Petroleum system analysis of the Hunton Group in West Edmond field, Oklahoma

Stephanie B. Gaswirth and Debra K. Higley

ABSTRACT

West Edmond field, located in central Oklahoma, is one of the largest oil accumulations in the Silurian–Devonian Hunton Group in this part of the Anadarko Basin. Production from all stratigraphic units in the field exceeds 170 million barrels of oil (MMBO) and 400 billion cubic feet of gas (BCFG), of which approximately 60 MMBO and 100 BCFG have been produced from the Hunton Group. Oil and gas are stratigraphically trapped to the east against the Nemaha uplift, to the north by a regional wedge-out of Hunton strata, and by intraformational diagenetic traps. Hunton Group reservoirs are the Bois d'Arc and Frisco Limestones, with lesser production from the Chimneyhill subgroup, Haragan Shale, and Henryhouse Formation.

Hunton Group cores from three wells that were examined petrographically indicate that complex diagenetic relations influence permeability and reservoir quality. Greatest porosity and permeability are associated with secondary dissolution in packstones and grainstones, forming hydrocarbon reservoirs. The overlying Devonian–Mississippian Woodford Shale is the major petroleum source rock for the Hunton Group in the field, based on one-dimensional and four-dimensional petroleum system models that were calibrated to well temperature and Woodford Shale vitrinite reflectance data. The source rock is marginally mature to mature for oil generation in the area of the West Edmond field, and migration of Woodford oil and gas from deeper parts of the basin also contributed to hydrocarbon accumulation.

Published by The American Association of Petroleum Geologists.

Manuscript received May 4, 2012; provisional acceptance August 1, 2012; revised manuscript received October 25, 2012; final acceptance December 3, 2012.

DOI:10.1306/12031212075

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ACKNOWLEDGEMENTS

We thank Chesapeake Energy Corporation for providing access to cores and data and Dan Boyd, Brian Cardott, and Gene Kullman of the Oklahoma Geologic Survey for help with the Gulf 1 Streeter core and geochemical data. We also thank the U.S. Geological Survey (USGS) Core Research Center and Stan Paxton and Marvin Abbott of the USGS Oklahoma Water Science Center. Nick Gianoutsos of the USGS assisted with core logging and photography, and Wayne Husband, with figure drafting. We thank Mark Kirshbaum, Kristen Marra, Dick Keefer, and Margaret Ellis of USGS for providing helpful internal reviews of the manuscript. We also thank Tom Rowland for his thoughtful feedback on the manuscript. Any use of trade, product, or firm names is for descriptive purposes only and does not imply endorsement by the U.S. government. The AAPG Editor thanks the following reviewers for their work on this paper: Edward A. Beaumont and Richard B. Koepnick.

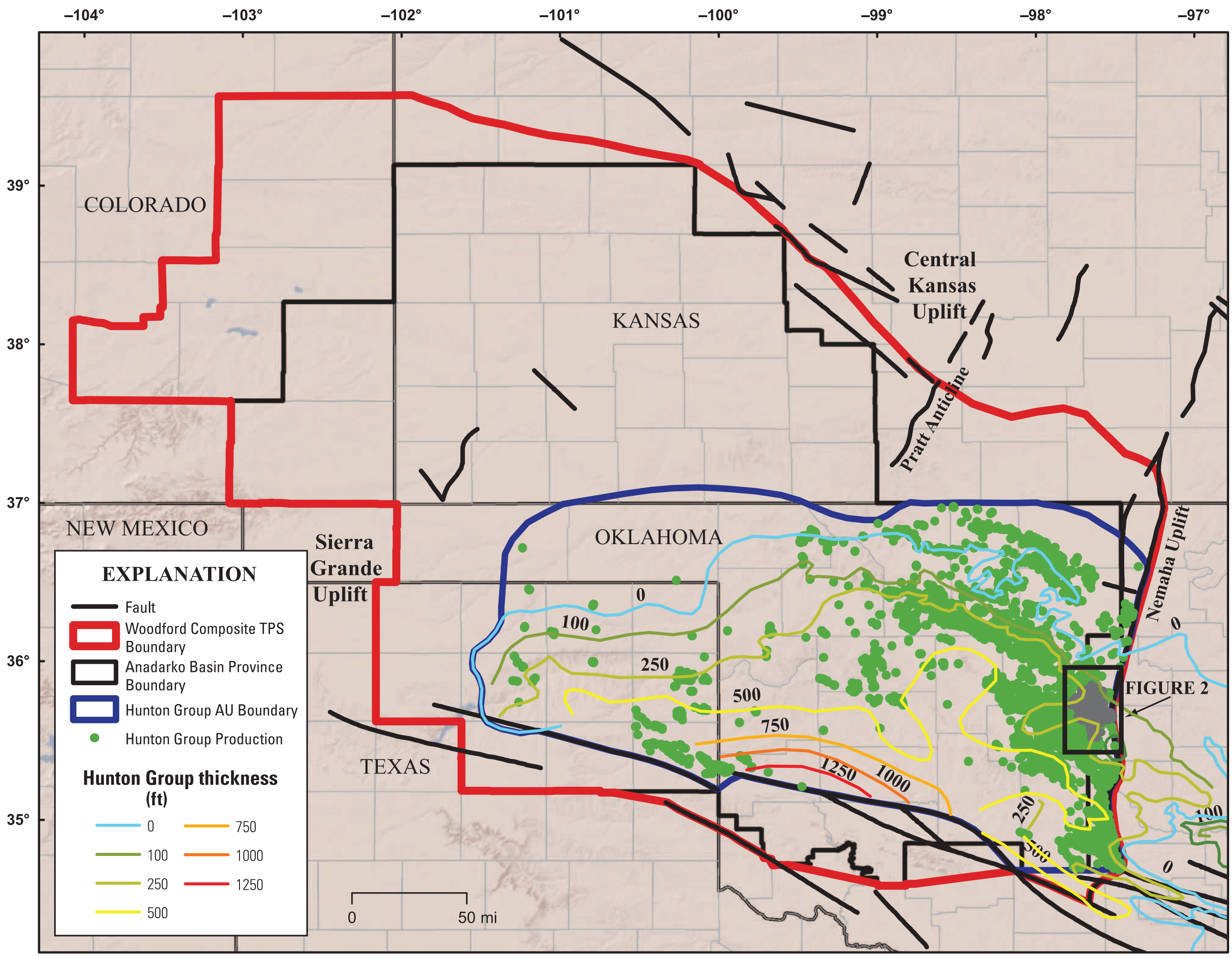


Figure 1. Map showing thickness and oil and gas production from the Hunton Group; isopach interval is 250 ft (76 m). Production beyond the Hunton subcrop is inferred to be isolated areas of Hunton rocks that remain in northern Oklahoma and the Texas Panhandle. West Edmond field is shaded gray, adjacent to the Nemaha uplift. Figure 2 location is outlined by the black rectangle. AU = assessment unit; TPS = total petroleum system.

INTRODUCTION

The U.S. Geological Survey (USGS) completed a geologic-based assessment of the undiscovered oil and gas resources of the Anadarko Basin province in western Oklahoma and Kansas, northern Texas, and southeastern Colorado in 2010 (Higley et al., 2011). The assessment was based on geologic elements and processes within a total petroleum system (TPS) framework . Each TPS contains multiple assessment units (AUs), the basic geologic unit of the oil and gas assessment, and undiscovered oil and gas resources were quantitatively estimated within each AU. Using this geologic framework, the USGS defined two TPSs in the Anadarko Basin, which contain nine conventional AUs and three continuous (unconventional) AUs (Higley et al., 2011).

The Hunton Group is a prolific oil- and gas-producing unit in the mid-continent. As such, it is critical to the USGS assessment of undiscovered petroleum resources in the Anadarko Basin province. The group was assessed as part of the Woodford composite TPS (Figure 1) and estimated to have a mean of 9 million bbl of undiscovered, technically recoverable oil and 38 bcf of gas (Gaswirth and Higley, in press).

The reservoir characterization of the Hunton Group in the West Edmond field was in conjunction

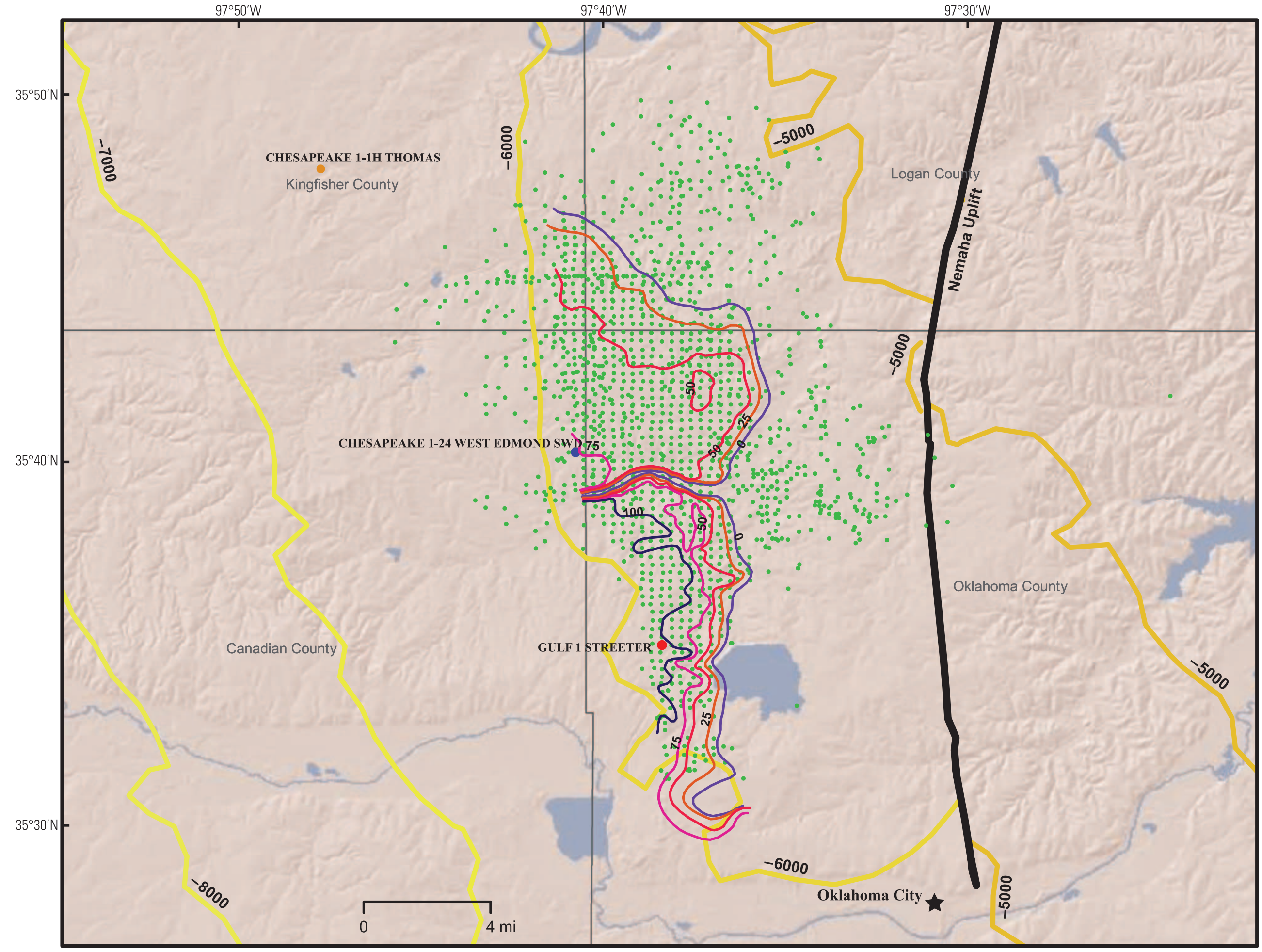


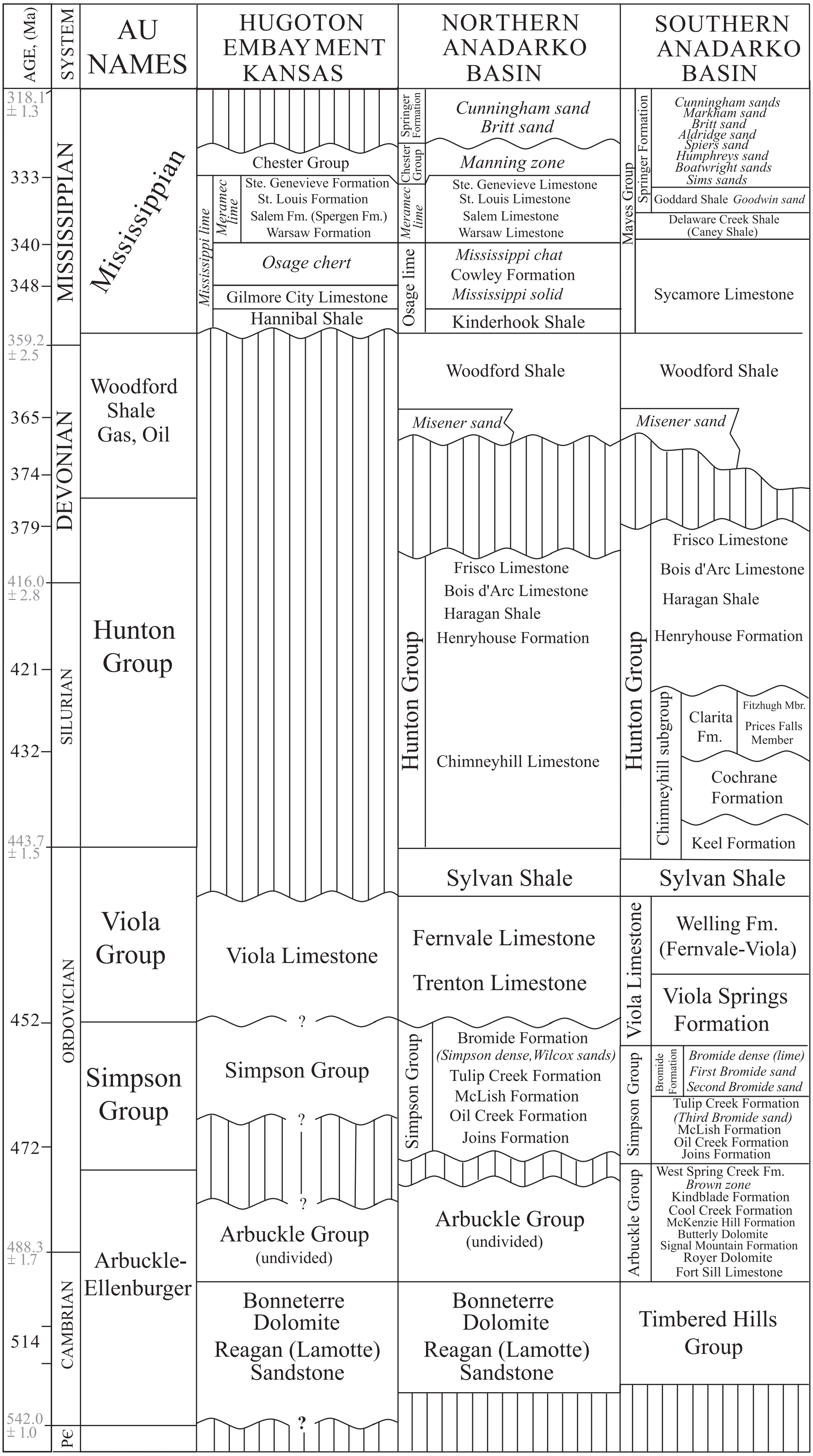
Figure 2. West Edmond field (see location in Figure 1). Rainbow contours (interval, 25 ft [8 m]) show an east-west incised channel through upper Hunton rocks and an associated erosional topographic relief on top of the formation (Swesnik, 1948). Wells mentioned in this study are Chesapeake 1-1H Thomas (orange dot), Gulf 1 Streeter (red dot), and Chesapeake 1-24 West Edmond SWD (blue dot).

with the USGS assessment of oil and gas resources. The West Edmond field is located on the eastern edge of the Anadarko Basin, adjacent to the Nemaha uplift, in central Oklahoma (Figures 1, 2), and is a major Hunton oil and gas field. A better understanding of the geologic model of the Hunton Group in the basin, including the source rock distribution, generation, and migration of hydrocarbons feeding the Hunton reservoirs, allowed for a more robust assessment of the Hunton Group in the field.

The main objectives of this study are to (1) determine the reservoir facies of Hunton Group reservoirs in the West Edmond field; (2) define the controls on hydrocarbon trapping; and (3) understand the sources(s), generation, migration, and trapping of hydrocarbons into this major Hunton Group field.

The Devonian–Mississippian Woodford Shale, probably the most prolific source rock in the basin, unconformably overlies the Hunton Group in the study area and is the major source for the West Edmond field. Determining controls on oil and gas accumulation and understanding porosity-permeability relations in the Hunton Group provides a better understanding of the West Edmond field and other Hunton reservoirs along the eastern edge of the Anadarko Basin. Following primarily oil production in the field, West Edmond is undergoing a secondary phase of development, with horizontal wells being drilled on tight spacing and dewatering and degassing of wells.

Figure 3. Generalized surface and subsurface stratigraphic columns for the Anadarko Basin and the southern Oklahoma fold-belt provinces for the Precambrian to Mississippian. Assessment units (AUs) are included in the Woodford composite total petroleum system (Higley et al., 2011). Italicized text indicates informal names. Formal formation- and member-rank units are not necessarily differentiated (as used by Bebout et al., 1993). Modified from Bebout et al. (1993) and Henry and Hester (1996). Ages in millions of years before present (Ma) are from Haq and van Eysinga (1998) and Gradstein et al. (2004) (gray text).



GEOLOGIC SETTING

The Anadarko Basin Province

The Anadarko Basin is a markedly asymmetrical sedimentary basin that originated during the Precambrian as the southern Oklahoma aulacogen (Rascoe and Adler, 1983). Basinward dip of strata resulted in a wide range of production depths for many of the Ordovician to Devonian units (Smith and Woods, 2000). As much as 15,000 ft (4600 m) of Upper Cambrian to Mississippian shallow-marine carbonates and clastics were deposited across the vast Oklahoma basin during an early epeirogenic phase of the Anadarko Basin area (Johnson, 1989). Increase in formation thickness toward the basin depocenter was caused mostly by an increased rate of subsidence during the Paleozoic.

Structurally, the Hunton Group ranges from 4000 ft (1200 m) below sea level to 24,000 ft (7300 m) in the deep basin. It is underlain by limestones of the Viola Group and the gray and green-gray shales of the Sylvan Shale (Figure 3). The Devonian–Mississippian Woodford Shale unconformably overlies the Hunton Group. An erosion of the upper Hunton Group associated with this unconformity, especially in the study area, which had a substantial effect on development of reservoir quality in the Hunton Group and the trapping of hydrocarbons was observed.

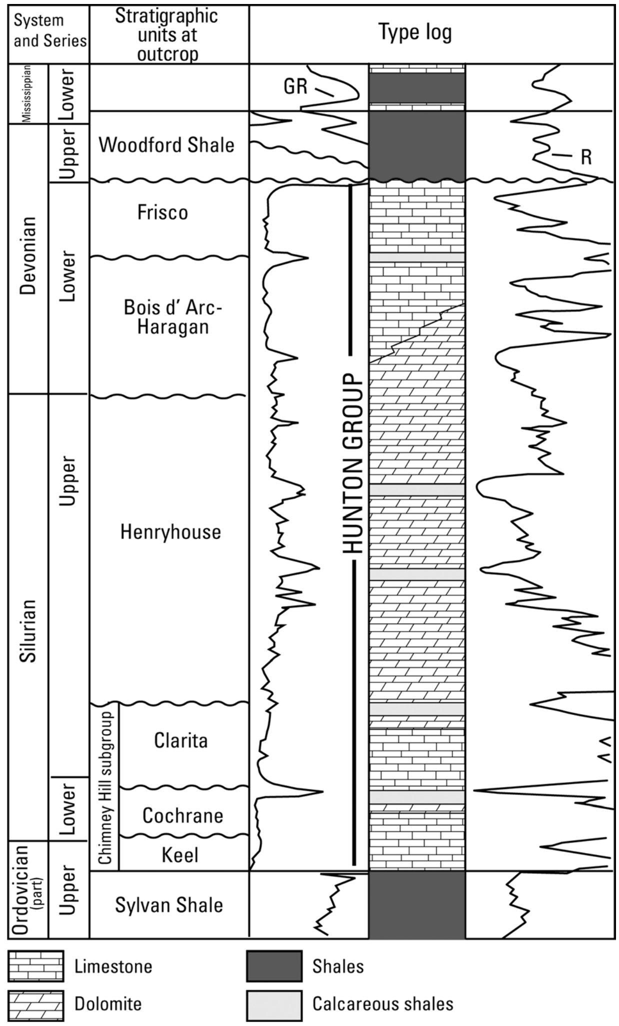


Figure 4. Type log of the Hunton Group in central Oklahoma (modified from Fritz and Medlock, 1994). GR = gamma ray; R = resistivity.

The Hunton Group

The Silurian–Devonian was a time of widespread marine carbonate deposition in the United States mid-continent, when it was covered by a shallow sea over a broad platform area. The strata were deposited as a veneer of limestones and dolomites in a ramp setting.

The Hunton Group consists of sequences of dolomite, limestone, and calcareous shale and is divided into several formations (Figures 3, 4). The youngest Ordovician unit in Oklahoma is the Keel Formation, at the base of the Hunton Group. The Keel is part of the Chimneyhill subgroup, which also contains the overlying Silurian Cochrane and Clarita Formations, which are dolomitic limestones and dolomite. The clean skeletal limestones and dolomites of the Chimneyhill are overlain by the argillaceous and silty limestones and dolomites of the Silurian Henryhouse Formation and Devonian Bois d'Arc Limestone (Haragan equivalent) (Figure 4). The Henryhouse reservoirs, characterized as being a dolomitized intertidal facies (Al Shaieb and Puckette, 2002), are overlain by the Devonian Frisco Limestone in central and southern Oklahoma. The Frisco Limestone consists of skeletal packstone and grainstones, whose main components are pelmatozoans, brachiopods, and corals (Morgan and Schneider, 1981). Several unconformities associated with the Hunton

Group exist, including one at the Silurian–Devonian contact and others between individual formations (Figure 4).

Several distinct depositional environments are interpreted from the Hunton strata, including subtidal, intertidal, and supratidal (Fritz and Medlock, 1994). These facies are in shallowing-upward cycles or parasequences, forming a series of progradational and aggradational sequences that built generally southward across the carbonate ramp into the deep basin (Fritz and Medlock, 1994).

The Hunton Group conformably overlies the Sylvan Shale and is unconformably overlain by either the Woodford Shale or, locally, by the informal Misener Sandstone, which is Middle to Late Devonian in age (Figure 3). The Hunton thickens from a wedge edge near the Kansas-Oklahoma border to more than 1600 ft (490 m) in the Washita and Beckman Counties, Oklahoma, in the deepest part of the basin (Figure 1). It is typically 100 to 400 ft (30–120 m) thick on the northern shelf, where in places, it is highly dolomitized (Johnson et al., 2000).

Following Hunton deposition, a widespread sub-Woodford unconformity developed (Johnson, 1989). This unconformity is unique, in that it is one of those few in the mid-continent in which the erosional geometry preserves incised channel features (Rottmann, 2000a). The inundation of Devonian seas was initially confined to the erosional channels, filling and preserving them with the informal Misener sand and overlying Woodford Shale.

The Hunton Group is a significant oil reservoir in the northern Anadarko Basin along the Hunton subcrop and a major gas producer in the deep (>–15,000 ft [–4600 m]) basin (Figure 2). Reservoir development is mostly facies dependent (Fritz and Medlock, 1994). A wide range of depositional environments, erosional events, and subsequent diagenesis contributed to reservoir development. Typical reservoir facies are low-relief skeletal buildups and oolite shoals, both of which underwent some postdepositional dolomitization (Johnson et al., 2000). Fracturing, dolomitization, and dissolution are important factors for porosity development in the Hunton Group. Most conventional Hunton reservoirs are in dolomitized rock.

Hunton Group accumulations are mostly in structure-stratigraphic combination traps, typically created by the truncation of porous carbonate beds across structural noses (Fritz and Medlock, 1994). Abundant production is from stratigraphic traps formed by dolomitization. The overlying Devonian–Mississippian Woodford Shale is both a seal and petroleum source for the carbonates over most of the extent of the Hunton Group. Tight low-porosity intervals that form intraformational seals for some reservoirs in the West Edmond area also exist. The pressure regime is normal to underpressured, in contrast to the overpressured overlying Woodford Shale.

WEST EDMOND FIELD

Discovered in 1943, the West Edmond field is located near the eastern edge of the Anadarko Basin (Figure 1). The depth range of the Hunton Group in the field is approximately 5000 to 6000 ft (1500–1800 m). The field is now in a later phase of development, with horizontal and vertical well completions and dewatering with subsequent gas production. Wells in the field produce from the Hunton carbonates, with additional production from Pennsylvanian sandstones, Mississippian carbonates, and other contributions from Paleozoic stratigraphic intervals (McGef and Jenkins, 1946; IHS Energy Group, 2011). Hunton reservoirs are dominated by grainstones and packstones in the southern part of the field, with dolomitized facies more common but forming lower-quality reservoirs in the northern part of the field, in contrast to most Hunton fields in the Anadarko Basin. The Lower Devonian Frisco Limestone is a prolific reservoir within the Hunton Group in the West Edmond field (Medlock, 1984). A detailed biostratigraphic work by Amsden and Rowland (1967) indicates that the formation is present in the southern and western areas of West Edmond and that production there is primarily from high-porosity limestones. The Bois d'Arc or Haragan strata, which are lateral equivalents, are possible reservoirs in West Edmond and are supplemented by yields from

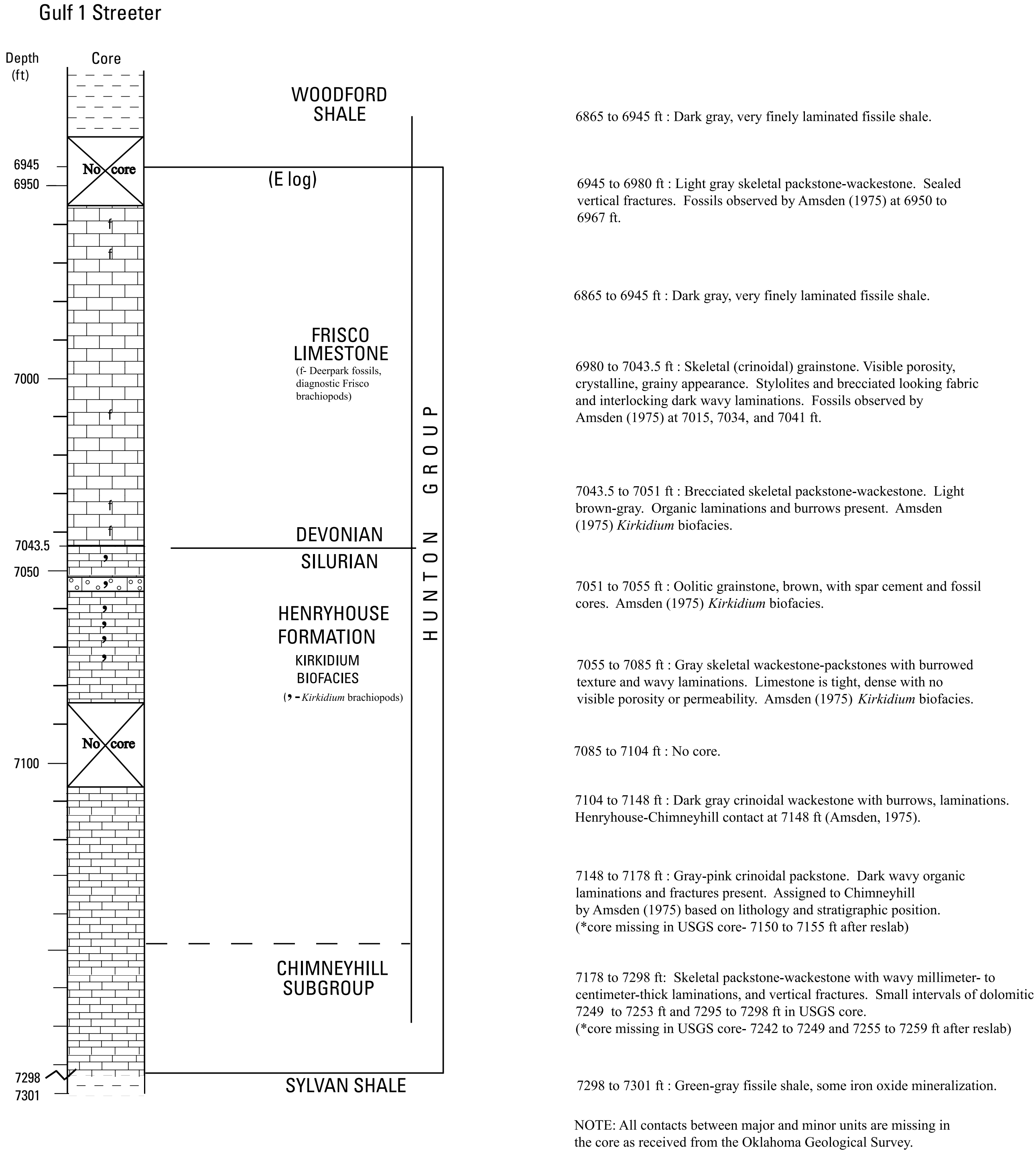


Figure 5. Core log of Gulf 1 Streeter, located in southern West Edmond field (Figure 2). Note that all contacts between major and minor units were missing in the core when it was received at the U.S. Geological Survey (USGS) in 2008. Previous work by Amsden (1975) was used to identify facies and fossils.

the Silurian Henryhouse Formation and Chimneyhill subgroup (Figure 3), especially where they have been dolomitized (Amsden and Rowland, 1971; Swesnik, 1948).

Hydrocarbons are in a stratigraphic trap that terminates updip to the east by truncation of the Bois d'Arc Limestone, to the north and northwest also by truncation, and to the west and south by downdip water (Culp and Barrett, 1957). The water flow to the west improved the permeability and porosity of the upper Hunton limestones by diagenetic alteration (dissolution). A stream channel through the middle of the West Edmond field incised completely through the Bois d'Arc Limestone following Hunton deposition, removing some 200 ft (60 m) of strata (Swesnik, 1948) and dividing the reservoir into northern and southern sections (Figure 2). If not for the West Edmond paleovalley, which provided the topographic relief necessary for the incision of channels, the West Edmond field might not have been a commercial oil field (Swesnik, 1948). Furthermore, uplift at West Edmond during the Carboniferous Wichita orogeny exposed the Hunton for a sufficient time to allow for erosion and secondary porosity development in both the Bois d'Arc and underlying strata (London, 1973).

Gulf 1 Streeter Well

The USGS acquired the Gulf 1 Streeter core from the Oklahoma Geological Survey in the summer of 2008; it was received in the USGS Core Research Center in Lakewood, Colorado. The core was slabbed, and half was retained by the USGS Core Research Center for study and sampling, with the other half returned to the Oklahoma Petroleum Information Center. The core had been handled extensively over the past 6 decades; as a result, the condition was mediocre to poor, making it difficult to identify some of the contacts that were previously described and published.

The Gulf 1 Streeter well was drilled and cored in 1945. It is located in Oklahoma County in the southern half of West Edmond field, proximal to and on the downthrown block of the fault bounding the western side of the Nemaha uplift (Figure 2). The cored interval is from 6875 to 7301 ft (2095–2225 m), penetrating and retaining the basal Woodford Shale, most of the Hunton Group, and the top of the underlying Sylvan Shale (Figure 5). From this well, 324 ft (99 m) of the Hunton Group was recovered, including a petroleum productive interval from 6943 to 7062 ft (2116–2152 m).

The core was extensively studied by Amsden and Rowland (1971), and their biostratigraphic work indicated that zones of highest porosity in the upper part of the Hunton Group may be in the Frisco Limestone. The biostratigraphic control in the Gulf 1 Streeter well is excellent; typical Frisco brachiopods are present at 7041 ft (2146 m), and *Kirkidium* biofacies help to definitively identify the underlying Henryhouse Formation (Amsden and Rowland, 1971; Figure 5). A conflict exists between the biostratigraphic work of Amsden (1975) and the stratigraphic work done by Swesnik (1948), who suggested that the uppermost Hunton, including the Frisco Limestone, had been eroded in the area of Gulf 1 Streeter.

Amsden and Rowland (1971) indicated that the Frisco Limestone is present in the southern and western parts of West Edmond and is distinguished from the underlying Bois d'Arc Limestone by biostratigraphic data and a coarsely crystalline texture. The Bois d'Arc is absent in the area of the Gulf 1 Streeter well, possibly related to the loss of the section by progressive marine onlap by a transgressing sea. The Bois d'Arc is a lateral facies equivalent of the Haragan Shale (Figures 3, 4) and confined to south and central Oklahoma. The Woodford Shale was identified in the core by its dark gray to dark brown color and its fine-grained, nonfissile nature. The formation is approximately 40 ft (12 m) thick in the area of the Gulf 1 Streeter well, based on well logs. A variety of facies is present in the Hunton Group section, including skeletal packstones and wackestone and crinoidal grainstone with visible porosity in the Frisco Limestone. The *Kirkidium* biofacies is confined to the Silurian strata between the Chimneyhill subgroup and the Frisco Limestone (Figure 3). A distinct 4-ft (1.2-m)–thick oolitic grainstone bed at 7051 to 7055 ft (2149–2150 m) exists (Figure 5). The underlying Chimneyhill subgroup is dominated by skeletal packstones and wackestones that are burrowed and less porous than the Frisco Limestone. Three feet of the underlying Sylvan Shale were recovered and are green gray and fissile.

Petrographic examination shows a variety of textures and pore types. The Frisco Limestone porosity in Gulf 1 Streeter is typically inter- and

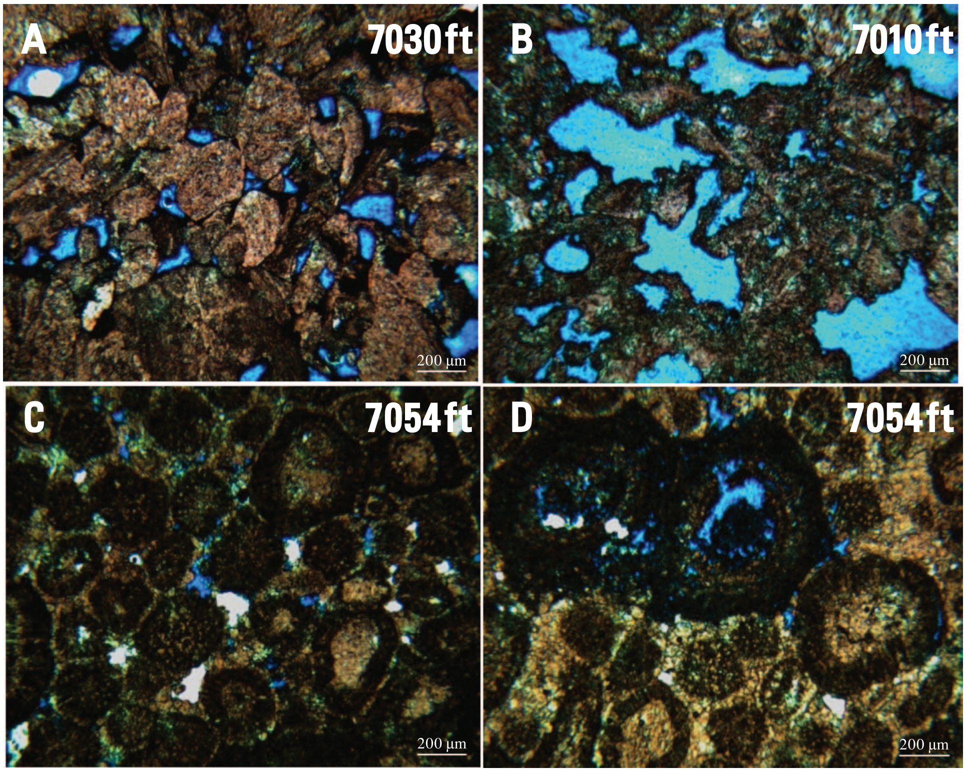


Figure 6. Plane-light photomicrographs from the Gulf 1 Streeter core. Images show the different pore types present in the well: interparticle porosity in a skeletal packstone in the Frisco Limestone (A); vuggy pores in the Frisco Limestone (B); interparticle porosity in an ooid grainstone in the Chimneyhill subgroup (C); and intraparticle porosity in the same ooid bed (D).

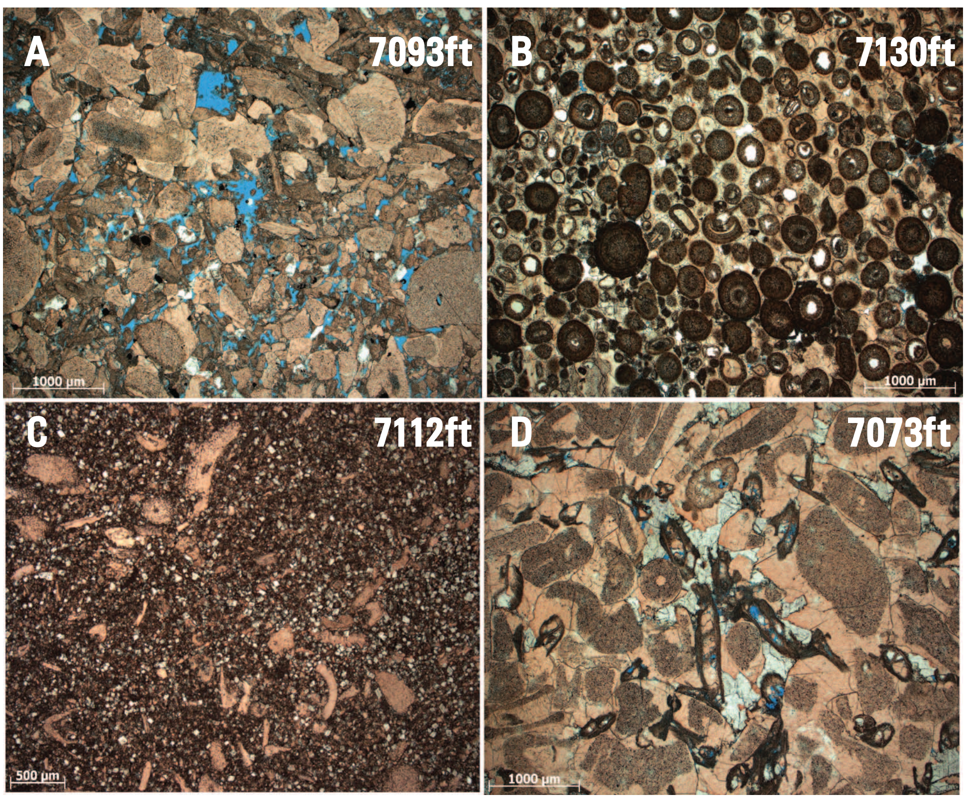


Figure 7. Plane-light photomicrographs from the Chesapeake 1-24 West Edmond SWD. Images show the different pore types present in the well and the increased dolomitization in the northern part of the field: interparticle and vuggy porosity in a skeletal packstone (A); interparticle porosity in an ooid grainstone (B); partial replacement of the matrix by euhedral dolomite crystals (C); intraparticle porosity with partial cementation by saddle dolomite (D). Images are courtesy of Chesapeake Energy Corporation.

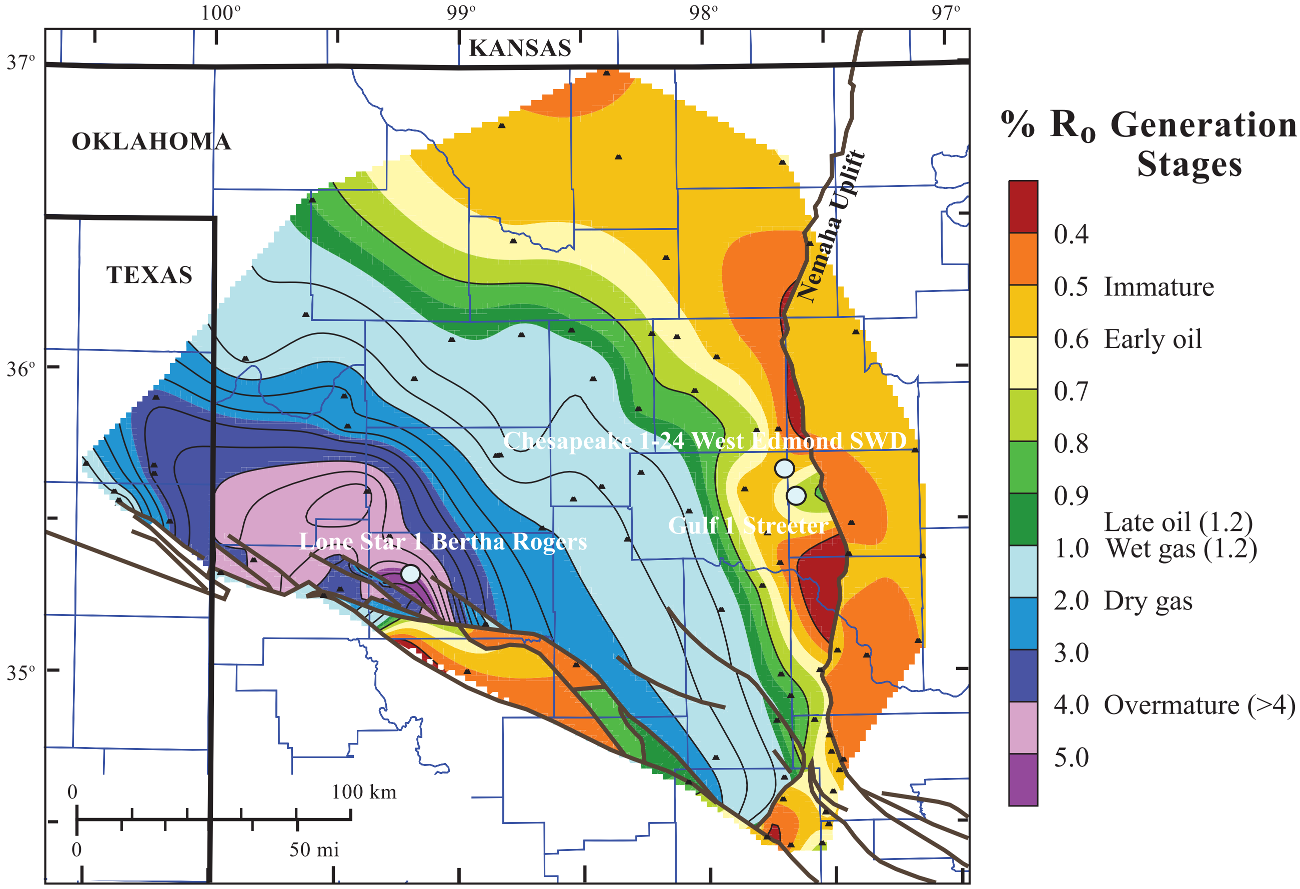


Figure 8. Vitrinite reflectance (R_o) data for the Woodford Shale. Contour interval is 0.4% R_o. Generation stages on the R_o legend are generalized because gas generation occurs within the oil generation range. Black triangles and white dots include R_o data from Cardott (1989, 2011 personal communication), Price (1997), and M. Pawlewicz (2010, personal communication). Brown lines indicate faults in the underlying Hunton Group (Rottmann, 2000b).

intraparticle, with moldic and diagenetic vuggy porosity (Figure 6). In both the Frisco Limestone and Chimneyhill subgroup, solution-enlarged fractures are common. The oolitic bed exhibits intergranular as well as intraparticle porosity (Figure 6C, D). Secondary porosity in the Frisco Limestone formed during subaerial exposure in the Early and Middle Devonian, which contributed substantially to its reservoir quality.

Diagenetic Alteration in West Edmond Field

Traps and reservoirs are commonly diagenetic within the Hunton. Porosity traps can be in the same unit in which secondary dissolution or diagenesis has enhanced or decreased porosity and permeability. Furthermore, facies changes, as well as variable dolomitization, impact reservoir development. Also, based on analysis of thin sections in the West Edmond field, a dual porosity system may be enhancing reservoir quality in certain beds of the Hunton Group.

Two Chesapeake Energy Corporation cores were examined as part of this study; this operator is focusing on infill drilling of the field, with both horizontal and vertical wells (IHS Energy Group, 2011). Production is from the upper and lower Hunton and is concentrated in the northern part of the field, north of the incised channel (Figure 2). The 1-1H Thomas and 1-24 West Edmond wells are both located in the northern half of the field, with the former located to the northwest of the field (Figure 2). Pore types in the Chesapeake wells are similar to those in the southern field in Gulf 1

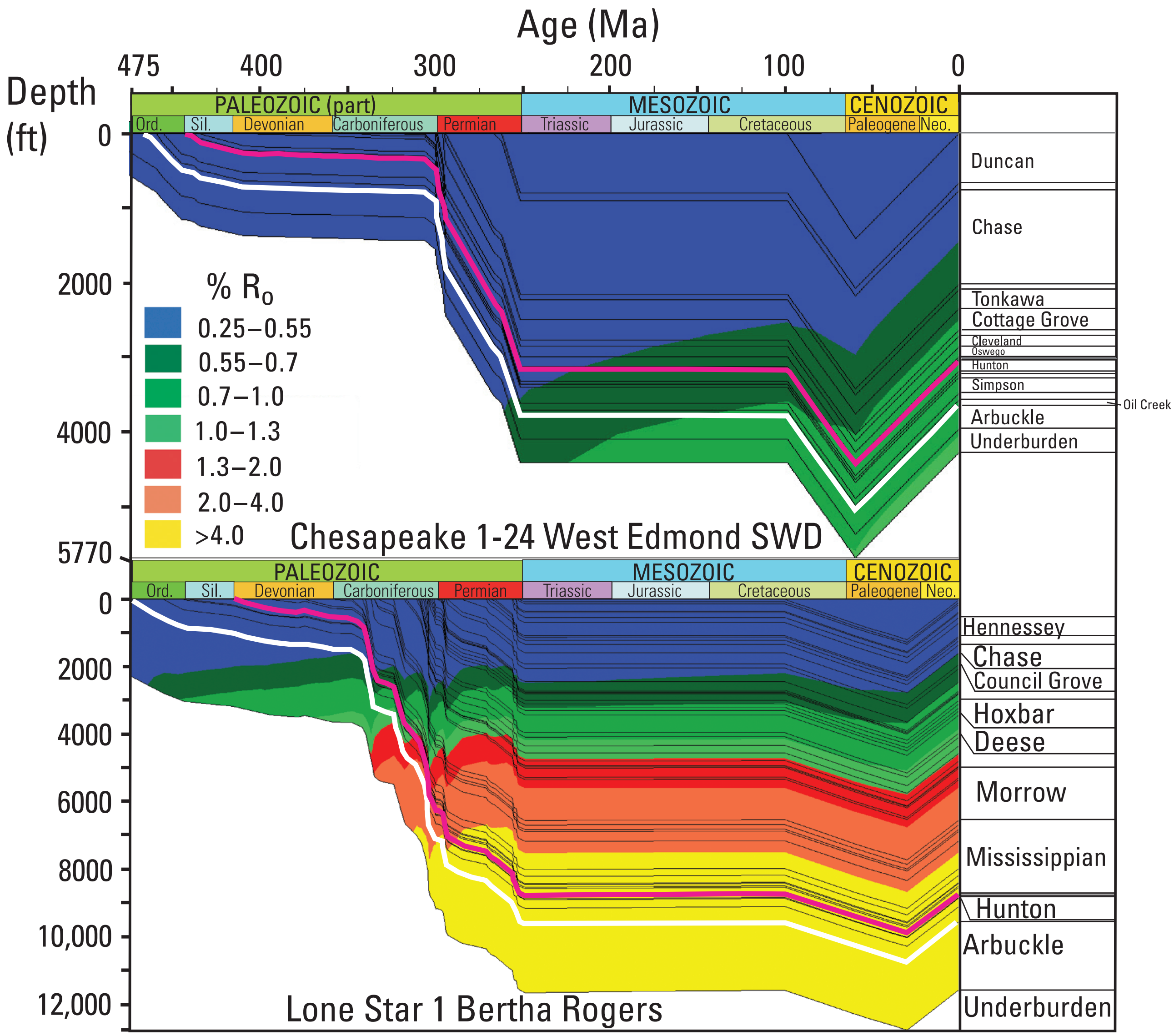
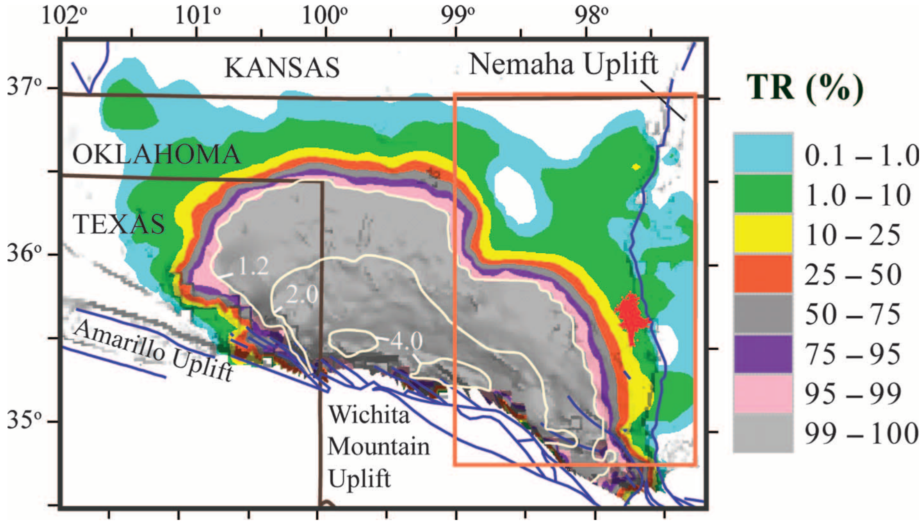


Figure 9. Burial history curves for the Lone Star 1 Bertha Rogers and Chesapeake 1-24 West Edmond SWD wells (Figure 8). Modeled vitrinite reflectance (R_o) through time includes heat flow of 70 mW/m^2 to 260 Ma, followed by 40 mW/m^2 for Lone Star 1 Bertha Rogers and 50 mW/m^2 for Chesapeake 1-24 West Edmond SWD. White and pink lines follow the upper part of the Arbuckle Group and Woodford Shale, respectively. Ord. = Ordovician; Sil. = Silurian; Neo. = Neogene.

Streeter (Figure 7). Intraparticle porosity is present in skeletal grainstones and packstones, there is vuggy porosity, and moldic pores. The ooid grainstone bed observed in the Streeter well is continuous into the northern part of the field and correlated into the 1-24 West Edmond well, where it increases in thickness to 8 ft (2 m).

Dolomitization increases in the northern part of the field; dolomite is present both in the matrix and as coarse cement that may suggest some degree of hydrothermal alteration, possibly related to fluid movement along the Nemaha uplift (Figure 7). Very little dolomite was observed in the southern half of the field. West Edmond is unique from other Hunton fields in Oklahoma in that production is primarily from limestone, whereas other Hunton fields are mostly dolomitized, a process that increases reservoir quality through porosity enhancement in these fields. Dolomitization in West Edmond is sporadic, and does not appear to

Figure 10. Transformation ratios (% TR) on the Woodford Shale layer from the four-dimensional petroleum system model. The West Edmond field (red) is within the area thermally mature for oil generation from the Woodford Shale based on 0.1% TR onset, 50% peak, and 99% completion of oil generation. White lines indicate modeled vitrinite reflectance of 1.2% end of oil generation, 2% start of dry gas, and 4% end of gas generation. The inset map (brown line) shows the petroleum migration study area (Figure 11). Faults (dark blue) are on the underlying Hunton Group (modified from Rottmann, 2000b) and Precambrian (Adler et al., 1971). The three-dimensional rendering results in variable shading within contours. Major structures are labeled.



have a substantial impact on the porosity development or the reservoir quality of the field.

WOODFORD SHALE SOURCE ROCKS

Description and Parameters

The Woodford Shale unconformably overlies the Hunton Group and is the primary petroleum source rock for Hunton reservoirs on the basis of geochemical analyses (Burruss and Hatch, 1989; Cardott, 1989) and four-dimensional (4-D) modeling. It is also a probable source for many of the lower Paleozoic reservoirs throughout the basin (Figure 3). The strata are organic rich, with abundant type A, type I (*Tasmanite alginite*) and amorphous type II kerogen, and minor type III kerogen (vitrinite) (Lewan, 1983; Crossey et al., 1986; Thompson and Dembicki, 1986; Comer and Hinch, 1987; Burwood et al., 1988; Krystyniak and Paxton, 2006). Burruss and Hatch (1989) showed the total organic carbon content of the formation in the Anadarko Basin to be as much as 14 wt. %. Measured (Figure 8) and modeled vitrinite reflectance (R_o) across the basin indicates that the Woodford is mature to overmature for oil and gas generation in most of the Oklahoma and Texas parts of the basin (Higley, 2011). The hydrocarbons likely migrated from the deep basin into Hunton reservoirs, although some indications exist, from one-dimensional (1-D) burial history models and measured R_o values, that the Woodford is marginally mature to mature for oil generation along the Nemaha uplift on the eastern edge of the basin as well, in the area of the West Edmond field (Figure 9). Note that some contribution of Ordovician oil into the Hunton reservoirs may also exist (J. Hatch, 2010, personal communication).

One-dimensional burial history models generated using PetroMod™ v. 10.0 on two wells in the basin, the 1 Bertha Rogers and the 1-24 West Edmond SWD (Figure 8), indicate that the onset of petroleum generation from Woodford source rocks in the deep basin was approximately 335 Ma. This was based on the modeling of the 1 Bertha Rogers well using variable heat flow through time and a transformation ratio (TR) of 0.1 and 0.55% R_o (Figure 9). The same parameters for the 1-24 West Edmond SWD well indicate that the onset of oil generation was at approximately 225 Ma for the Woodford Shale. Completion of oil generation for the 1 Bertha Rogers well was at approximately 310 Ma, and the 1-24 West Edmond SWD well is currently in the main oil generation window. Vitrinite reflectance data used to calibrate these models were from Cardott (1989) and Price (1997), and as provided by Chesapeake Energy Corporation.

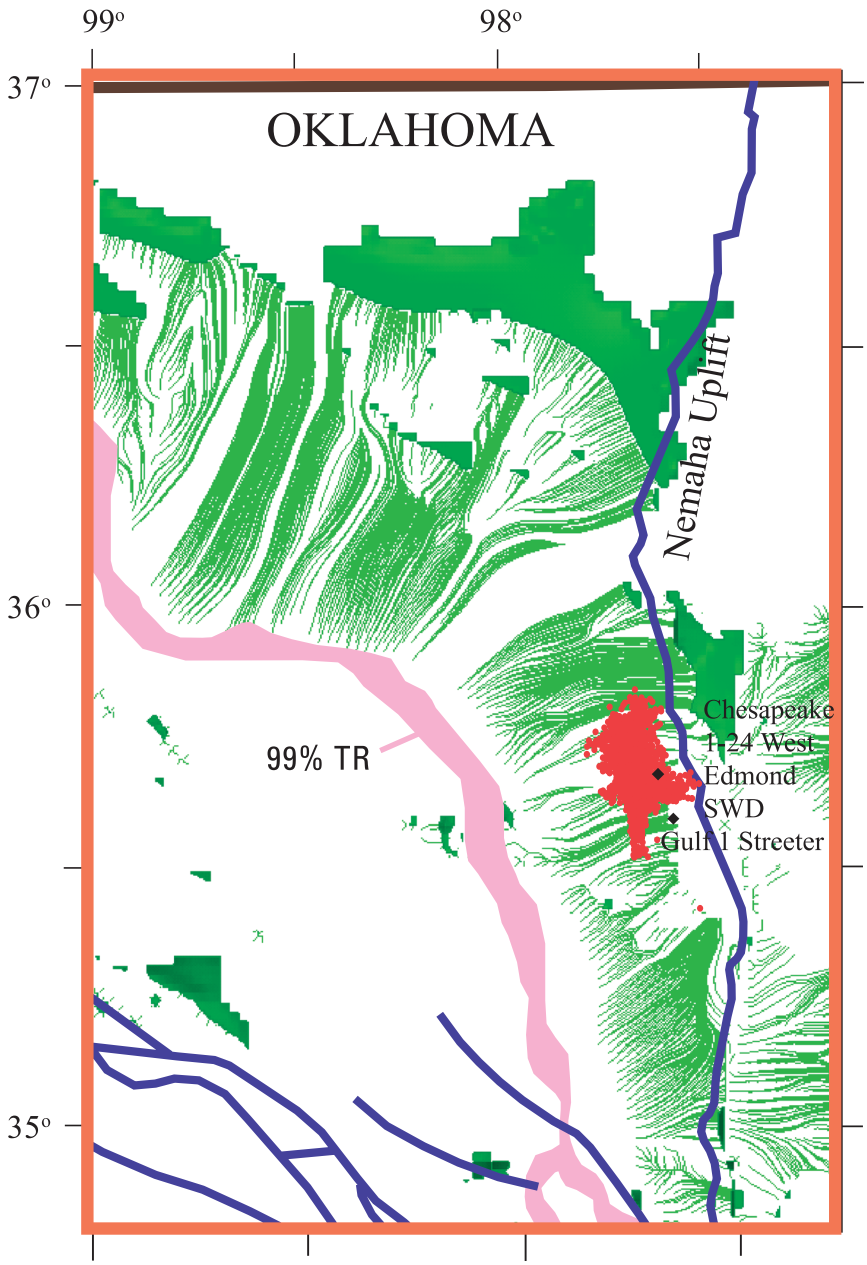


Figure 11. Present-day flow paths (green lines) radiate outward from the deep basin. Red dots indicate the West Edmond field, and black diamonds indicate Chesapeake 1-24 West Edmond SWD (north) and Gulf 1 Streeter (south) wells. Downdip limit of migration corresponds approximately to the 99% transformation ratio (TR) from the overlying Woodford Shale, which represents completion of oil generation. Blue lines indicate faults on the Hunton Group from Rottmann (2000b). Modeled accumulations of oil and gas (dark green) are trapped on structures by the updip limit of the facies against structures such as bounding faults of the Nemaha uplift or by the northern termination of the Hunton Group.

Petroleum System Model of the Hunton Accumulations

A 4-D petroleum system model of the Anadarko Basin was created using PetroMod® v. 11.3 software (Schlumberger, 2011). It consists of more than 30 grids that include Precambrian to present surfaces, erosional isopachs, basement heat flow, and Woodford Shale total organic carbon layers. One-dimensional and 4-D PetroMod® models were calibrated to Woodford Shale using (1) R_o data from Cardott (1989), Price (1997), and two wells in the Edmond West field (Chesapeake Energy Corporation, 2009, written communication; M. Pawlewicz, 2010, written communication); (2) temperature data from Carter et al. (1998), Gallardo and Blackwell (1999), and Price (1997); and (3) drillstem tests and corrected borehole temperatures. Burruss and Hatch (1989) indicated that there may be several petroleum source rocks within the basin but suggested minimal mixing among the following three types: Middle Ordovician Simpson Group, Silurian

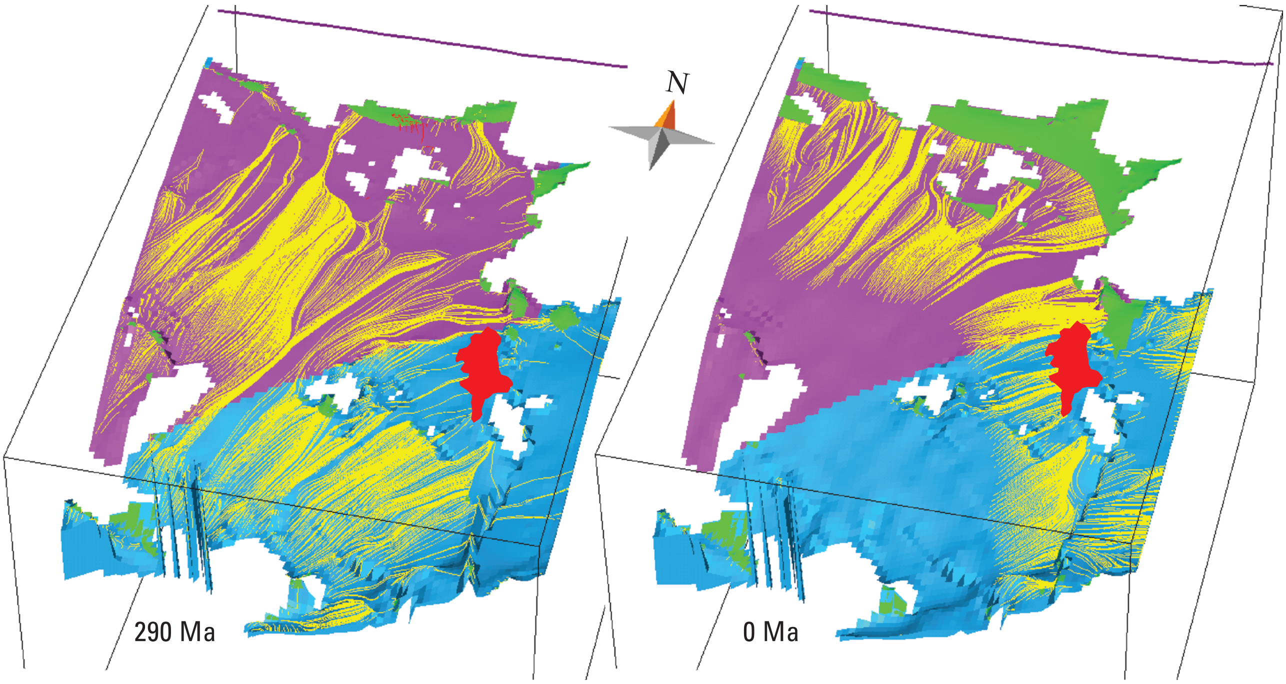


Figure 12. These rotated and tilted three-dimensional images are modeled oil migration flow paths (yellow lines) at 290 Ma and at present on the Hunton Group layer. Green areas indicate modeled petroleum accumulations. Migration flow paths (yellow lines) originated near the basin axis at 290 Ma and progressed up the flank of the basin through time. Generalized location of the West Edmond field is in red. Dolomite (purple) and limestone (blue) are modeled Hunton lithofacies from Howery (1993). Dolomite generally has greater permeability, porosity, and number of accumulations than the limestone. Peak oil generation from the Woodford Shale was from approximately 310 to 230 Ma. Views are 10× vertical exaggeration.

to Mississippian source rocks, and organic-rich Pennsylvanian strata. For the modeled source rock layers for the 4-D model of the West Edmond field, these are represented by the Ordovician Oil Creek Formation of the Simpson Group, Devonian-Mississippian Woodford Shale, and informal Atokan Thirteen Finger limestone layer, respectively.

Hydrocarbon generation through time was modeled using vitrinite reflectance (Sweeney and Burnham, 1990) and Woodford Shale hydrous pyrolysis kinetics (Lewan, 1983, 1985; Lewan and Ruble, 2002). Kerogen types are similar for the three assigned source intervals listed above. The Ordovician Simpson Group contains mainly oil-prone source intervals of types I and II kerogen based on Rock-Eval pyrolysis results (Burruss and Hatch, 1989; Rice et al., 1989). Wang and Philip (1997) indicated that the Woodford petroleum source rock is mostly type II kerogen based on Rock-Eval pyrolysis. Atokan petroleum source rocks are mainly types II and III kerogen (Rice et al., 1989).

The Woodford Shale in the West Edmond field is thermally mature for oil generation based on modeled TR (Figure 10). However, measured R_o values are more variable; for example, R_o measurements around the field by Cardott (1989) range from approximately 0.46% to 0.53%, less than the R_o of 0.6% and greater, which commonly marks the start of oil generation. However, Cardott (1989) also indicated that R_o values less than 1.3% were suppressed in the Woodford Shale. Scatter in R_o data and calibration problems can result from suppressing the reflectance of vitrinite macerals by liptinite macerals that are present in the Woodford Shale. Suppression would result in the level of thermal maturation being greater than is indicated by the measured R_o. Measured mean random R_o is greater in the West Edmond field, from the 1-24 West Edmond SWD (0.83% R_o) and Gulf 1 Streeter

(0.75% R_o) wells, but these elevated values relative to surrounding ones by Cardott (1989) are also influenced by the Woodford Shale mixed macerals, sample quality, and analysis.

Oil and gas generation in the Anadarko Basin began in the deep basin of southern Oklahoma and eastern Texas at approximately 370 Ma for the Oil Creek Formation, 335 Ma for the Woodford Shale, and 300 Ma for the informal Thirteen Finger limestone; petroleum migration was primarily radially outward from the deep basin (Higley, 2011). Figure 10 shows modeled TRs and R_o contours on the Woodford Shale layer. The extent and thickness of the Woodford Shale within the layer is illustrated in Higley (2011). Most of the modeled Hunton petroleum accumulated along the northern terminus of the formation against the sealing Woodford Shale and Mississippian layers (Figure 11). Hunton Group extent and lithofacies are shown in Figure 12. The dolomite generally has greater permeability and porosity than the limestone, and the flow path modeling shows greater accumulation in the dolomite facies, along the present subcrop. The Woodford Shale is the present-day primary source for Hunton Group accumulations, as shown in Figures 11 and 12, with approximately 83% of the petroleum; the remainder is sourced from the Oil Creek layer. The area south of 36° latitude is sourced approximately 96% from the Woodford and 4% from the Oil Creek.

CONCLUSIONS

Multiple carbonate facies and pore types in the upper Hunton Group of West Edmond field exist. The heterogenous nature of the carbonate facies and their porosity conditions have had a large effect on reservoir properties, especially in areas where secondary dissolution has enhanced porosity and permeability of limestones in the upper part of the Hunton Group. Vuggy porosity, the result of secondary dissolution in skeletal packstones, and preserved primary porosity in ooid grainstones are observed in the north and south of the channel that cuts through the center of West Edmond field. Significant vertical and horizontal variability in the porosity over short distances is common, contributing to reservoir heterogeneity and the potential success of horizontal infill wells.

The Woodford Shale in West Edmond field is mature for oil generation, based on 1-D and 4-D modeling, and measured vitrinite reflectance, suggesting some self-sourcing of reservoirs in the formation. Oil and gas also likely migrated into the field from the southwest, from the deep Anadarko Basin.

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