BEND ARCH-FORT WORTH BASIN PROVINCE (045)

By Mahlon M. Ball and William J. Perry, Jr.

INTRODUCTION

With the exception of the southwesternmost corner of Oklahoma, this province lies entirely within north-central Texas and covers an area of 54,000 sq mi. The southern and eastern province boundaries are defined by county lines that generally follow the Ouachita structural front, although a substantial portion of this structural feature is included in the province in the vicinity of Dallas, Tex. The northern boundary follows the Texas-Oklahoma State line (the Red River) in the east, where the province includes parts of the Sherman (Marietta) Basin and Muenster Arch. In the west, the northern boundary follows the northern and eastern county lines of Oklahoma's three southwesternmost counties, which include the south flank of the Wichita Mountains and the Hollis (Hardeman) Basin. The western boundary trends north-south along county lines that define the junction with the Permian Basin Province (044) where part of the eastern shelf of the Permian Basin lies in the Bend Arch-Fort Worth Basin Province (045).

The first indication of hydrocarbons in the province were shows of oil and gas in wells drilled for water during the mid-nineteenth century. Sporadic exploration for petroleum began at the conclusion of the Civil War, and the first commercial oil accumulations were found in the early 1900's. The province reached a mature stage of exploration and development in the 1960's. Oil and lesser amounts of gas are found throughout the Paleozoic section, but the majority of hydrocarbons consist of oil in Pennsylvanian-age reservoirs. Cumulative production in the province through 1990 was 21 BBO, 7.8 TCFG, and 0.5 BBNGL. Six conventional plays were individually assessed: Pre-Mississippian Carbonate (4501), Mississippian Carbonate (4502), Lower Pennsylvanian (Bend) Sandstone and Conglomerate (4504), Strawn (Desmoinesian) (4505), Post-Desmoinesian (4506), and Texas Ouachita Fold-Thrust Belt (4510). One continuous-type unconventional play, Mississippian Barnett Shale (4503), was considered.

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CONVENTIONAL PLAYS

4501. PRE-MISSISSIPPIAN PLAY

The play is mainly characterized by oil accumulations in Cambrian-Ordovician predominantly carbonate reservoirs in anticlines and combined structural/stratigraphic traps. These rocks are present over the

entire area of the province, with the exception of local absences on the crests of the Red River and Muenster Arches and a regional absence on the Llano Uplift.

Reservoirs: The Ellenburger Group is the most important reservoir unit and attains thicknesses up to 5,000 ft in the Marietta Basin in the northeasternmost corner of the province and thins to less than 500 ft in the vicinity of the Red River and Muenster Arches and on the Llano Uplift. The Ellenburger Group is underlain by the Cambrian Bliss Sandstone, Wilberns Shale, and Riley Sandstone, formations that are rarely drilled. There are fewer than 50 wells drilled through these units and into the Precambrian in the entire play. Simpson Sandstone gas production in Sherman Basin has been assigned to plays in the Southern Oklahoma Region because of shared geologic characteristics. Individual reservoir thicknesses in the Ellenburger range from 10 to over 100 ft, and porosities and permeabilities tend to be low; the former averages around 10 percent and the latter only a few millidarcies. Pennsylvanian shales seal the Ordovician reservoirs. Drilling depths vary between 2,000 and 9,000 ft.

Source rocks: The identity of the source rocks is controversial. The Upper Devonian Woodford Formation is the only well-studied source rock of potential importance to the Bend Arch-Fort Worth Basin Province. This organic-rich black shale and siltstone unit commonly has TOC (total organic carbon) values as high as 6 percent. It is present over most of the Permian Basin Region to the west, the Anadarko Basin to the north, and possibly in the eastern downdip reaches of the Fort Worth Basin, where its pelagic marine anaerobic biofacies may be delivering wet gaseous hydrocarbons at the present time. Earlier in its thermal maturation history, the Woodford, situated in structurally low positions, may have been the source of some of the oil trapped in Ellenburger reservoirs The Mississippian Barnett Shale is another likely source rock. This black-shale unit may be equivalent to the Woodford Formation in some downdip settings.

Permian shale in the Midland Basin to the west, and Pennsylvanian shale in the Fort Worth Basin to the east are both downdip from the pre-Mississippian section on the Bend Arch. In addition to faults, there are ample regional unconformities in the section that could have provided avenues for generated hydrocarbon to migrate from these particular shale source beds into the structurally higher pre-Mississippian section.

Timing and migration: Structural traps in this play were formed generally during Pennsylvanian time. Seals usually consist of Pennsylvanian shales. Thermal maturation of the Woodford Shale source probably was achieved during the Pennsylvanian time in deep structural depressions within the Ouachita fold belt toward the east. Migration of hydrocarbons updip toward the west to traps on the Bend Arch and other regional structural highs may have continued from the Pennsylvanian to the present.

Traps: Traps are in both simple and complex, faulted anticlines in 50 percent of the known fields in the play. Other fields have combined structural and stratigraphic traps.

Exploration status: Twenty-two oil fields in this play have produced a total of 126 MMBO through 1990. Hildreth, discovered in 1942, with a production of 22.6 MMBO, is the largest field. The resurgence of drilling during favorable price conditions in the early 1980's resulted in some new discoveries, indicating a modest potential for additional small oil discoveries in this play.

Resource potential: An encouraging aspect of the play is the relative success of new discoveries from tests drilled during the early 1980's, although the sizes of the accumulations are small. The potential for both oil and gas is fair.

4502. MISSISSIPPIAN CARBONATE PLAY

The definitive characteristics of this play are minor gas and oil accumulations in carbonate reservoirs in the Mississippian Chappel Limestone in stratigraphic traps on localized, low-relief erosional highs of the underlying Ordovician Ellenberger Group. The play is limited by the province boundaries on the northwest and southeast, and by a line marking erosion of Mississippian rocks on the southwest and north of the Llano Uplift. Mississippian rocks are also absent along the crests of the Red River and Muenster Arches.

Reservoirs: Reservoirs are termed pinnacle reefs, and they typically contain gas and condensate. Porosity is generally less than 10 percent, and permeabilities range from 100 to tenths of a mD. Pay thicknesses as much as 350 ft have been encountered in the reservoirs. Drilling depths vary between 3,000 and 9,000 ft.

Source rocks: Both the Late Devonian Woodford Shale and Mississippian Barnett Shale are logical potential source rocks for this play. Organic-rich Pennsylvanian and Permian shales in structural lows of the Ouachita Fold-Thrust Belt toward the east may also contribute oil and gas to traps on the Bend Arch.

Timing and migration: Traps and seals were formed by deposition of Pennsylvanian shales. Thermal maturation and migration into these traps may well have begun during the Pennsylvanian and may continue to the present time.

Traps: Traps are purely stratigraphic, resulting from a combination of depositional topography and erosion. Local porous zones of grainstone and packstone in the Chappel Limestone, for instance, are restricted to reefal highs. Reefs are sealed within the Mississippian Barnett Shale, which is also the probable source of the hydrocarbons. The reefs tend to occur in trends, and although they are typically small, the compactional drape of beds overlying the carbonate highs make these features detectable using seismic methods.

Exploration Status: Fields in this play produced 83 MMBO, 246 BCFG, and 16 MMBNGL through 1990. The largest oil field is Shackelford, discovered in 1954, with 10 MMBO. Lee Ray, discovered in 1978, is the largest gas field with production of 19 BCFG.

Resource potential: The past production history and small areal size of the Mississippian pinnacle-reef fields appears to limit the future potential of the play to small-size oil and gas fields.

4504. LOWER PENNSYLVANIAN (BEND) SANDSTONE AND CONGLOMERATE PLAY

The play is characterized by gas and relatively minor oil accumulations in stratigraphic and structural traps associated with predominantly Early Pennsylvanian (Morrowan and Atokan Series) quartz sandstone and conglomerate reservoirs. These units were derived from highlands uplifted during the late Paleozoic collision of the ancestral North America plate with South America and Africa. This collision gave rise to the present configurations of the Ouachita structural front, the Wichita Mountains, the Sherman and Hollis Basins, and the Muenster and Red River Arches. The play limits on the north are the Red River and Muenster Arches. On the east, the play boundary coincides with the province boundary, modified by the downdip extent of the Morrowan-Atokan section under the overhang of the Ouachita structural front. The pinch-out of reservoir facies on the eastern shelf and the Llano Uplift limits the play to the south and southwest. Maximum thickness of clastic wedges in this section exceeds 5,000 ft on the east, where the section disappears beneath the Ouachita structural front.

Reservoirs: Late subsidence of the Fort Worth Basin shifted the present Bend Arch crest some 30 mi westward from its position at the end of Atokan time. This subsidence imparted a slight eastward dip to the Morrowan-Atokan section so that hydrocarbons in the section are locked in the predominantly clastic reservoirs that pinch out toward the west. Morrowan and Atokan sandstone reservoirs are lithologically complex and differ in thickness and areal extent, with variations in sandbody facies, geometry, and diagenetic influences. Conglomeratic (Bend) series and clean sandstone facies have porosities as high as 20 percent and permeabilities as great as 100 mD. Most pay thicknesses are in the 20–25 ft range. Lower quality gas-bearing reservoirs have effective porosities of less than 10 percent and permeabilities of less than 1 mD. The Marble Falls Limestone (Morrowan) Series is the only noteworthy carbonate reservoir in the play. Production from carbonate reservoirs occurs in two belts bordering the ancestral Bend Arch crest, where post-Atokan erosion has cut out the upper Marble Falls platform carbonate reservoir facies. Drilling depths vary between 2,000 and 10,000 ft.

Source rocks: Probable sources for this play include the Late Devonian Woodford Shale, the Mississippian Barnett Shale, and organic-rich shales of Pennsylvanian and Permian Age in the downdip Fort Worth Basin and Ouachita Fold Belt toward the east.

Timing and migration: Most of the production in the play is on the east flank of the Bend Arch, and it is possible that the gas simply migrated westward into traps on the arch from Morrowan, Atokan, and

older source shales deeper in the Fort Worth Basin. This migration may have continued from the post-Middle Pennsylvanian to the present. Most of the oil in the play occurs on the crest and western flank of the Bend Arch. Oil on this flank may have originated in organic-rich Permian shale source rocks in the Midland Basin to the west, and oil on the crest of the arch may have originated in source rocks in either the Midland or Fort Worth Basins.

Traps: Traps consist of simple anticlines, fault-bounded anticlines, and stratigraphic traps with both facies-controlled and truncation pinch-outs. Shale beds in the section provide numerous seals. Drilling depths range from 3,500 to 6,000 ft.

Exploration status: The 63 oil fields and 100 gas fields of this play produced 245 MMBO, 5.5 TCFG, and 415 MMBNGL of gas through 1990. Drilling depths in the fields range from 1,000 to 10,000 ft. Ranger, the largest oil field, discovered in 1917, produced 78 MMBO before its abandonment. Boonsville, the giant gas field of this province, was discovered in 1950 and has produced 2.6 TCFG and 400 MMBNGL.

Resource potential: The play's potential for large oil and gas discoveries is limited because it has been drilled so extensively. Potential for discovery of additional small fields is good.

4505. STRAWN (DESMOINESIAN)

The play consists of oil accumulations in combined structural/stratigraphic traps in predominantly Pennsylvanian (Desmoinesian) quartz sandstone reservoirs. The sandstones were deposited in a fluvial-deltaic environment and are referred to locally as the Strawn Series; the Strawn is thickest in the northeast corner of the play, in the Sherman (Marietta) Basin, where it exceeds 5,000 ft, and decreases to about 1,000 ft in the western margin of the play. The Strawn is truncated on the north and east and onlapped by Cretaceous rocks.

Reservoirs: The sandstone reservoir facies interfingers basinward and shelfward with prodelta mudstone and shale beds. The Desmoinesian Caddo Limestone is the only important carbonate reservoir in the play and has a maximum thickness of 800 ft. Sandstone reservoirs present have complex geometries and depositional topographies with internal variations due to shale interbeds. Porosities range from 14 to 23 percent, permeabilities average more than 100 mD, and oil columns range from 65 to 400 ft. In the Caddo carbonate reservoir, porosities range from 7 to 14 percent, permeabilities range from 3 to 15 mD and oil columns range from 80 to 174 ft. Drilling depths vary from 1,000 to 7,000 ft.

Source rocks: Probable source rocks for this play include the Late Devonian Woodford Shale, Mississippian Barnett Shale, and organic-rich Pennsylvanian shales located toward the east in the deeper reaches of the Fort Worth Basin and Ouachita fold belt.

Timing and migration: The Desmoinesian reservoirs of this play could have been trapping oil supplied from the Woodford and Barnett Shales soon after deposition of the Pennsylvanian shales that seal the play's accumulations.

Traps: Trapping consists of porosity pinch-outs on structural noses, simple anticlines, and faulted anticlines; combined structural and stratigraphic traps are common. Isolated porosity lenses control reservoir distribution in the Caddo platform carbonates.

Exploration status: The fields of this play have produced 1.4 BBO, 1.6 TCFG, and 77 MMBNGL. The largest sandstone accumulation occurs at KMA, discovered in 1931, which has produced 184 MMBO. Breckeridge, the largest limestone field, was discovered in 1919 and has produced 147 MMBO. Breckeridge has produced over 75 percent of the play's total production from limestone reservoirs.

Resource potential: The play has been extensively drilled over a period of nearly 70 years, and it is estimated that the potential for the discovery of large accumulations is very limited. The future potential for medium-size oil and gas fields is fair.

4506. POST-DESMOINESIAN PLAY

This play is characterized by oil accumulations in combed structural/stratigraphic traps in Pennsylvanian (Missourian-Virgilian) shelf sandstone, Permian (Wolfcampian) sandstone, and Pennsylvanian local shelf-edge carbonate-buildup reservoirs on the eastern shelf of the Midland Basin.

Reservoirs: Reservoirs include prodelta-front bar and blanket sandstones, channel-mouth bars, and distributary-channel sandstone. Slope-derived sandstone reservoirs include submarine-channel fills and submarine-fan lobes. Reservoirs in platform carbonate buildups consist of packstone, wackestone, and grainstone with moldic and intercrystalline porosity. Reservoir units range in age from Pennsylvanian (Virgilian and Missourian) for shelf sandstone and platform edge-interior carbonate rocks, to Permian (Wolfcampian) for slope-derived sandstone. Maximum aggregate thickness of all units is 5,000 ft in the southwestern Oklahoma portion of the play; however, erosion of these units limits the play to the northwestern half of the province. Shelf-sandstone reservoirs have a porosity range of 14–25 percent, permeabilities ranging from 10 to 380 mD, and oil columns ranging from 55 to 215 ft. Carbonate reservoirs in the play have porosities that range from 5 to 20 percent and permeabilities that average about 10 mD. Drilling depths range from 500 to 7,500 ft.

Source rocks: Probable source rocks for this play include the Late Devonian Woodford Shale, the Mississippian Barnett Shale, and organic-rich Pennsylvanian and Permian shales in Midland Basin west of the play area.

Timing and migration: Effective thermal maturation and migration of source fluids probably was initiated as soon as indigenous shales sealed the reservoirs of this play.

Traps: Traps are related to the configuration of sandstone bodies, and include pinch-outs on low-relief anticlines and combined stratigraphic and structural traps. Shelf and slope sandstones tend to be predominantly stratigraphic in the form of updip pinch-outs of submarine-fan and submarine-channel sandstone. Traps in carbonate rocks are low relief paleotopographic highs, purely stratigraphic updip pinch-outs of facies, and diagenetically controlled porosity zones. Shale in the overall section provides numerous seals. Source rocks probably lie to the west in the Midland Basin. Drilling depths range from 500 to 7,500 ft.

Exploration status and resource potential: The fields of this play produced 384 MMBO, 250 BCFG, and 9 MMBNGL through 1990. The largest oil field, Fargo, was discovered in 1940 and has produced 34 MMBO. Branch South, the largest field and only nonassociated-gas field, was discovered in 1983 and has produced 16 BCFG. Prospects for additional oil and gas discoveries are limited because the play has been drilled extensively.

4510. TEXAS OUACHITA FOLD-THRUST BELT PLAY (HYPOTHETICAL)

The definitive characteristic of this hypothetical, conventional play is its structural style which consists of asymmetric folds and imbricate thrust sheets. No production is known from this play but it continues southward along strike into the Marathon Fold Belt where minor production occurs in two oil fields and one gas field.

Reservoirs: Reservoir rocks in the Marathon Fold belt include the Silurian(?), Devonian, and Mississippian Caballos Novaculite, the Pennsylvanian Tesnus Formation, and the Pennsylvanian Dimple Limestone. Reservoirs in the Caballos are 80-200 ft thick; porosity ranges from 5-15 percent and is fracture enhanced. Reservoirs in the Dimple are typically 100 ft in pay thickness, and porosities range from 8–12 percent. The Tesnus is a friable, fine to coarse-grained sandstone or arkose, and the Dimple locally contains layers of coarse-grained fossil debris. The Caballos Novaculite ranges from 200 to 600 ft thick; the Tesnus exceeds 6,500 ft in thickness; and the Dimple reaches a maximum thickness of 1,000 ft. Undiscovered natural-gas accumulations may range in depth from 3,500 to 18,000 ft, and oil accumulations may range in depth from 2,000 to 12,000 ft, based on cross sections by Reed and Strickler (1990).

Northward, this play continues into the hypothetical conventional Hinterland Oil Play (6201) of the western Ouachita Thrust Belt of the Arkoma Basin Province 062. The Hinterland Oil Play produces from shallow sandstones of the Upper Mississippian Stanley Group Bald and South Bald field (discovered 1932, 0.006 MMBO, cumulative), West and Southeast Daisy fields (600 BO and 169 MMCFG, cumulative),

East Wesley field (900 BO, cumulative), Potato Creek field (0.0012 MMBO, cumulative), Redden field (discovered in late 1913 or early 1914), and other small noncommercial oil occurrences (Suneson and others, 1990).

Inferred reservoir rocks in this play include sandstones of the Upper Mississippian Stanley Group and the Devonian to Mississippian Arkansas Novaculite.

Similar reservoir and source-rock characteristics seen to the north and south along strike may be inferred for the Texas Ouachita Fold-Thrust Belt.

Source rocks: Probabilities of adequate charge and sufficient seal integrity were deemed too low to justify individual assessment of this hypothetical play. Source rocks are probably black shale, bituminous limestone, and black chert of the Caballos Novaculite and the underlying Ordovician Maravillas Chert. Assuming an average geothermal gradient of 1.6¡F per 100 ft and present burial depths (as deep as 9,700 ft), Devonian rocks could have experienced a thermal history sufficient to have generated hydrocarbons as early as Upper Pennsylvanian time. Numerous faults present in the play could have provided avenues of migration for hydrocarbons. However, if hydrocarbons were generated during the late Paleozoic, subsequent faulting may have destroyed hydrocarbon-filled traps.

Resource potential: Risk for discoveries in this play is high but potential for additional discoveries does exist.

UNCONVENTIONAL PLAY

Continuous-Type Play

4503. MISSISSIPPIAN BARNETT SHALE (HYPOTHETICAL)

The definitive characteristic of this hypothetical continuous-type unconventional play is the organic shaly nature of the combined reservoir and source rock, the Mississippian Barnett Shale. Production of 34.5 BCFG through 1990, occurred in a single field, Newark East, in southwest Wise County. This play is classified as both hypothetical and unconventional because it is limited to a single production occurrence, and its reservoir permeability of 0.1 mD falls in the unconventional-play category. Reservoir depth is 7,000 ft. The limits of the play encircle the single known occurrence and were drawn simply to acknowledge the broad distribution of the reservoir facies in the province. The reservoir quality is the riskiest aspect of the play and was deemed to be so questionable that the play was not individually assessed.

Resource potential: Risk for additional producible discoveries in this play is high but potential for additional discoveries is also significant.

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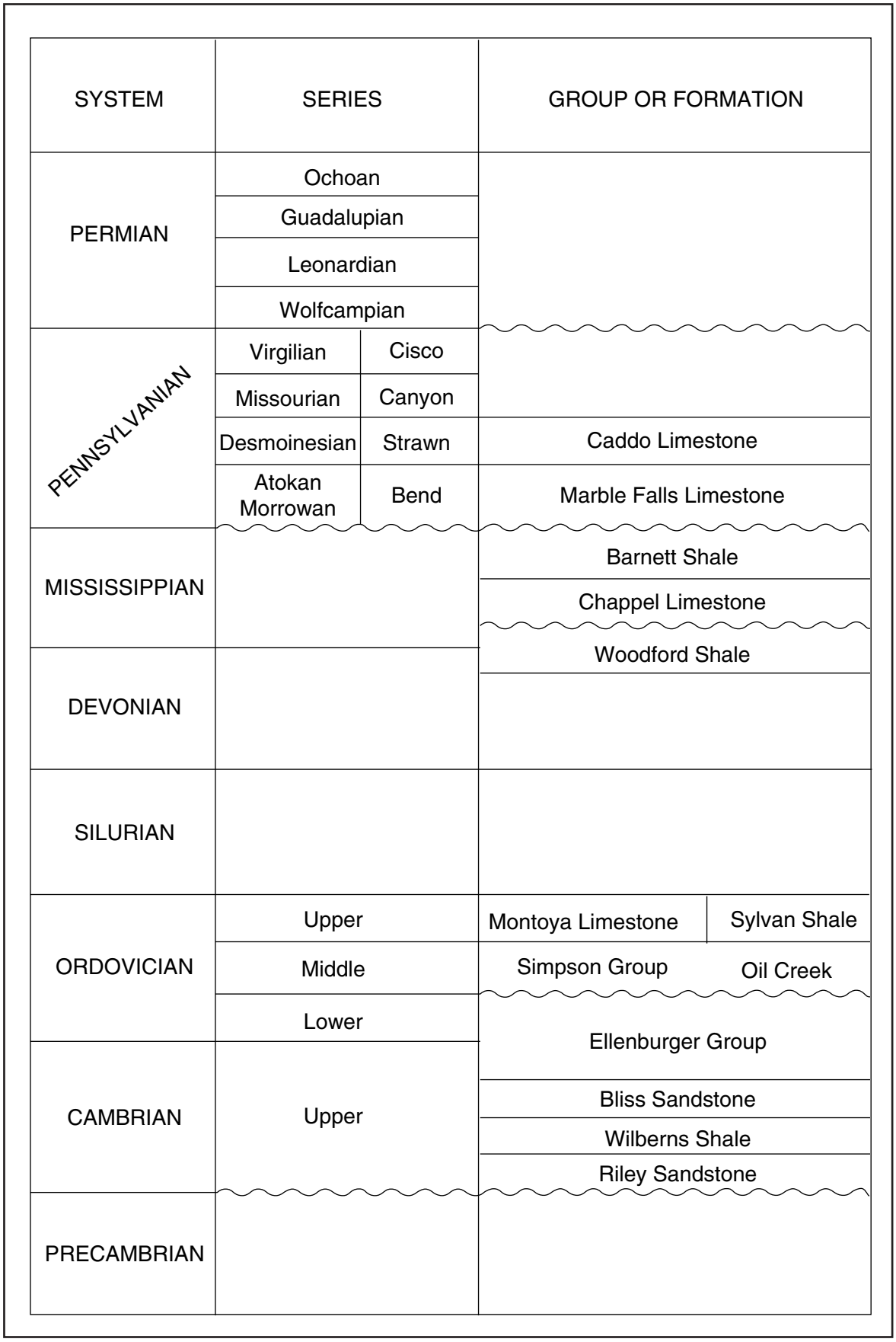
SYSTEM
SERIES
GROUP OR FORMATION
PERMIAN
Ochoan
Guadalupian
Leonardian
Wolfcampian
PENNSYLVANIAN
Virgilian
Cisco
Missourian
Canyon
Desmoinesian
Strawn
Caddo Limestone
Atokan
Morrowan
Bend
Marble Falls Limestone
MISSISSIPPIAN
Barnett Shale
Chappel Limestone
Woodford Shale
DEVONIAN
SILURIAN
ORDOVICIAN
Upper
Montoya Limestone
Sylvan Shale
Middle
Simpson Group
Oil Creek
Lower
Ellenburger Group
CAMBRIAN
Upper
Bliss Sandstone
Wilberns Shale
Riley Sandstone
PRECAMBRIAN