UINTA-PICEANCE BASIN PROVINCE (020)

By Charles W. Spencer

INTRODUCTION

This province trends west-east, extending from the thrust belt in north-central Utah, on the west, to the southern Park Range and Sawatch Uplift in northwestern Colorado on the east. The northern boundary is defined roughly by the Uinta Mountain Uplift, and the southern boundary is located along a line north of the axis of the Uncompahgre Uplift. The province covers an area of about 40,000 sq mi and encompasses the Uinta, Piceance, and Eagle Basins. Sedimentary rocks in the basin range in age from Cambrian to Tertiary. Spencer and Wilson (1988) provided a summary of the stratigraphy and petroleum geology of the province.

The Uinta and Piceance Basins were formed mainly in Tertiary time. The Eagle Basin is a structural feature east of the Piceance Basin and coincides in part with the Pennsylvanian-age Eagle Evaporite Basin, although the present-day Eagle Basin is much smaller than the paleodepositional basin. Numerous oil and gas fields have been discovered in the Uinta and Piceance basins; however, there have been no fields discovered in the Eagle *structural* basin. The lack of exploration success in the Eagle Basin is attributed to very thermal maturity levels in source rocks (Johnson and Nuccio, 1993) and the generally poor quality of reservoirs, and although gas might be present, the expected volume is small.

The Uinta Basin of Utah is about 120 mi long and is bounded on the west by the thrust belt and on the east by the Douglas Creek Arch. It is nearly 100 mi wide and bounded on the north side by the Uinta Mountains Uplift. Here, more than 30,000 ft of Phanerozoic sedimentary rocks may be present. The Piceance Basin of Colorado is kidney-shaped and oriented northwest-southeast. It is about 100 mi long and 40-50 mi wide, and bounded on the northeast by the Axial Uplift, and on the east by the White River Uplift. The basin is asymmetrical and deepest along its east side near the White River Uplift, where more than 20,000 ft of Phanerozoic sedimentary rocks are present.

Exploration in the province began in the late 1800’s. The first phase mostly consisted of drilling near surface oil seeps. The first field in the province, now called White River (T. 2N., R. 97 W., Rio Blanco Co., Colo.), was discovered in 1890 and produces from sandstone in the Tertiary Wasatch Formation that has an estimated ultimate recovery (EUR) of 12 billion cubic feet of gas (BCFG). The field also produces from sandstone in the Upper Cretaceous Mesaverde Group (EUR 4.5 BCFG). Starting in the 1920’s, a second phase of exploration was directed toward drilling obvious surface structures. The first discovery in Utah was made in 1925 in the Ashley Valley Anticline (T. 5 S., R. 22 E., Uinta County, Utah) when gas flowed from shallow sandstone in the Jurassic Morrison Formation. The main producing reservoir today is the Permian Upper Weber Sandstone which was discovered in 1948. The Weber pay has an estimated ultimate recovery of 21 million barrels of oil (MMBO). The Permian Park City Formation also produces some oil at Ashley Valley.

In the late 1950’s seismic mapping was becoming popular and in the 1960’s explorationists were realizing that production was stratigraphically controlled in many structural traps. Thus, in the 1960’s stratigraphic traps were being explored for on purpose. Today, most prospects are based on mapping stratigraphic traps in both conventional and continuous-type plays.

The largest field in the province is Rangely (T. 1-2, N., R. 102 W., Rio Blanco County, Colo.). Oil in shallow Upper Cretaceous fractured shales was found near surface seeps on the Rangley Anticline in 1902, but the main Permian-Pennsylvanian Weber reservoirs (EUR 955 MMBO, 706 BCFG) were not discovered until 1933. In the last 10 years exploration in the province has concentrated on drilling for oil and gas in stratigraphic traps in Tertiary and Cretaceous sandstone. Much of this drilling has been directed toward continuous-type (tight) gas accumulations in sandstone.

Six conventional plays in the province were assessed. These plays are the Piceance Tertiary Conventional Play (2001), Uinta Tertiary Oil and Gas Play (2002), Upper Cretaceous Conventional Play (2003), Cretaceous Dakota to Jurassic Play (2004), Permian-Pennsylvanian Sandstones and Carbonates Play (2005), and Basin Margin Subthrusts Play (2014).

Seven continuous-type unconventional plays were assessed: one self-sourced fractured-shale play that is present in both the Uinta and Piceance Basins, four tight gas plays in the Uinta Basin (Fouch and Schmoker, this chapter), and two tight gas plays in the Piceance Basin. These plays are: Cretaceous Self-Sourced Fractured Shales Play (2009); Tight Gas Piceance Mesaverde Williams Fork Play (2007); Tight Gas Piceance Mesaverde Iles Play (2010); Tight Gas Uinta Tertiary East Play (2015); Tight Gas Uinta Tertiary West Play (2016); Basin Flank Uinta Mesaverde Play (2018); and Deep Synclinal Uinta Mesaverde Play (2020). A small area in the Piceance Basin was identified as having some minor tight gas resource potential in the Tertiary Wasatch Formation but was not deemed significant enough to be assessed separately from the Tertiary Conventional Play (2001) in the present assessment.

Several other conventional plays were considered in this assessment but were not assessed separately. These minor play resources are included in the small-field resource estimates. Small accumulations of oil and gas may be found in Pennsylvanian fault blocks. Mississippian carbonates have known porosity at depth but lack adequate source-to-reservoir relationships and where tested have mostly yielded either water or CO_2. Triassic sandstones are present but are not prospective for discovery of significant fields.

Other unconventional plays in the province include coalbed methane resources, heavy oil and tar resources, and oil shale. Coalbed methane is assessed by D.D. Rice and others (see plays 2050 to 2057) and heavy oil and tar resources are described by Mark Pawlewicz (this CD-ROM). Oil shale resources are not included in the present National Assessment.

ACKNOWLEDGMENTS

The author would like to thank the following organizations for their technical assistance, data, and suggestions during this assessment: Colorado Geological Survey, especially Carol M. Tremain and James A. Cappa; Utah Geological Survey, especially Douglas Sprinkel; Snyder Oil Co.; Barrett Resources; Mobil Oil Co.; Meridian Oil Inc.; American Natural Resources; and Shell Western Exploration and Production. The following individuals are also thanked: John C. Osmond, Logan T. MacMillan, Charles A. Brown, Terry R. Barrett, Frank F. Farnham, and Kurt M. Reinecke. The U.S. Department of Energy (Morgantown) provided technical and financial support to the USGS for the research on tight gas reservoirs. Scientists affiliated with the American Association of Petroleum Geologists and from various State geological surveys contributed significantly to play concepts and definitions. Their contributions are gratefully acknowledged.

CONVENTIONAL PLAYS

2001. PICEANCE TERTIARY CONVENTIONAL PLAY

This gas play is entirely within the Piceance Basin. The play is confirmed and includes mostly fluvial sandstone in the Tertiary Wasatch Formation and some marginal lacustrine sandstone in the Douglas Creek Member of the Green River Formation. The play is limited updip by gas lost to outcrop. Play accumulations range from structural to stratigraphic. Undiscovered resources range in depth from less than 1,000 ft to about 7,000 ft with a median depth of 3,500 ft. Generally, the sandstones are fairly discontinuous.

Reservoirs: The reservoirs in the Tertiary Wasatch Formation and Douglas Creek Member are litharenites to feldspathic litharenites. Porosity ranges from about 11 percent to more than 15 percent and porous zones vary in thickness from about 10 ft to more than 50 ft.

Source rocks: Potential source rocks, which are interbedded with the reservoirs, are mostly thermally immature. Gas analyses indicate that the Tertiary gas migrated vertically from underlying Upper Cretaceous Mesaverde Group gas-prone source beds (Johnson and Rice, 1990). Locally, gas in the Douglas Creek Member of the Green River Formation may have a Tertiary source (D.D. Rice and R.C. Johnson, oral commun., 1988).

Timing and migration: Gas began to be generated in the underlying Mesaverde in early Tertiary time and continues to the present time (Spencer and Wilson, 1988, their fig. 6). We can only assume that this gas is still migrating vertically into Tertiary sandstones.

Traps: Traps are primarily stratigraphic and structural-stratigraphic. Seals are enclosing shale, mudstone, and siltstone. Some traps have diagenetic seals. Presently discovered fields range in depth from about 500 ft to less than 5,500 ft.

Exploration status and resource potential: The play is only moderately explored even though it has been penetrated by numerous wells drilled to Mesaverde objectives. The Tertiary gas reservoirs are underpressured, and it is possible that quite a few shallow gas reservoirs may have been bypassed. Also, because of higher Mesaverde per-well gas recoveries, the wells will be completed first in the Mesaverde and, after depletion, will be recompleted in the Wasatch. Five significant non-associated gas accumulations have been discovered. We expect that at least 12 more will be found and a maximum of 65 such accumulations could occur. This estimate is partly based on the postulated huge volume of gas that has been generated and escaped from rich Mesaverde coaly sources.

A small area in the deeper part of the basin has potential for gas production from tight Tertiary reservoirs but was not assessed separately because of its relatively low potential and the difficulty of separating conventional and unconventional Tertiary reservoirs. In this play, any gas that may be tight is included in the conventional assessment to avoid "double counting."

2002. UINTA TERTIARY OIL AND GAS PLAY

This Uinta Tertiary Oil and Gas Play (2002) is based on oil and gas accumulations in mostly stratigraphic traps in fluvial and lacustrine sandstones in the Wasatch and Green River Formations. The play area is limited updip by the presence of brackish and fresh water in rocks near the outcrop.

The stratigraphy of the Uinta Basin and complexities of defining tight versus conventional are well described by Fouch and others (1992, 1994). Tight **gas** reservoirs are described separately for resource estimate purposes; however, the deep, overpressured **oil** reservoirs in the Uinta Basin are also largely tight and grade updip into conventional oil and gas reservoirs, and all have been assessed in this play. Most of the deep (tight) oil reservoirs are discovered (Greater Altamont-Bluebell), but new fields continue to be found updip that are separate from the main discovered trend. However, although there is a stratigraphic overlap of Uinta Wasatch tight and conventional gas plays, close coordination by the author and T.D. Fouch has prevented "double counting."

Reservoirs: The Wasatch and Green River Formations reservoir sandstones are Paleocene and Eocene in age, are predominantly litharenites and feldspathic litharenites over most of the basin, but some lacustrine limestones produce in the deeper part of the basin. Porosities range from less than 10 percent in the deep Altamont-Bluebell field area to more than 15 percent at shallower depths (<4,000 ft).

Source rocks: The source rocks for much of the non-associated Wasatch gas in the basin is the underlying Mesaverde gas-prone coals, shales, and mudstones (D.D. Rice, oral commun., 1988; Rice and others, 1992; and Nuccio and others, 1992), but some may have a Tertiary origin. In the northern part of the basin, oil is the predominant hydrocarbon, and this oil was sourced by lipid-rich lacustrine shales and marlstones in the Green River Formation. A complex mixing of oil and gas from different sources has resulted in more gas fields at shallower depths and predominantly oil in deeper reservoirs. This is the opposite of what occurs in many other basins.

Timing and migration: The Mesaverde began generating gas in early Tertiary time, and the Green River began generating oil and gas in middle Tertiary time, continuing to the present. The deep (>10,000 ft) Tertiary oil fields are highly overpressured as a result of present-day hydrocarbon generation.

Traps: The traps are mostly stratigraphic, but some structural-stratigraphic traps occur, such as the Red Wash field area (ult. 175 MMBO, 373 BCFG). The largest producing area is the greater Altamont-Bluebell area, which has an ultimate recovery of 260 MMBO and 378 BCFG; however, the field is being actively downspaced from 640 acres per well to 320 acres, and this additional drilling should significantly increase ultimate recovery.

Exploration status and resource potential: The conventional gas part of this play is fairly well explored, but we estimate a maximum of 15 conventional fields greater than 6 BCFG may be found. Because of the very large volume of oil generated deep in the basin, we believe a maximum of 30 oil fields greater than 1 MMBO remain to be found.

2003. UPPER CRETACEOUS CONVENTIONAL PLAY

This play is mostly for gas in sandstones of the Mesaverde Group at shallow depths in both the Piceance and Uinta Basins; however, discovered fields are mostly in the Piceance Basin. Fields are localized by structure, but stratigraphic traps have also been found. The play is limited downdip where the reservoirs become unconventional (tight) and is limited updip by fresh-water flushing. The Mesaverde part of this play has some areal overlap with tight Mesaverde reservoirs. The tight rocks generally are beneath and (or) downdip of conventional Mesaverde reservoirs.

Reservoirs: The reservoir rocks are Cretaceous Mesaverde Group sandstones deposited in marginal-marine, fluvio-deltaic, and fluvial environments. Some very fine grained sandstone and siltstone reservoirs were deposited in a shallow-marine shelf environment seaward of, and in part beneath, the Mesaverde. These reservoirs include Mancos "B" and equivalents, but much of the Mancos "B" fields are tight and mostly developed by drilling, but have some potential for field growth.

Source Rocks: The Mesaverde source beds are organic shales (including some coals) interbedded with the sandstones.

Timing and Migration: Time of generation is late Tertiary to present.

Traps: Traps are predominantly structural-stratigraphic and stratigraphic. Accumulations will be found at depths of less than 1,000 ft to 6,000 ft, with a median depth of 3,500 ft.

Exploration Status: The conventional part of the play is well explored in the Piceance Basin and only moderately explored in the Uinta Basin.

Because of the large volume of gas generated by Mesaverde source beds, we estimate that a minimum of 10 conventional fields will be found and a maximum of 50 may be discovered. These resources will be found by high quality stratigraphic mapping and possibly three dimensional seismic work.

2004. CRETACEOUS DAKOTA TO JURASSIC PLAY

This is primarily a play for accumulations in conventional reservoirs, but tight reservoirs are mixed with the conventional rocks and the discovered fields are mostly structurally controlled. It is predominantly a gas play (90 percent gas, 10 percent oil) based on known fields. The Cretaceous Dakota Sandstone (including Cedar Mountain Formation) and Jurassic were combined into one play because many fields produce from rocks of both ages and any structure drilled has the potential for accumulations in rocks of one or both ages. The Wilson Creek field is the southeasternmost producing structure along a series of producing structures that includes the Maudlin Gulch field. All these **oil** fields are included in the Southwestern Wyoming Province (037), Axial Uplift Play (3703). The downdip limits of the play are where the rocks become tight and reservoirs unconventional (>6,000 ft).

It was very difficult to separate conventional fields from tight gas fields because within a given field both qualities of reservoir rocks produce. In situ permeability to gas of 0.1 mD or less is one criteria for the **legal** definition of tight reservoirs. Because of the close interassociation of conventional and tight reservoirs in this play, we chose not to separate them for this assessment and treated all as conventional. Many areas have been certified as tight, and we agree with these designations. A more detailed study of this problem may help to separate conventional and tight resources in the future. At the present time, our main concern was to avoid a double count.

Reservoirs: The Cretaceous Dakota reservoirs vary from lenticular to continuous and in the play area are predominantly fluvial. The Jurassic reservoirs range from discontinuous fluvial sandstones in the Morrison Formation to blanket eolian sandstones in the Entrada. Porosities range from less than 11 percent to about 25 percent.

Source rocks: Source rock data for this play are lacking in the public record, but some dark shales, mudstones, and thin coals are present in the Dakota. The overlying marine Cretaceous Mowry and Mancos Shales are both known source beds (mostly oil prone).

Timing and migration: The hydrocarbons were probably generated in Late Cretaceous to early Tertiary time, and some may have remigrated into younger Tertiary structures.

Traps: The known traps are predominantly structural, and some have stratigraphic modifications of the accumulation. Many of the fields are situated on surface anticlines; they tend to be large and were discovered relatively early in the exploration cycle. San Arroyo-East Canyon (EUR 174 BCFG) was discovered in 1955 and produces from the Dakota (including Cedar Mountain) and the Jurassic Entrada Sandstone. Many of the fields have significant amounts of nitrogen and CO_2 (as much as 25 percent).

Exploration status and resource potential: The play is maturely explored for large fields, but subtle structures and stratigraphic traps may contain as many as 25 significant accumulations.

2005. PERMIAN-PENNSYLVANIAN SANDSTONES AND CARBONATES PLAY

This is primarily a play for structural and stratigraphic traps in Permian and Pennsylvanian sandstones and carbonates. The objective reservoirs were deposited in predominantly marine and eolian environments. Some redbeds occur but are not part of the prospective facies.

The eastern part of the play is bounded by the expected limit of porous sandstones. The southern boundary is limited by expected presence of structural and stratigraphic traps in the Uinta Basin; the northern limit is based on expected limit of conventional reservoirs. The play is very high risk.

Reservoirs: The Permian-Pennsylvanian reservoirs will be both sandstone and carbonate. The sandstones have good reservoir quality at shallow depth (<8,000 ft). The carbonates are expected to be porous at least as deep as 12,000 ft. The shallow sandstones (Weber Sandstone) have about 11–14 percent porosity in the only two discovered fields in the play.

Source rocks: The source rocks for the discovered oil fields are not known, but probably the Park City (Phosphoria) Formation was the source, requiring long-range migration. Some local Pennsylvanian marine source beds (shale) may also be a source.

Timing and migration: The hydrocarbons must have migrated prior to the Tertiary tectonism; thus generation was probably in Upper Cretaceous time.

Exploration status and resource potential: Only two fields have been found in the province. They are both related to anticlinal closures. Both these fields are oil. The play is for oil with associated gas, but it is possible that some gas fields of less than minimum size (6 BCFG) may also be found. Several Pennsylvanian sandstone and carbonate reservoirs produce on closures just outside the province in the Maudlin Gulch field area (Danforth Hills Anticline), and a small amount of oil and condensate has been produced from the Pennsylvanian at Wilson Creek field, which is included in the Axial Uplift Play (3703) in the Southwestern Wyoming Province.

The two producing fields in the play are Ashley Valley in Utah (EUR 25.5 MMBO) and Rangely in Colorado (EUR 955 MMBO, 706 BCFG). Ashley Valley produces from about 4,000 ft and Rangely from 5,500 to more than 6,000 ft. The play depths for undiscovered accumulations range from 6,000 to 12,000 ft. The play deeper than 8,000 ft is relatively unexplored by drilling but quite well explored by seismic mapping. Rangely is believed to have been a stratigraphic accumulation that later was overprinted by a large Tertiary anticline. Rangely is the largest field in the province and one of the largest in the Rocky Mountains region.

There is a very high degree of uncertainty of success in this play, both in field size and numbers. It is estimated that at least one more field will be found, and a maximum of 15 may be found with a median number of 4 undiscovered accumulations.

2014. BASIN MARGIN SUBTHRUSTS PLAY (HYPOTHETICAL)

Many uplifts in the Rocky Mountains region are bounded by high- to low-angle thrusts. The Uinta-Piceance Province has many such thrusts. The play is primarily for closures beneath the thrusts. Figure 1 shows some of the flanking thrusts present along the northern to eastern part of the province. The play is hypothetical, and both oil and gas are expected to be found. The only nearby analog is the Tepee Flats field in the eastern Wind River Basin-Casper Arch area (Wind River Basin Province (035)). Here, thick unfractured Cretaceous marine shale provides a seal for an oil and gas accumulation in the Upper Cretaceous Frontier Formation.

Reservoirs: The reservoirs for this play range in age from Paleozoic to Tertiary. Reservoir quality may be poor, especially for prospects deeper than 12,000 ft. The Mississippian carbonates are expected to be porous in most parts of the play.

Source rocks: The source rocks can be within the subthrust section. Possible source rocks containing more than 1 percent total organic carbon (TOC) are found in the lower Tertiary, Upper Cretaceous, and Pennsylvanian Belden Shale. The Jurassic Curtis Formation may locally be a source bed.

Timing and migration: The timing is problematical, but most of the thrusting took place during the Laramide Orogeny.

Traps: Traps are expected to be structural and structural-stratigraphic. Play depths are expected to range from 5,000 ft to as much as 25,000 ft.

Exploration status and resource potential: The play is almost unexplored by drilling and moderately explored by seismic mapping. Based on the abundant fields **near** the thrusts in both basins, a median field size of 2 MMBO, non-associated gas at 15 BCFG, and a maximum field size of approximately 50 MMBO and 150 BCFG have been estimated for this play.

UNCONVENTIONAL PLAYS

CONTINUOUS-TYPE PLAYS

Three kinds of confirmed continuous-type unconventional plays are assessed in this province. The first consists of oil in fractured Upper Cretaceous marine shale, the second includes gas in tight (very low permeability) sandstone reservoirs, and the third is coalbed gas discussed by Dudley Rice and others. (Further discussion of coalbed gas plays, with references, may be found in the chapter by Rice, "Geologic framework and description of coalbed gas plays" elsewhere in this CD-ROM). The province also contains important resources of heavy oil and tar. Heavy oil resources will be discussed elsewhere (see chapter by Mark Pawlewicz, this CD-ROM). Moreover, the largest volume of **mineable** oil shale in the United States is present in the Uinta and Piceance basins.

There are many fields in Rocky Mountain basins that produce oil from fractured marine and lacustrine shales, siltstones, mudstones, and limestones. The characteristics of these accumulations are: (1) the source rock is also the reservoir rock, (2) water is not commonly produced, (3) there are no obvious oil/water contacts, (4) the location of the fractures is difficult to predict, and (6) horizontal drilling is commonly the best development method because the fractures are vertical.

Self-Sourced Fractured Shales Oil Play

2009. CRETACEOUS SELF-SOURCED FRACTURED SHALES PLAY (HYPOTHETICAL)

Oil is produced from fractured Upper Cretaceous Mancos Shale and its equivalents. The best fracturing occurs in brittle siltstones, carbonates, and calcareous shale. The play crosses the province boundary into the Southwestern Wyoming Province (037).

The play outline was based on the known occurrence of production and the tectonic features associated with known and suspected potential. In the play, the best open fractures occur at the maximum flexure on anticlines or monoclines. Fractures also produce well where shear zones or faults occur. The play boundary is fairly easy to define except in the area between Rangely and the Axial Uplift, where proprietary seismic data indicate the presence of several subsurface thrusts, including thrusts associated with the White River field structure.

Reservoirs: The reservoirs are open fractures in brittle siltstones, carbonates, and calcareous shale and siliceous shale. The producing interval can be 10 ft to more than 50 ft. The fracturing is highly variable and one well in the play has produced over 1 MMBO.

Source rocks: The source rocks are the enclosing marine shale. The richness varies from about one percent to more than four percent, based on unpublished information.

Timing and migration: The oil probably was generated in late Tertiary time during maximum burial.

Traps: The trap is formed by the enclosing unfractured, more plastic shale, which contains less silt and carbonate than the brittle facies, which contains more silt and carbonate. The largest accumulation in the play is at Rangely field (EUR 14 MMBO). The highest concentration of Mancos oil wells at Rangely is along the south flank of the structure at the point of maximum flexure.

Exploration Status and Resource Potential: The play is moderately well explored by vertical wells but nearly unexplored by slant- and horizontal-hole drilling. We assumed a low success ratio for the *overall* play area. Although this play is classified as a continuous-type play (e.g., tight gas), production will be localized by individual fractured structures and fracture trends. Per well, EUR estimates are extremely variable and, although we treated this as a continuous-type occurrence, we also simulated individual undiscovered fields or "sweet spots" within it to assist in assessment. The success ratio in well-mapped structural flexures will be quite high, perhaps more than 50 percent; and there is high potential for finding many areas of small production, and perhaps as many as 10 larger fields.

Tight gas plays of the Piceance Basin

Major resources of tight gas are present in the province. Many Federal Energy Regulatory Commission-designated tight gas areas in the province have been approved for Internal Revenue Service tax credits . The most common definition of a tight reservoir is one that has an **in-situ permeability** to **gas** of 0.1 mD or less (Spencer, 1989). The characteristics of these accumulations are discussed elsewhere in this CD-ROM by Schmoker and by Spencer (1989). However, natural fractures are always needed to provide commercial gas production rates. Commonly, the wells are hydraulically fractured to further improve productivity.

Tight gas resources in the Uinta Basin were assessed by Fouch and others (1994) as part of a cooperative study with the U.S. Department of Energy. The assessment in the Piceance basin has been divided into two plays on the basis of some differences in reservoir stratigraphy, differences in reservoir quality, and depth.

The two plays comprise the Iles Formation and Williams Fork Formation in the Mesaverde Group. The USGS has studied tight gas resources in the Mesaverde Group of the Piceance basin for about 10 years, and numerous papers have resulted. This work led to a modified volumetric assessment of gas resources by Johnson and others (1987). Johnson (1987) provided the details of the geology of Mesaverde tight reservoirs used to support this assessment. The play boundaries for the Iles and Williams Fork are very similar because they are parts of an overall sequence of gas-saturated rocks.

The assessment of recoverable tight gas in the Iles and Williams Fork was done by calculating various parameters for each play. The well spacing for Mesaverde tight gas areas in the basin is 160 acres and 80 acres. The 80-acre spacing was approved in 1994, and as of August 1994, only a few wells have been drilled on these spacing units. The assessment used 160-acre cells to calculate the number of untested cells because the EURs used in the fractile distributions were from wells all spaced at 160 acres. If 80-acre cells are used, it will almost double the estimated recoverable resources. In the future, there may be enough 80-acre EUR data to assess the plays using this cell size.

The assessment also considered that the Mesaverde has a considerable volume of behind pipe, potentially producible gas resources.

2007. TIGHT GAS PICEANCE MESAVERDE WILLIAMS FORK PLAY

This play consists of gas trapped in low-permeability sandstones in a typical continuous-type basin-center gas accumulation containing gas downdip and water updip. Boundaries of this play are based on mapping the thermal maturity of sandstone reservoirs in the Upper Cretaceous Williams Fork Member of the Mesaverde Group (Johnson and others, 1987, their fig. 15). Thermal maturity of the Mesaverde is not only a major control on gas generation but also is a major factor in determining reservoir quality (Johnson, 1987).

Reservoirs: The reservoirs in the Williams Fork Member are medium- to fine-grained litharenites that were deposited in fluvial environments. They vary in thickness from less than 10 ft to more than 50 ft. They are interbedded with organic-rich mudstones, siltstones, and shales, and some coals in the lower part. The porosity ranges from less than 5 percent to more than 8 percent. The thickness of the Williams Fork Member ranges from about 1,500 ft to 4,500 ft (Johnson and others, 1987). Drill depths for tight beds in the Williams Fork vary from 5,500 ft to more than 9,800 ft, with an average of 7,500 ft.

Source rocks: The source rocks are interbedded gas-prone shales, mudstones, siltstones, and coals. The play outline encompasses all the Williams Fork Member that has attained a vitrinite reflectance in oil (R_o) of 0.73 percent or higher, with the result that the entire play area is thermally mature.

Timing and migration: The gas was generated in Tertiary time and easily migrated into the reservoirs because of the interbedded relation of source and reservoir. We know large volumes of gas escaped because the sandstones are mostly filled to capacity. As noted earlier, most of the gas in the Tertiary Wasatch migrated upward from the Mesaverde.

Traps: The trapping mechanism is both stratigraphic and diagenetic.

Exploration status and resource potential: The play is only moderately well explored. Several “sweet spots” have been developed (for example, Rulison, EUR 19 BCFG). The play has major potential for additional recoverable gas resources, especially if prices increase and technology improves. Innovative techniques such as artificial fracturing with gas or slant- and horizontal-hole drilling will likely be used in the future. A few horizontal Mesaverde wells have been drilled, and anomalous amounts of water have been tested. Industry and the USGS are attempting to determine why water is being recovered from horizontal wells; whereas, vertical wells in the same areas do not produce significant amounts of water. The present author tentatively interprets that the water is coming from water at the bottom of **open** natural fractures. It is likely that the water in these open fractures could not be completely flushed by gas charging from adjacent source beds. I believe this condition is somewhat analogous to water found in coalbed cleats, and operators may need to attempt to dewater the wells through sustained production. Environmental and economic constraints will dictate if this approach is possible.

2010. TIGHT GAS PICEANCE MESAVERDE ILES PLAY

This play directly underlies the Williams Fork Play (2007), but the Iles reservoirs are predominantly marine and marginal marine, and some intertongue with the Mancos Shale. The play boundary is based on that part of the Iles that has attained a thermal maturity of 0.73 percent R_o or higher (Johnson and others, 1987, their fig. 17). The accumulation is a typical basin-center gas accumulation having almost complete gas saturation in the basin-center rocks and water updip. Some water-bearing sandstones do locally occur in the thermal maturity interval between 0.73 and 1.1 R_o. The conventional reservoirs are interbedded with the tight rocks in the upper part and at shallower depths.

Reservoirs: The Iles Member reservoirs are medium- to fine-grained litharenites that were deposited in mostly a regressive marginal marine environment including tongues of transgressive marine Mancos Shale (Johnson, 1987). The Iles is about 500–1,500 ft thick. Drill depths for tight beds in the Iles vary from about 5,800 ft to more than 10,000 ft, averaging 7,700 ft.

Source rocks: The source rocks are interbedded gas-prone shales, mudstones, and siltstones. The play outline encompasses all the Iles Member that has attained an R_o of 0.73 percent or higher.

Timing and migration: The gas was generated in Tertiary time, continuing until present, and easily migrated into the reservoirs because of the interbedded relation of the source and reservoir beds.

Traps: Traps are both stratigraphic and diagenetic with almost complete gas fill.

Exploration status: The play is only moderately explored by drilling. Several “sweet spots” have been developed. Increased gas prices and improved recovery technology will eventually cause local fields to join in one basin-wide gas field.

Tight Gas Plays of the Uinta Basin

By Thomas D. Fouch and James W. Schmoker

2015. TIGHT GAS UINTA TERTIARY EAST PLAY

This play is based on well-established gas production in the Uteland Butte, Chapita, and Buck Canyon zones (of subsidence usage of the Tertiary Wasatch Formation and levels of source-bed thermal maturation (Fouch and others, 1994). Updip to the south and east, the play limit is based on an increase in reservoir quality and a change to mostly conventional reservoirs that have gas-water contacts, which are included in Uinta Tertiary Oil and Gas Play (2002).

Downdip to the north, the limit is where the play becomes predominantly an oil play and is included in Play 2002. The west limit is along the Green River drainage, where the play becomes higher risk and has been assessed separately as Tight Gas Uinta Tertiary West Play (2016). The overall Wasatch tight gas plays (2015 and 2016) are based on vitrinite reflectance (R_O) levels in the underlying Cretaceous Mesaverde. Rice and others (1992) and Fouch and others (1992) showed Wasatch gas has migrated upward from the Mesaverde and that the play occurs between the basal Mesaverde R_O limits at 1.1–1.50 percent.

Reservoirs: Reservoir rocks are generally medium- to fine-grained feldspathic litharenites, and litharenites mostly deposited in fluvial environments. They are interbedded with mudstones, siltstones, and shales, and some coal. Porosity ranges from less than 5 percent to more than 9 percent. The reservoirs range in depth from about 3,000 ft to about 10,500 ft, having a median depth of 6,400 ft.

Source rocks: The predominant source of the gas is gas-prone source beds in the underlying Mesaverde (Fouch and others, 1992; Nuccio and others, 1992; Rice and others, 1992).

Timing and migration: The gas was generated in late Tertiary time, and may now be generated in the Mesaverde in the deeper parts of the play area.

Traps: Traps are both stratigraphic and diagenetic.

Exploration status: The play is moderately well explored, and several “sweet spots” have been found that have both conventional and tight reservoirs. The entire area of the play will eventually be nearly all productive having very few dry holes.

2016. TIGHT GAS UINTA TERTIARY WEST PLAY (HYPOTHETICAL)

This play is the western extension of Tight Gas Uinta Tertiary East Play (2015) and is separated from Play 2015 along the Green River drainage. Although the river is a surface feature, it more or less coincides with a decrease in drilling activity and reservoir quality westward. It is higher risk than Play 2015 and, on this basis, it was decided to use separate assessment parameters.

Reservoirs: This play has the same reservoir rocks as Play 2015 except for apparently lower porosity, ranging from less than 4 percent to about 8 percent in reservoir sandstones. The play depths range from about 4,500 ft to 11,000 ft, having a median depth of 7,500 ft.

Source rocks: The underlying Mesaverde is the gas source. The play limits approximately coincide with maturation levels of R_o 1.1–1.5 percent in gas-prone source beds in the basal part of the Mesaverde Group.

Timing and migration: Gas generation began in late Tertiary time and generation may still be going on now in the Mesaverde in the deeper parts; however, it is possible that vertical gas migration from the Mesaverde may not have been as effective as in Play 2015.

Traps: Traps are both stratigraphic and diagenetic.

Exploration status: There is considerably less drilling activity in this play relative to Play 2015. The play is only sparsely to moderately explored by drilling.

2018. BASIN FLANK UINTA MESAVERDE PLAY (HYPOTHETICAL)

This play is based on the widespread occurrence of tight, gas-saturated continental and marginal marine sandstone. The south, east, and west limits of the play are based on thermal maturation levels in the basal part of the Mesaverde Group. The reservoirs grade updip into more conventional Mesaverde reservoirs having gas-water contacts (see Upper Cretaceous Conventional Play 2003). The downdip (north) play boundary is based on Mesaverde burial depths greater than 15,000 ft (Fouch and others, 1994).

Reservoirs: The reservoirs are fine- to medium- grained litharenites to feldspathic litharenites, becoming coarser to the west. Permeabilities of most reservoirs are less than 0.1 mD. Porosity ranges from less than 4 percent to more than 12 percent, averaging about 8 percent (Nuccio and others, 1992). Play depth varies from 8,000 ft to 15,000 ft, having a median of 9,500 ft.

Source rocks: Source rocks are gas-prone thermally mature coals, carbonaceous shales, and mudstones in the Mesaverde Group.

Timing and migration: Gas generation began in Tertiary time and may be continuing to the present in the deeper parts of the play. The basal Mesaverde has a thermal maturity higher than R_o 1.1 percent.

Traps: Traps are both stratigraphic and diagenetic.

Exploration status: The play is essentially unexplored because of depth, economics, poor reservoir quality, and the fact that it is mostly overlain by oil- and gas-producing rocks from the Tertiary Green River Formation.

2020. DEEP SYNCLINAL UINTA MESAVERDE PLAY (HYPOTHETICAL)

This play is based on the expected occurrence of gas-saturated tight Mesaverde sandstone at depths greater than 15,000 ft. The limits of the play are based on depth and reservoir quality. This play borders Play 2018 and involves the same rocks.

Reservoirs: Reservoir rocks are sandstones interbedded with mudstones, siltstones, shales, and some coals. Porosity is generally poorer than in Play 2018, and, although there is almost no drilling, we expect porosity to be less than 8 percent to about 3 percent, having a median of 5–6 percent. Reservoir depths are more than 15,000 ft and as much as 25,000 ft, having a median of 20,000 ft.

Source rocks: Gas-prone organic material interbedded with the sandstone reservoirs has generated large volumes of gas.

Timing and migration: Gas generation began in Tertiary time and some gas may be still generating at the present time. The thermal maturity of the Mesaverde is in excess of R_o 1.5 percent and the deeper rocks are more than R_o 2.0 percent.

Traps: Traps are both stratigraphic and diagenetic.

Exploration status: The play is not well explored because the primary interest in the play area is the overlying Tertiary reservoirs.

Following are the coalbed gas plays for this province. Further information on coalbed gas is contained in the chapter “Geologic framework and description of coalbed gas plays by Dudley D. Rice.

Coal-Bed Gas Plays of the Uinta Basin

By Dudley D. Rice, Thomas M. Finn, and William B. Cashion

The Uinta Basin part of the Uinta-Piceance Basin Province (020) contains three coalbed methane plays: Uinta Basin–Book Cliffs Play (2050), Uinta Basin–Sego Play (2051), and Wasatch Plateau–Emery Play (2052).

Adams and Kirr (1984), Nuccio and others (1992), and Gloyn and Sommer (1993) present information on the geologic controls and coalbed methane potential of the Uinta Basin, eastern Utah and western Colorado.

In the Uinta Basin, potential areas for coalbed gas are along the south flank of the basin (Book Cliffs and Sego coal fields) and the Emery coal field area, which is south of the Book Cliffs, east of the Wasatch Plateau, and west of the San Rafael Swell. In these areas, coal beds are well developed and recoverable resources are at depths less than 6,000 ft. The Upper Cretaceous Ferron Sandstone and Mesaverde Group (Blackhawk Formation and Neslen Member of Price River Formation) are the main coal-bearing units.

In the Emery coal field area, the Ferron Sandstone is the coal-bearing interval, and it ranges from 400 to 500 ft in thickness. Thirteen coal beds have been identified, and the net coal thickness is as much as 35 ft. These coals are generally less than 2,000 ft deep and dip gently to the west (3_ to 5°).

In the Book Cliffs coal field, which is located on the south flank of the basin and west of the Green River, the following coal beds, in ascending order, are assigned to the Blackhawk Formation (400 to 1,300 ft thick) and have coalbed gas potential: Castlegate A, Castlegate B, Castlegate C, Kenilworth, Castlegate D, Castlegate E, Gilson, Fish Creek, Rock Canyon, and Sunnyside. Individual coal beds are as much as 25 ft thick, but the average thickness is 20 ft. The thickest coal beds occur in the lower 500 ft of the Blackhawk and are relatively continuous. The net coal is as much as 68 ft.

In the Sego coal field, which is east of the Green River, 4 major coal zones occur in the younger Neslen Member of the Price River Formation. The coal beds become fewer and thinner in an eastward (seaward) direction and eventually pinch out into marine shales of the Mancos Shale. As much as 23 ft of coal occur in the Neslen. In both the Book Cliffs and Sego coal fields, coal beds crop out along the border and dip gently (4° to 6°) to the north into the basin. Although depths of burial for these coals are greater than 20,000 ft along the axis of the basin, recoverable coalbed gas resources are probably restricted to depths less than 6,000 ft.

In the prospective areas (less than 6,000 ft depth), the rank of coals in the Ferron, Blackhawk, and Price River ranges from high-volatile C to A bituminous rank and increases with depth of burial. In the deepest part of the basin where depths of burial are greater than 20,000 ft, the rank of Blackhawk coals is probably low-volatile bituminous. In general, the thermal maturity trend follows the structural configuration on the base of the Mesaverde, which indicates that most of the thermal maturation was established prior to structural movement. On flanks of the basin, present-day rank was probably achieved prior to uplift. Some thermogenic gas was probably generated prior to uplift and erosion in Tertiary time.

In the Book Cliffs coal field, produced coalbed gas from depths of 4,200 to 4,400 ft averages 89 percent methane, 1 percent ethane, and 10 percent CO_2. Conventional reservoirs in nearby gas fields also produce high amounts of CO_2, but the origin is not known. The coals in the current area of production are marginal with respect to thermogenic gas generation. The gas may be thermogenic and (or) a mixture of thermogenic and relatively recent biogenic.

The Uinta Basin is a strongly asymmetric, east-west trending basin and the coalbed gas potential occurs on the gently dipping southern flank. A well-developed system of northwest-southeast trending faults and gilsonite veins probably cuts the coal-bearing Cretaceous rocks. These faults and veins developed along the north and northeast flanks of the Uncompahgre Uplift during late Paleozoic and Mesozoic time and were periodically reactivated. In the Book Cliffs, cleats are reported to be well-developed and two dominant face cleat sets have been identified: northwest and northeast.

Produced water in the Book Cliffs coal field area is moderately saline (TDS content of about 5,500 ppm, mostly bicarbonate). Water production rates are moderate (several hundred barrels per day initially) and the water will probably be injected into deeper Mesaverde sandstones or discharged on the surface after salinity and solids are reduced.

Abundant desorption data, particularly in the Book Cliffs area, indicate that gas contents are as much as 360 Scf/t within 5 mi of the outcrop. The data suggest three interesting relations. First, based on desorbed, lost, and residual gas calculations, more than 90 percent of the gas is probably recoverable when gas contents are greater than 150 Scf/t. When gas contents are less than 150 Scf/t, only 50 percent of the gas can probably be recovered. Second, gas contents generally increase with distance from outcrop and depth, indicating that some degassing has taken place. Third, although gas contents generally increase with depth for all of the samples, the rate of increase varies for different coal beds. Gas contents in coal beds in the lower part of the Blackhawk (Castlegate B and C and Kenilworth) increase at about 10 Scf/t per 100 ft; however, those in the upper part (Castlegate D, Gilson, Rock Canyon, and Sunnyside) increase at only 4.4 Scf/t per 100 ft. The explanation for the different rate of gas content increase for the two groups of coal beds is not known. Finally, data indicate that the coals may be undersaturated with respect to gas, probably as a result of degassing along faults or outcrop. Undersaturation has a significant effect on recoverability because of economics associated with depressurization.

In-place coalbed gas resources have been assessed for the Book Cliffs, Emery, Wasatch, and Sego coal fields. The estimates were made for coal beds greater than 4 ft thick, less than 9,000 ft deep, and using average gas contents for a depth range from 1,500 to 3,000 ft. The estimate for these areas is in the range from 8 to 11 TCF, with most of resources occurring in Book Cliffs coal field, followed, in descending order, by the Emery, Wasatch, and Sego coal fields. A significant part of this in-place resource may be at depths greater than 6,000 ft where recoverability may be a problem.

On the basis of 1991 tonnage statistics, Utah ranked 13th among states as a producer of coal, and all the production came from underground mines. Most of the production came from the Book Cliffs, Emery, and Wasatch coal fields in Carbon and Emery Counties which ranked 24th and 28th, respectively, in the country in terms of total tonnage. On the basis of 1988 statistics, Utah was 8th among the states for methane emissions related to underground mining. On the basis of 1977 information, most of the gassy mines (more than 100 MCF/D) are located in the Book Cliffs coal field and only one gassy mine was in the Emery coal field.

Since 1982, coalbed gas has been produced from the Soldier Creek mine in the Book Cliffs coal field. Gas is recovered from horizontal in-mine wells drilled in the Gilson, Rock Canyon, and Sunnyside coal beds. The wells are about 2,000 to 3,000 ft long and more than 300,000 ft of hole have been drilled. Current daily production rate for all wells are 1,500 MCF and cumulative production of 1.5 BCF is reported.

More than 40 vertical coalbed gas wells have been drilled in the basin; most have been completed since the middle of 1992. Existing wells are located in the Book Cliffs and Emery (Drunkards Wash Unit) coal fields. In the Drunkards Wash unit, production was established in the spring of 1993 from Ferron coal beds at depths of 1,800–2,100 ft. In the Book Cliffs coal field north of Price, several wells have been completed in Blackhawk coal beds at depths of 4,000–4,400 ft, and production tests were conducted for as much as one year. In both areas, gas production increased as water production decreased over the first few months.

Gas is produced from conventional and low-permeability sandstones in the central and eastern parts of the basin. Consequently, a regional gas pipeline has recently been completed that provides potential coalbed gas producers with an access to Midwest markets. However, localized infrastructure in potential areas for coalbed gas needed.

Target areas for recoverable coalbed gas occur on the south flank and in front of the Wasatch Plateau where coal beds are less than 6,000 ft deep. On the basis of coal resources, gas content, and depth, three plays have been identified, which are named after the major coal fields in the area: (1) Uinta Basin–Book Cliffs Play, (2) Uinta Basin–Sego Play, and (3) Uinta Basin–Emery Play.

2050. UINTA BASIN–BOOK CLIFFS PLAY

In the Uinta Basin–Book Cliffs Play (2050), coal resources of the Blackhawk Formation are significant (net coal thickness as much as 68 ft), gas contents may be as much as 400 Scf/t, and depths extend to 6,000 ft. However, data indicate that coal beds may be undersaturated with respect to gas, which would adversely affect economic production. The extent of this undersaturation is not known. Production has been established in an underground mine, and favorable production rates have been tested in vertical wells. The potential for additional reserves in this play is assessed to be good to fair. Possible regional undersaturation with regard to gas is a limiting factor.

2051. UINTA BASIN–SEGO PLAY (HYPOTHETICAL)

This play covers as large an area as the Book Cliffs Play (2050) because of the low dips, but the coal beds of the Neslen are fewer and thinner. No coalbed wells have been drilled, and the play is hypothetical. The potential for reserves of coalbed gas in this play is rated as fair because of the limited coal resources and possible undersaturation.

2052. WASATCH PLATEAU–EMERY PLAY

In this play, coal resources in the Ferron Sandstone are significant (net coal thickness as much as 35 ft), and gas contents, at least in the northern part, are similar to the those of the Uinta Basin–Book Cliffs Play (2050). In addition, coal beds are commonly at depths less than 2,000 ft. Economic production of the Drunkards Draw Unit has been established in this play, and the potential for additional reserves in this play is rated as good.

Coal-Bed Gas Plays of the Piceance Basin

By Ronald C. Johnson, Dudley D. Rice, and Thomas M. Finn

The Piceance Basin part of the Uinta-Piceance Basin Province (020) contains five identified plays: Piceance Basin–White River Dome Play (2053), Western Basin Margin Play (2054), Grand Hogback Play (2055), Divide Creek Anticline Play (2056), and Piceance Basin–Igneous Intrusion Play (2057)

Geologic controls and resource potential of coalbed gas in the Piceance Basin of western Colorado are given by McFall and others (1986b), Reinecke and others (1991), and Tyler and others (1991).

Significant coal deposits are found in the Upper Cretaceous Iles Formation, a marginal marine unit, and in the lower part of the overlying Upper Cretaceous Williams Fork Formation, which is mostly fluvial in origin. The Iles and Williams Fork Formations are both part of the Mesaverde Group. Maximum coal thickness in the Iles Formation is about 18 ft. The major coal resources occur in the Cameo-Fairfield Coal Zone in the lower part of the Williams Fork Formation. The coal-bearing zone is present throughout the basin, except in the southeast corner, and net coal thickness averages 35 ft and is as much as 114 ft. Maximum reported thickness for an individual seam within the Cameo-Fairfield Zone is about 35 ft. Coal beds within the Cameo-Fairfield Zone have been mined at many localities around the margins of the basin and has been the principal target for coalbed gas exploration in the basin. The Cameo-Fairfield Zone extends to depths greater than 23,000 ft, and a large part of the coal resources are at depths greater than 6,000 ft.

Coal rank for the Cameo-Fairfield Zone ranges from subbituminous A to high-volatile A bituminous at the surface to semianthracite along the deep basin trough. In general, coal rank increases with depth from north to south in the basin. In the southeastern part of the basin, intrusions have locally raised the ranks of coal beds exposed at the surface to as high as anthracite rank. High-quality coking coal has been mined in this intruded areas since the early part of the century. Most of the coalbed gas in the basin was probably generated during the period from about 35 to 10 Ma when the basin was under maximum burial conditions. Regional uplift and erosion began about 10 Ma resulting in significant cooling of the entire stratigraphic interval, including the Upper Cretaceous coal beds.

Produced coalbed gases in the Piceance Basin are quite variable in their composition, partly resulting from their variable rank. Heavier hydrocarbon gas content ranges from 0.1 to almost 18 percent and CO_2 content varies from 0 to more than 25 percent. Carbon isotope data indicate that these hydrocarbon gases are of thermogenic origin. In the White River Dome located on the north edge of the basin, wet gas and waxy oil are produced from the coal beds of high-volatile B bituminous rank. The wet gas and oil are interpreted to have been generated from the hydrogen-rich macerals in the coal. These wet gases are also associated with large amounts of CO_2, which resulted from thermal destruction of upper Paleozoic carbonates and (or) from deep-seated igneous activity. In the central part of the basin, the coalbed gases are drier (heavier hydrocarbons less 5 percent), with smaller amounts of CO_2 (less than 4 percent), and were generated from coals at higher rank.

The Piceance Basin is highly asymmetric with gently dipping southern and western flanks and a near vertical to overturned eastern flank (Grand Hogback). The White River Dome and the Divide Creek Anticline are structures on the north and southeast parts of the basin, respectively, which are probably underlain by northeast-dipping thrust faults. These two structures are areas of enhanced permeability because of tight folding and faulting.

Several well-developed regional fracture systems occur in the basin and the coal cleat systems seem to parallel these regional patterns. Cleat development can vary markedly between different coal beds in the same area. For example, in the area of Grand Valley-Parachute fields, the cleat system is poorly developed in the lower, thicker coal bed in the Cameo-Fairfield Coal Zone, and this bed is less productive than the thinner beds which overlie it. In general, the basin is characterized by relatively low permeabilities for both coalbed and sandstone reservoirs.

Coal beds of the Mesaverde Group are within a large, low-permeability, basin-center gas accumulation. Rates of water production from both sandstone and coalbed reservoirs within this accumulation are generally quite low. In the Grand Valley-Parachute fields area, coalbed gas wells produce less than 4 bbl/D. Some recharge takes place along the elevated and wet southeast and east margins, and to a lesser extent along the southwest and north margins. In the Divide Creek area, initial water production rates are as much as 2,500 bbl/D. However, fresh water only extends into the basin for a short distance (less than 10 mi) and underground mines are usually dry.

The pressure regime of Mesaverde coal beds is complex. An area of overpressuring occurs in the east-central part of the basin. This overpressuring is the result of (1) artesian conditions in the Divide Creek Anticline area where permeabilities are higher and relatively fresh water is produced and (2) hydrocarbon generation in the area where temperatures exceed 250°F. This overpressuring is surrounded by a large area of underpressuring, which was probably an area of previous overpressuring that has cooled.

Gas contents of Mesaverde coals are as much as 600 Scf/t at depths of about 7,000 ft. Pressure-core data indicate that gas contents may be as high as 765 Scf/t at a depth of about 7,100 ft. These values are some of the highest in the country and are a product of both high rank and great depth.

In-place coalbed gas resources have been estimated to be in the range from 84 to 103 TCF. The variability of the resource is the result of the different gas content values that have been reported and used in the basin. However, about two-thirds of the in-place coalbed gas resource in the basin is at depths greater than 5,000 ft. The combination of low permeability and increasing depths will greatly reduce the recoverability of the in-place gas.

At present, only a limited amount of high-quality coking coal is being mined in the southeastern part of the basin where the coal rank has been elevated by igneous intrusions. This intruded area contains some of the gassiest mines in the country with methane emissions as high as 10,500 MCF/D.

The first coalbed gas well was drilled in the basin in 1978. This well produced about 75 MMCF from a depth of about 7,800 to 8,050 until being abandoned in 1978. From 1978 until 1987, some activity took place in high rank coal beds in the southern part of the basin. None of these projects were commercial because of high water productivity.

More recently, coalbed gas activity has focused on the central and northern parts of the basin,. and, currently, five fields are producing: Grand Valley, Parachute, Pinyon Ridge, South Shale Ridge, and White River. The first commercial production was achieved in the Grand Valley and Parachute fields in the central part of the basin where 51 coalbed gas wells were completed between 1989 and 1992. Forty-two of the wells were also completed in adjacent low-permeability sandstone reservoirs of the Mesaverde Group. Coal beds in this area are characterized by high rank (low-volatile bituminous) and low permeability. Some coalbed gas wells were completed to depths as much as 8,400 ft, the deepest production to date. These coalbed gas wells were probably commercial only because of the tax credit and the commingling of the coalbed gas with that of adjacent reservoirs.

The White River Dome area contains the best commercial production of coalbed gas established in the basin (White River and Pinyon Ridge fields). Depth of production extends to about 7,500 ft, but the rank of the coal is lower (high-volatile B bituminous), and permeability is higher than in the central part of the basin. In this area, waxy oil is produced along with wet gas, and large amounts of CO_2 (as much as 30 percent) and water. The higher permeability, which is not characteristic of the basin as a whole, is probably the result of folding and faulting.

In 1992, 95 coalbed gas wells in the basin produced about 3.2 BCF gas for an average of about 95 MCF/D per well. Considering the large in-place coalbed gas resources in the basin, these production statistics are low and suggest that permeability may be a major obstacle to large-scale commercial development.

Large resources of gas, both conventional and unconventional, are estimated for the Piceance Basin. However, the development of these resources has been somewhat hampered by the availability of pipelines that are mainly intrastate. Recently, this situation has improved and the development of coalbed gas should take place if technology problems, mostly related to low permeability, can be overcome.

2053. PICEANCE BASIN–WHITE RIVER DOME PLAY

The Piceance Basin–White River Dome Play extends along the northeastern flank of the basin and includes the southeast-plunging White River Dome and a small anticlinal nose north of the dome. The White River and Pinyon Ridge fields are in this play and the production rates (as much as 400 MCF/D per well) are the best in the basin because of enhanced permeability due to folding and faulting. Potential for additional reserves in this play is considered to be good, although production will be probably be characterized by large amounts of water and CO_2.

2054. PICEANCE BASIN–WESTERN BASIN MARGIN PLAY

This play extends along the entire western flank of the basin and includes production from the Grand Valley, South Shale Ridge, and Parachute fields. Along the Colorado River, the limit of the play is extended to a depth of about 7,000 ft because of existing production in Grand Valley field. The gas production rates (less than 100 MCF/D) are much lower than at White River Dome Play and only minor amounts of water (less than 4 bbl/D per well) are produced. This is largest play area in the basin, but its potential for additional coalbed gas reserves is considered to be fair because of low permeability.

2055. PICEANCE BASIN–GRAND HOGBACK PLAY (HYPOTHETICAL)

This is a hypothetical play that extends along most of the eastern margin of the basin where dips vary from about 45° to overturned. Because of the steep dips, the coal beds reach a depth of 6,000 ft in a short distance from the outcrop. Only a few coalbed gas wells have been drilled in this play and, although significant gas shows were reported, no commercial production has been established. Potential for reserves in this play is rated as fair to poor based on structural complexity and limited extent of the play area.

2056. PICEANCE BASIN–DIVIDE CREEK ANTICLINE PLAY

This play includes the Divide Creek, Wolf Creek, and Coal Basin anticlines in the southeastern part of the basin. The coal beds are gassy as indicated by coal mines in the Coal Basin Anticline, but severe water problems have plagued attempts to produce coalbed gas in this area. The potential for reserves of coalbed gas is fair to poor based on previous high production rates of water.

2057. PICEANCE BASIN–IGNEOUS INTRUSION PLAY (HYPOTHETICAL)

This play in the southern part of the basin contains the highest coal ranks (anthracite) in the basin. The intrusions are mainly laccolithic, and in some cases coal has been mined beneath them. The area is highly dissected by tributary systems of the Gunnison River. As a result, the coal-bearing interval is exposed throughout the play area. Although the high coal ranks are favorable for coalbed gas generation, the shallow depths and proximity to outcrop indicate that much of the gas may have naturally desorbed.

Potential for reserves of coalbed gas is considered to be poor with shallow burial depths as a major restricting factor.

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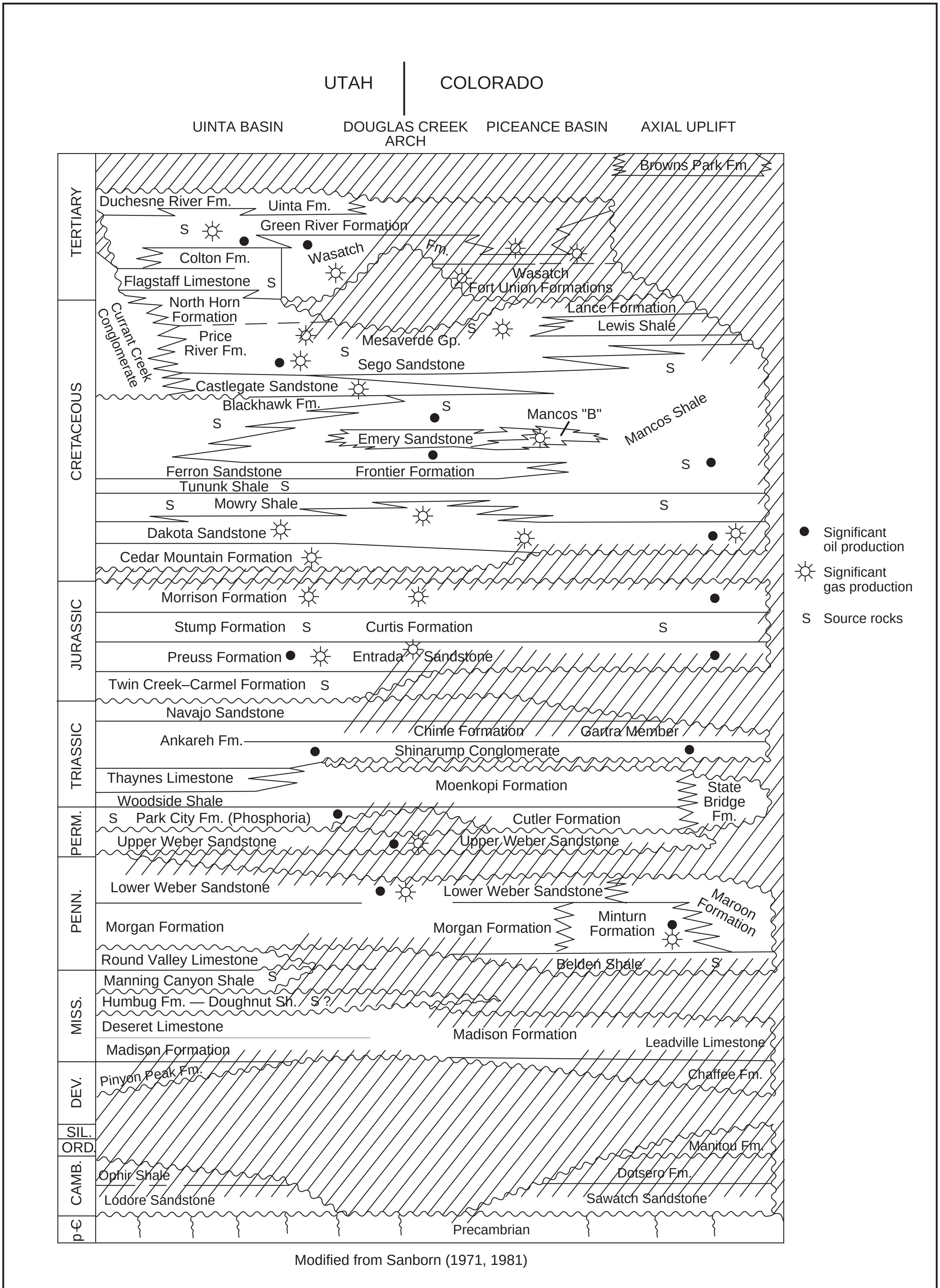

Modified from Sanborn (1971, 1981)