ARKOMA BASIN PROVINCE (062)

by William J. Perry, Jr.

INTRODUCTION

The Arkoma Basin Province includes portions of west-central Arkansas and southeastern Oklahoma and includes an area of about 33,800 sq mi. The maximum length of the province is about 315 mi, east-west, and the maximum width is about 175 mi, north-south. In Arkansas the province is bounded on the north by the Ozark Uplift and in Oklahoma it is bounded on the north by the Cherokee Platform. The northern part of the province is a major foreland basin, the Arkoma Basin, developed in front of and north of the Ouachita Fold and Thrust Belt. The exposed part of this fold and thrust belt forms the southern part of the province. The Arkoma Basin is characterized by down-to-the-south normal faults which affect Early Pennsylvanian and older rocks. The Ouachita folded and thrust-faulted sequence consists primarily of younger Paleozoic deep-water siliciclastic turbidites and older Paleozoic radiolarian cherts and shales. Sedimentary rocks in the Arkoma Basin range in thickness from 3,000 to 20,000 ft and consist primarily of pre-Mississippian carbonate shelf deposits, organic-rich Mississippian marine shales and Pennsylvanian fluvial deposits. Almost all of the Early and Middle Pennsylvanian section is represented in the basin. Eight conventional gas plays and one conventional oil play were assessed: Hinterland Oil Play (6201), Atoka-Desmoinesian Fluvial-Deltaic and Shelf Sandstone Gas Play (6202), Atoka Deep-Water Sandstone Gas Play (6203), Morrowan Shallow-Marine Sandstone and Limestone Gas Play (6204), Arbuckle through Misener Basement Fault and Shelf Gas Play (6205), Cromwell-Spiro-Wapanucka Sub-Choctaw-Thrust Gas Play (6206), Carboniferous Turbidite Thrust-Belt Gas Play (6207), Lower Paleozoic through Mississippian Eastern Arkoma Gas Play (6208), and Morrowan Clastic Wedge Gas Play (6209). Play descriptions for plays 6202 through 6206 relied heavily on the "Atlas of major Midcontinent gas reservoirs" edited by Bebout and others (1993). Producing oil fields on the northwestern edge of the province are included in the plays of Cherokee Platform Province (060). Two coalbed gas plays are described by Dudley D. Rice; these are Arkoma Basin–Anticline Play (6250) and Arkoma Basin–Syncline Play (6251). 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

6201. HINTERLAND OIL PLAY (HYPOTHETICAL)

This hypothetical conventional play in the hinterland of the western Ouachita Thrust Belt is based on the occurrence of small, generally shallow, oil and tar (grahamite) deposits discussed by Curiale (1983) and Suneson and Campbell (1990). Production has been primarily from sandstones of the Upper Mississippian Stanley Group in small accumulations including Bald and South Bald (discovered 1932, 0.006 MMBO), West and Southeast Daisy (600 BO and 169 MMCFG), East Wesley (900 BO), Potapo Creek (0.0012 MMBO), Redden (discovered in late 1913 or early 1914), and other small noncommercial oil occurrences (Suneson and others, 1990) total reported production.

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

Source rocks: Geochemical investigations by Curiale (1983) suggest that the source rock for the oil and tar deposits is primarily Ordovician to Silurian deep-water organic rich shale. One such tar deposit has been identified in a dike oriented northwest, cross strike with respect to the anticlinal nose on which it occurs. Curiale (1983) found that the Stanley and Arkansas Novaculite contained gas-prone Type III kerogen.

Exploration status and resource evaluation: In the Redden field, oil occurs in sandstones of the Stanley at depths of less than 500 ft and "appears to be a classical example of petroleum liquids trapped downdip from a tar seal" (J.A. Campbell, *in* Suneson and others, 1990), however, only 2 of 13 producing wells fit this model. Deeper production (Southeast Atoka Townsite field), from the underlying Mississippian Arkansas Novaculite at 7,101 to 7,165 ft, was originally 21 BOPD, 116 MCFGPD, and 22 BWPD. These small accumulations are all north and east of the Tishamingo Uplift or Reentrant.

The analog Isom Springs field beneath the Cretaceous overlap in Marshall County, Okla., in the frontal thrust belt south of the Tishamingo Reentrant, has produced 4.25 BCFG and 2.65 MMBO from the Arkansas Novaculite, minor oil (0.0046 MMBO) from the underlying Ordovician Bigfork Chert and 0.468 MMBO from overlying Desmoinesian (Pennsylvanian) sandstones. Cretaceous Trinity sandstones overlapping the folded Paleozoic sequence have themselves yielded 0.5 MMBO. Likely source rocks are the underlying complexly deformed Paleozoic rocks. The probability of the occurrence of an undiscovered oil deposit of minimum size (1 MMBO) is considered to be 0.3.

6202. ATOKA-DESMOINESIAN FLUVIAL-DELTAIC AND SHELF SANDSTONE GAS PLAY

The Atoka-Desmoinesian Fluvial-Deltaic and Shelf Sandstone Gas Play (9,985 sq mi in area) includes 46 gas fields in the northern and central Arkoma Basin. The basal Atokan part of the play represents south- to southeast-trending fluvial-deltaic sandstones in channels cut downward into Morrowan deposits (Brown and Woodward, 1993). These were overlain in part by transgressive shallow marine and tidally dominated sheet sandstones. Following deposition of these sandstones, the basin foundered along a set of down-to-south basement-involved growth faults (Houseknecht, 1986); the middle Atokan deep-water fan and channel deposits are treated in the Atoka Deep Water Sandstone Gas Play (6203). Upper Atokan shallow-water sheet sandstones represent a southward progradational shallow shelf sequence. These are overlain by fluvial-deltaic Desmoinesian sandstones which prograded from east to west and then north to south (Brown and Parham, 1993) during later phases of Gondwana-North American plate collision in this part of the collisional belt.

Reservoirs: The various sandstones referred to previously are the principal reservoir rocks in this play. Desmoinesian sandstone reservoirs in the play area range in depth from 1,185 to 3,326 ft; net pay ranges from 8 to 162 ft; porosity ranges from 10-18 percent, and permeability ranges from 6 to as high as 850 mD (Brown and Parham, 1993). Upper Atokan sandstone reservoirs range in depth from 1,958 to 5,120 ft; net pay ranges from 16-55 ft; porosity ranges from 10-17.5 percent, and permeability is not reported (Brown and Woodward, 1993). Lower Atokan sandstone reservoirs range in depth from 2,775 to 12,000 ft; net pay ranges from 15 to 55 ft; porosity ranges from 9 to 17.5 percent; and only two permeability values are given, 10 and 21 mD (Brown and Woodward, 1993).

Source rocks: Source rocks include dark-gray shales as thick as 660 ft (Houseknecht, 1987) in the lower part of the Atoka Formation and possibly older Paleozoic euxinic basinal shales including the Mississippian "Caney" and Upper Devonian to Mississippian Woodford Shale. Vitrinite values for the Desmoinesian Hartshorne coal bed range from $R_o < 0.9$ in the western part of the play to 1.5 along the Oklahoma-Arkansas boundary to > 2.0 along the eastern margin of the play (Houseknecht, 1986). A rapid increase in R_o values northeastward in the Atoka from less than 2 in the southeastern part of the play to > 4 near the eastern edge of the play are reported by Houseknecht (1986).

Traps: Traps are combination, structural and stratigraphic; many of the fields, particularly to the east are on anticlines or along the down-to-basin normal faults.

Exploration status and resource potential: Fluvial-deltaic to shallow marine Atokan sandstones have produced more than 3,360 BCFG of gas and predominantly fluvial Desmoinesian sandstones have produced more than 410 BCFG in the play through August, 1992. The first field in this play was discovered in 1910. Kinta, the largest field in the play, has produced more than 1,440 BCFG from shallow-marine and fluvial Atokan sandstones and more than 40 BCFG from Desmoinesian sandstones through August, 1992. The largest gas field producing from Desmoinesian sandstones is Greasy Creek, with total Desmoinesian production through August, 1992 of more than 120 BCFG. The probable number of accumulations yet to be discovered is estimated to be 10. The last gas accumulation found in this play was discovered in 1975.

6203. ATOKA DEEP-WATER SANDSTONE GAS PLAY

The confirmed conventional Atoka Deep-Water Sandstone Gas Play includes 10 fields in southeastern Oklahoma and 3 in Arkansas. Deposition of deep-water Atokan rocks occurred during the time of most rapid syndepositional down-to-south growth faulting, during the middle Atokan. The Atoka Formation thickens from about 1,500 ft near the northern edge of the Arkoma basin province to more than 18,000 ft thick near the southern edge of the basin at the Ouachita front. Most of this thickening is represented by the middle Atoka slope facies containing "lenticular sand bodies (1-3 mi wide; 30-165 ft thick) elongate parallel to and just downthrown to syndepositional faults" (Houseknecht, 1986). Houseknecht (1986) proposed that deposition occurred in slope channels localized by rapid subsidence close to the downthrown margin of these faults. The related submarine fan facies is now exposed in the frontal Ouachita thrust belt.

Reservoirs: Middle Atokan reservoir sandstones include the Brazil, Fanshawe, Red Oak, Thom, Middle Atoka, and Panola. Depth ranges from 4500 to more than 11,500 ft; net pay ranges from 11 to 75 ft; porosity ranges from 12 to 20 percent, and permeability ranges from 10 to 174 mD, data from Brown and Woodward (1993).

Source rocks: Source rocks are inferred to include deeper water organic-rich Atokan and possibly Morrowan and Springer Shales. Vitrinite values for the Desmoinesian Hartshorne coal bed range from $R_o < 0.9$ in the western part of the play to 1.5 along the

Oklahoma-Arkansas boundary to > 2.0 along the eastern margin of the play (Houseknecht, 1986). A rapid increase in R_o values northeastward in the Atoka from less than 2 in the southeastern part of the play to > 4 near the eastern edge of the play is reported by Houseknecht (1986).

Traps: Traps are combination, structural and stratigraphic; many of the fields, particularly to the east are on anticlines or along the down-to-basin normal faults.

Exploration status and resource potential: Deep-water Atokan sandstones have produced more than 1,810 BCFG within the play area through August, 1992. The first field in this play was discovered in 1924. Red Oak-Norris, the largest field in this play, has produced 929 BCF gas in deep-water Atokan sandstones through August, 1992. The probable number of accumulations (of more than 6 BCFG producible gas) yet to be discovered is estimated to be 4. The last gas accumulation of this size found in this play was discovered in 1982.

6204. MORROWAN SHALLOW MARINE SANDSTONE AND LIMESTONE GAS PLAY

This confirmed conventional play includes Morrowan accumulations with gas production reported from 40 fields in the central and western Arkoma Basin (same area as play 6202, fig. 1). In the play area, stacked sequences of Morrowan shallow-marine gas-bearing sandstone (Cromwell in Oklahoma, Hale in Arkansas) and interbedded shale are present. This sequence appears likely the result of numerous minor sealevel fluctuations or other pulse-like changes in baselevel or sediment supply. The Morrowan shelf sequence becomes more calcareous to the southwest where the Wapanucka Limestone is developed above the Cromwell.

Reservoirs: Fine to medium-grained calcareous sandstone reservoirs of the Cromwell range in thickness from 22 to 230 ft, in reported porosity from 10 to 14 percent, and in permeability from 5 to 55 mD (Bingham and Woodward, 1993). The Wapanucka Limestone wedges out to the north and thickens southward in the western part of the play to a maximum of 250 ft north of the frontal thrust belt. Limestone reservoirs are developed in what is reportedly a skeletal grainstone and (or) oolitic facies of the Wapanucka (Campbell, 1993a). In Arkansas, the sandstones are less calcareous and reservoirs are commonly developed on faulted anticlines at depths of from 1,735 to more than 8,000 ft with a reported porosity range of from 7 to 15 percent (Bingham and Woodward, 1993).

Source rocks: Source rocks are inferred to include organic-rich Morrowan and Springer shales, dark-gray deeper water shales of Mississippian age ("Caney") and possibly Upper Devonian to Mississippian Woodford Shale. Thermal maturity is higher than that of the Atoka described in the Atoka-Desmoinesian Fluvial-Deltaic and Shelf Sandstone Gas and Atoka Deep-Water Sandstone Gas Plays (6202, 6203).

Traps: Traps are combination structural and stratigraphic to the west in Oklahoma and dominantly structural to the east in Arkansas where fracture-enhanced porosity is suspected.

Exploration status and resource potential: Morrowan shallow-marine limestones and sandstones have produced more than 960 BCFG in the play through August, 1992, from 29 fields with ultimate Morrowan reserves of 6 or more BCFG. The first field in this play was discovered in 1912. Kinta, the largest field in this play, has produced about 260 BCFG Morrowan gas through August, 1992. Proprietary data suggests that the maximum field size yet to be discovered may be as much as 60 BCFG, with an undiscovered median of about 10 BCFG. The probable median number of accumulations yet to be discovered is estimated to be 5. The last gas accumulation found in this play was discovered in 1975.

6205. ARBUCKLE THROUGH MISENER BASEMENT FAULT AND SHELF GAS PLAY

This confirmed conventional play is predominantly structural in character, involving Cambrian through Devonian shelf rocks beneath and north of the front of the Ouachita Fold and Thrust Belt. The play area includes the central and western Arkoma Basin as well as poorly located basement structures beneath the frontal Ouachita Thrust Belt. The northern limit of the play is the Mulberry Fault, the northernmost of a series of generally down to basin faults in the central and eastern Arkoma Basin. The eastern boundary is based on secondary porosity reduction by Late Paleozoic calcite vein emplacement that filled fractures and remnant primary porosity. This is attributed to high levels of hydrothermal activity, associated pressure solution and recrystallization. The play is nearly 160 mi long (ENE), parallel to the Mulberry and Choctaw faults and as much as 47 mi wide (NNW). Just south of the Mulberry fault the Hunton Group is partly eroded and overlain unconformably by Upper Devonian black shale which is both a source rock and seal. In this area basal Middle Ordovician sandstones are locally very gas productive.

Reservoirs: Reservoirs are predominantly Arbuckle and Hunton carbonate rocks but may include some Ordovician Simpson and Devonian Misener sandstones. The erosional unconformity at the top of the underlying Arbuckle may be associated with a thick zone of karstic porosity in the upper Arbuckle. This element of the play has not been thoroughly tested, particularly in Arkansas. Depths to reservoirs are 5800 to more than 14,000 ft.

Source rocks: Source rocks include the Woodford Shale and possibly the Ordovician Sylvan Shale, although data on source-rock quality are unknown or unpublished. Basement involved growth faulting in the central, eastern, and southern parts of the basin has brought Devonian and younger source rocks in fault contact with Arbuckle through Hunton carbonate rocks. Timing of hydrocarbon generation and migration may have occurred as early as late Atokan and possibly continued through much of the Desmoinesian.

Traps: Traps are believed to be mainly structural, but size is indeterminate without broad seismic data coverage in areas of suspected paleostructures. These likely include fault blocks bounded by steep down-to-south normal faults, or paleotopography at the top of the Hunton Group. Possible seals are overlying Ordovician and Mississippian shales. However, low- permeability Simpson sandstones may have provided conduits whereby gas has been lost from the Arbuckle, as suggested by C. A. Sternbach (Shell Western Exploration and Production Co., Houston, 1993, written commun.).

Exploration status and resource potential: Exploration drilling below the top of the Hunton Group was very limited until 1987 when a major Arbuckle discovery, the Wilburton deep field, led to a significant increase in deep gas exploratory drilling (depths of more than 12,000 ft), which has not resulted in a single successful new discovery. However, I estimate that at least three new gas fields of at least minimum size remain to be discovered in this play and that the probable median undiscovered field size will be about 50 BCFG.

6206. CROMWELL-SPIRO-WAPANUCKA SUB-CHOCTAW THRUST GAS PLAY

This confirmed conventional gas play is characterized by gas accumulations in Mississippian and Pennsylvanian sandstone and carbonate reservoirs in thrust faulted structural traps beneath and in front of (north of) the Choctaw thrust. It extends northward beneath part of the Atoka Deep-Water Sandstone Gas Play (6203). The play extends westward and southwestward to a major upthrown block, the Tishamingo

Uplift, eroded to Precambrian basement, which projects southward into the Ouachita fold and thrust belt in the subsurface beneath Cretaceous rocks near the southwestern margin of the Arkoma Basin Province. The eastern limit is placed in western Arkansas. Here, rocks of the Ouachita belt have undergone eastward increasing high paleotemperatures and hydrothermal alteration in Late Paleozoic time, leading to tight cementation by calcite and quartz with very low apparent intergranular porosities. In addition, dickite and other clay minerals, as well as calcite and quartz, appear to plug fault and fracture zones in the eastern part of the frontal Ouachita Thrust Belt, reducing the effectiveness of possible fracture porosity.

Reservoirs: Reservoirs include the basal Atokan Spiro Sandstone (40-50 ft pay, 11-15 percent porosity), underlying Morrowan Wapanucka Limestone (25-87 ft pay, 6-15 percent porosity, fractured), and Morrowan Cromwell Sandstone (Campbell, 1993b). Depths of production range from 4,300 ft in the north to more than 12,100 ft in fields to the south.

Source rocks, timing and migration: Source rocks are inferred to include the "Caney" and Woodford Shales. No source rock data has been published for this play. Based on data published for the Atoka to the north (Houseknecht, 1987), these shales should be overmature with respect to oil generation, but oil generated has likely been converted to thermogenic gas and asphaltite. Generation and migration of gas into thrust-faulted reservoirs in this play likely took place in Late Paleozoic time during the time of maximum hydrothermal activity. The primary seal is the thick Atoka shale section above the Spiro Sandstone.

Exploration status and resource potential: Eleven fields in this play have produced more than 1,280 BCFG from reservoirs of Play 6206 through August, 1992; all 11 are above the minimum size (6 BCFG). The first field in this play was discovered in 1960 (table 3). The probable median number of accumulations yet to be discovered is estimated to be 6. The last gas accumulation found in this play was discovered in 1990. This represents the most active current play in the province and probably in the region, in terms of current exploration and field growth.

6207. CARBONIFEROUS TURBIDITE THRUST-BELT GAS PLAY (HYPOTHETICAL)

This hypothetical conventional gas play is characterized by possible gas accumulations of more than 6 BCFG in Mississippian and Pennsylvanian predominantly sandstone reservoirs in thrust-fault-related structural traps. It extends southward from the immediate hanging wall of the Choctaw Thrust in Oklahoma and co-extensive Ouachita Mountain front in Arkansas southeastward to the margin of the complexly deformed core of the Ouachita Fold and Thrust Belt. Thrusting started earlier to the south, probably during Middle Atokan time and reached what is now the southern Arkoma Basin by the end of early Desmoinesian time because here undeformed upper Desmoinesian rocks overlap contractionally deformed lower Desmoinesian rocks.

Reservoirs: Reservoirs include Pennsylvanian and Mississippian sandstones, particularly the Stanley and Jackfork Sandstones, offshelf equivalents of the Morrowan Wapanucka Limestone, Lower Mississippian chert of the upper Arkansas Novaculite and Ordovician Big Fork Chert. Reservoir quality is unknown but is suspected to decline eastward, as thermal maturity increases. Anticipated reservoir depths may exceed 20,000 ft.

Source rocks: Source rocks include shales in the Johns Valley Formation, Jackfork Sandstone, Stanley Shale, and Arkansas Novaculite. The eastern third of the play, in Arkansas, has been subjected to higher paleotemperatures (2.0 to 5.0 percent R_o, Houseknecht and Matthews, 1985) and hydrothermal activity, more severe than that described for Sub-Choctaw Thrust Gas Play (6206). To the west, in Oklahoma, vitrinite reflectance values range from < 0.5 in the frontal zone to > 3.0 in the core area (Houseknecht and Matthews, 1985). Northward migration of hydrocarbons generated in the south may have occurred during Atoka time.

Exploration status and resource evaluation: Numerous gas shows have been encountered in the Oklahoma portion of this play in various Mississippian and Pennsylvanian formations, as well as the small oil accumulations and asphaltite deposits described in and a part of Play 6201. Results to date are summarized by Suneson and Campbell (1990); no fields approaching 6 BCFG have been discovered in this play despite at least 70 years of exploration. The probability of discovering one accumulation of this size in Play 6207 is estimated to be 0.2. I estimate that if the play is successful, there could be at least 1 and perhaps as many as 6 gas fields to be discovered in this play with an estimated median size of 10 BCFG.

6208. LOWER PALEOZOIC THROUGH MISSISSIPPIAN EASTERN ARKOMA GAS PLAY (HYPOTHETICAL)

This hypothetical conventional gas play is based on the hypothesis that reduced thermal maturities east of central Arkansas (shown by Houseknecht and others, 1992) makes it possible that a gas accumulation of the minimum size (6 BCFG) will be present in structure traps containing Lower Paleozoic through Mississippian reservoirs. The play includes the eastern Arkoma Basin and adjacent parts of the Mississippi embayment.

Reservoirs: Inferred reservoirs include Lower Paleozoic through Devonian carbonate rocks and Middle Ordovician St. Peter Sandstone of Schwalb (1983a, b). Reservoir quality is unknown. The proximity of Mesozoic plutons (Schwalb, 1982a, fig. 23) in the eastern part of this play is expected to have a negative impact on porosity and permeability if hydrothermal fluids permeated the prospective reservoir section.

Source rocks: Possible source rocks include organic-rich Devonian and Mississippian shales present to the southwest down Late Paleozoic paleoslope from the play area. When vitrinite reflectance data across the basin are considered with respect to stratigraphic position, thermal maturity appears to decrease eastward from the westcentral Arkansas portion of the Arkoma Basin toward the extreme eastern part of the basin (Houseknecht and others, 1992). However, proximity to Mesozoic plutons along the eastern margin of the play (Schwalb, 1982a) should have reversed the trend noted by Houseknecht and others (1992).

Exploration status and resource potential: Very little exploration has taken place along the eastern margin of the Arkoma Basin. However, results to date have been generally unfavorable. This play is given a 0.08 probability of containing an accumulation of minimum size (6 BCFG), based on low probabilities of trap retention (deep erosion to immediate east-northeast prior to Cretaceous time) and expected problems with charge (source rock richness, timing, and source rock overmaturity).

6209. MORROWAN CLASTIC WEDGE GAS PLAY (HYPOTHETICAL)

This hypothetical conventional play is based on the hypothesis that prodelta and offshelf turbidite sands equivalent to the Morrowan Caseyville of the southern Illinois Basin should be present along the eastern edge of the Arkoma Basin. The area of the play includes the easternmost Arkoma Basin and adjacent Mississippi embayment south of the northern pinchout of Mississippian strata beneath Cretaceous cover along the southwestern margin of the Pascola arch (Schwalb, 1982a, b). The northeastern margin of the play is defined by the erosional edge of Pennsylvanian strata against the Pascola arch as shown by Schwalb (1982a, b).

Reservoirs: Possible reservoir rocks include prodelta and offshelf turbidite sandstones equivalent to the Caseyville fluvial-deltaic complex of the southern Illinois Basin. The nature of such rocks, if present is poorly documented; the only evidence of their existence is the presence of Mississippian rocks in the play area shown by Schwalb (1982a), and the presumption that they include prodelta and offshelf turbidite sands (D.W. Houseknecht, oral commun., 1993). Reservoir quality is unknown. The proximity of Mesozoic plutons (Schwalb, 1982a, fig. 23) northeast of the play along the western edge of the Mississippian embayment suggest a time of post-Paleozoic crustal heating that may have a negative impact on porosity and permeability if hydrothermal fluids permeated the prospective reservoir section.

Source rocks: Possible source rocks include Upper Mississippian and Lower Pennsylvanian organic-rich shales to the south down Late Paleozoic paleoslope. Thermal maturity appears to decrease eastward from the west-central Arkansas portion of the Arkoma Basin toward the extreme eastern part of the basin based on vitrinite reflectance profiles across the basin, considered with respect to stratigraphic position (Houseknecht and others, 1992). However, high heat flow associated with Mesozoic plutons along the eastern margin of the play (Schwalb, 1982a) may have reversed the trend noted by Houseknecht and others (1992).

Exploration status and resource evaluation: Very little exploration has taken place along the eastern margin of the Arkoma Basin. However, results to date have been generally unfavorable. The Morrowan Clastic Wedge Gas Play (6209) is given a 0.04 probability of containing an accumulation of minimum size (6 BCFG), based on expected problems with charge (source rock richness, timing, and source rock overmaturity), lack of documentation of the presence or quality of reservoirs, and low probabilities of trap retention (deep erosion to immediate east-northeast prior to the Cretaceous).

UNCONVENTIONAL PLAYS

Coalbed Gas Plays

by Dudley D. Rice

Two coalbed gas plays have been identified in the Arkoma Basin Province (062). They are the Arkoma Basin–Anticline Play (6250) and the Arkoma Basin–Syncline Play (6251), which is hypothetical.

Geologic controls and coalbed gas potential of the Arkoma Basin of east-central Oklahoma and west-central Arkansas are given by Friedman (1982), Rieke and Kirr (1984), Diamond and others (1988), and Houseknecht and others (1992).

The economic coal deposits of the Arkoma Basin are of Middle Pennsylvanian (Desmoinesian) age and are assigned to the Hartshorne (Sandstone), McAlester, Savanna, and Boggy Formations. Although more than 20 individual coal seams have been identified, the target coal beds for gas in Oklahoma, in ascending order, are the Hartshorne, McAlester/Stigler, Cavanal, Lower Witteville, and Secor. In Arkansas, the target coal beds for gas, in ascending order, are the Hartshorne, Charleston, and Paris. The Hartshorne Coal Zone, which forms the base of the coal-bearing interval, is economically important because of its thickness and continuity, and in the southern part of the basin splits into 2 beds (Lower and Upper). These 2 Hartshorne seams are separated by shale and sandstone, which are as much as 100 ft thick. Individual coal beds are as much as 10 ft thick in the basin, are relatively continuous, but are variable in thickness. The Hartshorne coal bed crops out on folds and faults within the basin and extends to depths of more than 7,000 ft. Most coal resources for the Hartshorne interval occur in the depth range of 500–1,500 ft.

Coal ranks increase significantly eastward from high-volatile C bituminous to semianthracite. The coals of semianthracite rank are in the Arkansas part of the basin and represent the highest ranks for an area that is considered to have potential for additions to reserves of coalbed gas. The lateral changes in thermal maturity within the Pennsylvanian and the overall high rank are difficult to explain by burial depth. The high rank is interpreted to be the result of hydrothermal fluids that originated in the Ouachita Orogenic Belt to the south. These hot fluids moved along syndepositional faults that were active during Atokan time. The postulated eastward fluid flow in the Desmoinesian coal-bearing rocks was controlled by sandier facies. Thermogenic hydrocarbons were probably generated in the Pennsylvanian coal beds during Late Paleozoic time during the time of high heat flow.

Gases from horizontal degasification wells and desorbed core from the Hartshorne coal bed are composed mostly of methane with minor amounts of CO_2 (less than 1.6 percent) and heavier hydrocarbon gases (generally less than 1 percent). On the basis of isotopic analyses, the gases are interpreted to be mainly of thermogenic origin, although probable mixing of biogenic gas has occurred, which was generated relatively recently in association with groundwater flow.

The Arkoma Basin is a foreland basin bounded by the Ouachita Orogenic Belt to the south. The main structural features of the basin that affect coalbed gas potential are a series of northeast- to east-trending synclines and tightly folded, faulted anticlines. The coal-bearing Pennsylvanian rocks are eroded in many of the anticlines and dips range from a few degrees in the synclines to nearly vertical on the anticlines. The synclinal folds form mountains with several hundred feet of relief. Anticlines occupy about 35 percent of the basin area, whereas the synclines occupy approximately 65 percent. Normal faults with large displacements, which are probably rooted in the basement, parallel the axes of the anticlines. The intensity of the structural deformation, both folding and faulting, decreases in a northward directions away from the Ouachita Orogenic Belt.

The orientation of face cleats ranges from N. 32¡ W. to N. 17¡W., which is essentially perpendicular to the folds and faults in the basin. In addition, inclined fractures dip at angles from 45¡ to 55¡ within the coal beds. These fractures are probably related to shear and are probably concentrated in the tightly folded anticlines. The coals, as observed in the Hartshorne coal bed, are friable due to the abundant shear fractures, which are superimposed on a closely spaced cleat system. The effect of this friability on permeability is not well-known.

Information is limited on the hydrogeology of coal beds in the Arkoma Basin. Coal-bed gas wells completed on structural highs are relatively dry; however, those completed in structural lows may have as much as 50 or more barrels of water/d.

As confirmed by mine emissions data, coal beds in the Arkoma Basin are very gassy and have been a serious hazard for underground mining in the past. Desorbed gas contents range from 200 to 675 Scf/t and are related to present-day depth. However, gas contents have only been measured to depths of about 1,500 ft, and higher values are expected at greater depths. On the basins of a minimum gas content of 200 Scf/t and a maximum value of 450 Scf/t, the in-place coalbed gas resources of the Arkoma Basin are estimated to range from 1.6 to 3.6 TCF.

Coals have not been produced from the steeply dipping coal beds of the Oklahoma part of the Arkoma Basin since 1984 because of high costs. As a result, emissions from underground coal mines have been minimal. In Arkansas, some surface mining is still taking place.

Starting about 1930, coalbed gas was produced for about 10 to 15 years from shallow wells (less than 500 ft) in the Kinta area, Oklahoma. The wells were drilled by cable tool and the gas was used locally. In addition, gas has been produced recently from sandstone reservoirs in the Hartshorne Sandstone from three small gas fields. Studies on gas geochemistry have shown that most of the gas in the sandstone reservoirs was probably generated in the adjacent coal beds. Since 1989, as many as 100 coalbed gas wells have been drilled, mainly to the Hartshorne coal bed. The only production to date is from the Kinta area where 40 wells at relatively shallow depths (600 to 800 ft) produce an average of 50 MCFG/D. These wells were drilled on the flank of an anticline; no water is produced.

An infrastructure of roads, pipelines, and field services is in place because of deeper, high pressure, conventional gas development. However, compression of coalbed gas will probably be required before the existing pipelines can be used. Shallow wells on the anticlines will have low drilling and operating costs. Deeper wells in the synclines will probably have water production and disposal of that water will increase the costs of development.

The target area for coalbed gas in the Arkoma Basin is where coal beds are generally deeper than 500 ft deep and where the Hartshorne coal bed has not been mined out along steeply dipping flanks of anticlines. The basin is favorable for in-place coalbed gas resources because of the abundant coal resources and high gas contents, but potential additions to reserves are questionable, especially in the eastern part of the basin where the structurally deformed coal beds are of high rank. Commercial production has not been established from coals of semianthracite rank in the United States.

6250. ARKOMA BASIN–ANTICLINE PLAY

Similar to the Northern Appalachian Basin, the Arkoma Basin has two coalbed gas plays based on structure: Arkoma Basin–Anticline Play (6250) and Arkoma Basin–

Syncline Play (6251). The anticline play (6250) is located on the crests and shallow flanks of tightly folded anticlines. Gas contents will be generally lower because of the shallower depths and partial degassing. Permeability may be higher because of tectonic enhancement, but the effects of abundant, inclined fractures on permeability and flow rates have not been fully evaluated. All the coalbed gas production to date in the basin comes from this play, and no water is produced. The potential for reserves of coalbed gas in this play is considered to be good. A limiting factor is the lack of knowledge of reservoir properties of high-rank coal in structurally deformed areas.

6251. ARKOMA BASIN–SYNCLINE PLAY (HYPOTHETICAL)

The syncline play (6251) is located in regionally extensive, broad synclines, covers a large part of the basin, and occurs below the gas-water contact. The gas contents in this play will be higher than in the anticline play because of depth; however the gas production will probably be accompanied by water production. In addition, the permeability is questionable because of the greater depths. Although some wells have been drilled, no long-term production has been established, and therefore the play is hypothetical. The undiscovered potential of this play is rated as good, although information is generally lacking on the permeability of deeply buried, high rank coal.

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