Geologic Assessment of Undiscovered Conventional Oil and Gas Resources in the Lower Paleogene Midway and Wilcox Groups, and the Carrizo Sand of the Claiborne Group, of the Northern Gulf Coast Region

Open-File Report 2017–1111

U.S. Department of the Interior
U.S. Geological Survey

Geologic Assessment of Undiscovered Conventional Oil and Gas Resources in the Lower Paleogene Midway and Wilcox Groups, and the Carrizo Sand of the Claiborne Group, of the Northern Gulf Coast Region

By Peter D. Warwick

Open-File Report 2017–1111

U.S. Department of the Interior
U.S. Geological Survey

U.S. Department of the Interior
RYAN K. ZINKE, Secretary

U.S. Geological Survey
William H. Werkheiser, Acting Director

U.S. Geological Survey, Reston, Virginia: 2017

For more information on the USGS—the Federal source for science about the Earth, its natural and living resources, natural hazards, and the environment—visit https://www.usgs.gov or call 1–888–ASK–USGS.

For an overview of USGS information products, including maps, imagery, and publications, visit https://store.usgs.gov.

Suggested citation:
Warwick, P.D., 2017, Geologic assessment of undiscovered conventional oil and gas resources in the lower Paleogene Midway and Wilcox Groups, and the Carrizo Sand of the Claiborne Group, of the northern Gulf Coast region: U.S. Geological Survey Open-File Report 2017–1111, 67 p., https://doi.org/10.3133/ofr20171111.

ISSN 2331-1258 (online)

Contents

Figures

Tables

Conversion Factors

Multiply	By	To obtain
	Length	
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
mile, nautical (nmi)	1.852	kilometer (km)
yard (yd)	0.9144	meter (m)
meters (m)	3.281	foot (ft)
kilometers (km)	0.6214	mile (mi)
	Volume	
barrel (bbl), (petroleum, 1 barrel=42 gal)	0.1590	cubic meter (m^3)
cubic foot (ft^3)	28.32	cubic decimeter (dm^3)
cubic foot (ft^3)	0.02832	cubic meter (m^3)

Geologic Assessment of Undiscovered Conventional Oil and Gas Resources in the Lower Paleogene Midway and Wilcox Groups, and the Carrizo Sand of the Claiborne Group, of the Northern Gulf Coast Region

By Peter D. Warwick

Abstract

The U.S. Geological Survey (USGS) recently conducted an assessment of the undiscovered, technically recoverable oil and gas potential of Tertiary strata underlying the onshore areas and State waters of the northern Gulf of Mexico coastal region. The assessment was based on a number of geologic elements including an evaluation of hydrocarbon source rocks, suitable reservoir rocks, and hydrocarbon traps in an Upper Jurassic-Cretaceous-Tertiary Composite Total Petroleum System (TPS) defined for the region by the USGS. Five conventional assessment units (AUs) were defined for the Midway (Paleocene) and Wilcox (Paleocene-Eocene) Groups, and the Carrizo Sand of the Claiborne Group (Eocene) interval including: (1) the Wilcox Stable Shelf Oil and Gas AU; (2) the Wilcox Expanded Fault Zone Gas and Oil AU; (3) the Wilcox-Lobo Slide Block Gas AU; (4) the Wilcox Slope and Basin Floor Gas AU; and (5) the Wilcox Mississippi Embayment AU (not quantitatively assessed).

The USGS assessment of undiscovered oil and gas resources for the Midway-Wilcox-Carrizo interval resulted in estimated mean values of 110 million barrels of oil (MMBO), 36.9 trillion cubic feet of gas (TCFG), and 639 million barrels of natural gas liquids (MMBNGL) in the four assessed units. The undiscovered oil resources are almost evenly divided between fluvial-deltaic sandstone reservoirs within the Wilcox Stable Shelf (54 MMBO) AU and deltaic sandstone reservoirs of the Wilcox Expanded Fault Zone (52 MMBO) AU. Greater than 70 percent of the undiscovered gas and 66 percent of the natural gas liquids (NGL) are estimated to be in deep (13,000 to 30,000 feet (ft)), untested distal deltaic and slope sandstone reservoirs within the Wilcox Slope and Basin Floor Gas AU.

Introduction

A primary mission of the U.S. Geological Survey (USGS) Energy Program is to conduct geologically based assessments of the undiscovered, technically recoverable quantities of oil and gas that have the potential to be added to the proved reserves in the United States. As part of the National Oil and Gas Assessment Project, these assessments are based on an integration and analysis of geologic elements such as hydrocarbon source rocks (source-rock maturation, hydrocarbon generation and migration), reservoir rocks (sequence stratigraphy and petrophysical properties), and hydrocarbon traps (trap formation and timing) within a total petroleum system (TPS) framework (Magoon and Dow, 1994; Schmoker and Klett, 2005; U.S. Geological Survey National Assessment Review Team, 2006). The last USGS assessment of the entire Gulf of Mexico coastal region was completed in 1995 (Schenk and Viger, 1996a,b; U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995). Since 1995, assessments of parts of the Jurassic and Cretaceous intervals in the Gulf coastal region were reported by Condon and Dyman (2006), Dyman and Condon (2006), and Pitman and others (2007). Recent USGS assessments in the Gulf of Mexico coastal region are updates of previous USGS assessments of the interval (Schenk and Viger, 1996a,b), and have focused on undiscovered resources in Paleogene and Neogene strata (Dubiel and others, 2007; Warwick and others, 2007a), and Jurassic and Cretaceous stratigraphic intervals (Dubiel and others, 2011).

In 2007, the USGS assessed undiscovered, technically recoverable conventional oil and gas resources and continuous coalbed gas resources in Cretaceous, Paleogene, and Neogene strata underlying the U.S. Gulf of Mexico Coastal Plain and State waters (figs. 1 and 2). State waters include those areas within 3 nautical miles of the coastline, except in Texas where State waters are within 9 nautical miles of the coastline. Thirty-three conventional assessment units for the Paleogene to Neogene interval were identified and assessed by the USGS (table 1). Four Cretaceous to Paleogene continuous (coalbed gas) assessment units were also assessed. The results of the assessment of the conventional and continuous resources can be found in USGS Fact Sheets by Dubiel and others (2007) and Warwick and others (2007a). The purpose of this paper is to describe the geological concepts, models, TPS, and assessment units developed for the 2007 assessment of the remaining technically recoverable oil and gas resources to be found in the onshore and State water portion of the lower Paleogene Midway (Paleocene) and Wilcox (Paleocene to Eocene) Groups, and the Carrizo Sand of the Claiborne Group (Eocene) stratigraphic section in the Gulf of Mexico coastal region (figs. 1 and 2). For descriptive purposes the Midway and Wilcox Groups and the Carrizo Sand of the Claiborne Group will collectively be referred to as the lower Paleogene assessment interval in this paper.

The Gulf of Mexico Basin is one of the major hydrocarbon-producing areas of the world (Nehring, 1991; Horn, 2003). The U.S. Energy Information Administration estimates that in 2004, about 19 percent of the Nation's producible gas reserves and about 6 percent of the Nation's oil reserves were found in onshore Gulf of Mexico reservoirs (Budzik, 2006). For a recent summary of the offshore reserves in the Federal outer continental shelf of the Gulf of Mexico region, refer to Crawford and others (2006) and French and others (2006). The recent onshore discovery of coalbed gas in Cretaceous and Paleocene strata identifies new petroleum systems not recognized in previous USGS assessments for the Gulf of Mexico coastal region.

Regional Geologic and Structural Setting

The Gulf of Mexico Basin is a generally circular structural and topographic depression that contains up to 60,000 ft of strata ranging in age from Late Triassic to Holocene (Ewing, 1991a; Nelson and others, 2000). The structural and stratigraphic setting of the northern Gulf of Mexico Coastal Plain has been well documented by previous studies (Murray, 1961; Salvador 1991; Ewing, 1991a; Cao and others, 1993; Zimmerman, 1995; Hosman, 1996; Galloway and others, 2000; Stephens, 2001). Figure 1 shows the major structural features of the U.S. onshore region of the Gulf of Mexico Coastal Plain. Strata in the Gulf of Mexico coastal region generally dip into the basin, except where local deformation occurs around structural uplifts, subbasins, faults, and folds. At different depths across the basin, strata exhibit overpressure and abnormal temperature conditions that can complicate hydrocarbon production (Dickinson, 1953; Riggs and others, 1991; Leftwich, 1993; Leftwich and Engelder, 1994; Engelder and Leftwich, 1997; Hunt and others, 1998; Flemings and others, 2000).

Table 1. Assessment units of the 2007 U.S. Geological Survey assessment of Tertiary strata of the northern Gulf Coast.

Interval on figure 2	Assessment unit name	Assessment unit number
1	Wilcox Stable Shelf Oil and Gas	50470116
1	Wilcox Expanded Fault Zone Gas and Oil	50470117
1	Wilcox Slope and Basin Floor Gas	50470118
1	Wilcox-Lobo Slide Block Gas	50470119
2	Lower Claiborne Stable Shelf Gas and Oil	50470120
2	Lower Claiborne Expanded Fault Zone Gas	50470121
2	Lower Claiborne Slope and Basin Floor Gas	50470122
2	Lower Claiborne Cane River	50470123
2	Upper Claiborne Stable Shelf Gas and Oil	50470124
2	Upper Claiborne Expanded Fault Zone Gas	50470125
2	Upper Claiborne Slope and Basin Floor Gas	50470126
3	Jackson Stable Shelf Oil and Gas	50470127
3	Jackson Expanded Fault Zone Gas and Oil	50470128
3	Jackson Slope and Basin Floor Gas	50470129
3	Jackson Louisiana-Mississippi-Alabama Area	50470130
3	Vicksburg Stable Shelf Oil and Gas	50470131
3	Vicksburg Expanded Fault Zone Gas and Oil	50470132
3	Vicksburg Slope and Basin Floor Gas	50470133
3	Vicksburg Mississippi-Alabama Area	50470134
	Continued	
4	Frio Stable Shelf Oil	50470135
4	Frio Expanded Fault Zone Oil and Gas	50470136
4	Frio Slope and Basin Floor Gas	50470137
4	Anahuac Gas	50470138
4	Hackberry Oil and Gas	50470139
5	Lower Miocene Shelf Oil and Gas	50470140
5	Lower Miocene Slope and Basin Gas	50470141
5	Middle Miocene Shelf Oil and Gas	50470142
5	Middle Miocene Slope and Basin Gas	50470143
5	Upper Miocene Shelf Oil and Gas	50470144
5	Upper Miocene Slope and Basin Gas	50470145
6	Plio-Pleistocene Shelf Oil and Gas	50470146
1	Wilcox Mississippi Embayment	50470147
4	Frio Basin Margin	50470148
C1	Cretaceous Olmos Coalbed Gas	50470281
C1	Rio Escondido Basin Olmos Coalbed Gas	53000281
C2	Wilcox Coalbed Gas	50470381
C3	Cretaceous-Tertiary Coalbed Gas	50470481

Structural Setting

The lower Paleogene Wilcox Group crops out around the northern edge of the Gulf of Mexico Basin (fig. 3). Structural contours drawn on the top of the Wilcox Group show that Wilcox strata dip southward at variable rates into the basin. The dip rate is gentle near the outcrop belt and within the Mississippi embayment and is moderate to substantial near the present-day coastline. Note that the southern boundary of the Mississippi embayment is somewhat arbitrary as shown on figure 3. A major increase in the rate of dip is observed as the Wilcox Group crosses over the Lower Cretaceous shelf margin which roughly lies between the -5,000 and -10,000 ft contours on figure 3.

The local structure of these lower Paleogene sedimentary units is influenced by flow of the Jurassic Louann Salt (fig. 2) and movement along local and regional fault systems. A detailed discussion of the structural setting of the lower Paleogene strata can be found in Ewing (1991a) and Salvador (1991). Maps showing the location of salt structures in the Gulf of Mexico Basin are found in Ewing and Lopez (1991) and Lopez (1995). Evacuation and allochthonous flow of the Louann Salt due to sedimentary loading has had a dramatic influence on the petroleum geology of the Gulf of Mexico Basin (Ewing, 1991a,b; McBride, 1998; McBride and others, 1998; Stover and others, 2001). In particular, the growth and emplacement of salt diapirs leads to the creation of complex structures which serve as petroleum migration pathways and traps (Halbouty, 1979). Stratigraphic units around salt dome margins are faulted by salt intrusion, creating fault traps, and are dragged upwards at the salt-rock contact, creating combination traps and accentuating stratigraphic traps. In the salt basins, diapirs frequently are aligned on major growth-fault trends suggesting that preexisting domes influence the initiation of faults and tend to control their location (Winker, 1982).

Stratigraphy and Depositional Systems

The lower Paleogene assessment interval is composed of the Midway and Wilcox Groups, and the Carrizo Sand of the Claiborne Group (fig. 2). The Midway Group is primarily composed of marine shale that is interbedded with a few local sandstone and limestone beds (Galloway and others, 1991, 2000). The unit was first defined by Harris (1894) from exposures at Midway Landing, southwest Alabama. The Midway Group is usually undifferentiated in the subsurface, however, locally multiple subunits of the Midway Group have been defined (table 2). Some oil and gas production does occur from Midway sand-rich intervals in southern Texas (such as the Poth sand, see table 3) (Palmer, 1954; Hopf, 1965, 1967, 1986a,b; Nehring, 1991). Because of the low number of Midway fields (9 fields, Nehring Associates, Inc., 2006), and limited production, the Midway Group is combined with the Wilcox Group and Carrizo Sand to form one lower Paleogene assessment interval.

The Wilcox Group is the primary oil and gas producer for the lower Paleogene assessment interval, with more than 1,200 known oil and gas fields (Nehring Associates, Inc., 2006). Thickness of the Wilcox Group ranges from less than 1,000 ft near the outcrop to over 7,000 ft in the Rio Grande embayment of south Texas (figs. 1 and 4). The Wilcox Group is composed of fluvial and deltaic coal-bearing facies consisting of sandstone, siltstone, mudstone, claystone, limestone, and coal intervals that become dominated by marine facies beyond the Lower Cretaceous shelf margin (Galloway and others, 1991, 2000). Recent exploration south of the modern outer continental shelf in the deep-water areas of the Gulf of Mexico indicates that thick sand-rich facies extend several hundred miles into the deepest part of the basin (Meyer and others, 2005). The Wilcox Group has multiple stratigraphic names and subunits that are used across the basin (table 2). In addition, table 3 lists informal field names and numerous driller's terms for the lower Paleogene assessment interval.

Depositional settings for Wilcox Group strata in the landward, stable shelf areas of the basin, have been interpreted to be prograding fluvial-deltaic systems with alluvial plain and deltaic peat mire environments (Murray, 1961; Fisher and McGowen, 1967; Galloway, 1968; Cleaves, 1980; Coates and others, 1980; Hamlin, 1983, 1988; Galloway and others 1991, 2000; Tye and others, 1991; Mancini and others, 1993; Glawe, 1995; Kinsland and others, 2003; Kull and Kinsland, 2006). Basinward of the Wilcox paleo-shelf break, the deltaic sediments merge with distal shelf, slope, and basin floor sediments (Galloway and others, 1991, 1994, 2000).

The basal Carrizo Sand of the Claiborne Group (fig. 2) was combined with the Wilcox and Midway Groups to form the lower Paleogene assessment interval primarily because the Carrizo interval is usually included with the Wilcox Group in drilling history and reservoir unit databases (IHS, 2005a,b; Nehring Associates, Inc., 2006). The Carrizo Sand crops out in Mexico, Texas, and Louisiana, and disconformably overlies the upper part of the Wilcox Group (Stenzel, 1940; Harris, 1962; Breyer, 1997). Galloway and others (2000) describe the Carrizo Sand as a late Wilcox-type delta-building sequence that was located primarily in south Texas. However, other studies have recognized the Carrizo Sand as a prominent subsurface sand-rich interval across much of the Gulf coastal region (Baker, 1979; Coates and others, 1980; Hamlin, 1983; Stoudt and others, 1990; Bellamy and Breyer, 2002).

Table 2. Alternate formal group, formation, or member names for the Midway and Wilcox Groups, and the Carrizo Sand of the Claiborne Group.

[States where these names are used are in parentheses. Data from U.S. Geological Survey (2008) National Geologic Map Database, Geolex: http://ngmdb.usgs.gov/Geolex/. Asterisks (*) indicate usage by the U.S. Geological Survey. Other usages by State geological surveys]

Name of group, formation, or member
Midway Group
Clayton Formation of the Midway Group (Ala.*, Ark.*, Ga.*, Ill.*, Ky.*, La.*, Mo.*, Miss.*, Tenn.*)
Clayton Limestone of the Midway Group (Miss.)
Kincaid Formation of the Midway Group (Ark.*, La.*, Tex.*)
Logansport Formation of the Midway Group (Tex.)
Matthews Landing Marl Member of Porters Creek Formation (Ala.*, Miss.*)
Naheola Formation of the Midway Group (Ala.*, Miss.*)
Porters Creek Clay of the Midway Group (Ala.*, Ark.*, Ill.*, Ky.*, La.*, Mo.*, Miss.*, Tenn.*, Ga.*)
Wills Point Formation of the Midway Group (Tex.)
Wilcox Group
Ackerman Formation of Wilcox Group (Ala., Miss., Tenn., Mo.)
Baker Hill Formation of Wilcox Group (Ga., Ala.*)
Bashi Formation of Wilcox Group (Ala.*, Fla.*, Ga.*, Miss.*)
Berger Formation of Wilcox Group (Ark.*)
Caldwell Knob Member of Rockdale Formation of Wilcox Group (Tex.)
Calvert Bluff Formation of Wilcox Group (Tex.)
Carrizo Sand of Claiborne Group (Ark.*, La.*, Tex.*)
Carrizo Formation of Wilcox Group (Tex.)
Converse Formation of Wilcox Group (La.)
Cow Bayou Formation of Wilcox Group (La.)
Detonti Sand of Wilcox Group (Ark.*)
Dolet Hills Formation of Wilcox Group (La.*)
Fearn Springs Formation of Wilcox Group (Miss.)
Fearn Springs Member of Nanafalia Formation (Miss.*)
Flour Island Formation of Wilcox Group (Mo.*, Tenn.*)
Fort Pillow Sand of Wilcox Group (Mo.*, Tenn.*)
Hall Summit Formation (La.)
Wilcox Group—Continued
Hatchetigbee Formation (Ala.*, Fla.*, Ga.*, Miss.*)
High Bluff Member of Pendleton Formation of Wilcox Group (La., Tex.)
Holly Springs Formation of Wilcox Group (Mo.)
Hooper Formation of Wilcox Group (Tex.)
Indio Formation of Wilcox Group (Tex.*)
Lime Hill Formation of Wilcox Group (La.)
Logansport Formation of Wilcox Group (La.)
Marthaville Formation of Wilcox Group (La., Tex.)
Mayous Bayou Member of Hall Summit Formation of Wilcox Group (La.)
Naborton Formation of Wilcox Group (Tex., La.*)
Nanafalia Formation of Wilcox Group (Ala.*, Ga.*, Miss.*)
Old Breastworks Formation of Wilcox Group (Tenn.*)
Pendleton Formation of Wilcox Group (La., Tex.)
Rockdale Formation of Wilcox Group (La.*, Tex.*)
Sabinetown Formation of Wilcox Group (La., Tex.*)
Saline Formation of Wilcox Group (Ark.*)
Salt Mountain Limestone of Wilcox Group (Ala., Ga.*)
Seguin Formation of Wilcox Group (La.*, Tex.*)
Simsboro Formation of Wilcox Group (Tex.)
Tuscahoma Formation of Wilcox Group (Ala.*, Ga.*, Miss.*)
Carrizo Sand of the Claiborne Group
Carrizo Sand of Claiborne Group (Ark.*, La.*, Tex.*)
Carrizo Formation of Claiborne Group (Tex.)
Carrizo Formation of Wilcox Group (Tex.)
Newby Sand Member of Reklaw Formation of Claiborne Group (Tex.)

Table 3. Some informal production unit and field names used for the lower Paleogene assessment interval.

[Lower Paleogene production unit names from IHS Energy Group (2005b) and Nehring Associates, Inc. (2006). Abbreviations: La., Louisiana; Miss., Mississippi; S., south; Tex., Texas]

Lower Paleogene production unit name	Assessment interval	References
4600 SD	Upper Wilcox (Miss.)	Dockery (2001)
Armstrong sand	Lower Wilcox (Miss.)	Holden (1951); Williams (1969)
Ashley sand	Lower Wilcox (Miss.)	Williams (1969)
Atrman	Lower Wilcox (Miss.)	Williams (1969)
Baker	Lower Wilcox (Miss.)	Williams (1969)
Bartosh (Bartosch Sand)	Lower Wilcox (Tex.)	Palmer (1954); Hargis (2000)
Campbell	Lower Wilcox	Williams (1969); Corcoran and others (1994)
Carrizo	Upper Wilcox	Hargis (2000)
Carrizo Wilcox	Upper Wilcox	Hargis (2000)
Deville Sand	Lower Wilcox (La Salle, La.)	Location and depth could be lower Wilcox; see Eversull (1984)
Falcon	Wilcox(?) Escobas field(?)	Meyerhoff and Braddock (1998)
Foster	Lower Wilcox (Miss.)	Williams (1969)
Freewoods	Lower Wilcox (Miss.)	Williams (1969)
French Fork	Lower Wilcox (La Salle, La.)	Location and depth could be lower Wilcox; see Eversull (1984)
Hinnant Upper	Upper Wilcox (S. Tex.)	Bornhauser (1979)
Hirsch	Lower Wilcox (S. Tex.)	Hargis (2000)
Lobo	Lower Wilcox (S. Tex.)	Long (1986)
Lobo1	Lower Wilcox (S. Tex.)	Long (1986)
Lobo6	Lower Wilcox (Hirsch, S. Tex.)	Long (1986)
Luling	Upper Wilcox (S. Tex.)	Hargis (2000)
Mackhank	Upper Wilcox (S. Tex.)	Hargis (2000)
Massive 2 sand (massive sand[?])	Upper Wilcox (S. Tex.)	Hargis (2000)
Mckittrick	Lower Wilcox (Miss.)	Williams (1969)
Miller	Lower Wilcox	Glawe and Echols (1997)
Minter A	Lower Wilcox (Miss.)	Williams (1969)
Nichols	Lower Wilcox (Miss.)	Glawe and others (1999); Williams (1969)
Pearline	Lower Wilcox (Miss.)	Williams (1969)
Poth sand	Midway (Tex.)	Palmer (1954); Hopf (1965, 1967)
Reagan	Upper Wilcox (S. Tex.)	Hargis (2000)
Roeder	Lower Wilcox (S. Tex.)	Hargis (2000)
Slick	Upper Wilcox (S. Tex.)	Hargis (2000)
Steinhauser	Carrizo	Ryman (1954)
Stewart B	Upper Wilcox (Miss.)	Williams (1969)
Stutson A Sand	Lower Wilcox(?) (Catahoula Parish, La.)	Location and depth could be lower Wilcox; see Eversull (1984)
Tew Lake	Lower Wilcox	Glawe and Echols (1997)
Walker	Lower Wilcox (Miss.)	Williams (1969)
Wilcox	Upper and lower Wilcox	Galloway and others (1991)
Wilcox 1	Upper Wilcox (Miss., La.)	Williams (1969); location and depth projects to be lower Wilcox; see Eversull (1984)
Wilcox 2	Upper Wilcox (Miss.)	Williams (1969)
Wilcox A	Upper Wilcox (Tex., La.)	Schenk and Viger (1995b, Play 4722)
Wilcox B	Upper Wilcox (La.)	Schenk and Viger (1995b, Play 4723)
Yakey Sand	Lower Wilcox (La.)	Echols and Goddard (1992)

Assessment Methodology

The methodology used for the Gulf coastal region conventional assessment units follows Charpentier and Klett (2005), Klett and others (2005), and Schmoker and Klett (2005). The methodology used for the continuous assessment units is described in Cook (2005), Crovelli (2005), Klett and Schmoker (2005), and Schmoker (2005). Peer reviews of the USGS oil and gas assessment methodology, as well as links to the above references can be found at the following web page: http://energy.cr.usgs.gov/oilgas/noga/methodology.html.

Assessment Unit and Petroleum System Concepts

In this report, assessment units (AUs) replaced the play concept that was applied for the 1995 USGS national assessment (Schenk and Viger, 1996a,b; U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995). The application of the AU concept is part of the petroleum system approach (described below) to resource assessments (Magoon and Dow, 1994). An AU is "a mappable part of a TPS in which discovered and undiscovered oil and gas accumulations constitute a single relatively homogeneous population such that the methodology of resource assessment is applicable" (Klett, 2004, p. 599). In other words, an AU is comprised of a three-dimensional volume of rock, which contains discovered and undiscovered hydrocarbon resources that are relatively similar in terms of their geological occurrence, exploration strategy, and risk characteristics (Ahlbrandt, 2000). Using AUs in place of the play concept may not necessarily result in quantitative differences in the volumes of undiscovered resources (Klett, 2004), but it supplies a common basis for resource assessment methodology within the USGS (Condon and Dyman, 2006). The petroleum system approach to resource assessment (Magoon and Dow, 1994) includes an analysis of "genetically related petroleum generated by a pod or by closely related pods of mature source rock" (Condon and Dyman, 2006). The AUs defined for the assessment of the lower Paleogene strata of the Gulf of Mexico coastal region are mappable subunits of the Upper Jurassic-Cretaceous-Tertiary Composite TPS (Warwick and others, 2007b). The term "composite" indicates that hydrocarbons were generated from more than one source rock, in this case the Jurassic Smackover Formation, the Cretaceous Eagle Ford Formation, and the Paleogene Wilcox Group and Sparta Sand (fig. 2). The composite TPS includes all of the geologic elements such as source, reservoir, seal, and overburden rocks, which control the processes of generation, migration, and trapping of hydrocarbon resources (Magoon and Dow, 1994; Klett, 2004). A map of the outline of the Upper Jurassic-Cretaceous-Tertiary Composite TPS of the Gulf of Mexico Basin consists of the total geographic extent of source and reservoir rocks (fig. 5).

Data Sources, Discovery History Analysis, and Forecast Period

The primary well and field production data used in the USGS assessment of the Gulf of Mexico Tertiary strata are proprietary commercial datasets of the IHS Energy Group (2005a,b) and Nehring Associates, Inc. (2006). Data from these commercial databases are subject to proprietary constraints, and the USGS may not publish, share, or serve any data from these databases. However, derivative representations in the form of graphs and summary statistics can be prepared and presented for each assessment unit. The IHS production database includes oil and gas production data for wells, leases, or producing units (collectively called "entities" in these databases). The IHS oil and gas wells database includes individual well data (including data for dry holes) such as well identification, locations, and information on penetrated and producing formations. Oil and gas field databases include location, geologic characterization, and oil and gas production data for domestic oil and gas fields and reservoirs (U.S. Geological Survey National Assessment Review Team, 2006). The USGS, however, cannot verify the accuracy, completeness, or currency of data reported in these commercial databases.

Interpretations of the lower Paleogene petroleum geology presented in this report are based on discovery history analysis of the spatial distribution of wells and known hydrocarbon reservoirs within a geographic information system (GIS). Spatial locations of lower Paleogene wells from IHS Energy Group (2005a,b), and hydrocarbon reservoirs from Nehring Associates, Inc. (2006) were examined using Esri software ArcMap 9.1. Other geologic data used in this assessment include the locations of Wilcox Group outcrop (Schruben and others, 1997; Warwick and others, 1997, 2002), major structural features of the Gulf of Mexico Basin (Ewing and Lopez, 1991), faults (Ewing and Lopez, 1991), salt (Ewing and Lopez, 1991; Lopez, 1995), geochemical data (Hood and others, 2002), Cenozoic depositional systems and shelf margins (Galloway and others, 2000), regional cross sections (Dodge and Posey, 1981; Bebout and Gutierrez, 1982, 1983; Eversull, 1984; Galloway and others, 1994), lower Paleogene isopach and structure maps (constructed from proprietary data contained in the IHS and Nehring databases), oil and gas field executive reference maps (Geomap, 1995a-c), and tectonic maps (Ewing and others, 1990). As an example of the spatial analysis, separation of lower Paleogene production well and reservoir data into AUs with different geologic characteristics (for example, stable shelf versus expanded fault zone) was completed through an evaluation of discovered reservoir depths, porosity-permeability-pressure-temperature characteristics, and reservoir thicknesses, in comparison with the distribution of reservoirs in the GIS maps. In addition to the analysis of Midway-Wilcox-Carrizo petroleum geology within the GIS framework, the interpretations contained in this report are based on data contained in the voluminous published literature on Gulf of Mexico petroleum geology, and from conversations with industry personnel involved in Gulf of Mexico oil and gas exploration and production.

The current assessment forecasts the ultimately recoverable hydrocarbon resources and thus is similar to that used for the 1995 assessment (Schenk and Viger, 1996a,b; U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995). In contrast, more recent USGS assessments (Condon and Dyman, 2006; Dyman and Condon, 2006; and Pitman and others, 2007), used a 30-year forecast span in the assessment methodology (Klett and others, 2003).

Elements of the Petroleum System

The Gulf of Mexico Basin is one of the world's most important petroleum provinces (Nehring, 1991; Horn, 2003). As such, an abundance of research has been directed at understanding the generation, migration, and trapping of its hydrocarbon resources (Koons and others, 1974; Laplante, 1974; Nunn and Sassen, 1986; Evans, 1987; Sassen and Moore, 1988; Sassen and others, 1988; Walters and Dusang, 1988; Sassen, 1990; Thompson and others, 1990; Gregory and others, 1991; Price, 1991; McDade and others, 1993; Zimmerman and Sassen, 1993; Echols and others, 1994; Wagner and others, 1994; Wenger and others, 1994; Wescott and Hood, 1994; Losh, 1998; Zimmerman, 1999; Nelson and others, 2000; Fillon, 2001; Gatenby, 2001; Hood and others, 2002; Lewan, 2002; Cathles, 2004; Mancini and others, 2006; among many others). Collectively, these workers have demonstrated that Gulf of Mexico Basin hydrocarbons are sourced from a number of stratigraphic intervals and that organic matter maturation and the generation and migration of hydrocarbon resources from a particular source interval are dependent on location within the basin. Most oils trapped in lower Paleogene strata are interpreted to be derived from the lower Tertiary stratigraphic intervals (fig. 6) (McDade and others, 1993; Hood and others, 2002). As described earlier, the conventional hydrocarbon resources contained in the approximately 1,250 known lower Paleogene reservoirs across the study area are considered to be part of the Upper Jurassic-Cretaceous-Tertiary Composite TPS that was defined for this assessment (fig. 5). Timing of the various elements of the Upper Jurassic-Cretaceous-Tertiary Composite TPS, which includes the stratigraphic position of major source rocks and the generation and accumulation of hydrocarbons in the lower Paleogene, are summarized in the events chart presented in figure 7.

Source Rocks and Thermal Maturation

Multiple source rock intervals (fig. 2) in the Gulf of Mexico Basin have been identified and discussed by numerous authors (Laplante, 1974; Evans, 1987; Sassen and Moore, 1988; Walters and Dusang, 1988; Jones, 1990; Price and Clayton, 1990; Sassen, 1990; Nehring, 1991; Price, 1991; Comet, 1992; Thompson and Kennicutt, 1992; McDade and others, 1993; Zimmerman and Sassen, 1993; Echols and others, 1994; Wescott and Hood, 1994; Nelson and others, 2000; Lewan, 2002; Hood and others, 2002; Warwick, 2006; Dennen and others, 2010). The primary source rock intervals for Mesozoic and Cenozoic strata of the northern, onshore Gulf of Mexico coastal region are organic-rich shale and limestone/marl of the Eagle Ford (Turonian) and Smackover (Oxfordian) Formations (numbers 3 and 8 on fig. 6) and mudstone, claystone, and coaly intervals of the Wilcox Group (Paleocene-Eocene), with some contributions from interbedded shales of the Sparta Sand in the lowermost Claiborne Group (Eocene) (fig. 2 and number 2 on fig. 6) (Wenger and others, 1990; Price, 1991; McDade and others, 1993; Hood and others, 2002).

For the current assessment, regional Wilcox Group thermal maturity data were obtained from the literature and unpublished databases to improve definitions of source rock maturity and distribution (Warwick, 2006; Dennen and others, 2010; Pitman and Rowan, 2012). Coal from the Wilcox Group ranges in coal rank from lignite at the outcrop scale to high volatile C bituminous at depths of about 1,675 m (~5,500 ft) (Warwick and others, 2006, 2008). For the thermal maturation modeling studies (Rowan and others, 2007; Pitman and Rowan, 2012) an average approximate total organic carbon (TOC) in weight percent for Wilcox source rocks was obtained from more than 1,000 outcrop and drill-hole samples; average TOC was determined to be 1.4 weight percent (fig. 8). The average is based on non-coaly samples (TOC values <10 percent) and samples with TOC values above a minimum value of 0.5 percent (fig. 8). Coal-rich samples with high TOC were excluded because they were over-represented in the database and the low TOC values were excluded because they did not have source rock potential. Wilcox mean vitrinite reflectance values (%Ro mean; $n \approx 450$ samples) range from about 0.3 percent updip near the outcrop, to more than 1.5 percent at elevations lower than about 15,000 ft below sea level in south Texas (fig. 9). Locally, %Ro values exceed 4.0 percent in south Texas (Dow and others, 1988; Dennen and others, 2010) possibly due to updip fluid circulation along faults or other undefined geologic phenomena. Regional trends in the vitrinite reflectance data suggest that gradients of Wilcox maturity versus elevation are not as great in the northeastern part of the basin (Arkansas, Louisiana, and Mississippi) as they are in the southwest (Texas), thereby implying a general increase in Wilcox maturity towards the south (fig. 10). However, a general elevation to %Ro relationship, expressed as the y-intercept on figure 9, was used to generate a regional contour map of expected vitrinite reflectance on the structural top of the Wilcox Group (fig. 11). The Wilcox %Ro map (fig. 11) was mathematically derived from the structural contour map of the top of the Wilcox Group (fig. 3) using the y-intercept equation from figure 9 and a commercial mapping and well-log management software package. These mean %Ro data and the maturity map (fig. 11) were used to calibrate burial history models, which constrain the oil and gas generating capacity of Wilcox source rocks in the northern part of Gulf of Mexico Basin (Warwick, 2006; Rowan and others, 2007; Pitman and Rowan, 2012) (fig. 12). Figure 12 shows burial history models for two wells in northeastern and south Texas. The Wilcox strata in well 3-10 in northeastern Texas are still in the oil generation window, whereas well 21-13 in south Texas completed oil generation at about 20 Ma (mega-annum) (early Miocene). This relationship supports the general increase in Wilcox maturity towards the south as shown in figure 10.

Migration of Hydrocarbons

Conventional oil and gas resources found in the shallow, immature section of the lower Paleogene in the Gulf of Mexico Coastal Plain are thought to have originated from updip or vertical migration of hydrocarbons produced from thermally mature source beds (Evans, 1987; Sassen, 1990; Price, 1991; Zimmerman and Sassen, 1993; Echols and others, 1995). Hydrocarbon migration in this area is illustrated by a diagram from Sassen (1990) that shows both vertical and updip oil and gas migration from mature Smackover, Eagle Ford, and Wilcox-Sparta source rocks in southern Louisiana (fig. 13). Updip migration of oil and gas from mature Wilcox-Sparta Sand source rocks is responsible for the shallow large oil accumulations in lower Paleogene strata in northeastern Louisiana and adjoining areas of southwestern Mississippi (Sassen, 1990). The updip migration of hydrocarbons may also be the best explanation for shallow oil and gas accumulations in the lower Paleogene subsurface of Texas; however, oil accumulation in lower Paleogene strata is less common in Texas. The importance of vertical migration of hydrocarbons should not be ignored. Hydrocarbons derived from any of the major Gulf Coast source rock intervals are liable to move vertically along the numerous conduits associated with the growth faults and salt domes (fig. 13). Echols and others (1995) argued that vertical hydrocarbon migration along faults is the dominate mechanism for charging shallow lower Paleogene reservoirs in northern Louisiana. Recent work by Warwick and others (2008) and McIntosh and others (2010) has shown that Wilcox Group coal beds may also serve as a source rock for biogenic gas generation, and isotopic data suggest that this biogenic gas is probably the source of much of the conventional gas produced from the Wilcox in northern Louisiana. This may also be the case in other parts of the basin where shallow accumulations of gas occur in the lower Paleogene.

Table 4. Lower Paleogene Gulf Coast assessment results.

Total Petroleum Systems (TPS) and Assessment Units (AU)	Field Type	Total Undiscovered Resources											
		Oil (MMBO)				Gas (BCFG)				NGL (MMBNGL)			
		F95	F50	F5	Mean	F95	F50	F5	Mean	F95	F50	F5	Mean
Upper Jurassic-Cretaceous-Tertiary Composite TPS (504701)													
Conventional Oil and Gas Resources													
Wilcox Stable Shelf Oil and Gas AU (50470116)	Oil	12	49	111	54	8	33	83	38	0	1	3	1
	Gas	—	—	—	—	117	403	846	434	4	13	30	14
Wilcox Expanded Fault Zone Gas and Oil AU (50470117)	Oil	18	49	95	52	74	215	459	234	2	6	14	7
	Gas	—	—	—	—	714	2,114	4,299	2,264	20	61	136	68
Wilcox Slope and Basin Floor Gas AU (50470118)	Oil	0	0	0	0	0	0	0	0	0	0	0	0
	Gas	—	—	—	—	5,173	23,629	56,486	26,398	78	366	959	423
Wilcox-Lobo Slide Block Gas AU (50470119)	Oil	1	4	9	4	6	20	48	23	0	0	1	1
	Gas	—	—	—	—	1,543	6,803	15,732	7,498	24	109	276	125
Total conventional resources		**31**	**102**	**215**	**110**	**7,635**	**33,217**	**77,953**	**36,889**	**128**	**556**	**1,419**	**639**

Reservoir Rocks, Traps, and Seals of the Lower Paleogene Assessment Interval

Midway Group

Limited oil and gas production occurs from sand-rich intervals in the Midway Group in southern Texas (for example, the Poth sand; Palmer, 1954; Hopf, 1965, 1967, 1986a,b; Nehring, 1991) and in Mississippi (for example, the Clayton Formation; Warner and Moody, 1991). Because of the low number of Midway fields (9 fields, Nehring Associates, Inc., 2006), the Midway Group was combined with the Wilcox Group and Carrizo Sand of the Claiborne Group to form the lower Paleogene assessment interval. According to Nehring Associates, Inc. (2006), known resources (produced and reported reserves) from Midway Group reservoirs range from 325 to 2,280 million barrels of oil (MMBO) and 1,000 to 1,079 million cubic feet of gas. Midway Group hydrocarbon reservoirs are sandstone and the traps are a combination of structural and stratigraphic. Generally, traps are formed by growth faults, faulted anticlines, salt diapirs, and deltaic sandstone pinch outs.

Wilcox Group

The majority of oil and gas produced from the lower Paleogene assessment interval in the onshore Gulf Coastal region is from the Wilcox Group. Nehring Associates, Inc. (2006) identified 1,218 reservoirs that are associated with the Wilcox Group (see tables 2 and 3 for some reservoir names). Like the Midway Group, the Wilcox reservoirs are sandstone, and the traps are a combination of structural and stratigraphic. Traps are formed by growth faults, faulted rollover anticlines, salt diapirs, and fluvial and deltaic sandstone pinch outs.

Many studies have described Wilcox reservoir quality (Grubbs, 1953; Berg, 1979; Straccia, 1981; McBride and others, 1991; Goddard and others, 2002; Dutton and Loucks, 2007, 2008, 2010). In a typical example, Straccia (1981) describes the characteristics of Wilcox sandstone reservoirs of the Rosita gas field (fig. 14) that produce abundant gas from highly faulted reservoirs at depths of 9,500 to 15,300 ft. Reservoir quality varies according to rock type and degree of deformation, with porosity ranging from 8 to 25 percent and permeability ranging from 0.02 to 0.5 millidarcies (md). Goddard and others (2002) indicated that in the Livingston oil and gas field of southeastern Louisiana (fig. 15) the best reservoir quality is located within the uppermost 10 to 16 ft of a thick (40 to 70 ft) sandstone interval, where fine to very fine grained silty sandstone has porosity and permeability averaging 24 percent and 290 md, respectively. Porosity and permeability decrease toward the base of the sandstone interval. Two intra-reservoir impermeable hard layers were identified as barriers to vertical fluid movement in the reservoir. In general, Wilcox porosity and permeability decrease with depth (McBride and others, 1991), however, recent work by Dutton and Loucks (2007, 2008, 2010) indicates that an increase of microporosity by feldspar dissolution at depths greater than 19,500 ft may help to maintain some porosity and permeability for ultradeep reservoirs. For additional discussions of individual Wilcox Group field characteristics, refer to Williams (1969), Galloway and others (1983), and Kosters and others (1989).

Carrizo Sand

In general, the Carrizo Sand has similar reservoir characteristics as those described above for the Wilcox Group. Because of the relatively few Carrizo Sand reservoirs (24) identified in the Nehring Associates, Inc. (2006) database, and because the Carrizo is generally included in Wilcox field completions, the unit was assessed as part of the lower Paleogene assessment interval (fig. 2). For a discussion of Carrizo Sand reservoir characteristics refer to Hamlin (1983, 1988), McBride and others (1991), and Enos and Kyle (2002). Examples of Carrizo Sand fields are discussed by Greenberg and Swinbank (1998).

Resource Assessment

In October of 2006, the USGS Gulf Coast Tertiary Assessment team met at the USGS offices in Denver, Colorado, to review the petroleum geology of the Tertiary stratigraphic interval for the onshore and State waters portion of the U.S. Gulf of Mexico Coastal Plain. The Paleogene strata were assessed by a team led by P.D. Warwick, whereas the Neogene strata were assessed by a team led by R.F. Dubiel. The results of the Tertiary assessment are contained in Dubiel and others (2007). Five assessment units (AUs) were established for the lower Paleogene assessment interval and are described below. The AUs include: Wilcox Stable Shelf Oil and Gas (50470116), Wilcox Expanded Fault Zone Gas and Oil (50470117), Wilcox Slope and Basin Floor Gas (50470118), Wilcox-Lobo Slide Block Gas (50470119), and Wilcox Mississippi Embayment (50470147) (fig. 16).

The AU numbering system was established by the USGS to facilitate petroleum resource assessment (U.S. Geological Survey, 2000). The unique number assigned to the Upper Jurassic-Cretaceous-Tertiary Composite TPS is 504701, of which “5” denotes the region (North America), “047” denotes the province (Western Gulf), and “01” denotes the TPS. Recent assessment studies in the Gulf region (Condon and Dyman, 2006; Dyman and Condon, 2006; Pitman and others, 2007) also are considered to be part of the Upper Jurassic-Cretaceous-Tertiary Composite. A review of the geologic model used to define the assessment units is presented below. Digital versions of the AU boundary lines are available for download at the following USGS Energy Resources Program website: https://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment/USBasinSummaries.aspx?provcode=5047.

In January 2007, the Paleogene and Neogene Gulf of Mexico assessment teams met in Denver to present to a USGS review panel a thorough analysis of all the available geologic data, petroleum exploration data, and petroleum development data for each AU. The result of the meeting was to arrive at consensus data values used for estimating the remaining hydrocarbon resources in each assessment unit (appendixes 1–4). Among these values were estimates of the sizes and numbers of undiscovered oil and gas accumulations, based on a tabulation of existing field and well records provided by Timothy Klett (written commun., 2007). The default minimum accumulation size that has potential for additions to reserves is 0.5 million barrels of oil equivalent (MMBOE) (Schmoker and Klett, 2005). Additional data compiled or calculated in appendixes 1 to 4 for each assessment unit to aid in the final estimate of undiscovered resources include gas to oil ratios, natural gas liquids to gas ratios, API gravity, sulfur content, and drilling depth. Additionally, allocations of undiscovered resources were calculated for Federal, State, and private lands and for various ecosystem regions. Table 4 summarizes the technically recoverable undiscovered resource results for each of the four assessed AUs and a total for the lower Paleogene. The Wilcox Mississippi Embayment AU was not quantitatively assessed.

Geologic Model

For the assessment of Paleogene strata (lower and upper parts), the USGS used a generalized structural and stratigraphic model to better define the various AUs for the Gulf of Mexico Coastal Plain (figs. 16 to 19). Each of the twenty-one assessed Paleogene AUs (four in Wilcox, six in the Claiborne, six in the Jackson/Vicksburg, and five in the Frio/Anahuac; figs. 2 and 17) has a well-defined zone of extensional growth faults where stratigraphic units have been greatly expanded (Ewing, 1990, 1991a,b). In general, growth faults were active during sedimentation. The primary factor that defines the onset of coastal plain expansion for a particular stratigraphic unit is the location of the shelf margin of the underlying stratigraphic unit (fig. 17). For example, the northwest boundary of the Wilcox expansion zone is defined by the underlying Lower Cretaceous shelf margin (fig. 17). The expansion zones for the younger stratigraphic intervals (Claiborne to Frio) were defined using a combination of the fault zone data of Ewing (1990, 1991a,b) and the paleo-shelf margins defined by Galloway and others (2000).

In the most simplistic interpretation of the model, three AUs (updip, middip, and downdip) were defined for each of the assessed stratigraphic intervals (the Wilcox, Claiborne, Jackson, and Vicksburg Groups; and the Frio, Hackberry, and Anahuac Formations) (fig. 18). Some of the stratigraphic intervals were further subdivided into upper and lower parts (table 1).

Stable Shelf

In the updip, stable shelf AU, relatively shallow reservoirs (mostly at a depth <8,000 ft) are characterized by minimal expansion due to growth faulting, and primarily consist of highstand and transgressive systems tracts including regional fluvial-deltaic complexes, delta mouth and barrier bars, shelf sandstones, and incised valley fill (AU 1, fig. 18). Reservoir facies may have high and predictable lateral continuity. Stratigraphic expansion is absent or minor and reservoir intervals are thin in AU 1 when compared to those in the middip AU (AU 2, fig. 18). Traps generally occur as faulted traps or roll-over anticlines against reactivated growth faults which flatten out in the underlying strata. Less frequent are back barrier sandstone pinchout stratigraphic traps. Reservoirs are normally pressured, usually produce both oil and gas by pumping, and eventually typically have a high water cut. In the Gulf of Mexico Coastal Plain, this AU constitutes a mature exploration and production trend, with few remaining undiscovered fields and little potential for field growth by infill development wells. Exploration in the updip stable shelf AU is very mature and production trends produce both oil and gas from reservoirs with normal temperature and pressure depth gradients. Based on thermal modeling studies (Rowan and others, 2007; Pitman and Rowan, 2012), Paleogene strata in the stable shelf AU are generally thermally immature, indicating that oil and gas produced in the area probably migrated from deeper mature source rocks (fig. 13). This interpretation is supported by production data from IHS Energy Group (2005a) and Nehring Associates, Inc. (2006).

Expanded Fault Zone

The middip, expanded fault zone AU exhibits the maximum amount of expansion for each of the assessed stratigraphic intervals (AU 2, fig. 18). The stratigraphic intervals in the expansion zone thicken to their maximum extent due to syndepositional growth faulting. The middip AU consists mostly of deltaic and marine highstand and lowstand systems tract sedimentary strata. Reservoir intervals in the middip AU range from thin to thick, and hydrocarbon exploration and production trends are characterized as mature to frontier. Reservoir pressure gradients range from normal to high and temperatures range from normal to high due to the overpressured zones at depth. Based on production data (IHS, 2005a; Nehring Associates, Inc., 2006) and thermal modeling studies (Rowan and others, 2007; Pitman and Rowan, 2012), Paleogene strata in the middip expansion AU are generally mature to overmature with respect to oil and gas generation, indicating that some oil and predominately gas is produced from the AU.

In plan view, the expanded fault zone AU occurs over a relatively narrow area of the coastal plain, bracketing the contemporary shelf edge basinward of the stable shelf (fig. 16). Reservoirs are characterized by maximum stratigraphic expansion over syndepositional growth faults. Cumulative reservoir thickness increases greatly (fig. 18), although the thickness of individual sands is not necessarily greater than in the stable shelf environment. Reservoir sands are deep (mostly 8,000 to 12,000 ft) and consist of highstand and lowstand systems tracts including delta mouth and front facies, incised valley fill, outer shelf storm retreat sands, and upper slope sands occurring in turbidite and debrite deposits and slump blocks. Reservoir facies generally have low and unpredictable lateral continuity because of stratigraphic and structural complexities. Traps are associated with the ubiquitous contemporary growth faults, including rollover anticlines and upthrown and downthrown fault closures. Reservoirs are overpressured, remaining in hydrostatic isolation since their rapid deposition, and produce both non-associated gas and condensate by natural flow. Fields are highly compartmentalized and have a wide range of areal extents compared to those of the stable shelf (Galloway and others, 1983; Kosters and others, 1989; Bebout and others, 1992). In the Gulf coastal plain region, this AU constitutes late mature to frontier exploration and production trend with a high likelihood for new discoveries and excellent potential for development wells within existing fields.

Slope and Basin Floor

The downdip slope and basin floor AU occurs downdip of the expanded fault zone and is characterized by minimal to moderate expansion of reservoir sands due to their distal position with respect to contemporaneous shelf edge growth faulting (AU 3, fig. 18). Reservoir sands are deep (mostly >12,000 ft) and consist of distal highstand and lowstand systems tracts including slope turbidite fans, slope apron fans, shelf slump sands, incised valley fill, and blanket sand deposits on the basin floor (AU 3, fig. 18). Reservoir facies are laterally continuous, but their locations are hard to predict or project from shallower updip strata or depositional environments. Traps include stratigraphic pinchouts at sand body margins, complicated by structural offset resulting from growth faults, which sole out from the overlying expansion zone (fig. 18, fault zone 3). Reservoirs are likely to be overpressured, high-temperature, and produce nonassociated gas and condensate. For the lower Paleogene interval, this AU constitutes a hypothetical exploration and production trend with very high potential for new discoveries.

The downdip, slope and basin floor AU (AU 3, fig. 18) shows minor to no fault-related expansion and consists mostly of deltaic and marine distal highstand and lowstand systems tract sedimentary rocks. Reservoir intervals are thin to moderate when compared to the reservoir intervals in AU 2 (fig. 18). The slope and basin floor AU is defined as a frontier to hypothetical hydrocarbon production area due to the lack of drilling and production data from the area. Recent deep drilling (conducted mostly after the 2007 resource assessment) to Paleogene reservoirs in the Federal and State waters of Louisiana have proven the existence of petroleum charge and reservoirs in the Wilcox, Claiborne, Vicksburg, and Frio intervals beneath previously established Neogene pay horizons (Moffat, 2010; Enomoto, 2014). In these discoveries, reservoirs are under high temperature and pressure conditions due to deep burial. Based on thermal modeling studies (Rowan and others, 2007; Pitman and Rowan, 2012), Paleogene strata in the downdip expansion AU are likely to be overmature with respect to oil and gas generation, indicating that gas is the predominate hydrocarbon in the AU.

Consequence of Progradation

Each assessed Paleogene interval (fig. 2), consists of a period of dominant progradation into the Gulf of Mexico, a period of regional highstand and deposition of transgressive shale and thin marine sands, or a combination of the two periods. During dominantly progradational periods, deposition occurred in stable shelf environments on the landward margin of the basin, in expanded fault zone environments and slightly beyond at the contemporary shelf edge, and in slope and basin floor environments basinward of the contemporary shelf edge (fig. 18). This motif is repeated in each of the progradational clastic sequences, resulting in a systematic stepping-out of the three environments into the Gulf during deposition of each overlying stratigraphic sequence. Within individual stratigraphic intervals (for example, the Wilcox or Claiborne Groups) the boundaries between the structural-depositional environments are time-transgressive (fig. 19). For example, the shelf margin gradually advances basinward, in effect bringing stable shelf structural-depositional environments over the previously deposited expansion zone within the same stratigraphic package (the Wilcox or Claiborne Group). In other words, the real boundaries between the structural-depositional environments overlap in plan view, and overlap in the depth range of reservoirs. For the purposes of the assessment and for the analysis of exploration and production history of individual AUs, this has the unintended consequence of misplacing discovered reservoirs which lie near the structural-depositional boundary between the stable shelf and expanded fault zone environments. Thus, characteristics of two AUs may be unintentionally grouped and assessed as one dataset.

Wilcox Stable Shelf Oil and Gas (AU 50470116)

The Wilcox Stable Shelf Oil and Gas Assessment Unit (figs. 16 and 20) extends from the approximate updip limit of Wilcox outcrop (Schruben and others, 1997) downdip to the Lower Cretaceous shelf margin as defined by Galloway and others (2000). IHS (2005a) data show shallow gas production within the outcrop zone of the Wilcox, so the shallow outcrop areas were included in the AU. The AU extends mainly across southeastern Texas, eastern Texas, and northern Louisiana, but also extends into Arkansas, Mississippi, and Alabama where local Wilcox production is present. The eastern boundary of the AU is the eastern boundary of the USGS Louisiana-Mississippi Salt Basin Province (fig. 16; U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995). The southwestern boundary of the AU is the United States-Mexico border. The downdip extent of the AU is the approximate updip boundary of the Wilcox expansion zone (fig. 17; Ewing, 1990). The AU includes the Paleocene-Eocene Midway and Wilcox Groups, and the Carrizo Sand of the lowermost Claiborne Group (Eocene) (fig. 2).

Wilcox Stable Shelf Oil and Gas Assessment Unit reservoir-size and (or) field-size data (from Nehring Associates, Inc., 2006) (fig. 20) show that oil and gas accumulations above the minimum cutoff sizes of 0.5 MMBO and 3 BCFG, respectively, are distributed throughout middip and downdip parts of the AU. Oil reservoirs are more common in northeastern Louisiana and southeastern Mississippi. Sassen (1990), Wenger and others (1994), and Hood and others (2002) indicated that Wilcox oil and gas production in this area is primarily derived from lower Tertiary marine source rocks that in some places is mixed with oil and gas derived from Upper Cretaceous marine source rocks (figs. 6 and 13). In Texas, gas reservoirs are more common in the downdip areas of the AU (fig. 20); however, oil is more prevalent in the shallow, updip parts of the AU. Wilcox petroleum produced from Texas is suggested by several studies to be primarily derived from lower Tertiary terrestrial source rocks (fig. 6). Interestingly, the downdip parts of the AU in northeastern Texas and central and southern Louisiana have few reservoirs and (or) fields that meet the minimum accumulation cutoff requirements for the assessment.

The Wilcox Stable Shelf Oil and Gas AU is a mature exploration area, where more than 45,000 drill holes have penetrated the Wilcox interval within the AU boundaries (IHS, 2005b). Geographic information system files that illustrate the density of drilling and production for the Wilcox Stable Shelf Oil and Gas AU can be downloaded from the USGS Energy Resources Program Gulf Coast website at: https://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment/USBasinSummaries.aspx?provcode=5047.

For the purposes of the assessment, an analysis of accumulation discovery year and accumulation size is helpful to predict the potential sizes and numbers of undiscovered accumulations of both gas and oil for each AU. Figures 21 and 22 show the results of both discovered oil and gas accumulations for the Wilcox Stable Shelf Oil and Gas AU shown on figure 20. The discovered accumulations have been divided into thirds, based on the year of discovery, and a median size is indicated for each discovery third. Expected undiscovered minimum, median, and maximum field sizes are shown on the right of each plot for an undetermined time in the future. For both oil and gas, maximum undiscovered accumulation sizes are expected to decrease, however, undiscovered median accumulation sizes are not expected to decline significantly from the present value (figs. 21 and 22). Input data for the AU can be found in appendix 1 of this report.

The results of the assessment for the Wilcox Stable Shelf Oil and Gas AU are given on table 4. The estimate mean technically recoverable undiscovered resources for the AU are as follows: 54 MMBO; 472 BCFG; and 15 MMBNGL.

Wilcox Expanded Fault Zone Gas and Oil (AU 50470117)

The updip limit of the Wilcox Expanded Fault Zone Gas and Oil AU is defined by the updip boundary of the Wilcox expansion zone (fig. 17; Ewing, 1990), and the trace of the Lower Cretaceous shelf margin as defined by Galloway and others (2000) (fig. 17). The downdip boundary is approximately the updip boundary of the Claiborne expansion zone (Ewing, 1990), and the trace of the upper Wilcox shelf margin (Galloway and others, 2000) (fig. 17). The AU narrows towards the eastern boundary, which is formed by the Louisiana State/Federal water boundary (fig. 16). The southwestern boundary is the northernmost extent of the Wilcox-Lobo slide-block deformation as defined by the seismic interpretations of Anderson and

Fiduk (2003). The AU includes the Paleocene-Eocene Midway and Wilcox Groups, and the Carrizo Sand of the lowermost Claiborne Group (fig. 2).

Wilcox Expanded Fault Zone Gas and Oil AU reservoir-size and (or) field-size data (from Nehring Associates, Inc., 2006) (fig. 23) shows that oil and gas accumulations above the minimum cutoff sizes of 0.5 MMBO and 3 BCFG, respectively, are most abundant in the Texas portion of the AU. Wilcox petroleum (primarily gas) produced from Texas is suggested to be sourced from lower Tertiary terrestrial source rocks (Sassen, 1990; Wenger and others, 1994; and Hood and others, 2002) (fig. 6). The downdip parts of the AU in Texas and areas in central Louisiana may not be adequately explored or they have few reservoirs that meet the minimum accumulation cutoff requirements for the assessment.

The Wilcox Expanded Fault Zone Gas and Oil AU is a moderately mature exploration area, with more than 2,500 dry holes that penetrated the Wilcox interval within the AU boundaries and approximately 500 oil or gas reservoirs and (or) fields identified (IHS, 2005b; Nehring Associates, Inc., 2006). Geographic information system files that illustrate the density of drilling and production for the Wilcox Expanded Fault Zone Gas AU can be downloaded from the USGS Energy Resources Program Gulf Coast website at: https://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment/USBasinSummaries.aspx?provcode=5047.

For the purposes of the assessment, an analysis of accumulation discovery year and accumulation size is helpful to predict the potential sizes and numbers of undiscovered accumulations of both gas and oil for each AU. Figures 24 and 25 show the results of discovered oil and gas accumulations for the AU. The discovered accumulations have been divided into thirds, based on the year of discovery and the median discovered accumulation size is indicated for each discovery third. Expected undiscovered minimum, median, and maximum field sizes are shown on the right of each plot for an undetermined time in the future. For both oil and gas, maximum accumulation sizes are expected to decrease, however, undisclosed median accumulation sizes are not expected to decline significantly (figs. 24 and 25). Input data for the AU can be found in appendix 2 of this report. The expected reservoir depths for undiscovered oil reservoirs range from 6,000 to 15,000 ft, and the expected gas reservoir depth for undiscovered gas reservoirs range from 6,000 to 20,000 ft.

The results of the assessment for the Wilcox Expanded Fault Zone Gas and Oil AU are given on table 4. The estimated mean technically recoverable undiscovered resources for the AU are as follows: 52 MMBO; 2,498 BCFG; and 75 MMBNGL.

Wilcox-Lobo Slide Block Gas (AU 50470119)

The northeastern and northwestern boundaries of the Wilcox-Lobo Slide Block Gas AU (figs. 26 and 27) were drawn to include the area of lower Tertiary slide block deformation as defined by the seismic interpretations of Anderson and Fiduk (2003) (fig. 27). The downdip, southeastern boundary is based on limited (or sparse) proprietary seismic data that show diminished lower Tertiary slide-block deformation styles towards the modern Texas coast. The AU also includes the lower Wilcox Lobo structural and depositional basin that has been described by Adams (1993), Schenk and Viger (1996b), and Stricklin (1996). The southwestern boundary of the AU is the United States-Mexico border. The AU includes the Paleocene-Eocene Midway and Wilcox Groups, and the Carrizo Sand of the lowermost Claiborne Group (fig. 2).

Wilcox-Lobo Slide Block Gas Assessment Unit reservoir-size and (or) field-size data (from Nehring Associates, Inc., 2006) (fig. 26) show that gas and a few oil reservoirs above the minimum cutoff sizes of 3 BCFG and 0.5 MMBO, respectively, are distributed throughout the updip half of the AU. The downdip, southeastern half of the AU is relatively unexplored and has no established production. Wilcox petroleum produced from the Wilcox-Lobo Slide Block Gas AU is suggested to be generated from lower Tertiary terrestrial source rocks (fig. 6) (Wenger and others, 1994; Hood and others, 2002).

The updip northwestern half of the Wilcox-Lobo Slide Block Gas AU is a well explored area, with more than 800 drill holes that penetrated the Wilcox interval (IHS, 2005b). However, relatively few (<75) wells have been drilled to test the Wilcox interval in the downdip part of the AU. With the exception of the structural deformation style of the AU (fig. 27), reservoir characteristics of the updip part of the AU are similar to those described above for the Wilcox Expanded Fault Zone Gas and Oil AU. The reservoir characteristics of the downdip areas of the AU are thought to be similar to those for the Wilcox Slope and Basin Floor Gas AU. Geographic information system files that illustrate the density of drilling and production for the Wilcox-Lobo Slide Block Gas AU can be downloaded from the USGS Energy Resources Program Gulf Coast website at: https://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment/USBasinSummaries.aspx?provcode=5047.

For the purposes of the assessment, an analysis of accumulation discovery year and accumulation size is helpful to predict the potential sizes and numbers of undiscovered accumulations of both gas and oil for each AU. Figures 28 and 29 show the results of both discovered oil and gas accumulations for the Wilcox-Lobo Slide Block Gas AU. For oil, there are only five oil accumulations in the AU, and these have been divided into two groups (halves) based on the accumulation discovery year (fig. 28). The median discovered accumulation size is indicated for each discovery half. Expected undiscovered minimum, median, and maximum accumulation sizes are shown on the right of the plot for an undetermined time in the future that will use current recovery technologies. Maximum undiscovered oil accumulation sizes are expected to maintain their sizes, whereas the median undiscovered oil accumulation size is expected to decline (fig. 28). For gas, the discovered accumulation sizes have been divided into thirds, based on the year of discovery (fig. 29). The median discovered accumulation size is indicated for each discovery third. Expected undiscovered minimum, median, and maximum field sizes are shown on the right of the plot for an undetermined time in the future. Both the maximum and median undiscovered accumulation sizes are expected to be maintained at present values for an undetermined time in the future (fig. 29). Input data for the AU can be found in appendix 3 of this report.

The results of the assessment for the Wilcox-Lobo Slide Block Gas AU are given on table 4. The estimated mean technically recoverable undiscovered resources for the AU are as follows: 4 MMBO; 7,521 BCFG; and 126 MMBNGL.

Wilcox Slope and Basin Floor Gas (AU 50470118)

The updip extent of the Wilcox Slope and Basin Floor Gas AU (fig. 30) is the approximate updip boundary of the Claiborne expansion zone (figs. 16 and 17; Ewing, 1990), and the trace of the upper Wilcox shelf margin defined by Galloway and others (2000). The eastern boundary of the AU is the Louisiana State/Federal water boundary. The southwestern boundary is the United States-Mexico border. The downdip boundary is the Texas-Louisiana State/Federal water boundary. The AU includes the Paleocene-Eocene Midway and Wilcox Groups, and the Carrizo Sand of the lowermost Claiborne Group (fig. 2).

There are only two reservoir-size and field-size data points in the Wilcox Slope and Basin Floor Gas AU (Nehring Associates, Inc., 2006) (fig. 30). These gas accumulations are on the updip margin of the AU and are probably an extension of the Wilcox Expanded Fault Zone Gas and Oil AU described above. The AU is a frontier exploration area, with only about 180 drill holes that penetrate some portion of the Wilcox interval within the AU boundaries (IHS, 2005b). Geographic information system files that illustrate the density of drilling and production for the Wilcox Slope and Basin Floor Gas AU can be downloaded from the USGS Energy Resources Program Gulf Coast website at: https://energy.usgs.gov/OilGas/AssessmentsData/NationalOilGasAssessment/USBasinSummaries.aspx?provcode=5047.

Because very little production has occurred in the Wilcox Slope and Basin Floor Gas AU, an analysis of accumulation discovery year and accumulation size is not possible. Recent exploration and discoveries of Wilcox gas in the deep, offshore part of the basin indicate that several thousand feet of Wilcox strata, containing thick (~1,000 ft) intervals of Wilcox sandstone-dominated reservoirs are preserved in the distal parts of the basin (Meyer and others, 2005, 2007). Analysis of reservoir quality in the deep (>19,000 ft) onshore Wilcox interval suggests the presence of sandstone reservoirs that maintain some porosity and permeability (Dutton and Loucks, 2007, 2008, 2010). Given the probable widespread occurrence of sandstone reservoirs in slope and basin floor Wilcox environments, and the limited deep drilling information from the AU, the USGS assessment team reports a broad range of uncertainties for the resource potential for the Wilcox Slope and Basin Floor Gas AU (table 4). Input data for the AU can be found in appendix 4 of this report. The expected reservoir depths for undiscovered oil range from 6,000 to 15,000 ft, and for gas reservoirs expected depths range from 13,000 to 30,000 ft.

The results of the assessment for the Wilcox Slope and Basin Floor Gas AU are given on table 4. The mean technically recoverable undiscovered resources for the AU are as follows: 26,398 BCFG; and 423 MMBNGL.

Wilcox Mississippi Embayment (AU 50470147)

The Wilcox Mississippi Embayment AU extends northward from the Wilcox Stable Shelf Oil and Gas AU and the Louisiana-Mississippi Salt Basin Province boundary (fig. 16) to the updip extent of Wilcox-age strata that crop out on the margins of the Mississippi embayment. Cushing and others (1964) presented a detailed discussion of the geology of the Mississippi embayment and Coleman and Pratt (2015) have reviewed the petroleum potential of the Reelfoot rift and overlying sediments of the northern part of the Mississippi Embayment AU (fig. 1). The AU includes the Paleocene-Eocene Midway and Wilcox Groups, and the Carrizo Sand of the lowermost Claiborne Group (fig. 2). This AU was not formally assessed by the USGS because of the low resource potential for hydrocarbons in the area (Dubiel and others, 2007).

Comparison of Results of the Lower Paleogene Assessment with other 2007 U.S. Geological Survey Tertiary Assessments

The summary graphs of the Gulf Coast region (fig. 31) show the results of all USGS 2007 assessed undiscovered oil and gas resources in the Gulf Coast region (total of 22,689 MMBOE). Figure 31*A* illustrates the results of the lower Paleogene AUs, whereas figure 31*B* shows the results of the Tertiary stratigraphic AUs. The Wilcox Stable Shelf Oil and Gas AU contains the most undiscovered oil and the least amount of undiscovered gas resources of all the assessed AUs in the lower Paleogene assessment interval. The Wilcox Expanded Fault Zone Gas and Oil AU contains similar amounts of undiscovered oil as might be found in the updip Wilcox Stable Shelf Oil and Gas AU, and significantly more gas than found in the shallow parts for the basin.

The Wilcox-Lobo Slide Block Gas AU contains the second greatest undiscovered accumulations of gas and the third greatest accumulation of undiscovered oil in comparison to the other lower Paleogene AUs. The assessment results for the Wilcox Slope and Basin Floor Gas AU indicates that the AU is dominated by gas and is estimated to hold about one third (or 26.4 trillion cubic feet) of the undiscovered gas resources for all of the Wilcox assessed intervals. Of the assessed total of undiscovered conventional resources in the Gulf Coast Tertiary (22,689 MMBOE), the Wilcox and Neogene AUs contain more than 50 percent of the remaining resources, 30.4 percent and 23.2 percent, respectively (fig. 31*B*).

Summary

The U.S. Geological Survey (USGS) recently conducted an assessment of the undiscovered, technically recoverable conventional oil and gas resources in Paleogene sediments underlying the U.S. Gulf of Mexico Coastal Plain and State waters. For purposes of the assessment, an Upper Jurassic-Cretaceous-Tertiary Total Petroleum System (TPS) was defined for the entire Gulf of Mexico Basin. Paleogene strata were divided into the following stratigraphic study intervals and assessed accordingly: (1) Wilcox Group (including the Midway Group and the basal Carrizo Sand of the Claiborne Group; Paleocene-Eocene); (2) Claiborne Group (Eocene); (3) Jackson and Vicksburg Groups (Eocene-Oligocene); and (4) Frio and Anahuac Formations (Oligocene). Based on a generalized structural and stratigraphic model, each assessed Paleogene stratigraphic interval was subdivided into an updip, stable shelf assessment unit (AU); a middip, expanded fault zone AU; and a downdip, slope and basin floor AU. A significant controlling factor for the location of the middip expansion zone AU is the location of underlying, stratigraphically older shelf margins. Using the geology-based assessment methodology, the USGS assessed a mean of 36.9 trillion cubic feet (or 6,148 MMBOE) of undiscovered, technically recoverable natural gas; a mean of 110 million barrels of undiscovered, technically recoverable oil; and a mean of 0.6 billion barrels of undiscovered, technically recoverable natural gas liquids in the Midway and Wilcox Groups and the Carrizo Sand of the Claiborne Group. A significant portion of these undiscovered resources (26.4 trillion cubic feet of gas, or 4,400 MMBOE) is estimated to occur in the Wilcox Slope and Basin Floor Gas AU.

Acknowledgments

The author wishes to thank all members of the U.S. Geological Survey Gulf Coast Tertiary assessment team for their contributions to this paper. In addition, discussions with staff members of the Bureau of Ocean Energy Management, Regulation and Enforcement (former Minerals Management Service) Gulf of Mexico Region; the Mississippi Department of Environmental Quality Office of Geology; the Louisiana Geological Survey; and The University of Texas at Austin Bureau of Economic Geology greatly contributed to the concepts presented in this paper. The report was greatly improved by technical reviews by Susan Tewalt and Robert Ryder.

References Cited

Adams, R.L., 1993, Effects of inherited pre-Jurassic tectonics on the U.S. Gulf Coast: Gulf Coast Association of Geological Societies Transactions, v. 43, p. 1–9, accessed at http://archives.datapages.com/data/gcags/data/043/043001/pdfs/0001.pdf.

Ahlbrandt, T.S., 2000, Introduction, *in* U.S. Geological Survey world petroleum assessment 2000; Description and results: U.S. Geological Survey Digital Data Series DDS–60, 4 CD-ROMs. [Also available at http://pubs.usgs.gov/dds/dds-060/.]

Anderson, L.E., and Fiduk, J.C., 2003, Raft tectonics in the Gulf of Mexico?–A possible example in south Texas, *in* Rosen, N.C., ed., Structure and stratigraphy of south Texas and northeast Mexico; Applications to exploration: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Foundation and South Texas Geological Society, San Antonio, Tex., April 11–12, 2003, p. 158–163, CD-ROM.

Baker, E.T., Jr., 1979, Stratigraphic and hydrologic framework of part of the coastal plain of Texas: Texas Department of Water Resources Report 236, 43 p., accessed at https://www.twdb.texas.gov/publications/reports/numbered_reports/doc/R236/R236.pdf.

Barker, C.E., Biewick, L.R.H., Warwick, P.D., and SanFilipo, J.R., 2009, Preliminary Gulf Coast coalbed methane exploration maps; Depth to Wilcox, apparent Wilcox thickness and vitrinite reflectance: U.S. Geological Survey Open File Report 2000–113, 2 p., 2 sheets, accessed May 1, 2015, at http://pubs.usgs.gov/of/2000/ofr-00-0113/.

Bebout, D.G., and Gutiérrez, D.R., 1982, Regional cross sections, Louisiana Gulf Coast, western part: Louisiana Geological Survey Folio Series No. 5, 11 p.

Bebout, D.G., and Gutiérrez, D.R., 1983, Regional cross sections, Louisiana Gulf Coast, eastern part: Louisiana Geological Survey Folio Series No. 6, 10 p.

Bebout, D.G., White, W.A., Garrett, C.M., Jr., and Hentz, T.F., 1992, Atlas of major central and eastern Gulf Coast gas reservoirs: The University of Texas at Austin, Bureau of Economic Geology AT0005, 88 p., 4 pls.

Bellamy, J.B., and Breyer, J.A., 2002, A test case of the new stratigraphies using subsurface data, Wilcox Group (Paleogene), south Texas: Gulf Coast Association of Geological Societies Transactions, v. 52, p. 45–56, accessed at http://archives.datapages.com/data/south-texas-geosoc-bulletins/data/042/042007/11_stb420011.htm.

Berg, R.R., 1979, Characteristics of lower Wilcox reservoirs, Valentine and South Halletsville fields, Lavaca County, Texas: Gulf Coast Association of Geological Societies Transactions, v. 29, p. 11–23, accessed at http://archives.datapages.com/data/gcags/data/029/029001/pdfs/0011.pdf.

Bornhauser, M.A., 1979, Subsurface stratigraphy of the Midway-Wilcox, Zapata County, Texas: Gulf Coast Association of Geological Societies Transactions, v. 29, p. 29–34, accessed at http://archives.datapages.com/data/gcags/data/029/029001/pdfs/0029.pdf.

Breyer, J.A., 1997, Sequence stratigraphy of Gulf Coast lignite, Wilcox Group (Paleogene), south Texas: Journal of Sedimentary Research, v. 67, no. 6, p. 1,018–1,029, accessed at http://archives.datapages.com/data/sepm/journals/v66-67/data/067/067006/pdfs/1018.pdf.

Budzik, P.M., 2006, United States producing and nonproducing crude oil and natural gas reserves from 1985 through 2004: U.S. Department of Energy, Energy Information Administration web page, accessed December 1, 2015, at http://www.eia.doe.gov/oiaf/analysispaper/congr/index.html.

Cao, S., Petersen, K., Lerche, I., Lowrie, A., and Sullivan, N., 1993, Cretaceous and Tertiary structural history in northern Louisiana, *in* Pindell, J.A., and Perkins, B.F., eds., Mesozoic and early Cenozoic development of the Gulf of Mexico and Caribbean region; A context for hydrocarbon exploration: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Foundation, 13th Annual Research Conference Proceedings, Houston, Tex., July 1, 1993, p. 77–86, CD-ROM.

Cathles, L.M., 2004, Hydrocarbon generation, migration, and venting in a portion of the offshore Louisiana Gulf of Mexico Basin: The Leading Edge, v. 23, no. 8, p. 760–770.

Charpentier, R.R., and Klett, T.R., 2005, A Monte Carlo simulation method for the assessment of undiscovered, conventional oil and gas, *in* U.S. Geological Survey Southwestern Wyoming Province Assessment Team, comps., Petroleum systems and geologic assessment of oil and gas in the Southwestern Wyoming Province, Wyoming, Colorado and Utah: U.S. Geological Survey Digital Data Series DDS–69–D, chap. 21, 5 p., accessed January 30, 2009, at http://certmapper.cr.usgs.gov/data/noga00/natl/text/CH_21.pdf.

Cleaves, A.W., 1980, Depositional systems and lignite prospecting models, Wilcox Group and Meridian Sandstone of northern Mississippi: Transactions of the Gulf Coast Association of Geological Societies 30, p. 283–307, accessed at http://archives.datapages.com/data/gcags/data/030/030001/0283.htm.

Coates, E.J., Groat, C.G., and Hart, G.F., 1980, Subsurface Wilcox lignite in west-central Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 30, p. 309–332, accessed at http://archives.datapages.com/data/gcags/data/030/030001/0309.htm.

Coleman J.L., Jr., and Pratt, T.L., 2015, Examination of the Reelfoot rift petroleum system, south-central United States, and the elements that remain for potential exploration and development, *in* Post, P.J., Coleman, J.L., Jr., Rosen, N.C., Brown, D.E., Roberts-Ashby, Tina, Khan, Peter, and Rowan, Mark, eds., Petroleum systems in "rift" basins: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Foundation, 34th Annual GCSSEPM Foundation Perkins-Rosen Research Conference December 13–16, 2015 (Omni Houston Westside), Houston, Tex., p. 345–371, CD-ROM.

Comet, P.A., 1992, Maturity mapping of northern Gulf of Mexico oils using biomarkers: Gulf Coast Association of Geological Societies Transactions, v. 42, p. 433–448, accessed at http://archives.datapages.com/data/gcags/data/042/042001/pdfs/0433.pdf.

Condon, S.M., and Dyman, T.S., 2006, 2003 geologic assessment of undiscovered conventional oil and gas resources in the Upper Cretaceous Navarro and Taylor Groups, Western Gulf Province, Texas, *in* U.S. Geological Survey Western Gulf Province Assessment Team, comps., Petroleum systems and geologic assessment of undiscovered oil and gas, Navarro and Taylor Groups, Western Gulf Province, Texas: U.S. Geological Survey Digital Data Series DDS–69–H, chap. 2, 42 p., accessed January 30, 2009, at http://pubs.usgs.gov/dds/dds-069/dds-069-h/REPORTS/69_H_CH_2.pdf.

Cook, Troy, 2005, Calculation of estimated ultimate recovery (EUR) for wells in continuous-type oil and gas accumulations, *in* U.S. Geological Survey Southwestern Wyoming Province Assessment Team, comps., Petroleum systems and geologic assessment of oil and gas in the Southwestern Wyoming Province, Wyoming, Colorado and Utah: U.S. Geological Survey Digital Data Series DDS–69–D, chap. 23, 6 p., accessed January 30, 2009, at http://pubs.usgs.gov/dds/dds-069/dds-069-d/REPORTS/69_D_CH_23.pdf.

Corcoran, M.K., Harrelson, D.W., and Hennington, G.W., 1994, Petrography and petrology of the Wilds Sand, Wildsville field, Concordia Parish, Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 127–132, accessed at http://archives.datapages.com/data/gcags/data/044/044001/pdfs/0127.pdf.

Crawford, T.G., Burges, G.L., Kinler, C.J., Pendergast, M.T., and Shepard, N.K., 2006, Estimated oil and gas reserves, Gulf of Mexico, December 31, 2003: U.S. Department of the Interior Minerals Management Service, Gulf of Mexico OCS Regional Office, OCS Report MMS 2006–069, 48 p., accessed at http://www.boem.gov/BOEM-Newsroom/Library/Publications/2006/2006-069.aspx.

Crovelli, R.A., 2005, Analytic resource assessment method for continuous petroleum accumulations; The ACCESS assessment method, *in* U.S. Geological Survey Southwestern Wyoming Province Assessment Team, comps., Petroleum systems and geologic assessment of oil and gas in the Southwestern Wyoming Province, Wyoming, Colorado and Utah: U.S. Geological Survey Digital Data Series DDS–69–D, chap. 22, 10 p., accessed January 30, 2009, at http://pubs.usgs.gov/dds/dds-069/dds-069-d/REPORTS/69_D_CH_22.pdf.

Cushing, E.M., Boswell, E.H., and Hosman, R.L., 1964, General geology of the Mississippi embayment: U.S. Geological Survey Professional Paper 448–B, p. B1–B28. [Also available at http://pubs.er.usgs.gov/usgspubs/pp/pp448B.]

Dennen, K.O., Warwick, P.D., and McDade, E.C., 2010, Thermal maturity data used by the U.S. Geological Survey for the U.S. Gulf Coast region oil and gas assessment: U.S. Geological Survey Open-File Report 2010–1072, 7 p., plus appendix. [Also available at http://pubs.usgs.gov/of/2010/1072/.]

Dickinson, George, 1953, Geological aspects of abnormal reservoir pressures in Gulf Coast Louisiana: American Association of Petroleum Geologists Bulletin, v. 37, no. 2, p. 410–432, accessed at http://archives.datapages.com/data/bulletns/1953-56/images/pg/00370002/0400/04100.pdf.

Dockery, D.T., III, 2001, Correlation of the Wilcox producing zones (late Paleocene-early Eocene) of southwestern Mississippi with the type Midway/Wilcox section of Alabama: Gulf Coast Association of Geological Societies Transactions, v. 51, p. 63–73, accessed at http://archives.datapages.com/data/gcags/data/051/051001/pdfs/0063.pdf.

Dodge, M.M., and Posey, J.S., 1981, Structural cross sections, Tertiary formations, Texas Gulf Coast: University of Texas at Austin, Bureau of Economic Geology, U.S. Department of Energy contract no. DE–AC08–78ET11397, 6 p., 32 pls.

Dow, W.G., Mukhopadhyay, P.K., and Jackson, T., 1988, Source rock potential and maturation of deep Wilcox from south-central Texas: American Association of Petroleum Geologists Bulletin, v. 72, no. 2, p. 179.

Dubiel, R.F., Pitman, J.K., Pearson, O.N., Condon, S.M., Warwick, P.D., Karlsen, A.W., Coleman, J.L., Hackley, P.C., Hayba, D.O., Swanson, S.M., Charpentier, R.R., Cook, T.A., Klett, T.R., Pollastro, R.M., and Schenk, C.J., 2007, Assessment of undiscovered oil and gas resources in Tertiary strata of the Gulf Coast, 2007: U.S. Geological Survey Fact Sheet 2007–3066, 4 p. [Also available at http://pubs.usgs.gov/fs/2007/3066/.]

Dubiel, R.F., Warwick, P.D., Swanson, Sharon, Burke, Lauri, Biewick, L.R.H., Charpentier, R.R., Coleman, J.L., Cook, T.A., Dennen, Kris, Doolan, Colin, Enomoto, Catherine, Hackley, P.C., Karlsen, A.W., Klett, T.R., Kinney, S.A., Lewan, M.D., Merrill, Matt, Pearson, Krystal, Pearson, O.N., Pitman, J.K., Pollastro, R.M., Rowan, E.L., Schenk, C.J., and Valentine, Brett, 2011, Assessment of undiscovered oil and gas resources in Jurassic and Cretaceous strata of the Gulf Coast, 2010: U.S. Geological Survey Fact Sheet 2011–3020, 4 p. [Also available at http://pubs.usgs.gov/fs/2011/3020/.]

Dutton, S.P., and Loucks, R.G., 2007, Reservoir quality and pore-type evolution in deep to ultradeep Tertiary sandstones of the northern Texas Gulf of Mexico Coast [abs.]: American Association of Petroleum Geologists 2007 Annual Convention and Exhibition Abstracts, v. 16, p. 39, accessed at http://www.searchanddiscovery.com/abstracts/html/2007/annual/abstracts/lbDutton.htm?q=%2BtextStrip%3Adutton.

Dutton, S.P., and Loucks, R.G., 2008, Extending diagenetic trends in the Eocene Wilcox Formation with data from deep to ultradeep sandstones of the northern Texas Gulf of Mexico Coast [abs.]: American Association of Petroleum Geologists 2008 Annual Convention and Exhibition Abstracts, v. 17, p. 51, accessed January 30, 2009, at http://www.searchanddiscovery.net/abstracts/html/2008/annual/abstracts/408369.htm?q=%2Btext%3Adutton.

Dutton, S.P., and Loucks, R.G., 2010, Diagenetic controls on evolution of porosity and permeability in lower Tertiary Wilcox sandstones from shallow to ultradeep (200–6700 m) burial, Gulf of Mexico Basin, U.S.A.: Marine and Petroleum Geology, v. 27, no. 8, p. 1,775–1,787, accessed at http://www.sciencedirect.com/science/article/pii/S0264817209002359.

Dyman, T.S., and Condon, S.M., 2006, Assessment of undiscovered conventional oil and gas resources; Upper Jurassic-Lower Cretaceous Cotton Valley Group, Jurassic Smackover interior salt basins total petroleum system, in the East Texas Basin and Louisiana-Mississippi Salt Basins Provinces, *in* U.S. Geological Survey Gulf Coast Region Assessment Team, comps., Petroleum systems and geologic assessment of undiscovered oil and gas, Cotton Valley Group and Travis Peak–Hosston Formations, East Texas Basin and Louisiana-Mississippi Salt Basins Provinces of the northern Gulf Coast region: U.S. Geological Survey Digital Data Series DDS–69–E, chap. 2, 48 p., accessed January 30, 2009, at http://pubs.usgs.gov/dds/dds-069/dds-069-e/.

Echols, J.B., and Goddard, D.A., 1992, Sea level fluctuations, Paleocene middle Wilcox stratigraphy and hydrocarbon distribution in east-central Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 42, p. 459–466, accessed at http://archives.datapages.com/data/gcags/data/042/042001/pdfs/0459.pdf.

Echols, J.B., Zimmerman, R.K., and Goddard, D.A., 1994, An integrated geochemical and geological approach for determining hydrocarbon generation-migration patterns; Central Gulf Coast Basin: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 193–203, accessed at http://archives.datapages.com/data/gcags/data/044/044001/pdfs/0193.pdf.

Echols, J.B., Zimmerman, R.K., and Goddard, D.A., 1995, Geological and geochemical evidence for vertical migration of Upper Cretaceous sourced oils into Tertiary reservoirs; Winn and Grant Parishes, Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 45, p. 173–179, accessed at http://archives.datapages.com/data/gcags/data/045/045001/pdfs/0173.pdf.

Engelder, Terry, and Leftwich, J.T., Jr., 1997, A pore-pressure limit in overpressured south Texas oil and gas fields, *in* Surdam, R.C., ed., Seals, traps, and the petroleum system: American Association of Petroleum Geologists Memoir 67, chap. 15, p. 255–267, accessed at http://archives.datapages.com/data/specpubs/mem67/ch15/images/ch15.pdf.

Enomoto, C.B., 2014, Well log and 2D seismic data character of the Wilcox Group in south-central Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 64, p. 105–118, accessed at http://archives.datapages.com/data/gcags/data/064/064001/pdfs/105.pdf.

Enos, J.S., and Kyle, J.R., 2002, Diagenesis of the Carrizo Sandstone at Butler salt dome, east Texas Basin, U.S.A.; Evidence for fluid-sediment interaction near halokinetic structures: Journal of Sedimentary Research, v. 72, no. 1, p. 68–81, accessed at http://archives.datapages.com/data/sepm/journals/v72/data/072/072001/pdfs/0068.pdf.

Evans, Robert, 1987, Pathways of migration of oil and gas in the south Mississippi salt basin: Gulf Coast Association of Geological Societies Transactions, v. 37, p. 75–86, accessed at http://archives.datapages.com/data/gcags/data/037/037001/pdfs/0075.pdf.

Eversull, L.G., 1984, Regional cross sections, north Louisiana: Louisiana Geological Survey Folio Series 7, 11 p.

Ewing, T.E., 1991a, Structural framework, *in* Salvador, Amos, ed., The Gulf of Mexico Basin, v. J *of* The geology of North America: Boulder, Colo., Geological Society of America, p. 31–52.

Ewing, T.E., 1991b, The tectonic framework of Texas: University of Texas at Austin, Bureau of Economic Geology, Publication SM0001, 36 p. [Accompanying text to "Tectonic map of Texas."]

Ewing, T.E., comp. (with contributions by Budnik, R.T., Ames, J.T., Ridner, D.M., and Dillon, R.L.), 1990, Tectonic map of Texas: University of Texas at Austin, Bureau of Economic Geology SM0001, 4 sheets, scale 1:750,000.

Ewing, T.E., and Lopez, R.F., 1991, Principal structural features, Gulf of Mexico Basin, *in* Salvador, Amos, ed., The Gulf of Mexico Basin, v. J *of* The geology of North America: Boulder, Colo., Geological Society of America, pl. 2.

Fiduk, J.C., and Hamilton, D.S., 1995, Seismic analysis of the Duval County Ranch area, south Texas; Assessment of exploration potential of the Wilcox, Queen City, and Jackson-Yegua plays: University of Texas at Austin, Bureau of Economic Geology Geologic Circular 95–04, 42 p.

Fillon, R.H., 2001, Late Mesozoic and Cenozoic deposystem evolution in the eastern Gulf of Mexico; Implications for hydrocarbon migration, *in* Fillon, R.H., Rosen, N., Weimer, P., Lowrie, A., Pettingill, H., Phair, R.L., Roberts, H.H., and van Hoorn, B., eds., Petroleum Systems of deep-water basins; Global and Gulf of Mexico experience: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Foundation, 21st Annual Bob F. Perkins Research Conference, Houston, Tex., December 2–5, 2001, p. 549–560, CD-ROM.

Fisher, W.L., and McGowen, J.H., 1967, Depositional systems in the Wilcox Group of Texas and their relationship to occurrence of oil and gas: Gulf Coast Association of Geological Societies Transactions, v. 17, p. 105–125, accessed at http://archives.datapages.com/data/gcags/data/017/017001/pdfs/0105.pdf.

Flemings, P.B., Stump, B.B., Finkbeiner, Thomas, and Zoback, M.D., 2000, How pressure, stress, and column height interact to control secondary migration within geopressured strata, *in* Shoup, Robert, Watkins, Joel, Karlo, John, and Hall, Dave, eds., Integration of geologic models for understanding risk in the Gulf of Mexico: American Association of Petroleum Geologists Hedberg Research Conference, Galveston, Tex., September 20–24, 1998, p. 1–4, CD-ROM, accessed at http://archives.datapages.com/data/specpubs/discovery1/D0130/IMAGES/3_11.pdf.

French, L.S., Richardson, G.E., Kazanis, E.G., Montgomery, T.M., Bohannon, C.M., and Gravois, M.P., 2006, Deepwater Gulf of Mexico 2006; America's expanding frontier: U.S. Department of the Interior Minerals Management Service, Gulf of Mexico OCS Regional Office, OCS Report MMS 2006–022, 144 p.

Frezon, S.E., Finn, T.M., comps., and Varnes, K.L., ed., 1988, Map of sedimentary basins in the conterminous United States: U.S. Geological Survey Oil and Gas Investigation Map OM–223, 1 sheet, scale: 1:5,000,000. [Also available at http://ngmdb.usgs.gov/Prodesc/proddesc_5378.htm.]

Galloway, W.E., 1968, Depositional systems of the lower Wilcox Group, north-central Gulf Coast Basin: Transactions of the Gulf Coast Association of Geological Societies, v. 18, p. 275–289, accessed at http://archives.datapages.com/data/gcags/data/018/018001/pdfs/0275.pdf.

Galloway, W.E., Bebout, D.G., Fisher, W.L., Dunlap, J.B., Jr., Cabrera-Castro, R., Lugo-Rivera, J.E., and Scott, T.M., 1991, Cenozoic, *in* Salvador, Amos, ed., The Gulf of Mexico Basin, v. J *of* The geology of North America: Boulder, Colo., Geological Society of America, p. 245–324.

Galloway, W.E., Ewing, T.E., Garrett, C.M., Tyler, N., and Bebout, D.G., 1983, Atlas of major Texas oil reservoirs: University of Texas at Austin, Bureau of Economic Geology AT0002, 139 p., 5 pls. in pocket.

Galloway, W.E., Ganey-Curry, P.E., Li, X., and Buffler, R.T., 2000, Cenozoic depositional history of the Gulf of Mexico Basin: American Association of Petroleum Geologists Bulletin, v. 84, no. 11, p. 1,743–1,774, accessed at http://archives.datapages.com/data/bulletns/2000/11nov/1743/images/00_1743.pdf.

Galloway, W.E., Liu, X., Travis-Neuberger, D., and Xue, L., 1994, Reference high-resolution correlation cross sections, Paleogene section, Texas Coastal Plain: University of Texas at Austin, Bureau of Economic Geology, 19 p., 5 pls.

Gatenby, G., 2001, Phase changes; A major aspect of deepwater hydrocarbon migration, *in* Fillon, R.H., Rosen, N., Weimer, P., Lowrie, A., Pettingill, H., Phair, R.L., Roberts, H.H., and van Hoorn, B., eds., Petroleum Systems of deep-water basins; Global and Gulf of Mexico experience: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Foundation, 21st Annual Bob F. Perkins Research Conference, Houston, Tex., December 2–5, 2001, p. 453–468, CD-ROM.

Geomap, 1995a, Southwest Louisiana; Geomap standard executive reference map 303: Plano, Tex., Geomap Company, 1 sheet, scale 1:316,800.

Geomap, 1995b, Southeast Louisiana; Geomap standard executive reference map 304: Plano, Tex., Geomap Company, 1 sheet, scale 1:316,800.

Geomap, 1995c, Northeast Texas Gulf Coast; Geomap standard executive reference map 312: Plano, Tex., Geomap Company, 1 sheet, scale 1:380,160.

Glawe, L.N., 1995, Paleoenvironments and sequences of subsurface Paleocene Wilcox in Sabine Parish, Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 45, p. 219–227, accessed at http://archives.datapages.com/data/gcags/data/045/045001/pdfs/0219.pdf.

Glawe, L.N., and Echols, J.B., 1997, Middle Wilcox correlation of central Louisiana: Louisiana Geological Survey, Basin Research Institute, publication CS–2–97, 9 p., 7 sheets, scale: 1:316,800.

Glawe, L.N., Young, L.M., and Roberts, H.H., 1999, Petrology, paleontology, and paleoenvironments of Wilds and lower Nichols Sands-subsurface Paleocene Wilcox units in Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 49, p. 266–273, accessed at http://archives.datapages.com/data/gcags/data/049/049001/pdfs/0266.pdf.

Goddard, D.A., Zimmerman, R.K., White, C.D., and Birdwell, M.N., 2002, Dominant structural and stratigraphic characteristics influencing hydrocarbon production distribution in Louisiana's Livingston field: Gulf Coast Association of Geological Societies Transactions, v. 52, p. 337–349, accessed at http://archives.datapages.com/data/gcags/data/052/052001/pdfs/0337.pdf.

Greenberg, R.L., and Swinbank, T.W., 1998, Dilworth (Carrizo) field, McMullen County, Texas, *in* Allen, J.L., Brown, T.S., John, C.J., and Lobo, C.E., eds., 3-D seismic case histories from the Gulf Coast Basin: Gulf Coast Association of Geological Societies Special Publication, June 1998, p. 91–97, accessed at http://archives.datapages.com/data/gcags_spec/data/001/3d-seismic/091/images/091.pdf.

Gregory, W.A., Chinn, E.W., Sassen, Roger, and Hart, G.F., 1991, Fluorescence microscopy of particulate organic matter; Sparta Formation and Wilcox Group, south central Louisiana: Organic Geochemistry, v. 17, no. 1, p. 1–9, accessed at http://www.sciencedirect.com/science/journal/01466380/17/1.

Grubbs, E.L., 1953, Variations in porosity and permeability in the Wilcox Group of the Texas upper Gulf Coast: Gulf Coast Association of Geological Societies Transactions, v. 3, p. 54–70, accessed at http://archives.datapages.com/data/gcags/data/003/003001/pdfs/0054.pdf.

Halbouty, T.M., 1979, Salt domes, Gulf region, United States and Mexico, 2d ed.: Houston, Tex., Gulf Publishing, 561 p.

Hamlin, H.S., 1983, Fluvial depositional systems of the Carrizo-upper Wilcox in south Texas: Gulf Coast Association of Geological Societies Transactions, v. 33, p. 281–287, accessed at http://archives.datapages.com/data/gcags/data/033/033001/pdfs/0281.pdf.

Hamlin, H.S., 1988, Depositional and ground-water flow systems of the Carrizo-upper Wilcox, south Texas: University of Texas at Austin, Bureau of Economic Geology Report of Investigations 175, 61 p.

Hargis, R.N., 2000, Regional stratigraphy and subdivision, lower part of upper Wilcox, Duval Delta area, south Texas: Gulf Coast Association of Geological Societies Transactions, v. 50, p. 269–280, accessed at http://archives.datapages.com/data/gcags/data/050/050001/pdfs/0269.pdf.

Harris, G.D., 1894, On the geological position of the Eocene deposits of Maryland and Virginia: American Journal of Science, 3d ser., v. 47, p. 301–304, accessed at http://www.ajsonline.org/content/s3-47/280/301.full.pdf+html?sid=d22a2cca-caeb-40b0-b1de-841fc8417559.

Harris, J.R., 1962, Petrology of the Eocene Sabinetown-Carrizo contact, Bastrop County, Texas: Journal of Sedimentary Petrology, v. 32, no. 2, p. 263–283, accessed at http://jsedres.geoscienceworld.org/content/32/2/263.full.pdf+html?sid=4852eee5-6907-4057-b63f-a32f0a147a2c.

Holden, F.T., 1951, Developments in southeastern states in 1950: American Association of Petroleum Geologists Bulletin, v. 35, no. 6, p. 1,352–1,365, accessed at http://archives.datapages.com/data/bulletns/1949-52/images/pg/00350006/1350/13520.pdf.

Hood, K.C., Wenger, L.M., Gross, O.P., and Harrison, S.C., 2002, Hydrocarbon systems analysis of the northern Gulf of Mexico; Delineation of hydrocarbon migration pathways using seeps and seismic imaging, *in* Schumacher, Dietmar, and LeSchack, L.A., eds., Surface exploration case histories; Applications of geochemistry, magnetics, and remote sensing: American Association of Petroleum Geologists Studies in Geology no. 48 and Society of Exploration Geophysicists Geophysical Reference Series no. 11, p. 25–40, accessed at http://archives.datapages.com/data/specpubs/study48/st48ch02/images/st48ch02.pdf.

Hopf, R.W., 1965, Part II; The Poth Sand trend of southwest Texas Glen Hummel field, Wilson County, Texas: South Texas Geological Society Bulletin, v. 5, no. 15, p. 4–12, accessed at http://archives.datapages.com/data/south-texas-geosoc-bulletins/data/005/005015/pdfs/4.pdf.

Hopf, R.W., 1967, The Poth Sand trend of southwest Texas, *in* Ellis, W.G., ed., Contributions to the geology of south Texas: San Antonio, Tex., South Texas Geological Society, p. 46–55.

Hopf, R.W., 1986a, Delta environments in the upper Midway Formation of Wilcon County, Texas, *in* Stapp, W.L., Dutton, L.A., Weise, B.R., Jones, L.P., and Fergeson, W.G., eds., Contributions to the geology of south Texas 1986: San Antonio, Tex., South Texas Geological Society, p. 294–306.

Hopf, R.W., 1986b, Extrapolated reserve estimates from past and present production in the Poth Sand trend of south Texas, *in* Stapp, W.L., Dutton, L.A., Weise, B.R., Jones, L.P., and Fergeson, W.G., eds., Contributions to the geology of south Texas 1986: San Antonio, Tex., South Texas Geological Society, p. 307–322.

Horn, M.K., 2003, Giant fields 1868–2003, *in* Halbouty, M.K., ed., Giant oil and gas fields of the decade 1990–1999: American Association of Petroleum Geologists Memoir 78, 340 p., CD-ROM.

Hosman, R.L., 1996, Regional stratigraphic and subsurface geology of Cenozoic deposits, Gulf coastal plain, south-central United States: U.S. Geological Survey Professional Paper 1416–G, p. G1–G35, 14 pls., accessed January 30, 2009, at http://pubs.er.usgs.gov/usgspubs/pp/pp1416G.

Humble Geochemical Services, Geochemical and Environmental Research Group, BEICIP, Inc., Brame Geosciences, 2002, Petroleum systems of the Gulf of Mexico; Prediction of hydrocarbon charge, GOM source rock, and oil asphaltene kinetics in Temispack 2D basin modeling, proposal 2002: 16 p.

Hunt, J.M., Whelan, J.K., Eglinton, L.B., and Cathles, L.M., III, 1998, Relation of shale porosities, gas generation, and compaction to deep overpressures in the U.S. Gulf Coast, *in* Law, B.E., Ulmishek, G.F., and Slavin, V.I., eds., Abnormal pressures in hydrocarbon environments: American Association of Petroleum Geologists Memoir 70, p. 87–104, accessed at http://archives.datapages.com/data/specpubs/memoir70/m70ch05/images/m70ch05.PDF.

IHS Energy Group, 2005a [includes data current as of December, 2005], PI/Dwights PLUS U.S. production data: Englewood, Colo., IHS Energy Group, database available from IHS Energy Group, 15 Inverness Way East, D205, Englewood, CO 80112, U.S.A.

IHS Energy Group, 2005b [includes data current as of December, 2005], PI/Dwights PLUS U.S. well data: Englewood, Colo., IHS Energy Group, database available from IHS Energy Group, 15 Inverness Way East, D205, Englewood, CO 80112, U.S.A.

Jones, R.W., 1990, Conference highlights, *in* Schumacher, Dietmar, and Perkins, B.F., eds., Gulf Coast oils and gases; Their characteristics, origin, distribution, and exploration and production significance: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Foundation, 9th Annual Research Conference, December 1988, New Orleans, La., Proceedings, Austin, Tex., v. 9, p. 1–8.

Kinsland, G.L., Zeosky, J.E., Smith, G.B., and Schneider, R.V., 2003, Integrated exploration scheme for lower Wilcox coalbed methane in central Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 53, p. 398–409, accessed at http://archives.datapages.com/data/gcags/data/053/053001/pdfs/0398.pdf.

Klett, T.R., 2004, Oil and natural gas resource assessment; Classifications and terminology: Encyclopedia of Energy, Amsterdam, Elsevier, Inc., v. 4, p. 595–605.

Klett, T.R., and Schmoker, J.W., 2005, U.S. Geological Survey input-data form and operational procedure for the assessment of continuous petroleum accumulations, 2002, *in* U.S. Geological Survey Southwestern Wyoming Province Assessment Team, comps., Petroleum systems and geologic assessment of oil and gas in the Southwestern Wyoming Province, Wyoming, Colorado and Utah: U.S. Geological Survey Digital Data Series DDS–69–D, chap. 18, 8 p., accessed January 30, 2009, at http://certmapper.cr.usgs.gov/data/noga00/natl/text/CH_18.pdf.

Klett, T.R., Schmoker, J.W., and Charpentier, R.R., 2003, U.S. Geological Survey input-data form and operational procedure for the assessment of conventional petroleum accumulations, *in* U.S. Geological Survey Uinta-Piceance Assessment Team, comps., Petroleum systems and geologic assessment of oil and gas in the Uinta-Piceance Province, Utah and Colorado: U.S. Geological Survey Digital Data Series DDS–69–B, chap. 20, 7 p., accessed January 30, 2009, at http://pubs.usgs.gov/dds/dds-069/dds-069-b/REPORTS/Chapter_20.pdf.

Klett, T.R., Schmoker, J.W., and Charpentier, R.R., 2005, U.S. Geological Survey input-data form and operational procedure for the assessment of conventional petroleum accumulations, *in* U.S. Geological Survey Southwestern Wyoming Province Assessment Team, comps., Petroleum systems and geologic assessment of oil and gas in the Southwestern Wyoming Province, Wyoming, Colorado and Utah: U.S. Geological Survey Digital Data Series DDS–69–D, chap. 20, 7 p., accessed January 30, 2009, at http://certmapper.cr.usgs.gov/data/noga00/natl/text/CH_20.pdf.

Koons, C.B., Bond, J.G., and Peirce, F.L., 1974, Effects of depositional environment and postdepositional history on chemical composition of lower Tuscaloosa oils: American Association of Petroleum Geologists Bulletin, v. 58, no. 7, p. 1,272–1,280, accessed at http://archives.datapages.com/data/bulletns/1974-76/images/pg/00580007/1250/12720.pdf.

Kosters, E.C., Bebout, D.G., Seni, S.J., Garrett, C.M., Jr., Brown, L.F., Jr., Hamlin, H.S., Dutton, S.P., Ruppel, S.C., Finley, R.J., and Tyler, N., 1989, Atlas of major Texas gas reservoirs: The University of Texas at Austin, Bureau of Economic Geology, Austin, Tex., 161 p. [R.J. Finley, Project Director, Gas Research Institute.]

Kull, Joshua, and Kinsland, G.L., 2006, Logfacies distribution of the Wilcox coal-bearing interval in north-central Louisiana; A quick-look technique for coalbed methane resource evaluation: Gulf Coast Association of Geological Societies Transactions, v. 56, p. 405–409, accessed at http://archives.datapages.com/data/gcags/data/056/056001/pdfs/405.pdf.

Laplante, R.E., 1974, Hydrocarbon generation in the Gulf Coast Tertiary sediments: American Association of Petroleum Geologists Bulletin, v. 58, no. 7, p. 1,281–1,289, accessed at http://archives.datapages.com/data/bulletns/1974-76/images/pg/00580007/1250/12810.pdf.

Leftwich, J.T., Jr., 1993, The development of zones of “undercompacted” shale relative to abnormal subsurface pressures in sedimentary basins: University Park, Pa., Pennsylvania State University, Ph.D. dissertation, 169 p., plus appendixes.

Leftwich, J.T., Jr., and Engelder, Terry, 1994, The characteristics of geopressure profiles in the Gulf of Mexico Basin, *in* Ortoleva, P.J., ed., Basin compartments and seals: American Association of Petroleum Geologists Memoir 61, p. 119–129, accessed at http://archives.datapages.com/data/specpubs/memoir61/ch08/images/ch08.pdf.

Lewan, M.D., 2002, New insights on timing of oil and gas generation in the central Gulf Coast interior zone based on hydrous-pyrolysis kinetic parameters: Gulf Coast Association of Geological Societies Transactions, v. 52, p. 607–620, accessed at http://archives.datapages.com/data/gcags/data/052/052001/pdfs/0607.pdf.

Long, John, 1986, The Eocene Lobo gravity slide, Webb and Zapata Counties, Texas, *in* Stapp, W.L., Dutton, L.A., Weise, B.R., Jones, L.P., and Fergeson, W.G., eds., Contributions to the geology of south Texas: San Antonio, Tex., South Texas Geological Society, p. 270–293.

Lopez, J.A., comp., 1995, Salt tectonism of the United States Gulf Coast Basin: New Orleans Geological Society Publication, 2d ed. map, 1 sheet, scale 1:1,524,000, accessed at http://archives.datapages.com/data/nogs/data/006/006034/pdfs/0001.pdf.

Losh, Steven, 1998, Oil migration in a major growth fault; Structural analysis of the Pathfinder core, South Eugene Island block 330, offshore Louisiana: American Association of Petroleum Geologists Bulletin, v. 82, no. 9, p. 1,694–1,710, accessed at http://archives.datapages.com/data/bulletns/1998/09sep/1694/images/98_1694.pdf.

Magoon, L.B., and Dow, W.G., 1994, The petroleum system, *in* Magoon, L.B., and Dow, W.G., eds., The petroleum system; From source to trap: American Association of Petroleum Geologists Memoir 60, p. 3–24, accessed at http://archives.datapages.com/data/specpubs/methodo2/images/a077/a0770001/0000/00030.pdf.

Mancini, E.A., Goddard, D.A., Aharon, P., and Barnaby, R., 2006, Resource assessment of the in-place and potentially recoverable deep natural gas resource of the onshore interior salt basins, north-central and northeastern Gulf of Mexico: Department of Geological Sciences, University of Alabama, Department of Energy contract no. DE–FC26–03NT41875, 173 p., accessed at http://www.netl.doe.gov/File%20Library/Research/Oil-Gas/Natural%20Gas/NT41875_FinalRpt.pdf.

Mancini, E.A., Tew, B.H., and Carrol, R.E., 1993, Paleocene-Eocene lignite beds of southwest Alabama; Parasequence beds in highstand systems tracts: Gulf Coast Association of Geological Societies Transactions, v. 43, 249–256, accessed at http://archives.datapages.com/data/gcags/data/043/043001/pdfs/0249.pdf.

McBride, B.C., 1998, The evolution of allochthonous salt along a megaregional profile across the northern Gulf of Mexico Basin: American Association of Petroleum Geologists Bulletin, v. 82, no. 5B, p. 1,037–1,054, accessed at http://archives.datapages.com/data/bulletns/1998/05may_b/1037/images/98_1037.pdf.

McBride, B.C., Rowan, M.G., and Weimer, Paul, 1998, The evolution of allochthonous salt systems, northern Green Canyon and Ewing Bank (offshore Louisiana), northern Gulf of Mexico: American Association of Petroleum Geologists Bulletin, v. 82, no. 5B, p. 1,013–1,036, accessed at http://archives.datapages.com/data/bulletns/1998/05may_b/1013/images/98_1013.pdf.

McBride, E.F., Diggs, T.N., and Wilson, J.C., 1991, Compaction of Wilcox and Carrizo sandstones (Paleocene-Eocene) to 4420 m, Texas Gulf Coast: Journal of Sedimentary Petrology, v. 61, no. 1, p. 73–85, accessed at http://jsedres.geoscienceworld.org/content/61/1/73.full.pdf+html?sid=9f8ae954-b49a-4200-ba4a-deb5532edf71.

McDade, E.C., Sassen, Roger, Wenger, Lloyd, and Cole, G.A., 1993, Identification of organic-rich lower Tertiary shales as petroleum source rocks, south Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 43, p. 257–267, accessed at http://archives.datapages.com/data/gcags/data/043/043001/pdfs/0257.pdf.

McIntosh, J.C., Warwick, P.D., Martini, A.M., and Osborn, S.G., 2010, Coupled hydrology and biogeochemistry of Paleocene-Eocene coal beds, northern Gulf of Mexico: Geological Society of America Bulletin, v. 122, nos. 7–8, p. 1,248–1,264, accessed at http://gsabulletin.gsapubs.org/content/122/7-8/1248.full.pdf+html?sid=4bcd2398-de17-414a-920c-259a7e3b9d68.

Meyer, Dave, Zarra, Larry, Rains, David, Meltz, Bob, and Hall, Tom, 2005, Emergence of the lower Tertiary Wilcox trend in the deepwater Gulf of Mexico: American Association of Petroleum Geologists Search and Discovery Article 10084, unpaginated, accessed on January 30, 2009, at http://www.searchanddiscovery.com/documents/2005/meyer/images/meyer.pdf.

Meyer, Dave, Zarra, Larry, and Yun, Janet, 2007, From BAHA to Jack, evolution of the lower Tertiary Wilcox trend in the deepwater Gulf of Mexico: SEPM Society for Sedimentary Geology, The Sedimentary Record, v. 5, no. 3, p. 4–9, accessed at http://www.sepm.org/CM_Files/SedimentaryRecord/SR_205-3Final.pdf.

Meyerhoff, J.C., and Braddock, Rion, 1998, Loma Vieja field; Structural geology and related velocity fault shadow in the upper Wilcox (Fandango) in south Texas: Gulf Coast Association of Geological Societies Transactions, v. 48, p. 235–251, accessed at http://archives.datapages.com/data/gcags/data/048/048001/pdfs/0235.pdf.

Milici, R.C., 1980, Relationship of regional structure to oil and gas producing areas in the Appalachian Basin: U.S. Geological Survey Miscellaneous Investigations Series Map I–917–F, 5 sheets, scale 1:2,500,000. [Also available at http://pubs.er.usgs.gov/publication/i917F.]

Murray, G.E., Jr., 1961, Geology of the Atlantic and Gulf Coastal Province of North America: New York, Harper Brothers, 692 p.

Nehring Associates, Inc., 2006 [includes data current as of December 31, 2004], The significant oil and gas fields of the United States: Colorado Springs, Colo., Nehring Associates, Inc., database available from Nehring Associates, Inc., P.O. Box 1655, Colorado Springs, CO 80901, U.S.A.

Nehring, Richard, 1991, Oil and gas resources, *in* Salvador, Amos, ed., The Gulf of Mexico Basin, v. J *of* The geology of North America: Boulder, Colo., Geological Society of America, p. 445–494.

Nelson, E.J., Weimer, Paul, Caldaro-Baird, Julia, and McBride, Barry, 2000, Timing of source rock maturation in the northern Gulf of Mexico Basin; Results from thermal modeling of a regional profile: Gulf Coast Association of Geological Societies Transactions, v. 50, p. 309–319, accessed at http://archives.datapages.com/data/gcags/data/050/050001/pdfs/0309.pdf.

Nunn, J.A., and Sassen, Roger, 1986, The framework of hydrocarbon generation and migration, Gulf of Mexico continental slope: Gulf Coast Association of Geological Societies Transactions, v. 36, p. 257–262, accessed at http://archives.datapages.com/data/gcags/data/036/036001/pdfs/0257.pdf.

Palmer, A.R., and Geissman, John, comps., 1999, 1999 geologic time scale: The Geological Society of America, product code CTS004, 1 p., accessed at http://www.geosociety.org/science/timescale/timescl-1999.pdf.

Palmer, L.L., 1954, Structural significance of the Floresville-Stockdale trend: Gulf Coast Association of Geological Societies Transactions, v. 4, p. 19–24, accessed at http://archives.datapages.com/data/gcags/data/004/004001/pdfs/0019.pdf.

Pitman, J.K., Dubiel, R.F., Nelson, P.H., Kibler, Joyce, Charpentier, R.R., Cook, T.A., Klett, T.R., Pollastro, Richard, and Schenk, C.J., 2007, Assessment of undiscovered gas resources in the Upper Cretaceous Tuscaloosa and Woodbine Formations, Western Gulf Province of the Gulf Coast region, Louisiana and Texas, 2007: U.S. Geological Survey Fact Sheet 2006–3146, 2 p. [Also available at http://pubs.usgs.gov/fs/2006/3146/.]

Pitman, J.K., and Rowan, Elisabeth, 2012, Temperature and petroleum generation history of the Wilcox Formation, Louisiana: U.S. Geological Survey Open-File Report 2012–1046, 51 p. [Also available at http://pubs.usgs.gov/of/2012/1046/.]

Price, L.C., 1991, On the origin of the Gulf Coast Neogene oils: Gulf Coast Association of Geological Societies Transactions, v. 41, p. 524–541, accessed at http://archives.datapages.com/data/gcags/data/041/041001/pdfs/0524.pdf.

Price, L.C., and Clayton, J.L., 1990, Reasons for and significance of deep, high-rank hydrocarbon generation in the south Texas Gulf Coast, *in* Schumacher, Dietmar, and Perkins, B.F., eds., Gulf Coast oils and gases; Their characteristics, origin, distribution, and exploration and production significance: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Foundation, 9th Annual Research Conference, December 1988, New Orleans, La., Proceedings, Austin, Tex., p. 105–137.

Reinson, G.E., 1984, Barrier island and associated strand-plain systems, *in* Walker, R.G., ed., Facies models: Geological Association of Canada, Geoscience Canada Reprint Series 1, p. 119–140.

Riggs, S.R., Ellison, S.P., Jr., Fisher, W.L., Galloway, W.E., Jackson, M.L.W., and Morton, R.A., 1991, Mineral resources and geopressured-geothermal energy, *in* Salvador, Amos, ed., The Gulf of Mexico Basin, v. J *of* The Geology of North America: Boulder, Colo., Geological Society of America, p. 495–528.

Rowan, E.L., Pitman, J.K., and Warwick, P.D., 2007, Thermal maturation history of the Wilcox Group (Paleocene-Eocene), Texas; Results of regional-scale multi-1D modeling, *in* Kennan, Lorcan, Pindell, James, and Rosen, N.C., eds., The Paleogene of the Gulf of Mexico and Caribbean Basins; Processes, events, and petroleum systems: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Foundation, 27th Annual Bob F. Perkins Research Conference, Houston, Tex., December 2–5, 2007, v. 27, p. 714–743, CD-ROM.

Ryman, L.J., 1954, Southwest Muldoon field Fayette County, Texas: Gulf Coast Association of Geological Societies Transactions, v. 4, p. 27–37, accessed at http://archives.datapages.com/data/gcags/data/004/004001/pdfs/0027.pdf.

Salvador, Amos, 1991, Cross sections of the Gulf of Mexico Basin, *in* Salvador, Amos, ed., The Gulf of Mexico Basin, v. J *of* The Geology of North America: Boulder, Colo., Geological Society of America, pl. 6.

Salvador, Amos, and Quezada Muneton, J.M., 1991, Stratigraphic correlation chart; Gulf of Mexico Basin, *in* Salvador, Amos, ed., The Gulf of Mexico Basin, v. J *of* The Geology of North America: Boulder, Colo., Geological Society of America, pl. 5.

Sassen, Roger, 1990, Lower Tertiary and Upper Cretaceous source rocks in Louisiana and Mississippi; Implications to Gulf of Mexico crude oil: American Association of Petroleum Geologists Bulletin, v. 74, no. 6, p. 857–878, accessed at http://archives.datapages.com/data/bulletns/1990-91/images/pg/00740006/0000/08570.pdf.

Sassen, Roger, and Moore, C.H., 1988, Framework of hydrocarbon generation and destruction in eastern Smackover trend: American Association of Petroleum Geologists Bulletin, v. 72, no. 6, p. 649–663, accessed at http://archives.datapages.com/data/bulletns/1988-89/images/pg/00720006/0600/06490.pdf.

Sassen, Roger, Tye, R.S., Chinn, E.W., and Lemoine, R.C., 1988, Origin of crude oil in the Wilcox trend of Louisiana and Mississippi; Evidence of long-range migration: Gulf Coast Association of Geological Societies Transactions, v. 38, p. 27–34, accessed at http://archives.datapages.com/data/gcags/data/038/038001/pdfs/0027.pdf.

Schenk, C.J., and Viger, R.J., 1996a, East Texas Basin Province (048) and Louisiana-Mississippi Salt Basins Province (049): U.S. Geological Survey Digital Data Series DDS–30, release 2, accessed at http://certmapper.cr.usgs.gov/data/noga95/prov49/text/prov49.pdf.

Schenk, C.J., and Viger, R.J., 1996b, Western Gulf Province (047): U.S. Geological Survey Digital Data Series DDS–30, release 2, accessed at http://certmapper.cr.usgs.gov/data/noga95/prov47/text/prov47.pdf.

Schmoker, J.W., 2005, U.S. Geological Survey assessment concepts for continuous petroleum accumulations, *in* U.S. Geological Survey Southwestern Wyoming Province Assessment Team, comps., Petroleum systems and geologic assessment of oil and gas in the Southwestern Wyoming Province, Wyoming, Colorado and Utah: U.S. Geological Survey Digital Data Series DDS–69–D, chap. 13, 7 p., accessed January 2, 2009, at http://certmapper.cr.usgs.gov/data/noga00/natl/text/CH_13.pdf.

Schmoker, J.W., and Klett, T.R., 2005, U.S. Geological Survey assessment concepts for conventional petroleum accumulations, *in* U.S. Geological Survey Southwestern Wyoming Province Assessment Team, comps., Petroleum systems and geologic assessment of oil and gas in the Southwestern Wyoming Province, Wyoming, Colorado and Utah: U.S. Geological Survey Digital Data Series DDS–69–D, chap. 19, 6 p., accessed January 30, 2009, at http://pubs.usgs.gov/dds/dds-069/dds-069-d/REPORTS/69_D_CH_19.pdf.

Schruben, P.G., Arndt R.E., and Bawiek, W.J., comps. (display software by Ambroziak, R.A., 1997), Geology of the conterminous United States at 1:2,500,000 scale; A digital representation of the 1974 P.B. King and H.M. Beikman map: U.S. Geological Survey Digital Data Series DDS–11, release 2, accessed January 2, 2009, at http://pubs.usgs.gov/dds/dds11/.

Stenzel, H.B., 1940–1941, The surface relationships of the Carrizo Sand of Texas: Tulsa Geological Society Digest, v. 9, p. 70–72, accessed at http://archives.datapages.com/data/tgs/digest/data/009/009001/pdfs/70.pdf.

Stephens, B.P., 2001, Basement controls on hydrocarbon systems, depositional pathways, and exploration plays beyond the Sigsbee escarpment in the central Gulf of Mexico, *in* Fillon, R.H., Rosen, N.C., Weimer, P., Lowie, A., Pettingill, H., Phair, R.L., Roberts, H.H., and van Hoorn, R., eds., Petroleum systems of deep-water basins; Global and Gulf of Mexico experience: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Foundation, 21st Annual Bob F. Perkins Research Conference, Houston, Tex., December 2–5, 2001, p. 129–158, CD-ROM.

Stoudt, D.L., Hutchinson, P.J., and Gordon, P.T., 1990, Gulf Coast regional cross section; East Texas-Texas coastal plain sector: American Association of Petroleum Geologists map, sheet 2 of 3.

Stover, S.C., Ge, Shemin, Weimer, Paul, and McBride, B.C., 2001, The effects of salt evolution, structural development, and fault propagation on Late Mesozoic-Cenozoic oil migration; A two-dimensional fluid-flow study along a megaregional profile in the northern Gulf of Mexico Basin: American Association of Petroleum Geologists Bulletin, v. 85, no. 11, p. 1,945–1,966, accessed at http://archives.datapages.com/data/bulletns/2001/11nov/1945/images/01_1945_1.pdf.

Straccia, J.R., 1981, Stratigraphy and structure of the Rosita gas fields, Duval County, Texas: Gulf Coast Association of Geological Societies Transactions, v. 31, p. 191–200, accessed at http://archives.datapages.com/data/gcags/data/031/031001/pdfs/0191.pdf.

Stricklin, F.L., Jr., 1996, Trap types vs. productivity of significant Wilcox (early Eocene) gas fields in the listric growth fault trend of south Texas; And the divergent origin of its two largest producers: Gulf Coast Association of Geological Societies Transactions, v. 46, p. 401–412, accessed at http://archives.datapages.com/data/gcags/data/046/046001/pdfs/0401.pdf.

Swanson, S.M., Karlsen, A.W., and Valentine B.J., 2013, Geologic assessment of undiscovered oil and gas resources—Oligocene Frio and Anahuac Formations, United States Gulf of Mexico coastal plain and State waters: U.S. Geological Survey Open-File Report 2013–1257, 66 p., accessed at http://dx.doi.org/10.3133/ofr20131257.

Thompson, K.F.M., and Kennicutt, M.C., II, 1992, Correlations of Gulf Coast petroleums on the basis of branched acyclic alkanes: Organic Geochemistry, v. 18, no. 1, p. 103–119, accessed at http://www.sciencedirect.com/science/article/pii/014663809290148Q.

Thompson, K.F.M., Kennicutt, M.C., II, and Brooks, J.M., 1990, Classification of offshore Gulf of Mexico oils and gas condensates: American Association of Petroleum Geologists Bulletin, v. 74, no. 2, p. 187–198, accessed at http://archives.datapages.com/data/bulletns/1990-91/images/pg/00740002/0000/01870.pdf.

Tye, R.S., Moslow, T.F., Kimbrell, W.C., and Wheeler, C.W., 1991, Lithostratigraphy and production characteristics of the Wilcox Group (Paleocene-Eocene) in central Louisiana: American Association of Petroleum Geologists Bulletin v. 75, no. 11, p. 1,675–1,713, accessed at http://archives.datapages.com/data/bulletns/1990-91/images/pg/00750011/0000/16750.pdf.

U.S. Geological Survey World Energy Assessment Team, 2000, U.S. Geological Survey world petroleum assessment 2000; Description and results: U.S. Geological Survey Digital Data Series DDS–60, 4 CD-ROMs. [Also available at http://pubs.usgs.gov/dds/dds-060/.]

U.S. Geological Survey Geologic Names Committee, 2007, Divisions of geologic time; Major chronostratigraphic and geochronologic units: U.S. Geological Survey Fact Sheet 2007–3015, 2 p. [Also available at http://pubs.usgs.gov/fs/2007/3015/.]

U.S. Geological Survey Geologic Names Committee, 2010, Divisions of geologic time; Major chronostratigraphic and geochronologic units: U.S. Geological Survey Fact Sheet 2010–3059, 2 p. [Also available at http://pubs.usgs.gov/fs/2010/3059/.]

U.S. Geological Survey National Assessment Review Team, 2006, U.S. Geological Survey methodology for the assessment of undiscovered oil and gas resources, *in* U.S. Departments of the Interior, Agriculture, and Energy, Scientific inventory of onshore Federal lands' oil and gas resources and the extent and nature of restrictions or impediments to their development; Phase II cumulative inventory: appendix 6, p. 227–235, accessed January 2, 2009, at http://www.blm.gov/epca/.

U.S. Geological Survey, 2008, National geologic map database, Geolex: U.S. Geological Survey web page, accessed February 2, 2009, at http://ngmdb.usgs.gov/Geolex/NewUnits/unit_6974.html.

U.S. Geological Survey National Oil and Gas Resource Assessment Team, 1995, 1995 National assessment of United States oil and gas resources: U.S. Geological Survey Circular 1118, 20 p. [Also available at http://pubs.usgs.gov/circ/1995/circ1118/circ1118.pdf.]

Wagner, B.E., Sofer, Zvi, and Claxton, B.L., 1994, Source rock in the Lower Tertiary and Cretaceous, deepwater Gulf of Mexico: Gulf Coast Association of Geological Societies Transactions, v. 44, p. 729–736, accessed at http://archives.datapages.com/data/gcags/data/044/044001/pdfs/0729.pdf.

Walters, C.C, and Dusang, D.D., 1988, Source and thermal history of oils from Lockhart Crossing, Livingston Parish, Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 38, p. 37–44, accessed at http://archives.datapages.com/data/gcags/data/038/038001/pdfs/0037.pdf.

Warner, John, and Moody, Jack, 1991, The flank shallow piercement plays of Mississippi: Gulf Coast Association of Geological Societies Transactions, v. 41, p. 667–668, accessed at http://archives.datapages.com/data/gcags/data/041/041001/pdfs/0667.pdf.

Warwick, P.D., 2006, Thermal maturity of the Wilcox Group (Paleocene-Eocene); A key to the Cenozoic petroleum systems of the northern Gulf of Mexico Basin, USA [abs.]: 23rd Annual Meeting of the Society for Organic Petrology, Abstracts and Programs, Beijing, China, v. 23, p. 271–272.

Warwick, P.D., Breland, F.C., Jr., and Hackley, P.C., 2008, Biogenic origin of coalbed gas in the northern Gulf of Mexico coastal plain, U.S.A.: International Journal of Coal Geology, v. 76, nos. 1–2, p. 119–137, accessed at http://www.sciencedirect.com/science/article/pii/S0166516208000888.

Warwick, P.D., Charpentier, R.R., Cook, T.A., Klett, T.R., Pollastro, R.M., and Schenk, C.J., 2007a, Assessment of undiscovered oil and gas resources in Cretaceous-Tertiary coal beds of the Gulf Coast region, 2007: U.S. Geological Survey Fact Sheet 2007–3039, 2 p. [Also available at http://pubs.usgs.gov/fs/2007/3039/.]

Warwick, P.D., Coleman, J.L., Hackley, P.C., Hayba, D.O., Karlsen, A.W., Rowan, E.L., and Swanson, S.M., 2007b, U.S. Geological Survey assessment of undiscovered oil and gas resources in Paleogene strata of the U.S. Gulf of Mexico Coastal Plain and State waters, *in* Kennan, Lorcan, Pindell, James, and Rosen, N.C., eds., The Paleogene of the Gulf of Mexico and Caribbean Basins; Processes, events, and petroleum systems: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Foundation, 27th Annual Bob F. Perkins Research Conference, Houston, Tex., December 2–5, 2007, p. 2–44, CD-ROM.

Warwick, P.D., SanFilipo, J.R., Crowley, S.S., Thomas, R.E., and Fried, John, comps. (Tully, J.K., digital comp.), 1997, Map showing outcrop of the coal-bearing units and land use in the Gulf Coast coal region: U.S. Geological Survey Open File Report 97–72, 1 sheet, scale 1:2,000,000. [Also available at http://pubs.usgs.gov/of/1997/of97-172/.]

Wenger, L.M., Goodoff, L.R., Gross, O.P., Harrison, S.C., and Hood, K.C., 1994, Northern Gulf of Mexico; An integrated approach to source, maturation, and migration, *in* Scheidermann, N., Cruz, P., and Sanchez, R., eds., Geological aspects of petroleum systems: 1st Joint American Association of Petroleum Geologists/Asociación Mexicana de Geólogos Petróleos Research Conference, Mexico City, Mexico, October 2–6, 1994, p. 6.

Wenger, L.M., Sassen, Roger, and Schumacher, Dietmar, 1990, Molecular characteristics of Smackover, Tuscaloosa and Wilcox-reservoired oils in the eastern Gulf Coast, *in* Schumacher, Dietmar, and Perkins, B.F., eds., Gulf Coast oils and gases; Their characteristics, origin, distribution, and exploration and production significance: Society of Economic Paleontologists and Mineralogists, Gulf Coast Section Foundation, 9th Annual Research Conference, December 1988, New Orleans, La., Proceedings, Austin, Tex., p. 37–57.

Wescott, W.A., and Hood, W.C., 1994, Hydrocarbon generation and migration routes in the east Texas Basin: American Association of Petroleum Geologists Bulletin, v. 78, no. 2, p. 287–307, accessed at http://archives.datapages.com/data/bulletns/1994-96/images/pg/00780002/0250/0287.pdf.

Williams, C.H., Jr., ed., 1969, Wilcox fields of southwest Mississippi: Mississippi Geological Society Special Publications, 350 p.

Winker, C.D., 1982, Cenozoic shelf margins, northwestern Gulf of Mexico: Gulf Coast Association of Geological Societies Transactions, v. 32, p. 427–448, accessed at http://archives.datapages.com/data/gcags/data/032/032001/pdfs/0427.pdf.

Zimmerman, R.K., 1995, Evidence and effects of wrench faulting, north central Gulf Coast region: Gulf Coast Association of Geological Societies Transactions, v. 45, p. 629–635, accessed at http://archives.datapages.com/data/gcags/data/045/045001/pdfs/0629.pdf.

Zimmerman, R.K., 1999, Potential oil generation capacity of the north Louisiana hydrocarbon system: Gulf Coast Association of Geological Societies Transactions, v. 49, p. 532–540, accessed at http://archives.datapages.com/data/gcags/data/049/049001/pdfs/0532.pdf.

Zimmerman, R.K., and Sassen, Roger, 1993, Hydrocarbon transfer pathways from Smackover source rocks to younger reservoir traps in the Monroe gas field, northeastern Louisiana: Gulf Coast Association of Geological Societies Transactions, v. 43, p. 473–480, accessed at http://archives.datapages.com/data/gcags/data/043/043001/pdfs/0473.pdf.

Figures 1–31

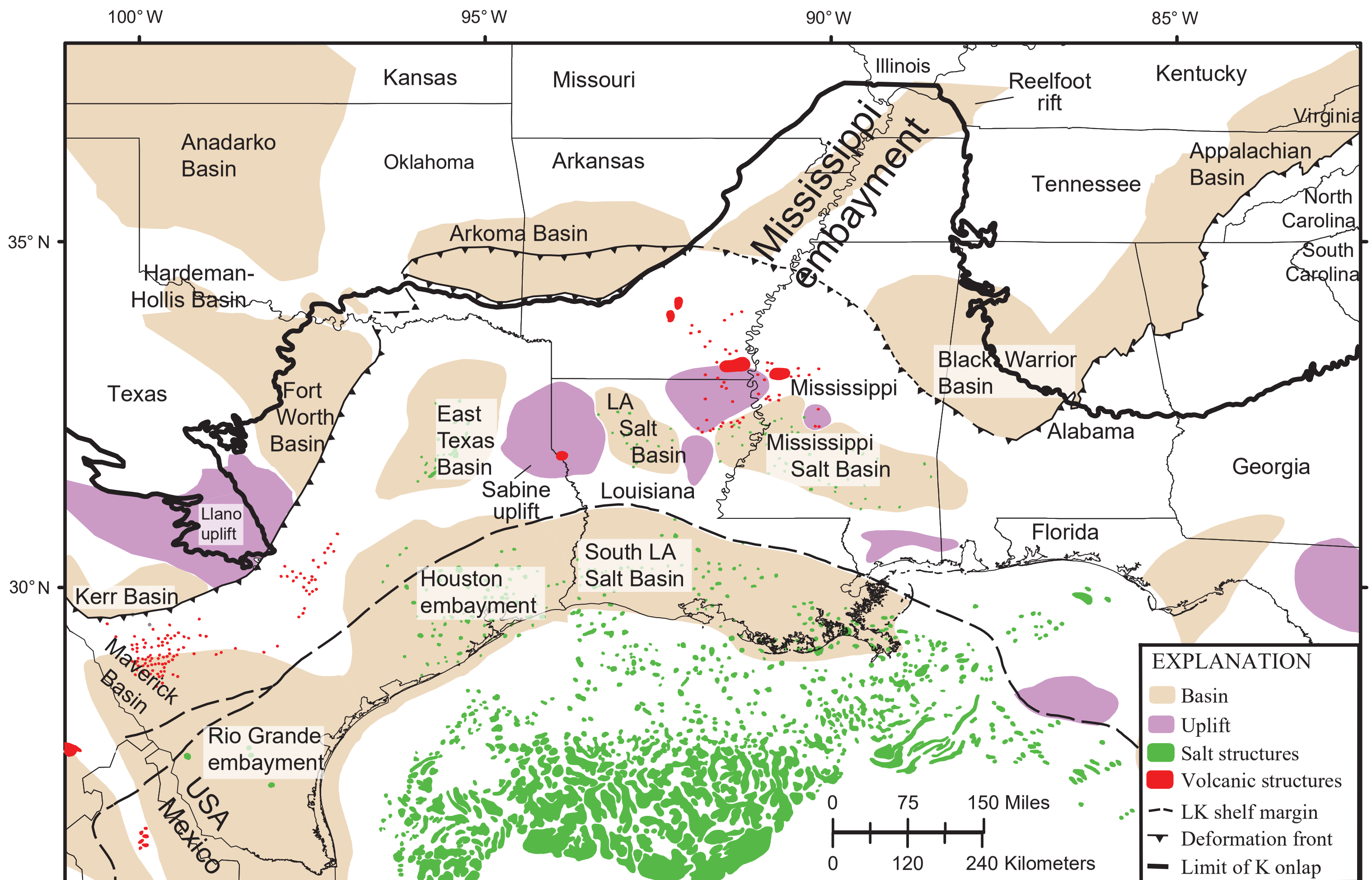


Figure 1. Major surface and subsurface structural features of the northern Gulf of Mexico Basin. Modified from Milici (1980), Frezon and others (1988), Ewing (1991a,b), Ewing and Lopez (1991), Salvador and Quezada Muñeton (1991), Warwick and others (1997, 2008), Galloway and others (2000), and Coleman and Pratt (2015). Abbreviations: K, Cretaceous; LK, Lower Cretaceous; LA, Louisiana.

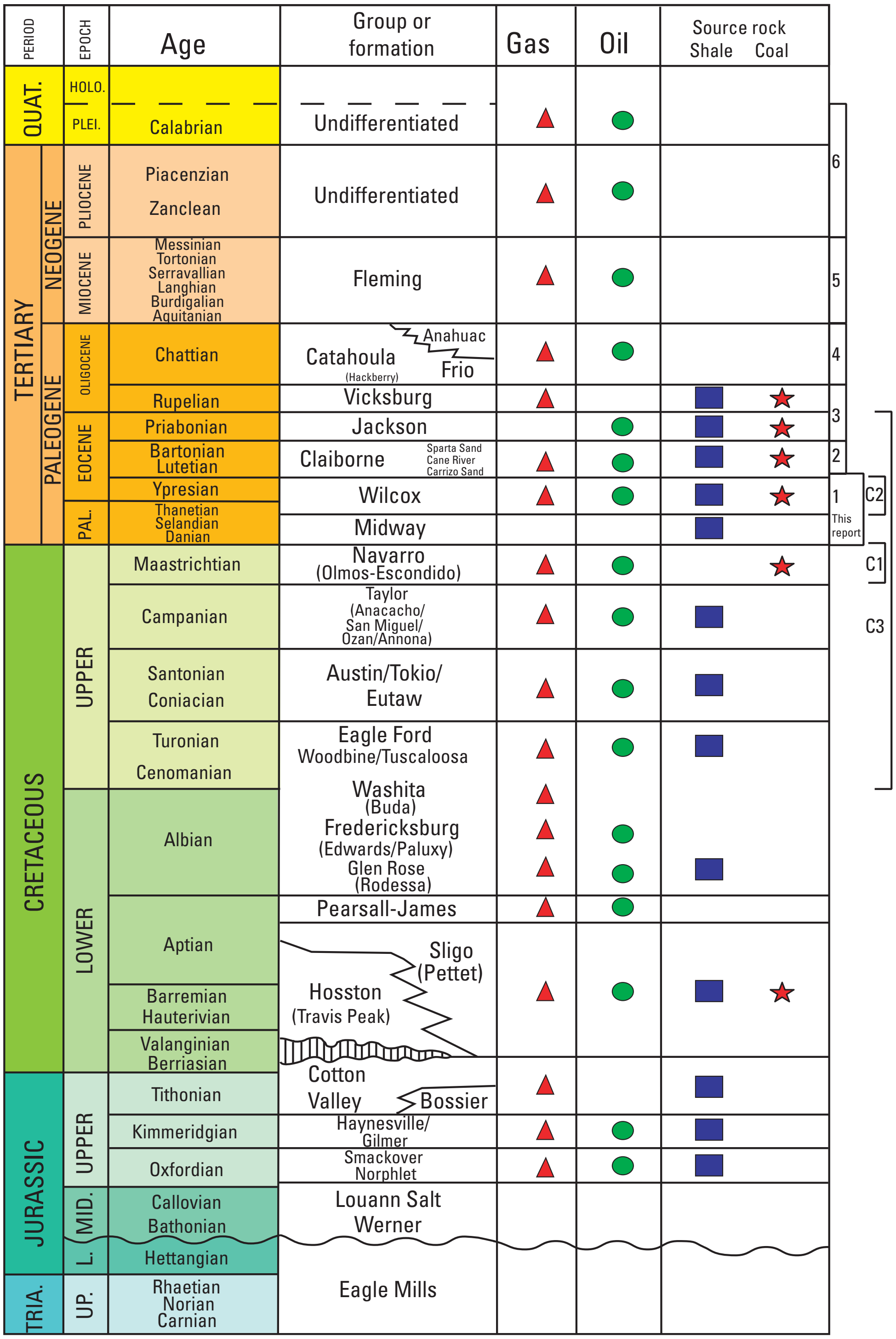


Figure 2. Generalized stratigraphic section of the northern Gulf of Mexico Coastal Plain showing gas (red triangles) and oil (green circles) occurrences, potential shale source rocks (blue boxes), and potential coal source rocks (red stars). Numbered intervals refer to the major Paleogene and Neogene, and coalbed gas assessment intervals assessed by the U.S. Geological Survey in 2007 including: (1) lower Paleogene (Midway, Wilcox, and Carrizo Sand) reported in this chapter, (2) Claiborne, (3) Jackson and Vicksburg, (4) Frio, Anahuac, and Hackberry, (5) Miocene, (6) Plio-Pleistocene, (C1) Olmos-Escondido coalbed gas, (C2) Wilcox coalbed gas, and (C3) Cretaceous-Tertiary coalbed gas. Abbreviations: Holo., Holocene; L., Lower; Mid., Middle; Pal., Paleocene; Plei., Pleistocene; Tria., Triassic; Quat., Quaternary; Up., Upper. Vertical lines represent an unconformity; wavy line, disconformity; jagged line, interfingering; dashed line, uncertain (modified from Salvador and Quezada Muñeton, 1991; Nehring, 1991; Humble Geochemical Services and others, 2002; and Warwick and others, 2007b). The time scale follows Palmer and Geissman (1999) and U.S. Geological Survey Geologic Names Committee (2007, 2010).

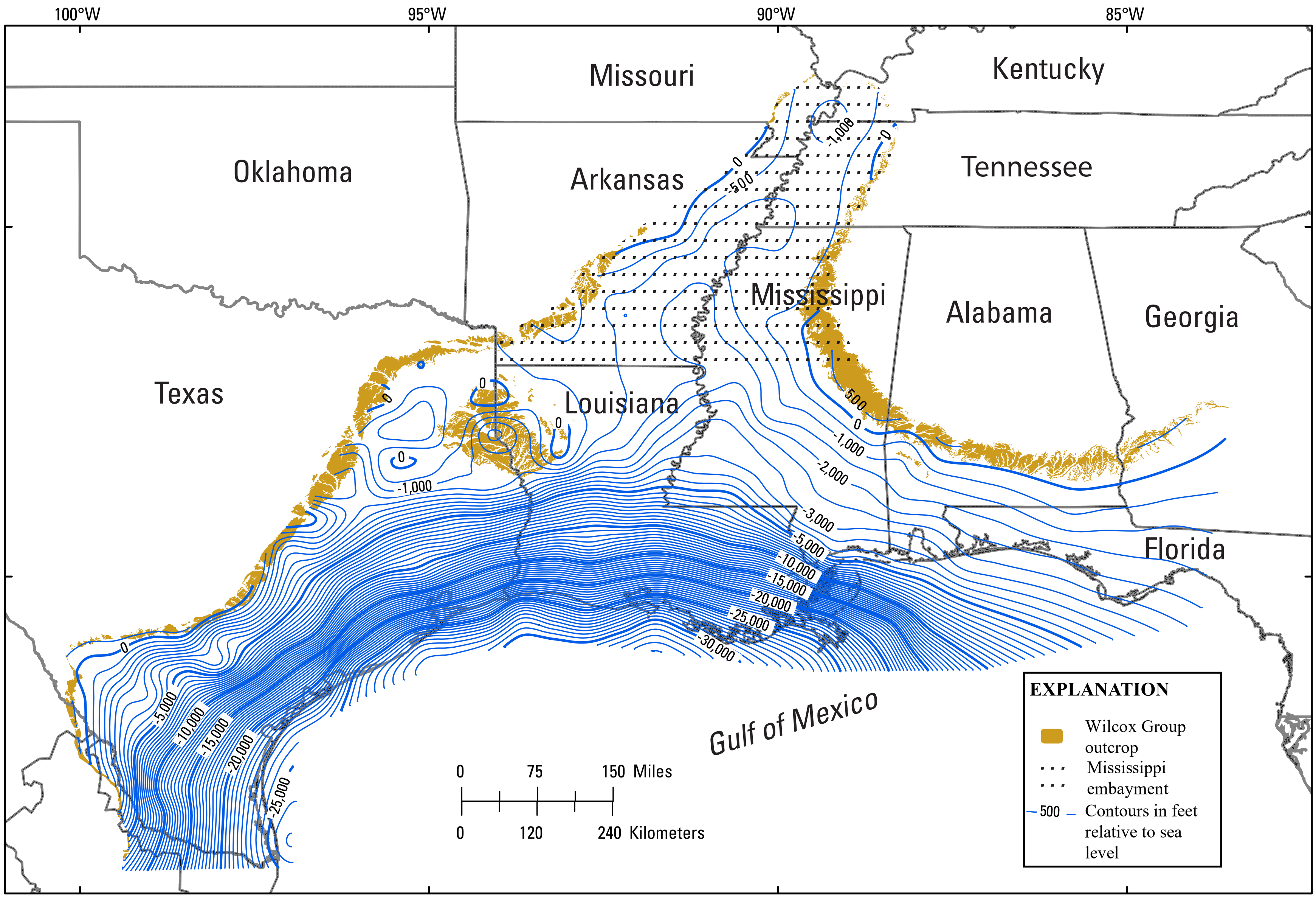


Figure 3. Structure contour map for the top of the Wilcox Group. The map is based on more than 42,000 wells where the top of the Wilcox Group has been determined from the IHS database (IHS Energy Group, 2005b). Structure contours have been extended to beyond the coastal areas by using control points based on depths to the top of the Wilcox from regional cross sections and seismic lines (Ewing, 1991a; Salvador, 1991). Recent, ultra-deep Wilcox wells in the outer continental shelf have not been incorporated into this map. The contours have been smoothed to remove the local effect of uplifts associated with salt structures. Outcrops of the Wilcox Group are from Warwick and others (1997).

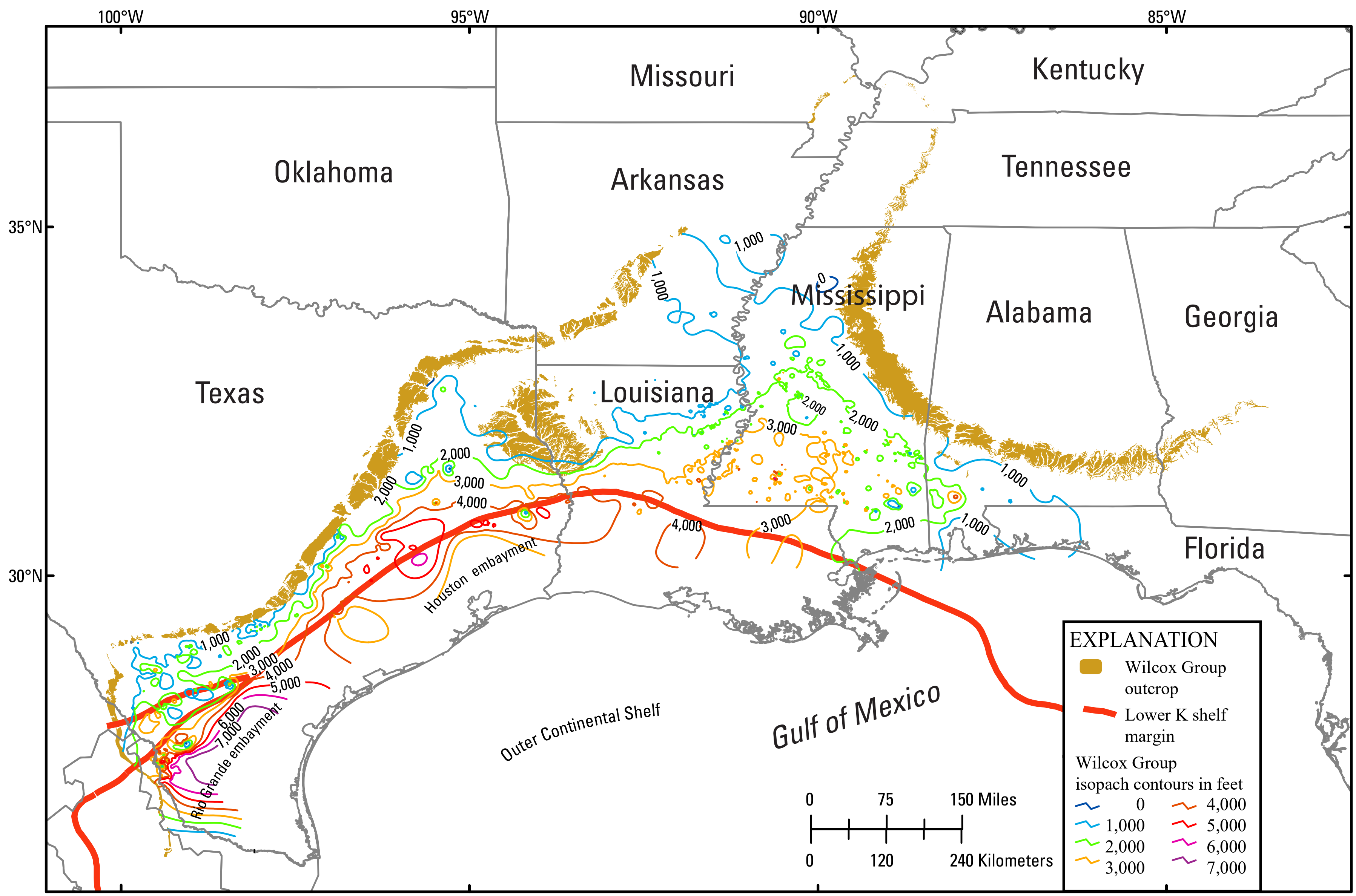


Figure 4. Generalized isopach map of the Wilcox Group (modified from Barker and others, 2009). Outcrop geology from Warwick and others (1997); Lower Cretaceous (K) shelf margin is from Galloway and others (2000).

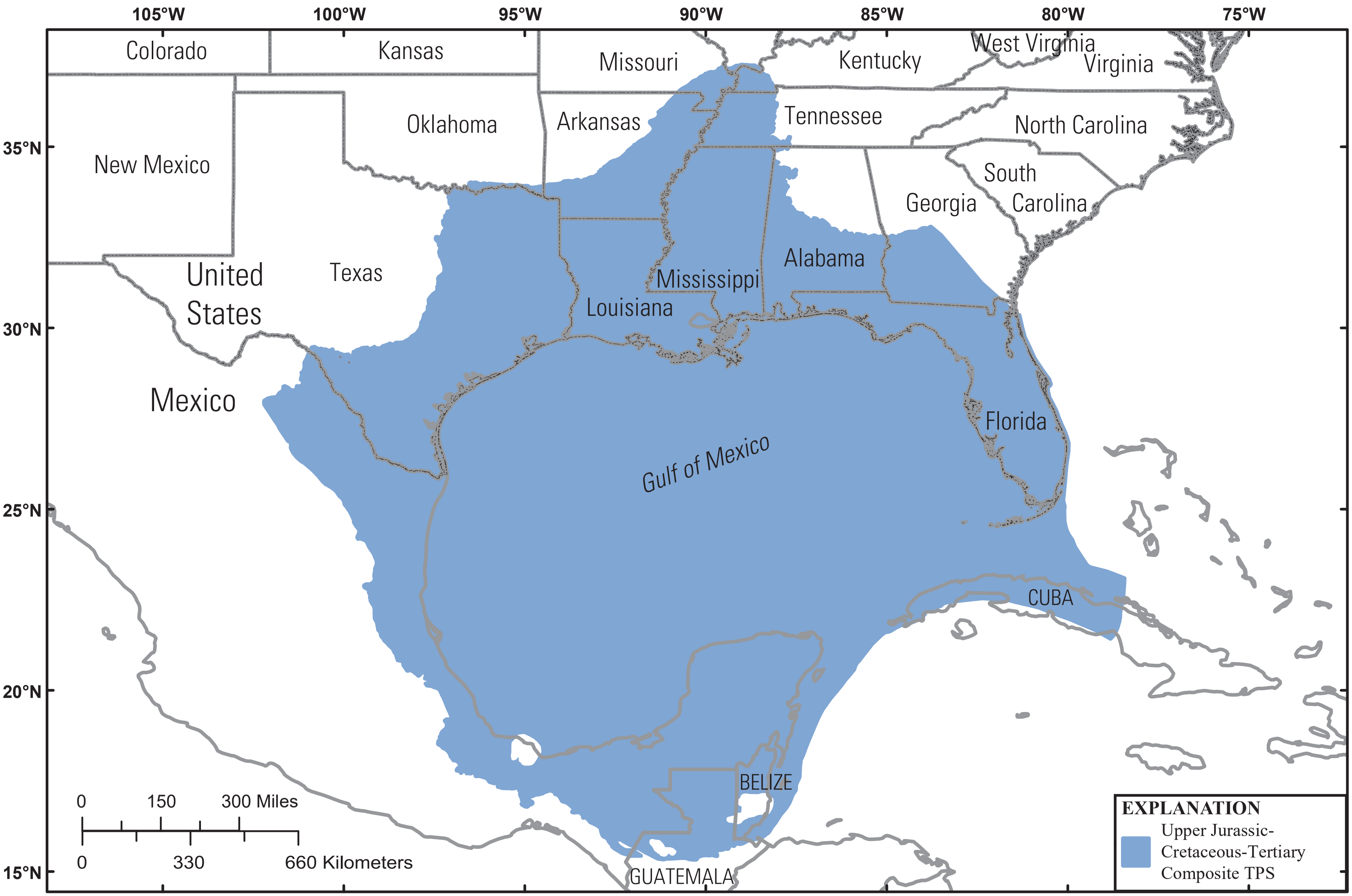
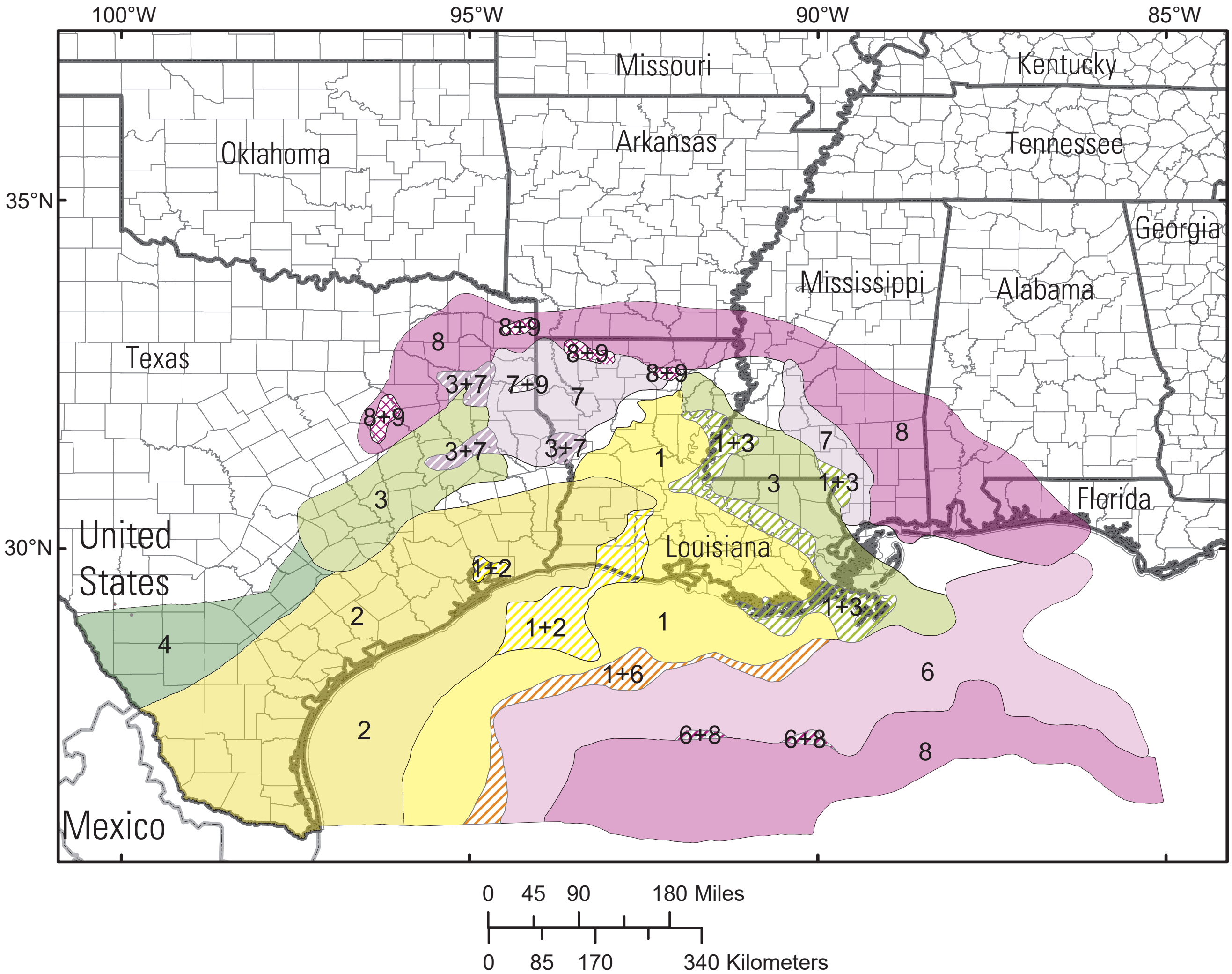


Figure 5. Upper Jurassic-Cretaceous-Tertiary Composite Total Petroleum System (TPS) for the Gulf of Mexico Basin. Refer to Warwick and others (2007b) for a discussion on how the TPS boundary was drawn.



EXPLANATION

[Source rock stratigraphic position, depositional environment, and avaialble sulfur or salinity content]

- Not designated
- 1 = Lower Tertiary (centered on Paleocene-Eocene Wilcox-Sparta), marine, intermediate sulfur
- 1+2 = Lower Tertiary (centered on Paleocene-Eocene Wilcox-Sparta), terrestrial
- 1+3 = Lower Tertiary (centered on Paleocene-Eocene Wilcox-Sparta), marine, intermediate sulfur; and Upper Cretaceous (centered on Turonian Eagle Ford), marine, low sulfur
- 1+6 = Lower Tertiary (centered on Eocene), marine, intermediate sulfur; uppermost Jurassic (centered on Tithonian), marine, moderate to high sulfur
- 2 = Lower Tertiary (centered on Paleocene-Eocene Wilcox-Sparta), terrestrial
- 3 = Upper Cretaceous (centered on Turonian Eagle Ford), marine, low sulfur
- 3+7 = Upper Cretaceous (centered on Turonian Eagle Ford), marine, low sulfur; and Upper Jurassic or Lower Cretaceous?, marine
- 4 = Upper Cretaceous (centered on Turonian Eagle Ford) and Lower Cretaceous (centered on Aptian), calcareous, moderate sulfur
- 6 = Uppermost Jurassic (centered on Tithonian), marine, moderate to high sulfur
- 6+8 = Uppermost Jurassic (centered on Tithonian), marine, moderate to high sulfur; and Upper Jurassic (Oxfordian Smackover), carbonate, high salinity
- 7 = Upper Jurassic or Lower Cretaceous?, marine
- 7+9 = Upper Jurassic (Oxfordian Smackover) or Lower Cretaceous?, marine; and Triassic (Eagle Mills), lacustrine
- 8 = Upper Jurassic (Oxfordian Smackover), carbonate, high salinity
- 8+9 = Upper Jurassic (Oxfordian Smackover), carbonate, high salinity; and Triassic, lacustrine

Figure 6. Map showing the ages and distribution of trapped petroleum from correlated source rocks in the northern Gulf of Mexico region. The complex two-dimensional pattern of the source rock ages, depositional setting, salinity, and sulfur content was derived from oil geochemistry data and suggests numerous three-dimensional petroleum systems are in the region. “Intermediate” denotes a depositional environment that is transitional between marine and terrestrial; “centered on” denotes primary interval (modified from Wenger and others, 1994; Hood and others, 2002; and Warwick and others, 2007b).

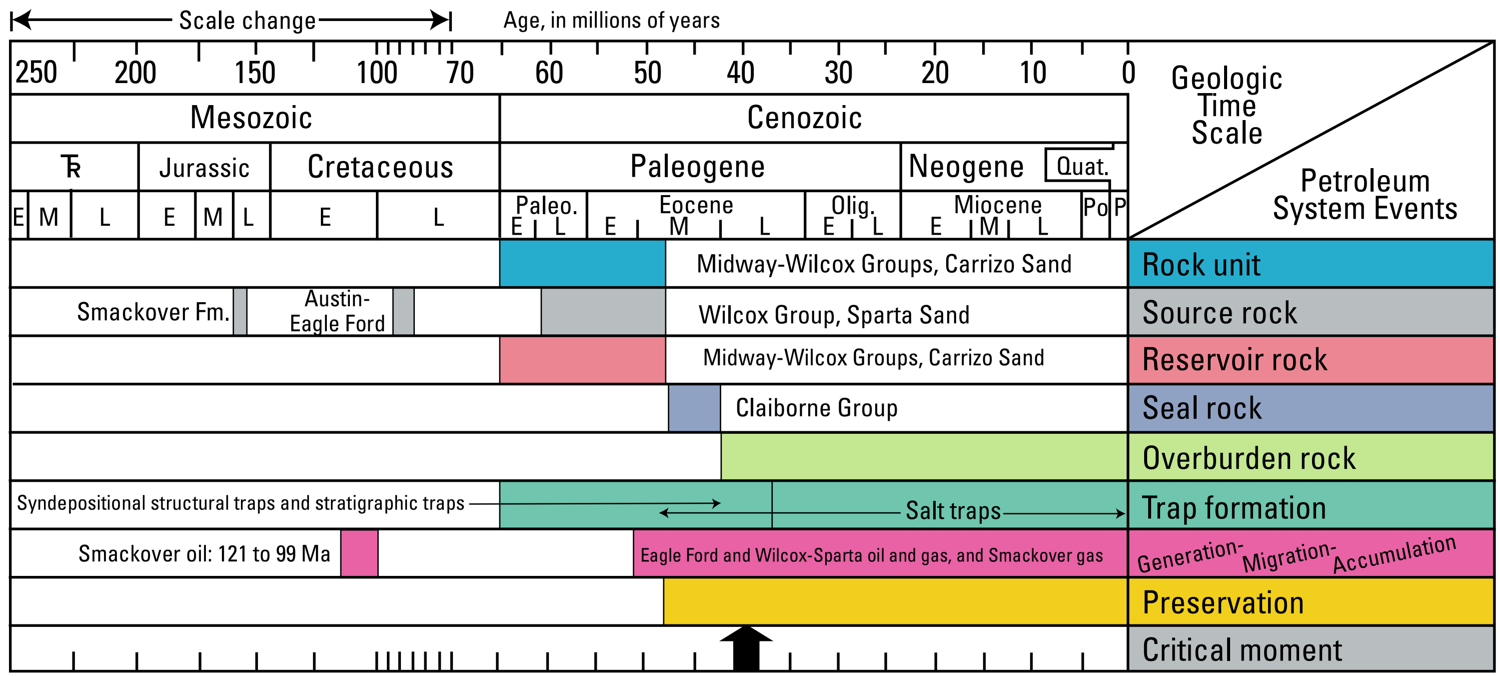


Figure 7. Events chart summarizing the major elements of the Upper Jurassic-Cretaceous-Tertiary Composite Total Petroleum System (TPS) of the northern Gulf of Mexico Basin. This events chart shows the Midway-Wilcox-Carrizo Sands AUs of the TPS. To show all AUs of the TPS would require a more complex chart. The critical moment is defined as the point in time (marked by arrow) that best represents the generation, migration, and accumulation of most of the hydrocarbons in the Upper Jurassic-Cretaceous-Tertiary Composite TPS (modified from Condon and Dyman, 2006). Abbreviations: E, Early; Fm., Formation; L, Late; M, Middle; Ma, mega-annum; Olig., Oligocene; P, Pleistocene; Paleo., Paleocene; Po, Pliocene; Quat., Quaternary; Ʀ, Triassic.

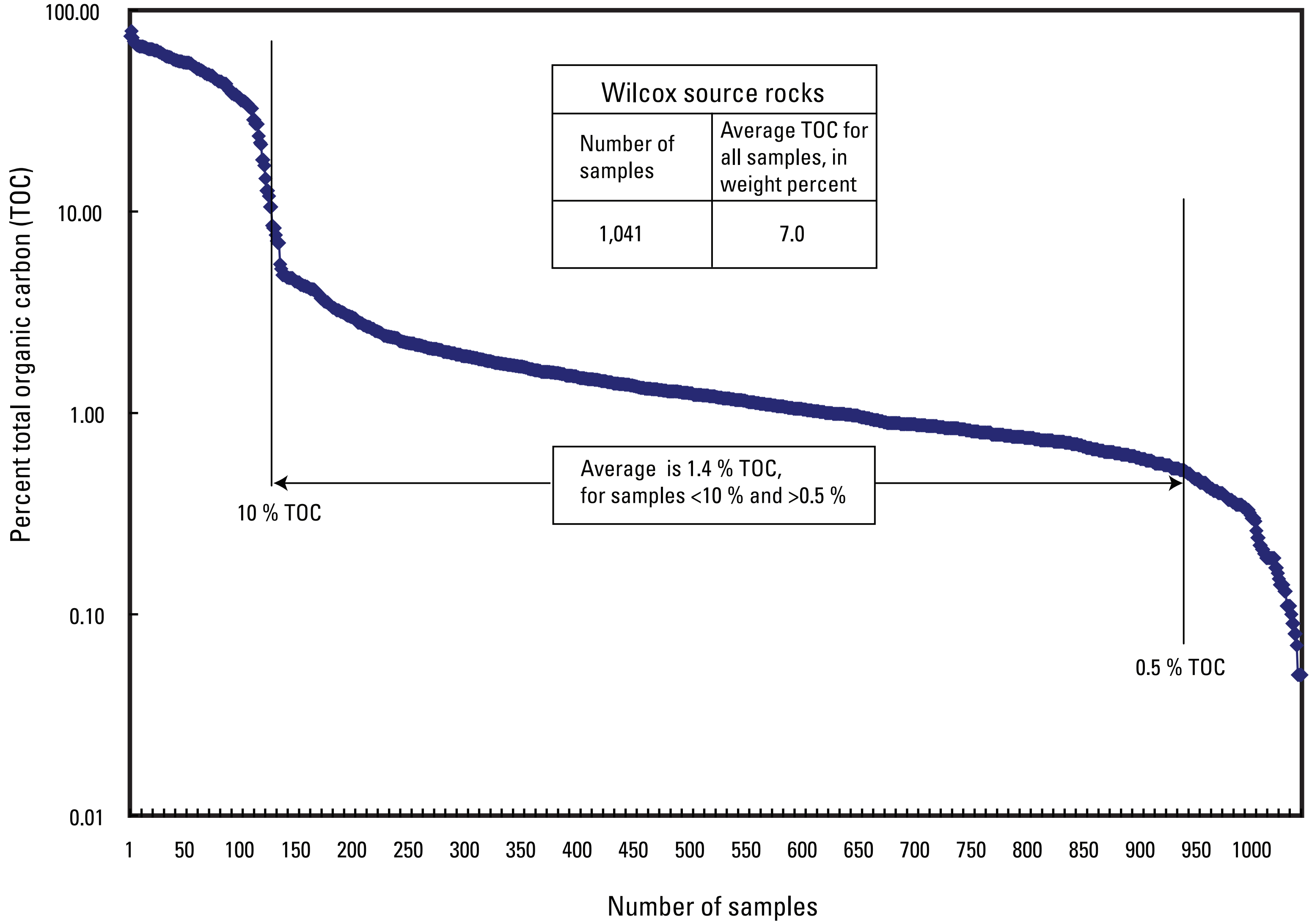


Figure 8. Sequential plot of Wilcox Group total organic carbon (TOC) content data in weight percent obtained from more than 1,000 outcrop and drill-hole samples. The averages for all samples and for samples with less than 10 percent TOC and greater than 0.5 percent TOC are shown. Data are from Dennen and others (2010).

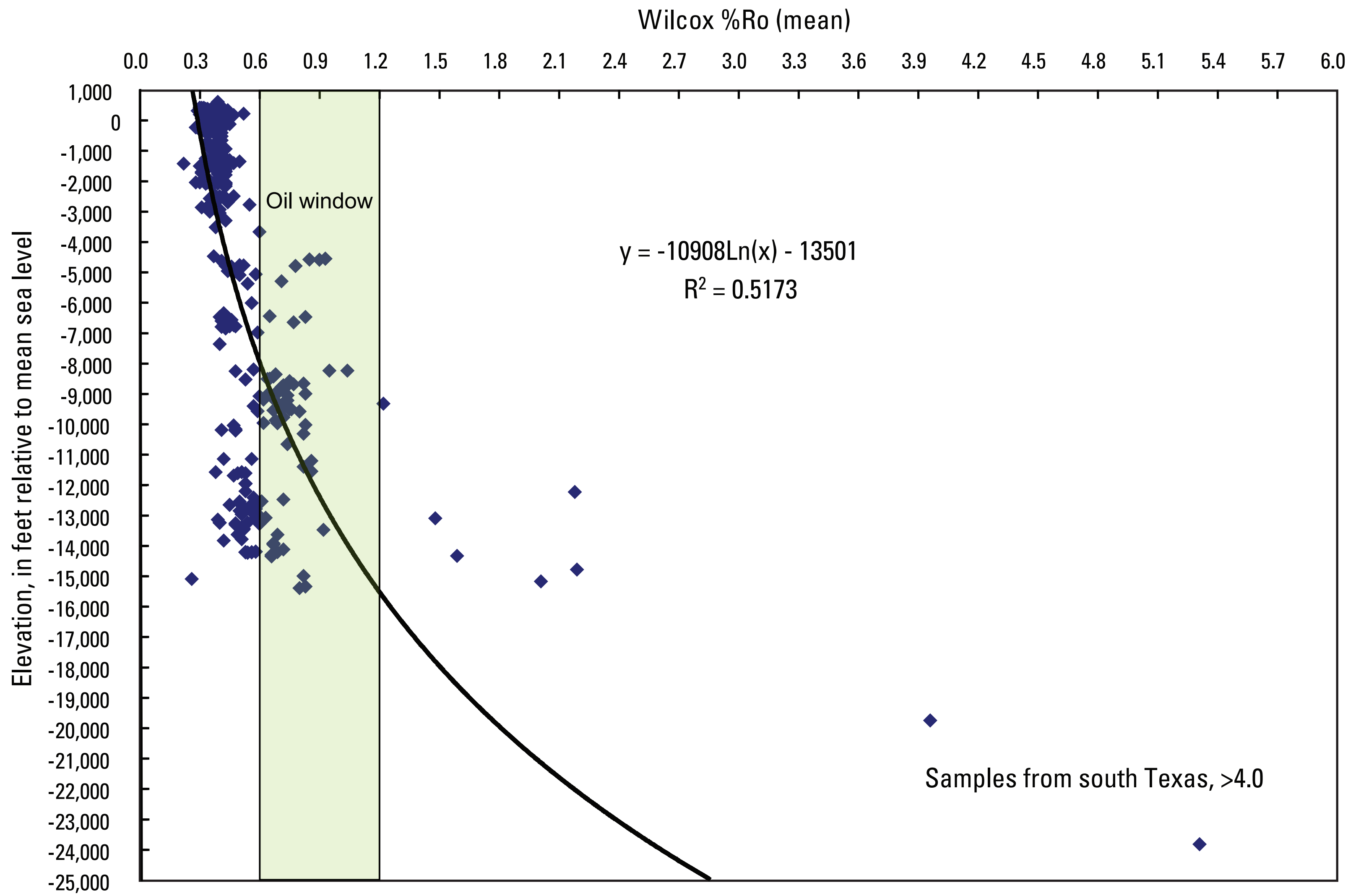


Figure 9. Wilcox Group mean vitrinite reflectance (%Ro) values plotted by sample elevation. Data are from Dennen and others (2010).

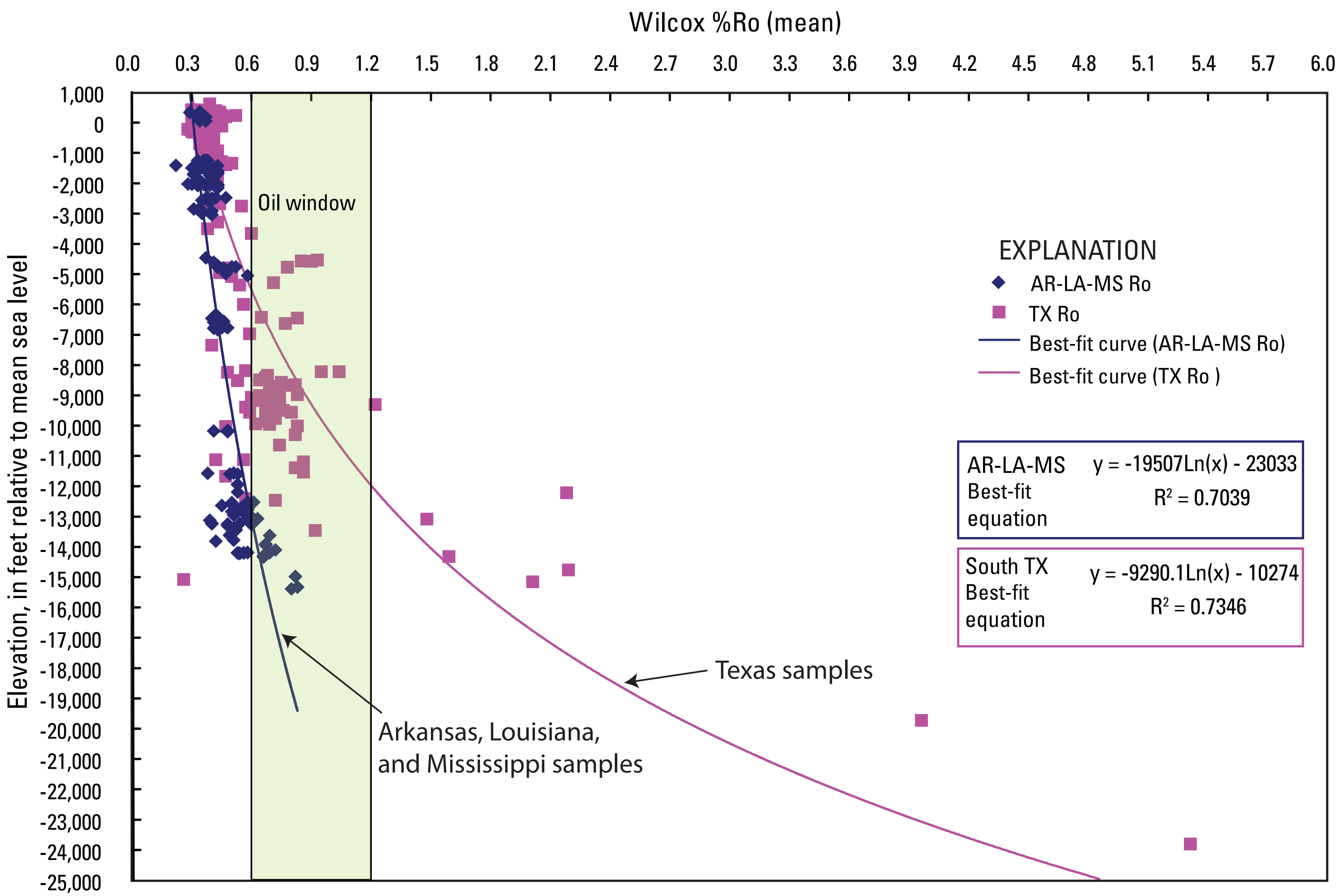


Figure 10. Regional trends in the mean vitrinite reflectance (%Ro) data suggesting that gradients of Wilcox maturity versus elevation are not as great in the northeastern part of the basin (Arkansas, AR; Louisiana, LA; and Mississippi, MS) as they are in the southwest (Texas, TX). This implies a general increase in Wilcox maturity towards the south. Data are from Dennen and others (2010).

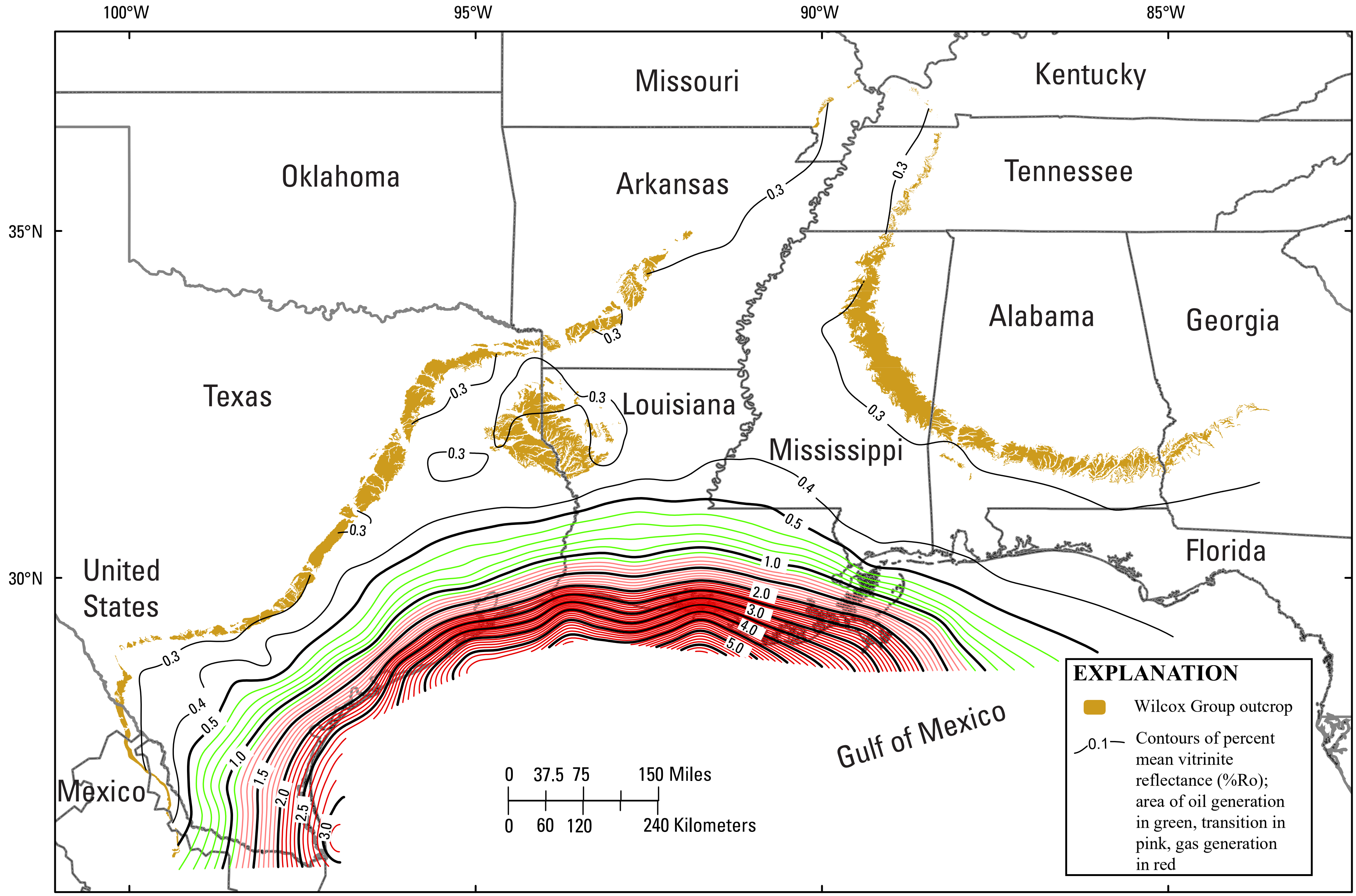


Figure 11. Present-day thermal maturity model for the top of the Wilcox Group. The map was mathematically derived from the structural contour map of the top of the Wilcox Group (fig. 3) using the y-intercept equation for the best-fit curve of vitrinite reflectance and elevation shown on figure 9. Outcrop geology from Warwick and others (1997).

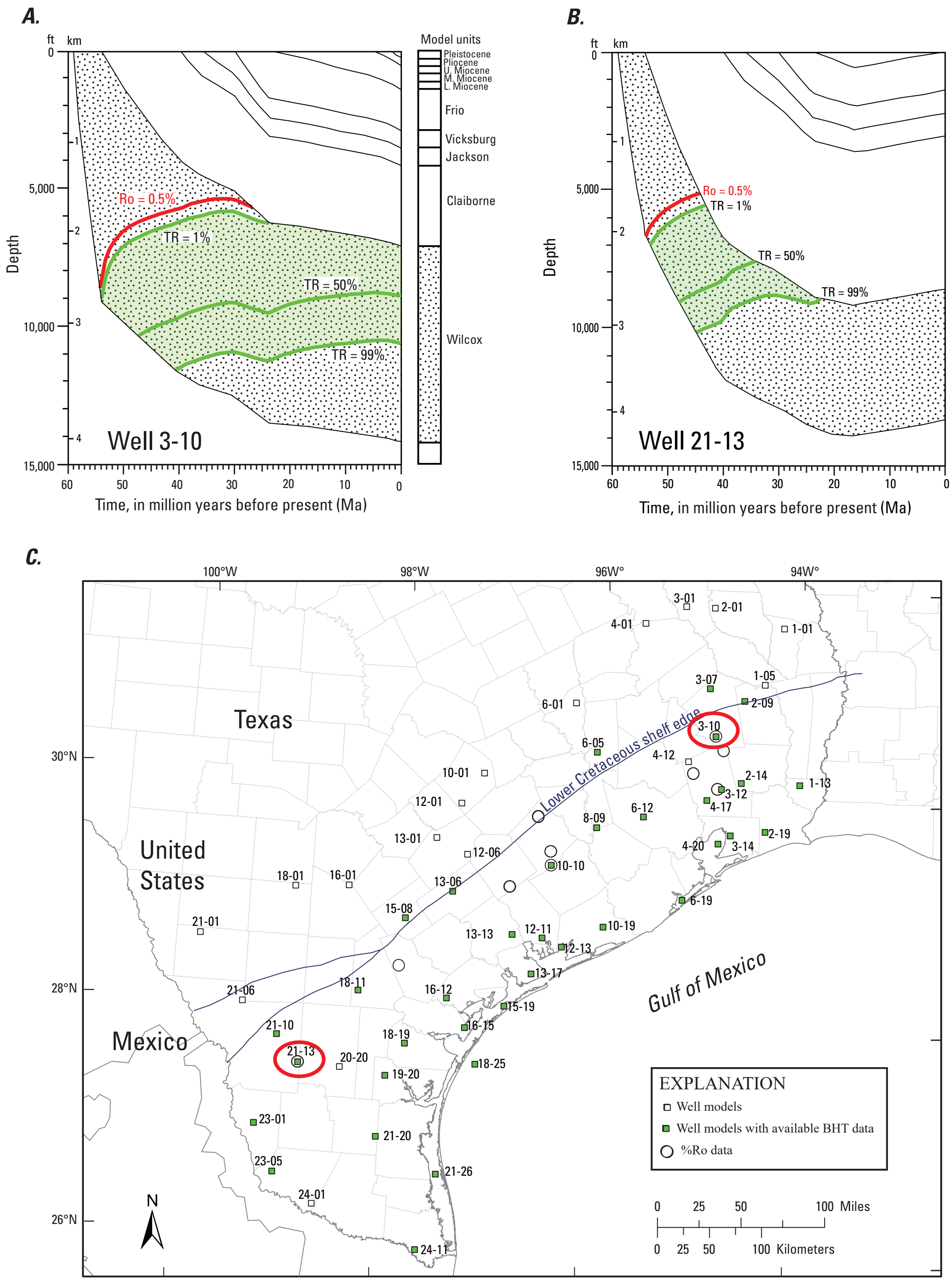


Figure 12. Burial history curves for two Wilcox wells in Texas where mean vitrinite reflectance (%Ro) and bottom-hole-temperature (BHT) data were available. The green shaded area in *A* and *B* represents the oil window for the Wilcox, defined by transformation ratios (TR). The onset, peak, and end of oil generation in the Wilcox, are represented by 1 percent, 50 percent, and 99 percent TR curves, respectively. The curves were calculated using kinetic parameters for the Wilcox listed in Rowan and others (2007, table 4). The 0.5 %Ro contour represents the onset of gas generation from Type III kerogen. *A*, Well 3-10; *B*, Well 21-13; and *C*, locations of burial history models discussed in Rowan and others (2007). Solid green squares indicate wells for which BHT data were available and black circles show locations of %Ro data from the Wilcox Group. The Lower Cretaceous shelf edge is shown for reference (Ewing and Lopez, 1991, plate 2). Red circles show locations of Wells 3-10 and 21-13. Abbreviations: ft, feet; km, kilometers; L, lower; M, middle; U, upper.

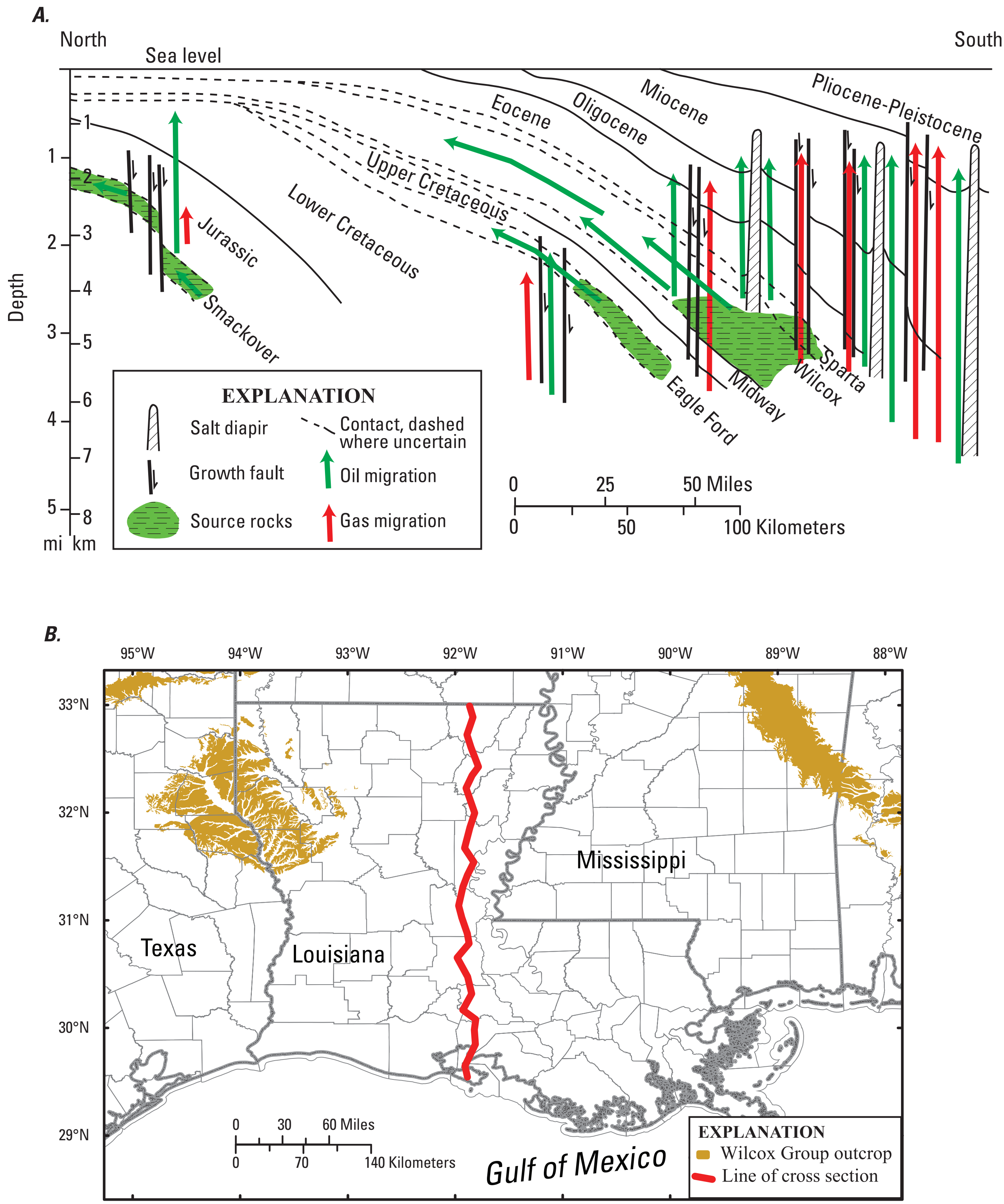


Figure 13. Migration pathways of oil and gas in southern Louisiana. *A*, Line of cross section showing geologic framework, stratigraphic units, source rocks, and proposed migration pathways. *B*, Map showing location of cross section in *A* (red line). Modified from Sassen (1990). Abbreviations: km, kilometers; mi, miles.

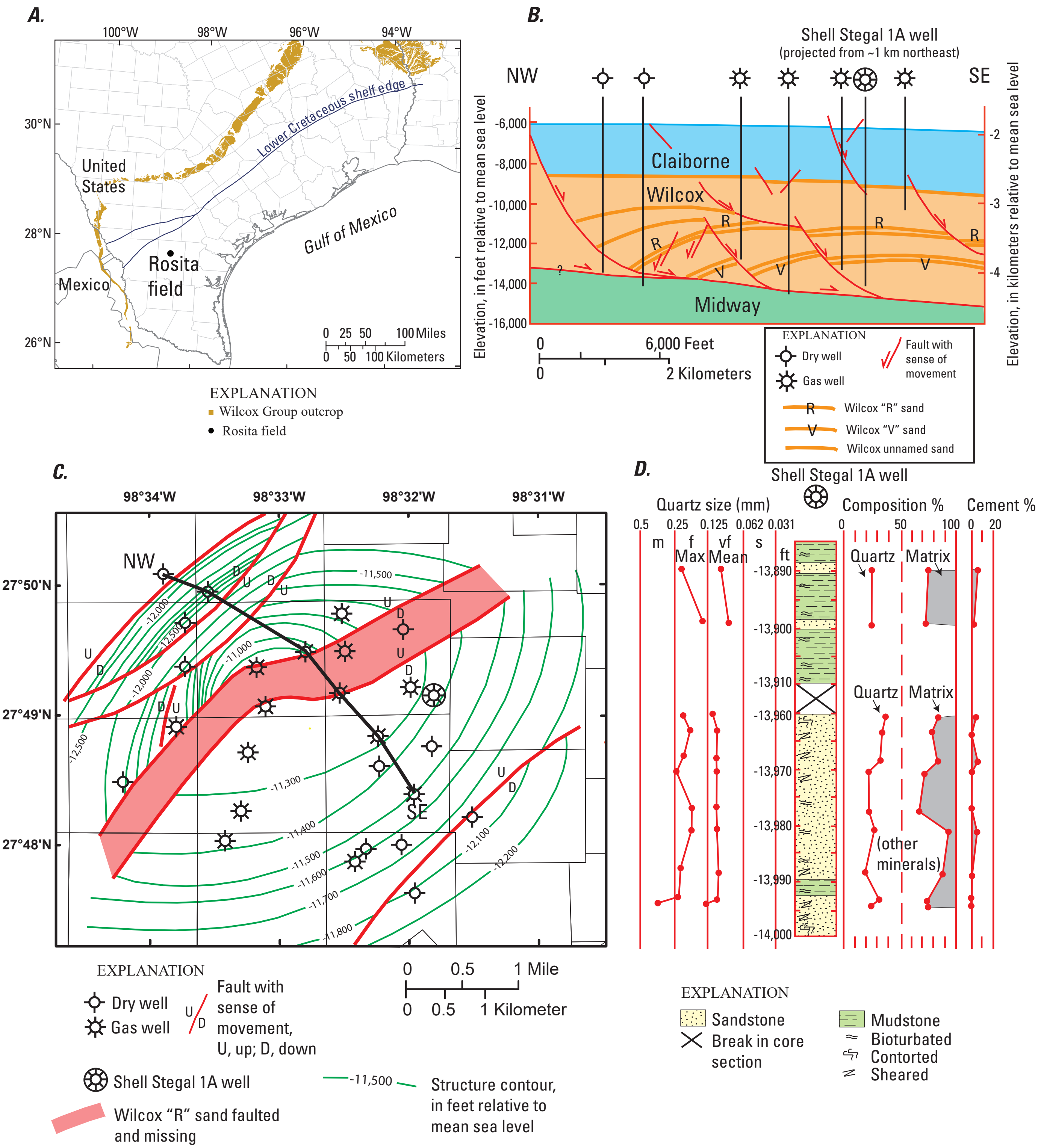


Figure 14. Petroleum geology of the Rosita field that produces from the Wilcox Group in south Texas. *A*, Location map. *B*, Generalized cross section illustrating the major faults and sandstones in the Rosita field. *C*, Structure contour map of the "R" sand and location of the cross section in *B*. *D*, Grain size, composition, and bedsets of part of the middle "V" sand in the Shell Stegal 1A well (location of well shown on *C*). Modified from Straccia (1981). Abbreviations: f, fine; ft, feet; km, kilometer; m, medium; max, maximum; s, silt; vf, very fine.

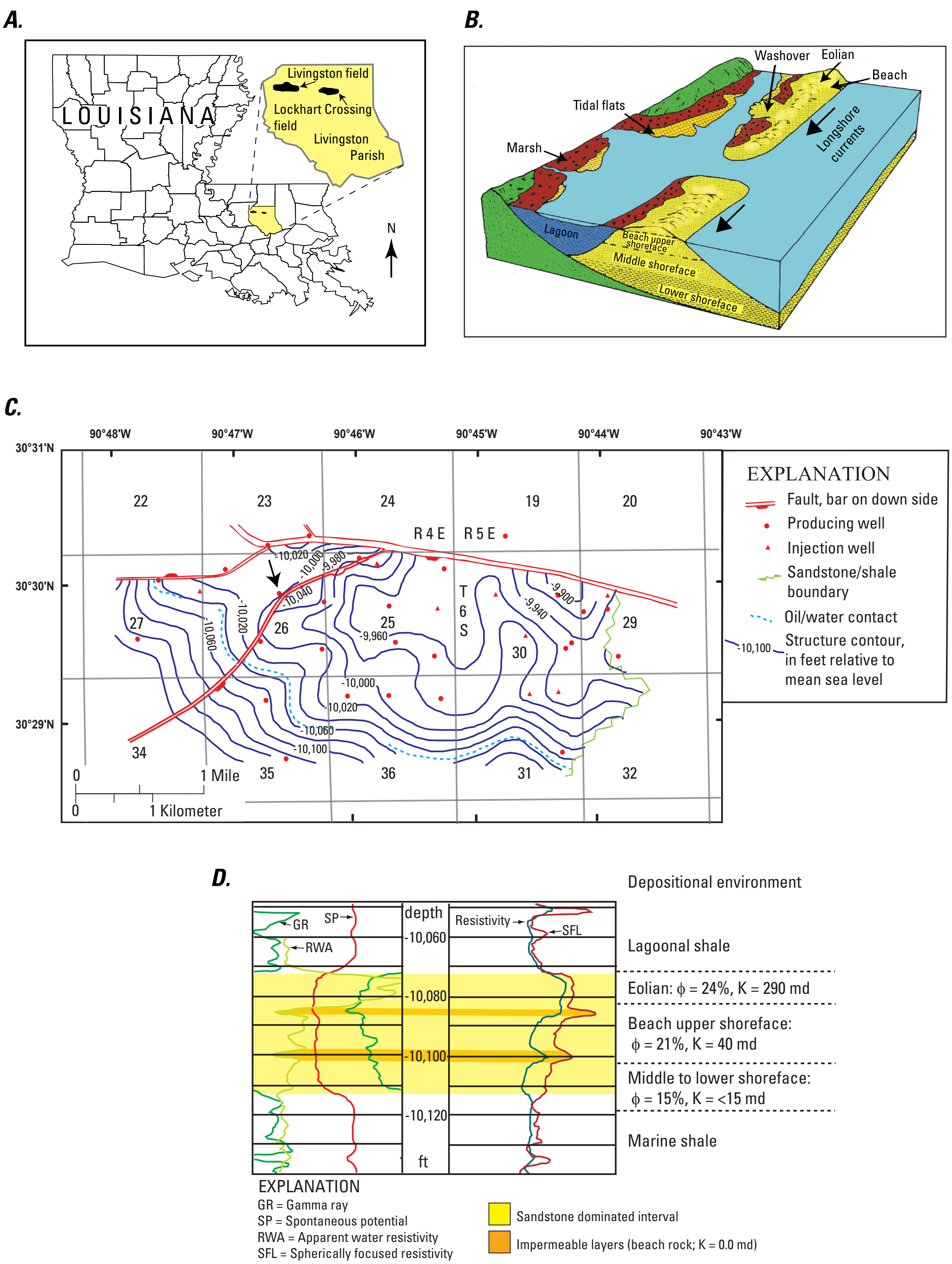


Figure 15. Petroleum geology of the Livingston field that produces from the Wilcox Group in southeastern Louisiana. *A*, Location map. *B*, Depositional model for Wilcox Group barrier island sandstone deposits in the Livingston field (modified from Reinson, 1984; and Goddard and others, 2002). *C*, Structure contour map of the "1st Wilcox Sand", Livingston field. An east-west structural trend and a slight rollover toward the northern east-trending fault can be observed. *D*, Geophysical log from the well with an arrow shown on *C*. From Goddard and others (2002). Abbreviations: ϕ, porosity; K, permeability; md, millidarcies; ft, feet.

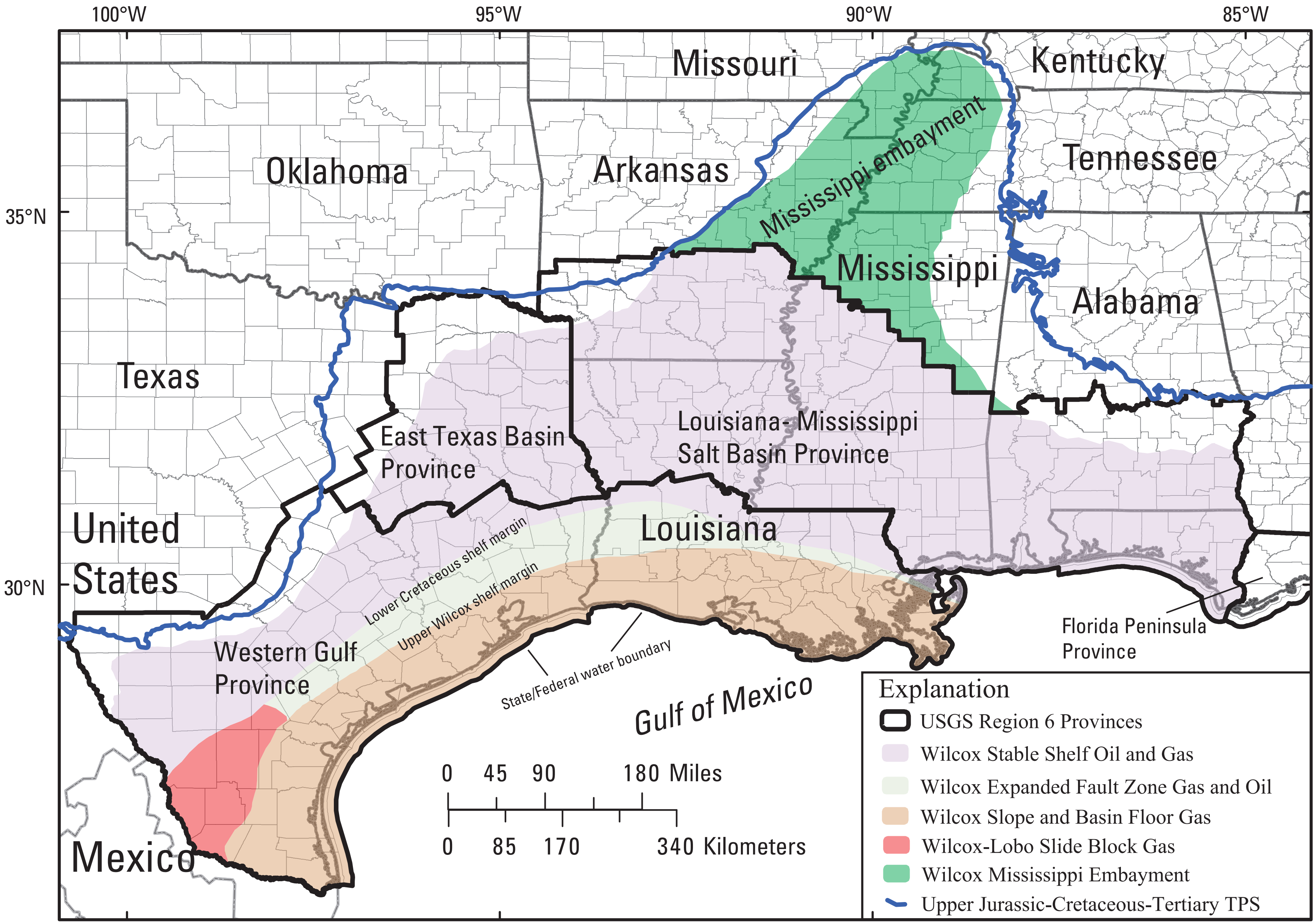


Figure 16. Assessment units (AUs) and their boundaries for the lower Paleogene (Midway-Wilcox-Carrizo Paleocene-Eocene) stratigraphic intervals (fig. 2). The U.S. Geological Survey Region 6 Province boundaries (heavy black lines) are from the U.S. Geological Survey National Oil and Gas Resource Assessment Team (1995). See text for a discussion of how the AU boundaries were determined. Abbreviations: TPS, total petroleum system.

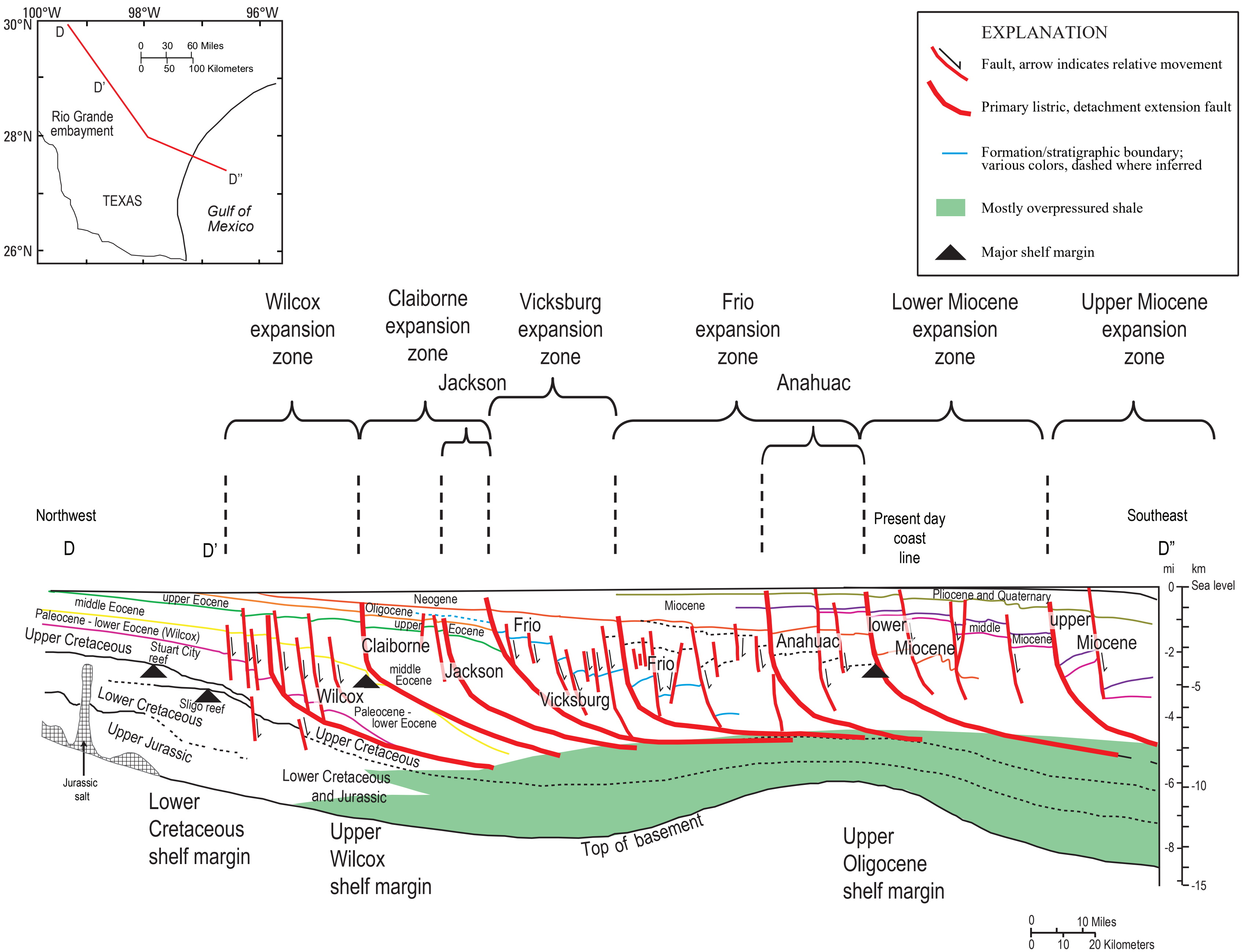


Figure 17. Generalized cross section showing Tertiary expansion zones across the south Texas Gulf of Mexico Coastal Plain (modified from Ewing, 1991b; and Warwick and others, 2007b). Abbreviations: km, kilometers; mi, miles.

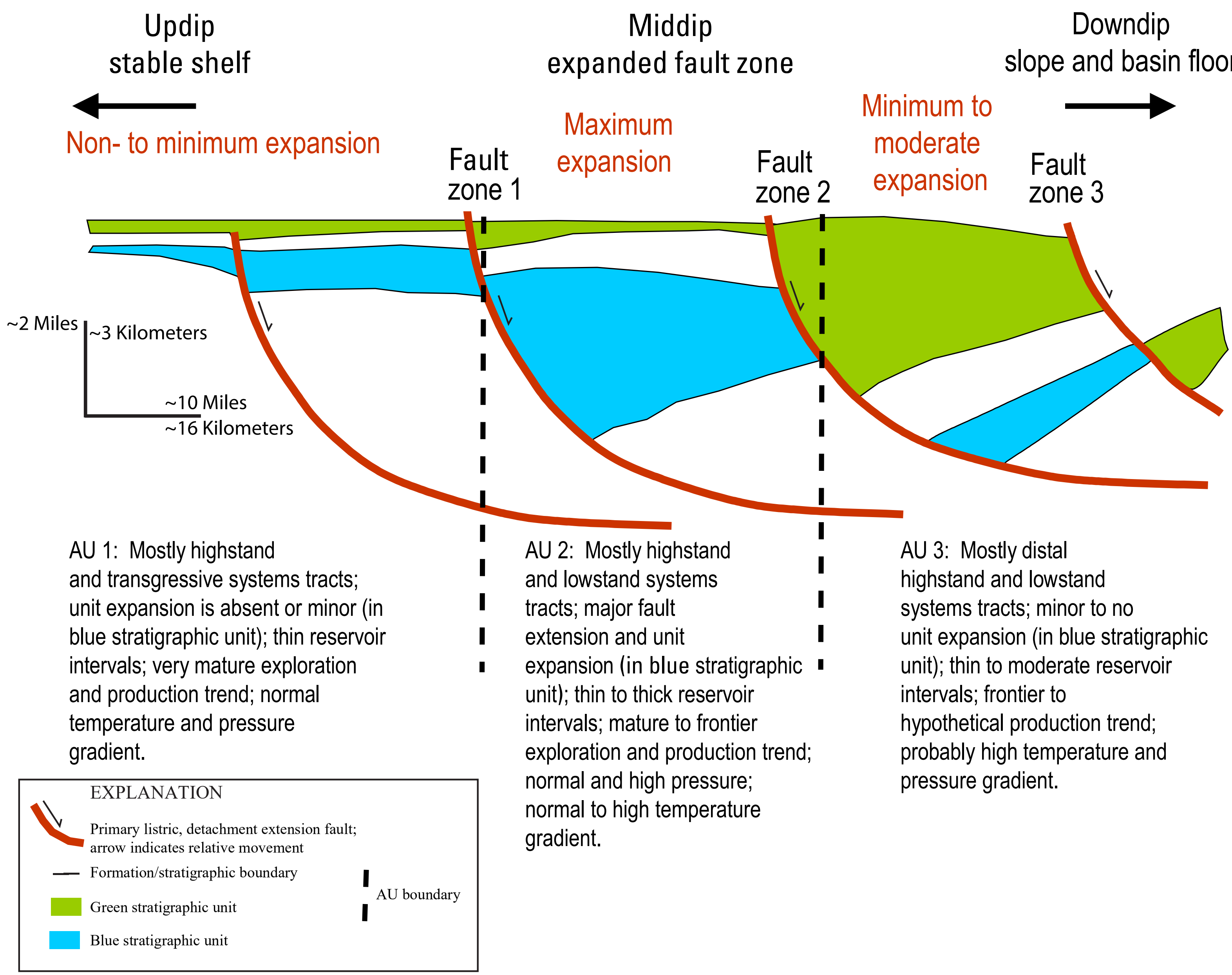


Figure 18. Model used to define assessment units (AUs) in the U.S. Geological Survey assessment of Paleogene strata in Gulf of Mexico onshore and State water areas. Assessment unit 1 (AU 1) defines the stable shelf structural area (shown by the blue stratigraphic unit); AU 2 defines the main unit expansion and thickening zone (shown by the blue stratigraphic unit); and AU 3 is composed of sediments deposited in slope and basin floor depositional environments (shown by the blue stratigraphic unit). Modified from Swanson and others (2013).

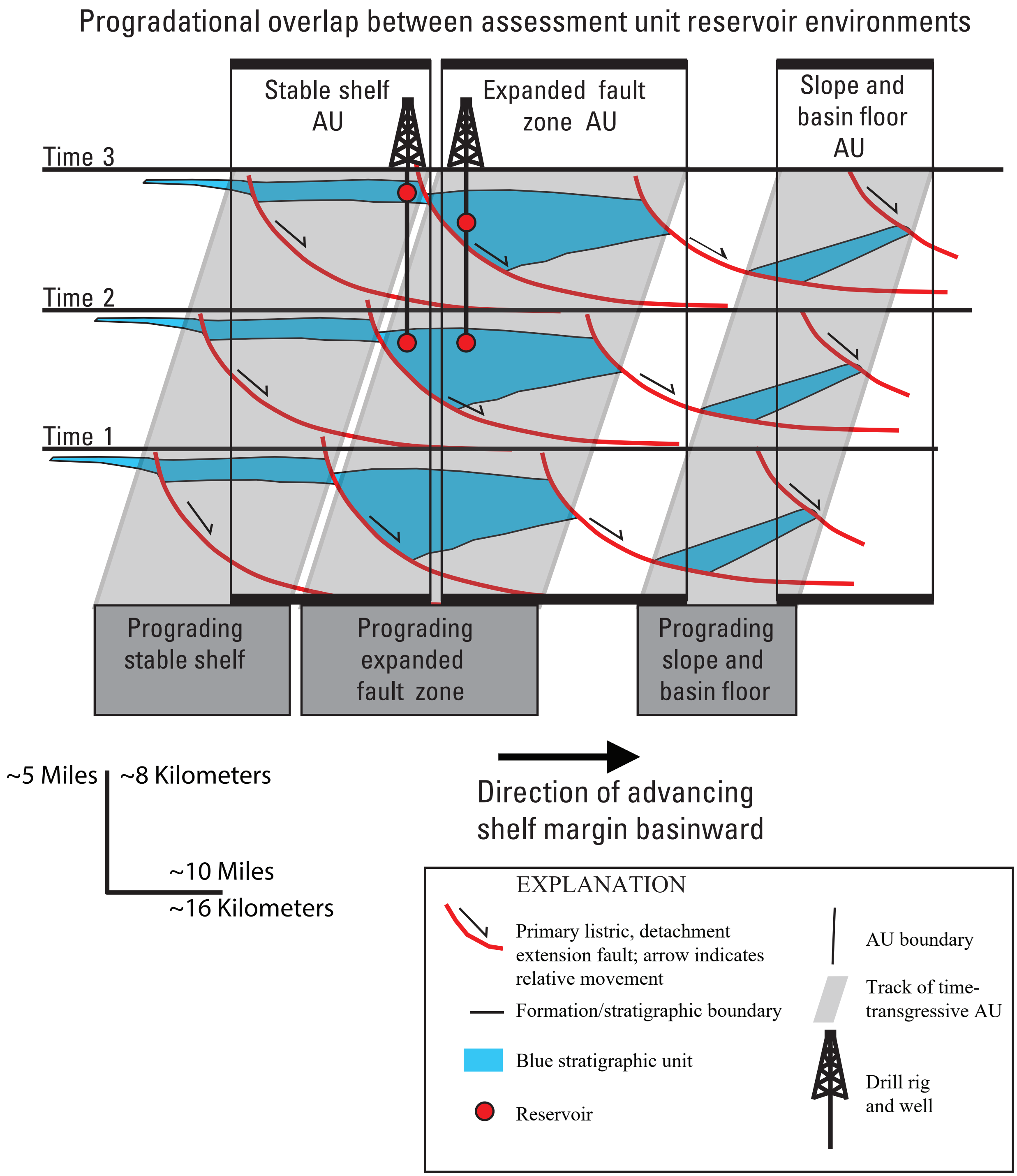


Figure 19. Stacked reservoirs and assessment units (AUs) in the Gulf Coast Tertiary assessment model showing the offset and overlapping character of the assessment units through time and the advance of the shelf margin basinward (see fig. 17).

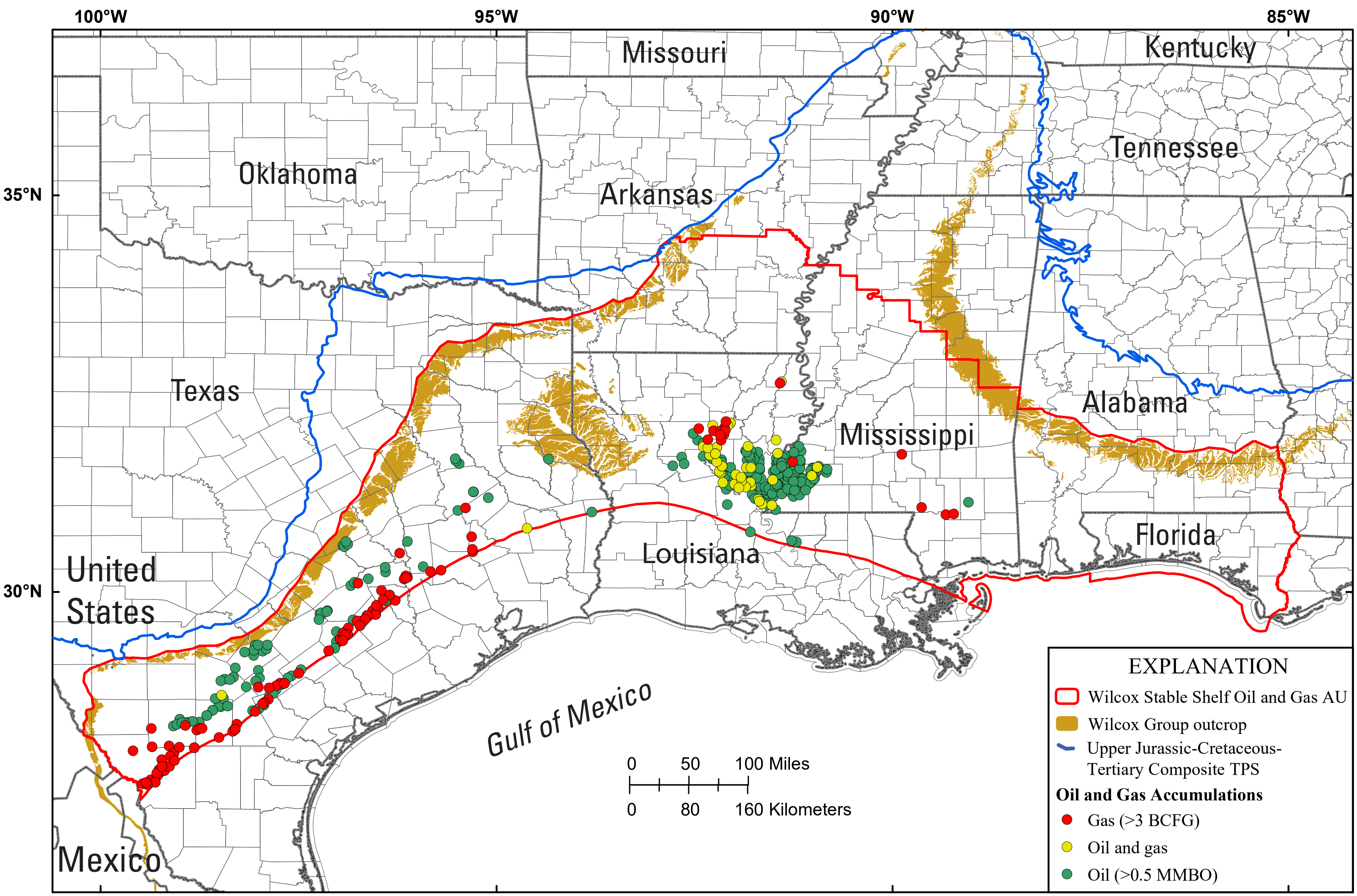


Figure 20. Wilcox Stable Shelf Oil and Gas Assessment Unit (AU), showing oil and gas accumulations (reservoirs) that existed at the time of the assessment. Field and reservoir data are from Nehring Associates Inc. (2006). Outcrop geology from Warwick and others (1997). Abbreviations: BCFG, billion cubic feet of gas; MMBO, million barrels of oil; TPS, Total Petroleum System.

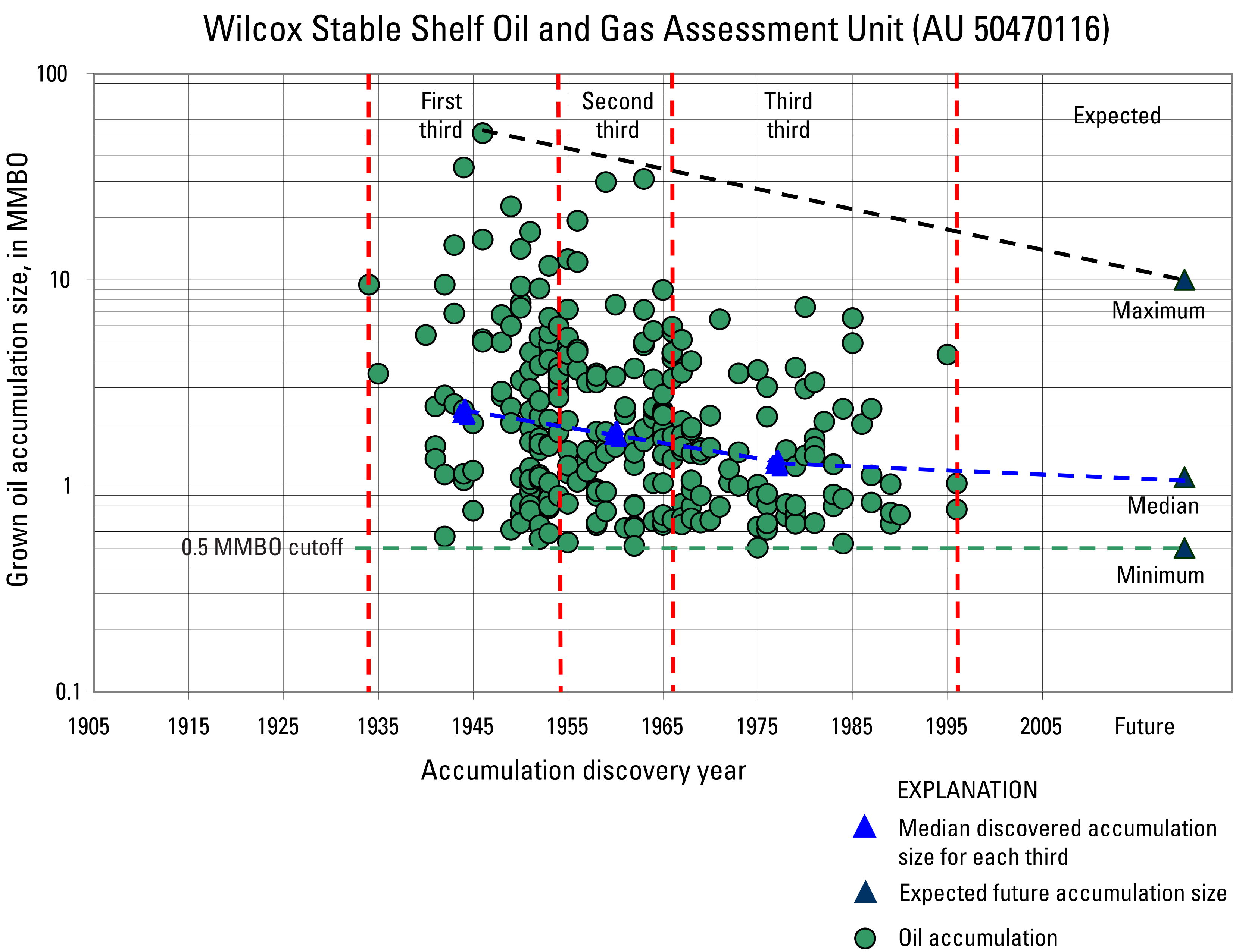


Figure 21. Plot of grown oil accumulation size versus discovery year for the Wilcox Stable Shelf Oil and Gas Assessment Unit (AU). Also shown are the expected sizes of future oil accumulations. Data from Nehring Associates Inc. (2006) and T.R. Klett (written commun., 2006). Abbreviations: MMBO, million barrels of oil.

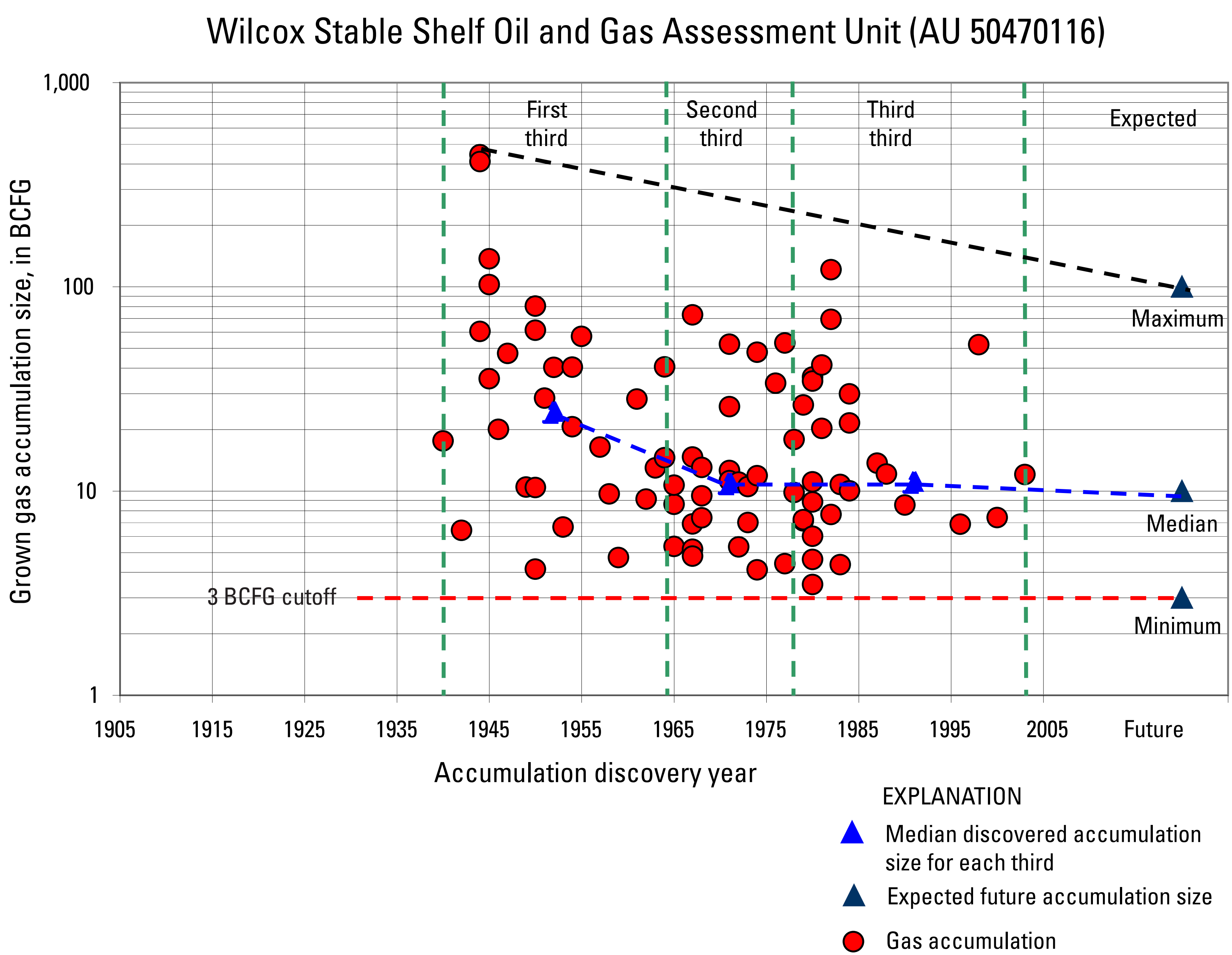


Figure 22. Plot of grown gas accumulation size versus discovery year for the Wilcox Stable Shelf Oil and Gas Assessment Unit (AU). Also shown are the expected sizes of future gas accumulations. Data from Nehring Associates Inc. (2006) and T.R. Klett (written commun., 2006). Abbreviations: BCFG, billion cubic feet of gas.

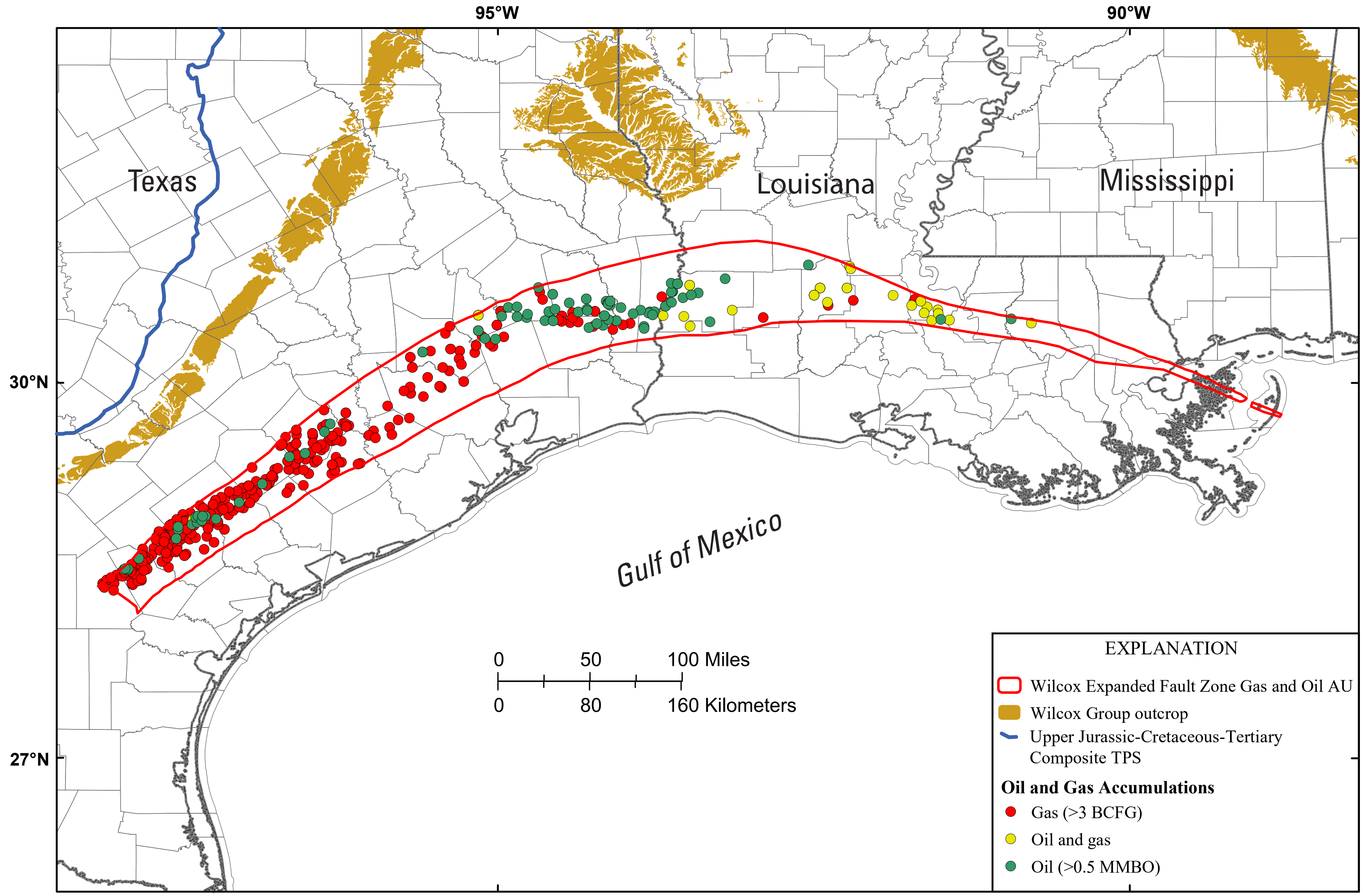


Figure 23. Wilcox Expanded Fault Zone Gas and Oil Assessment Unit (AU), showing oil and gas accumulations. Field and reservoir data from Nehring Associates Inc. (2006). Outcrop geology from Warwick and others (1997). Abbreviations: BCFG, billion cubic feet of gas; MMBO, million barrels of oil; TPS, Total Petroleum System.

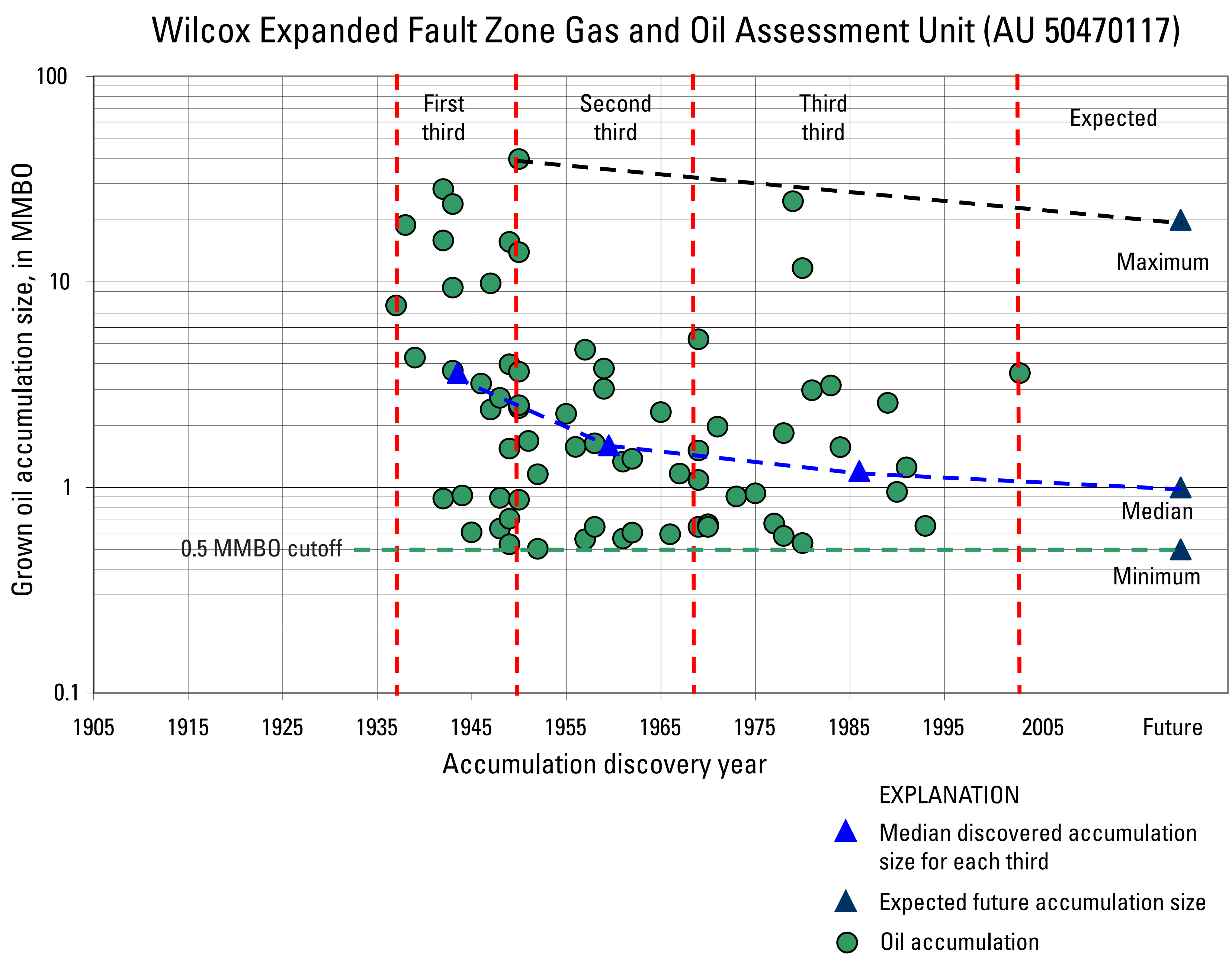


Figure 24. Plot of grown oil accumulation size versus discovery year for the Wilcox Expanded Fault Zone Gas and Oil Assessment Unit (AU). Also shown are the expected sizes of future oil accumulations. Data from Nehring Associates Inc. (2006) and T.R. Klett (written commun., 2006). Abbreviations: MMBO, million barrels of oil.

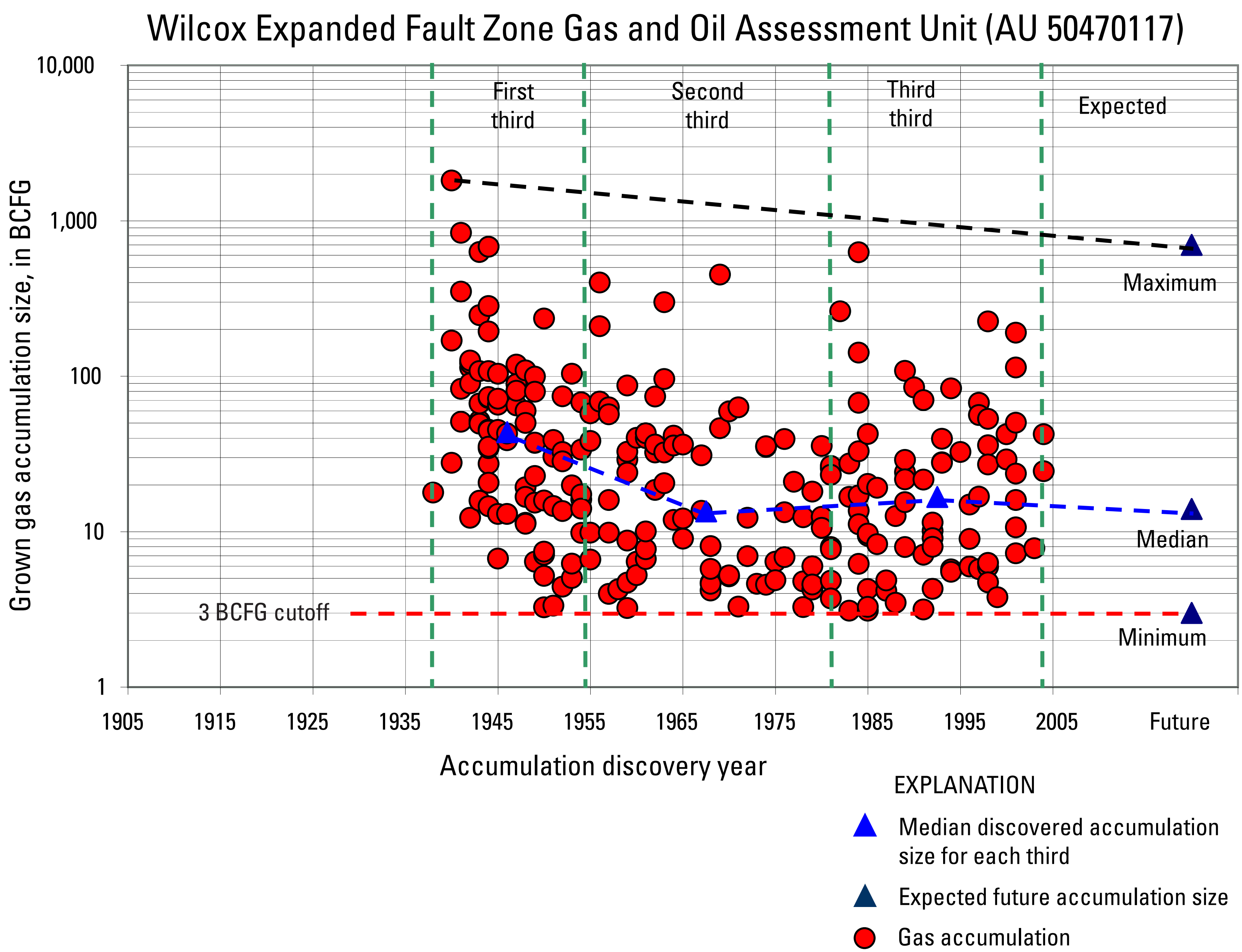


Figure 25. Plot of grown gas accumulation size versus discovery year for the Wilcox Expanded Fault Zone Gas and Oil Assessment Unit (AU). Also shown are the expected sizes of future gas accumulations. Data from Nehring Associates Inc. (2006) and T.R. Klett (written commun., 2006). Abbreviations: BCFG, billion cubic feet of gas.

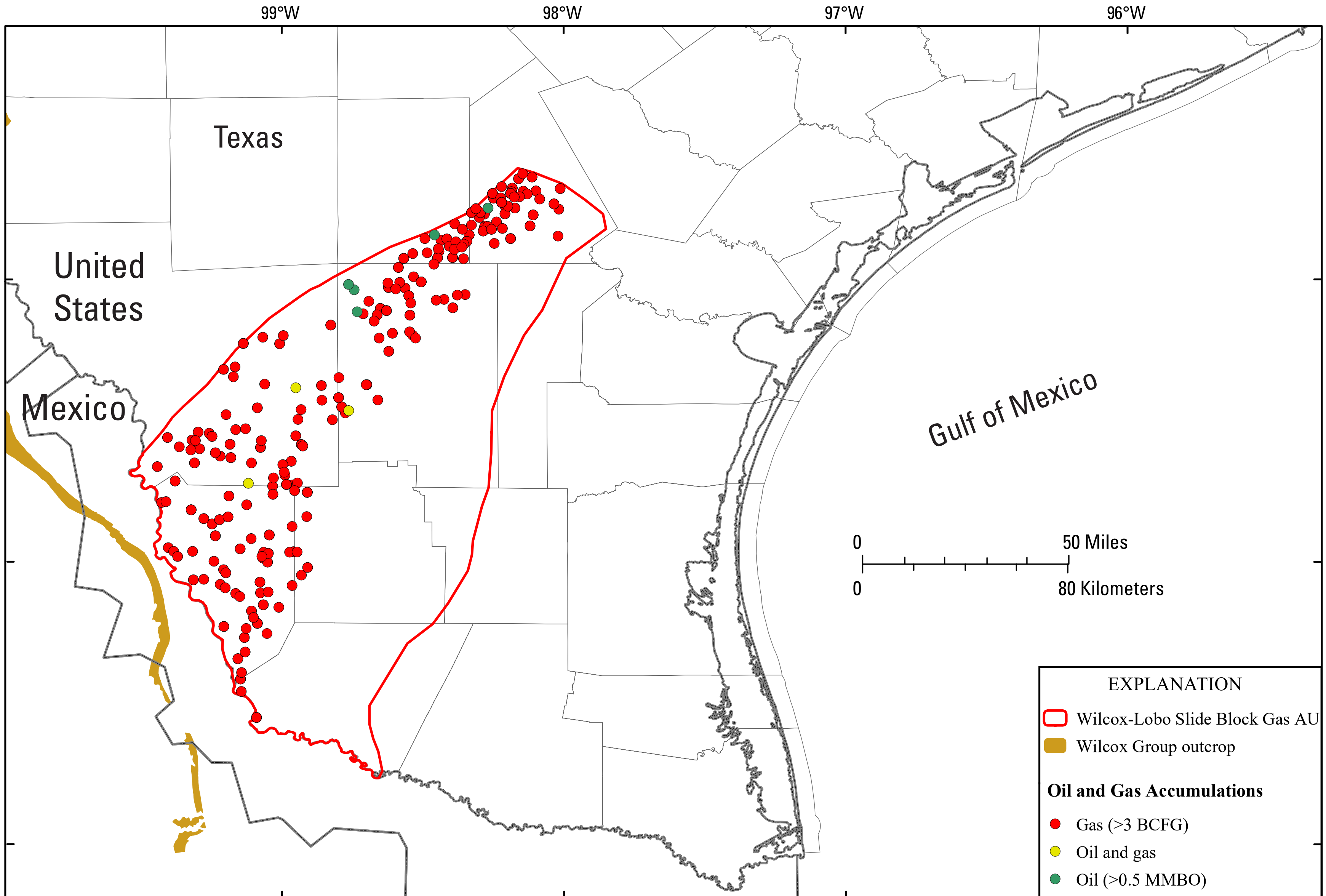


Figure 26. Wilcox-Lobo Slide Block Gas Assessment Unit (AU), showing oil and gas accumulations. Field and reservoir data from Nehring Associates Inc. (2006). Outcrop geology from Warwick and others (1997). Abbreviations: BCFG, billion cubic feet of gas; MMBO, million barrels of oil.

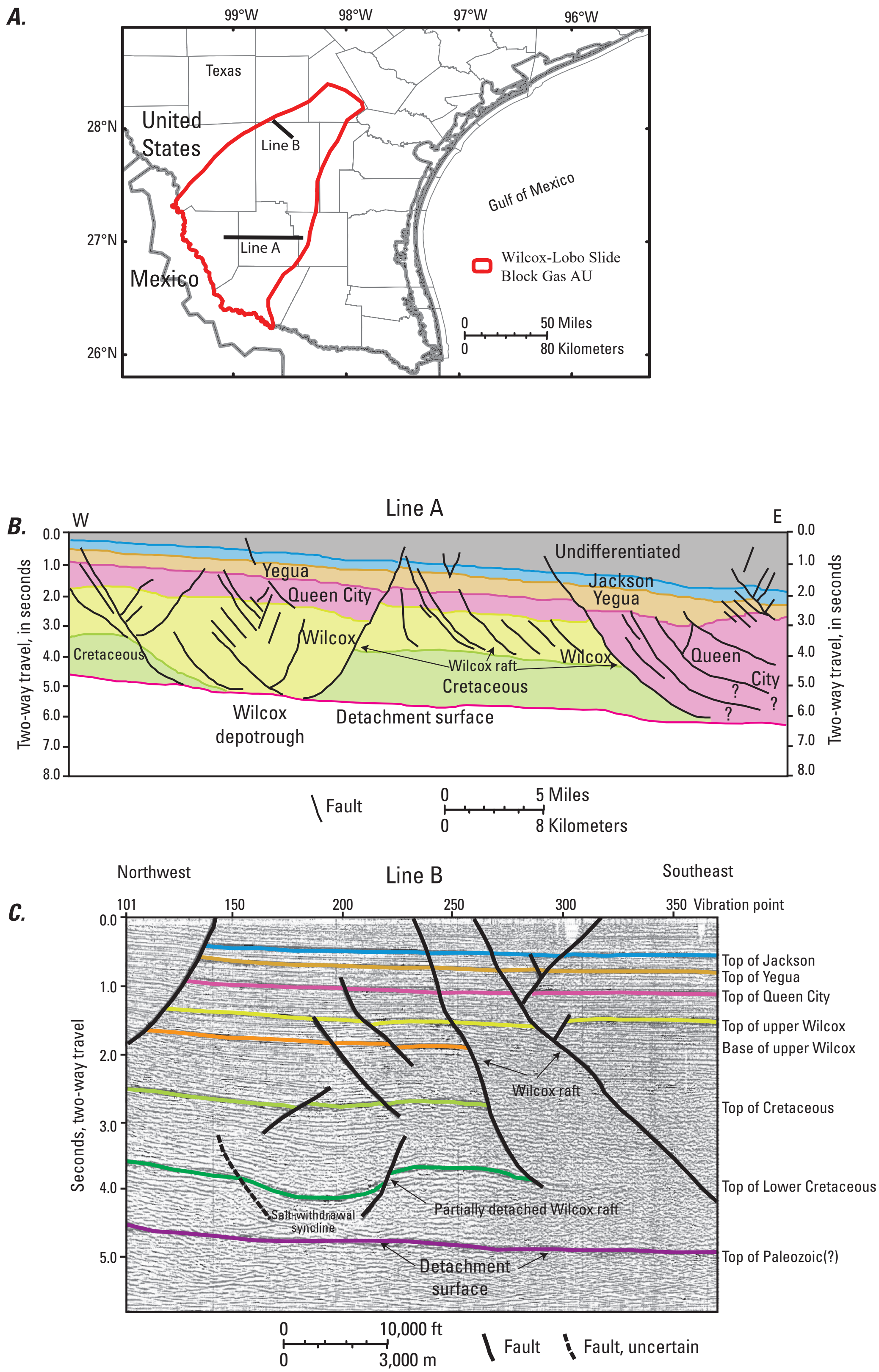


Figure 27. Structural characteristics of the Wilcox-Lobo Slide Block Gas Assessment Unit (AU). *A*, Regional location map and location of seismic section lines. *B*, Drawing of east-west oriented Line A across the Wilcox detachment and "raft" structures. *C*, Line B showing extension of Cretaceous strata associated with "raft" structures. Modified from Fiduk and Hamilton (1995); Anderson and Fiduk (2003). Abbreviations: ft, feet; m, meters.

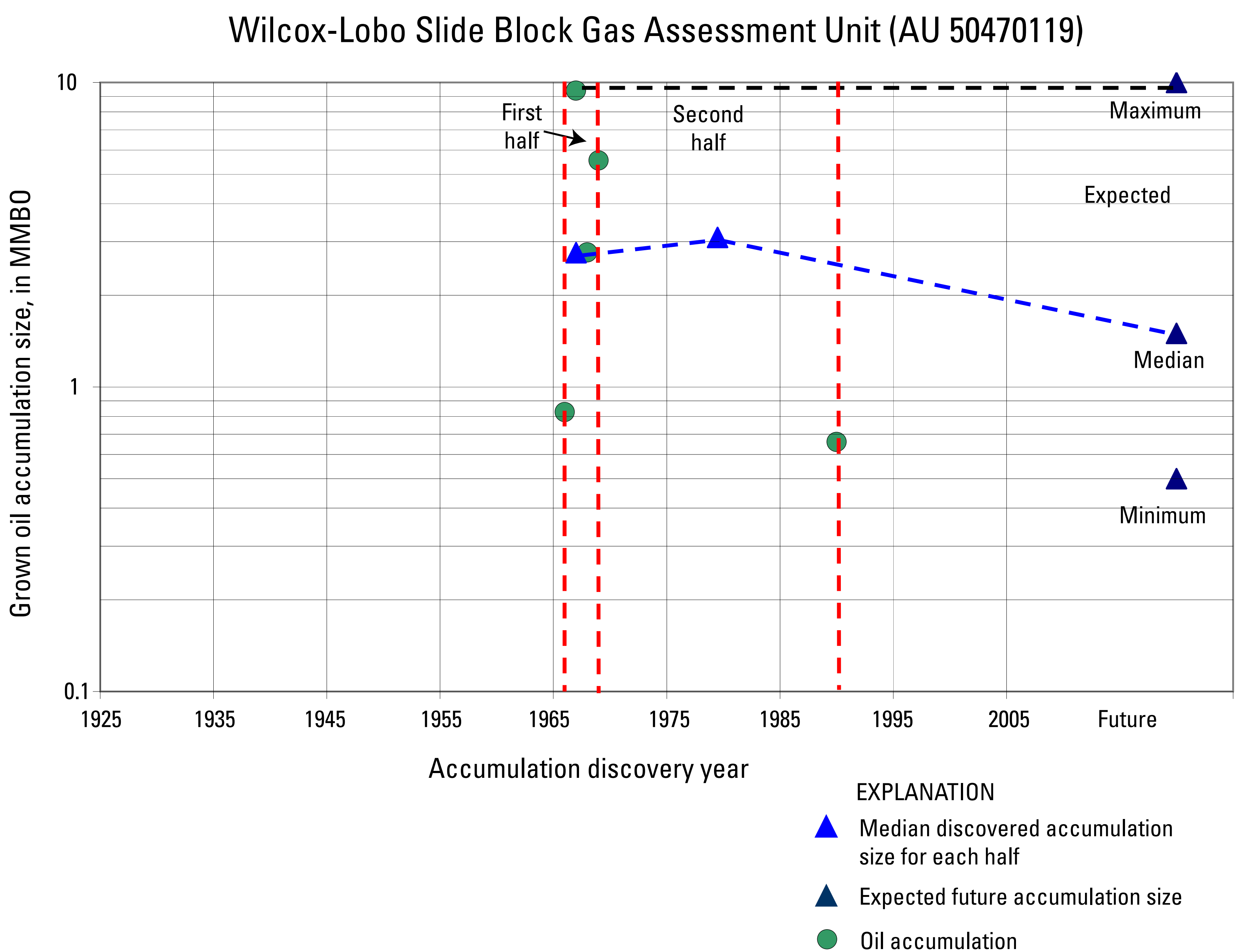


Figure 28. Plot of grown oil accumulation size versus discovery year for the Wilcox-Lobo Slide Block Gas Assessment Unit (AU). Also shown are the expected sizes of future oil accumulations. Data from Nehring Associates Inc. (2006) and T.R. Klett (written commun., 2006). Abbreviations: MMBO, million barrels of oil.

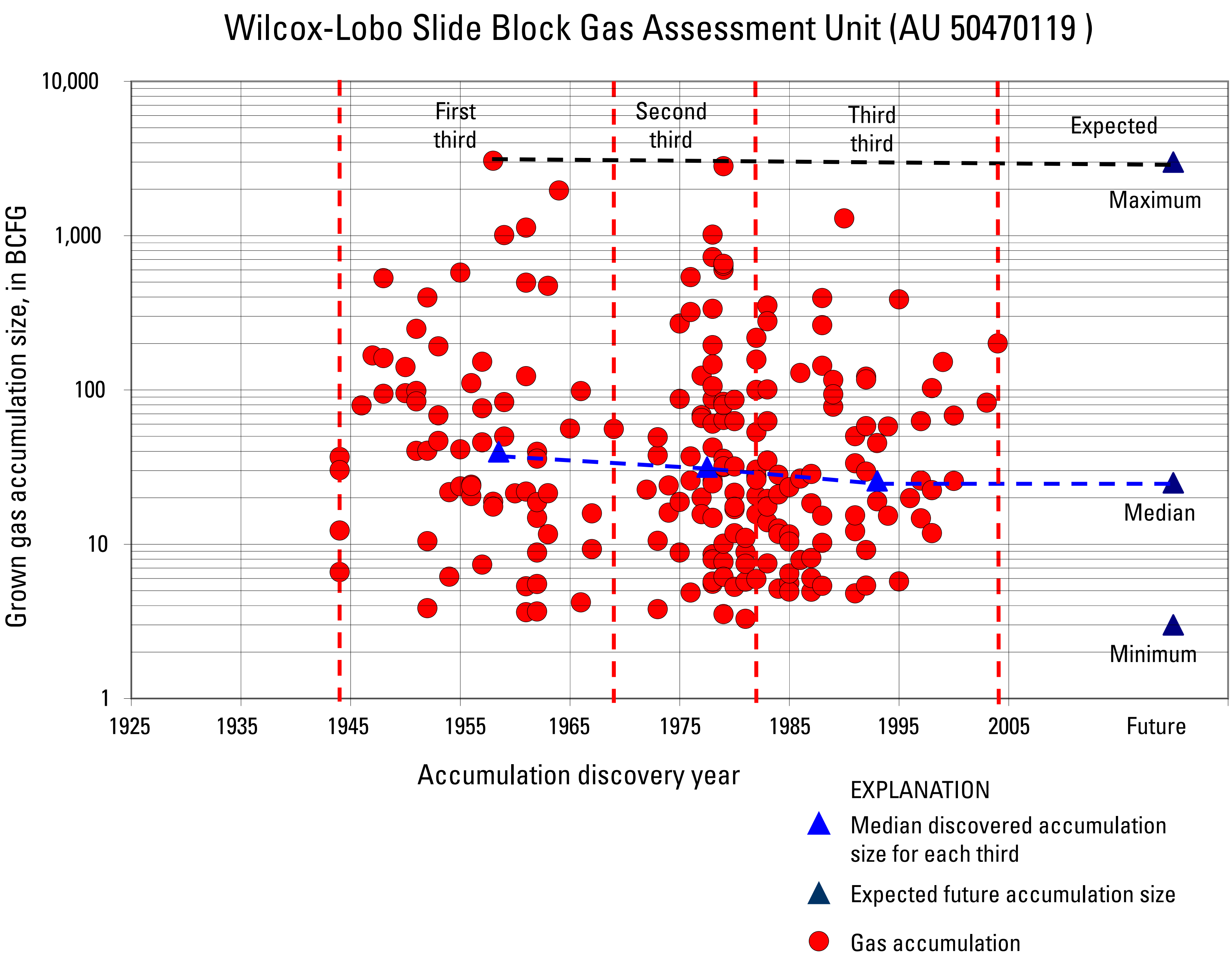


Figure 29. Plot of grown gas accumulation size versus discovery year for the Wilcox-Lobo Slide Block Gas Assessment Unit (AU). Also shown are the expected sizes of future gas accumulations. Data from Nehring Associates Inc. (2006) and T.R. Klett (written commun., 2006). Abbreviations: BCFG, billion cubic feet of gas.

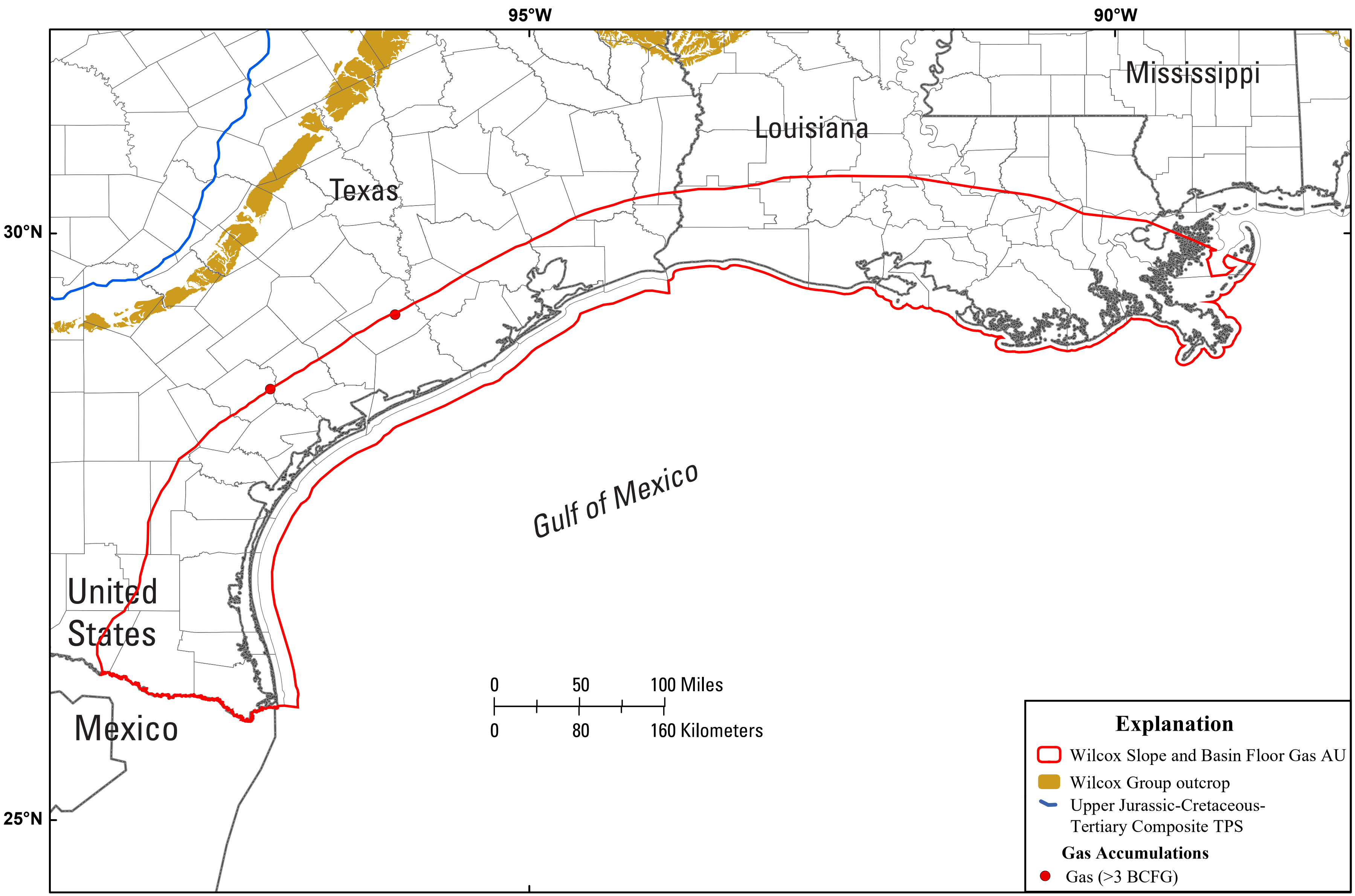


Figure 30. Wilcox Slope and Basin Floor Gas Assessment Unit (AU), showing gas accumulations. Field and reservoir data from Nehring Associates Inc. (2006). Outcrop geology from Warwick and others (1997). Abbreviations: BCFG, billion cubic feet of gas; TPS, Total Petroleum System.

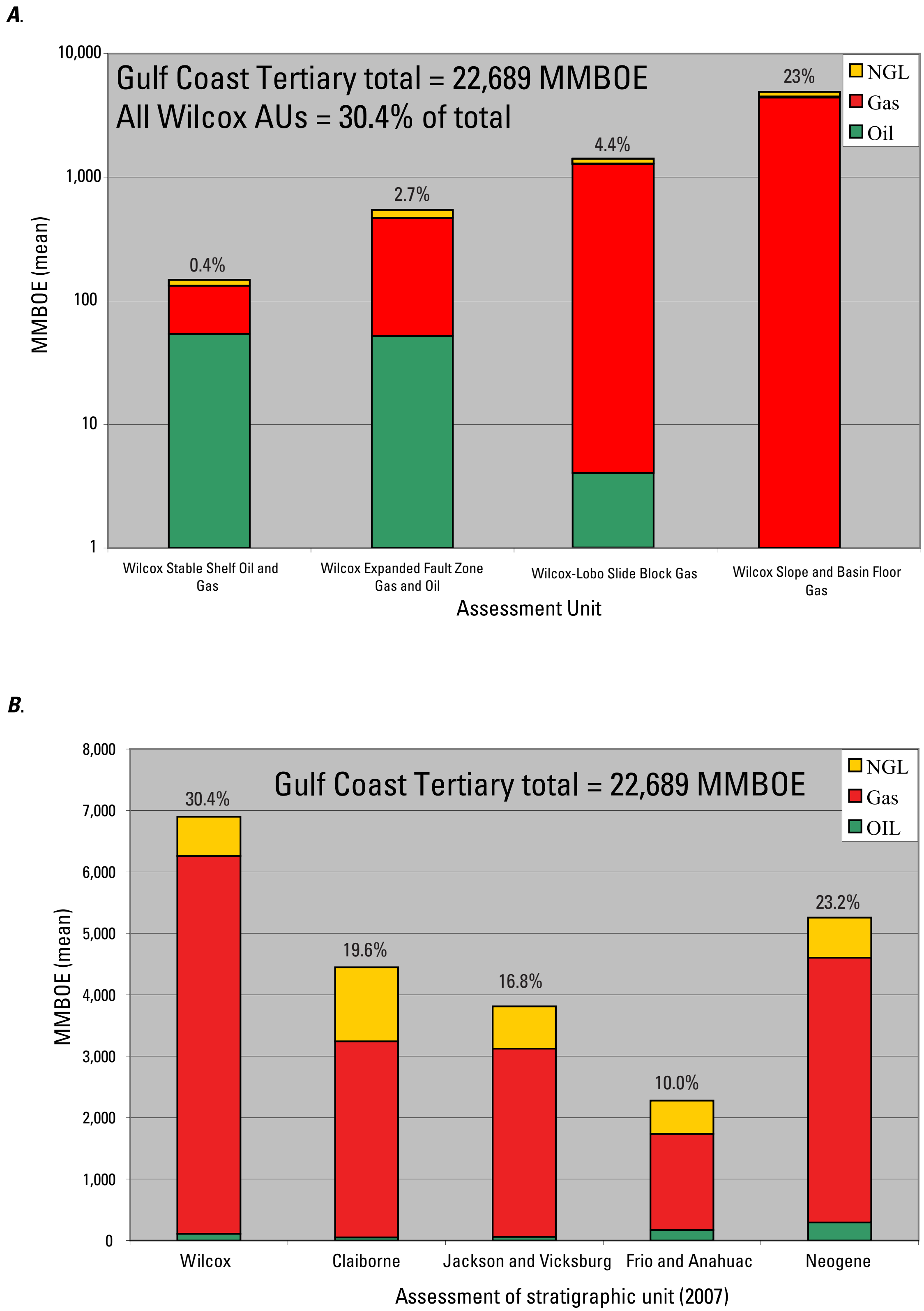


Figure 31. U.S. Geological Survey Gulf Coast assessment results. *A*, Results for all lower Paleogene undiscovered, technically recoverable conventional oil, gas, and natural gas liquids. *B*, Results for all Tertiary undiscovered, technically recoverable conventional oil, gas, and natural gas liquids (Dubiel and others, 2007). The percentages shown are of the Gulf Coast Tertiary total of 22,689 MMBOE and are by major assessment intervals and lower Paleogene assessment units. Abbreviations: AUs, Assessment Units; MMBOE, million barrels of oil equivalent; NGL, natural gas liquids.

Appendix 1. Input Data Form for the Wilcox Stable Shelf Oil and Gas Assessment Unit (50470116)

Input data form in appendix 1 for evaluating the Wilcox Stable Shelf Oil and Gas Assessment Unit (50470116). [Abbreviations: accum., accumulations; AU, assessment unit; bcfg, billion cubic feet of gas; bliq/mmcfg, barrels of liquid per million cubic feet of gas; bngl/mmcfg, barrels of natural gas liquids per million cubic feet of gas; cfg/bo, cubic feet of gas per barrel of oil; m, meters; min., minimum; mmbo, million barrels of oil; NGL, natural gas liquids; no., number]

Appendix 2. Input Data Form for the Wilcox Expanded Fault Zone Gas and Oil Assessment Unit (50470117)

Input data form in appendix 2 for evaluating the Wilcox Expanded Fault Zone Gas and Oil Assessment Unit (50470117). [Abbreviations: accum., accumulations; AU, assessment unit; bcfg, billion cubic feet of gas; bliq/mmcfg, barrels of liquid per million cubic feet of gas; bngl/mmcfg, barrels of natural gas liquids per million cubic feet of gas; cfg/bo, cubic feet of gas per barrel of oil; m, meters; min., minimum; mmbo, million barrels of oil; NGL, natural gas liquids; no., number]

Appendix 3. Input Data Form for the Wilcox-Lobo Slide Block Gas Assessment Unit (50470119)

Input data form in appendix 3 for evaluating the Wilcox-Lobo Slide Block Gas Assessment Unit (50470119). [Abbreviations: accum., accumulations; AU, assessment unit; bcfg, billion cubic feet of gas; bliq/mmcfg, barrels of liquid per million cubic feet of gas; bngl/mmcfg, barrels of natural gas liquids per million cubic feet of gas; cfg/bo, cubic feet of gas per barrel of oil; m, meters; min., minimum; mmbo, million barrels of oil; NGL, natural gas liquids; no., number]

Appendix 4. Input Data Form for the Wilcox Slope and Basin Floor Gas Assessment Unit (50470118)

Input data form in appendix 4 for evaluating the Wilcox Slope and Basin Floor Gas Assessment Unit (50470118). [Abbreviations: accum., accumulations; AU, assessment unit; bcfg, billion cubic feet of gas; bliq/mmcfg, barrels of liquid per million cubic feet of gas; bngl/mmcfg, barrels of natural gas liquids per million cubic feet of gas; cfg/bo, cubic feet of gas per barrel of oil; m, meters; min., minimum; mmbo, million barrels of oil; NGL, natural gas liquids; no., number]

Manuscript approved August 23, 2017
For more information concerning this report, contact:
Director, Eastern Energy Resources Science Center
U.S. Geological Survey
Mail Stop 956
12201 Sunrise Valley Drive
Reston, VA 20192
http://energy.usgs.gov/
http://energy.usgs.gov/GeneralInfo/ScienceCenters/Eastern.aspx

Prepared by the USGS Science Publishing Network
Reston Publishing Service Center
Edited by David A. Shields
Layout by Jeannette Foltz

Warwick—**Geologic Assessment of Oil and Gas in Midway and Wilcox Groups, and Carrizo Sand of Northern Gulf Coast Region**—Open-File Report 2017–1111

ISSN 2331-1258 (online)
https://doi.org/10.3133/ofr20171111