ANADARKO BASIN PROVINCE (058)

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With a section on the Woodford/Chattanooga/Arkansas/Novaculite of Mdcontinent Play

By J.W. Schmoker

INTRODUCTION

The Anadarko Basin Province covers almost the entire western part of Oklahoma, the southwestern part of Kansas, the northeastern part of the Texas Panhandle, and the southeastern corner of Colorado. The province is bounded by major uplifts--the Wichita-Amarillo Uplift to the south, the Cimarron and Las Animas Arches to the west, the Central Kansas Uplift to the north, the Pratt Anticline to the northeast, the Nemaha Uplift to the east, and the Southern Oklahoma fold belt to the southeast. The Anadarko Basin is a large, deep, two-stage Paleozoic basin that is petroleum rich, and generally well explored (mature).

The province, as defined herein, includes an area of about 50,000 sq mi, and contains a thickness of sedimentary rocks that probably exceeds 40,000 ft in the deep southern part. Most strata range in age from Cambrian to Permian with some minor occurrences of Mesozoic and Cenozoic strata in the northwestern part of the province. Mississippian and older rocks are predominately carbonates, whereas Pennsylvanian and younger rocks are mostly shales with some sandstones. Although these sandstones comprise only a small part of the overall volume of basin rocks, they account for much of the petroleum production in the basins. The Morrowan sandstones, in particular, are major hydrocarbon producers. The number of sandstone reservoirs, relative to carbonate reservoirs, generally increases toward the deeper southern part of the basin. Carbonate-rock reservoirs are most common in the shallower northern shelf areas. Permian Council Grove and Chase Group carbonate-rock gas fields are by far the largest hydrocarbon producers in the basin.

Every Paleozoic system represented in the basin has produced some hydrocarbon. The province overall produces primarily gas. According to recent production data more than 2.3 BBO and more than 65.5 TCFG have been produced from the province since the early 1900's.

Stratigraphic trapping mechanisms are the most common, with combination types less common and structural types least common. Pennsylvanian and Permian rocks have produced the largest volumes of petroleum to date.

The Woodford Shale is considered to be one of the most important hydrocarbon source rocks in the province. It contains abundant organic matter, with both types II and III kerogens, and produces both oil and gas. It ranges from marginally mature (with respect to oil generation) in the shallow shelf areas to post mature in the deep basin. Ordovician and Pennsylvanian shales are also important source rocks and they too exhibit a wide range of thermal maturity levels from immature to post mature.

The surface area of the province has been drilled at least 200,000 times for an average of about 1 well for each 0.25 sq mi. This drilling density decreases significantly with depth. At the top of the Arbuckle, for example, drilling density is reduced to about 1 well for each 27 sq mi. Drilling density in the deep basin is even lower.

Twenty-five plays are identified in this province. Assigned to these plays are more than 1,100 known accumulations, each with a minimum expected ultimate recovery of 1 MMBO or 6 BCFG. Play boundaries generally coincide with province boundaries, except in areas where geologic conditions warrant. Where strata are absent, play boundaries are based on published maps or on the distribution of reported formation and (or) group tops. Quantitative, historical field-, reservoir-, and well-production data were heavily weighted in the assessment of undiscovered hydrocarbon resources of each play.

Twenty-four conventional plays were defined. The one unconventional continuous-type play, Woodford/Chattanooga/Arkansas Novaculite of Midcontinent Play (5811) is described by J.W. Schmoker. Further discussion of the Woodford as a continuous-type unconventional play is included in the section on continuous-type plays by Schmoker elsewhere in this CD-ROM.

A numerical list of the plays follows:

CONVENTIONAL PLAYS

5801	Deep Structural Gas
5802	Uppermost Arbuckle
5803	Internally Sourced Arbuckle Oil and Gas
5804	Wichita Mountains Uplift
5805	Simpson Oil and Gas
5807	Viola Oil and Gas
5809	Hunton Stratigraphic-Unconformity Gas and Oil
5810	Misener Oil
5812	Deep Stratigraphic Gas
5813	Lower Mississippian Stratigraphic Oil and Gas
5814	Upper Mississippian Stratigraphic Gas and Oil
5815	Springer Stratigraphic Gas and Oil
5816	Morrow Sandstone Gas and Oil Stratigraphic
5817	Atokan Sandstone Stratigraphic Gas
5818	Atokan Limestone Stratigraphic Gas and Oil
5819	Lower Desmoinesian Stratigraphic Gas and Oil
5820	Upper Desmoinesian Oil and Gas
5821	Lower Missourian Stratigraphic Oil and Gas
5822	Upper Missourian Oil and Gas
5823	Lower Virgilian Sandstone Gas and Oil
5824	Upper Virgilian Stratigraphic Oil and Gas
5825	Permian Carbonate Stratigraphic Gas
5827	Washes

5828 Permian Sandstone Oil and Gas

UNCONVENTIONAL PLAY

5811 *Woodford/Chattanooga/Arkansas Novaculite of Midcontinent*

ACKNOWLEDGMENTS

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

5801. DEEP STRUCTURAL GAS PLAY

This play exists in the deep southern part of the province north of the fault zone along the Wichita Mountains and ranges in depth from 13,000 to more than 40,000 ft (estimated). This play includes all rock strata from basement (Middle to Upper Cambrian) upward through and including the Hunton Group of carbonate rocks (Early Devonian) that are deeper than 13,000 ft. The 13,000 ft depth limit approximates the level of thermal maturity (vitrinite reflectance (R_o) = 1.30 percent) required for the onset of gas generation in the Anadarko Basin (Cardot and Lambert, 1985; Schmoker, 1986; Cardot 1989) and defines the areal extent of the play at any given stratigraphic level. The major pre-Mississippian structures (principally, faulted anticlines; Wroblewski, 1968) and the propensity for gas production are the principal defining features of this play.

Reservoirs: Reservoir rocks include the Cambrian Reagan Sandstone, Cambrian and Ordovician Arbuckle Group (including Ellenberger, generally carbonate rock), Middle and Upper Ordovician Simpson Group (sandstone), Upper Ordovician Viola Limestone, and the Silurian Hunton Group (generally carbonate rock). The Reagan Sandstone is as thick as 300 ft and is thought to exist throughout most of the play area, although officially recorded in only 2 wells. The Arbuckle Group ranges in thickness from about 2,500 ft to possibly 10,000 ft. The Simpson Group ranges in thickness from about 200 to 1,400 ft. Simpson Group sandstone are generally clean, exhibit good porosity and permeability, and are well mixed with potential source rocks. However, their blanket nature (Johnson, 1991) may make them more efficient as pathways for hydrocarbon migration than as reservoirs. The Viola Limestone is present throughout the play and ranges in thickness from 500 to 1,000 ft. The Hunton Group of carbonate rocks is the most prolific hydrocarbon producer in this play, and is as thick as 500 ft.

The Reagan Sandstone does not produce hydrocarbons in the play area but is a minor producer in the eastern part of the province along the western flank of the Nemaha Uplift. The Arbuckle Group contains a few major accumulations but overall has not been an important reservoir unit in the Anadarko Basin. If the Arbuckle Group harbors an effective internal hydrocarbon source and sufficient porosity, significant amounts of undiscovered gas may exist in this thick layer of rock. Historically the Viola Limestone has neither been an important reservoir rock in this province nor is it considered to have a high potential for future discoveries. The Hunton Group contains the most major accumulations of all the units in the play combined. This probably results from two factors, (1) the regional post-Hunton pre-Woodford unconformity has enhanced Hunton Group reservoir properties, and, (2) the Hunton rocks are directly overlain by a major source rock, the Woodford Shale.

Source rocks: The Woodford Shale, Simpson Group shales, and possibly organic-rich portions of the Arbuckle Group may have all served as source rocks for this play. Total organic carbon (TOC) content for the Woodford Shale ranges from 1 to 14 percent; for the Simpson Group shales, 0 to 8.5 percent (Burruss and Hatch, 1989); and for the Arbuckle Group, 1 to 2 percent (Trask and Patnode, 1942). The Woodford Shale occurs throughout the play and thickens to more than 700 ft (Amsden, 1975) along the Wichita Mountains front. The Woodford Shale is thought to be the primary hydrocarbon source for the Hunton Group reservoirs and possibly for reservoirs in older rocks in areas that are sufficiently fractured to allow downward migration of hydrocarbons. Simpson Group shales are the probable source for Simpson Group reservoirs and are also a possible source for Viola Limestone and uppermost Arbuckle Group reservoirs. For the massive Arbuckle Group of carbonate rocks and the Reagan Sandstone in the deep basin, a hydrocarbon source within the Arbuckle is postulated. All of the potential hydrocarbon sources in this play are presently above the level of thermal maturation required for the onset of gas generation, therefore gas is the expected commodity in this play.

Timing and migration: Lopatin modeling of the thermal history of the Anadarko Basin (Schmoker, 1989) indicates that the structural elements that dominate the trapping mechanisms of this play (Wroblewski, 1967) were in place some 300 Ma before the entire play progressed rapidly (within about 25 Ma) through both zones of oil and gas generation. Faults and fractures associated with those structures, along with other likely conduits for petroleum migration such as erosional surfaces, bedding planes, and the highly porous and permeable, blanket-like Simpson sands were also in place before petroleum generation began in this play. Therefore, timing of trap development, and hydrocarbon generation and migration was favorable for charging of reservoirs.

Traps: Known accumulations exist almost exclusively in structural traps and appear to be related to major northwest-trending pre-Mississippian faults and (or) anticlines (Wroblewski, 1967). Stratigraphic and combination traps also may exist in this play but are difficult to identify in the deep subsurface. Seals for reservoirs in the Arbuckle Group may include low-porosity limestone strata; sandstone reservoirs in the Simpson Group are probably sealed by interbedded shales; the Sylvan Shale is a probable seal for Viola Limestone reservoirs; and the Woodford Shale probably seals most Hunton Group reservoirs.

Exploration status: The first major field discovered in this play was North Bradley in 1948, with condensate production from Simpson Group rocks. In total, 34 major accumulations larger than 1 MMBO, or 6 BCFG, are assigned to this play. Four reservoirs report API gravity values ranging from 50¡ to 55¡, indicating condensate; all others produce dry gas. Washita Creek field contains the largest estimated ultimately recoverable accumulation at 794 BCFG followed closely by Buffalo Wallow with 723 BCFG. Eleven reservoirs are expected to produce between 100 and 700 BCFG and it is estimated that the remaining reservoirs will produce between 7 and 100 BCFG. Known major reservoirs occur at depths of 13,080 ft to 24,065 ft. Future discoveries are expected to be almost exclusively gas.

Resource potential: Although not well explored overall, major known structures have been fairly well tested. The cost of drilling to the great depths necessary in much of this play is a serious problem and higher gas prices will probably be necessary to revive this play. In addition, this play may be affected by the possible existence of a thermal limit to gas preservation and a trend of decreasing reservoir quality with depth. A more recent study than that of Trask and Patnode (1945) challenges the source rock potential of the Arbuckle and has concluded that the Arbuckle Group (or equivalent) contains no viable source rocks (Cardwell, 1977). Estimates of the undiscovered accumulations of this play are based largely on extrapolation of the discovery history of known accumulations.

5802. UPPERMOST ARBUCKLE PLAY

This play consists of approximately the upper 250 ft of the Cambrian to Ordovician Arbuckle Group and extends over the entire province except in the area where uppermost Arbuckle rocks are included in Deep Structural Gas Play (5801) (i.e., except where the uppermost Arbuckle is below 13,000 feet in depth). Depths for the top of the Arbuckle Group in this play range from about 1,000 ft to 13,000 ft (the upper limit of play 5801). The "upper 250 feet" thickness limit for this play is a conceptual boundary that divides the Arbuckle Group based on a perceived level of exploration intensity rather than any type of geologic marker. That is, the level of exploration of this upper part is much greater throughout the province than is that of the lower part. Many wells that report Arbuckle penetrations, however, were actually testing the deep Simpson Group above, and only penetrate the upper part of the Arbuckle by a few feet. Even though these particular wells probably do not represent an adequate Arbuckle test (R.A. Northcutt, Oklahoma Geological Survey, oral commun., 1993), the upper part of the Arbuckle still remains significantly more well explored than the lower, main body of the Arbuckle. Known accumulations are probably the result of the combined effects of diagenetic reservoir enhancement and proximity to major structural features. The higher level of exploration (relative to lower Arbuckle Group strata) and a limestone and dolomite lithology are the principal defining features of this play.

Reservoirs: Reservoir rocks for this play are Cambrian and Ordovician Arbuckle Group limestones and dolomites; dolomite is expected to form the better reservoirs. Solution enhanced porosity zones are important components of this play. Reservoir quality is difficult to predict and is probably quite variable (Gao and others, 1992). The Arbuckle Group in this play is limited to about the upper 250 ft of the formation. Overall, the Arbuckle Group ranges in thickness from about 300 ft in the northwestern to more than 4,000 ft at the southern boundary of the play. The top of the Arbuckle Group may be regionally unconformable.

Source rocks: Because most of the play is thought to have a strong stratigraphic component and because only the upper 250 ft of strata is included in this play, organic-rich rocks directly above or in the remainder of the Arbuckle Group are considered the most likely hydrocarbon sources. In areas where the Arbuckle Group is directly overlain by potential source rocks, self-sourcing is not as important. Ordovician Simpson Group shales directly overlie the Arbuckle Group in most of the province and are considered possible hydrocarbon source rocks. Simpson Group rocks are in the zone of oil generation (0.50 percent and 1.30 percent R_O) throughout the play but are thought to be generally low in organic content, with admixed types I and III organic matter (Burruss and Hatch, 1988). Regarding the internal source potential of the Arbuckle, published reports contain conflicting conclusions (Trask and Patnode, 1942; Cardwell, 1977).

Timing: Potential Simpson and Arbuckle Group source rocks probably reached the thermal zone of oil generation about 320 Ma (Schmoker, 1989). Porosity enhancing unconformities at the top of and in the Arbuckle Group developed prior to 320 Ma, significantly predating any petroleum generation. Diagenetic porosity development by deep burial dolomitization probably occurred after the Early Pennsylvanian (Gao and others, 1992) but still within a time frame favorable for charging of reservoirs.

Traps: Known major accumulations are found in combination traps and are near major structural features. It is expected that most undiscovered accumulations would also exist in combination traps. Arbuckle Group production is generally restricted to the upper 250 ft of section and located in the eastern and northeastern parts of the play along the western flanks of the Nemaha Uplift, southern flank of the Pratt Anticline, and southwestern flank of the Central Kansas Uplift. Seals for this play may result from low-porosity zones of Arbuckle carbonates in the Group or from overlying low-porosity rocks.

Exploration status and resource potential: The earliest major discovery assigned to this play was at the Garber field in 1925. The largest accumulation is in the Bradbridge field with an estimated ultimate recovery of 27 BCFG. More than 1,800 wells contain reports of Arbuckle-Ellenberger Group rocks and about 110 of these are producing wells. Four major reservoirs were assigned to the play, two of these are gas and two are oil accumulations. Reported API gravity for the two oil accumulations is 38¡. Depth of known major reservoirs ranges from about 4,200 to 6,300 ft.

This play is not well explored. Drilling intensity and hydrocarbon production generally increases toward the major structural features in the northern and eastern parts of the play. Because of the apparent relationship between reservoir quality and the presence of major structural features, the less explored portions of the play are also considered less prospective for production. However, because the Arbuckle Group is not well explored, there is considerable uncertainty as to the potential for this play to contain significantly large petroleum accumulations. This uncertainty is shared with other plays that include Arbuckle Group rocks. Overall, the future potential of this play is not considered high.

5803. INTERNALLY SOURCED ARBUCKLE PLAY (HYPOTHETICAL)

This hypothetical play is restricted to Cambrian-Ordovician Arbuckle and Ellenberger Groups below about the upper 250 ft of Arbuckle and Ellenberger strata. These rocks extend throughout the province as does the Play 5802 except where these rocks are included in Deep Structural Gas Play (5801) (i.e. where these rocks are found at depths below 13,000 ft). Depths to the play range from about 1,000 ft in the northwest part of the play to 13,000 ft at the southern play boundary (the upper depth limit of Play 5801). The exclusion of the upper 250 ft of Arbuckle Group strata effectively relegates this play to more speculative status because this lower part of the Arbuckle Group is virtually unexplored. The play is considered to be primarily stratigraphic because of the lack of large structural features, however, local structural influence is expected to exist. The lack of exploration, the possibility of an internal hydrocarbon source, and massive thickness are the primary defining features of this speculative play.

Reservoirs: Reservoir rocks in this play include limestones and dolomites of the Arbuckle and Ellenberger Groups. The Arbuckle Group in this play is estimated to range in thickness from about 300 ft in the northwestern part of the play to about 4,000 ft at the southern boundary (adjacent to Play 5801). Reservoir quality is expected to be highly variable (Gao and others, 1992).

Source rocks: The concept of this play essentially excludes all hydrocarbon sources except those totally enclosed in the Arbuckle or Ellenberger Groups. Thus, the internal-source potential is a crucial element of the play, and one that is not well understood. Most of the Arbuckle Group, with the exception of the northeastern and western parts of the province, is within the thermal zone of oil generation. Source rock potential is discussed in Deep Structural Gas Play (5801). Little is known about kerogen types in the Arbuckle Group, however, in view of the trend of increasing thermal maturity toward the deep basin, oil is the expected commodity in the shallower parts of the play and gas seems more likely in the deeper parts.

Timing: Timing of hydrocarbon generation and reservoir development for this play is similar to that of the Uppermost Arbuckle Play (5802). Diagenetic processes leading to porosity enhancement may have occurred both syn- and post-depositionally. Subaerial weathering and deep-burial dolomitization processes that occurred in the uppermost Arbuckle Group (Gao and others, 1992), may also have affected the lower part of the section. In any case, effects of both early and late processes on reservoir development are likely to have been in place in this play prior to petroleum formation.

Traps: Although large structural features are not prominent in this play, recent work suggests that stratigraphic traps could be numerous (Gao and others, 1992). With sufficient internal hydrocarbon sourcing, the quantity of undiscovered petroleum could be large. Seals for such stratigraphic traps could be easily formed in the Arbuckle Group by impermeable limestone beds. Although difficult to predict with certainty, the potential for traps and seals in the Arbuckle Group seems likely.

Exploration status: No major hydrocarbon reservoirs are known in this play. The minor Arbuckle production present is restricted to the northern and eastern two-thirds of the province. As discussed in the Uppermost Arbuckle Play (5802), assessment of such a large, relatively unexplored volume of rock is riddled with uncertainty. The top of the Arbuckle Group is about 1,000 ft deep in the westernmost part of the play near the Las Animas Arch and deepens southward to about 4,200 ft in western Kansas. Along the Wichita Mountains front in Deep Structural Gas Play (5801), the top of the Arbuckle Group reaches depths of at least 31,000 ft. Although about 1,800 wells have penetrated the Arbuckle Group (mostly in Play 5802), exploration in this play is limited. Arbuckle Group penetrations average only about 250 ft; fewer than 90 wells penetrate more than 1,000 ft. Thus, the question of whether an internal source for oil and gas exists within the Arbuckle remains unanswered. One of the most serious negative factors related to the potential of future Arbuckle discoveries though, is the general lack of production in most of the province outside the influence of major structural features. This evidence suggests that the Arbuckle Group has not been an effective self-sourcing reservoir and that structural deformation is required to either improve reservoir quality and (or) trapping mechanisms, or to provide sufficient hydrocarbon migration pathways.

Resource potential: General lack of current production is a primary concern in evaluating this play. The few measured TOC values indicate that source beds are uncommon and of poor quality, and that the quantity of disseminated organic matter is generally low. Overall, the internal hydrocarbon source potential of these rocks is considered low and therefore, the potential for future hydrocarbon discoveries for this play is also projected to be low.

5804. WICHITA MOUNTAINS UPLIFT PLAY

This play is located along the southern edge of the Anadarko Basin Province (058) where the formations involved were detached and uplifted from their original position by the tectonic upheaval that began with the Wichita Orogeny (Early Pennsylvanian) and culminated in the development of the present-day Anadarko Basin. After the Wichita Orogeny, these detached and uplifted formations were downwarped as part of the northern shelf of the Southern Oklahoma Aulacogen. These rocks range in age from Cambrian to Permian and range in depth from basement (40,000 ft) to surface outcrops. The play does not include the various erosional washes that developed as the Wichita Mountains were uplifted. The northern boundary of this play approximates the northern edge of the frontal fault zone of the Wichita Mountains uplift. The southern limit is formed by the province boundary. The play is defined by its tectonic origin and intense structural nature.

Reservoirs: Reservoir rocks in this play display a wide range of lithologies including sandstone, arkose, chert, limestone, and dolomite, and admixtures, ranging in age from Cambrian to Permian. Reservoir units include Arbuckle and Simpson Groups, the Viola Limestone, the Hunton Group, the Misener

Sandstone, the Woodford Shale, Mississippian-age carbonates, and Springer, Morrow, Atoka, Cherokee, Marmaton, Kansas City, Lansing, Douglas, Shawnee, Wabaunsee, Admire, Council Grove, and Chase Groups strata. Because of the structural complexity of the area, reservoir heterogeneity between and within units is highly variable. Thickness of reservoir units is also variable because of structural deformation and (or) erosion. Some strata are absent, while others are tilted or doubled in recumbent folds.

Source rocks: Because of the large vertical offsets common in this play, there is ample opportunity for mature source rocks to exist adjacent to or in close proximity to an almost unlimited variety of reservoir rocks. Ordovician Simpson Group shales, Devonian to Mississippian Woodford Shale, and Pennsylvanian shales are all likely source rocks for this play. Source-rock characteristics have been previously discussed for the Simpson Group and Woodford Shale in play 5801. Pennsylvanian shales were evaluated by Burruss and Hatch (1989), who concluded that Morrowan-, Desmoinesian-, and Missourian-age rocks all have good genetic potential for hydrocarbon generation, with TOC values as high as 18 percent. Pennsylvanian shales generally contain a mixture of all three organic matter types with a predominance of type II. Pennsylvanian source rocks (Morrowan through Missourian) may be as thick as 12,000 ft in the deep Anadarko Basin.

Timing and migration: In the deep basin, Cambrian- through Devonian-age rocks reached the thermal zone of oil generation as early as 320 Ma, Mississippian- through Desmoinesian-age rocks reached the zone of oil generation about 300 to 260 Ma, Pennsylvanian-age rocks younger than Desmoinesian entered the window about 260 Ma, and Permian-age rocks entered the oil window between about 250 to 60 Ma (Schmoker, 1989). Regional tectonism, which began in the Early Pennsylvanian and continued into the Virgilian, ultimately created the Wichita Mountains--a tremendous structural complex of faults, folds, and anticlines--while thrusting huge volumes of hydrocarbon source rocks through the oil and gas generating zones. The timing of trap development and petroleum generation and migration is favorable for the charging of reservoirs.

Traps: Traps in this play are predominately structural. They consist of anticlines and faulted anticlines that formed during multiple tectonic events during Pennsylvanian time. Seals are probably formed by shales or impermeable limestones, overlying or juxtaposed to reservoir units, and by sealing faults. Major accumulations range in depth from about 1,000 to 12,500 ft.

Exploration status and resource potential: The earliest major discovery was in 1922 at Sayer district. The accumulation with the largest expected ultimate recovery is at the Apache field with about 97 MMBO from Simpson Group rocks. Fourteen major gas and eight major oil accumulations are assigned to this play. This play is well explored at shallower depths but undiscovered hydrocarbons probably still exist deeper. Future discoveries are expected to be mostly gas. Factors limiting future prospects in this play include the difficulty in locating structures beneath the thick washes that blanket much of the area, and the possibility that many early-formed traps may have been destroyed during later tectonic activity, particularly in the deeper parts of the play. However, we think that overall potential for undiscovered resources in this play is good. Estimates of undiscovered hydrocarbon resources are based on extrapolation of historical discovery data.

5805. SIMPSON OIL AND GAS PLAY

This play consists of the entire Ordovician Simpson Group except for that portion included in the Deep Structural Gas Play (5801). Early work shows that Simpson Group rocks are absent from the northwest part of the province (Dapples, 1955; Cole, 1975). However, Simpson Group well penetrations are reported in that same area. We conclude that the Simpson Group probably does exist throughout the province, therefore this play also extends province wide. Depths range from about 4,000 ft on the shelf to 13,000 ft (the upper depth limit of Play 5801). From north to south, the Simpson Group increases in thickness and becomes more shale-rich. Individual sand beds also increase in thickness and number (Dapples, 1955). The play is predominantly structural but stratigraphic traps related to unconformities and porosity development are likely. The principal defining feature of this play is its shaly lithology with blanket-like interbedded sandstones.

Reservoirs: Reservoir rocks within the Simpson Group are sandstone units interbedded with shales. Dapples (1955) shows more than 16 individual sandstone beds thicker than 5 ft and, in the southern part of the play, a net sandstone thickness of about 400 ft. In the northern part of the play (southwestern Kansas and northwestern Oklahoma), the Simpson Group is bounded above and below by unconformities. Simpson Group sands are described as well sorted (Dapples, 1955) and often highly porous and permeable where uncemented (Johnson, 1991). Reservoir quality is expected to be good in much of the play.

Source rocks: Possible hydrocarbon sources for Simpson Group reservoirs are Woodford Shale, Sylvan Shale, the Arbuckle Group, and Simpson shales. Oil-source rock studies indicate that Simpson reservoirs contain oils characteristic of Ordovician sources (Burruss and Hatch, 1989; 1992), minimizing the possible role of Woodford Shale. Additionally, the Woodford Shale has been removed by erosion in much of the northern and western parts of the play. Sylvan Shale is above and separated from the Simpson Group by the Ordovician Viola Limestone; the source-rock quality of the Arbuckle is questionable. Therefore, Simpson Group shales appear to be the most likely hydrocarbon source for this play. TOC values in this play are some of the highest measured for Simpson Group shales (Burruss and Hatch, 1989). Oil is the expected commodity in this play.

Timing and migration: The Simpson Group entered the thermal zones of oil generation about 275 Ma in the southern part of the play and about 160 Ma in the northern part of the play (Schmoker, 1986). Because reservoir sands were already in place, the timing of reservoir development and hydrocarbon generation was favorable for charging. The general lack of production in the Simpson Group may be partially explained by the continuity of highly permeable sand beds that, in this play, probably served better as migration conduits than trapping mechanisms except where structure was present.

Traps: All major hydrocarbon accumulations (and most minor production) in the Simpson Group occur between 5,000 and 12,700 ft near major structural features such as the Nemaha Uplift, the Pratt Anticline, and the Central Kansas Uplift, which lie along the eastern and northeastern boundary of the province. All reported field information indicates strong structural influence, such as anticlines or faulted anticlines, with minor influence related to facies change. Seals are probably interbedded Simpson Group shales.

Exploration status: Explored to a greater extent than the Uppermost Arbuckle (5802) the Simpson Oil and Gas Play (5805) has also been drilled in a non-uniform fashion. Most wells have been drilled along the flanks of the large structures near the eastern and northeastern province boundary. New discoveries will probably also be associated with these large structures. The earliest major discovery in this play was in 1926 at Garber field where total Simpson Group production is expected to reach about 7 BCFG. The ultimate production of the largest single accumulation (El Reno field) is estimated to be about 38 BCFG. Hydrocarbon accumulations are nearly evenly split between gas (8) and oil (7). Future discoveries are likely to contain about the same ratio of commodities.

Resource potential: The lack of significant hydrocarbon production and the lack of structural development in the Simpson Group of the greater part of the central basin, coupled with the moderately high drilling density in the most prospective areas, suggest that the Simpson Group may contain few major undiscovered accumulations. Estimates of undiscovered hydrocarbon resources are based largely on historical discovery trends, number of known accumulations, and drilling density.

5807. VIOLA OIL AND GAS PLAY

This play is composed of carbonate rocks of the Viola Limestone. The play extends throughout the province except in the westernmost part and that part included in the Deep Structural Gas Play (5801). As with the Simpson Group, early work by Cole (1975) showed that the Viola Limestone was absent in the northern and western part of the play. Recent well data, however, indicate that it is absent only in southeastern Colorado and part of the Texas panhandle. These rocks range in depth from about 4,000 ft in the northern and western parts of the province to 13,000 ft in the southern part (the upper depth limit of Deep Structural Gas Play 5801). Carbonate rock lithology is the primary defining feature of this play.

Reservoirs: Reservoir rocks are limestone and dolomite. The entire formation ranges in thickness from near zero in the northern part of the play to an estimated 500 feet at the southern boundary (adjacent to Play 5801). Only six major accumulations are known. According to Cole (1975) the lithology is variable in the Viola Limestone and includes some sandstones.

Source rocks, timing, and migration: The most likely source rocks for this play are Simpson Group shales. In the northern part of the play, however, where the Silurian Hunton Group is absent and the Woodford Shale directly overlies the Viola Limestone, the Woodford Shale may also be a viable source rock. The upper Ordovician Sylvan Shale may also contribute to Viola Limestone production in some areas of the province. Burrus and Hatch (1989) mention the Sylvan Shale as a potential source rock with a wide genetic potential ranging from poor to good. They list TOC values (0 to 8.5 percent) not for the Sylvan Shale in particular, but for undifferentiated Ordovician samples (Simpson Group and Sylvan Shale combined). Thermal maturity levels for the Sylvan Shale and Simpson Group are similar; 0.5 percent R_o (or greater) throughout the play. Timing of trap development and hydrocarbon generation is favorable for charging of Viola Limestone reservoirs.

Traps: Only one description of trap type was found for all the accumulations assigned to this play. It was identified as a faulted anticline. Because the areal distribution of major Viola Limestone reservoirs is virtually identical to that of major Simpson Group reservoirs, this play is also thought to be strongly influenced by structure. Reservoirs in the Viola Limestone may be enhanced by fracturing or some subaerial or near-surface stratigraphic modification possibly related to the major structural uplifts along the eastern and northern province boundaries. Probable seals for this play are the Viola Limestone or Sylvan Shale.

Exploration status: The Viola has been penetrated by about 6600 wells; about 150 of these wells are productive. Drilling intensity of the Viola Limestone mirrors that of the Simpson and Arbuckle Groups in that exploration is concentrated along the eastern and northern province boundaries, where virtually all known major accumulations are located. Away from these productive areas, the Viola is uniformly but not intensely explored. Gas is the primary product produced in four of the five major accumulations. The largest accumulation is at the Union City field which has an estimated ultimate recovery of 30 BCFG. Known reservoirs are found at depths ranging from 5,600 to 10,000 ft.

Resource potential: It appears that reservoir enhancement and trap formation in this play are strongly dependent on proximity to major structural features. Although parts of the play are not well explored, they are not close to major structural features and are thus, not highly prospective. Therefore, this play is not expected to contain significant quantities of undiscovered hydrocarbons. The outlook is based primarily on historical drilling and reservoir discovery data.

5809. HUNTON STRATIGRAPHIC-UNCONFORMITY GAS AND OIL PLAY

This play consists of Silurian Hunton Group rocks, generally limestone and dolomite, outside of the Deep Structural Gas Play (5801). Depths for this play range from about 5,000 to about 13,000 ft (the upper depth limit of Play 5801). Two of the most important defining features and the factors controlling the productivity of this play are its proximity to a major hydrocarbon source--the overlying Woodford Shale--and its widespread reservoir and trap development, resulting from regional unconformities at the top and within the Hunton Group.

Reservoirs: Reservoir rocks may include the Chimneyhill Limestone, and the Henryhouse, Haragan, Bois d'Arc, and Frisco Formations, but are often identified only as undifferentiated Hunton Group. The Hunton Group ranges in thickness from 0, where it has been removed by erosion, to 13,000 ft (the upper limit of Deep Structural Gas Play 5801). Erosional modification and the effects of local structure contribute to highly variable reservoir quality (Amsden, 1975).

Source rocks: The Woodford Shale is considered by many workers to be the most important source rock in the Anadarko Basin, and it is of particular importance to this play. Source rock quality and timing of petroleum generation from the Woodford Shale have been discussed previously. The proximity of the Woodford Shale to the Hunton creates a near ideal situation for short distance vertical migration (downward). Because of the broad range of thermal maturity (0.5 to 1.3 percent R_o) of this part of the Woodford Shale and because of its organic matter type (generally mixed Types II and III) both oil and gas are expected commodities in future discoveries.

Traps: Trapping mechanisms for the major accumulations of this play are most commonly stratigraphic or combination. Reservoir seals may be Hunton Group limestones or the Woodford Shale. In addition to being a hydrocarbon source rock, the Woodford Shale may be an effective seal for uppermost Hunton Group accumulations in all areas of the play except the western part (Oklahoma and Texas Panhandles) where the Hunton is laterally more extensive than the Woodford.

Exploration status: A total of 14 major oil and 17 major gas accumulations are assigned to this play. The largest oil accumulation is the Edmond, West field with an estimated ultimate recovery of about 100 MMBO. The largest gas accumulation is the Ringwood field where ultimate recovery is estimated at 700 BCFG. The distribution of production reflects the influence of major structures, and the extent and importance of the regional stratigraphic unconformity as a trapping mechanism. Most production from the Hunton Group is near major structural features but, unlike the Arbuckle and Simpson Groups and the Viola Limestone, Hunton Group production extends well away from these features. Known major accumulations occur at depths from 6,000 to 11,000 ft.

Resource potential: The Hunton Group has been fairly well explored. At least 10,000 wells have penetrated the Hunton Group; almost 1,500 are completed and producers. Hunton Group rocks in the northeastern half of the play are very well explored, those in the southwestern half are not. The possibility for additional stratigraphic traps and new hydrocarbon discoveries for this play is good. The most serious drawback for this play is its limited extent; the Hunton Group covers only about one fifth of the province. Estimates of undiscovered resources draw heavily on data from historical field discoveries, and well location and completion data.

5810. MISENER OIL PLAY

This play exists along the southern and eastern boundaries of the province, except that part included in the Deep Stratigraphic Gas Play (5812) and in isolated parts of eastern Colorado, southwestern Kansas, and the extreme northwestern tip of the Oklahoma panhandle. The Misener Sandstone of this play ranges in depth from about 4,000 ft in the northeastern part of the province to 13,000 ft (the upper depth limit of Play 5812). The Misener Sandstone was deposited with the transgression that also deposited the Woodford Shale. The Misener occurs rather sporadically, often in isolated low areas in the eroded, karst surface of the Hunton Group, sandwiched between the Hunton Group and the Woodford Shale. Where the Hunton Group is truncated, the Misener Sandstone overlies Viola Limestone or Simpson Group strata. Where the Woodford Shale is not present, the Misener Sandstone is overlain by Mississippian shales or carbonates. The geologic habit, sandstone lithology, and propensity for oil production are the principal defining features of this play.

Reservoirs: The reservoir rock in this play is the Middle and Upper Devonian (Amsden and Klapper, 1972) Misener Sandstone, which reaches a maximum thickness of about 160 ft in the deep basin (Deep Stratigraphic Gas Play 5812) and may be as much as 30 ft thick in this play. In most of the Oklahoma portion of the play, the Misener Sandstone rests unconformably upon the Hunton Group and is overlain by Woodford Shale. The sands are rather clean and homogeneous, and where porosity is not occluded by cement, reservoir quality is expected to be good.

Source rocks and timing: The hydrocarbon source for this play is most likely the Woodford Shale. Where the Woodford Shale is absent, lateral migration of hydrocarbons updip from the Woodford is possible. A second possible source rock is Simpson Group shale. Source-rock characteristics of these shales are discussed under Deep Structural Gas Play (5801). Misener Sandstone reservoirs were in place with both traps and seals before hydrocarbon generation began in the suggested source rocks. Timing of trap development and hydrocarbon generation is therefore favorable for charging of reservoirs.

Traps: Trap types are mostly stratigraphic. Some combination-type traps include minor structural influence. Traps and reservoirs were formed as sands were deposited in low areas on the surface of the regional post-Hunton unconformity. The traps were then sealed by deposition of the Woodford Shale.

Exploration status: Eleven major reservoirs are assigned to this play. The largest accumulation is the Sooner Trend with an estimated ultimate recovery from the Misener Sandstone of about 16 MMBO of oil. Most of the production occurs in the eastern part of the Anadarko Basin between depths of 5,800 and 6,200 ft, and is often discovered as a byproduct of Hunton Group exploration. Little production occurs outside of Oklahoma, where Woodford Shale and Hunton Group rocks are truncated.

Resource potential: The Misener Sandstone has been fairly well explored in the eastern Anadarko Basin, Oklahoma. Because it is relatively thin and exists sporadically in isolated areas, the overall volume of rock available for exploration in this play is very limited, and even encountering the Misener Sandstone is often serendipitous. New major discoveries in this play are seriously limited.

5812. DEEP STRATIGRAPHIC GAS PLAY

This play exists in the deep southern part of the Anadarko Basin Province north of the fault zone along the Wichita Mountains front and is positioned directly above Play 5801–Deep Structural Gas Play. The Deep Stratigraphic Gas Play includes all rock strata, from the top of the Hunton Group (Early Devonian) to the top of the Prue Sand (Early Desmoinesian), that are deeper than 13,000 ft. As in Play 5801, the 13,000 ft depth limit approximates the level of thermal maturity (R_o =1.3 percent) required for the onset of gas generation in the Anadarko basin and defines the areal extent of the play at any given stratigraphic level. Depths range from 13,000 ft (its upper limit) to as much as 28,000 ft (deepest part of the top of the Hunton Group). The importance of stratigraphic traps and the propensity for gas production are the principal defining features of this play.

Reservoirs: Reservoir rocks include the Misener Sandstone, the Woodford Shale (hypothetical), the Mississippian limestones and dolomites (including the Chester Group), the Springer and Morrow Formations, the Atoka Group, the Lower Desmoinesian Cherokee Group, and a very small part of the Upper Desmoinesian Marmaton Group. This group of strata may be as thick as 15,000 ft along the Wichita Mountains front. The reservoir rocks include a wide range of depositional environments and lithologies, each with its own unique characteristics. Most of the reservoirs, however, seem to be stratigraphically controlled with some structural influence. Reservoir characteristics of the stratigraphic units in this play (named above) are similar to those described for the individual units in the adjacent plays (to the north) of the greater Anadarko Basin. The differences between reservoirs of this play and those of the greater Anadarko Basin plays are less related to quality (although in this play they are generally deeper and more thermally mature) and more related to their principal expected commodity, which for this play is nonassociated gas.

Source rocks: Source rocks for this play include the Woodford Shale, and Springer, Morrow, Atoka, and Cherokee Group shales. The Woodford Shale ranges from about 50 to more than 700 ft thick in this play and is probably the principal hydrocarbon source for the Misener Sandstone and the Lower Mississippian carbonate rocks. In areas of fracturing, the Woodford could be expected to charge reservoirs in any of the Mississippian carbonate rocks, and perhaps younger rocks as well. Most Pennsylvanian age reservoirs are probably charged by the organic-rich shales that enclose them. All reservoirs and source rocks in this play are deeper than 13,000 ft and above the thermal threshold required for the onset of gas generation (R_o =1.30 percent). Gas is the expected commodity for this play.

Timing: Reservoirs, seals, and trapping mechanisms for this play were, for the most part, in place before or during the rapid downwarping of the Anadarko Basin in the Pennsylvanian. Timing of hydrocarbon generation and migration is therefore favorable for charging of reservoirs in this play.

Traps: Trap types in this play are predominantly stratigraphic with some structural influence. The vast majority of known accumulations are in Pennsylvanian Morrow, Springer, and Atoka Group sandstone reservoirs, enclosed in shales, and stratigraphically sealed. Seals for possible Misener Sandstone reservoirs would be Woodford Shale, possible Woodford Shale reservoirs would be internally sealed, and possible Mississippian carbonate reservoirs would probably be sealed by tight enclosing limestones.

Exploration status: Only one major accumulation below the Springer Group is known in this play. The earliest major discovery in this play was at Custer City field in 1959 with gas production from the Springer Group. In total, 81 major accumulations are assigned to this play, 79 gas and 2 oil (high API gravities of 58¡ indicate condensate). The largest reservoir is at Reydon field, which produces from the Morrow Group with an estimated ultimate recovery of about 1.4 TCFG. The second largest reservoir also produces from the Morrow, at West Cheyenne field, with an estimated ultimate recovery of about 1.3 TCFG. The average depth of production is about 15,000 ft, the deepest reservoir is more than 22,000 ft. Known production from the Springer Group occurs mostly in the southeastern part of the play. The Morrow Group generally produces from the western part of the play. Atoka Group sands produce from the central part. Production from Mississippian age (and older) rocks is negligible. Future discoveries are expected to be exclusively gas or condensate.

Resource potential: This play is not well explored below the Springer Group, therefore, this is a likely area for major new discoveries. Although source rocks and the possibility of traps both exist, the drilling depths to new discoveries are likely to be between 15,000 and 28,000 ft. With the lack of major structural features, traps will be more or less stratigraphically controlled, probably not well defined, and difficult to detect. The overall potential for undiscovered resources in this play is considered good, but with some reservations as to the difficulty of exploration.

5813. LOWER MISSISSIPPIAN STRATIGRAPHIC OIL AND GAS PLAY

This play extends throughout the province, with the exception of the extreme southern and southwestern parts where Mississippian age strata are missing. The play consists of all Kinderhookian, Osagian, and Meremecian age strata except the St. Louis Formation and those parts included in the Deep Stratigraphic Gas Play (5812). Depths range from about 4,000 ft on the northeastern shelf to 13,000 ft at the southern play boundary (the upper depth limit of Play 5812). Some individual units within the above named strata appear to be absent along the eastern and northeastern part of the play, probably due to subareal erosion and ultimate truncation along the Nemaha and Central Kansas Uplifts, and the Pratt Anticline. The stratigraphic units included in this were selected largely on the basis of the distribution of major accumulations and on lithology. Most major accumulations occur along the eastern and northeastern boundary of the province, suggesting a relationship between reservoir and trap development and the presence of major structural features. The distribution of major accumulations and a carbonate lithology are the principal defining features of this play.

Reservoirs: Reservoir rocks consist of all Kinderhookian, Osagian, Meremecian age carbonate rocks (except those parts previously noted). Attempting to differentiate these rocks in the subsurface can be very difficult (Harris, 1975). Lithologies are generally limestone or cherty limestone (for example, Mississippi Chat), or mixed. Thickness ranges from a few tens of feet on the uplifts along the eastern and northeastern parts of the province to an estimated 1,800 ft in southern Oklahoma and the Texas Panhandle at the boundary of Deep Stratigraphic Gas Play 5812. Reservoir quality is variable depending on depositional facies trends or fracture patterns (Harris, 1975), or the presence of regional erosional surfaces.

Source rocks, timing, and migration: The most probable source rock for this play is the Woodford Shale. Source-rock characteristics of the Woodford are described under Deep Structural Gas Play (5801) and, in detail, in Hester and others (1990). Large quantities of petroleum produced from lower Mississippian strata verify the favorable timing of trap formation, and oil and gas generation and migration in this play. Oil accumulations occur about twice as often as gas accumulations. Future discoveries are expected to occur in about the same ratio.

Traps: Trapping mechanisms are fairly evenly divided among stratigraphic, structural, and combination. Traps found in the Sooner Trend are attributed to lateral variability of fracture patterns and conventional top and bottom seals (Harris, 1975). Fracture development in the limestone is related to increasing silica (chert) content (Harris, 1975). Hill (1981) called attention to the northwest-southeast lineation of fields in the area of the Sooner Trend and attributed trap formation there to linear subcrops of Mississippian erosional remnants. Depth of known major accumulations in this play range from about 4,400 to 10,000 ft. Most of these, as well as most minor production, occur in the eastern and northeastern parts of the province, a pattern which serves, in part, to distinguish this play from the Upper Mississippian Stratigraphic Gas and Oil Play (5814). Play 5814 produces mostly from the central part of the shelf area.

Exploration status: Hydrocarbon production in this play is dominated by the Sooner Trend, with an estimated ultimate recovery of 180 MMBO. Treated here as a single field, the Sooner Trend is actually a conglomerate evolved from many smaller fields. The largest gas deposit is found at Glick field with an estimated ultimate recovery of 722 BCFG. The earliest known major discovery in the play was the Pleasant Valley field in 1938. Fifty-four oil accumulations and 28 gas accumulations are assigned to this play. Drilling depths, estimated to the top of the Meremecian Series, range from about 4,000 ft in the northeastern part of the province to 13,000 ft at the southern play boundary (upper depth limit of Deep Stratigraphic Gas Play 5812). Play 5813 has been well explored near the Sooner Trend, moderately well explored along the northeastern boundary, and less explored in the remainder of the play. In total, more than 11,600 wells have penetrated the Meremec (top of this play) and more than 1,600 of those are reported as hydrocarbon producers. Most production is concentrated around the Sooner Trend area and along the northeastern boundary of the play.

Resource potential: Although much of this play is not well explored, most production is from reservoirs associated with stratigraphic traps largely controlled by subareal exposure, unconformity surfaces, and facies changes associated with the major uplifts along the eastern and northeastern boundaries. This suggests that much of the play, away from major structural influence, does not have the potential for developing reservoirs necessary to contain large undiscovered petroleum resources, which is a serious limitation. Many local structures large enough to be defined using seismic data, have already been drilled.

5814. UPPER MISSISSIPPIAN STRATIGRAPHIC GAS AND OIL PLAY

Like the Lower Mississippian Stratigraphic Gas and Oil Play (5813), this play extends throughout the province except in the extreme southern, southwestern, and northeastern parts where Mississippian age strata are missing. The strata in this play consists of the St. Louis Formation and all Mississippian Chester Group rocks, except those strata included in Deep Stratigraphic Gas Play (5812). Depths range from about 4,000 ft on the northeastern shelf to 13,000 ft at the southern play boundary (the upper depth limit of Play 5812). Some individual units in the included strata appear to be absent along the eastern and northeastern part of the play, probably due to subareal erosion and ultimate truncation along the Nemaha and Central Kansas Uplifts, and the Pratt Anticline. The stratigraphic units included in this were selected largely on the basis of the distribution of major accumulations and on lithology. The major accumulations in this play generally occur in the central and north-central parts of the basin, away from significant influence of major province-bounding uplifts. The play is viewed as principally stratigraphic but with some local structural influence. The distribution of major accumulations and a carbonate lithology are the principal defining features of this play.

Reservoirs: Reservoirs rocks consist of the St. Louis Formation and the Chester Group. Lithologies are almost exclusively limestone on the shelf areas, although Chester Group rocks become increasingly shaly to the southeast, and sandstones become more common in the deep basin. Chester Group rocks range in thickness from erosional truncation in the northeastern and southwestern parts of the province to 1,000 ft in the southern part of the province at the boundary of Deep Stratigraphic Gas Play (5812). The upper surface of rocks in the Chesterian Series has undergone extensive weathering and erosion in much of the play (Northcutt and Parham, 1993), and in those areas reservoir quality is expected to be good. In deeper parts of the play and in lower parts of the section, reservoir quality is expected to be more variable and poorer overall. Oil and gas production is generally concentrated in areas of the unconformity surfaces--a band trending east-west across the central part of the province. This pattern of reservoir development, although resulting predominately from uplift and subareal erosion, shows little dependence on proximity to the major structural features that bound the province. Stratigraphic trapping mechanisms dominate in this play, with only local structural influence.

Source rocks: Rice and others (1989) identified interbedded shales as the most likely source for central basin gas accumulations found in Upper Mississippian sandstone reservoirs. Organic carbon content (TOC) of shales of the Upper Mississippian Springer Formation ranges from 0.5 to 3.4 percent. Variability in chemical and isotopic composition, however, suggests some mixing of hydrocarbons from other sources. Although it seems reasonable to assume that the gas produced from carbonate rock and sandstone reservoirs in the same (or adjacent) play could have the same source, the organic matter (type III) described by Rice and others (1989) is not a likely source for the oil found in this play. Type III kerogen is highly gas prone. A probable source for the oil, and perhaps some of the gas as well, is the Woodford Shale. Woodford Shale source-rock properties are described in detail in Hester and others (1990).

Timing and migration: On the basis of the late-stage generation of gas suggested by Rice and others (1989) and burial history modeling by Schmoker (1989) we estimate that much of the gas in this play was probably generated between 225 and 100 Ma. Since much of the production from this play is from stratigraphically controlled reservoirs developed largely from subareal exposure, reservoirs and traps were in place before hydrocarbon generation began. Timing of hydrocarbon generation and migration is therefore favorable for charging of reservoirs in this play.

Traps: Traps for this play are mostly stratigraphic, with some combination and minor structural types. Traps are generally sealed by shales deposited over eroded carbonate strata or over ooid sand bars (Ball, 1967; Asquith, 1984) at or near the top of the Mississippian carbonates. The shales range in age from Chesterian through Pennsylvanian, Morrowan, Atokan, and Desmoinesian (Northcutt and Parham, 1993). Major accumulations occur at depths from 4,000 to 10,000 ft.

Exploration status and resource potential: The earliest major discovery assigned to this play was made in 1921 at the Webb field. The largest gas accumulation is at Mocane-Laverne with an estimated ultimate recovery of about 1.2 TCFG. The largest oil accumulation is estimated to produce about 44 MMBO from the Big Bow field. Of the 99 accumulations assigned to this play, 40 are oil and 59 are gas. Drilling depths for this play range from about 4,200 ft in the northern part of the play to 13,000 ft at the southern play boundary (the upper depth limit of Deep Stratigraphic Gas Play 5812).

More than 23,000 wells are reported to have penetrated rocks of this play. Of these, nearly 5,000 were completed as producing wells. This play is the most thoroughly and most uniformly explored play yet discussed. There are still some areas that are not so well explored, for example along the northern and northeastern parts of the play, but they are historically poor producers. Because stratigraphic traps are so prevalent in this play, and because stratigraphic traps are relatively difficult to target, we expect that there are still new accumulations to be discovered. The potential for new major hydrocarbon discoveries in this play is moderate. Historical production and well completion data were used to evaluate the potential of this play.

5815. SPRINGER STRATIGRAPHIC GAS AND OIL PLAY

This play is restricted to the southern and southeastern parts of the basin, and is composed of sands of the Upper Mississippian Springer Formation, except those parts included in the Deep Stratigraphic Gas Play (5812). Depths range from about 7,500 ft on the shelf to 13,000 ft at the southern play boundary (the upper depth limit of Play 5812). Also included in this play is a relatively small area in the southeast corner of the province, where several small blocks of strata have been detached and uplifted well above their normal stratigraphic level. This uplifted area involves a nearly complete section of strata, including Arbuckle Group through Permian age. In this area, the Springer Formation is the oldest stratigraphic interval to have any major hydrocarbon production. Stratigraphically controlled reservoirs are predominant in most of the play, with some minor structural influence. In the uplifted area, however, structural control is predominant, with some stratigraphic and combination-type traps. The physical limits of the Springer Formation, with its interbedded sands and shales and stratigraphically controlled reservoirs, are the principal defining features of this play.

Reservoirs: The reservoir rocks in this play are sandstone units in the Upper Mississippian Springer Formation, which ranges in thickness from truncation along its northern boundary to as much as 2,000 ft at its southern boundary (adjacent to Play 5812). These reservoirs, generally interbedded with shales, include the Simms, Boatwright, Humphries, Spires, Britt, Markham, and Cunningham sands. In the nearby Ardmore Basin these sandstones have been interpreted as fluvial-deltaic and gravity deposits (Meek and others, 1983). Reported porosity of similar rocks in the nearby Cyril Basin ranges from 6 to 14 percent, which may be too low in some wells for commercial production. Permeability also varies but is generally less than 1 mD.

Source rocks: The most probable hydrocarbon source for this play are the interbedded Upper Mississippian shales of the Springer Formation. Source rock qualities of these shales are discussed in the previous play.

Timing and migration of hydrocarbons: Because the trapping mechanisms for many of the reservoirs in this play are stratigraphic and syndepositional, both reservoirs and traps were in place before hydrocarbon generation began. Therefore, the timing of trap formation, and petroleum generation and migration is favorable for charging of reservoirs in this play. The timing of petroleum generation can be estimated from burial histories of Schmoker (1989, fig. 5). His data suggest that Chesterian rocks in this play entered the oil window about 260 Ma and the gas window about 125 Ma. Because gases produced from this play may be mixtures of gases from sources in addition to those generated from Springer Formation shales (Rice and others, 1989), the timing of hydrocarbon generation may also span a wider range than that indicated by burial histories of the Springer Formation shales.

Traps: Trap types for reservoirs in this play range from predominantly structural, such as those at Cement field, to predominantly stratigraphic with only minor structural influence, such as those at Watonga-Chickasha Trend. The Watonga-Chickasha Trend, treated as a single field in this report, is actually a conglomeration of at least eighteen individual fields. The most common trapping mechanism in most of the play seems to be the stratigraphically controlled updip pinchout of Springer Formation sandstones such as those at Watonga-Chickasha Trend. In reservoirs of the uplifted area such as those at the Cement field, which is located on a large faulted anticline, trap types are mostly structural with only minor stratigraphic influence. Seals for the stratigraphically controlled reservoirs are probably interbedded Springer Formation shales. Seals for structurally controlled reservoirs are probably anticlinal highs, fault-juxtaposed tight formations (shales), and (or) healed joints or fractures. Producing reservoirs occur throughout the depth range of the play and form a northwest-southeast trend in the southeastern part of the province that probably reflects the distribution of stratigraphic pinch outs of Springer Formation sands.

Exploration status and resource potential: Ten major reservoirs have been assigned to this play; 7 gas and 3 oil. The largest gas accumulation is at the Watonga-Chickasha Trend with an estimated ultimate recovery of almost 1.8 TCFG. The largest oil accumulation is at Knox field with 45 MMBO. The earliest known major discovery in this play was in 1947, also at Knox field. At least 1600 wells have penetrated the Springer Formation in this play, with about 400 completed as producers. The play has been fairly well drilled along the eastern and northeastern parts, which are also the most productive. The western part of the play is neither well explored nor highly productive.

Although some stratigraphic traps may still remain to be discovered in this area, limited thickness and lateral extent of the sands may cause difficulties in pinpointing drillable targets. Poor reservoir quality and overpressuring may also hinder exploration in the play. Overall, we consider the potential for future major discoveries in this play to be poor. Historical production and well completion data were used to evaluate this play.

5816. MORROW SANDSTONE GAS AND OIL STRATIGRAPHIC PLAY

This play includes all Pennsylvanian Morrow Group sandstones and shales and is oriented in a broad band that occupies most of the province, except the part along the northeastern and southwestern edges of the province where Morrowan age strata are absent, and that part included in the Deep Stratigraphic Gas Play (5812). Depths range from about 4,000 ft on the northern shelf to 13,000 ft at the southern play boundary (upper depth limit of Play 5812). Similar to the Springer Stratigraphic Gas and Oil Play (5815) but much more extensive, this play is gas prone and accumulations are almost always trapped stratigraphically in sandstone reservoirs.

Reservoirs: Reservoirs are all sandstones of the Morrow Group, and include the Keyes, Puryear, Purdy, and Primrose sands. The Morrow Group ranges in thickness from erosional truncation along the northeastern and southwestern province boundaries to about 1,500 ft at the southern play boundary (adjacent to Play 5812). The predominate lithology of Morrowan strata is shale but significant thicknesses of sand exist, generally increasing from northwest to southeast.

Morrow Group sands are generally fine grained and often well cemented (Pate, 1959). Reported porosities range from about 6 to 26 percent, with an approximate median value of 13 percent; permeability ranges from 1 to 600 mD with an approximate median value of 20 mD. Reservoir quality is expected to be good in much of the play area.

Source rocks: Because most reservoirs of this play are stratigraphically enclosed by shale and mudstone, the most probable hydrocarbon source is Morrow Group shales. Burruss and Hatch (1989) measured TOC values of selected Pennsylvanian shales (including Morrow Group shales) as high as 18 percent and concluded that these rocks have good genetic potential. However, Burruss and Hatch (1992) present evidence against a Morrowan source for Morrowan reservoirs in western Kansas and southeastern Colorado. Although Burruss and Hatch (1989) determined that Morrowan organic matter is both oil and gas prone (kerogen types II and III), gas is by far the most abundant resource produced from the Morrow Group. Modeling by Schmoker (1989) and others suggests that Morrowan age rocks in Oklahoma and Texas, and therefore most major hydrocarbon accumulations in the Morrow Group, are at or above the thermal maturity level required for the onset of oil generation (about R_o = 0.6 percent). In Kansas, Morrowan rocks are less mature.

Timing: Timing of petroleum formation and migration, and trap formation in this play is favorable as evidenced by the fact that more than 330 major accumulations have been discovered. Modeling by Schmoker (1989) indicates that Morrowan rocks entered the thermal zone of oil generation as early as 260 Ma in the southern part of the play, at about 50 Ma in the central part of the play, and may not yet have entered the thermal zone of oil generation in the northern part of the play. Hydrocarbon migration has probably occurred over very short distances in most areas of the play.

Traps: Traps types for reservoirs in the Morrow Group are almost exclusively stratigraphic. Reservoir origins are interpreted as valley fill, beach and offshore bar, and deltaic deposits (Rascoe and Adler, 1983). Seals are generally formed by enclosing Morrowan shales and mudstones. Major accumulations are distributed throughout western Oklahoma, Texas Panhandle, and southwestern Kansas, with a few in southeastern Colorado.

Exploration status: More than 26,000 wells penetrate Morrowan rocks in this play. Of these, more than 10,000 are hydrocarbon producers. Hydrocarbon production is more or less centered in the play, with the southeastern and northwestern ends being less productive. The northwestern part of the play is least productive and least well explored. Of the 333 major accumulations assigned to this play, 257 are gas and 76 are oil. The largest gas accumulation is at Watonga-Chickasha Trend, with an estimated ultimate recovery of 4.3 TCFG. The largest oil accumulation is at Postle field, with an estimated ultimate recovery of 120 MMBO.

Resource potential: This play is well explored in Oklahoma and Texas but less so in Kansas and Colorado. Future major hydrocarbon discoveries are expected, however, in spite of the present exploration density. Most new discoveries are expected to exist primarily in stratigraphic traps (R.A. Northcutt, oral commun., 1993). Some factors limiting the potential for new discoveries include the already high drilling density in many areas, and the fact that in some apparently unproductive areas, Morrowan rocks are composed of more shale and less sand (Rascoe and Adler, 1983). The potential for future discoveries in this play is expected to be moderately good. Trends in historical discoveries and completion data were used to estimate undiscovered resources.

5817. ATOKAN SANDSTONE STRATIGRAPHIC GAS PLAY

Much like Morrow Group strata, (play 5816) Atoka Group strata are oriented in a broad band that occupies most of the province, except that part along the northeastern and southwestern edges of the province where absent. Unlike the Morrow Group, Atokan strata include a significant number of hydrocarbon-producing limestone reservoirs. The limestone and sandstone reservoirs are separated geographically, with the limestone reservoirs more prevalent in the central and northwestern part of the province and the sandstone reservoirs more prevalent in the southeastern part. Therefore, the Atokan Sandstone Stratigraphic Gas Play includes all Atokan Group rocks southeast of a line that runs from about T. 13 N., R. 26 W. in Roger Mills County, Okla., to about T. 19 N., R. 14 W. in Dewey County, Okla., except that part included in the Deep Stratigraphic Gas Play (5812). Depths range from about 7,000 ft in the northeast part of the play where the Atoka Group is truncated to 13,000 ft at the southern play boundary (the upper depth limit of Play 5812).

Reservoirs: Reservoir rocks in this play are all sandstones of the Early Pennsylvanian Atoka Group. Predominantly shale with locally developed sands (Bingham, 1993), the entire Atoka Group ranges in thickness from truncation along the northeastern and southern parts of the play to about 500 ft at the southern play boundary (adjacent to Play 5812). Bingham (1993) reported average porosity values of about 8 percent for each of 2 Atokan reservoirs in the southern Anadarko Basin. Atoka Group reservoirs are, for the most part, stratigraphically imbedded in shales and are expected to be of fair quality where they exist.

Source rocks: The most likely hydrocarbon sources for this play are Atoka and Morrow Group shales, which are either interbedded with Atoka reservoirs or in the adjacent group of strata. Because Atoka Group rocks are thin and directly overlie the Morrow Group, they have a similar thermal history. That is, Atokan rocks throughout the play have reached or exceeded the level of thermal maturation required for the onset of oil generation ($R_o > 0.6$ percent). The area of major Atokan sandstone production, however, is much more restricted. Poor reservoir quality or perhaps an overall lack of reservoir rock are possible explanations for the limited distribution of production. All major accumulations in this play are gas, therefore, the source may be Morrowan shale, which has abundant type III organic matter (Burruss and Hatch, 1989). High thermal maturation levels near the boundary of Play 5812 may also have generated some gas from the type II kerogen, or generated but did not expel oil.

Timing and migration: Timing of trap formation and hydrocarbon generation is favorable for the charging of reservoirs in this play. Petroleum generation probably began between 300 and 250 Ma in this play (Schmoker, 1989). The limited distribution of production in this play requires only short distance migration of hydrocarbons.

Traps and exploration status: Trap types for this play include stratigraphic (Bingham, 1993) and combination. Seals are formed by Atokan and Desmoinesian shales. Major reservoirs range in depth from approximately 9,700 to 13,000 ft. Reported well penetrations for the entire Atoka Group number only about 8,400, as compared to about 26,000 for the entire Morrow Group. This number may be low because of the difficulty in determining the top of the Atoka Group in the subsurface. The actual number of well penetrations is probably similar to, or greater than, that of the Morrow Group (~26,000). Consequently, the Atoka Group is probably at least as well explored as the Morrow Group. Of the 8,400 well penetrations in the Atoka, about 542 are hydrocarbon producers. Six major accumulations are assigned to this play; all are gas. The largest accumulation is at Watonga-Chickasha Trend with an estimated ultimate recovery of 320 BCFG. All major future discoveries are also expected to be gas.

Resource potential: Because of the relatively high level of exploration and the general lack of major discoveries, the potential for future major discoveries in this play is considered limited. The very localized nature of sand development (Bingham, 1993) may be the most serious limitation for future discoveries in this play. Historical production and well completion data are the foundation for the assessment of this play.

5818. ATOKAN LIMESTONE STRATIGRAPHIC GAS AND OIL PLAY

The overall distribution of Atoka Group strata, similar to that of the Morrow Group, is described in Atokan Sandstone Stratigraphic Gas Play (5817). Limestone reservoirs, which are most prevalent is the central and northwestern part of Atoka Group strata, are the dominant hydrocarbon producers in Play 5818. The Atokan Limestone Stratigraphic Gas and Oil Play then, includes all Atoka Group strata northwest of a line that runs from about T. 13 N., R. 26 W. in Roger Mills County, Okla. to about T. 19 N., R. 14 W. in Dewey County, Okla., except that part included in the Deep Stratigraphic Gas Play (5812). Depths range from about 3,500 ft in eastern Colorado to 13,000 ft at the southern play boundary (the upper depth limit of Play 5812). The preponderance of limestone reservoirs and the distribution of Atoka Group strata are the principal defining features of this play.

Reservoirs: Reservoirs rocks include all Early Pennsylvanian Atokan limestones. The thickness of the Atoka Group in this play ranges from truncation along its northeastern boundary to about 500 ft at its southern boundary (adjacent to Plays 5812 and 5817). Porosity values from major reservoirs range from 7 to 15 percent, with a median value of 9 percent. Because most major accumulations in this play are concentrated at the southern end, data regarding reservoir quality is not available for much of the northern, rather unproductive, part of the play.

Source rocks: The most likely hydrocarbon sources for this play are Atoka and Morrow Group shales. Because Atokan rocks directly overlie Morrowan rocks, they have had a similar thermal history. That is, Atokan rocks in most of the Oklahoma and Texas parts of this play, have reached or exceeded the level of thermal maturity required for the onset of oil generation (R_o > 0.6 percent), whereas Atokan rocks in western Kansas and eastern Colorado are probably immature with respect to oil generation. Virtually all of the Atokan strata in the areas that produce hydrocarbons, however, are thermally mature, while the northern, less mature areas of the play have poor hydrocarbon production histories. A lack of reservoir-quality rocks, poor source-rock quality, or low thermal maturity in the northern half of the play are possible explanations for the observed production distribution. Because major accumulations are mixed oil and gas, source-rock organic matter composition (types II and III) is probably also mixed.

Timing and migration: Timing of trap formation and hydrocarbon generation was favorable for the charging of reservoirs in this play. Migration was probably over short distances. Petroleum generation in Atokan rocks probably began in the southern part of the play about 250 Ma (Schmoker, 1989). Strata in the northern half of the play are immature with respect to oil generation; thus, the occurrence of production is found, almost exclusively, in the southern part of the play where thermal maturity is greater.

Traps: Traps, which are found at depths ranging from 6,600 to 11,400 ft, are all combination-type. Seals for these traps are interbedded Atoka Group shale, dolomite, and anhydrite. Major accumulations are generally restricted to west central Oklahoma and the Texas Panhandle with some minor production in southwestern Kansas.

Exploration status and resource potential: Ten major accumulations are assigned to this play, 5 oil and 5 gas. The largest known gas accumulation is at Lipscomb field, with an estimated ultimate recovery of 50 BCFG. The largest oil accumulation is at Arnett field with an estimated ultimate recovery of 13 MMBO. As discussed in Atokan Sandstone Stratigraphic Gas Play (5817), the Atoka Group as a whole is much more extensively explored than is indicated by the reported number of penetrations. That is, Atoka Group tops are not always reported when the Morrow Group is drilled. We think that this is true for plays 5817 and 5818 as well.

Atokan rocks have been drilled extensively in the Oklahoma and Texas parts of the play but not in Colorado and Kansas. There are several limitations on the prospects of future major discoveries in this play are several. The play is already well drilled in the areas that are most likely to be productive. The play has been fairly well drilled, with little success, even in the areas where production is historically poor. Thermal maturity of Atokan rocks in the northern part of the play, the least well-explored area and least productive area, is below the level required for the onset of oil generation. The richness of Atokan shales is unknown. And, there is little evidence for long distance migration of oil or gas from more thermally mature or more productive areas. Future discoveries are not expected to be significant.

Historical production data and individual well completion data are the primary considerations for the assessment of this play.

5819. LOWER DESMOINESIAN STRATIGRAPHIC GAS AND OIL PLAY

Desmoinesian, Missourian, and Virgilian strata were deposited in transgressive-regressive cycles that periodically inundated the Anadarko Basin area with marine environments. These depositional cycles are reflected in alternating sandstone and limestone lithologies (interbedded with shale) that can be separated into stratigraphic packages of mostly sandstone or mostly limestone reservoirs (Moore, 1979; Rascoe and Adler, 1983). Each epoch consists of 1 sandstone-limestone cycle, which we have then subdivided into 2 plays, a mostly-sandstone play (lower part) and a mostly limestone play (upper part). Because the upper boundaries of the limestone plays coincide with epoch boundaries, stratigraphic correlations are relatively straightforward and universally understandable (for example, top of the Desmoinesian, top of the Missourian, and so forth). However, within epochs, chronostratigraphic and nomenclatural inconsistencies greatly complicate a precise definition of the play boundaries. Nevertheless, a rough description of these somewhat conceptual boundaries are given for each play.

The Lower Desmoinesian Stratigraphic Gas and Oil Play contains mostly sandstone reservoirs, and consists of all strata of the Middle Pennsylvanian Cherokee Group and those correlative strata in the lower part of the Middle Pennsylvanian Deese Group. The upper boundary of this play is the top of the Lower Desmoinesian Cherokee Group, which is represented in most areas by the Prue sand or its correlatives. This play extends throughout the province, except that part near the southern boundary where Lower Desmoinesian strata are absent, parts of eastern Colorado, and that part included in Deep Stratigraphic Gas Play (5812). Depths to the top of the Prue sand (the uppermost unit of the Cherokee Group) range from 3,500 ft on the northern shelf to about 12,000 ft near the Wichita Mountains front. Almost all major reservoirs assigned to this play are sandstone, but limestone reservoirs do exist. The predominance of sandstone reservoirs is the principal defining feature of this play.

Reservoirs: Reservoirs consist of all Lower Desmoinesian sandstones and limestones, including the Burgess, Bartlesville, Red Fork, Skinner, Prue, Osborne, Pooler, Hart, and Charleston sands. Rocks in this play generally thicken to the south, reaching an estimated 1,500 ft along the Wichita Mountains front. The Red Fork sands in north-central Oklahoma, which were deposited as stream channels and offshore sand bars (Withrow, 1968), are probably typical of other Lower Desmoinesian sands as well. The relative proportions of sandstone and shale in the Red Fork sand vary in the play from mostly sand in the northeastern part of the province (Withrow, 1968) to mostly shale in the deeper-water facies (Whiting, 1984). Porosity of these rocks ranges from 12 to 15 percent. Farther south and west, toward the deep Anadarko Basin, Red Fork sands developed as the result of channelized density transport (Whiting, 1984). Porosity of these deeper sands range from 1 to 17 percent, with an average of about 8 percent.

Permeabilities in all areas are often low, averaging about 0.1 mD (Whiting,1984). Reservoir quality in both areas is expected to be variable (Withrow, 1968; Whiting, 1984; Levine, 1984).

Source rocks: Middle and Upper Pennsylvanian black shales overall have good genetic potential (Burruss and Hatch, 1989). TOC, which ranges from 0 to 18 percent, is from a mixture of types II and III kerogens. Burial histories (Schmoker, 1989) indicate most of the Oklahoma and Texas parts of this play are thermally mature with respect to oil generation; the Kansas and Colorado parts are not. Major accumulations located in thermally mature areas are probably sourced by the surrounding shales. In the immature areas of Kansas, petroleum migration from Woodford Shale or Ordovician shales may have occurred. Some immature areas in Colorado may even have been sourced from the Denver basin (Burruss and Hatch, 1992).

Timing and migration: Modeling by Schmoker (1989) suggests that potential source rocks of the Cherokee Group may have entered the thermal zone of oil generation at about 250 Ma. Favorable timing of trap development and hydrocarbon generation and migration is evidenced by the presence of numerous major accumulations in this play.

Traps: Reservoir trap types are mostly stratigraphic (Bingham, 1993), with a few influenced by structure. Traps probably formed as shales were deposited over porous channel-filling subaerial or submarine sands, or over offshore bars; seals are probably formed by enclosing shales (Withrow, 1968).

Exploration status: This play is well explored, with more than 37,000 reported wells although the actual total probably exceeds 53,000. The play is most densely drilled in Oklahoma and Texas. Seventy-nine major accumulations are assigned to this play, 24 oil and 55 gas. The largest oil accumulation is at Cherokita Trend, with an estimated ultimate recovery of 30 MMBO. The largest gas accumulation is at North Moorwood field, with an estimated ultimate recovery of 1.5 TCFG.

Resource potential: In spite of being well explored and already producing from a large number of major accumulations, this play is expected to contain significant undiscovered resources. The parts of this play in Kansas and Colorado, however, show low thermal maturity levels, have poorer reservoir quality and overall fewer sands than the parts of the play in Oklahoma and Texas and are therefore not projected to have as much resource potential. Historical data on major discoveries, individual well completions, and thermal maturity were used extensively in assessing this play.

5820. UPPER DESMOINESIAN OIL AND GAS PLAY

The Upper Desmoinesian Oil and Gas Play contains mostly limestone reservoirs, and consists of all Upper Desmoinesian Marmaton Group strata, including those correlative units in the Middle Pennsylvanian Deese Group. The upper boundary of this play is the top of the Desmoinesian. The play extends throughout the province except that part at the southern boundary where Desmoinesian strata are apparently absent. Depths range from 3,500 ft at the top of the Marmaton Group on the northern shelf to near 13,000 ft at its base near the Wichita Mountains front. The predominance of limestone reservoirs is the principal defining feature of this play.

Reservoirs: Reservoirs consist of undifferentiated Marmaton Group strata, and the upper part of the Deese Group, including the Oswego lime, and the Gibson, Glover, and Culberson sands. The Marmaton Group consists primarily of limestone with thin shale beds in the northern Oklahoma and Kansas portion of the play (Bingham, 1993) but it contains mostly terrigenous clastics to the south (Moore, 1979). Marmaton rocks range in thickness from about 175 ft in the northernmost part of the province to an estimated 1,700 ft at the southern play boundary. Porosity of productive Marmaton strata ranges from 2 to almost 18 percent.

Source rocks: Source rocks for this play may be the Marmaton shales (or other Pennsylvanian shales) in the deeper, more thermally mature parts of the basin. South of the Kansas-Oklahoma border, all of these potential source rocks have probably reached the thermal zone of oil generation (Schmoker, 1989). The mixed types of produced hydrocarbons suggest a mixture of kerogen types in the source rock. Other source rock qualities of Middle and Upper Pennsylvanian shales are discussed in Lower Desmoinesian Stratigraphic Gas and Oil Play (5819).

Timing and migration: Past success in this play indicates favorable timing of generation and migration of hydrocarbons and trap formation. Hydrocarbon generation probably began as early as 250 Ma in the deeper parts of the play. Most major accumulations occur in the area of thermally mature Marmaton strata and are concentrated near the Oklahoma and Texas Panhandles. Reservoirs in immature areas, located near the Central Kansas Uplift or in west-central Kansas, were probably charged by long-distance migration (Burruss and Hatch, 1989).

Traps: Structural traps resulting from anticlines and structural noses are most common in this play. Seals are formed by interbedded Pennsylvanian shales. Fifty-two major accumulations are assigned to this play, 38 oil and 14 gas. The largest oil accumulation is at Putnam field, with an estimated ultimate recovery of 65 MMBO. The largest gas accumulation is at South Lambert field, with an estimated ultimate recovery of 123 BCFG.

Exploration status and resource potential: This play is well explored. Wells reporting penetration of Marmaton rocks number more than 40,000. The actual number is probably much greater, perhaps 64,000 or more. Because of this high level of exploration where structural influence is dominant, the potential for major new discoveries seems rather low. Resource estimates are based largely on historical production and well completion records.

5821. LOWER MISSOURIAN STRATIGRAPHIC OIL AND GAS PLAY

The Lower Missourian Stratigraphic Oil and Gas Play consists of all Upper Pennsylvanian Pleasanton, and Kansas City Group strata, and the lower part of the Lansing and Hoxbar Groups, and this play produces oil and gas principally from sandstone reservoirs. The play extends throughout the province except in the extreme northern and western parts, and on the Wichita Mountains Uplift to the south. Depths range from 2,500 to about 11,000 ft. The concentration of reservoirs in the southern half of the play, and the sandstone lithology of most reservoirs are the principal defining features of this play.

Reservoirs: Reservoir rocks are almost exclusively sandstone, and include the Cleveland, Layton, Melton, Culp, Marchand, Medrano, Wade, and Briscoe sands, and the Cottage Grove Sandstone. Total thickness of strata reaches about 3,000 ft in the southeastern part of the play. Reported porosity from producing areas ranges from 1 to 18 percent with a median value of about 12 percent. Porosity and permeability within the Marchand, a sand that is probably typical of the sands in this play, are both highly variable (Baker, 1979). In the northern part of the play where alternating limestone and shale units comprise a large part of the strata, hydrocarbon production is historically poor. Hydrocarbon production is concentrated to the south and east where terrigenous clastics become increasingly important as reservoirs (Moore, 1979).

Source rocks: Source rocks for this play are probably Upper Pennsylvanian shales that contain both types II and III organic matter (Burruss and Hatch, 1989). Thermal maturity modeling (Schmoker, 1989) suggests that these rocks have not reached the thermal zone of oil generation in the Kansas and Colorado parts of the play. Missourian rocks in Oklahoma and Texas, however, probably reached that oil zone as early as 250 Ma (Schmoker, 1989). All major hydrocarbon accumulations occur in the area where R_o values meet or exceed 0.5 percent. Timing of hydrocarbon generation and migration, and trap formation are favorable for charging of reservoirs in this play.

Traps: Most traps are combination types but stratigraphic traps also occur. Reservoir seals resulting from interbedded shales and mudstones are common (Galloway and others, 1977; Morse, 1963). Major accumulations range in depth from about 3,500 to 10,000 ft. Most are located in the southern half of the play.

Exploration status: This play is generally well explored with nearly 28,000 reported well penetrations. The actual number is probably closer to 68,000. Fifty-two accumulations are assigned to this play, 27 oil and 25 gas. The largest oil accumulation is at Elk City field, with an estimated ultimate recovery of 110 MMBO. The largest gas accumulation is at Ellis Ranch field, with an expected ultimate recovery of 360 BCFG.

Resource potential: The overall future potential for major hydrocarbon discoveries in this play is expected to be only fair. Because of the general decrease in productive sandstones to the north (Bingham, 1993) this play is expected to have limited potential in either Kansas or Colorado. Thermal maturity of rocks in Kansas and Colorado is low, although long-distance migration has probably charged some reservoirs in the northeastern parts of the play. The expected mediocre potential for future major discoveries in the remainder of the play results from the already high density of drilling into the structural features that are important to trap development in this play. Historical discovery trends and well completion data were used to evaluate this play.

5822. UPPER MISSOURIAN OIL AND GAS PLAY

The Upper Missourian Oil and Gas Play consists of the upper part of the Upper Pennsylvanian Lansing and Hoxbar Groups, which produce oil and gas almost exclusively from limestones. The play extends throughout the province except in parts of eastern Colorado and on the Wichita Mountains Uplift. Depths to the top of the Lansing Group range from about 2,800 ft in southeastern Colorado to about 11,000 ft in the deep southern part of the play. The concentration of reservoirs in the northern half of the play and the predominantly limestone lithology of reservoir rock are the principal defining features of this play.

Reservoirs: Reservoir lithology in this play is generally limestone. Producing intervals are usually identified only to the group level, however, two examples of individual units included in the play are the Avant Limestone and the Upper Oolitic lime (Daube Limestone). This play ranges in thickness from less than 100 ft in the northern part of the play to about 600 ft in the southern part of the play. Porosity typically ranges from about 2 to almost 17 percent and has a median value of about 15 percent.

Source rocks: Probable source rocks for this play are the Pennsylvanian shales in the deeper parts of the basin. Modeling by Schmoker (1989) indicates that petroleum generation may have begun as early as 210 Ma in the southern part of the basin, but that potential source rocks in the Lansing Group in the northern part of the play have probably not generated hydrocarbons. For petroleum found in Upper Pennsylvanian reservoirs in that area, Burruss and Hatch (1992) suggest long-distance migration possibly from Simpson and Woodford shales. A more detailed description of Pennsylvanian source rock characteristics is given in Burruss and Hatch (1992). Timing of hydrocarbon generation and migration, and trap formation is favorable for charging of reservoirs in this play.

Traps: Reservoir trap types are generally structural, commonly with a stratigraphic component. Combination-type traps reportedly result from local structure and porosity variability (Parham, 1993). Seals are often formed by enclosing Lansing shales. Nearly all major accumulations occur in the northwestern half of the play, the area that is probably the least likely to have generated petroleum. This distribution supports the idea of long-distance migration of petroleum, and is probably related to better reservoir quality in the shallow carbonates than in the basinward carbonates.

Exploration status: This is a well explored play. More than 24,000 wells are reported to have reached the Lansing Group rocks. With the addition of wells that reached Chesterian through middle Missourian rocks, where Lansing Group tops were not identified, total number of wells in the Lansing Group increase to nearly 75,000. Sixteen major accumulations are assigned to this play, 11 oil and 5 gas. The largest oil accumulation is at Victory field, with an estimated ultimate recovery of 17 MMBO. The largest gas accumulation is at Southeast Falkner field, with an estimated ultimate recovery of 28 BCFG. Known major accumulations range in depth from 3,800 to 5,600 ft.

Resource potential: Based on past successes that have been rather small and few, future discoveries in this play are not expected to be significant. The large number of wells that have been drilled does not indicate a high probability for future discoveries. In addition, nearly all major accumulations are in thermally immature areas on the northern shelf, suggesting long-distance migration of hydrocarbons from a deeper source. The lack of major accumulations in the more thermally mature areas may also indicate a lack of traps or reservoir rocks or both. Historical discovery and well completion data were used extensively in evaluating this play.

5823. LOWER VIRGILIAN SANDSTONE GAS AND OIL PLAY

The Lower Virgilian Sandstone Gas and Oil Play consists of all Lower Virgilian Douglas and Vamoosa Group rocks and extends throughout the province, except in parts of eastern Colorado and on the Wichita Mountains Uplift where Lower Virgilian strata are absent. Drilling depths to the top of Douglas Group range from about 3,800 ft in the northeastern part of the play to about 11,000 ft in the southern part of the play. Reservoirs in this play are developed almost exclusively in sandstone. The concentration of major reservoirs in the southwestern and central part of the play, and the preponderance of sandstone reservoirs are the principal defining features of this play.

Reservoirs: Reservoirs are generally Lower Virgillian sandstones of the Douglas and Vamoosa Groups. Some carbonate reservoirs may also exist. Lower Virgilian strata generally thicken to the south from truncation in parts of eastern Colorado to near 2,000 ft at the Wichita Mountains front. Reservoirs are generally concentrated in western Oklahoma and the Texas Panhandle. Reservoir porosity ranges from 10 to 22 percent, with a median value of about 15 percent. Reservoir quality in many producing areas is very good, but because the depositional environments are interpreted to be fluvial deltaic, and submarine fan (Fies, 1988), quality may be quite variable.

Source rocks: Source rocks are probably the thermally mature Pennsylvanian shales enclosing the reservoir rocks in the deeper parts of the basin. Major accumulations are generally restricted to the area of thermally mature Lower Virgilian strata in northwestern Oklahoma, and the Oklahoma and Texas Panhandles. Rice and others (1989) have suggested that gas reservoirs in Virgillian rocks of the central basin were formed during the mature stage of hydrocarbon generation from a mixture of types II and III kerogens. Source rock qualities of potential Pennsylvanian source rocks have been discussed in some detail in previous Pennsylvanian plays (see Upper Missourian Oil and Gas Play 5822). The presence of almost 70 major hydrocarbon accumulations indicates favorable timing between generation, migration, and trap formation. Because the major accumulations are adjacent to the most probable source rocks, migration distances are probably short.

Traps: Traps consist primarily of combination types, secondarily of stratigraphic types, and lastly of structural types. Trapping mechanisms are often described as purely stratigraphic, resulting from lateral facies changes and updip pinch-outs of sandstones into shales (Bingham, 1993), fault-related structural traps, or combinations of these mechanisms. Seals are interbedded shales and possibly limestone beds. Accumulations exist at depths from about 4,300 to 8,500 ft.

Exploration status: This play is well explored. Wells reported to have reached Douglas Group and Tonkawa sand number more than 26,000. If the estimated number of nonreported penetrations are added, the total number of wells that reached Douglas Group rocks probably exceeds 78,000. Forty-six major accumulations are assigned to this play, 25 gas and 21 oil. The largest gas accumulation is at Mocane-Laverne field, with an estimated ultimate recovery of 1.1 TCFG. The largest oil accumulation is at Chickasha field, with an estimated ultimate recovery of 71 MMBO.

Resource potential: The future potential for major hydrocarbon discoveries in this play is considered good, in spite of the fact that it is extensively drilled. The potential is expected to be less favorable in the northern parts of the play; primarily because of the lack of thermally mature source rocks, and secondarily, because of poor development of reservoir quality rocks in the northern part of the play (Rascoe, 1978). Historical discovery data and well completion data were used extensively in the assessment of this play.

5824. UPPER VIRGILIAN STRATIGRAPHIC OIL AND GAS PLAY

This play extends throughout the province, except in the southwest part of the Texas Panhandle and on the Wichita Mountains front where Upper Virgilian strata are absent. Strata consists of all Middle and Upper Virgilian Shawnee, Wabaunsee, and Admire Group rocks, including correlative units in the Ada Group and in the lower part of the Ponotoc Group. Drilling depths to the top of rocks in this play range from about 2,000 ft in the east-central part to about 9,000 ft in the deep southern part. The principal defining features of this play are that both oil and gas are produced, primarily from limestone reservoirs.

Reservoirs: Reservoir rocks are generally limestones of the Shawnee, Wabaunsee, and Admire Groups. Most of these rocks are oolitic and skeletal grainstones, originally formed in high- energy environments, in which subsequent leaching resulted in secondary porosity development (Parham, 1993). Reported porosity values range from 8 to 17 percent, with a median value of 13 percent. Because most porosity is secondary, porosity in yet undiscovered reservoirs is expected to be good but highly variable.

Source rocks and timing: Source rocks for this play are unknown, but the general lack of thermally mature rocks in the immediate producing areas suggests that longer distance migration of hydrocarbons may be involved (Rice and others, 1989). Quality of possible source rocks for this play has been discussed in other Pennsylvanian plays such as plays 5816 and 5817. Strata in this play generally thicken southward from about 400 to about 3,500 ft. The presence of major accumulations indicates that the timing of hydrocarbon generation and migration, and trap formation is favorable for the charging of reservoirs in this play.

Traps: The most common trap type in this play is stratigraphic, although structural and combination types do exist. Stratigraphic traps are probably formed by overlying shales. Hydrodynamic trapping is an important mechanism at the Greenwood gas area (Pippin, 1985). Known accumulations occur at depths of about 3,000 to 6,100 ft with a median depth of about 4,000 ft.

Exploration status: This play is extensively explored. Almost 16,000 wells have been reported to reach rocks of this play. The large number of wells targeting Chesterian through Lower Virgilian rocks could bring that total to about 79,000. Seventeen major accumulations are assigned to this play; 13 gas and 4 oil. The largest gas accumulation is at Greenwood gas area, with an estimated ultimate recovery of 1.8 TCFG. The largest oil accumulation is at Quinduno north field, with an estimated ultimate recovery of 13 MMBO.

Resource potential: The potential for future major hydrocarbon discoveries in this play is projected to be insignificant, primarily because of the relatively few major accumulations contained in a very intensely explored area. Because of the evidence of long distance migration of thermally generated gas, the lack of thermally mature source rocks is not a serious liability for this play. Historical discovery and well completion data were the major sources of information used for assessment of this play.

5825. PERMIAN CARBONATE STRATIGRAPHIC GAS PLAY

This play extends throughout the province and consists of all Lower Permian, Wolfcampian Council Grove, and Chase Group strata, except those included in the Wichita Mountains Uplift Play (5804). Drilling depths to the top of the Chase Group range from about 800 to about 4,850 ft. This play is the most significant hydrocarbon producer in the province. The play is dominated by the Panhandle-Hugoton gas field, the largest gas field in the United States. Panhandle-Hugoton has coalesced, through the years, from what were then considered individual gas discoveries in Texas, Kansas, and Oklahoma, into a single huge producing entity. Although this is considered a single field, there are some differences in its various parts. The part of Panhandle-Hugoton located in the Texas Panhandle has significant oil accumulations in addition to a huge gas accumulation. The oil and gas accumulations in the Texas Panhandle part are primarily structurally controlled, whereas gas in other parts of Panhandle-Hugoton is stratigraphically trapped; hydrodynamics plays a role in both areas (Pippin, 1970). In the Texas Panhandle, the oil is located downdip from the gas, held in that position by the balance between gas and hydrostatic pressure (Rogatz, 1935). The oil part of the accumulation, which is now considered a single field, has amalgamated from more than 40 individual oil fields, an outcome predicted by Rogatz in 1935. The enormity of the gas production, the interconnected fields, and a predominantly carbonate lithology, are the principal defining features of this play.

Reservoirs: Reservoir rocks of this play include arkosic washes, and limestone and dolomite units of the Lower Permian Council Grove and Chase Groups. Thickness ranges from about 500 ft on the shelf areas to more than 2,000 ft near the Wichita Mountains front. Data from nine reservoirs show porosity ranging from 12 to 16 percent, with a median of about 15 percent. However, a study by Cities Service Oil and Gas Corp. (Shirley, 1986) found that porosity and permeability are not as uniform as previously thought. Hugoton reservoirs do not produce well without fracture treatment (Oil and Gas Journal, 1984).

Source rocks: Likely sources for hydrocarbons in this play may be virtually any of the thermally mature source rocks previously discussed in this province. No conclusive evidence is found for the existence of Permian source rocks in the province, however, Campbell and others (1988) discuss several lines of evidence to support that possibility. High-quality thermally mature source rocks are abundant just north of the oil and gas accumulations in the Texas Panhandle, and some workers have speculated that hydrocarbons may have migrated from a normally pressured Texas oil and gas field that was breached (Shirley, 1986). Panhandle-Hugoton gas pressure is characteristically low, initially 482 pounds per square inch (psi), less than half that expected for a given depth. Rice and others (1989) have suggested long distance migration (as much as several hundred miles) for gas found in the Panhandle-Hugoton area. They proposed that the gas may have been derived from Pennsylvanian or older source rocks in the central basin during the mature stage of hydrocarbon generation. Oil, on the other hand, may have come from Simpson or Woodford shales (Burruss and Hatch, 1989), and may not have migrated such great distances. The hydrocarbon source for Panhandle-Hugoton is not positively known. It is possible that generation and migration could have occurred over a long period of time with hydrocarbons trapped in multiple stages. The existence of huge quantities of hydrocarbon in this play indicates favorable timing between generation, migration and, trap formation.

Traps: Trapping mechanisms for the oil accumulations in the Texas Panhandle are primarily structural, and are related to the anticline and smaller structural features formed by the buried Amarillo-Wichita Uplift (Rogatz, 1935). Gas in the Texas Panhandle is localized by the same anticlinal structures. Hydrodynamics also plays an important role in localizing both oil and gas in this play (Rogatz, 1935, 1939; Hubbert, 1967; Pippin 1970). In the Oklahoma and Kansas parts of the field, gas is trapped along the western side by porosity loss where reservoir rocks grade into tight red beds. The overall distribution of the gas is modified by subsurface water flow toward the east (Rogatz, 1935, 1939; Hubbert, 1967). Seals for this play are dolomite and anhydrite beds of the overlying Permian Wichita Formation (Pippin 1970).

Exploration status: Nearly 30,000 wells penetrated the Permian carbonates in this play. Because many are not reported, the actual number of wells is much larger, probably in excess of 96,000. The Panhandle-Hugoton field has an estimated ultimate recovery of about 83 TCFG. Production from major accumulations ranges in depth from about 1,400 to about 4,300 ft.

Resource potential: The future potential for new major hydrocarbon discoveries in this play is not expected to be great. Undiscovered accumulations are not expected west of the Panhandle-Hugoton field boundary because of the apparent lack of rocks of reservoir quality; to the east, reservoir rocks are generally water wet. The large number of wells in the play leave little unexplored area. Our view of the play recognizes the fact that known accumulations are underpressured, and therefore, some accumulations may exist in already extensively drilled areas and may have simply been overlooked (Campbell and others 1988). An important implication here is that a extensively drilled area is not always well explored. Although additional production from infill drilling may prove significant, this part of the resource is not considered undiscovered. Historical discoveries, and well completion and production data were used to evaluate this play.

5827. WASHES PLAY

The Washes Play exists in the southwestern part of this province and extends into parts of the fold belt of the Southern Oklahoma Province. The play consists of eroded and recycled sedimentary and igneous debris (washes) weathered from the rocks uplifted during the Pennsylvanian and Early Permian tectonism (principally the Amarillo-Wichita Uplift) that created the present-day Anadarko Basin. These undifferentiated strata range in age from Pennsylvanian Morrowan through Permian Wolfcampian and generally drape over and interfinger with the strata of other Pennsylvanian and Permian plays adjacent to the Wichita Mountains front. Drilling depths to the top of these washes range from less than 100 ft to an estimated maximum of about 15,000 ft. We recognize that these rocks do not represent a single homogeneous package of so-called "granite" wash, but are eroded remnants and mixtures of many lithologies. However, their detrital nature, their proximity to the source, their genetic relationship to the tectonic development of the Amarillo-Wichita Uplift, and their similarities with respect to hydrocarbon source and trap type are their defining features, and are the characteristics that group these rocks into a single play.

Reservoirs: Reservoir rocks are washes that range in age from Pennsylvanian to early Permian. Clast lithologies include limestones, cherts, dolomites, granites, and mixtures eroded from Mississippian, Devonian, Cambrian, and Ordovician sedimentary rocks, and Precambrian crystalline rocks. Compositionally, they lie in reverse stratigraphic order to that of the parent rocks, that is, Mississippian parent rocks sourced the oldest of the washes and Precambrian crystalline parent rocks are the sources of the youngest washes. These washes produce primarily gas but some oil as well. Production begins at depths as shallow as 300 ft but most major reservoirs produce between depths of 4,700 and 13,000 ft.

Source rocks and timing: Because of the proximity of this play to virtually all source rocks in the basin, a variety of petroleum source rocks are expected. Because of the highly faulted nature of the area, thermally mature shales of the nearby deep Anadarko Basin are viable source rocks. Mature Pennsylvanian shales that interfinger with the washes along the northern play boundary are also likely source rocks. Both vertical and horizontal migration are probably important in this play. Detailed discussions of these (and other) hydrocarbon sources can be found in other play descriptions. The wide variety of source rocks, with varying mixtures of types II and III organic matter, is expected to generate both oil and gas. The favorable timing of hydrocarbon generation, migration, and trap formation in this play is evidenced by the presence of several major accumulations.

Traps: Examples of all three common trap types--structural, stratigraphic, and combination--exist in this play, but structure seems to play the dominant role. Pennsylvanian and Permian shales, and Pennsylvanian limestones provide seals for reservoirs.

Exploration status: This play is in a mature stage of exploration. More than 7,600 wells have penetrated various wash lithologies in the Anadarko Basin Province (055). About 2,700 of those produce from 32 major reservoirs assigned to this play; of these, 25 are gas fields and 7 are oil fields. The earliest producing well was completed in 1934, the latest in 1991. The largest gas accumulation assigned to this play is at Hemphill Granite Wash field, with an estimated ultimate recovery of 1.1 TCFG. The largest oil accumulation is at Mobeetie field, with 7 MMBO. Although some washes in this play have been drilled to depths of 15,000 ft or more, only 39 wells reported tops deeper than 13,000 ft.

Resource potential: The potential for future major hydrocarbon discoveries in this play is projected to be fair to moderate. It has an excellent production history, including a few discoveries in recent years. Limiting factors for future discoveries include diagenetic porosity loss in parts of these deposits (Dutton, 1982) and a possible lack of hydrocarbon seals. Historical discovery, production, and well completion data were used to assess this play.

5828. PERMIAN SANDSTONE OIL AND GAS PLAY

The Permian Sandstone Oil and Gas Play is located in the eastern and southeastern part of the province and includes a small group of major accumulations that share several defining features. They are all relatively shallow, Permian sandstone reservoirs, located in the same small area, with the same types of structural trapping mechanisms on the same structural features. In fact, the association between the hydrocarbon accumulations and the structural features that define the play, are so strong that, for all practical purposes, the play does not exist beyond these structural features. For that reason, the boundary of this play represents a departure from the practice of including, in layer-cake fashion, all stratigraphic units of similar age or lithology, and instead, includes only the areas of major production. Drilling depths to the top of rocks assigned to this play range from about 800 to 3,800 ft.

Reservoirs: Permian reservoir rocks are Wolfcampian and Leonardian sandstones; these include the Noble-Olsen, Fortuna, Ramsey, and Nichols sands, and the Garber Sandstone. Porosity ranges from 10 to 20 percent, with a median value of about 18 percent (Campbell and others, 1988). Thickness ranges from about 30 ft along the eastern province boundary to about 2,600 ft in the southern part of the play.

Source rocks, timing, and migration: Source rocks for the play could include a wide variety of possible candidates, including thermally mature Pennsylvanian and older Paleozoic (Simpson and Woodford) source rocks located nearby. Permian source rocks are not necessarily required. Accumulations in this play are located on structures that in many cases also produce from deeper zones, therefore, oil and gas from older reservoirs could simply have migrated upward. Timing of hydrocarbon generation and migration, and trap formation were favorable for reservoir charging.

Traps: Traps are generally anticlines or faulted anticlines with some influence from facies changes. The Cement field is a classic example of a faulted anticline trap (Harrison and Routh, 1981). Major reservoirs range in depth from about 900 to 2,000 ft.

Exploration status: This play is well explored. In the northern part of the play, drilling intensity results in large part from the search for deeper targets (Mississippian rocks of the Sooner Trend). In the southern part of the play, much of the drilling appears to be the result of exploration of Springer and Morrow targets. The pattern of production from Permian sandstones closely follows the pattern of structural trapping. Oil is the most common hydrocarbon found to date.

Resource potential: The potential for major new hydrocarbon discoveries in this play is considered extremely low, and therefore, the play was not formally assessed. Some reasons for this finding include the following: The area is already very well drilled. The last major discovery was in 1923. Oil is the most common product and it is not likely that major accumulations were simply overlooked and not produced. The association between major accumulations and structural elements is very strong and, given the relatively shallow nature of reservoir rocks and the density of seismic coverage, an unknown structure large enough to contain a 1 MMBO accumulation is very unlikely. Historical discovery, production, and well completion data were used to evaluate this play.

UNCONVENTIONAL PLAY

Continuous-Type Play

By J.W. Schmoker

5811. *WOODFORD/CHATTANOOGA/ARKANSAS/NOVACULITE OF MIDCONTINENT PLAY (HYPOTHETICAL)*

The Woodford/Chattanooga/Arkansas Novaculite of Midcontinent Play (5811) is a hypothetical play erected to address the possibility that one or more continuous-type oil or gas accumulation exist in the Midcontinent Region. Such self-sourced accumulations would be limited to areas where the reservoir is thermally mature, which might exclude most of Kansas. Because of the hypothetical nature of the play, its boundaries are not mapped according to precise geologic criteria. Rather, the boundaries are regional borders. The play encompasses the Oklahoma portion of the Anadarko Basin, the Southern Oklahoma Fold Belt, the Arkoma Basin, the Oklahoma portions of the Nemaha Uplift and Cherokee Platform, and possibly parts of the Permian Basin.

Reservoir and source rocks: The Mississippian and Devonian Woodford Shale and equivalents were deposited over a large portion of the Midcontinent. In the Anadarko Basin, the Woodford Shale is a dark-gray to black shale that is widely regarded as an important source rock. Total thickness ranges from near zero to about 125 ft on the northeast shelf of the Anadarko Basin and increases to more than 900 ft in limited areas of the deep basin. Organic-carbon content generally exceeds source-rock minimums and averages about 5 wt. percent on the northeast shelf. The organic-matter type is a mixture of type II and type III kerogens. Vitrinite-reflectance values range from 0.5 percent at present depths of roughly 5,000 ft to well over 2.0 percent in the deep Anadarko basin at present depths exceeding 20,000 ft.

In addition to the Anadarko Basin, where it is perhaps most studied, the Woodford is present in eastern Oklahoma, the Southern Oklahoma Fold Belt, and the Arkoma Basin. The Woodford becomes more siliceous to the southeast where it grades into the Arkansas Novaculite. The Woodford is also present in the Permian Basin of western Texas and southeastern New Mexico.

In Kansas, the equivalent formation is commonly called the Chattanooga Shale and this terminology is sometimes extended southward into eastern Oklahoma. The Chattanooga (Woodford) Shale is present over most of the eastern half of Kansas. Thickness ranges from near zero up to several hundred feet. Organic-carbon content averages as high as 5 wt. percent in some localities and is typically above source-rock minimums. In Kansas, levels of thermal maturation appear to be at or below the onset of hydrocarbon generation.

The Woodford/Chattanooga/Arkansas Novaculite depositional system, where thermally mature, may form one or more self-sourced, continuous-type oil or gas accumulations. However, production from such a continuous-type accumulation is not documented. Fields known to have Woodford production, such as Isom Springs, Sho-Vel-Tum, and Caddo appear to be structurally controlled, conventional accumulations that are amenable to standard assessment methods based on sizes and numbers of discrete fields.

Two lines of reasoning support the concept of Woodford/Chattanooga/Arkansas Novaculite continuous-type accumulations. The first is based on geological and geochemical similarities to the shale members of the Mississippian and Devonian Bakken Formation of the Williston Basin. The well established Bakken continuous-type accumulation could be invoked as an analog. The second is based on resistivity logs of the Woodford Shale in the Anadarko Basin. If Woodford resistivity values greater than 35 ohm-meters are interpreted as indicating the presence of internally generated oil or gas, a considerable area of the Woodford Shale could be hydrocarbon saturated, forming a continuous-type accumulation in the Anadarko Basin.

Exploration status and resource potential: Petroleum exploration within the play area has generally reached a mature stage, and a continuous-type accumulation has not been confirmed. However, exploration has been directed toward conventional structural and stratigraphic traps. The possibility remains that a continuous-type accumulation exists but has not been recognized, since people commonly do not see something for which they are not looking.

Given the large area of the play, the play probability is greater than 10 percent. However, the play is so speculative that an effort at quantitative assessment could not be defended. The concept of the play is documented here; quantitative assessment is deferred until more data and better geologic understanding are available.

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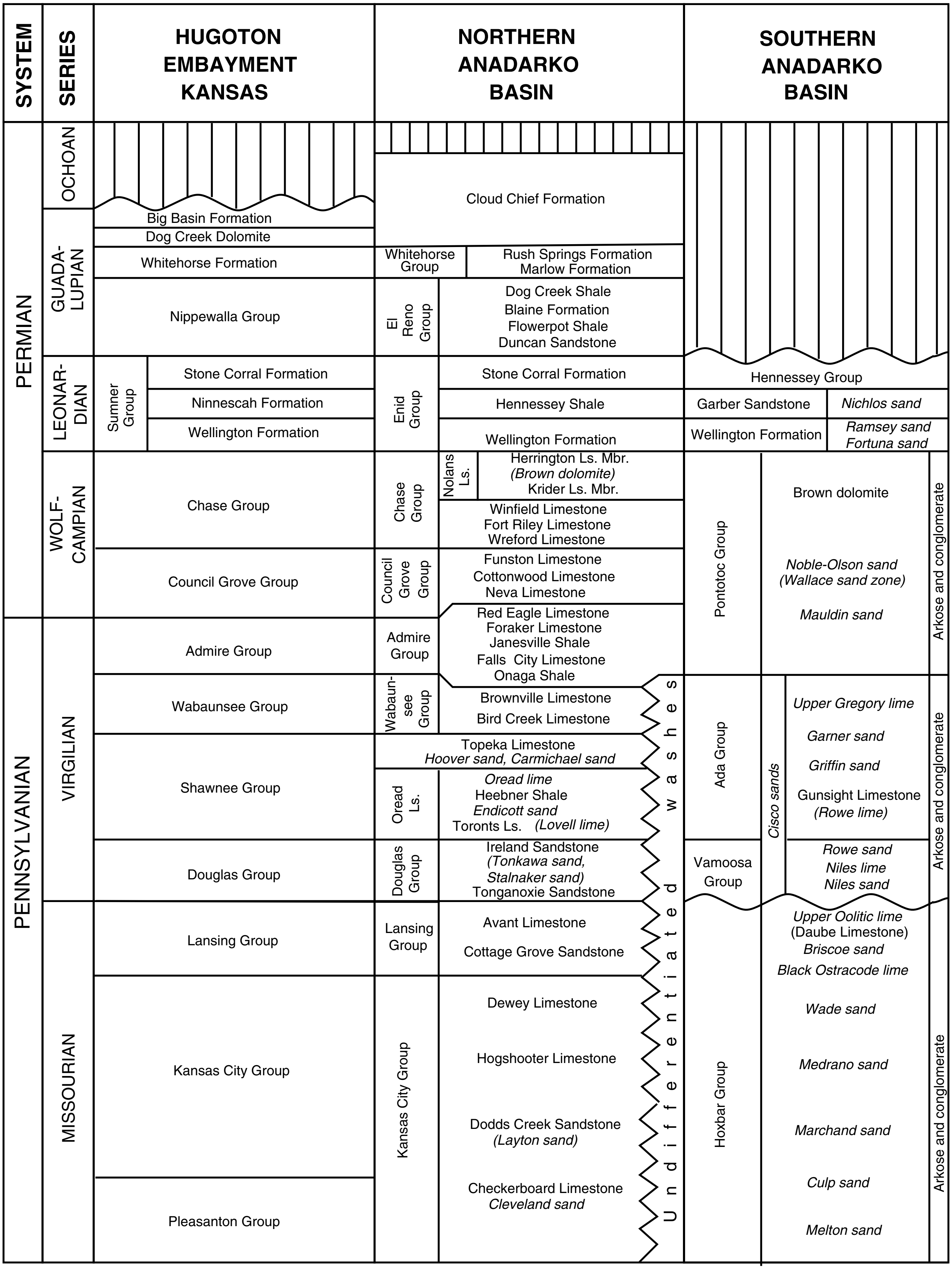

Figure 2. Generalized surface and subsurface stratigraphic columns for the Anadarko Basin and the Southern Oklahoma Fold Belt Provinces (058 and 061). Italics indicate informal names and double columns of informal names indicate different local usage and unknown correlation of units. Modified from Bebout and others (1993). Modifications are limited to the appearance of the chart.

SYSTEM	SERIES	HUGOTON EMBAYMENT KANSAS	NORTHERN ANADARKO BASIN	SOUTHERN ANADARKO BASIN
PENNSYLVANIAN	DESMOINESIAN	Marmaton Group	Marmaton Group: Oologah Limestone *(Big lime)*; Englevale Sandstone *(Peru sand)*; Fort Scott Limestone *(Oswego lime)*	Deese Group: *Culberson sand*; *Glover sand*; *Gibson sand*; *Charlson sand*; *Hart sand*; *Pooler sand*; *Osborne sand*
PENNSYLVANIAN	DESMOINESIAN	Cherokee Group	Lagonda Sandstone *(Prue sand)*; Verdigris Limestone; Chelsea Sandstone *(Skinner sand)*; Tiawah Limestone *(Pink lime)*; Taft Sandstone *(Red Fork sand)*; Inola Limestone; Bluejacket Sandstone *(Bartlesville sand)*; Warner Sandstone *(Burgess sand)*	Dornick Hills Group, *upper*: Pumpkin Creek Limestone
PENNSYLVANIAN	ATOKAN	Atoka Group	Atoka Group; *Thirteen Finger lime*	Dornick Hills Group, *upper*: *Atoka shale*; Arkose and conglomerate
PENNSYLVANIAN	MORROWAN	Morrow Group: Kearny Formation	Morrow Formation, upper: *Morrow shale*; *Purdy sand*; Puryear sand	Dornick Hills Group, *lower*: *Dornick Hills shale*; Primrose Sandstone; ?; Arkose and conglomerate
PENNSYLVANIAN	MORROWAN	Morrow Group: *Keyes sand*	Morrow Formation, lower: *Keyes sand*	Dornick Hills Group, *lower*

Undifferentiated washes (Northern Anadarko Basin, Desmoinesian through Atokan)

Figure 2. Continued

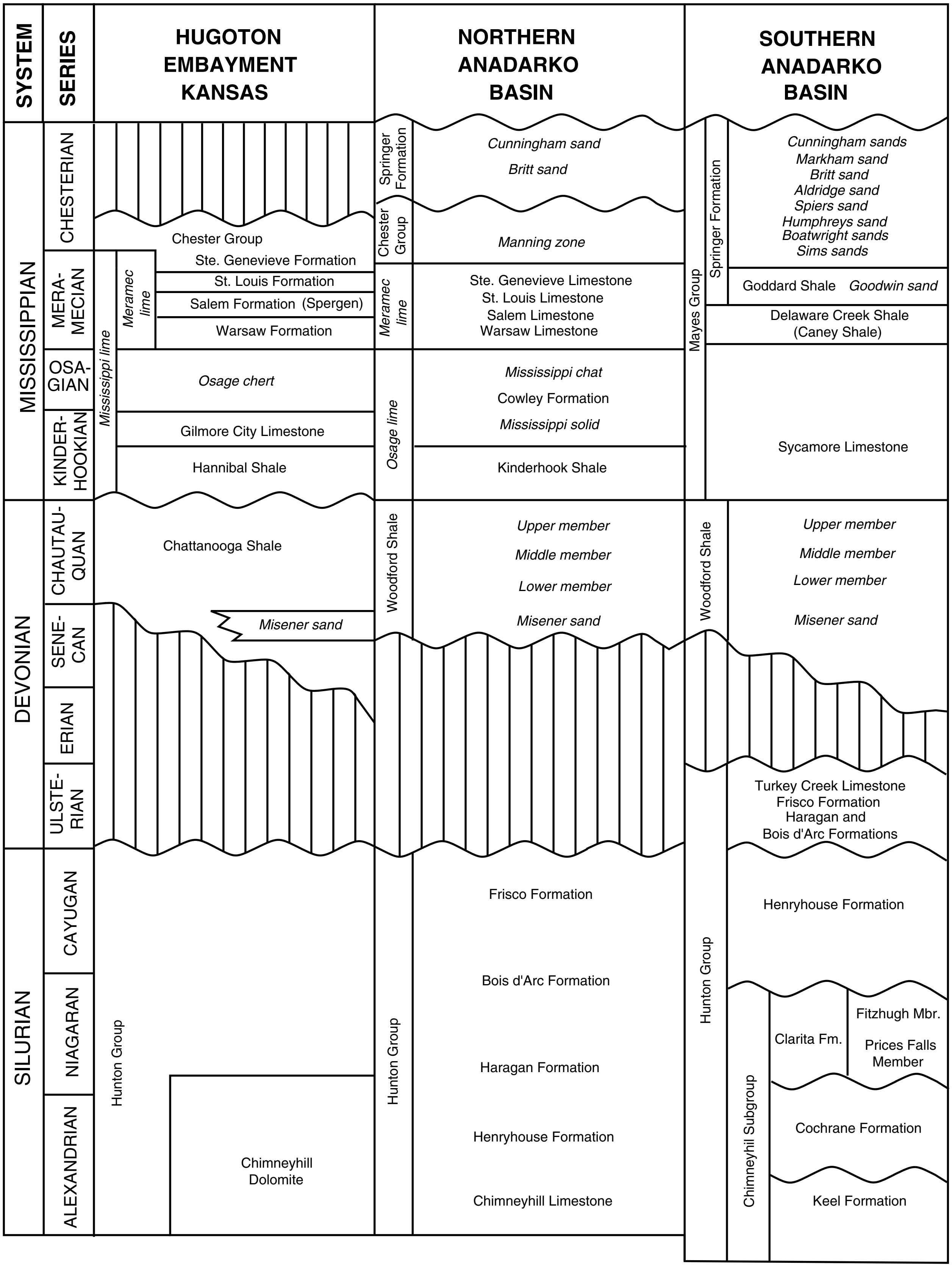

Figure 2. Continued

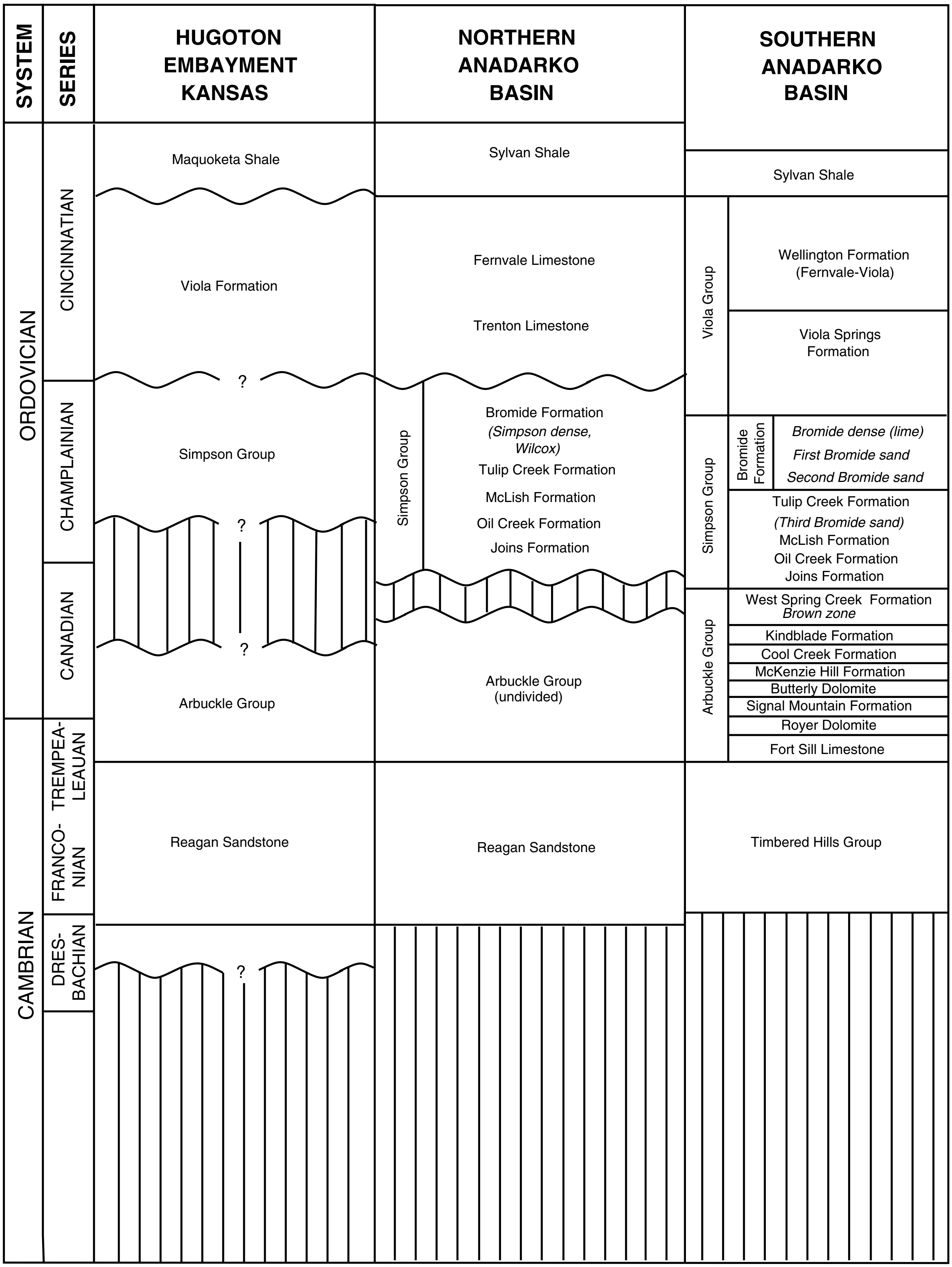

Figure 2. Continued