

# CHEROKEE PLATFORM PROVINCE (060)

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*With a section on coalbed gas by Dudley D. Rice and Tom Finn*

## INTRODUCTION

The Cherokee Platform Province (060) extends from southeastern Kansas and part of southwestern Missouri to northeastern Oklahoma. It consists of 37 counties; all boundaries of this province follow county boundaries. The province is 235 miles long (north-south) by 210 miles wide (east-west) and has an area of 26,500 sq mi.

Petroleum exploration in the Cherokee Platform Province began in the 1860's with drilling in Bourbon and Cherokee Counties, Kansas. The first discovery was in 1873 in Allen County, Kansas (Iola field). Over 200,000 wells have been drilled in the province, and 431 fields larger than 1 MMBOE have been discovered. Discovered resources as of the end of 1990 have been over 5.3 BBO and 4.3 TCFG. Among the largest fields in the province are Burbank field (over 500 MMBO), in Kay and Osage Counties, Oklahoma; Cushing field (over 500 MMBO), in Creek and Payne Counties, Oklahoma; Glennpool field (over 300 MMBO), in Creek and Tulsa Counties, Oklahoma; Iola field (over 150 BCFG), in Allen County, Kansas; and Buffalo-Vilas field (over 120 BCFG), in Wilson and Woodson Counties, Kansas.

The plays were erected for the Cherokee Platform Province primarily by grouping the accumulations by the age of the reservoir rocks. Thus, the reservoirs and prospects in the pre-Woodford Paleozoic rocks are in Pre-Woodford Paleozoic Play (6001), except for those significantly below the top of the Arbuckle Group, which are in Internal Arbuckle/Reagan Play (6007). Woodford Shale reservoirs are part of a regional unconventional play, the Woodford/Chattanooga/Arkansas Novaculite of Midcontinent Play (5811), described in the section for the Anadarko Basin Province (058). Mississippian reservoirs are assigned to Mississippian Play (6003). The Pennsylvanian reservoirs are divided into two plays by primary trap type. Pennsylvanian Structural Play (6004) includes Pennsylvanian reservoirs or prospects with structural or combination traps. Pennsylvanian Stratigraphic Play (6005) includes Pennsylvanian, primarily but not exclusively Desmoinesian, reservoirs with stratigraphic traps. The unconventional coalbed gas play, described by Dudley D. Rice, is Cherokee Basin-Central Basin Play (6050). Further discussion of coalbed gas plays,

with references, may be found in the chapter by Rice, "Geologic framework and description of coalbed gas plays" elsewhere in this CD-ROM.

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## CONVENTIONAL PLAYS

### 6001. PRE-WOODFORD PALEOZOIC PLAY

The Pre-Woodford Paleozoic Play is a confirmed, conventional play defined by being within the bounds of the Cherokee Platform Province and by having reservoir rocks ranging from the top few tens of feet of the Arbuckle Group up to the base of the Woodford Shale. The play is bounded geographically by similar Lower Paleozoic plays in the Nemaha Uplift and Forest City Basin Provinces (055 and 056). It is underlain by the Internal Arbuckle/Reagan play (6007) and overlain by the Woodford/Chattanooga/Arkansas Novaculite of Midcontinent Play (5811). The play excludes areas, particularly in the northern part of the province, where the sub-Woodford rocks are completely eroded. Most accumulations are in structural traps.

**Reservoirs:** There are five main reservoirs included. The uppermost Arbuckle Group (Lower Ordovician) consists of karsted dolomite reservoirs with an average of 27 feet net pay. The Middle to Upper Ordovician Simpson Group reservoirs are mostly sandstones with an average of 38 feet net pay. The Viola Limestone reservoirs, Upper Ordovician, average 38 feet of net pay. Hunton Group (Upper Ordovician to Lower Devonian) carbonate-rock reservoirs average 39 feet net pay. Misener Sandstone (Middle to Upper Devonian) reservoirs average 74 feet net pay.

**Source rocks:** The Ordovician Simpson Group shales are probably the most important source. The Devonian-Mississippian Woodford Shale is another likely source, by long-range migration from deeper parts of the Anadarko or Arkoma basins.

**Traps:** Traps are primarily structural. In some of the carbonate-rock reservoirs, some stratigraphic component is also involved. Depths of current production are from 1200 to 6300 feet and undiscovered accumulations are expected to be at similar depths.

**Exploration status:** Hydrocarbon exploration began in this play prior to 1900. Since then, 85 oil and 5 nonassociated gas accumulations larger than 1 MMBOE have been discovered. The largest oil accumulations are in Earlsboro field and St. Louis field, both over 200 MMBO and both in Pottawatomie and Seminole Counties, Oklahoma. The largest nonassociated gas accumulation (over 70 BCFG) is in Yeager field in Hughes County, Oklahoma.

**Resource potential:** The play is very mature with few accumulations larger than 1 MMBO or 6 BCFG expected. The number of discoveries for amount of wildcat drilling is decreasing. When compared with how heavily the area has been drilled, there is little

expectation for large numbers of accumulations larger than 1 MMBOE. Large numbers of accumulations smaller than that size are still likely to occur, however.

### **6003. MISSISSIPPIAN PLAY**

The Mississippian Play is a confirmed conventional play defined by being within the bounds of the Cherokee Platform Province and by having reservoirs and prospects within Mississippian rocks. The play is bounded geographically by similar Mississippian plays in the Nemaha Uplift and Forest City Basin Provinces (055 and 056). The play excludes areas, particularly in the northern part of the province, where the Mississippian rocks are completely eroded. The play is underlain by the Woodford/Chattanooga/Arkansas Novaculite of Midcontinent Play (5811) and overlain by the Pennsylvanian Structural and Pennsylvanian Stratigraphic plays (6004 and 6005). Most accumulations are in combination traps.

**Reservoirs:** The main reservoirs are limestones and cherts of Mississippian age. The "Mississippian chat", actually a residual deposit of Mississippian-age chert fragments deposited at the base of the Pennsylvanian, is included in this play. Net pay averages 38 feet.

**Source rocks:** The Devonian-Mississippian Woodford Shale is probably the most important source, partly by long-range migration from deeper parts of the Anadarko or Arkoma basins. The Ordovician Simpson Group shales are likely another source.

**Traps:** Traps are primarily combination. Depths of current production are from 800 to 5300 feet and undiscovered accumulations are expected to be at similar depths.

**Exploration status:** Hydrocarbon exploration began in this play before 1900. Since then, 24 oil and no non-associated gas accumulations larger than 1 MMBOE have been discovered. The largest oil accumulation (over 19 MMBO) is in North Virgil field in Clay, Coffey, and Greenwood Counties, Kansas.

**Resource potential:** The play is very mature with few accumulations larger than 1 MMBO or 6 BCFG expected. The number of discoveries for amount of wildcat drilling is decreasing. When compared with how heavily the area has been drilled, there is little expectation for large numbers of accumulations larger than 1 MMBOE. Large numbers of accumulations smaller than that size are still likely to occur, however.

#### **6004. PENNSYLVANIAN STRUCTURAL PLAY**

The Pennsylvanian Structural Play is a confirmed conventional play defined by being within the bounds of the Cherokee Platform Province, by having reservoirs and prospects within Pennsylvanian rocks, and by having a primarily structural or combination trap type. The play is bounded geographically by similar Pennsylvanian plays in the Nemaha Uplift and Forest City Basin Provinces (055 and 056). It is underlain by the Mississippian Play (6003).

**Reservoirs:** The main reservoirs are sandstones of Pennsylvanian age. Desmoinesian fluvial-deltaic sandstones are the most significant reservoirs. Net pay averages 73 feet.

**Source rocks:** The Devonian-Mississippian Woodford Shale is probably the most important source, partly by long-range migration from deeper parts of the Anadarko or Arkoma basins. The dark, marine shales of the Pennsylvanian (especially Desmoinesian) cyclothem are likely local sources. The Ordovician Simpson Group shales are possibly a minor source.

**Traps:** Traps are structural and combination types. Depths of current production are from 150 to 5000 feet and undiscovered accumulations are expected to be at similar depths.

**Exploration status:** Hydrocarbon exploration began in this play in the 1860's in southeastern Kansas. The first significant discovery was Domes-Pond Creek in 1894 in Osage County, Oklahoma. Since then 163 oil and 11 non-associated gas accumulations larger than 1 MMBOE have been discovered. The largest oil accumulations are in Burbank field (over 500 MMBO), in Kay and Osage Counties, Oklahoma; Cushing field (over 500 MMBO), in Creek and Payne Counties, Oklahoma; and Glennpool field (over 300 MMBO), in Creek and Tulsa Counties, Oklahoma. The largest non-associated gas accumulation is in Buffalo-Vilas field (over 120 BCFG), in Wilson and Woodson Counties, Kansas.

**Resource potential:** The play is very mature with few accumulations larger than 1 MMBO or 6 BCFG expected. The number of discoveries for amount of wildcat drilling is decreasing. When compared with how heavily the area has been drilled, there is little expectation for large numbers of accumulations larger than 1 MMBOE. Large numbers of accumulations smaller than that size are still likely to occur, however.

## **6005. PENNSYLVANIAN STRATIGRAPHIC PLAY**

The Pennsylvanian Stratigraphic Play is a confirmed conventional play defined by being within the bounds of the Cherokee Platform Province, by having reservoirs and prospects within Pennsylvanian rocks, and by having a primarily stratigraphic trap type. The play is bounded geographically by similar Pennsylvanian plays in the Nemaha Uplift and Forest City Basin Provinces (055 and 056). It is underlain by the Mississippian play (6003).

**Reservoirs:** The main reservoirs are sandstones of Pennsylvanian age. Most of these are fluvial-deltaic sandstones of Desmoinesian age, but some Atokan and Missourian age sandstones are also included. Net pay averages 31 feet.

**Source rocks:** The Devonian-Mississippian Woodford Shale is probably the most important source, partly by long-range migration from deeper parts of the Anadarko or Arkoma basins. The dark, marine shales of the Pennsylvanian (especially Desmoinesian) cyclothems are likely local sources. The Ordovician Simpson Group shales are possibly a minor source.

**Traps:** Traps are primarily stratigraphic. Depths of current production are from 400 to 4900 feet and undiscovered accumulations are expected to be at similar depths.

**Exploration status:** Hydrocarbon exploration began in this play in the 1860's in southeastern Kansas. The first significant discovery was the Iola field in 1873 in Allen County, Kansas. Since then, 90 oil and 5 non-associated gas accumulations larger than 1 MMBOE have been discovered. The largest oil accumulations are in Cromwell field (over 75 MMBO) in Okfuskee and Seminole Counties, Oklahoma, and Naval Reserve field (over 50 MMBO) in Osage County, Oklahoma. The largest non-associated gas accumulation is in Iola field (over 150 BCFG), in Allen County, Kansas.

**Resource potential:** The play is very mature with few accumulations larger than 1 MMBO or 6 BCFG expected. The number of discoveries per amount of wildcat drilling is decreasing. When compared with how heavily the area has been drilled, there is little expectation for large numbers of accumulations larger than 1 MMBOE. Large numbers of accumulations smaller than that size are still likely to occur, however.

## **6007. INTERNAL ARBUCKLE/REAGAN PLAY (HYPOTHETICAL)**

The Internal Arbuckle/Reagan Play is a hypothetical conventional play defined as prospects within the Arbuckle Group, Reagan Sandstone, and equivalents within the

bounds of the Cherokee Platform Province. The play is bounded geographically by similar Internal Arbuckle/Reagan plays in the Nemaha Uplift and Anadarko Basin Provinces (055 and 058). The play is overlain by the Pre-Woodford Paleozoic Play (6001).

**Reservoirs:** The potential reservoirs are carbonate-rocks, especially dolomites, of the Upper Cambrian to Lower Ordovician Arbuckle Group. The Arbuckle Group ranges in thickness from about 500 ft in the northern part of the province to about 4,500 ft in the southern part of the province. Other possible reservoirs are sandstones of the Upper Cambrian Reagan Sandstone and equivalents.

**Source rocks:** Hypothesized source rocks are organic-rich carbonate-rocks within the Arbuckle Group. Little is known about Arbuckle source-rock potential, but any mature sources would likely lie within the oil window. Younger sources (e.g. Woodford Shale) could possibly contribute by lateral migration.

**Traps:** Traps would be lateral and vertical variations in permeability in the carbonates within the Arbuckle Group. These would likely have resulted from either subaerial weathering or dolomitization processes.

**Exploration status:** Relatively little drilling has taken place in this province below the top few tens of feet of the Arbuckle Group. A very large volume of rock is thus unexplored, making this a very immature play.

**Resource potential:** Risk is high for this play, especially because of a low probability for good source rocks and seals. If good source rocks do exist within the Arbuckle Group, there is potential for large accumulations.

## UNCONVENTIONAL PLAY

### *Coal-bed Gas Play*

*By Dudley D. Rice*

One coalbed gas play, the Cherokee Platform–Central Basin Play (6050) is identified in this province.

Stoeckinger (1989, 1990) has evaluated the coalbed gas potential of the Cherokee Platform (province 060), southeast Kansas. Barker and others (1992) provided new information on thermal maturity patterns that will affect coalbed gas potential. The geologic framework and many of the characteristics pertaining to coalbed gas are the same for both the Cherokee Platform and Forest City Basins. The big difference is that development of coalbed gas has taken place in the Cherokee Platform, and more data are available for better assessing the recoverable coalbed gas potential.

The thickest coal seams in the Cherokee Platform are assigned to the Middle Pennsylvanian (Desmoinesian) Cherokee Group, which varies in thickness from 300 to 500 ft. The Cherokee Group consists mostly of black shales, with lesser amounts of limestone, sandstone, and coal. The main coalbeds in the basin, in ascending order, are Riverton, Rowe, Weir-Pittsburg, Mineral, Fleming, Croweburg, Bevier, and Mulky. The Riverton, Weir-Pittsburg, Bevier, and Mulky are the thickest, and the Weir-Pittsburg seam can be as much as 5 ft thick. Net thickness of the coals in the Cherokee Group, based on geophysical logs, is greater than 15 ft. Depths of burial for the target coal beds are in the range of 600–1,200 ft.

The Pennsylvanian coals in the Cherokee Platform are generally high-volatile B to A bituminous in rank, and this coalification pattern is related to maximum burial in Permian time. However, “hot spots” exist where rank of the coal beds may be as much as medium-volatile bituminous. These “hot spots”, which are restricted to the southeast part of the basin, are interpreted to be the result of warm waters, which originated from southerly basins during late Paleozoic time. These warm waters flowed upward from permeable Mississippian rocks along fractures and (or) faults into locally permeable Pennsylvanian rocks. These localized areas of higher rank resulted in conditions favorable for the significant generation of thermogenic hydrocarbons during late Paleozoic time.

Methane makes up more than 97 percent of the hydrocarbon fraction of the produced coalbed gases in the Cherokee Platform. Minor amounts of CO<sub>2</sub> (average 1.1 percent)

and nitrogen (average 1.6 percent) are also produced with the methane. Although isotopic values are not available, the gases were probably generated by thermogenic processes in late Paleozoic time. In addition, minor amounts of waxy oil, which are the result of thermogenic processes, are also produced.

The Cherokee Platform is generally characterized by beds gently dipping to the west. However, there are local folds and normal faults with small relief that have distinct northeast-southwest and northwest-southeast orientations. These structures appear to be basement-controlled, and some experienced recurrent movement during deposition. Relief on these structures increases with depth. In addition, differential compaction of thick shales that underlie most coal beds also influenced the orientation and intensity of cleating in the coal.

As much as 20 barrels of saline water (TDS as much as 90,000 ppm) are produced from typical coalbed gas wells per day. The high salinity and low quantity of water suggest that there is not active groundwater flow. The water is injected into the Ordovician Arbuckle carbonates, which are only 400 ft below the Pennsylvanian coals.

Gas contents as high as 240 Scf/t have been reported from the deeper Weir-Pittsburg coal seams, and a strong relation exists between gas content and depth. Although data are not available, a probable relation also exists between higher gas contents and the "hot spots". On the basis of an average coal thickness of 6 ft and a gas content of 200 Scf/t, in-place gas resources of 1.3 BCF/ sq mi have been estimated for the area.

Southeast Kansas, where part of the Cherokee Platform is located, has produced 99 percent of the coal mined in the State. Production has generally been declining since World War II and production from surface mining has exceeded that from underground mining since 1931. Future coal mining is limited by the thin coal seams and high sulfur content. However, these two factors do not limit the coalbed gas potential.

Following the depletion of oil and gas in conventional Pennsylvanian sandstone reservoirs, a type of unconventional gas, which was referred to as "shale gas," was developed in southeast Kansas in the 1920's. Although the presence of this type of gas was known earlier, accumulations were not commercial because of the low gas volumes and produced salty water. The Mulky coal bed, which is less than 2 ft thick and the shallowest coal seam in the Cherokee Group, is now considered to be the main source of this "shale gas". The shallow "shale gas" wells were characterized by slow decline, long life, low operating costs, and few dry holes. The wells were drilled by cable tool

and all completions were open hole. Wells lasted 8 to 10 years with some initial flows as much as 100 MCFGPD. Wells in large areas (several hundred sq mi) had the same general characteristics and organic richness and fracturing were considered to be the key characteristics of commercial production. Structural position was considered to be important in establishing commercial production, and wells were placed on structural highs probably resulting in less water production and enhanced fracturing.

As a result of the tax credit, exploration has been ongoing since the late 1980's for coalbed gas in the Cherokee Platform with the activity concentrated around Montgomery County, Kansas. In 1992, more than 230 wells produced approximately 5 BCF of coalbed gas. Although many completions are newly drilled wells, older oil and gas wells have also been recompleted in nearby coal beds. In contrast to earlier "shale gas" development in 1920's, one or more coal seams are stimulated in present-day wells.

Because of earlier development of shallow oil and gas in conventional Cherokee sandstone reservoirs, the infrastructure is generally in place for development of coalbed gas resources in southeast Kansas. The keys to the current development of the coalbed gas resource have been the low drilling, completion, and water-disposal costs and existing infrastructure.

#### **6050. CHEROKEE PLATFORM-CENTRAL BASIN PLAY**

One coalbed gas play, Cherokee Platform-Central Basin Play (6050), is identified in the Cherokee Platform. The play area is bounded on the west by the Nemaha Uplift, on the north by the Bourbon Arch, and on the south by the Chataqua Arch. On the east side, the play limit is defined by the area where Pennsylvanian coal beds are less than 300 ft deep or have been surface mined. Localized hot spots have resulted in higher gas contents and small-scale structural features have increased permeability. A good potential for additions to reserves of coalbed gas is estimated, especially in the "hot spots" where the gas contents are higher.

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