PSUSGS Assessment of Undiscovered, Technically Recoverable Oil and Natural Gas Resources of the Lower Paleogene Midway and Wilcox Groups, and Carrizo Sand, Claiborne Group, Onshore Gulf of Mexico Basin, U.S.A.*

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*This report contains the abstract, figures, and references presented April 22, 2008, in a poster session at AAPG Annual Convention, San Antonio, Texas. Author's note: No attempt has been made herein to provide other than the bare minimum of text to support each of the figures as presented at the AAPG meeting. This same material currently is in manuscript format in internal peer review at the U.S. Geological Survey, where it will ultimately be presented in a formal-series publication. Readers of the current presentation are encouraged to contact the author via email with their questions and comments.

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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, the availability of suitable reservoir rocks, and the presence of hydrocarbon traps in an Upper Jurassic-Cretaceous-Tertiary Composite Total Petroleum System (TPS) defined for the region by the USGS. Five assessment units (AUs) were defined for the Midway (Paleocene) and Wilcox (Paleocene-Eocene) Groups, and the Carrizo Sand of the Claiborne Group (Eocene) interval: (1) the Wilcox Stable Shelf Oil and Gas AU; (2) the Wilcox Expanded Fault Zone Gas and Oil AU; the (3) Wilcox Slope and Basin Floor Gas AU; (4) the Wilcox-Lobo Slide Block 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, 36.9 trillion cubic feet of gas, and 639 million barrels of natural gas liquids (NGL) 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) and deltaic sandstone reservoirs of the Expanded Fault Zone (52 MMBO) AUs. Greater than 70 percent of the undiscovered gas and 66 percent of the NGL are estimated to be in deep (13,000 to 30,000 ft), unexplored distal deltaic and slope sandstone reservoirs within the Wilcox Slope and Basin Floor Gas AU.

Overview of Current USGS National Assessment of Oil and Gas Activities

Goal of the National Assessment

The primary goal of the USGS National Oil and Gas Assessment (NOGA) project is to develop geologically based estimates of the quantities of oil and gas that have the potential to be added to proved reserves in the United States.

Objectives of the National Assessment:

The current objectives of the USGS National Oil and Gas Assessment project are to:

- Assess the 30 priority basins that contain approximately 96 % of the resources; a map showing the current status of the NOGA assessments can be found at: http://energy.cr.usgs.gov/oilgas/noga/ (accessed November 6, 2008).
- Define petroleum systems within the basins
- Define geologically based assessment units (AU)
- Assess both conventional and continuous resources

A summary of the current USGS NOGA results can be found on Figures 1a, 1b, 1c, and 1d.

Methodology

The methodology used for the Gulf Coast conventional AUs follows that described in Klett et al. (2005), Schmoker and Klett (2005), and Charpentier and Klett (2005). The methodology used for the Gulf Coast continuous assessment units is described in Cook (2005), Crovelli (2005), Schmoker (2005), and Klett 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 address:
http://energy.cr.usgs.gov/oilgas/noga/methodology.html (accessed March 19, 2009).

Examples of conventional and continuous hydrocarbon accumulations used in U.S. Geological Survey assessments are shown on Figure 2.

Results

A summary of the Gulf of Mexico basin geology, stratigraphy, and petroleum systems can be found on Figures 3, 4, 5, 6, and 7. A geologic model used to help define assessment units for the Lower Paleogene Assessment interval (Midway-Wilcox-Carrizo Sand) is shown on Figure 8. Maps showing Wilcox structure, thickness, and estimated thermal maturities are shown on Figures 9, 10, and 11. Details of the various Lower Paleogene assessment units are shown on Figures 12, 13, 14, 15, 16, 17, 18, and 19. Numerical results of the Lower Paleogene Assessment interval are shown on Figure 20. A comparison of the Tertiary assessment intervals for the Gulf of Mexico Coastal Plain is shown on Figure 21.

Conclusions

This report presents a review of the U.S. Geological Survey (USGS) 2007 assessment of the undiscovered conventional oil and gas resources in Midway-Wilcox-Carrizo Sand strata (Paleocene-Eocene) underlying the U.S. Gulf of Mexico Coastal Plain and State waters. Numerical results of the assessment are presented in Figure 20 and in Dubiel et al. (2007) and Warwick et al. (2007b). For purposes of the assessment, an Upper Jurassic-Cretaceous-Tertiary total petroleum system (TPS) was defined for the Gulf of Mexico basin (Figure 6). Five assessment units (AUs) were defined for the Midway (Paleocene) and Wilcox (Paleocene-Eocene) Groups, and the Carrizo Sand of the Claiborne Group (Eocene) interval: (1) the Wilcox Stable Shelf Oil and Gas AU; (2) the Wilcox Expanded Fault Zone Gas and Oil AU; (3) the Wilcox Slope and Basin Floor Gas AU; (4) the Wilcox-Lobo Slide Block Gas AU; and (5) the Wilcox Mississippi Embayment AU (not quantitatively assessed) (Figure 12).

A generalized structural and stratigraphic model for Paleogene strata was developed to help define a generic updip, stable shelf AU; a middip, expansion (extension) zone AU; and a downdip, slope and basin floor AU for each assessed stratigraphic interval (Figure 8). A significant controlling factor for the location of the middip expansion zone AU is the location of underlying, stratigraphically older shelf margins. Using this geology-based assessment methodology, the USGS estimated a mean of 36.9 trillion cubic feet of undiscovered natural gas, a mean of 110 million barrels of undiscovered oil, and a mean of 639 million barrels of undiscovered natural gas liquids in onshore lands and State waters of the Gulf Coast.

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 Minerals Management Service Gulf of Mexico Region, Mississippi Department of Environmental Quality Office of Geology, Louisiana Geological Survey, and The University of Texas at Austin Bureau of Economic Geology greatly contributed to the concepts presented in this paper.

As noted above, this report contains the abstract, figures, and references presented April 22, 2008, in a poster session at the AAPG Annual Convention in San Antonio, Texas. No attempt has been made herein to provide other than the bare minimum of text to support each of the figures as presented at the AAPG Meeting. This same material currently is in manuscript format in internal peer review at the U.S. Geological Survey, where it will ultimately be presented in a formal-series publication. Readers of the current presentation are encouraged to contact the author via email with their questions and comments.

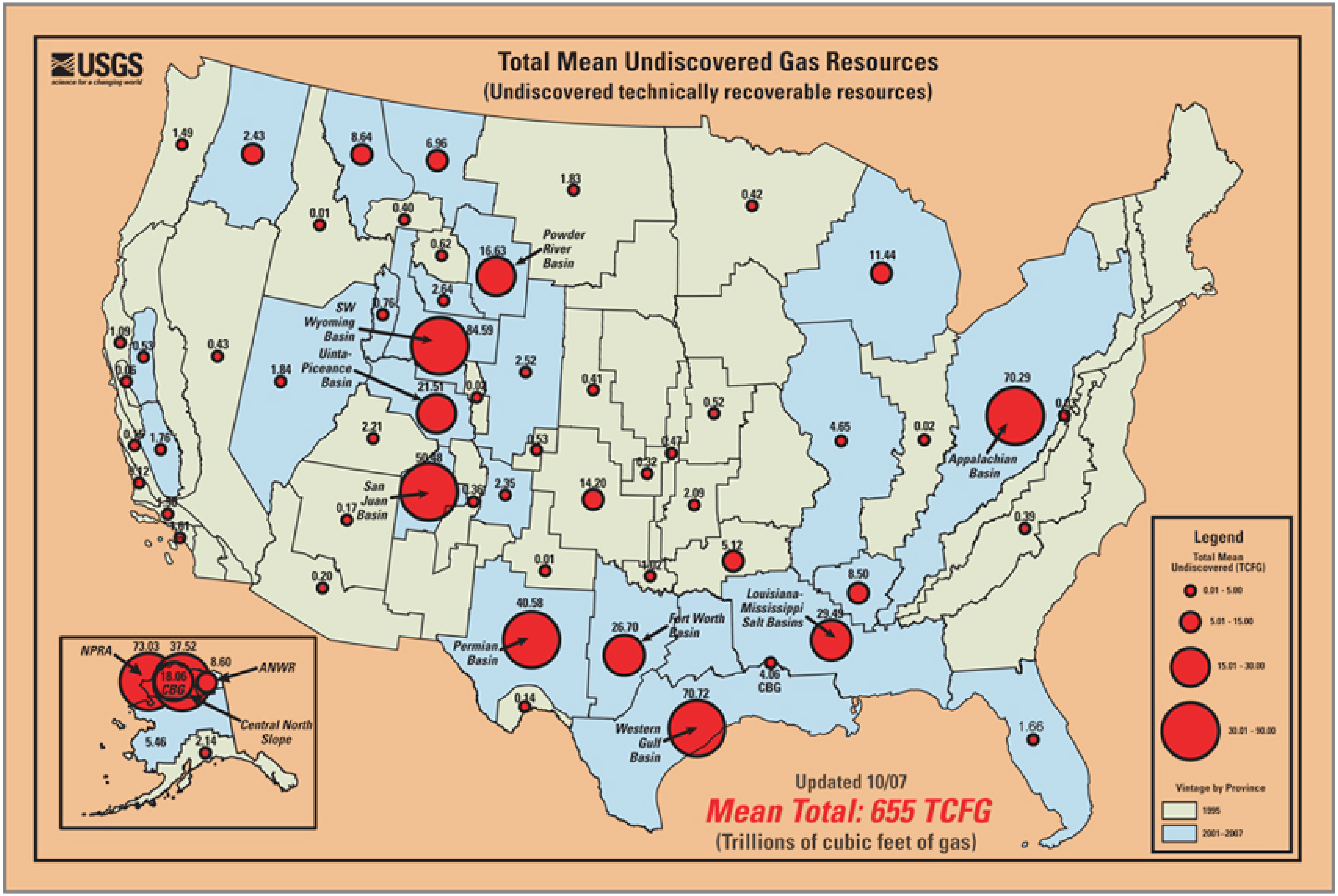


Figure 1a. Status of USGS conventional gas assessments in 2007. Source: http://certmapper.cr.usgs.gov/data/noga00/natl/graphic/2007/total_gas_mean_07.pdf (accessed March 19, 2009)

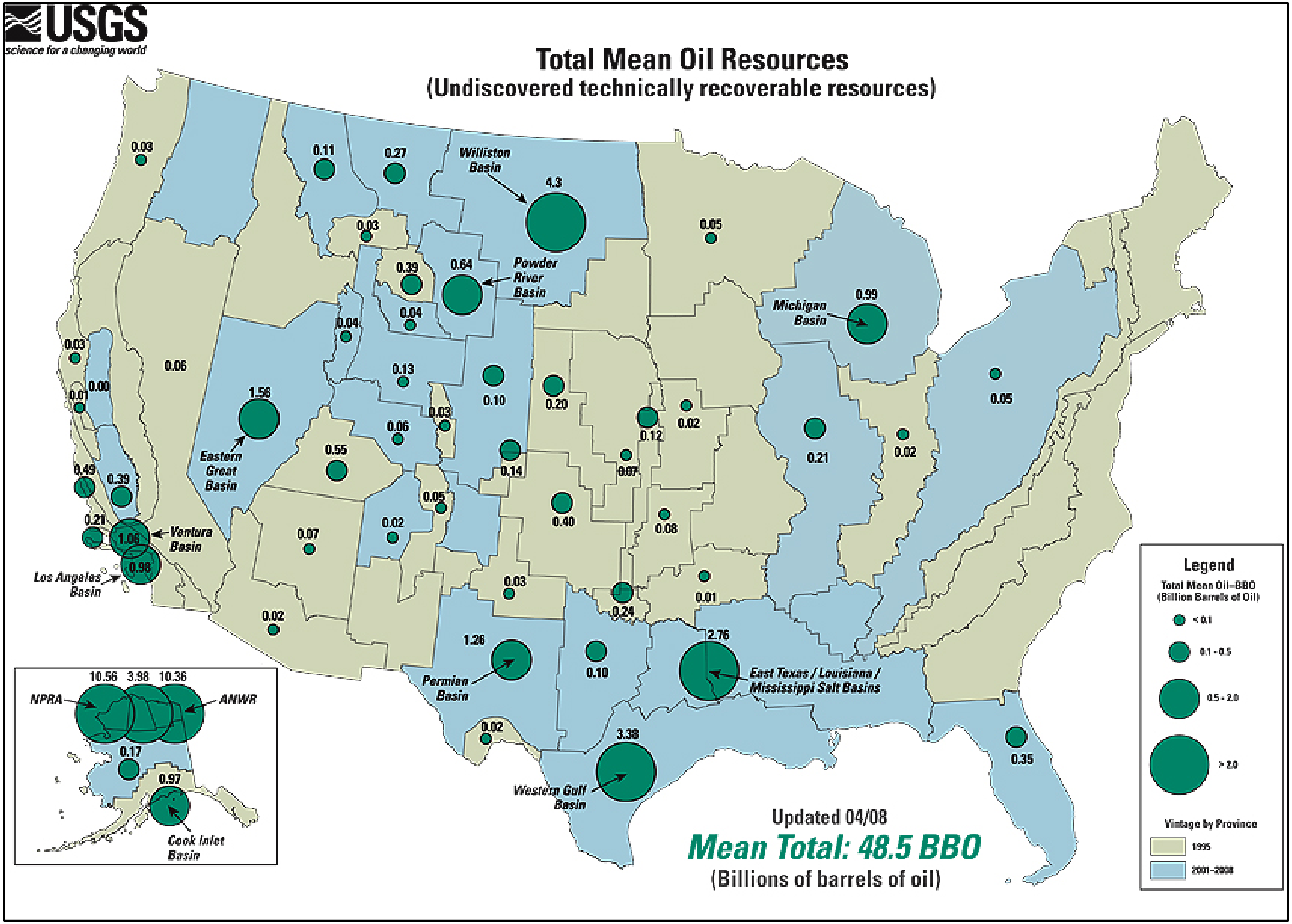


Figure 1b. Status of USGS conventional oil assessments in 2008. Source: http://certmapper.cr.usgs.gov/data/noga00/natl/graphic/2008/total_oil_mean_08.pdf (accessed March 19, 2009)

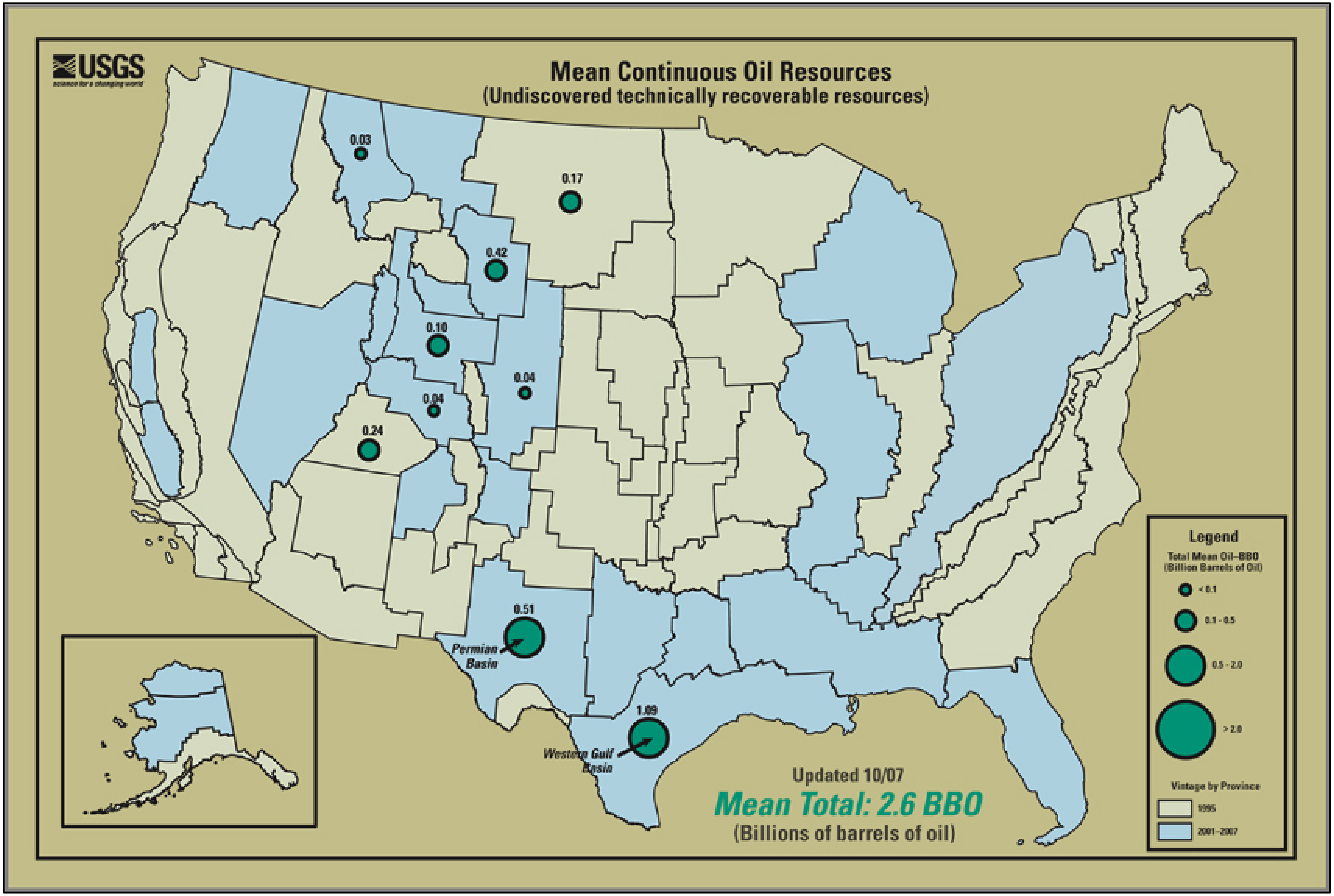


Figure 1c. Status of USGS continuous oil assessments in 2007. Source: http://certmapper.cr.usgs.gov/data/noga00/natl/graphic/2007/mean_cont_oil_07.pdf (accessed March 19, 2009)

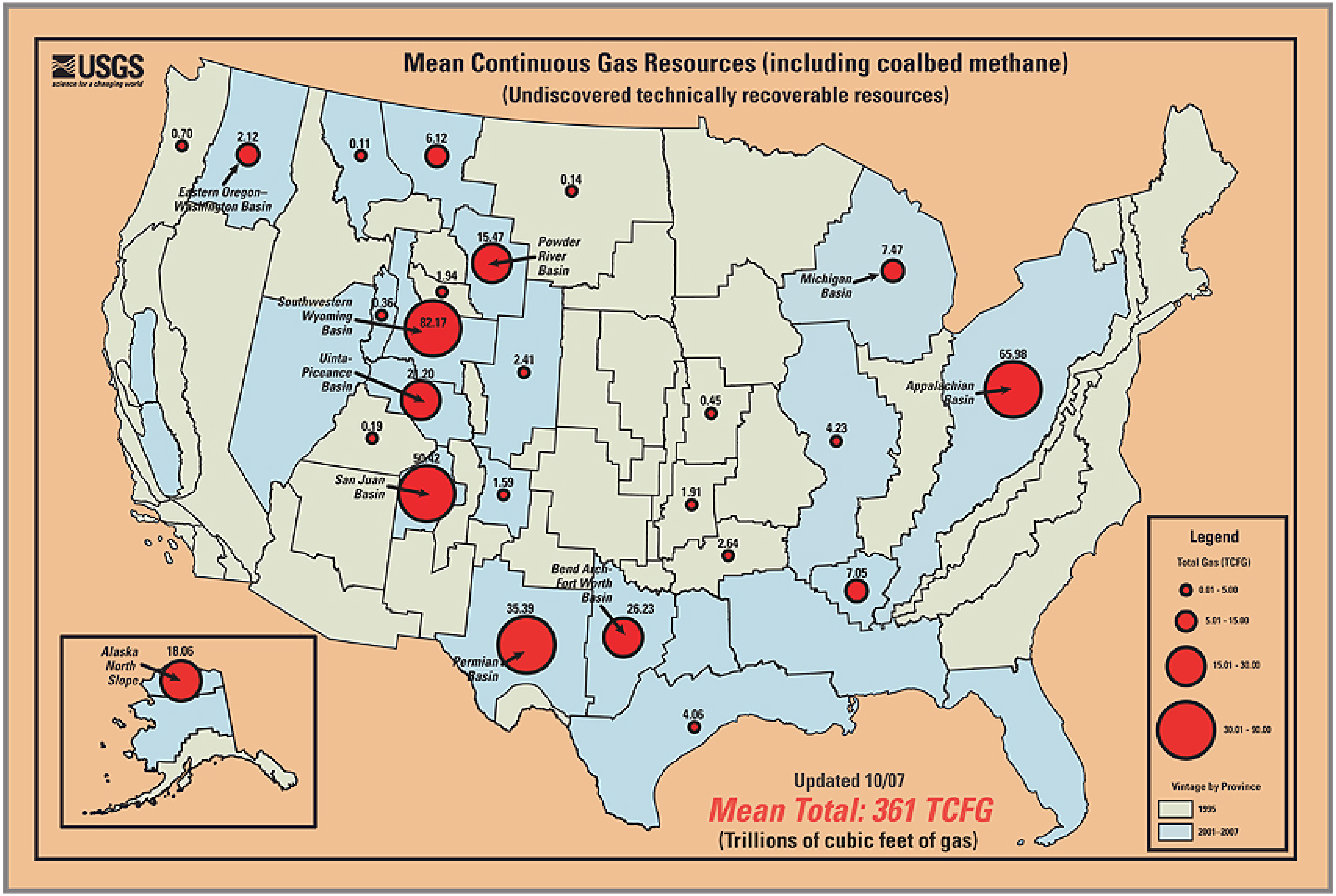


Figure 1d. Status of USGS continuous gas assessments in 2007. Source: http://certmapper.cr.usgs.gov/data/noga00/natl/graphic/2007/mean_cont_includ_cbm_07.pdf (accessed March 19, 2009)

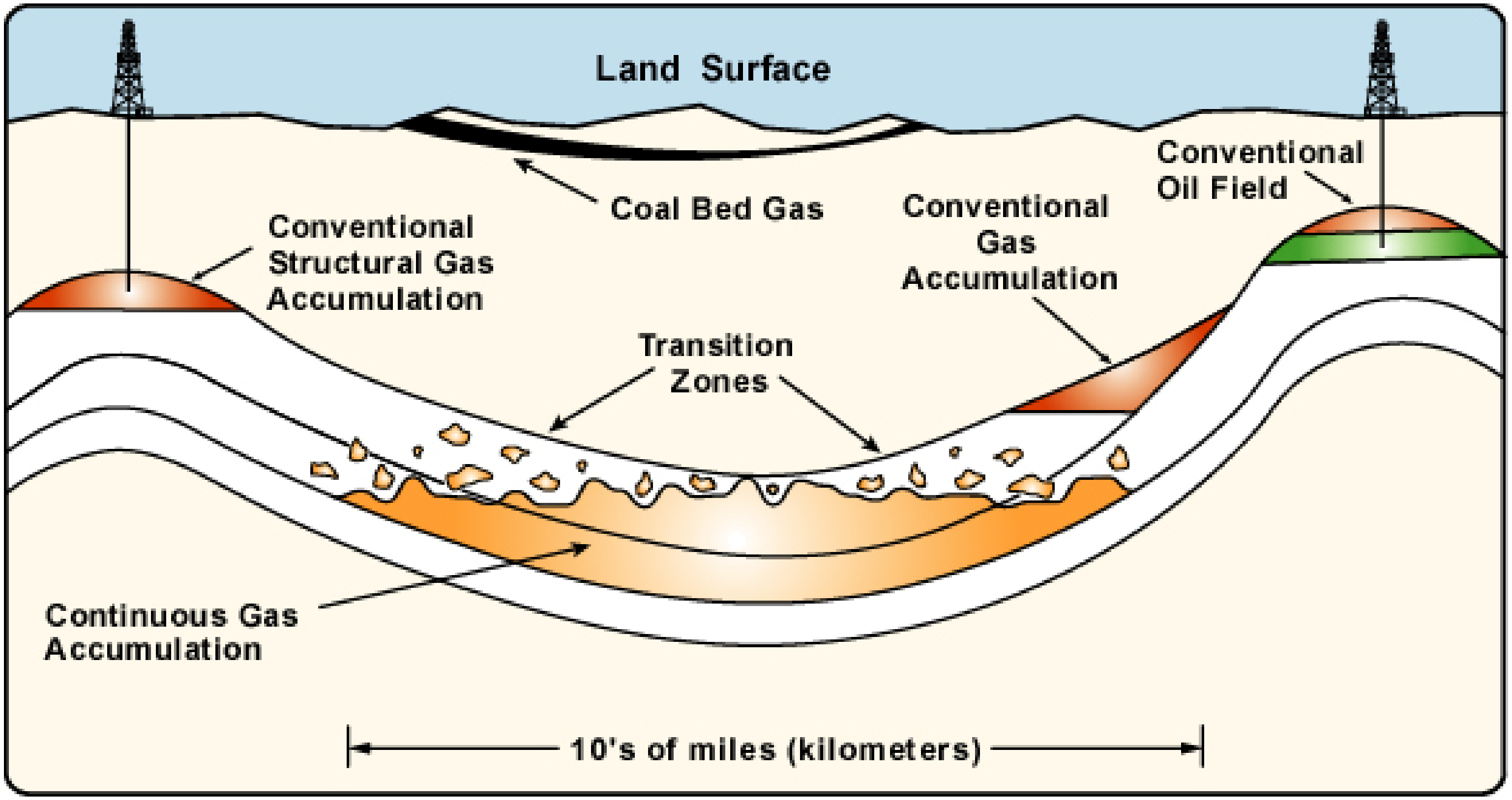


Figure 2. Examples of conventional and continuous hydrocarbon accumulations used in USGS assessments.
From Charpentier and Ahlbrandt (2003).

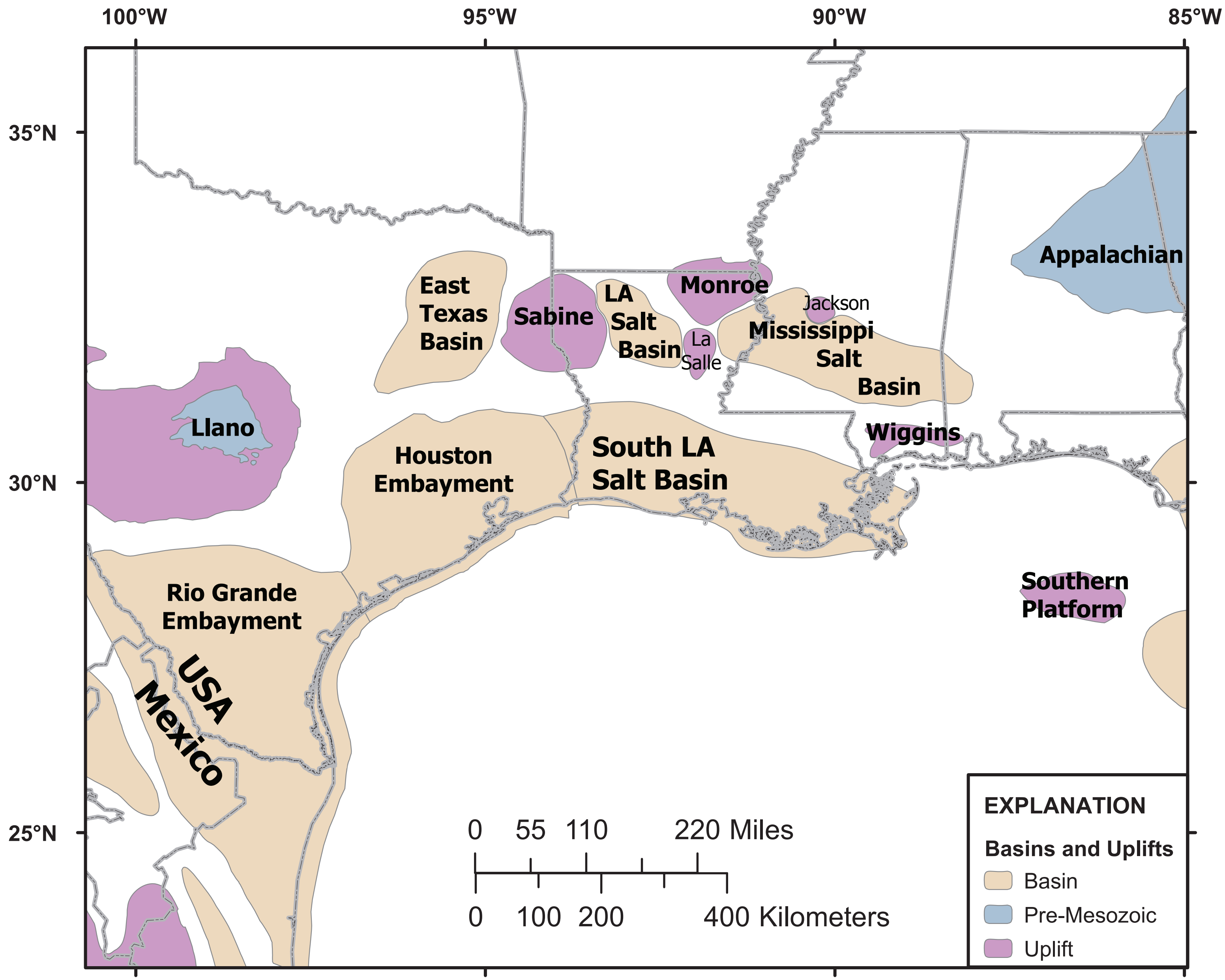


Figure 3. Major structural features of the northern onshore portion of the Gulf of Mexico basin. LA = Louisiana; (modified from Frezon et al., 1988; Ewing, 1991a; Ewing and Lopez, 1991; Salvador, 1991; and Warwick et al., 2007a).

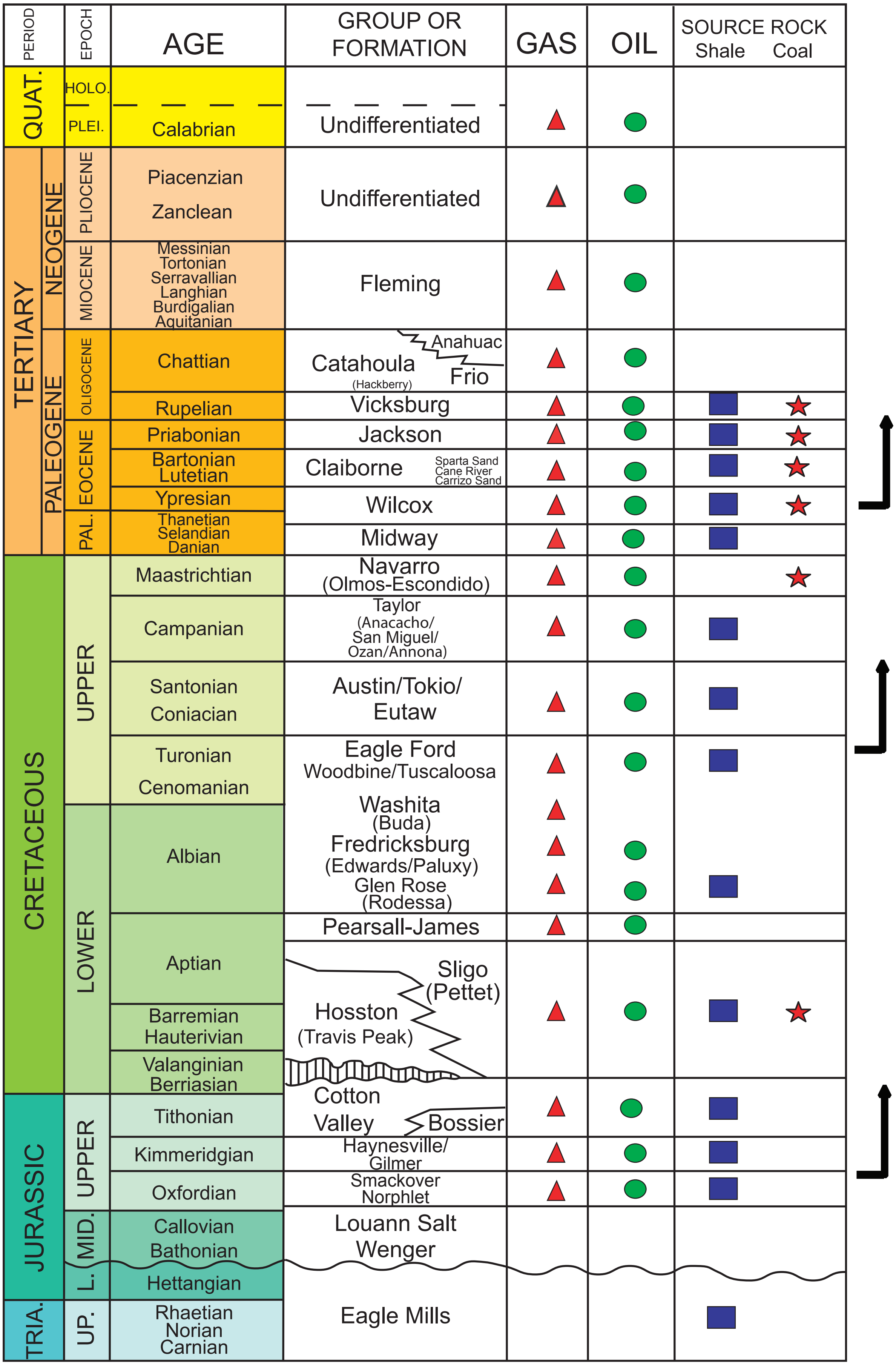
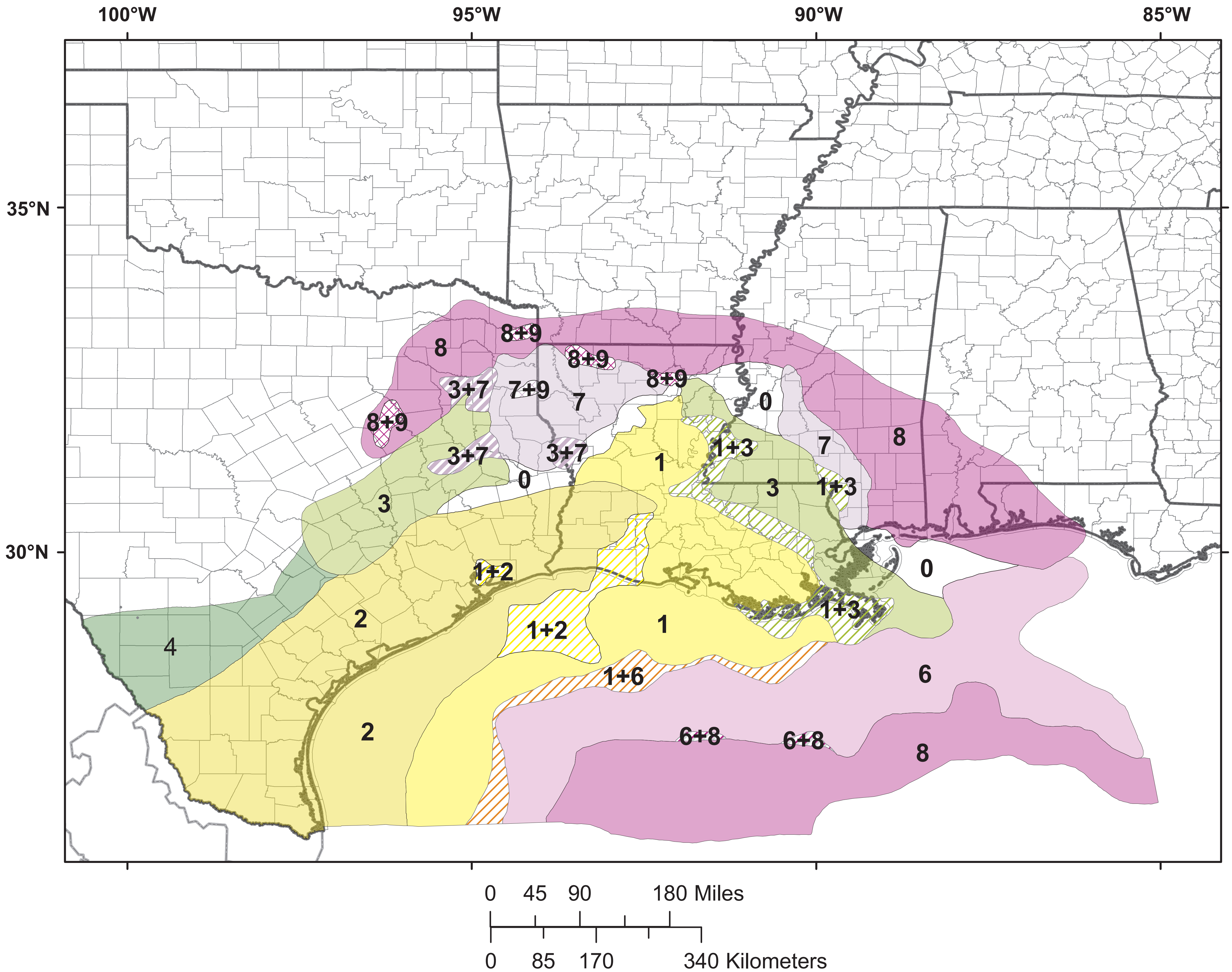


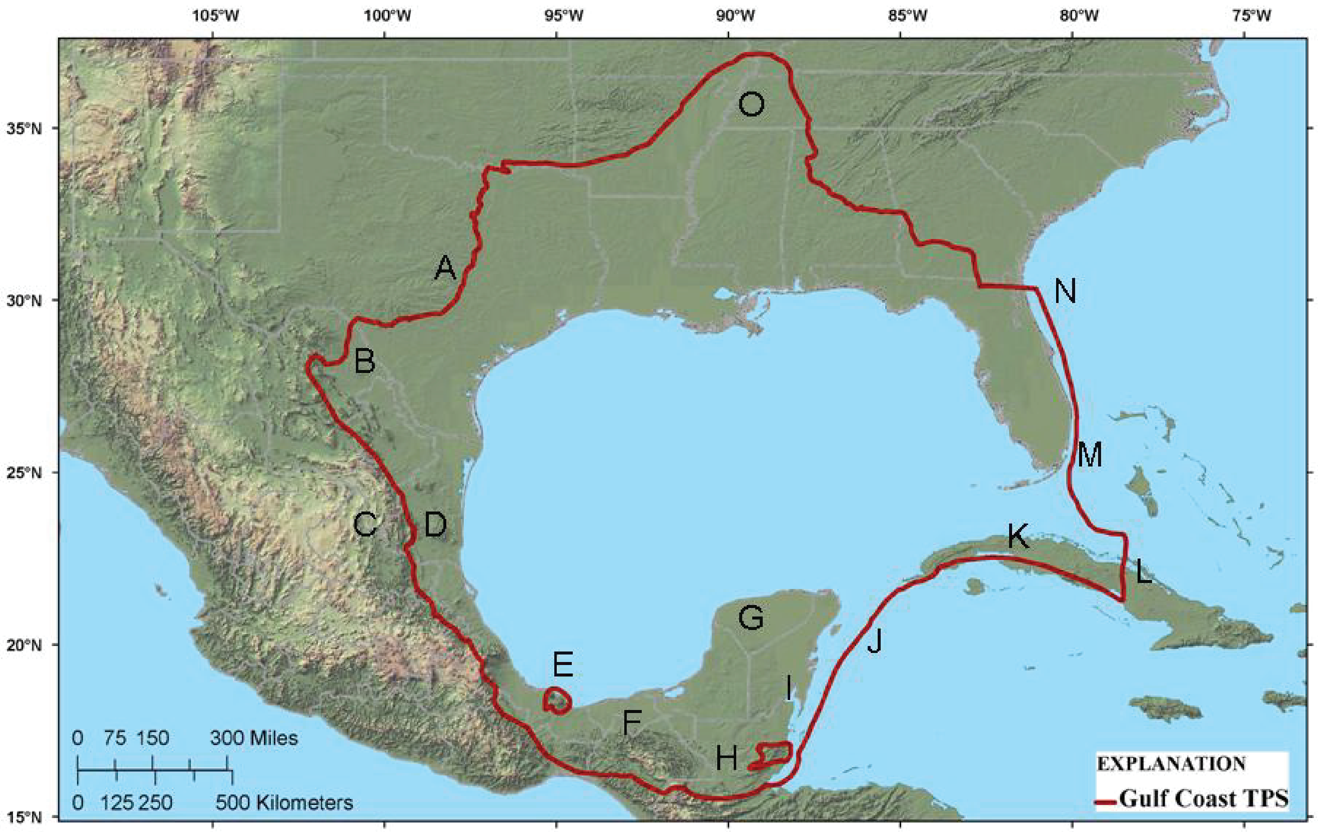
Figure 4. Generalized stratigraphic section of the northern Gulf of Mexico coastal plain showing gas (triangles) and oil (circles) occurrences and potential source rocks (boxes and stars). Arrows along the right side indicate major source rock intervals. L. = Lower; Mid. = Middle; Up. = Upper; Tria. = Triassic; Pal. = Paleocene; Plei. = Pleistocene; Holo. = Holocene; Quat. = Quaternary; vertical lines = unconformity; wavy line = disconformity; jagged line = interfingering; dashed line = uncertain (modified after Salvador and Quezada Muñeton, 1991; Nehring, 1991; Palmer and Geissman, 1999; Humble Geochemical Services et al., 2002; and Warwick et al., 2007a).



EXPLANATION
(SOURCE ROCK AGE, DEPOSITIONAL ENVIRONMENT, AND SULFUR CONTENT)

- 0 = Not designated
- 1 = Lower Tertiary (centered on Eocene) marine and intermediate
- 1+2 = Lower Tertiary (centered on Eocene) terrestrial
- 1+3 = Lower Tertiary (centered on Eocene) marine and intermediate Upper Cretaceous (centered on Turonian) marine-low sulfur
- 1+6 = Lower Tertiary (centered on Eocene) marine and intermediate uppermost Jurassic (centered on Tithonian) marine-moderate to high sulfur
- 2 = Lower Tertiary (centered on Eocene) terrestrial
- 3 = Upper Cretaceous (centered on Turonian) marine-low sulpur
- 3+7 = Upper Cretaceous (centered on Turonian) marine-low sulfur Upper Jurassic or Lower Cretaceous? marine
- 4 = Upper Cretaceous (centered on Turonian) and Lower Cretaceous (centered on Aptian) calcareous-moderate sulpur
- 6 = Uppermost Jurassic (centered on Tithonian) marine-moderate to high sulpur
- 6+8 = Uppermost Jurassic (centered on Tithonian) Marine-Moderate to high sulfur Upper Jurassic (Oxfordian) carbonate-elevated salinity
- 7 = Upper Jurassic or Lower Cretaceous? marine
- 7+9 = Upper Jurassic or Lower Cretaceous? marine Triassic (Eagle Mills) lacustrine
- 8 = Upper Jurassic (Oxfordian) carbonate-elevated salinity
- 8+9 = Upper Jurassic (Oxfordian) carbonate-elevated salinity Triassic (Eagle Mills) lacustrine

Figure 5. Interpreted petroleum systems map of the northern Gulf of Mexico region. "Intermediate" denotes depositional environments that are intermediate between marine and terrestrial (after Wenger et al., 1994; Hood et al., 2002; and Warwick et al., 2007a).



The boundary line:
A) coincides with the Upper-Lower Cretaceous outcrop boundary (Schruben et al., 1998); this line may be somewhat arbitrary as the area may include some Interior Platform Paleozoic-derived oil that has migrated into Cretaceous reservoirs and is not part of the Gulf of Mexico TPS;
B) includes both Maverick and Sabinas basins, which have Gulf of Mexico basin source and reservoir rock (Eguiluz de Antuñano, 2001; Scott, 2003);
C) excludes Sierra Madre Oriental, which has stratigraphic equivalents to Gulf of Mexico basin source and reservoir rocks, but probably has experienced too much structural deformation and erosion to retain any significant hydrocarbon volumes (see Ewing, 1991a,b);
D) includes the Magiscatzin basin, which has production from units of the main Tampico-Misantla basin, and contains similar strata and structural styles as found in the Gulf of Mexico basin (Nehring, 1991; USGS World Energy Assessment Team, 2000);
E) excludes Tuxla Uplift, an Upper Cenozoic volcanic area (see Ewing, 1991a);
F) includes the Pimienta-Tamabra TPS (USGS World Energy Assessment Team, 2000);
G) includes north Yucatan, because hydrocarbons are present in Chicxulub Crater cores (Lüders et al., 2003);
H) excludes the Maya Mountains, a metamorphic orogenic complex (Ewing, 1991a; Ewing and Lopez, 1991).
I) includes the south Yucatan because of the occurrence of isolated oil and gas production and shows (Rosenfeld, 2003);
J) line drawn along major sea-floor crustal structural boundary between oceanic crust in the Yucatan basin and back-arc Cuban basins and ocean crust of the Greater Antilles Deformed Belt (Ewing, 1991a; Rodriguez et al., 1995; James, 2004; and Schenk et al., 2005);
K) includes north Cuba, where there are the same source rocks as in South Florida and the deep-water Gulf of Mexico (Schenk et al., 2000; French and Schenk, 2004);
L) follows an arbitrary limit to the TPS in the Gulf of Mexico basin;
M) follows an arbitrary line drawn to separate the Bahamas from the Florida Platform (Ewing, 1991a);
N) follows the Smackover-Austin-Eagle Ford TPS boundary of Condon and Dyman (2006); however, the potential occurrence of source rocks and hydrocarbons in this area is highly speculative.
O) Mississippi Embayment - includes Tertiary and Cretaceous coal beds as potential sources of biogenic gas, although there is no known hydrocarbon production from this area. The TPS outline is also based on data from French and Schenk (2005).

Figure 6. Upper Jurassic-Cretaceous-Tertiary Composite Total Petroleum System (TPS) for the Gulf of Mexico basin. The letters on this Figure (A-O) refer to the notes above on how the TPS boundary was drawn. From Warwick et al. (2007a).

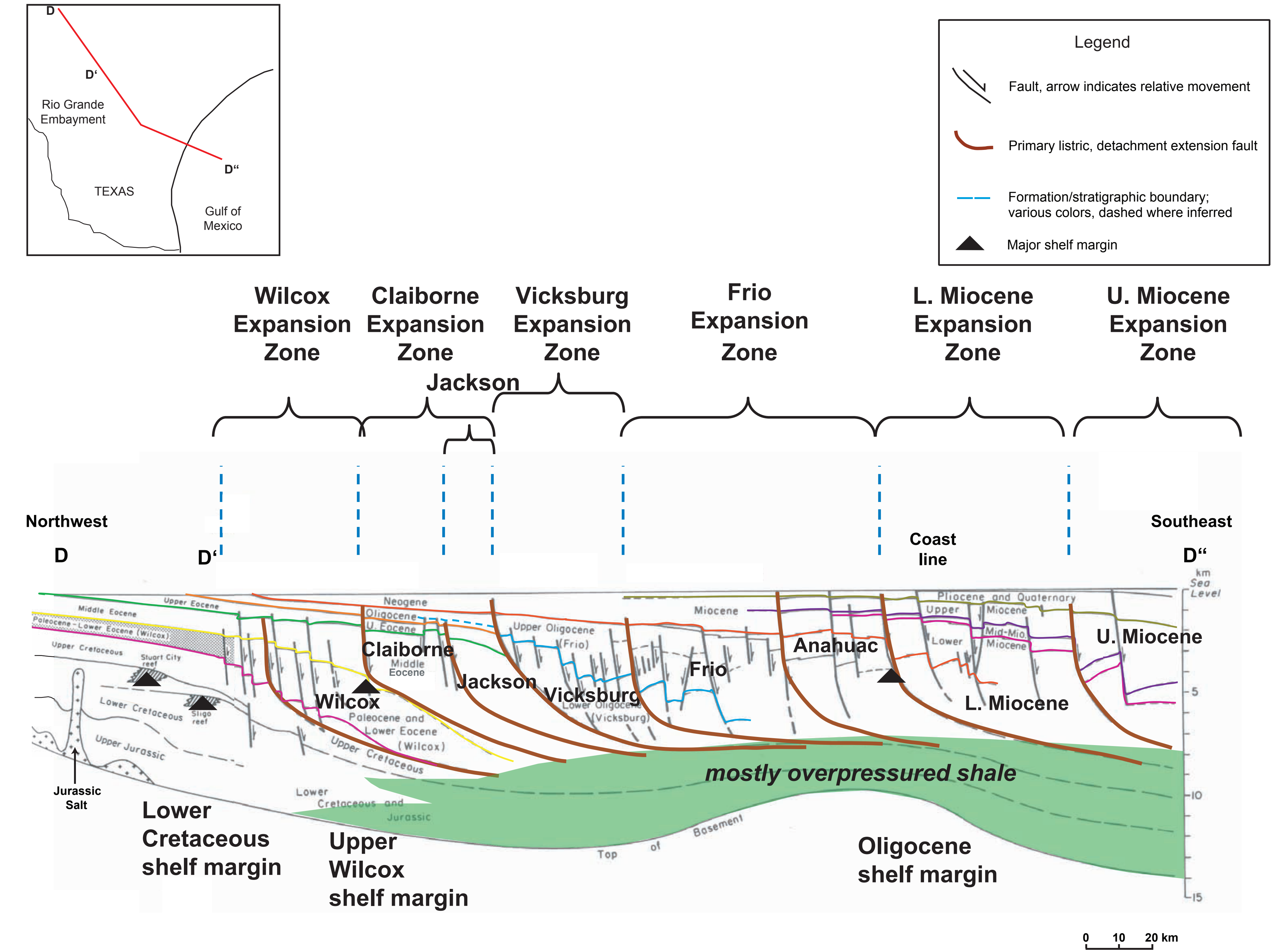


Figure 7. Generalized cross section showing Tertiary expansion zones across the south Texas Gulf of Mexico Coastal Plain (modified from Ewing, 1991b; and Warwick et al., 2007a). L. = Lower; U. = Upper; Mid. = Middle; Mio. = Miocene.

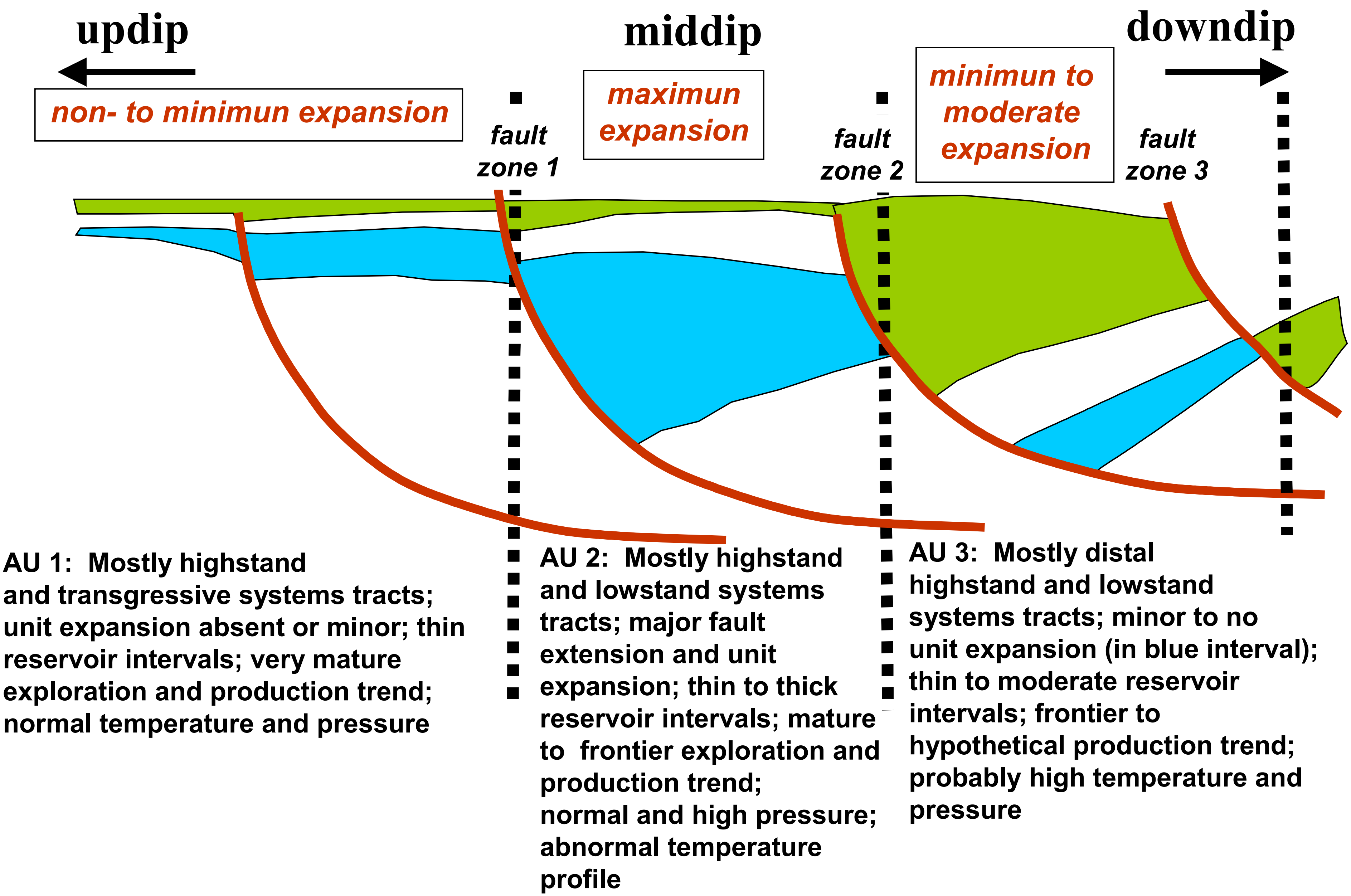


Figure 8. Model used to define assessment units in the USGS assessment of Tertiary strata in Gulf of Mexico onshore and State water areas. For the Blue Stratigraphic Unit, Assessment Unit (AU) 1 is the stable shelf structural area; AU 2 defines the main unit expansion and thickening zone; and AU 3 comprises sediments deposited in slope and basin floor depositional environments. After Warwick et al. (2007a).

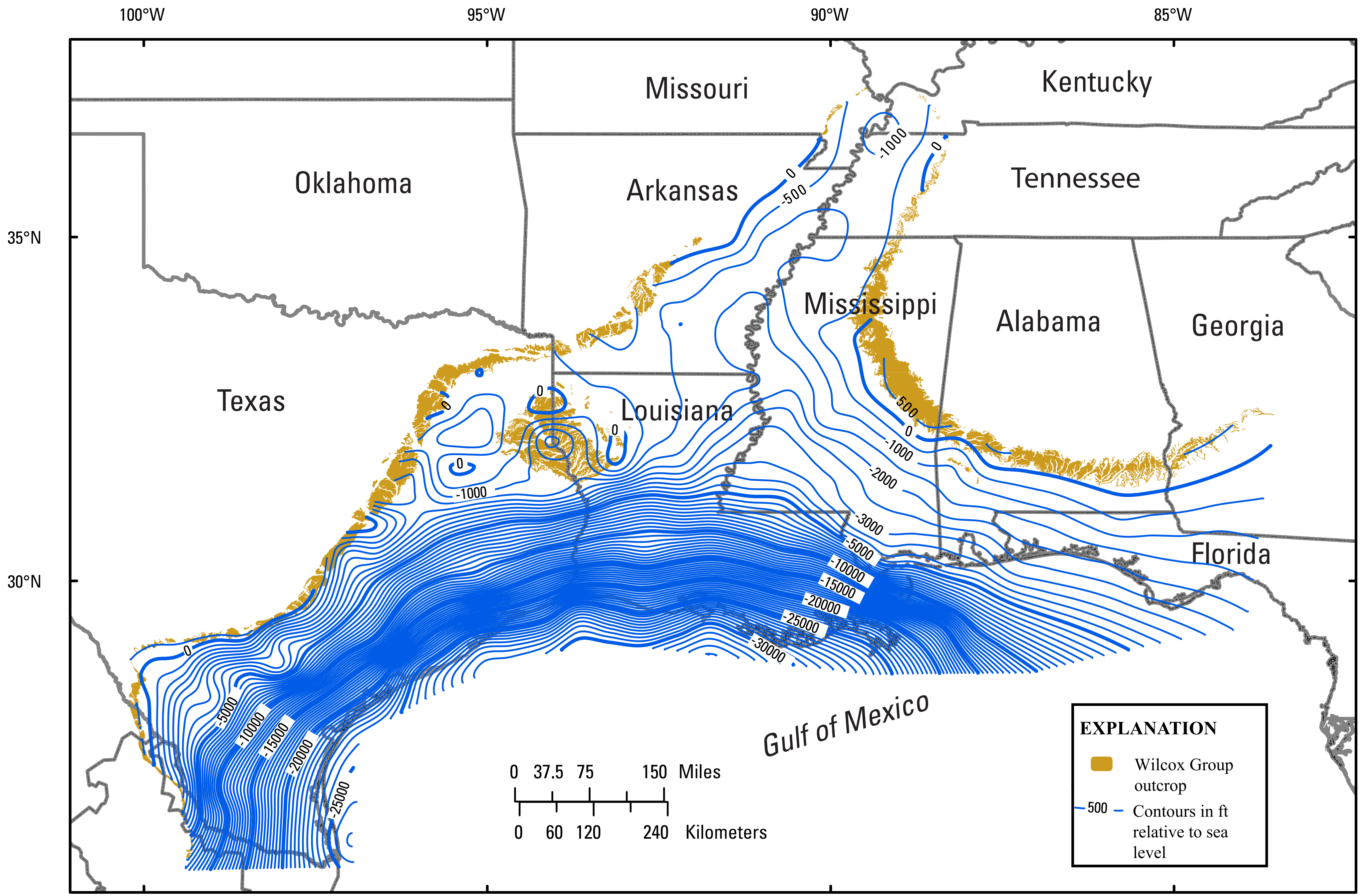


Figure 9. Structure contour map for the top of the Wilcox Group. The map is based on more than 42,000 wells with Wilcox Group top picks in the IHS data base (IHS Energy Group, 2005). Structure contours have been extended to the coastal areas by using control points based on Wilcox top depths from regional cross sections and seismic lines (Ewing, 1991a; Salvador and and Quezada Muneton, 1991). The contours have been smoothed to remove the effect of uplifts associated with salt structures.

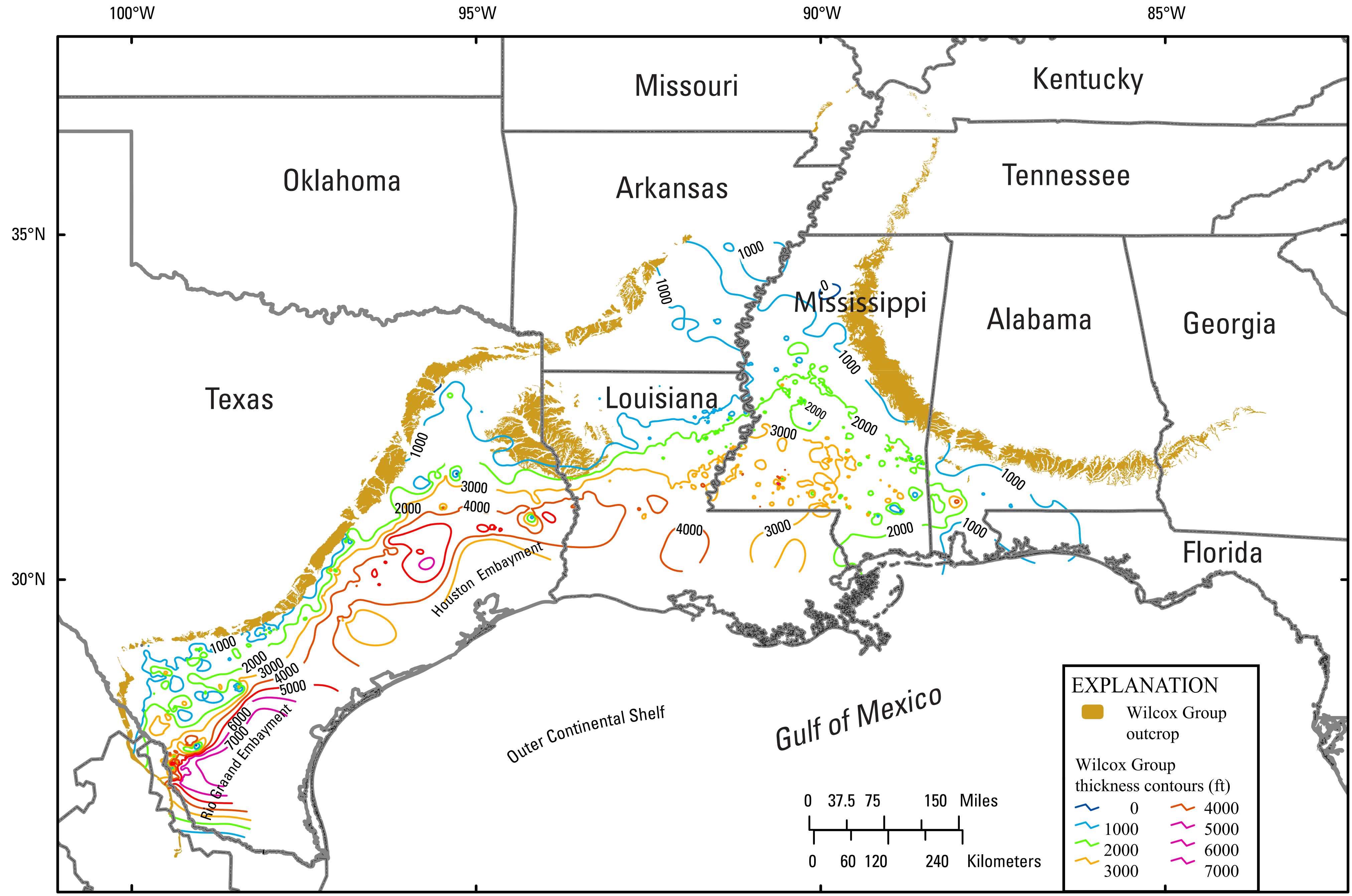


Figure 10. Generalized Wilcox Group thickness map (modified from Barker et al., 2000).

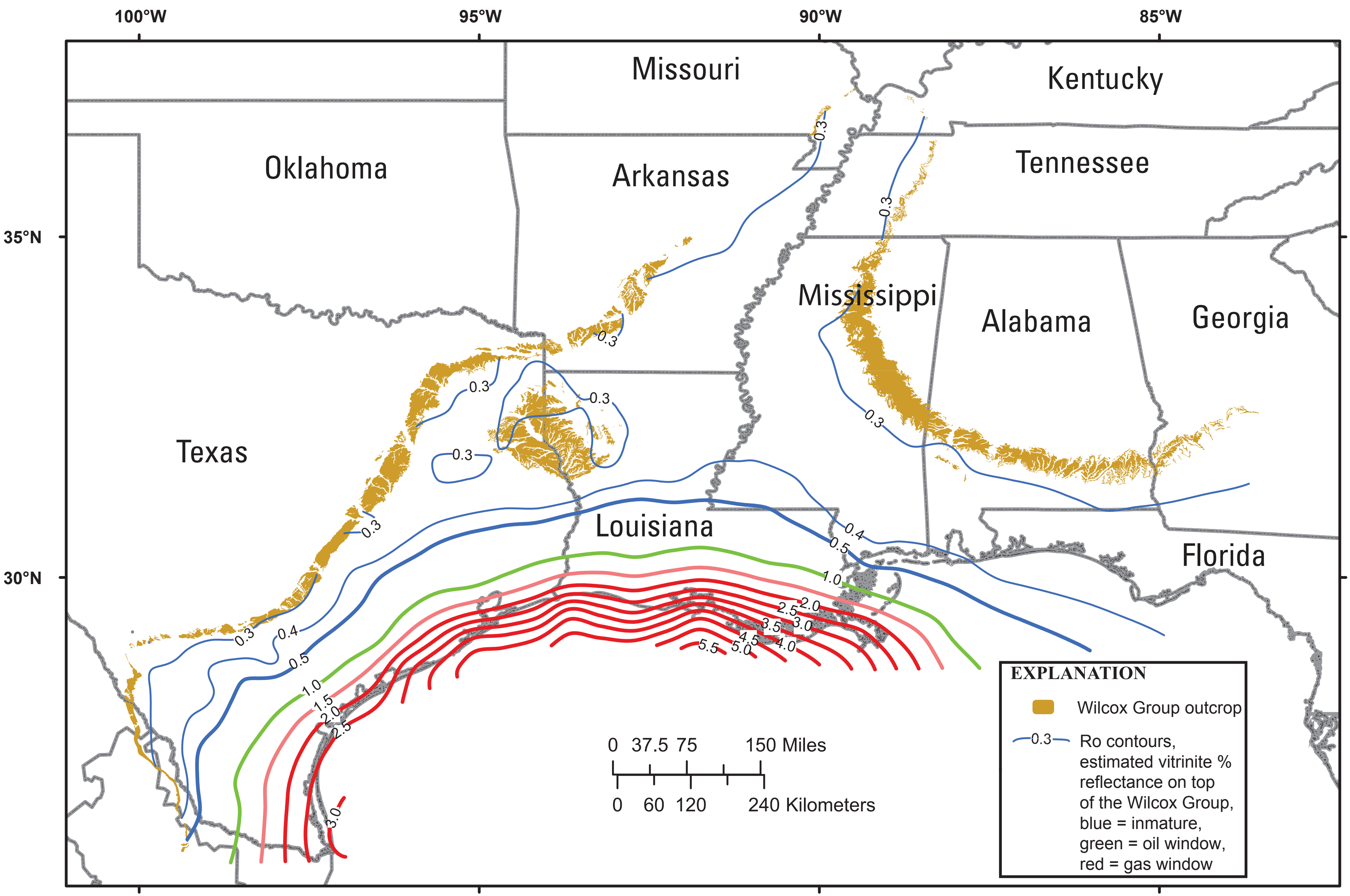


Figure 11. Modeled thermal maturity (%Ro, vitrinite refectance) for the top of the Wilcox Group. Ro was calculated using the Wilcox surface elevation (Fig. 9) and more than 450 values of unpublished USGS Wilcox %Ro. Wilcox vitrinite reflectance values range from about 0.3 %Ro up-dip, near the outcrop to more than 2.4 %Ro at depths greater than 24,000 ft in south Texas (after Warwick, 2006).

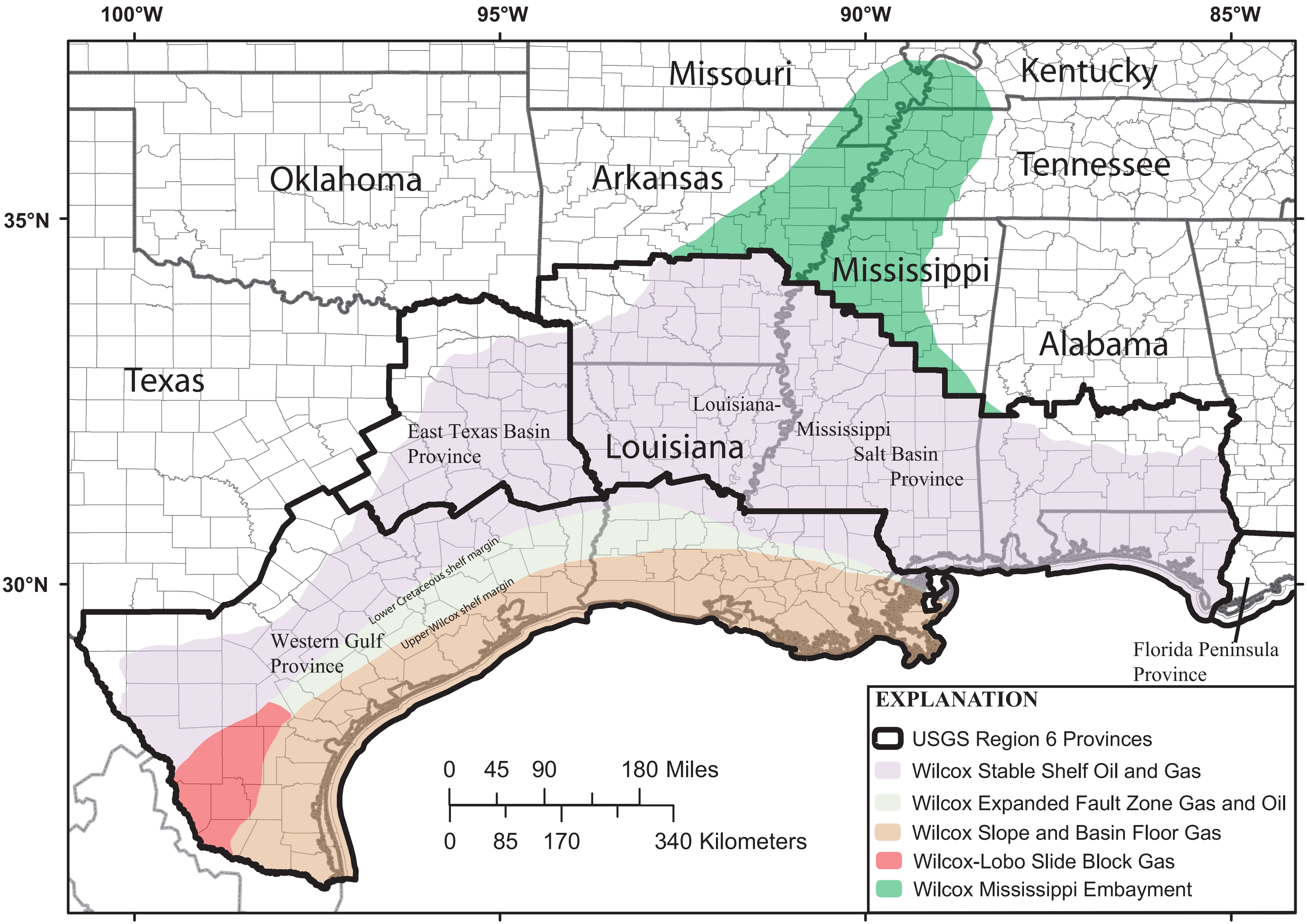


Figure 12. Assessment Unit boundaries for the Midway-Wilcox-Carrizo (Paleocene-Eocene) stratigraphic intervals (see Fig. 4). The USGS Region 6 Province boundaries (heavy black lines) are from the USGS National Oil and Gas Resource Assessment Team (1995).

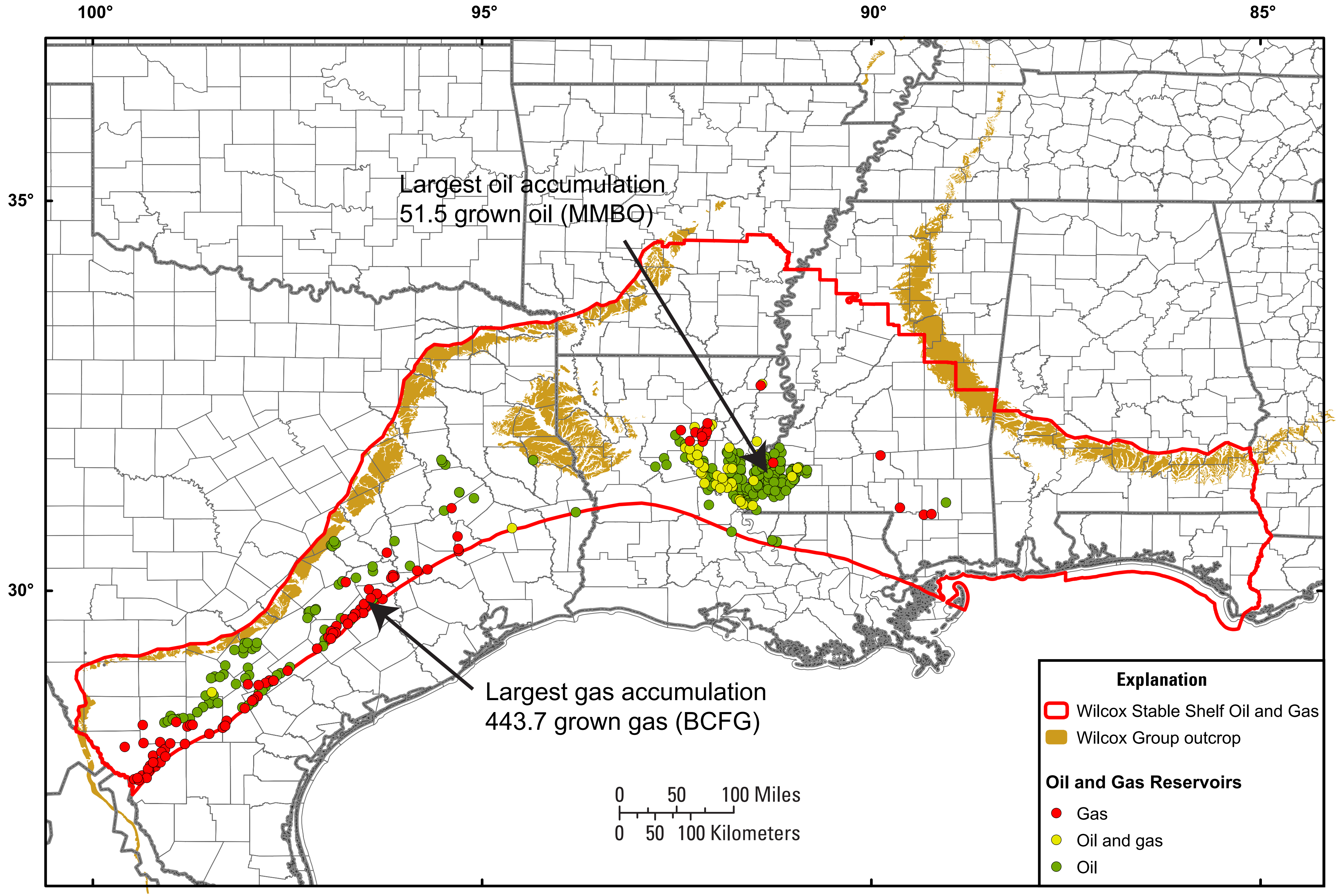


Figure 13. Wilcox Stable Shelf AU, showing oil and gas fields. Largest oil and gas accumulations are shown. Data from Warwick et al. (1997); Nehring Associates, Inc. (2006); Warwick et al. (2007a); and T.R. Klett, USGS, written personal communication (2006).

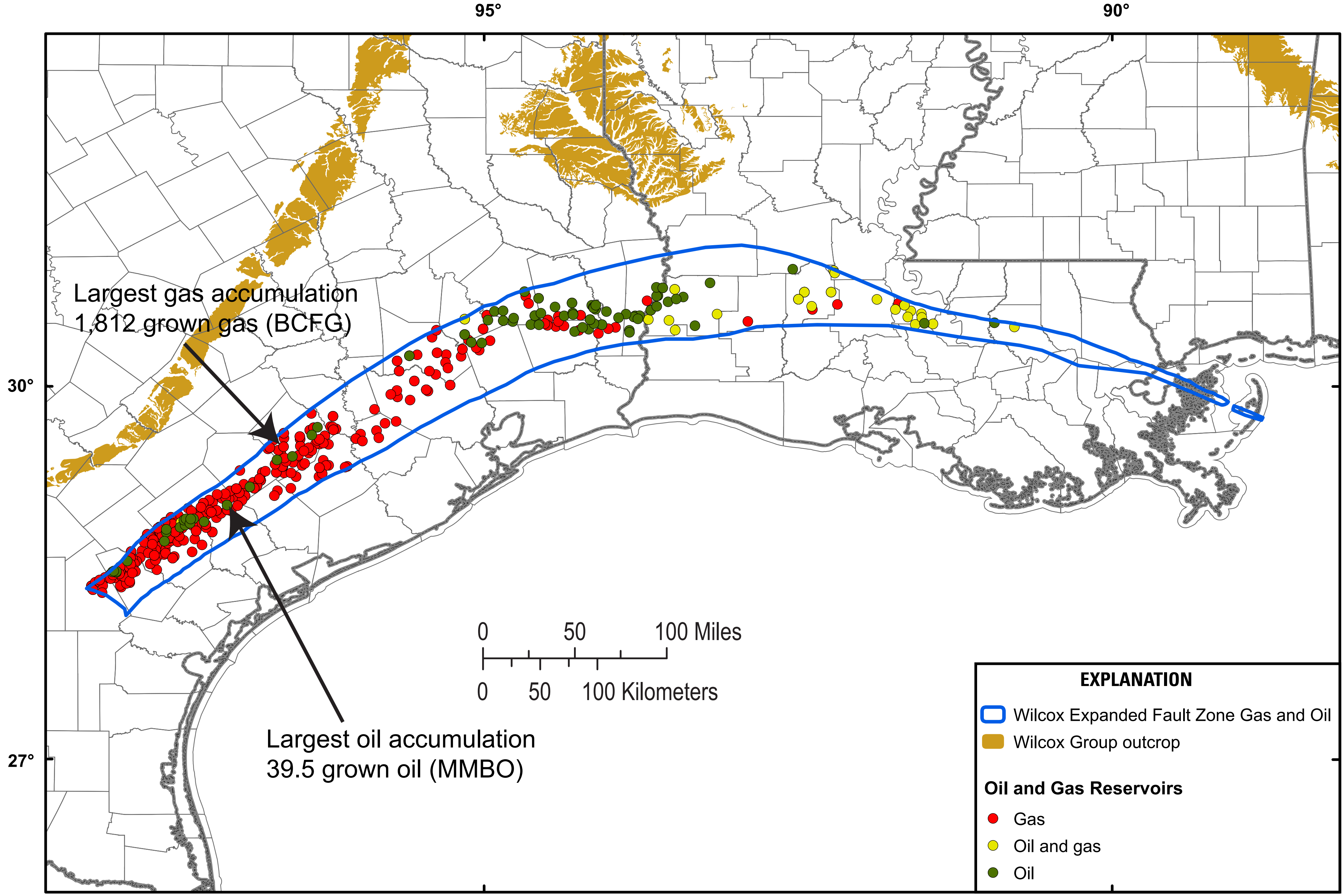


Figure 14. Wilcox Expanded Fault Zone AU, showing oil and gas fields. Largest oil and gas accumulations are shown. Data from Warwick et al. (1997); Nehring Associates, Inc. (2006); Warwick et al. (2007a); and T.R. Klett, USGS, written personal communication (2006).

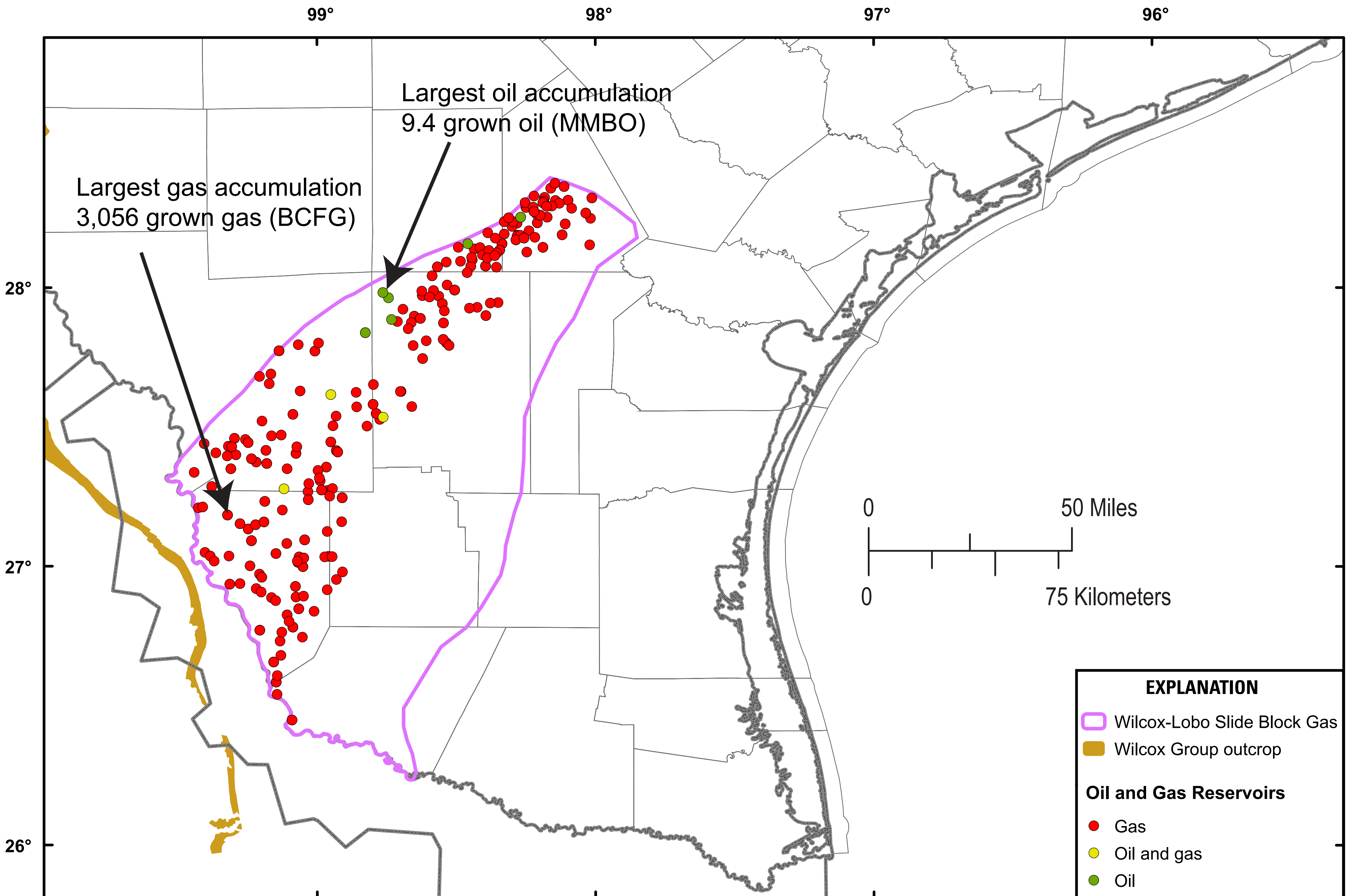


Figure 15. Wilcox-Lobo Slide Block Gas AU, showing oil and gas fields. Largest oil and gas accumulations are shown. Data from Warwick et al. (1997); Nehring Associates, Inc. (2006); Warwick et al. (2007a); and T.R. Klett, USGS, written personal communication (2006).

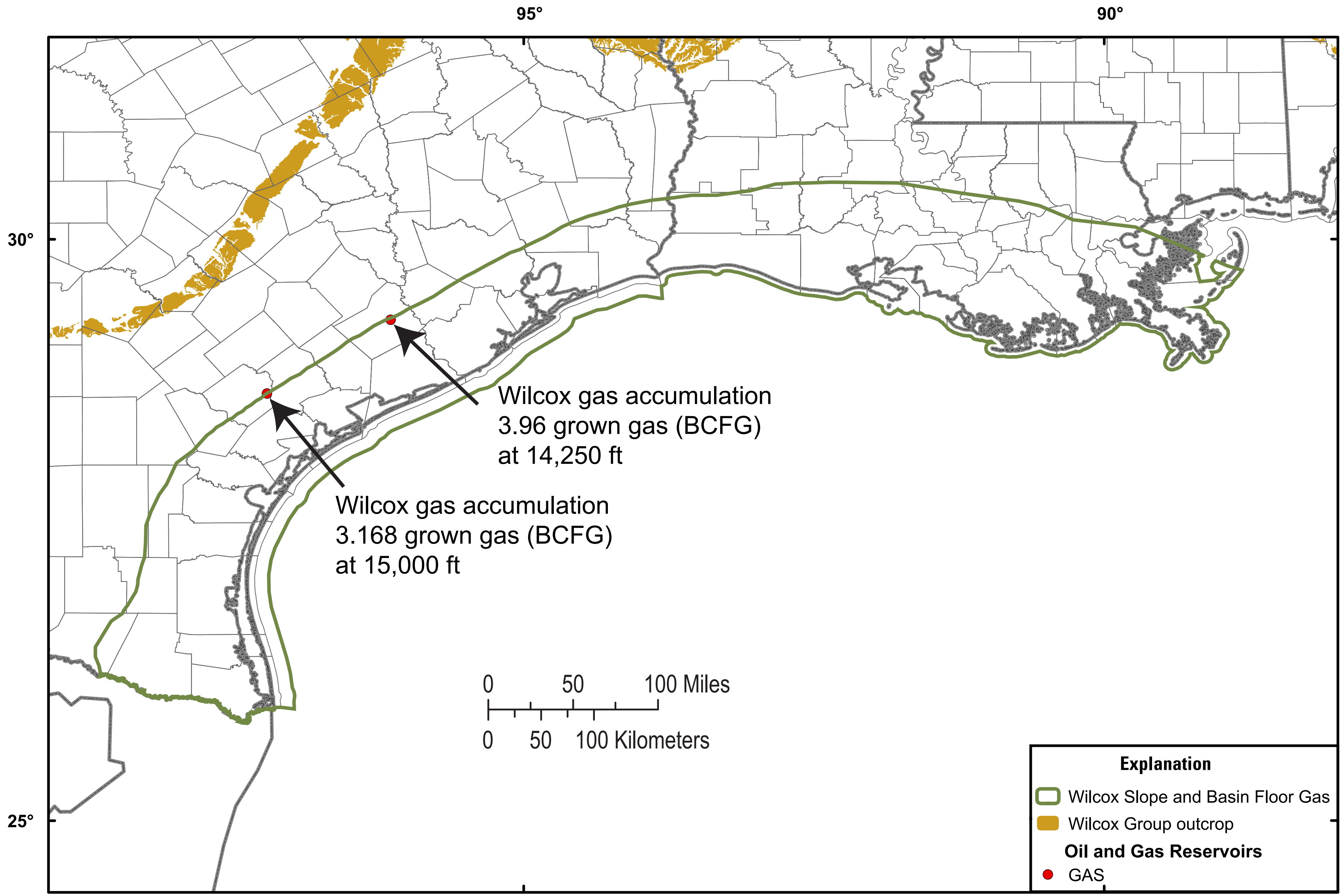
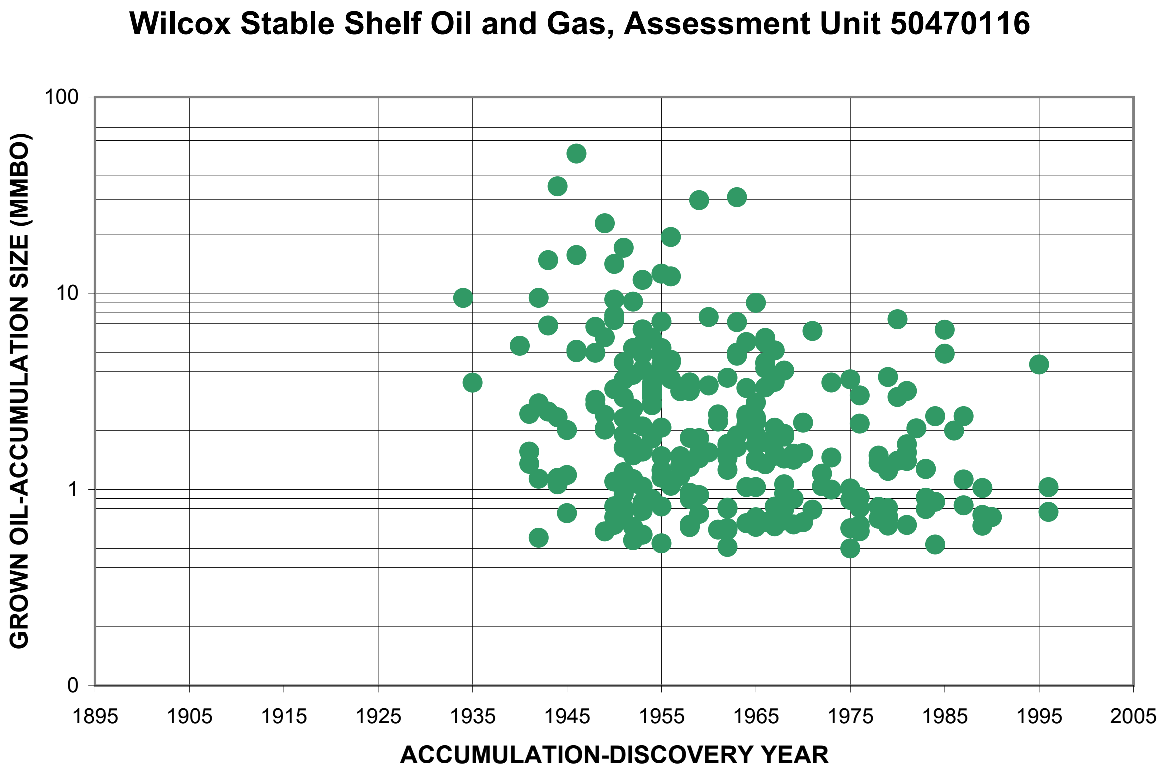


Figure 16. Wilcox Slope and Basin Floor Gas AU, showing gas fields. Largest gas accumulations are shown. Data from Warwick et al. (1997); Nehring Associates, Inc. (2006); Warwick et al. (2007a); and T.R. Klett, USGS, written personal communication (2006).



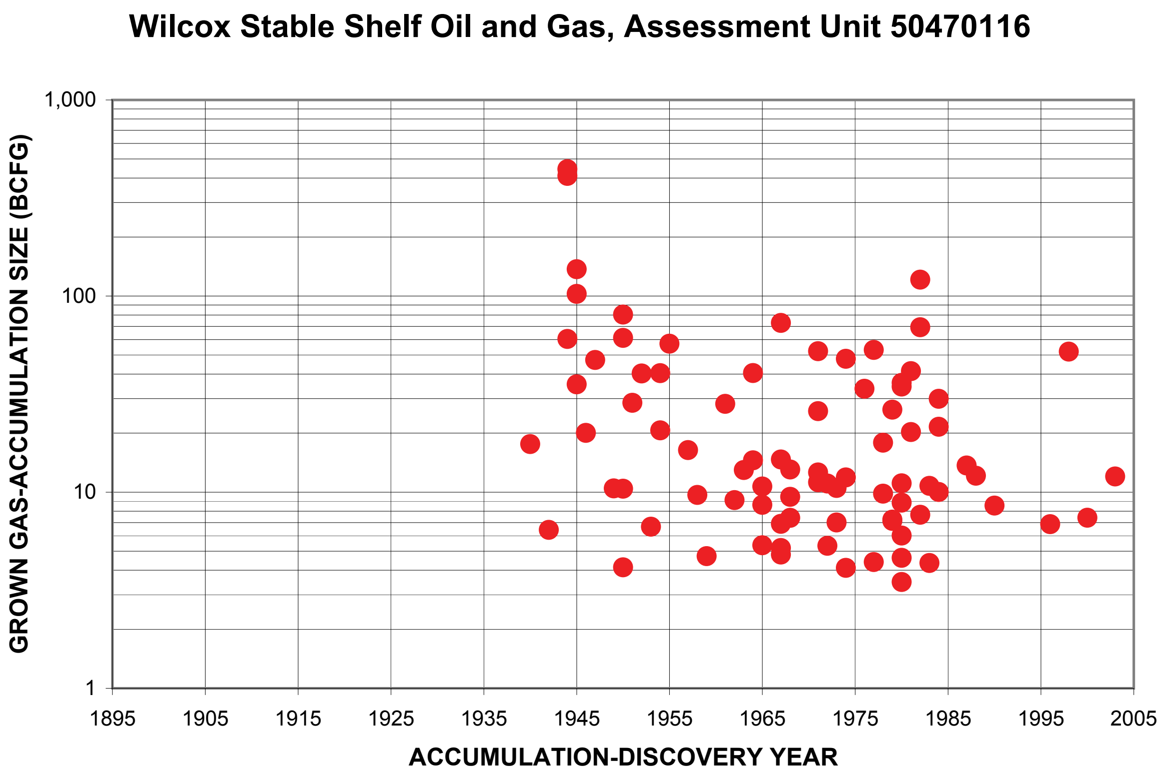
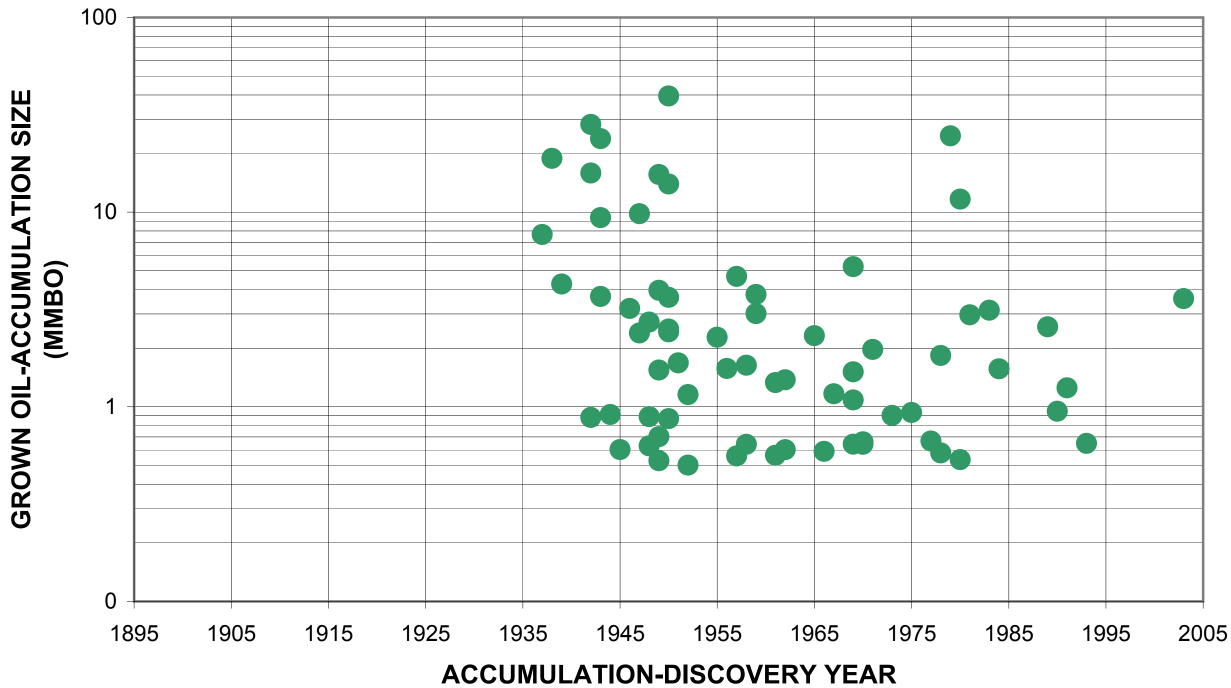


Figure 17. Plots showing size of grown oil and gas accumulations (fields) relative to the discovery year for the Wilcox Stable Shelf Oil and Gas Assessment Unit 50470116. Data from Nehring Associates, Inc. (2006); and T.R. Klett, USGS, written personal communication (2006).

Wilcox Expanded Fault Zone Gas and Oil, Assessment Unit 50470117



Wilcox Expanded Fault Zone Gas and Oil, Assessment Unit 50470117

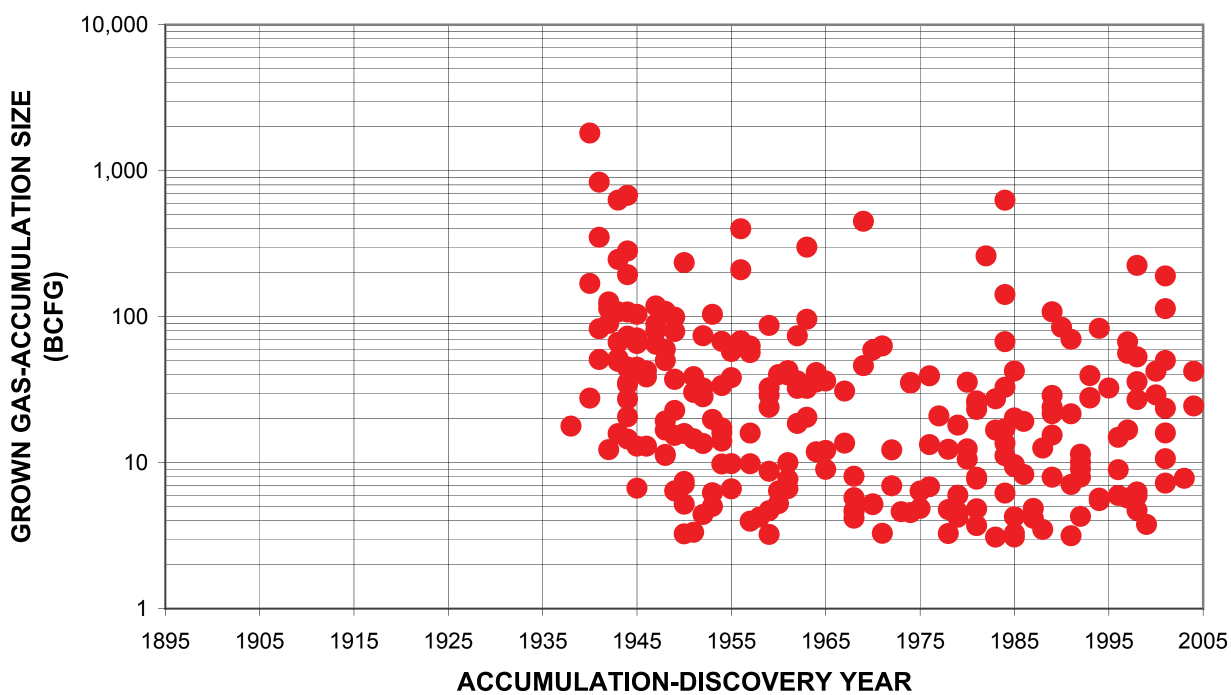
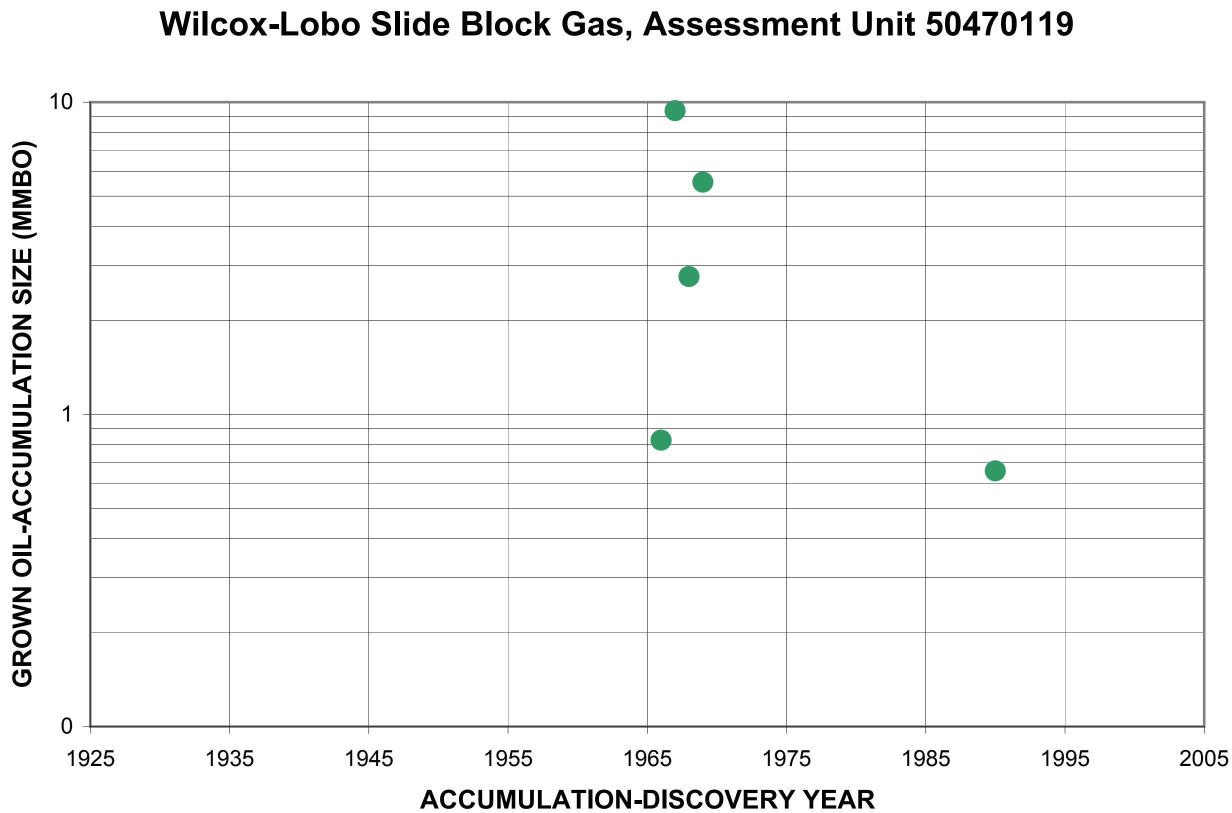


Figure 18. Plots showing size of grown oil and gas accumulations (fields) relative to the discovery year for the Wilcox Expanded Fault Zone Gas and Oil Assessment Unit 50470117. Data from Nehring Associates, Inc. (2006); and T.R. Klett, USGS, written personal communication (2006).



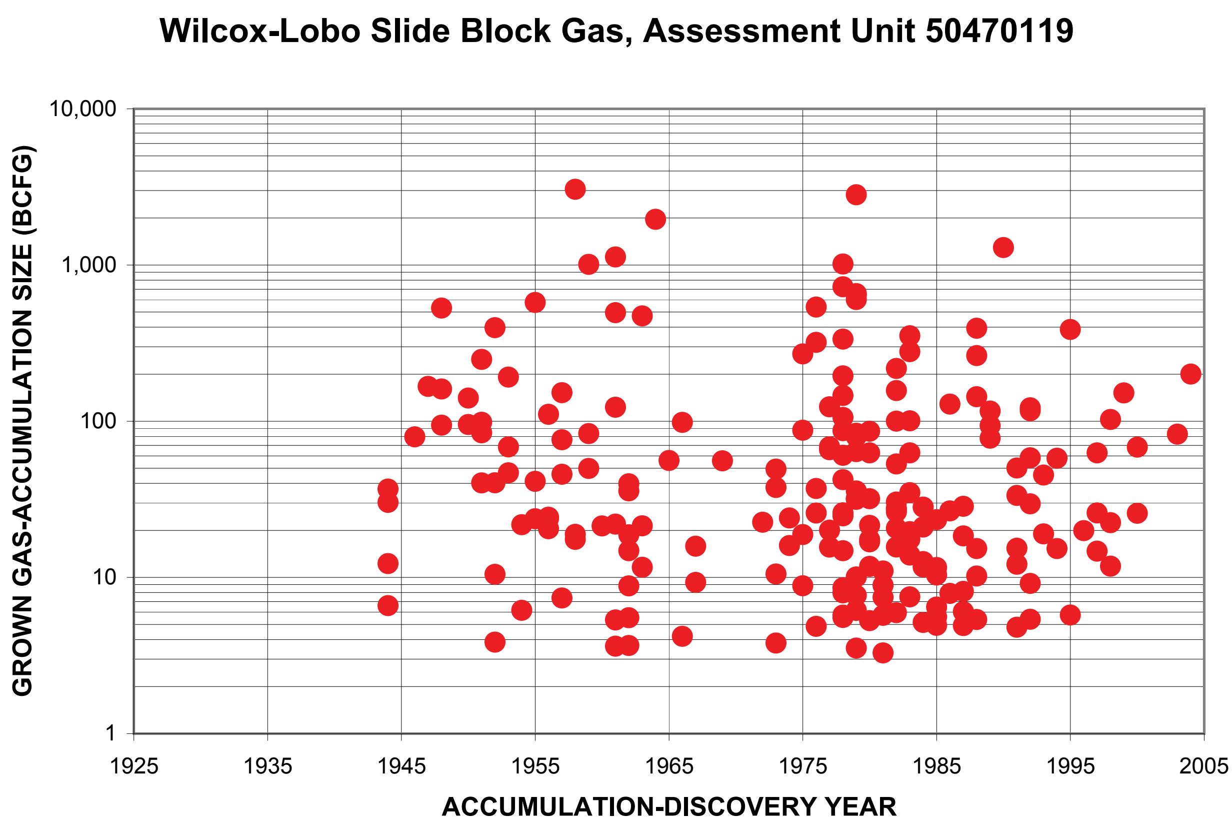


Figure 19. Plots showing size of grown oil and gas accumulations (fields) relative to the discovery year for the Wilcox-Lobo Slide Block Gas Assessment Unit 50470119. Data from Nehring Associates, Inc. (2006); and T.R. Klett, USGS, written personal communication (2006).

Conventional Oil and Gas Resources

Gulf Coast assessment results.

[MMBO, million barrels of oil. BCFG, billion cubic feet of gas. MMBNGL, million barrels of natural gas liquids. Results shown are fully risked estimates. For gas accumulations, all liquids are included as NGL (natural gas liquids). F95 represents a 95 percent chance of at least the amount tabulated; other fractiles are defined similarly. Fractiles are additive under the assumption of perfect positive correlation. TPS, total petroleum system; AU, assessment unit. Gray shading indicates not applicable]

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)													
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**

Figure 20. Assessment results for the Lower Paleogene Midway and Wilcox Groups, and the Carrizo Sand, Claiborne Group. Adapted from Dubiel et al. (2007).

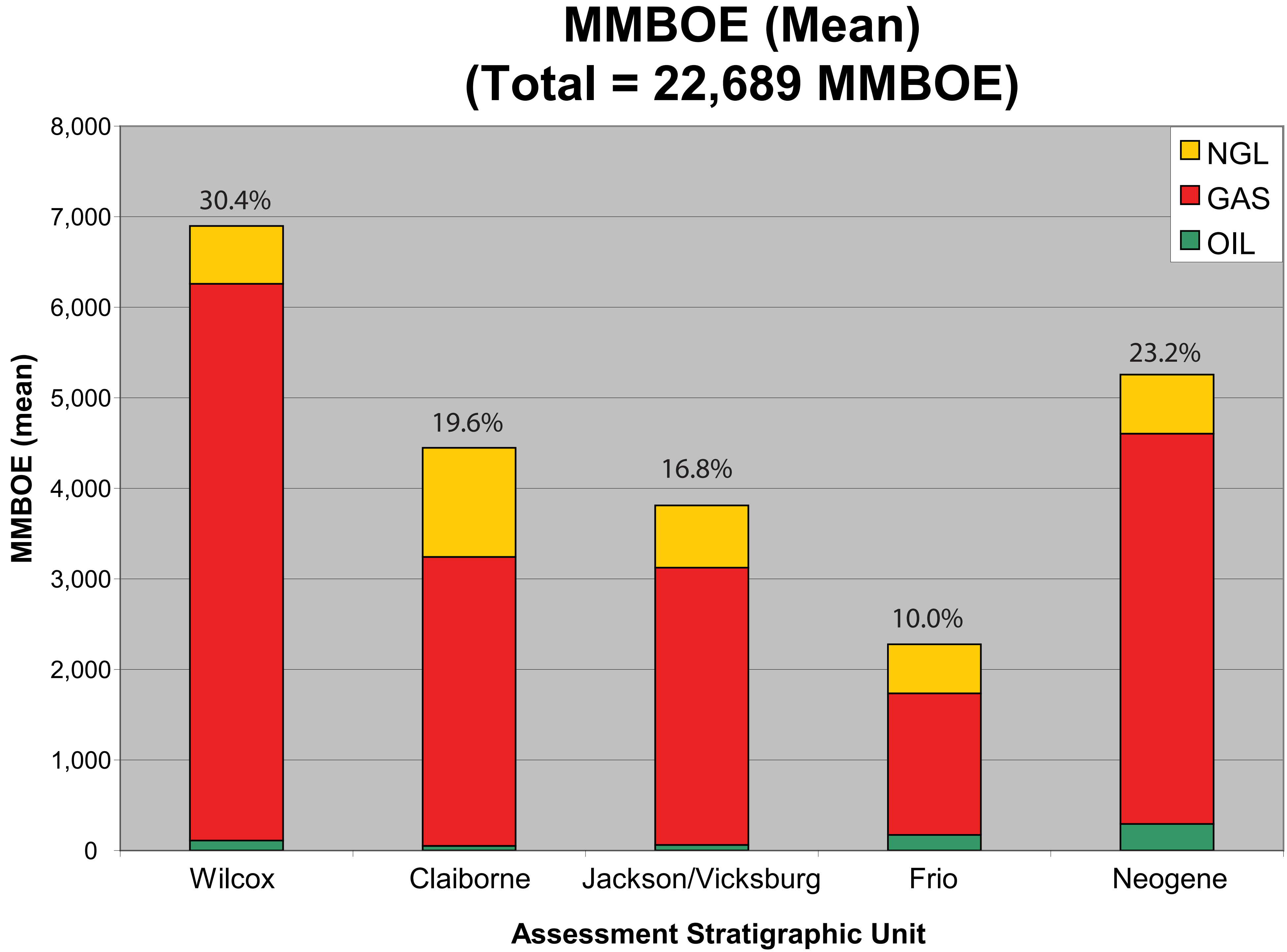


Figure 21. USGS Gulf Coast assessment results for undiscovered, technically recoverable oil, gas and NGL (natural gas liquids). MMBOE = million barrels of oil equivalent. Percentages of the total 22,689 MMBOE by major assessment intervals are shown. Adapted from Dubiel et al. (2007).

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