

# **SOUTHERN OKLAHOMA PROVINCE (061)**

**By Mitchell E. Henry and Timothy C. Hester**

## **INTRODUCTION**

The Southern Oklahoma Province (061) is a relatively well explored (mature), petroleum-rich, province of Paleozoic age located in south-central Oklahoma. The province is bounded to the northeast by the Ada Dome, to the east by the Ouachita Mountains, to the south by the Waurika-Muenster Uplift, and to the west and northwest by the Anadarko Basin. The province covers about 8,000 sq mi and contains a sedimentary rock package that may locally exceed 40,000 ft in thickness. Sedimentary rocks range in age from Cambrian to Cretaceous. The pre-Mississippian section is composed mainly of carbonate rocks, whereas the Mississippian and younger rocks are mostly shale and sandstone. Generally absent or present in small amounts are Triassic through Jurassic rocks. Each system of rocks present in the province has produced some hydrocarbons. The intense regional deformation and the removal of much of the sedimentary record from uplifted areas, combined with a lack of data in many local areas, precludes any detailed discussion of thicknesses of source and reservoir facies in most plays. Recent production data show that the province has produced more than 3.9 TCFG and more than 2.6 BBO since the early 1900's.

Because of the extent of structural deformation that occurred in the province during late Paleozoic, structural traps are the most common type, although stratigraphic traps are also important. Pennsylvanian sandstones are the most prolific petroleum producers in the province but rocks of the Simpson and Arbuckle Group have also produced significant quantities of petroleum.

The Woodford Shale is a primary source rock for many plays in this province but Ordovician (Simpson Group and Sylvan Shale) and Pennsylvanian shales are also probable sources (Wavrek, 1992; Comer, 1992). Thermal maturity levels of the Woodford Shale are probably sufficient in most parts of the province for the generation of petroleum (Comer, 1992). In contrast to the Anadarko Basin Province (058), this province produces mostly oil. This may be a result of the presence of more oil-prone organic matter (Comer, 1992).

About 63,000 wells have been drilled in the province for an average density of about one well for each 0.125 sq mi. That drilling density decreases significantly with depth. At the top of the Arbuckle, well density is only about one well for every 4 sq mi. Most

Arbuckle penetrations occur where the Arbuckle is not deeply buried. The Ardmore and Marietta Basins, the deeper parts of the province, are not intensely drilled.

About 160 petroleum accumulations, each of which has an estimated ultimate recovery of at least 1 MMBO or 6 BCFG, have been assigned to a total of 12 conventional plays in this province. These plays are:

**CONVENTIONAL PLAYS**

- 6101 Deep Gas
- 6102 Arbuckle Oil
- 6103 Simpson Structural Oil
- 6104 Viola Oil and Gas
- 6105 Hunton Oil
- 6107 Misener-Woodford-Sycamore Gas and Oil
- 6108 Springer Sandstone Oil and Gas
- 6109 Atokan Sandstone Oil
- 6110 Desmoinesian Sandstone Oil
- 6111 Missourian Sandstone Oil and Gas
- 6112 Virgilian Sandstone Oil and Gas
- 6113 Permian Sandstone Oil and Gas

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## CONVENTIONAL PLAYS

### 6101. DEEP GAS PLAY

The Deep Gas Play exists in a narrow band through the center of the province, oriented in a northwest-southeast direction, and is composed of all strata from basement through the Desmoinesian Deese Group that occur at depths greater than 13,000 ft. The estimated depth of onset of predominantly gas generation, 13,000 ft, is selected for this play by analogy with the Anadarko Basin. However, other studies (Cardott, 1989; Comer, 1992) indicate that vitrinite reflectance ( $R_o$ ) values in parts of the Southern Oklahoma Fold Belt Province may be somewhat lower than those at equivalent depths in the Anadarko Basin. The implication is that the onset of gas generation in the Southern Oklahoma Fold Belt area may occur at a somewhat greater depth, or that  $R_o$  measurements are suppressed and do not reflect the true thermal maturation. Although some relatively high-grade oil is produced in this play, most production is gas or condensate. Therefore, the 13,000-ft-depth ceiling used here is considered conservative and adequate for our purposes. Depths may exceed 40,000 ft in the northern part of the play.

**Reservoirs:** Reservoir rocks in this play include the Cambrian-Ordovician Arbuckle Group and intervening strata up to and including strata as young as the Desmoinesian Deese Group. Because such a diverse group of rocks is included in this play, virtually every reservoir lithology is represented. Ordovician Simpson sandstones are the exception to the predominantly limestone-dolomite lithology found in most Cambrian, Ordovician, Silurian, and lower Devonian rocks in the province. The Devonian-Mississippian Woodford Shale is included as a reservoir rock in this play. The Sycamore Limestone represents most of the potential reservoir rock in the lower Mississippian section. Upper Mississippian sands, within the Meremecian Goddard Shale and Meremecian to Chesterian Springer Group, also form reservoirs in the play. Much of the Atokan section in this province is shale but is included in this play because of one major sandstone reservoir. The Desmoinesian Deese Group is a significant producer in much of the province, and for that reason is included here as a reservoir rock, but only a small, nonproducing area below 13,000 ft is found in this play. Data regarding reservoir quality or heterogeneity is all but nonexistent, but considering the mix of reservoir lithologies in the play, variable is the proper descriptive term.

**Source rocks:** Comer (1992) reported that Devonian black shales in central and southern Oklahoma are rich oil-source rocks in an early stage of hydrocarbon

generation, and  $R_o$  values measure from 0.5 to 0.67 percent. However, small areas of Woodford Shale, drilled to depths of almost 20,000 ft, are probably much more thermally mature. Woodford Shale probably exists at depths exceeding 23,000 ft in some parts of the province. Compared to the Anadarko Basin, Cardot (1989) shows slightly lower  $R_o$  values (at similar depths) for Woodford Shale in the Southern Oklahoma area. The reason for this discrepancy is not clear. In any case, abundant hydrocarbon production in this play, and in the province overall, is positive proof of thermally mature, oil- and gas-prone source rocks. Total organic carbon (TOC) values of Devonian-Mississippian black shales, which reach a thickness of at least 600 ft in the play, range from about 1 to 10 percent (Comer 1992). The presence of major hydrocarbon accumulations in the play indicate a favorable relationship among hydrocarbon generation, migration, and trap formation.

**Traps:** The trapping mechanisms in this play are generally combinations of both structural and stratigraphic types.

**Exploration status:** Although this play is more thoroughly explored in younger rocks than in older ones, it is generally not well explored overall. Only 6 major accumulations, 5 gas and 1 oil, produce from depths greater than 13,000 ft. The largest accumulations are at Sterling field with an estimated ultimate recovery of 31 BCFG and 1.5 MMBO. Major reservoirs produce from depths of about 14,000 to almost 20,000 ft.

**Resource potential:** The potential for new major hydrocarbon discoveries in this play is considered fair to good. There are many areas that have not been well explored. The most important factor limiting future discoveries in this play may be the relatively small geographic area where sedimentary rocks reach depths greater than 13,000 ft. Another factor, an economic limitation, is the great expense of exploring and drilling to these depths. Historical production data and well completion information were used to assess this play.

## **6102. ARBUCKLE OIL PLAY**

The Arbuckle Oil Play includes all strata of the Upper Cambrian Reagan Sandstone and the Upper Cambrian-Lower Ordovician Arbuckle Group, and extends throughout the province except in the extreme northwestern and southeastern parts (Johnston and Commanche Counties) where basement rocks outcrop (Miser, 1954) and that part included in the Deep Gas Play (6101). Virtually the entire province contains Arbuckle Group rocks. The Reagan Sandstone is assumed to underlie the Arbuckle throughout

the province. Depth to the Arbuckle in this play extends from surface outcrops to 13,000 ft (the upper depth limit of Play 6101).

**Reservoirs:** Reservoir rocks are dolomitic zones within the Arbuckle, a result of subaerial and subsurface diagenesis, often enhanced by fracturing (Lynch and Al-Shaieb, 1991; Gao and others, 1992). The recently discovered Cottonwood Creek field produces from vuggy to cavernous porosity in the diagenetically altered, highly fractured Brown zone of the Arbuckle (Read and Richmond, 1993). This altered zone extends as much as 1,500 ft below the top of the preserved Arbuckle section (Read and Richmond, 1993). Reservoir heterogeneity is high because of the erratic distribution of dolomite over small distances (Read and Richmond, 1993).

**Source rocks:** Because of the complex structure of this province, source rocks may be virtually any of those present in the province. Wavrek (1992) identified 7 distinct groups of oils (types A through G) in the Ardmore and Marietta Basins, and correlated 5 of these with the following source rocks: Atokan (type A); Mississippian Goddard Shale, Caney Shale, and Sycamore Limestone (type B); Devonian to Mississippian Woodford Shale (type C); upper Middle Ordovician Viola Group (type D); and Middle Ordovician Simpson shales (type E). The most common oil type found in the province was type C (generated from the Woodford) by a factor of four above the next most common type (A). Comer (1992) reports that 70 to 85 percent of the commercial oil reserves in southern and central Oklahoma also correlates with bitumen from Upper Devonian black shales. Thermal maturity and organic richness of Devonian to Mississippian Woodford and Chattanooga Shales are discussed in the Deep Gas Play (6101).

Data detailing the timing of hydrocarbon generation are not available for this province but the presence of large volumes of oil assures the favorability among generation, migration, and trap formation.

**Traps:** Traps for this play are generally created by anticlines and faults (Read and Richmond, 1993), with associated facies changes. Major accumulations occur at depths of about 1,900 to 8,300 ft.

**Exploration status:** This play is well explored only in areas where the Arbuckle is near the surface. These areas form four northwest-southeast trends that, from south to north, include the Waurika-Muenster, Criner Hills, and Arbuckle Mountain Uplifts, and the Hunton Anticline. Five accumulations are assigned to this play, they all produce

primarily oil. The largest accumulation is at Cottonwood Creek field, with an estimated ultimate recovery of 52 MMBO.

**Resource potential:** Considering the recent major discovery of the prolific Cottonwood Creek field, the structural complexity of the province overall, and the lack of exploration in areas where the Arbuckle is relatively deep, we think this play has the best potential for new major hydrocarbon discoveries in the province. The known productive area for the Cottonwood Creek field is about 1,200 acres (Read and Richmond, 1993). Finding these relatively deep, structurally complex traps may be the most difficult obstacle for future development of the play. Historical discovery data and well completion data were used in assessing this play.

### **6103. SIMPSON STRUCTURAL OIL PLAY**

The Simpson Structural Oil Play is scattered throughout much of the central part of province, except along the western edge and in isolated areas in the east where Simpson Group strata are missing; all Simpson Group strata are included except those parts included in the Deep Gas Play (6101). Depths extend from surface outcrops to 13,000 ft (the upper depth limit of Play 6101). A sandstone lithology is the principal defining feature of this play.

**Reservoirs:** Reservoir rocks in the play are mostly Middle Ordovician Simpson Group sandstones, including the Joins, Oil Creek, McLish, Tulip Creek, and Bromide Formations. With the exception of one limestone reservoir, all major reservoirs are of sandstone. Average porosity values from 5 of the major reservoirs ranges from 14 to 24 percent, with a median of 14 percent. Reservoir quality for Simpson Group sands is expected to be very good although cementation occludes porosity and increases heterogeneity in some cases (Johnson, 1991). Thickness of the Simpson Group reaches 2,000 ft in the play.

**Source rocks:** Because of the structural character of this province, possible source rocks are virtually any of those in the sedimentary section. However, a particularly important hydrocarbon source for this play is interbedded Simpson Group shale. According to Wavrek (1992), oil from Simpson Group shales is found in some of the major Simpson and Arbuckle Group reservoirs. Gas is often associated with the oil produced in this play, but oil is the principal commodity in all the major accumulations.

**Timing:** Timing of oil generation and migration, and trap formation is favorable for charging the reservoirs of this play. Hydrocarbon migration probably occurred over

relatively short distances through faults or fractures, or along bedding planes within the Simpson Group, or directly into shale-enclosed reservoirs.

**Traps:** Structural traps are the most common type, although facies changes occur in combination with structure in 7 of 26 documented traps. Many anticlinal traps of varying size result from the major folds formed during the late Paleozoic deformation (Johnson, 1991). Seals are often interbedded Simpson shales and limestones.

**Exploration status:** The pattern of exploration in Simpson rocks is similar to that of the Arbuckle Group, although the Simpson Group has been more extensively drilled in Garvin and Murray Counties, Okla. Oil is the principal product in this play, with 26 major accumulations assigned. The largest accumulation is at Eola-Robberson field, with an estimated ultimate recovery of 213 MMBO.

**Resource potential:** Although this play has produced significant quantities of oil, only three major discoveries have been made during the past twenty years. Deeper parts of the play, however, are not well explored. The existence of yet unidentified traps in Simpson sands, perhaps structurally similar to that recently discovered in the Cottonwood Creek field, seems possible. The outlook for future major hydrocarbon discoveries in this play, then, is projected to be fair to good. Historical discovery, production and well completion data were used for assessment of this play.

#### **6104. VIOLA OIL AND GAS PLAY**

The Viola Oil and Gas Play is composed of all strata of the Upper Ordovician Viola Group, and extends throughout much of the central part of the province, except that part included in the Deep Gas Play (6101). Viola rocks are apparently absent from the southwestern third, and from some parts of the eastern end of the province. Depths extend from surface outcrops to 13,000 ft (the upper depth limit of Play 6101).

**Reservoirs:** Reservoir rocks for major accumulations in this play are all limestones of the Upper Ordovician Viola Group. Thickness of Viola Group strata may reach 1,500 ft in the northern part of the play.

**Source rocks:** Because of the structural character of this province, possible source rocks are virtually any of those in the sedimentary section. However, a particularly important hydrocarbon source for this play may be the Viola itself. According to Wavrek (1992), oils commonly found in some major Viola Group reservoirs may have been generated from within the Viola. In these cases, hydrocarbon migration distances were probably

short. The presence of major accumulations in Viola reservoirs indicates favorable timing among hydrocarbon generation, migration, and trap formation.

**Traps:** Structural trapping is the primary mechanism controlling hydrocarbon accumulations, but facies change is commonly reported as a secondary factor. Viola production forms northwest-southeast trends that generally occur on top of, but sometimes on the flanks of large anticlines. A major seal for this play is the overlying Sylvan Shale. Reservoirs generally occur at depths from 1,500 to 10,500 ft.

**Exploration status:** The drilling intensity for this play is similar to that of the Simpson Structural Oil Play (6103). There have been some penetrations in deeper parts of the play, but wells are most common over uplifted areas. This is primarily an oil play, but of the 17 total major hydrocarbon accumulations that produce from Viola rocks, three are gas. The largest oil accumulation is at Golden Trend, with an estimated ultimate recovery of 17 MMBO. The largest gas accumulation is at Ravia West field, with an estimated ultimate recovery of 35 BCFG.

**Resource potential:** The potential for future major hydrocarbon discoveries in this play is expected to be fair to good. New accumulations have been discovered in recent years. Drilling intensity maps indicate areas in the play that are not well explored. Limiting factors for future discoveries in this play are similar to those for the Arbuckle Oil and Simpson Structural Oil Plays (6102 and 6103), where identification of small traps at greater depths may be difficult. Historical discovery, production, and well completion data were used in assessing this play.

### **6105. HUNTON OIL PLAY**

The Hunton Oil Play includes all Silurian-Devonian Hunton Group strata, and extends throughout most of the central part of the province, except that part included in the Deep Gas Play (6101). The Hunton is absent from most of the southwestern half and parts of the northeastern quarter of the province. Depths extend from surface outcrops to 13,000 ft (the upper depth limit of Play 6101).

**Reservoirs:** Reservoir rocks are all Hunton Group limestones. Thickness of the Hunton approaches 1,700 ft in the northern part of the play. Only one average porosity value was found for one major reservoir in this play, it is 10 percent.

**Source rocks:** The Woodford Shale is the most probable hydrocarbon source for the play but, as mentioned in the discussion of Play 6101, it is likely that other source rocks have also generated some of the oil reseroired in the Hunton Group.

**Timing:** Timing of hydrocarbon generation and migration, and trap formation is favorable for charging reservoirs in this play, as evidenced by the major accumulations in Hunton Group reservoirs.

**Traps:** Trap types in this play are primarily structural, with some minor stratigraphic control in the form of facies changes. The trends formed by Hunton production generally reflect the position of known anticlines or faults in the play. Seals for reservoirs are Woodford Shale, the Mississippian Caney or Goddard Shales, or tight limestones in the Hunton Group. Known reservoirs occur at depths from about 4,500 to 9,100 ft.

**Exploration status and resource potential:** Six major accumulations are assigned to the play; they are all primarily oil producers. The largest Hunton Group reservoir is at Joiner City field, with an estimated ultimate recovery of 28 MMBO.

This play is not expected to contain significant undiscovered hydrocarbon accumulations. The most recent major discovery was in 1960, with an estimated ultimate recovery just above the required minimum for this assessment, 1 MMBO. The play is also fairly well drilled. One important limitation to its future hydrocarbon potential may be the fact that it covers such a small area. Historical discovery and production data and well completion information were used to assess the play.

#### **6107. MISENER-WOODFORD-SYCAMORE GAS AND OIL PLAY**

The Misener-Woodford-Sycamore Gas and Oil Play includes rocks with widely differing lithologies, and forms a northwest-southeast trending band in the central one-third of the province, except that part included in the Deep Gas Play (6101). The strata of this play are apparently absent from the southwestern third and parts of the northeastern third of the province. Depths extend from surface outcrops to 13,000 ft (the upper depth limit of Play 6101). The 3 groups of strata were lumped together in a single play for several reasons. They form a group of reservoirs that are either adjacent to or within, what may be the best source rock (Woodford Shale) in the province (Wavrek, 1992). Generation and migration, trapping, and production of hydrocarbons between members of the group are related by proximity, fracturing, and an overall cherty lithology. As a group, these three formations contain much of the gas in the province.

**Reservoirs:** Reservoir rocks include the Devonian Misener Sandstone, the Devonian-Mississippian Woodford Shale, the Sycamore Limestone, and the Arkansas Formation

cherts. Thickness ranges from 0 at erosional truncation to as much as 1,000 ft in isolated areas. Porosity data are generally lacking, but isolated measurements of Sycamore Limestone reservoirs range from 8 to 15 percent (Northcutt, 1993); a single measurement in an Arkansas chert reservoir is 10 percent. Sycamore Limestone reservoirs, which have been modified by subaerial exposure and related diagenetic processes (Kershnik, 1957), are expected to be highly heterogeneous and, like the Woodford Shale, are expected to produce in areas where fracturing is common.

**Source rocks:** Because of the proximity of the Woodford Shale to other reservoir rocks in the play, the Woodford is the most likely hydrocarbon source. Woodford Shale in this province is considered to be primarily oil-prone (Comer, 1992); the reason for the abundant gas in the play is unclear. Source rock qualities of the Woodford are discussed in Deep Gas Play (6101). The presence of major accumulations indicates favorable timing of hydrocarbon generation and migration, and trap formation in the charging of reservoirs in this play.

**Traps:** The play is primarily structural, but combination- and unconformity-type traps do exist (Northcutt, 1993). In the Mississippian Sycamore Limestone, traps are generally formed by faulted anticlines, by combinations of structure and facies changes, or by erosional remnants sealed by tight limestones or shales. Trap types in the Misener are not known but, by analogy with the Anadarko basin area, stratigraphic and combination traps are expected. Traps in the Woodford Shale and the Arkansas cherts are expected to be controlled by presence of fractures. Seals include the Woodford Shale, Caney Shale, and rocks as young as the Middle Pennsylvanian Deese Group (Northcutt, 1993). Most accumulations are located on or near major positive structural features.

**Exploration status:** Seven major accumulations are assigned to this play; 5 are oil. The largest oil accumulation is at Sho-Vel-Tum field, with an estimated ultimate recovery of 46 MMBO. The largest gas accumulation is at Golden Trend, with an estimated ultimate recovery from the Sycamore of 883 BCFG. Drilling density in this play is highest on, and adjacent to, large anticlines, however, many areas are not highly drilled.

**Resource potential:** This play is expected to have fair to good potential for future major hydrocarbon discoveries. Gas is expected to be the most significant undiscovered product. The Woodford Shale and Sycamore Limestone may offer attractive horizontal drilling opportunities. The rather small area of the play is a possible limiting factor for

future major discoveries. Historical discovery, production, and well completion data were used for assessment of the play.

#### **6108. SPRINGER SANDSTONE OIL AND GAS PLAY**

The Springer Sandstone Oil and Gas Play includes all Late Mississippian Meramecian and Chesterian Springer Formation strata, and extends in a northwest-trending band through much of the central third of the province, except that part included in the Deep Gas Play (6101). Depths extend from surface outcrops to 13,000 ft (the upper depth limit of Play 6101).

**Reservoirs:** Reservoir rocks in this play include all sandstones of the Springer Formation. Total thickness reaches at least 4,000 ft in the northern part of the play (Lindberg, 1986). Only a single average porosity value was found for one reservoir in this play, 18 percent. Porosity values for Springer sands in the nearby Anadarko Basin range from 6 to 14 percent.

**Source rocks:** Wavrek (1992) concluded that oils (type B, see Arbuckle Oil Play 6102) found in some major Springer Group reservoirs were probably derived from Mississippian source rocks. The presence of significant quantities of gas in the play, and the presence of types II and III organic matter in Pennsylvanian (including Springer Group) source rocks (described by Burruss and Hatch, 1989) support the conclusion that Springer Group shales are likely source rocks for this play. However, this play, like previous ones, is likely to have had multiple sources. Source rock characteristics are discussed in Deep Gas Play (6101). The presence of major gas and oil accumulations demonstrates the favorable timing of hydrocarbon generation and migration, and trap formation.

**Traps:** The play is primarily structural but facies changes affect some traps. Trap descriptions for 7 of the 11 major accumulations assigned to this play are faulted anticlines, 2 others indicate that facies change may be an additional control. Springer Formation accumulations are generally located along or near major anticlines. The largest oil accumulation is at Sho-Vel-Tum field, with an estimated ultimate recovery of 785 MMBO. The largest gas accumulation is at Bray Southeast field, with an estimated ultimate recovery of 75 BCFG. Known reservoir depths range from 2,700 to 8,800 ft.

**Exploration status and resource potential:** This play is fairly well explored on the major structures, although there are a few relatively unexplored areas where drilling density is low. The potential for future major hydrocarbon discoveries in this play is

expected to be fair to poor. The association between major known accumulations and major structures is high. Combined with the high level of exploration near major structures and the relatively small size of the play area, we feel that the future potential is largely exhausted. Historical discovery, production, and well completion data were used for assessment of this play.

#### **6109. ATOKAN SANDSTONE OIL PLAY**

The Atokan Sandstone Oil Play consists of Dornick Hills Group rocks, which include all Morrowan and Atokan, and some lower Desmoinesian strata. These rocks form a narrow northwest-southeast trending band through the central third of the province, except that small part included in the Deep Gas Play (6101). Depths extend from surface outcrops to 13,000 ft (the upper depth limit of Play 6101).

The influence of structure on the exploration strategy of this play was of critical importance before about 1950, after that time the strategy changed and stratigraphic trapping became the predominant focus. Selk (1951) pointed out that, although highly successful, the search for anticlinal traps was yielding fewer prospects. He pointed out the significance of stratigraphic trapping along the flanks of major structures. Plots of reservoir size versus year of discovery show an interesting pattern related to this discovery. During the early 1900's the size of individual discoveries increased, as major structural traps were discovered, and then began to decline. When the idea of stratigraphic traps took hold, the size of individual discoveries again began to increase. At present the general trend of reservoir size is again on the decline. Although many economic, political, and technological factors may also have affected this "rebirth" of production, the recognition of the importance of stratigraphic traps by Selk in 1951, was apparently of major importance.

**Reservoirs:** Reservoir rocks in this play include all sands of the Dornick Hills Group. These rocks may reach a thickness of 1,600 ft in parts of the play.

**Source rocks:** Possible source rocks for this play are virtually any of those in the sedimentary section, however, interbedded Atokan shales may be the most important source rocks (Wavrek, 1992). Most of the production in this play is oil, although Burruss and Hatch (1989) reported that Pennsylvanian source rocks contain a mixture of types II and III organic matter which is capable of generating both oil and gas. Timing of hydrocarbon generation and migration, and trap formation is favorable for

the charging of reservoirs in this play, as evidenced by the presence of major accumulations.

**Traps:** Most known traps are structural, with some influence of facies change. Known major reservoirs are found at depths from 2,500 to 8,200 ft.

**Exploration status:** This play is fairly well explored, although there are areas in the southern part of the Marietta Basin that are not well drilled. Drilling intensity is greater on and near the major uplifts in the play. The largest oil accumulation in the play is at Sho-Vel-Tum field, with an estimated ultimate recovery of 8 MMBO.

**Resource potential:** This play is not expected to contain significant undiscovered resources. The play is limited in size, and only one major accumulation has been discovered in the past 24 years. Historical discovery, production, and well-completion data were used in assessing the play.

#### **6110. DESMOINESIAN SANDSTONE OIL PLAY**

The Desmoinesian Sandstone Oil Play consists of all Deese Group strata, and extends throughout most of the central part of the province, except that small part included in the Deep Gas Play (6101). This play forms a broad northwest-southeast trending band that occupies more than half of the area. Depths extend from surface outcrops to 13,000 ft (the upper depth limit of Play 6101).

**Reservoirs:** Reservoir rocks are mostly sandstones. Porosity values reported from three major reservoirs range from 13 to 18 percent. Desmoinesian rocks are truncated near the southern play boundary and may reach a thickness of more than 10,000 ft in other parts of the play (Lindberg, 1986).

**Source rocks:** Possible source rocks for this play are virtually any of those in the province. Desmoinesian shales may have been the most important source rock for this play (Wavrek, 1992). Burruss and Hatch (1989) reported that Pennsylvanian source rocks generally contain mixtures of types II and III organic matter, and are capable of generating both oil and gas. The favorable timing of hydrocarbon generation, migration, and trap formation is evidenced by the presence of the major accumulations in the play.

**Traps:** Trapping mechanisms are described as primarily structural, with some stratigraphic influence. In the future the influence of stratigraphic trapping may become more important for exploration in this play as it has in Atokan Sandstone Oil

Play (6109). Of the 10 trap descriptions found for this play, 8 are primarily structurally controlled, with 5 of those described as also having facies changes; two others are described as primarily controlled by facies changes. Known major reservoirs are found at depths from 540 to 8,800 ft.

**Exploration status:** This play is well explored, although there are areas in the southwestern and southeastern parts of the play that are not extensively drilled. Twenty major oil accumulations are assigned to this play. Drilling intensity is greater on and near the major uplifts, but is more uniformly distributed in this play than in those plays based on some older rocks. The largest oil accumulation in the play is at Golden Trend field, with an estimated ultimate recovery of 160 MMBO.

**Resource potential:** The future for this play is considered to be fair to good, with one major discovery made as recently as 1982. This projection is based on the discovery history, production, and well completion data.

#### **6111. MISSOURIAN SANDSTONE OIL AND GAS PLAY**

The Missourian Sandstone Oil and Gas Play consists of all Missourian strata, extends throughout a broad area in the central part of the province, and occupies about three-fourths of the total area. All but one reservoir is developed in sandstone. Depths extend from surface outcrops to about 11,000 ft. This play is primarily structurally controlled, but facies changes are important as a secondary control.

**Reservoirs:** Reservoir rocks are Missourian sandstones. The strata of the play are truncated at the southeastern and northwestern parts of the province and may reach a thickness of 3,000 ft in isolated areas. Porosity values are limited but suggest an average of about 20 percent.

**Source rocks:** Possible source rocks for this play are virtually any of those in the province. Wavrek (1992) suggested that oils found in Pennsylvanian reservoirs are probably derived from Pennsylvanian source rocks. Burruss and Hatch (1989) report that Pennsylvanian source rocks can generate both oil and gas, although in this play, most hydrocarbon production is oil. Timing of hydrocarbon generation and migration, and trap formation is favorable for the charging of reservoirs, as evidenced by the presence of major accumulations in the play.

**Traps:** Trap descriptions were found for 10 of 27 major reservoirs in the play. Of those 10, 8 are primarily structural, with facies changes or unconformities as secondary

influences, and 2 are primarily controlled by facies changes. Known major reservoirs are found at depths of 700 to 7,900 ft.

**Exploration status:** This play is generally well explored. Although there are limited areas in the southwestern part of the play that are not intensely drilled, Missourian rocks become quite shallow as one approaches the Wichita Mountains. Drilling intensity is greater on and near the major uplifts in the play but, as with some of the previous plays, wells are fairly uniformly distributed. The largest oil accumulation in the play is at Healdton field, with an estimated ultimate recovery of 274 MMBO. The largest gas accumulation is at Southwest Hope field, with an estimated ultimate recovery of 99 BCFG.

**Resource potential:** The future potential for major hydrocarbon discoveries in this play is considered to be only fair. Of 27 major accumulations, 22 are oil. Although the most recent gas accumulation was discovered in 1982, with an estimated ultimate recovery of 14 BCFG, the most recent major oil discovery was almost 30 years ago. The high drilling intensity coupled with few major discoveries in recent years suggest that this play will probably not yield significant new discoveries. Historical discovery, production, and well completion data were used in assessing the play.

## **6112. VIRGILIAN SANDSTONE OIL AND GAS PLAY**

The Virgilian Sandstone Oil and Gas Play consists of Virgilian strata, and extends throughout a broad area that occupies most of the central part of the province. Depths extend from surface outcrops to about 9,000 ft.

**Reservoirs:** Reservoir rocks are mostly sandstones. Limited porosity data from 2 major reservoirs average about 24 percent. Virgilian rocks are truncated near the play boundaries toward the east and west, and may reach a thickness of more than 3,000 ft in other parts of the play. Eleven major reservoirs produce from this play, 8 oil and 3 gas.

For this play possible source rocks are virtually any of those in the province, however interbedded Virgilian shales may have been the most important source rock. Other Pennsylvanian source rocks are also capable of generating both oil and gas. The favorable timing of hydrocarbon generation, migration, and trap formation is evidenced by the presence of the major accumulations in the play.

**Traps:** Trapping mechanisms are primarily structural, consisting of anticlines, faulted anticlines, and faulted anticlinal noses. Some minor stratigraphic influence is also noted. The influence of stratigraphic trapping may become more important for

exploration in this play in the future. Known major reservoirs are found at depths from near surface (about 600 ft) to more than 5,000 ft.

**Exploration status:** Although heavily explored overall, some isolated areas are less well-drilled. Drilling intensity in this play, as in many others in this province, is much greater on and near the major uplifts. Of the 11 major reservoirs, the largest is a gas accumulation at West Marlow field, with more than 200 BCFG. The largest oil accumulation in the play is at Empire-Comanche field, with an estimated ultimate recovery of almost 11 MMBO.

**Resource Potential:** The future for this play is considered to be poor and the play was not formally assessed. Only one major discovery (3 MMBO) has been made since 1962. This appraisal is based on the discovery history, production, and well completion data.

### **6113. PERMIAN SANDSTONE OIL AND GAS PLAY**

The Permian Sandstone Oil and Gas Play consists of all Permian Wolfcampian and Leonardian strata, and covers most of the center part of the province, except the northwestern corner and the southeastern quarter. Depths extend from near surface to as much as 5,000 ft (estimated) in the deepest parts.

**Reservoirs:** All known reservoirs are relatively shallow, Permian sandstones, located on or near major structural features in the province. Reservoir rocks (Wolfcampian and Leonardian sandstones) include the Noble-Olsen, Fortuna, Ramsey, and Nichols sands, and the Garber Sandstone. Porosity values were not found for Permian reservoirs in this province, however, porosity values for Permian sandstones in the Anadarko Basin (Permian Sandstone Oil and Gas Play 5828) range from about 10 to 20 percent, with a median value of about 18 percent (Campbell and others, 1988). Permian rocks in southern Oklahoma surface most of the province and reach an estimated thickness of as much as 5,000 ft in the northern part of the play.

**Source rocks:** Source rocks for the play may include 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 deeper reservoirs could simply have migrated upward. Timing of hydrocarbon generation, migration, and trap formation were favorable for charging the reservoirs.

**Traps:** Traps are generally anticlines or faulted anticlines with some influence from facies changes. Major reservoirs range in depth from about 200 to 1,600 ft. Nine

accumulations are assigned to the play. The largest oil accumulation is at Sho-Vel-Tum field, with an estimated ultimate recovery of 44 MMBO. The only major gas accumulation is at Marlow West field, with an estimated ultimate recovery of 33 BCFG.

**Exploration status and resource potential:** This play is very well explored. The pattern of production from Permian sandstones closely follows the pattern of structural trapping. The play was not formally assessed because potential for major new hydrocarbon discoveries is considered extremely low for the following reasons: The area has been very well drilled. The last major discovery was in 1946. 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 PLAYS**

There are no unconventional plays described in this province report. However, unconventional plays listed in the surrounding provinces may include parts of this province. Individual unconventional plays are usually discussed under the province in which the play is principally located.

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