time, the time of maximum generation and expulsion of hydrocarbons may be similar for many of the petroleum systems, but the migration pathways may not be the same. Hydrocarbons that have been generated in the more mature parts of the petroleum system source beds and that have migrated away from this area may form discrete, conventional accumulations in stratigraphic and structural traps marginal to the deep basin.

Hydrocarbons that formed within source rocks in the deepest part of the basin and migrated only short distances into interbedded reservoirs and local structural or stratigraphic traps commonly form continuous-type accumulations. In the San Juan Basin, the continuous accumulations occur over a large area that is gas-charged, although not all wells drilled within the gas-charged area will be economic (Schmoker, 2003). In continuous-type accumulations, exclusive of coal-bed or shale gas accumulations, gas is commonly found in sandstone or sandy reservoirs, and thus, reservoir geometry within the basin setting is an important constraint on where gas might be found. Stratigraphic, unconformity, and structural traps as well as zones of better permeability within reservoirs found within deep central parts of basins may serve as focal points for gas charge. These areas may constitute some of the "sweet spots" within an overall gas-charged system. This 2002 assessment of the San Juan Basin employed the concept of "sweet spot" location when determining the percentage of the gas-charged area that held the potential for additions to reserves of undiscovered resources.

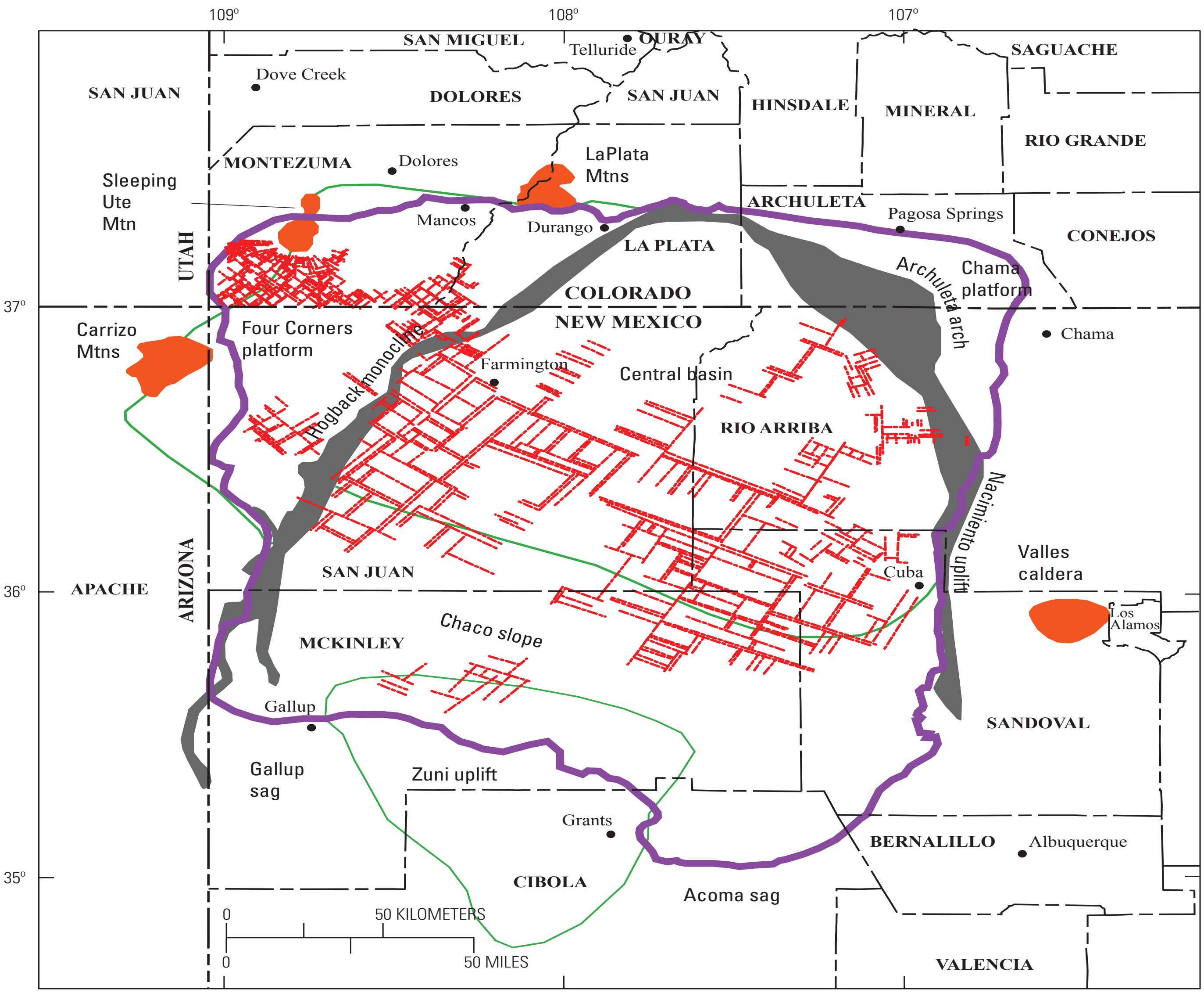


Figure 2. Map showing the location of inferred basement structural blocks (dashed red lines) and other structural elements in the San Juan Basin. Modified from Taylor and Huffman (1998, 2001), Fassett (2000), and Huffman and Taylor (2002). San Juan Basin Province (5022) boundary (purple line). Orange polygons are Late Cretaceous and Tertiary intrusive and extrusive igneous centers; gray polygons are areas of steep dip along monoclines; green line outlines some of the main structural elements.

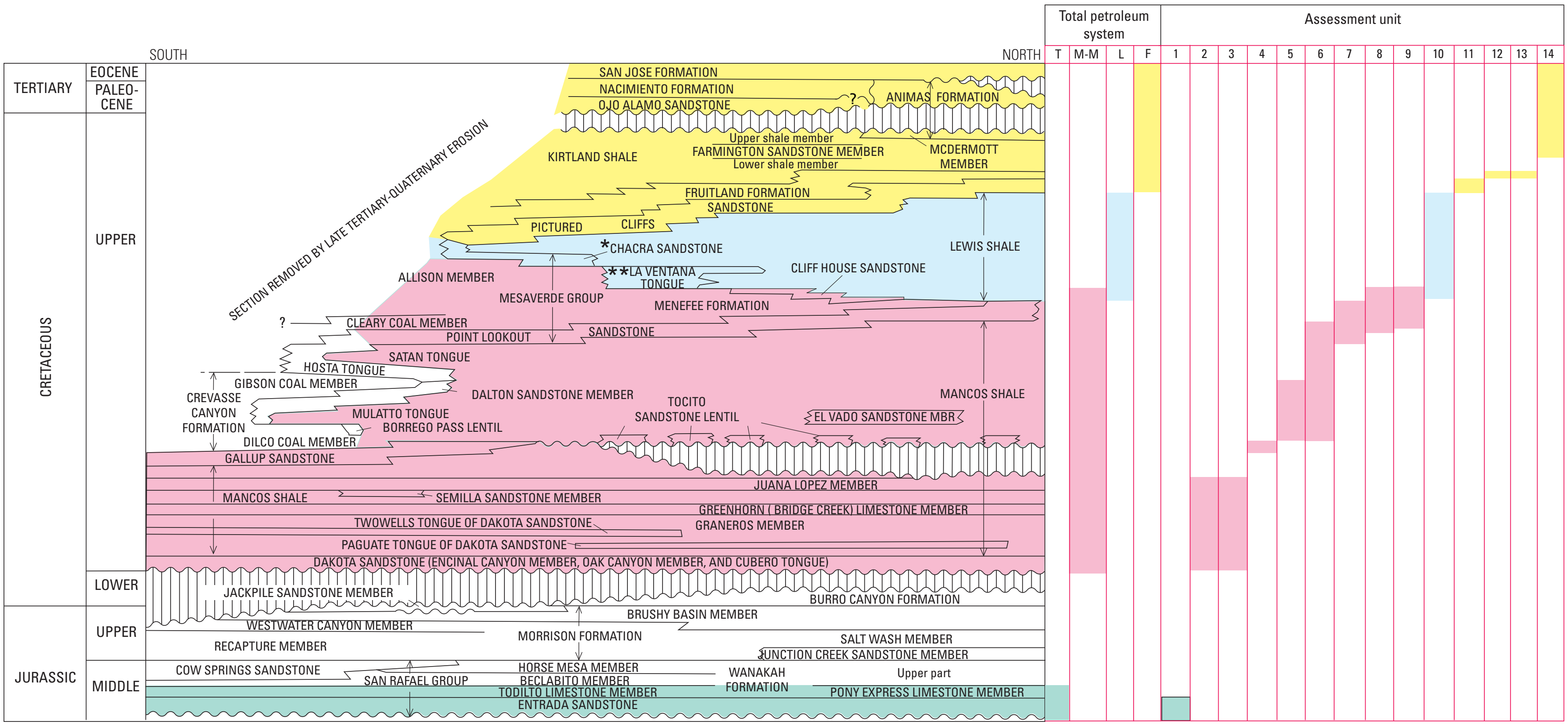


Figure 3. Chart showing regional chronostratigraphic correlations in the San Juan Basin (modified from Molenaar, 1977) to the base of the Jurassic, and the extent of the total petroleum systems and assessment units defined in the 2002 National Oil and Gas Assessment of the San Juan Basin Province (5022), New Mexico and Colorado. [Total petroleum systems: F, Fruitland; L, Lewis Shale; M-M, Mancos-Menefee Composite; and T, Todilto. Assessment units: 1, Entrada Sandstone Conventional Oil; 2, Dakota-Greenhorn Conventional Oil and Gas; 3, Dakota-Greenhorn Continuous Gas; 4, Gallup Sandstone Conventional Oil and Gas; 5, Mancos Sandstone Conventional Oil and Gas; 6, Mancos Sandstone Continuous Gas AU; 7, Mesaverde Updip Conventional Oil; 8, Mesaverde Central-Basin Continuous Gas; 9, Menefee Coalbed Gas; 10, Lewis Continuous Gas; 11, Pictured Cliffs Continuous Gas; 12, Basin Fruitland Coalbed Gas; 13, Fruitland Fairway Coalbed Gas; and 14, Tertiary Conventional Gas. *Chacra sandstone is an informal term used by drillers and geologists in the basin; **La Ventana Tongue of the Cliff House Sandstone. Vertical lines indicate unconformities.

Commodities Assessed and Assessment Categories

The commodities evaluated in this study include oil, gas, nonhydrocarbon gases, and natural gas liquids, but only oil, gas, and natural gas liquids were quantitatively assessed. There are two accumulation categories used in this assessment, conventional and continuous. Although both of these categories use a different methodology to estimate the potential for additions to reserves, each uses the same evaluation of risk. Risk reflects the uncertainty that hydrocarbons may or may not be present in an area. There are three attributes of risk:

1. charge,
2. reservoir, and
3. trap,

each having a probability of occurrence ranging between zero and one. The definition of each attribute can be found in Klett and Schmoker (2003) for continuous-type accumulations and in Klett and others (2003) for conventional accumulations.

Conventional oil and gas accumulations generally occur in stratigraphic and structural traps within fields; gas-water or gas-oil contacts are common. For inclusion in this study, a field is expected to produce at least 0.5 million barrels of oil (MMBO) or 3 billion cubic feet (BCF) of gas. The assessment methodology for conventional accumulations incorporates a field number and field-size distribution approach, and the minimum, median, and maximum numbers and sizes of undiscovered accumulations are estimated (see Schmoker and Klett, 2003).

Continuous oil and gas accumulations include those types of accumulations where the source rock and reservoir rock are interbedded or the same; the reservoir rocks are characterized by low permeability (except coal-bed methane reservoirs) and abnormal pressures, and there is no well-defined gas-water or gas-oil contact. An important attribute is lateral continuity of an accumulation over a large area (Law, 2002; Schmoker, 2003). Included in the continuous category are tight, low-permeability continuous-type accumulations (including basin-centered), shale gas, and coal-bed gas. Two geologic characteristics of continuous gas accumulations are

1. large volumes of rocks that are pervasively charged with gas or oil, although not all areas may be economic, and
2. lack of dependency upon buoyancy of oil or gas in water for their existence (Schmoker, 2003).

Continuous accumulations have no set minimum production or potential production cutoff like that used in the conventional assessment methodology. Rather, minimum production cutoff is determined for each assessment unit using data from the estimated ultimate recovery (EUR) distribution of wells already drilled, or using analogs from other areas. The continuous assessment methodology uses a cell-based approach to estimate the potential additions to reserves of undiscovered resources. Schmoker (2003) explained the specifics of continuous assessment methodology.

The bulk of the oil and gas resources in the San Juan Basin Province are in rocks of Cretaceous age (fig. 3). Small amounts of oil occur in the Middle Jurassic Entrada Sandstone or in various reservoirs in rocks of Pennsylvanian age. Resources in rocks of Paleozoic age are not included in this San Juan Basin National Oil and Gas Assessment.

Data Sources

Two principal sources of production data were used in the assessment. Data for conventional oil and gas accumulations were obtained from the 2001 Significant Oil and Gas Fields of the United States file (NRG Associates, 2001), a database that is commercially available from NRG Associates. Field data through 2001 were used. Production data for wells from the continuous assessment units were obtained from the PI/Dwights PLUS database, which is commercially available from IHS Energy Group (IHS Energy Group, 2001, 2002, 2003). Background data for the geology used in each description of the total petroleum system as well as the individual assessment units were obtained from published literature, as well as from new scientific efforts at the USGS or existing, unpublished data in USGS geochemistry databases.

Assessment Results

In this assessment, four TPSs were defined. These are, in ascending order, Todilto, Mancos-Menefee Composite, Lewis Shale, and Fruitland (fig. 3). The stratigraphic distribution of the TPSs is shown on the regional chronostratigraphic chart, which excludes formations older than those covered in this report (fig. 3). Each TPS is composed of one or more assessment units, which are principally lithostratigraphic in nature, but are also tied to the primary source interval by migration pathways.

There were six conventional AUs and eight continuous AUs defined (table 2). Three AUs, Lewis Continuous Gas AU, Menefee Coalbed Gas AU, and Tertiary Conventional Gas AU, were defined to include rock units not specifically assessed in 1995. The Menefee Coalbed Gas AU is hypothetical because the Menefee Formation has yet to produce coal-bed gas outside of the thermally mature deep basin center. The Tertiary AU has production from several Tertiary formations. Several of the 1995 plays have been redefined, based on new thinking about the depositional systems and the geologic controls on oil and gas accumulation. Most of the boundary changes involved assessment units in the Mancos-Menefee Composite TPS and in the Fruitland TPS. These reconfigurations are discussed more fully in the accompanying geologic reports (see chaps. 4 and 6, this CD-ROM); the changes make direct comparison to the 1995 assessment results difficult.

Table 2. List of total petroleum systems and their associated assessment units that were defined for the 2002 National Oil and Gas Assessment of the San Juan Basin Province (5022).

[N/A, not quantitatively assessed].

Total petroleum system (TPS)	Conventional assessment unit (AU)	Continuous assessment unit (AU)
Fruitland TPS	Tertiary Conventional Gas AU	Fruitland Fairway Coalbed Gas AU
		Basin Fruitland Coalbed Gas AU
		Pictured Cliffs Continuous Gas AU
Lewis Shale TPS		Lewis Continuous Gas AU
Mancos-Menefee Composite TPS	Mesaverde Updip Conventional Oil AU (N/A)	Mesaverde Central-Basin Continuous Gas AU
	Mancos Sandstones Conventional Oil AU	Menefee Coalbed Gas AU
	Gallup Sandstone Conventional Oil and Gas AU	Mancos Sandstones Continuous Gas AU
	Dakota-Greenhorn Conventional Oil and Gas AU	Dakota-Greenhorn Continuous Gas AU
Todilto TPS	Entrada Sandstone Conventional Oil AU	

The stratigraphic interval covered by each assessment unit is shown in figure 3. Chapters 3–6 in this CD-ROM contain discussions of geology and geochemistry of specific total petroleum systems in addition to a discussion of each associated assessment unit. Chapter 7 includes companion data used in making assessments of undiscovered petroleum resources for each AU. The relationship between each petroleum system and its associated assessment units is summarized in table 2 and figure 3.

Results of this 2002 assessment are presented in table 1 and in the discussion of each assessment unit. These potential additions to reserves are evaluated regardless of political, economic, or other considerations. The assessment incorporates a more thorough understanding of the geology and geochemistry of the total petroleum systems and "sweet spot" (areas having the highest potential to contain resources) development, and thus, the potential additions to reserves of undiscovered resources is geologically based.

The assessment results are shown by TPS and AU in table 1. The USGS estimated a mean of 19.10 million barrels of oil (MMBO), 50.585 trillion cubic feet of gas (TCFG), and 148.37 million barrels of natural gas liquids (MMBNGL) of undiscovered resources. All of the undiscovered oil resources are in conventional accumulations in the Todilto TPS and in the Mancos-Menefee Composite TPS. Over 99 percent of the total undiscovered gas resources are to be found in continuous accumulations, primarily in the Fruitland TPS, which accounts for 57.9 percent of this estimate. The Fruitland Formation alone accounts for 46.8 percent of the estimated undiscovered gas in continuous accumulations. Over 97 percent of the undiscovered natural gas liquids are in continuous accumulations in the Mancos-Menefee Composite TPS, Lewis Shale TPS, and Fruitland TPS (table 1). A comparison of total undiscovered resources between the 1995 assessment and the 2002 assessment is shown in table 3.

Table 3. Comparison of undiscovered, oil, gas, and natural gas liquids between the 1995 and 2002 oil and gas assessment of the San Juan Basin Province, New Mexico and Colorado.

[MMBO, million barrels of oil; TCFG, trillion cubic feet of gas; MMBNGL, million barrels of natural gas liquids.

Total Mean Undiscovered Resources	
2002 USGS Assessment	1995 USGS Assessment
19.10 MMBO	280 (91)[1] MMBO
50.584 TCFG	29.23 TCFG
148.37 MMBNGL	18.51 MMBNGL

[1]*280 (91) First value included all oil; second value excludes oil from the continuous Mancos Fractured Shale Play 2008.]

References Cited

Fassett, J.E., 2000, Geology and coal resources of the Upper Cretaceous Fruitland Formation, San Juan Basin, New Mexico and Colorado, chap. Q *of* Kirschbaum, M.A., Roberts, L.N.R., and Biewick, L.R.H., eds., Geologic assessment of coal in the Colorado Plateau—Arizona, Colorado, New Mexico, and Utah: U.S. Geological Survey Professional Paper 1625–B, p. Q1–Q132.

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, 1 CD-ROM.

Huffman, A.C., Jr., 1996, San Juan Basin Province (22), *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, 1 CD-ROM.

Huffman, A.C., Jr., and Taylor, D.J., 2002, Fractured shale reservoirs and basement faulting, San Juan Basin, New Mexico and Colorado: American Association of Petroleum Geologists Rocky Mountain Section Meeting, Laramie, Wyo., p. 30.

IHS Energy Group, 2001, 2002, and 2003, PI/Dwights Plus U.S. well data [includes data current as of September 2001, June 2002, and January 31, 2003, respectively]: Englewood, Colo., IHS Energy Group; database available from IHS Energy Group, 15 Inverness Way East, D205, Englewood, CO 80112, U.S.A.

Klett, T.R., and Schmoker, J.W., 2003, U.S. Geological Survey input-data form and operational procedure for the assessment of continuous petroleum accumulations, chap. 18 *of* USGS Uinta-Piceance Assessment Team, Petroleum systems and geologic assessment of oil and gas in the Uinta-Piceance Province, Utah and Colorado: U.S. Geological Survey Digital Data Series 69–B, 8 p. [*http://pubs.usgs.gov/dds/dds-069/dds-069-b/chapters.html,* last accessed 04/2008]

Klett, T.R., Schmoker, J.W., and Charpentier, R.R., 2003, U.S. Geological Survey input-data form and operational procedure for the assessment of conventional petroleum accumulations, chap. 20 *of* USGS Uinta-Piceance Assessment Team, Petroleum systems and geologic assessment of oil and gas in the Uinta-Piceance Province, Utah and Colorado: U.S. Geological Survey Digital Data Series 69–B, 7 p. [*http://pubs.usgs.gov/dds/dds-069/dds-069-b/chapters.html*, last accessed 04/2008]

Law, B.E., 2002, Basin-centered gas systems, *in* Law, B.E., and Curtis, J.B. eds., Unconventional petroleum systems: American Association of Petroleum Geologists Bulletin, v. 86, no. 11, p. 1891–1919.

Magoon, L.B., and Dow, W.G., 1994, The petroleum system, *in* Magoon, L.B., and Dow, W.G., eds., The petroleum system—From source to trap: American Association of Petroleum Geologists Memoir 60, p. 3–24.

Molenaar, C.M., 1977, San Juan Basin time-stratigraphic nomenclature chart, *in* Fassett, J.E., James, H.L. and Hodgson, H.E., eds., San Juan Basin III: New Mexico Geological Society Guidebook, p. xii.

NRG Associates, 2001, The significant oil and gas fields of the United States [includes data current as of December, 31, 2001]: Colorado Springs, Colo., NRG Associates, Inc. [database available from NRG Associates, Inc., P.O. Box 1655, Colorado Springs, CO 80901]

Schmoker, J.W., 2003, U.S. Geological Survey assessment concepts for continuous petroleum accumulations, chap. 17 *of* USGS Uinta-Piceance Assessment Team, Petroleum systems and geologic assessment of oil and gas in the Uinta-Piceance Province, Utah and Colorado: U.S. Geological Survey Digital Data Series 69–B, 7 p. [*http://pubs.usgs.gov/dds/dds-069/dds-069-b/chapters.html*, last accessed 04/2008]

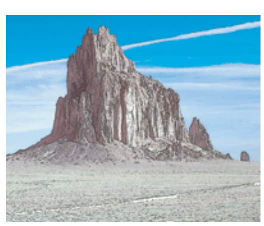
Schmoker, J.W., and Klett, T.R., 2003, U.S. Geological Survey assessment concepts for conventional petroleum accumulations, chap. 19 *of* USGS Uinta-Piceance Assessment Team, Petroleum systems and geologic assessment of oil and gas in the Uinta-Piceance Province, Utah and Colorado: U.S. Geological Survey Digital Data Series 69–B, 6 p. [*http://pubs.usgs.gov/dds/dds-069/dds-069-b/chapters.html*, last accessed 04/2008]

Stevenson, G.M., and Baars, D.L., 1986, The Paradox—A pull-apart basin of Pennsylvanian age, *in* Peterson, J.A., ed., Paleotectonics and sedimentation in the Rocky Mountain region, United States: American Association of Petroleum Geologists Memoir 41, p. 513–539.

Taylor, D.J., and Huffman, A.C., Jr., 1998, Map showing inferred and mapped basement faults, San Juan Basin and vicinity, New Mexico and Colorado: U.S. Geological Survey Geological Investigations Series 2641, scale 1:500,000.

Taylor, D.J., and Huffman, A.C., Jr., 2001, Seismic evaluation study report: Jicarilla Apache Indian Reservation: U.S. Department of Energy Report DE-AI26-98BC15026R10 (CD-ROM).

U.S. Geological Survey San Juan Basin Assessment Team, 2002, Assessment of undiscovered oil and gas resources of the San Juan Basin Province of New Mexico and Colorado, 2002: U.S. Geological Survey Fact Sheet 147–02, 2 p.



Click here to return to
Volume Title Page