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"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"

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Abstract

The principal research effort for Year 2 of the project has been petroleum system characterization and modeling. Understanding the burial, thermal maturation, and hydrocarbon expulsion histories of the strata in the onshore interior salt basins of the North Central and Northeastern Gulf of Mexico areas is important in hydrocarbon resource assessment. The underburden and overburden rocks in these basins and subbasins are a product of their rift-related geohistory. Petroleum source rock analysis and initial thermal maturation and hydrocarbon expulsion modeling indicated that an effective regional petroleum source rock in the onshore interior salt basins and subbasins, the North Louisiana Salt Basin, Mississippi Interior Salt Basin, Manila Subbasin and Conecuh Subbasin, was Upper Jurassic Smackover lime mudstone. The initial modeling also indicated that hydrocarbon generation and expulsion were initiated in the Early Cretaceous and continued into the Tertiary in the North Louisiana Salt Basin and the Mississippi Interior Salt Basin and that hydrocarbon generation and expulsion were initiated in the Late Cretaceous and continued into the Tertiary in the Manila Subbasin and Conecuh Subbasin. Refined thermal maturation and hydrocarbon expulsion modeling and additional petroleum source rock analysis have confirmed that the major source rock in the onshore interior salt basins and subbasins is Upper Jurassic Smackover lime mudstone. Hydrocarbon generation and expulsion wee initiated in the Early to Late Cretaceous and continued into the Tertiary.

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“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”

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April 1, 2005—September 30, 2005

Introduction

The University of Alabama and Louisiana State University have undertaken a cooperative 3-year, advanced subsurface methodology resource assessment project, involving petroleum system identification, characterization and modeling, to facilitate exploration for a potential major source of natural gas that is deeply buried (below 15,000 ft) in the onshore interior salt basins of the North Central and Northeastern Gulf of Mexico areas. The project is designed to assist in the formulation of advanced exploration strategies for finding and maximizing the recovery from deep natural gas domestic resources at reduced costs and risks and with minimum impact.

The results of the project should serve to enhance exploration efforts by domestic companies in their search for new petroleum resources; especially those deeply buried (below 15,000 ft) natural gas resources, and should support the domestic industry’s endeavor to provide an increase in reliable and affordable supplies of fossil fuels.

Executive Summary

The principal research effort for Year 2 of the project has been petroleum system characterization and modeling. Understanding the burial and thermal maturation histories of the strata in the onshore interior salt basins and subbasins of the North Central and Northeastern Gulf of Mexico areas is critical in hydrocarbon resource assessment. The underburden and overburden rocks in these basins and subbasins are a product of their rift-related geohistory.

Petroleum source rock analysis and thermal maturation and hydrocarbon expulsion modeling have shown that the Upper Jurassic Smackover Formation served as an effective regional petroleum source rock in the North Louisiana Salt Basin, Mississippi Interior Salt Basin, Manila Subbasin and Conecuh Subbasin. Also, previous studies have indicated that Upper Cretaceous Tuscaloosa shale was an effective local petroleum source rock in the Mississippi Interior Salt Basin and a possible local source bed in the North Louisiana Salt Basin given the proper organic facies; that Lower Cretaceous lime mudstone was an effective local petroleum source rock in the South Florida Basin, and a possible local source bed in the North Louisiana Salt Basin and Mississippi Interior Salt Basin given the proper organic facies; that uppermost Jurassic strata were effective petroleum source rocks in Mexico and were possible local source beds in the North Louisiana Salt Basin given the proper organic facies; and that lower Tertiary shale and lignite were petroleum source rocks in south Louisiana and southwestern Mississippi. These lower Tertiary beds have not been subjected to favorable burial and thermal maturation histories required for petroleum generation in the North Louisiana Salt Basin, Mississippi Interior Salt Basin, Manila Subbasin and Conecuh Subbasin.

Petroleum reservoir rocks in the North Louisiana Salt Basin, Mississippi Interior Salt Basin, Manila Subbasin and Conecuh Subbasin include Jurassic, Cretaceous and Tertiary siliciclastic and carbonate strata. These reservoir rocks include Upper Jurassic Norphlet, Smackover, Haynesville, and Cotton Valley units, Lower Cretaceous Hosston, Sligo, James, Rodessa, Mooringsport, Paluxy, and Fredericksburg-Washita units, the Upper Cretaceous Tuscaloosa, Eutaw-Austin, Selma-Taylor/Navarro, and Jackson gas rock-Monroe gas rock units, and the Lower Tertiary Wilcox unit.

Petroleum seal rocks in these basins and subbasins include Upper Jurassic Smackover lime mudstone, Buckner anhydrite, Haynesville shale, and Cotton Valley shale beds, Lower

Cretaceous Pine Island shale, Ferry Lake anhydrite, Mooringsport shale, and Fredericksburg-Washita shale beds, Upper Cretaceous Tuscaloosa shale, Eagle Ford shale, and Selma Chalk beds, and Lower Tertiary Midway shale beds.

Petroleum traps include structural and combination traps in these basins and subbasins. Halokinesis is the principal process that formed these traps producing a complex array of salt structures. These structures include peripheral salt ridges, low relief salt pillows, salt anticlines and turtle structures, and piercement domes. Structures associated with basement paleotopographic highs are also present.

Project Objectives

The objectives of the study are: to perform resource assessment of the in-place deep (>15,000 ft) natural gas resource of the onshore interior salt basins of the North Central and Northeastern Gulf of Mexico areas through petroleum system identification, characterization and modeling and to use the petroleum system based resource assessment to estimate the volume of the in-place deep gas resource that is potentially recoverable and to identify those areas in the interior salt basins with high potential to recover commercial quantities of the deep gas resource.

The project objectives will be achieved through a 3-year effort. First, emphasis is on petroleum system identification and characterization in the North Louisiana Salt Basin, the Mississippi Interior Salt Basin, the Manila Subbasin and the Conecuh Subbasin of Louisiana, Mississippi, Alabama and Florida panhandle. This task includes identification of the petroleum systems in these basins and the characterization of the overburden, source, reservoir and seal rocks of the petroleum systems and of the associated petroleum traps. Second, emphasis is on petroleum system modeling. This task includes the assessment of the timing of deep (>15,000 ft) gas generation, expulsion, migration, entrapment and alteration (thermal cracking of oil to gas). Third, emphasis is on resource assessment. This task includes the volumetric calculation of the total in-place hydrocarbon resource generated, the determination of the volume of the generated hydrocarbon resource that is classified as deep (>15,000 ft) gas, the estimation of the volume of deep gas that was expelled, migrated and entrapped, and the calculation of the potential volume of gas in deeply buried (>15,000 ft) reservoirs resulting from the process of thermal cracking of liquid hydrocarbons and their transformation to gas in the reservoir. Fourth, emphasis is on identifying those areas in the onshore interior salt basins with high potential to recover commercial quantities of the deep gas resource.

Experimental

Work Accomplished (Table 1)

***Data Compilation*—**The existing information on the North Louisiana Salt Basin, Mississippi Interior Salt Basin, Manila Subbasin and Conecuh Subbasin (Figure 1) have been evaluated and an electronic database of these data for each basin has been compiled. Eleven (11) cross sections consisting of 141 wells for the North Louisiana Salt Basin have been selected and constructed. The log curves for the wells used in the cross sections have been digitized. Five (5) cross sections consisting of 48 wells for the Mississippi Interior Salt Basin have been prepared. The log curves for the wells used in the cross sections have been digitized. Five (5) cross sections consisting of 18 wells for the Manila and Conecuh Subbasins have been prepared. These log curves for the wells used in the cross sections have been digitized. Subsurface structure and isopach maps have been prepared using the digitized database for the North Louisiana Salt Basin, the Mississippi Interior Salt Basin and the Manila Subbasin and Conecuh Subbasin. Burial history, thermal maturation history, and hydrocarbon expulsion profiles have been constructed for key wells in each of these basins.

Source rock geochemical data for the Mississippi Interior Salt Basin and Manila and Conecuh Subbasins have been reviewed and compiled. Source rock geochemical data for the North Louisiana Salt Basin have been reviewed, and additional samples have been analyzed by GeoChem Laboratories for source rock characterization and analysis (Table 2).

Table 1

Milestone Chart—Year 2

	O	N	D	J	F	M	A	M	J	J	A	S
Petroleum System Characterization												
	xxxxxxxxxxxxxxxxxxxxxx											
Petroleum System Modeling												
							xxxxxxxxxxxxxxxxxxxxxx					
In-Place Resource Assessment												
										xxxxxxxxxxx		

Work Planned	
Work Completed	xxx

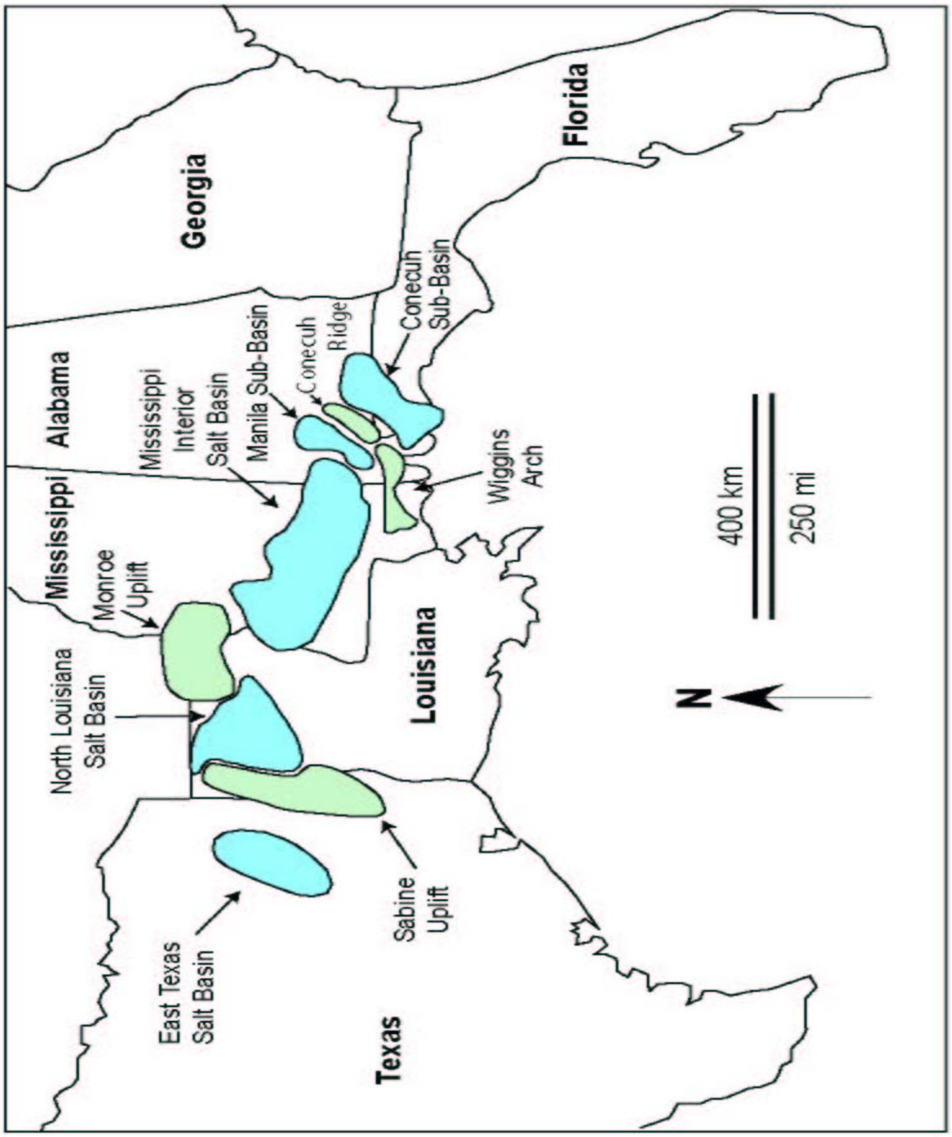

Figure 1. Location map of interior salt basins and subbasins in the north central and northeastern Gulf of Mexico area.

Table 2. Organic geochemical analyses of core samples, North Louisiana Salt Basin.

Sample no.	Well	Parish	Depth (ft)	Unit	TOC (%)	Kerogen[1]	TAI
1	HAMNER ATLANTIC REF. #1	BIENVILLE	5,819	Rodessa	0.46	Am	2.9
2	HAMNER ATLANTIC REF. #1	BIENVILLE	7,547	Hosston	0.17	Am	3.2
3	CON CAN SOUTHERN NAT GAS #2	BIENVILLE	10,802	Cotton Valley	0.43	H	3.4
4	LAWHORN AMOCO #1	BIENVILLE	10,774	Cotton Valley	1.25	H	2.3
5	PRATHER WHELESS #1	CLAIBORNE	11,866	Smackover	0.32; 0.33R	H	2.7
6	MILLER HERD BOB #1	CLAIBORNE	10,707	Smackover	0.36	H	2.8
7	MARSHALL EXPL IPCO #1	DE SOTO	10,364	Cotton Valley	0.48	W/I	2.7
8	CRYSTAL DAVIS #1	JACKSON	11,188	Cotton Valley	0.31	Am/H	2.5
9	FRANKS PARNELL #1	LINCOLN	9,127	Cotton Valley	0.60	H	2.4
10	AMOCO JAMES #1	LINCOLN	10,443	Cotton Valley	0.12	H	3.2
11	PHILLIPS CROWN-ZELLERBACH #1	NATCHITOCHES	13,421	Smackover	0.09	H	3.7
12	PHILLIPS GODFREY "B" #1	NATCHITOCHES	13,305	Smackover/Norphlet	1.80	H	3.7
13	HUMBLE TERZIA F.C. #1	OUACHITA	10,193	Cotton Valley	1.65	H	2.4
14	PAN AM WEBB #1	OUACHITA	9,620	Cotton Valley	0.20	Am/H	2.3
15	SUN KENNEDY #2	OUACHITA	9,915	Cotton Valley	0.76; 0.75R	Am/H	2.4
16	PIONEER TEER #1	RED RIVER	14,060	Smackover/Norphlet	1.22	H/I	3.8
17	AMOCO SAMPLE #1	RED RIVER	9,676	Cotton Valley	0.45	H	2.7
18	AMOCO SAMPLE #2	RED RIVER	9,911	Cotton Valley	0.29	H	2.7
19	PAN AM GREEN #1	UNION	10,683	Smackover	0.08	H	3
20	PAN AM GREEN #1	UNION	10,825	Smackover	0.12	H	3.7
21	ATLANTIC HOLLEY PHILLIP #1	WEBSTER	10,290	Cotton Valley	1.07	H	2.7
22	ATLANTIC HOLLEY PHILLIP #1	WEBSTER	10,640	Cotton Valley	0.25	H/I	2.7
23	ARCO HUFFMAN-MCNEELY #1	NATCHITOCHES	7,685	Austin	0.26	H	2.5
24	ARCO HUFFMAN-MCNEELY #1	NATCHITOCHES	9,747	Mooringsport	1.00; 1.02R	H/I	2.7
25	ARCO HUFFMAN-MCNEELY #1	NATCHITOCHES	11,771	James	0.17	H	2.7
26	ARCO HUFFMAN-MCNEELY #1	NATCHITOCHES	15,507	Sligo	0.23	H	3.2
27	SUN ENGLISH #2	BOSSIER	9,382	Cotton Valley	0.29	I	2.5
28	SUN ENGLISH #2	BOSSIER	9,432	Cotton Valley	0.32	H	2.5
29	SUN ENGLISH #2	BOSSIER	11,136	Bossier	0.55	W/I	2.7
30	SUN ENGLISH #2	BOSSIER	11,168	Bossier	0.91	Am/H	2.7
31	SUN FIRST BANK #1	BOSSIER	11,108	Bossier	0.35	W/I	2.9
32	SUN FIRST BANK #1	BOSSIER	11,173	Smackover	0.47	W/I	2.9
33	SUN FIRST BANK #1	BOSSIER	11,178	Smackover	0.80; 0.82R	W/I	2.9

1Kerogen: Am=amorphous, H=herbaceous, W=woody, I=inertinite.

Representative geologic cross section, and representative thermal maturity profiles, representative burial history profiles, representative thermal maturation history and representative hydrocarbon expulsion profiles for each of the studied basins and subbasins have been constructed. These burial history profiles (Figures 2-23), thermal maturation history profiles (Figures 24-45) and hydrocarbon expulsion profiles (Figures 46-67) have been modified from the initial profiles reported. This refined petroleum system modeling is based on the methodologies established by Roger Barnaby at LSU. His methodologies include procedures for estimating the amount of erosion, the amount of sediment compaction, the lithologies of the stratigraphic units, the thermal conductivities of the rock units, the present-day heat flow, the paleoheat flow, the original percent of total organic carbon in the source rocks, and the percent of oil saturation of the source rock.

***Petroleum System Characterization*—**The various components of each of the petroleum systems determined to be active in the North Louisiana Salt Basin, the Mississippi Interior Salt Basin, the Manila Subbasin and the Conecuh Subbasin have been characterized. These components include the underburden, source, reservoir and seal rocks (Figure 68) of these petroleum systems that are associated with the petroleum traps in these onshore interior salt basins. A summary of the Upper Jurassic Smackover petroleum system in each of these basins and subbasins is presented in Figures 69 and 70. The timing of hydrocarbon generation, expulsion and migration in these basins and subbasins has been modified based on the refined petroleum system modeling.

***In-Place Assessment*—**Total oil and natural gas production was obtained from the States of Louisiana for the North Louisiana Salt Basin (Table 3), Mississippi for the Mississippi Interior Salt Basin (Table 4), Alabama for the eastern portion of the Mississippi Interior Salt Basin and Manila and Conecuh Subbasins (Table 5) and Florida for the Conecuh Subbasin (Table 6). This production information is important in estimating the remaining deep (>15,000 ft) gas resource in the North Louisiana Salt Basin, the Mississippi Interior Salt Basin, the Manila Subbasin, and the Conecuh Subbasin.

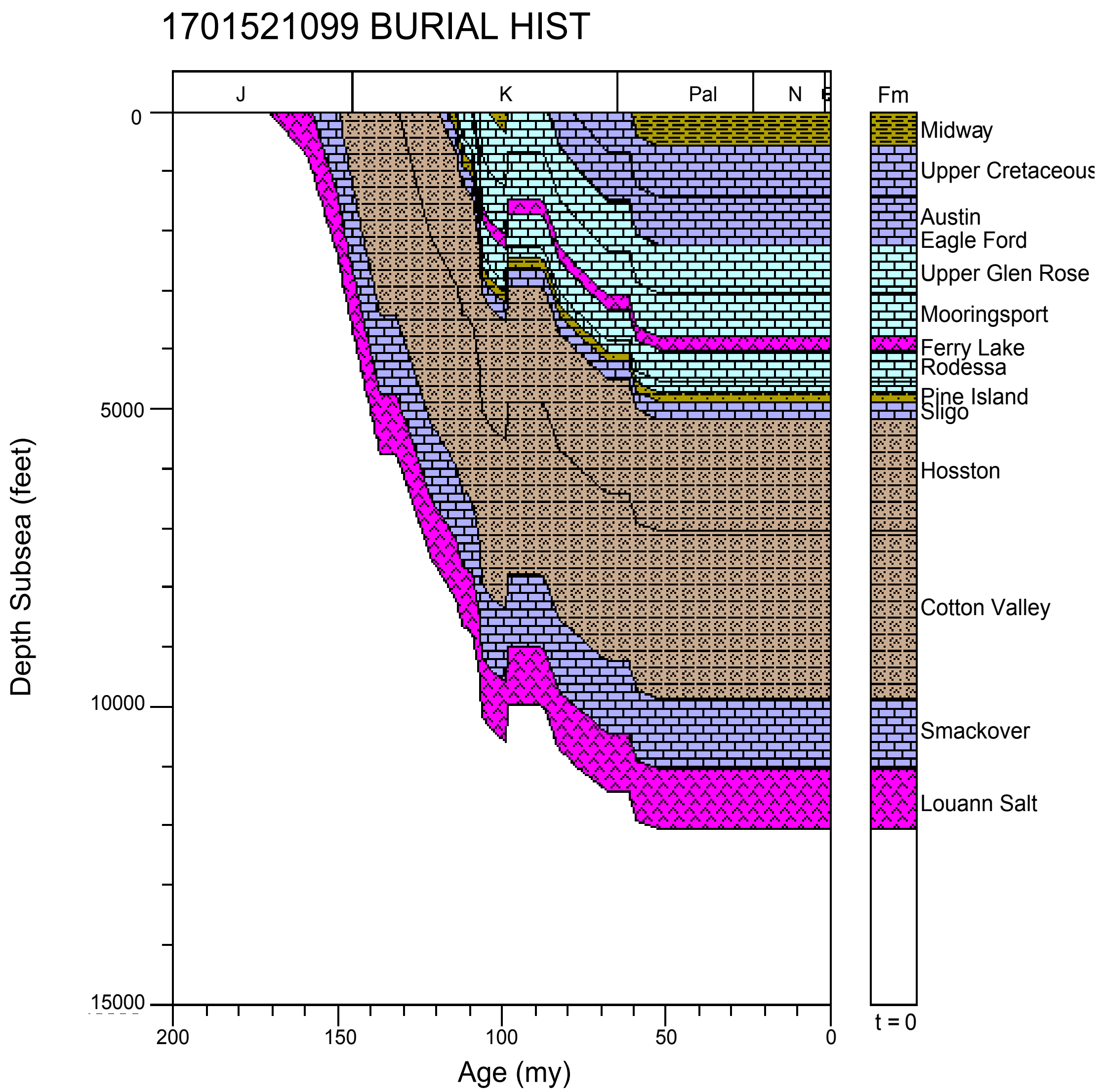

Figure 2. Burial history for well 1701521099, North Louisiana Salt Basin.

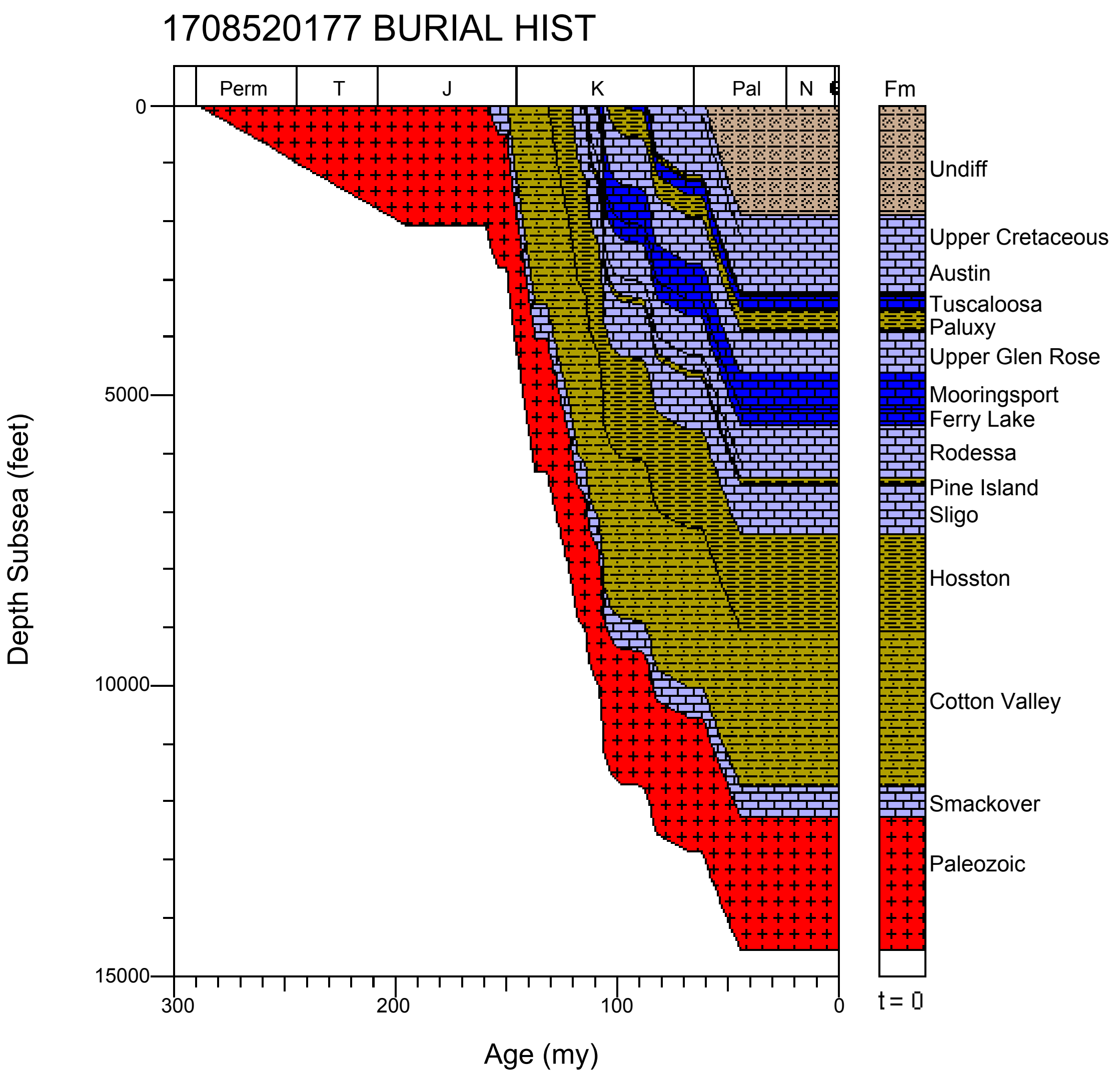

Figure 3. Burial history for well 1708520177, North Louisiana Salt Basin.

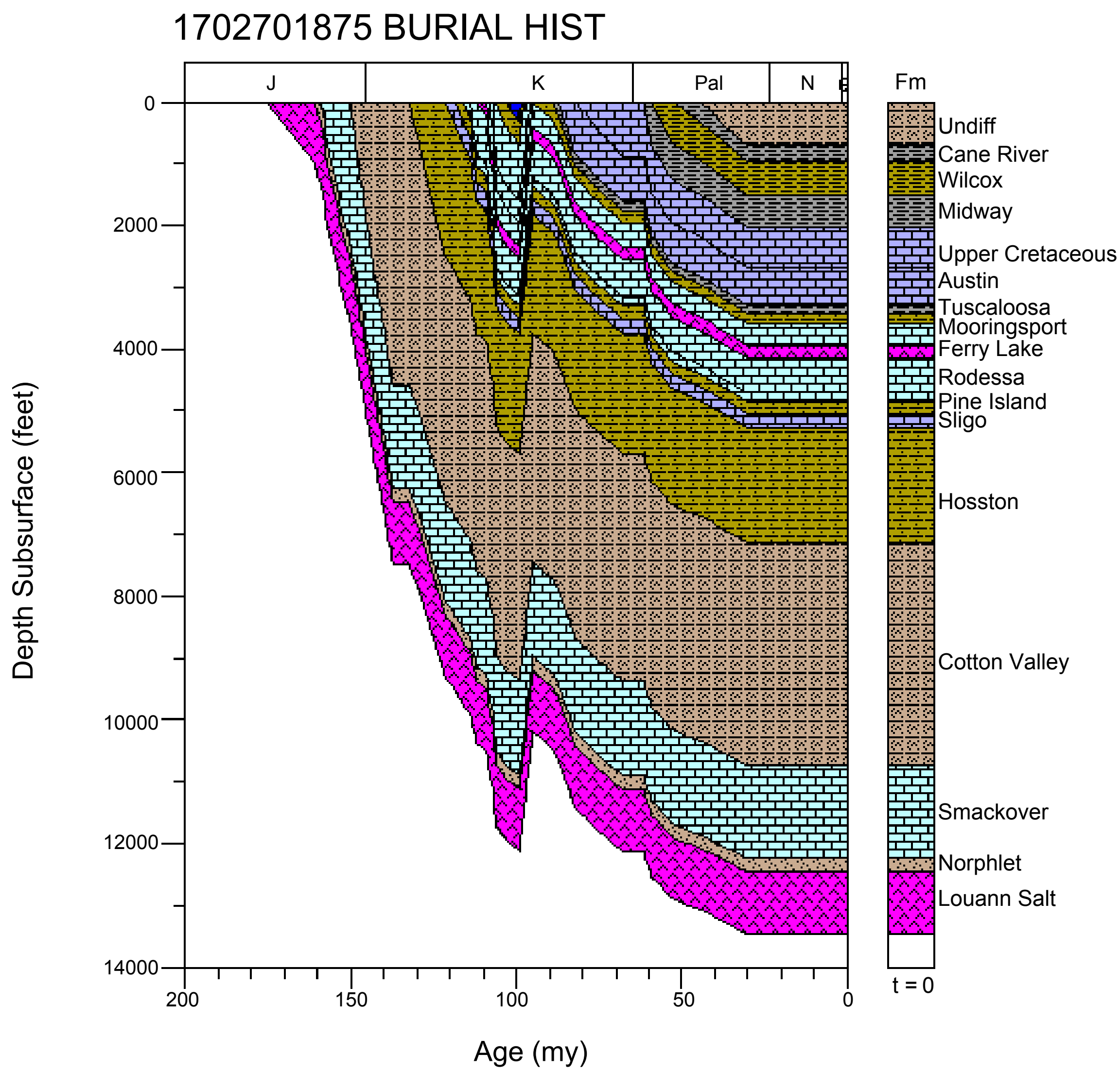

Figure 4. Burial history for well 1702701875, North Louisiana Salt Basin.

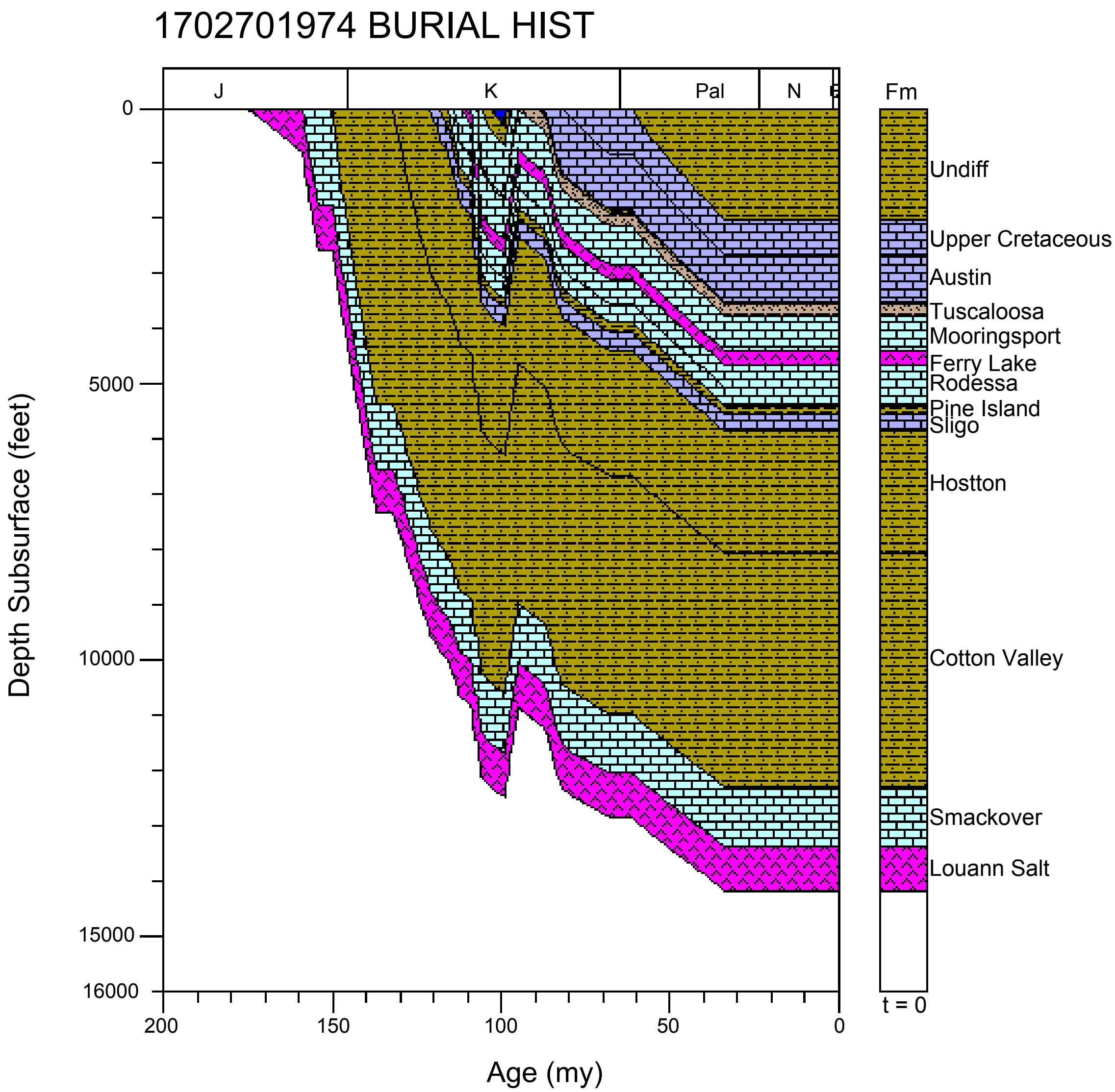

Figure 5. Burial history for well 1702701974, North Louisiana Salt Basin.

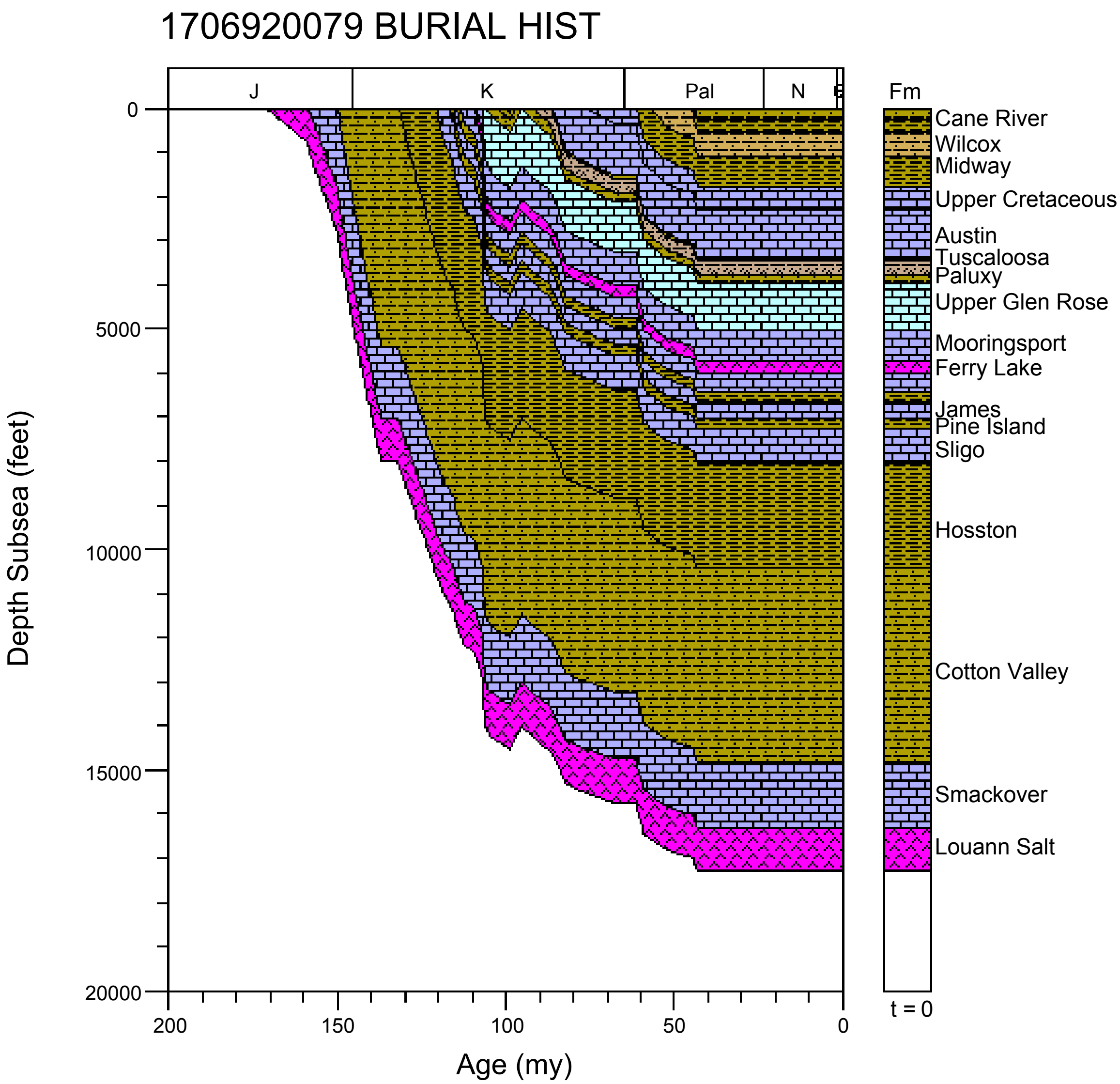

Figure 6. Burial history for well 1706920079, North Louisiana Salt Basin.

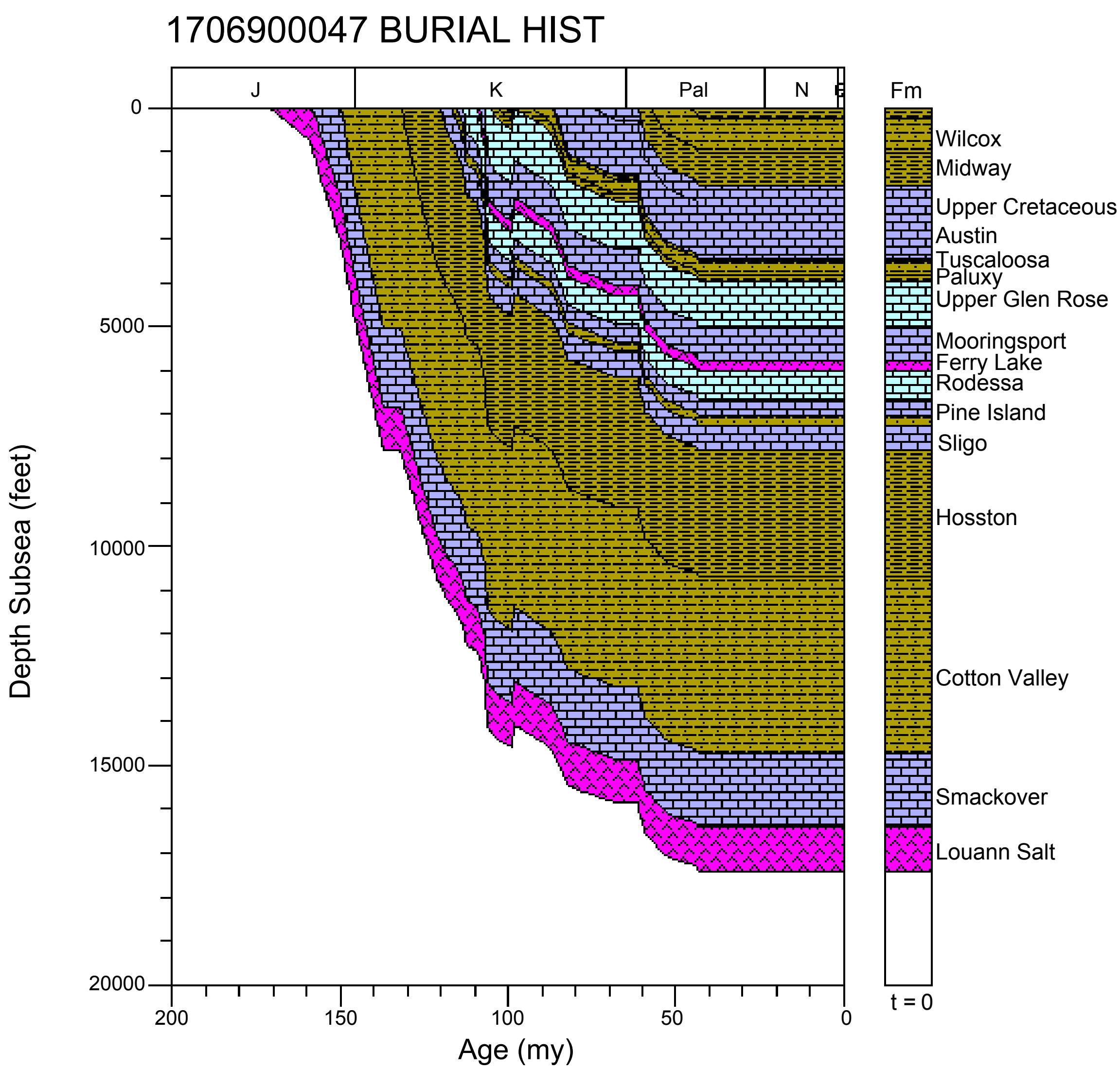

Figure 7. Burial history for well 1706900047, North Louisiana Salt Basin.

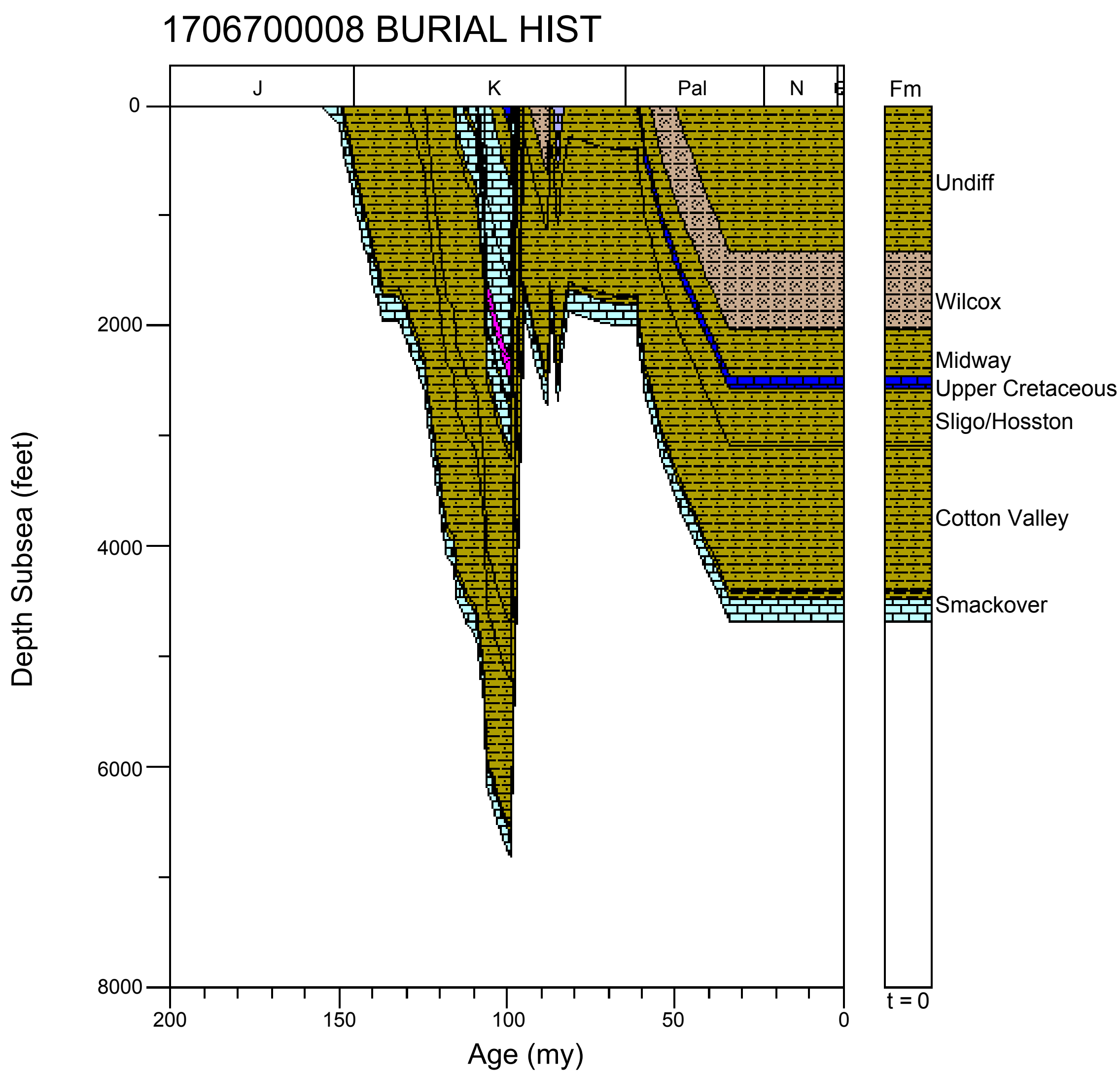

Figure 8. Burial history for well 1706700008, North Louisiana Salt Basin.

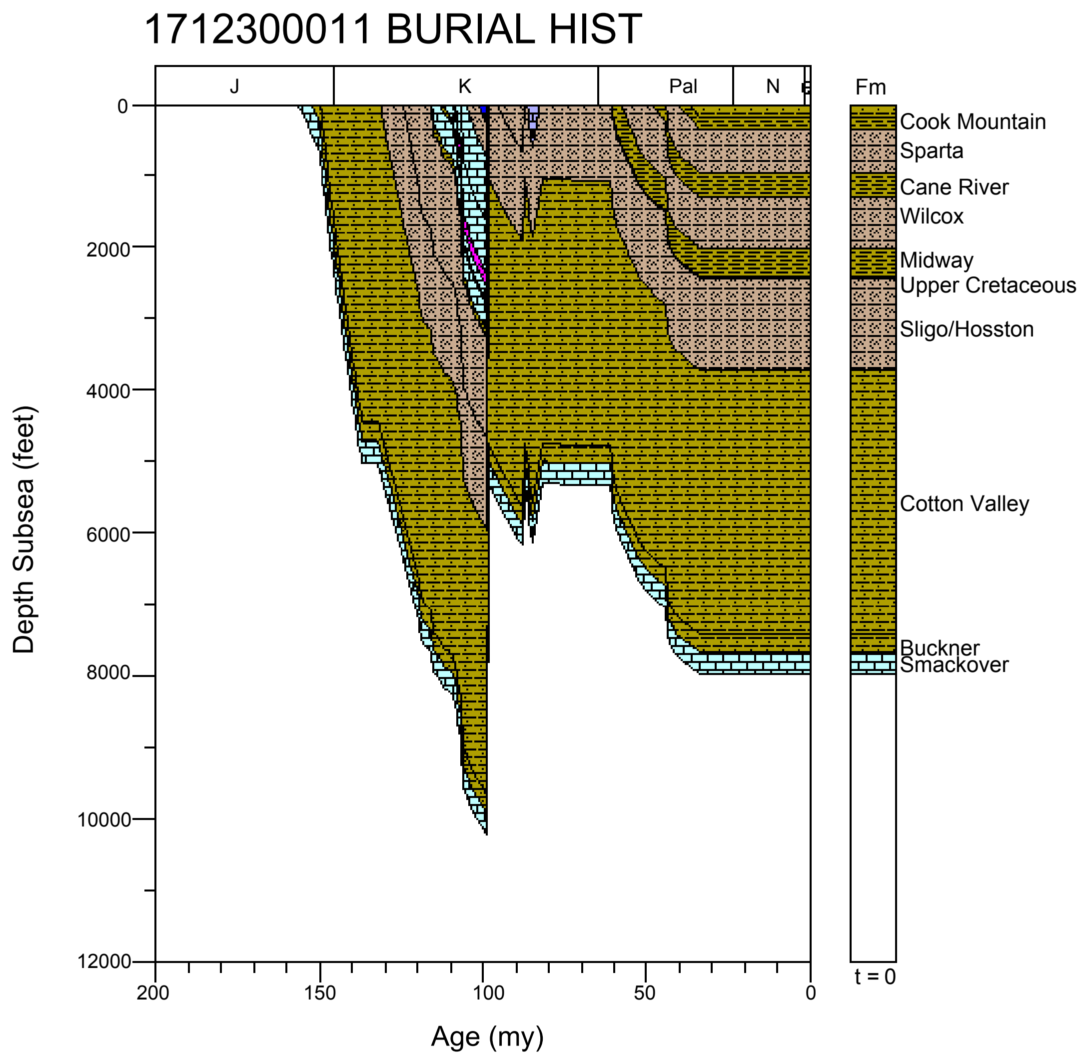

Figure 9. Burial history for well 1712300011, North Louisiana Salt Basin.

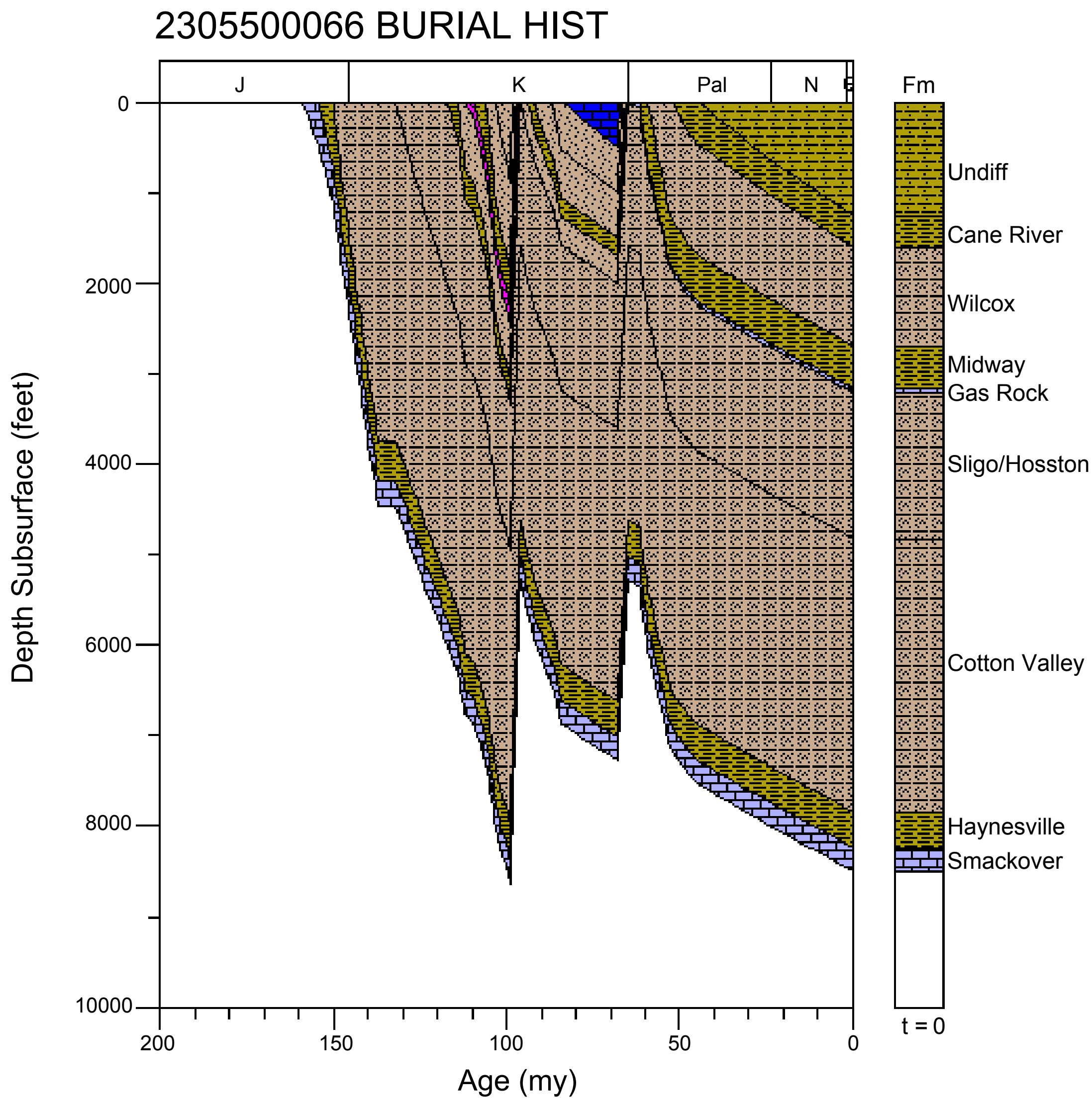

Figure 10. Burial history for well 2305500066, Mississippi Interior Salt Basin.

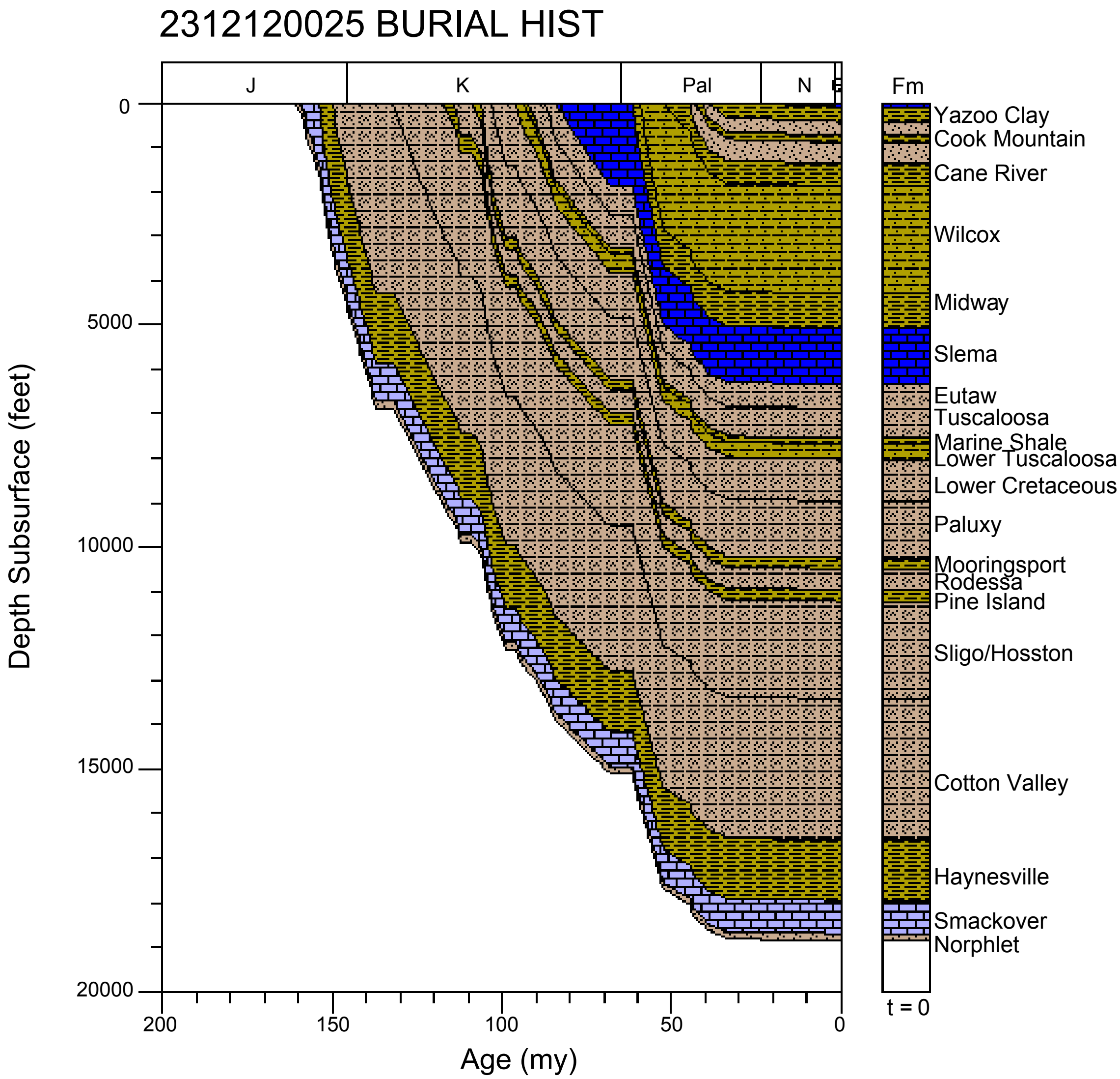

Figure 11. Burial history for well 2312120025, Mississippi Interior Salt Basin.

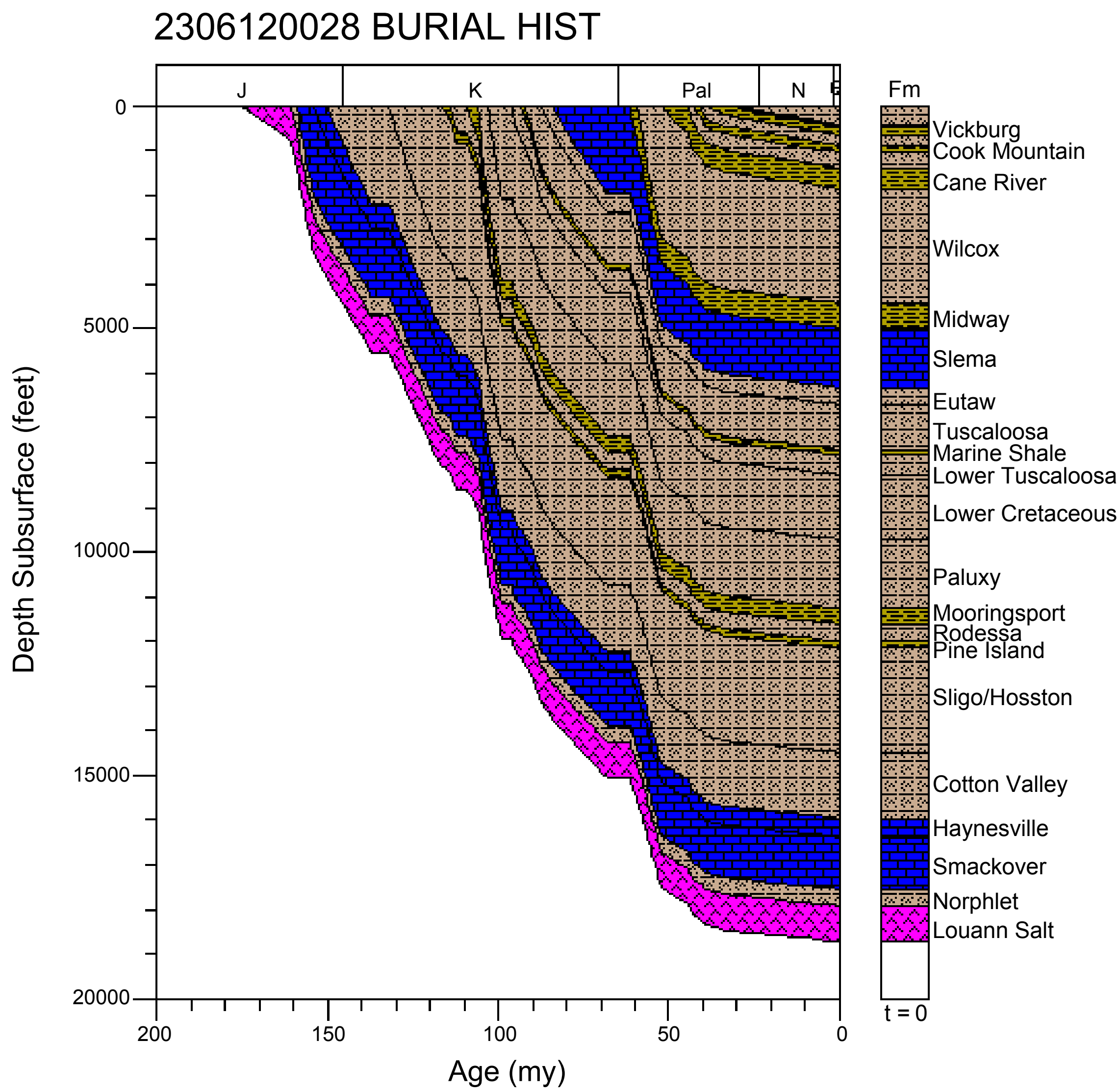

Figure 12. Burial history for well 2306120028, Mississippi Interior Salt Basin.

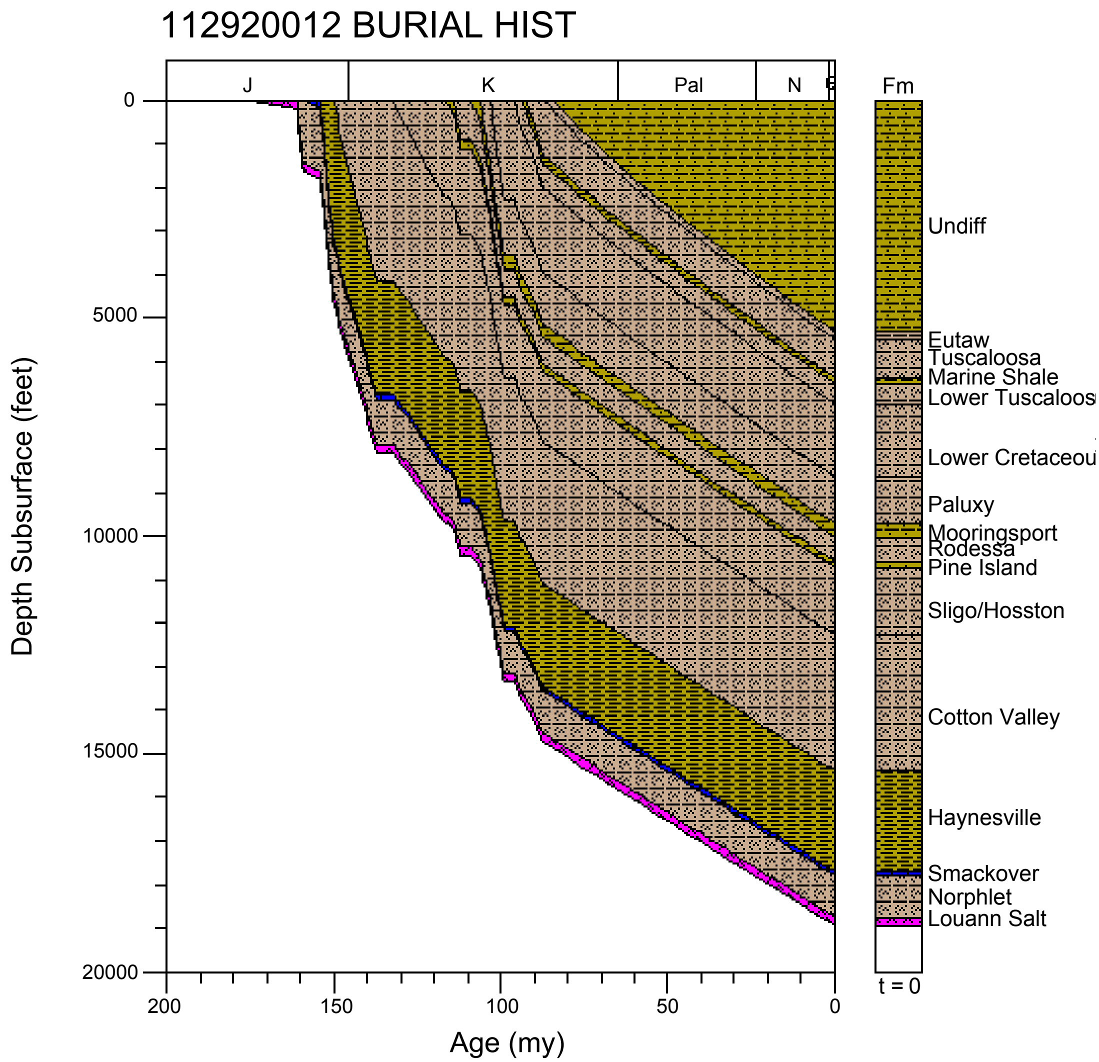

Figure 13. Burial history for well 112920012, Mississippi Interior Salt Basin.

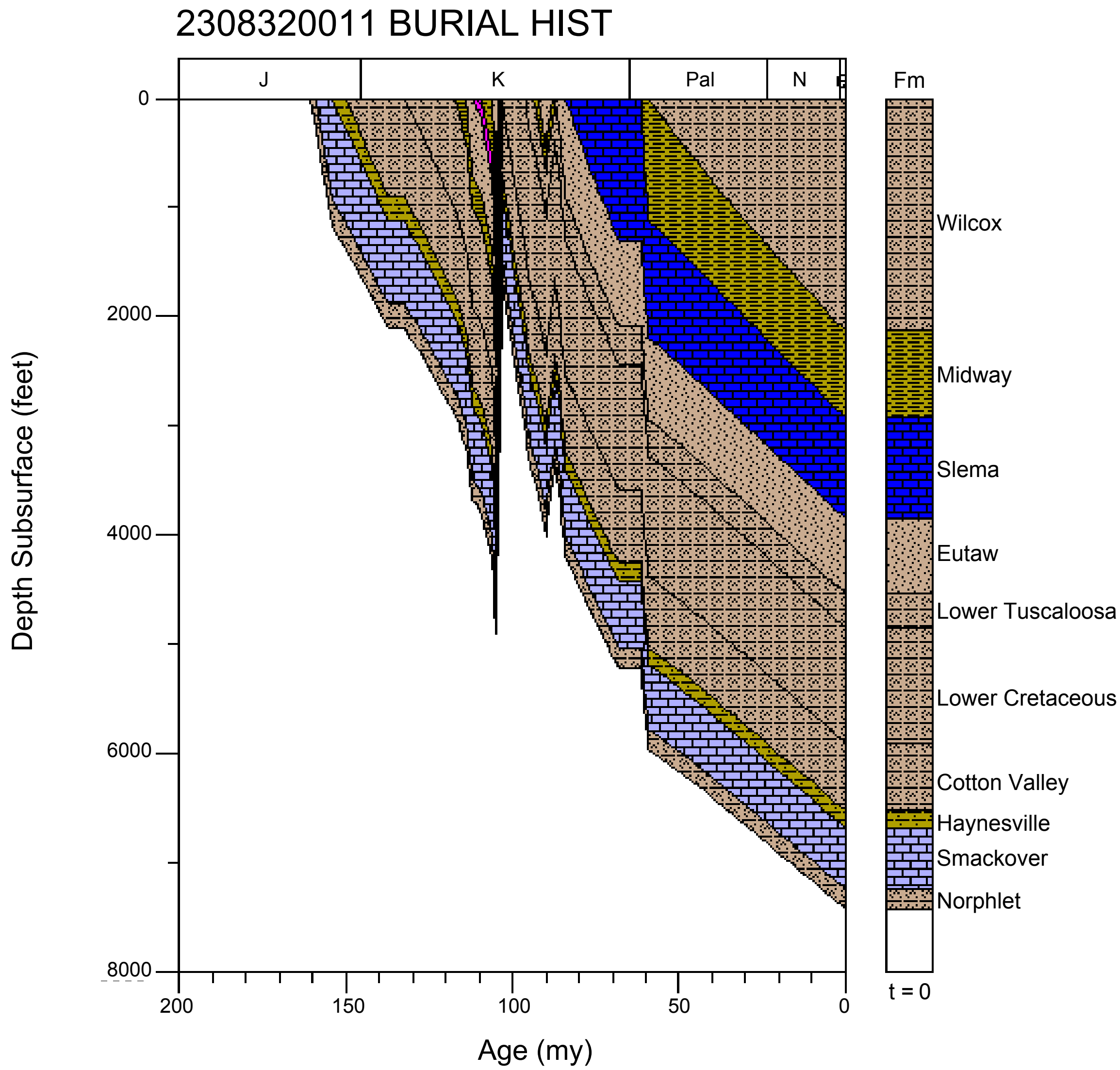

Figure 14. Burial history for well 2308320011, Mississippi Interior Salt Basin.

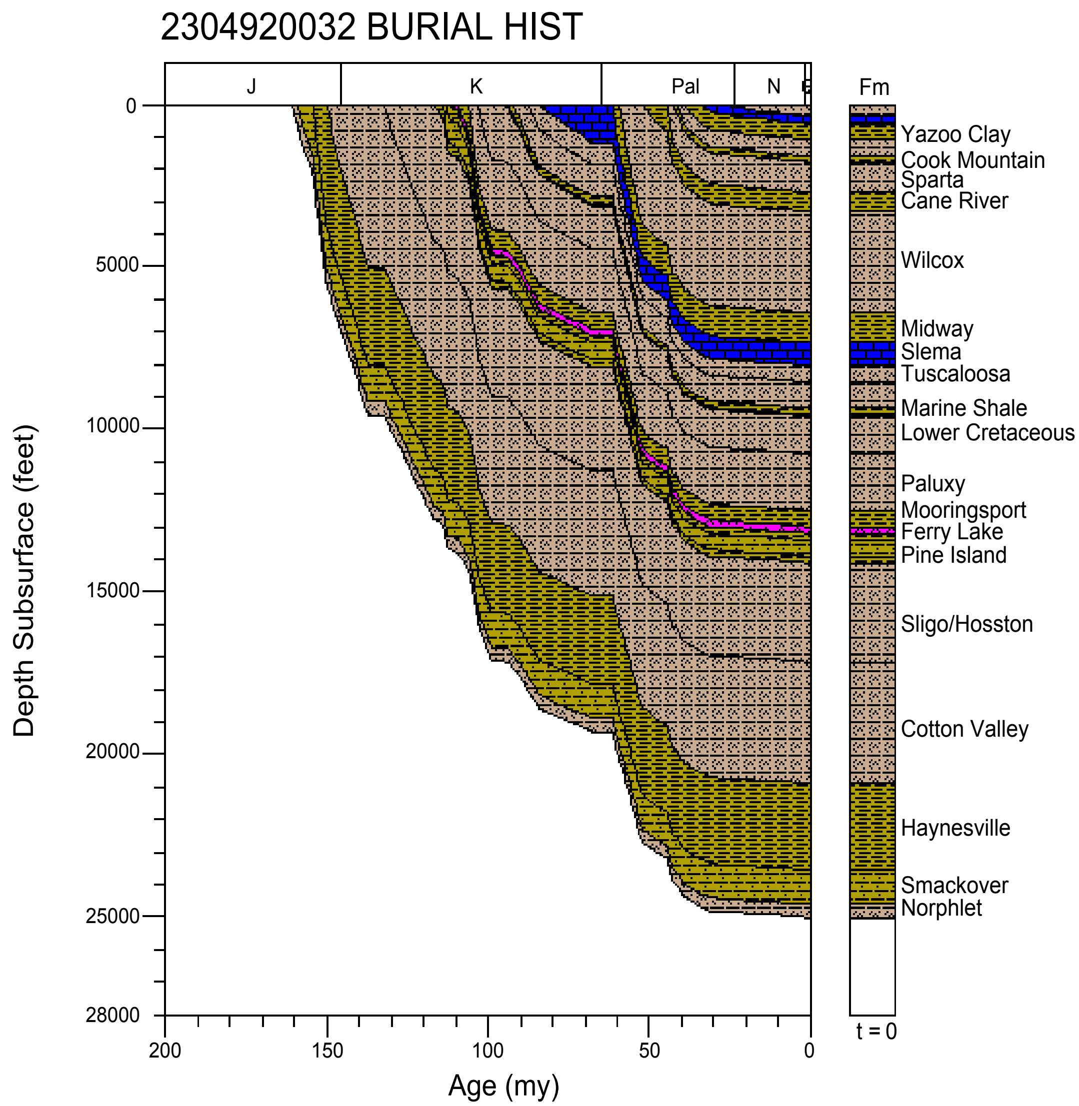

Figure 15. Burial history for well 2304920032, Mississippi Interior Salt Basin.

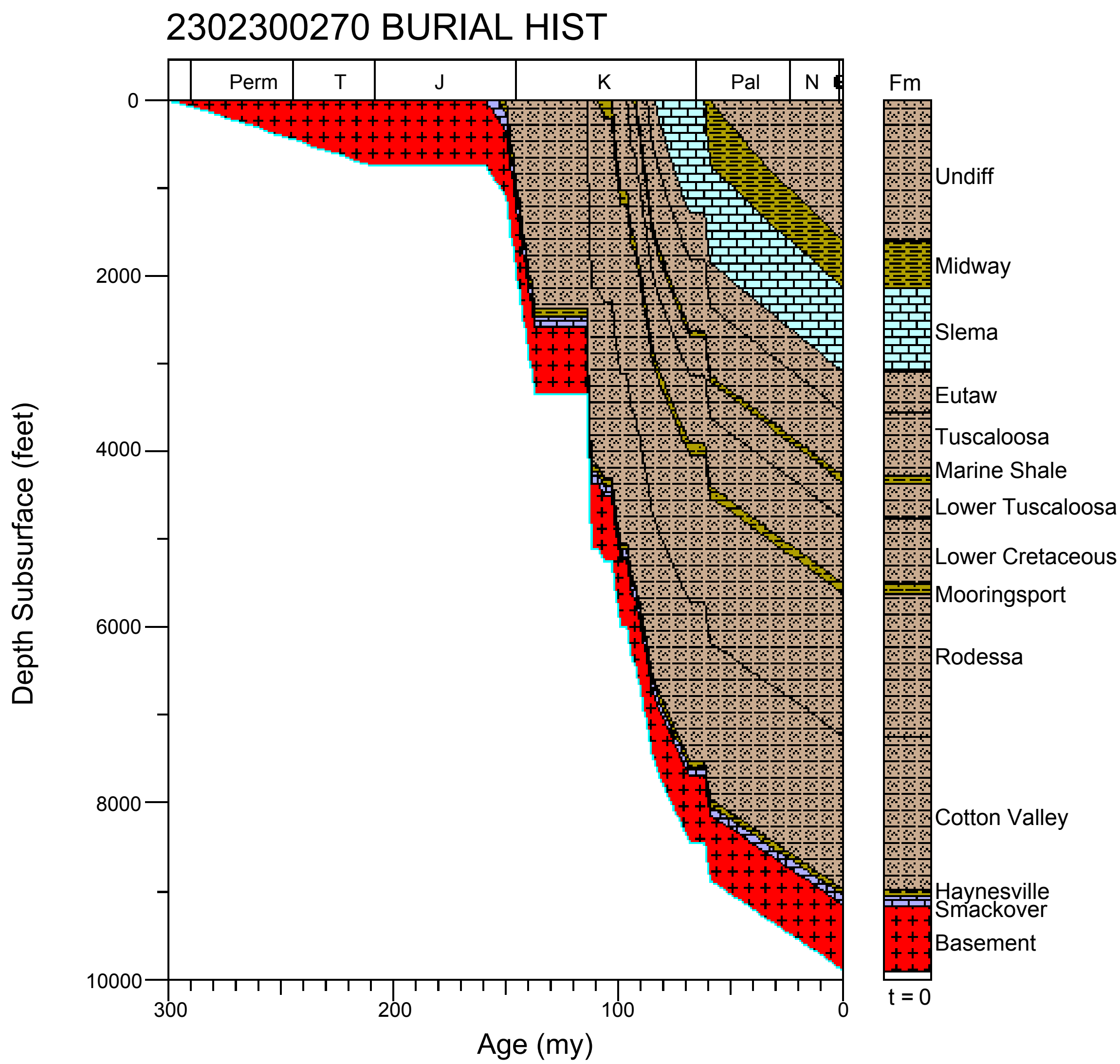

Figure 16. Burial history for well 2302300270, Mississippi Interior Salt Basin.

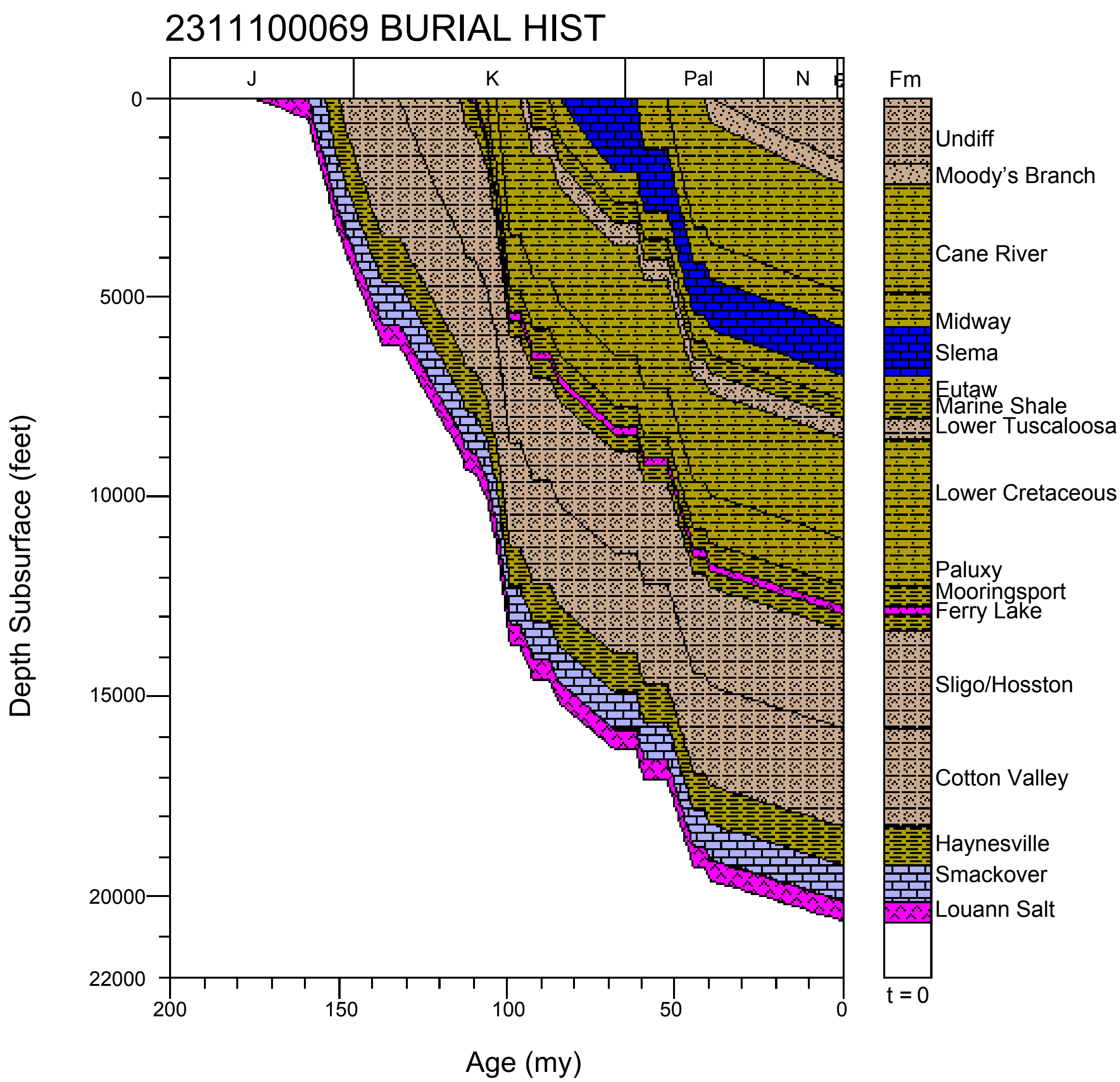

Figure 17. Burial history for well 2311100069, Mississippi Interior Salt Basin.

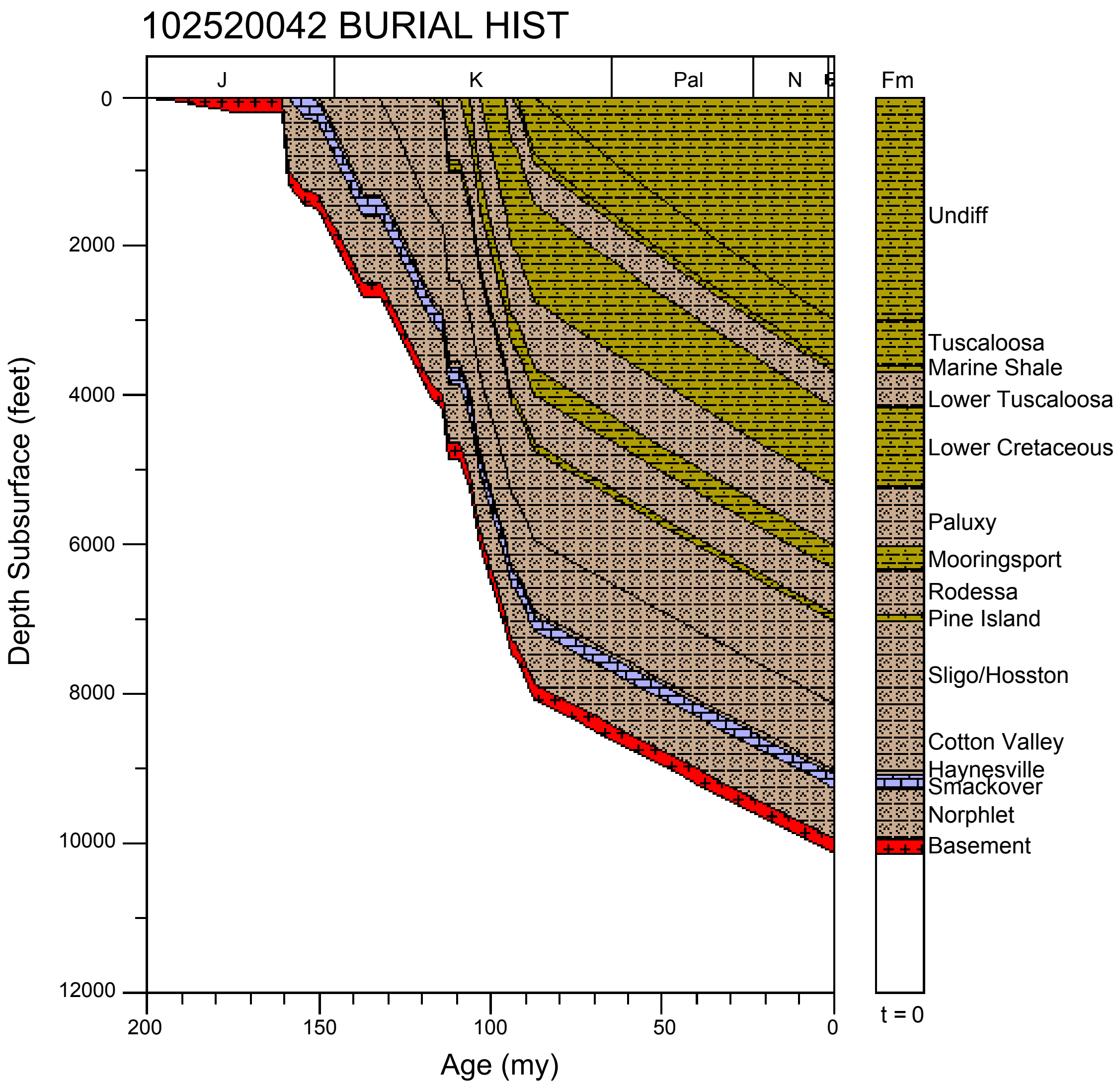

Figure 18. Burial history for well 102520042, Manila Subbasin.

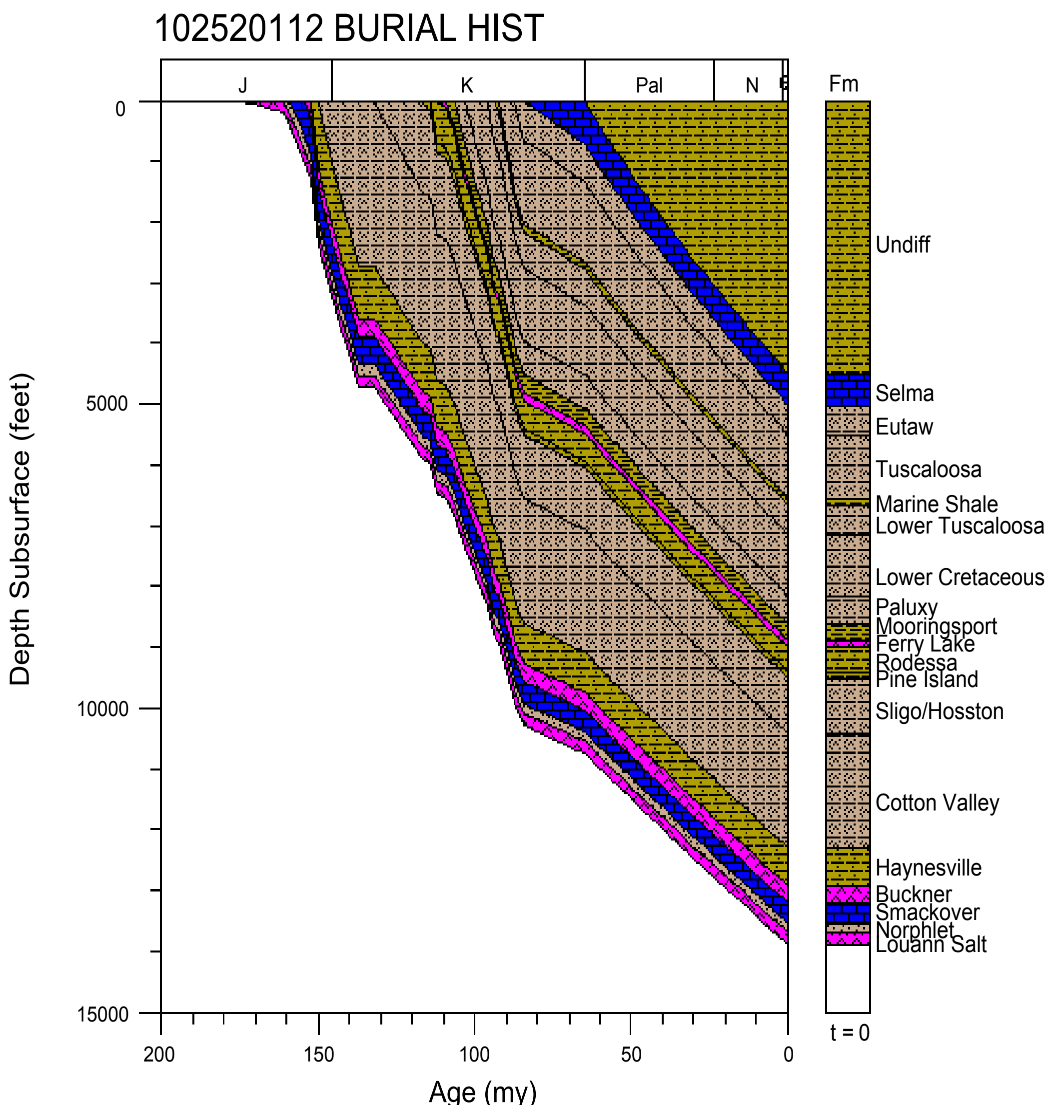

Figure 19. Burial history for well 102520112, Manila Subbasin.

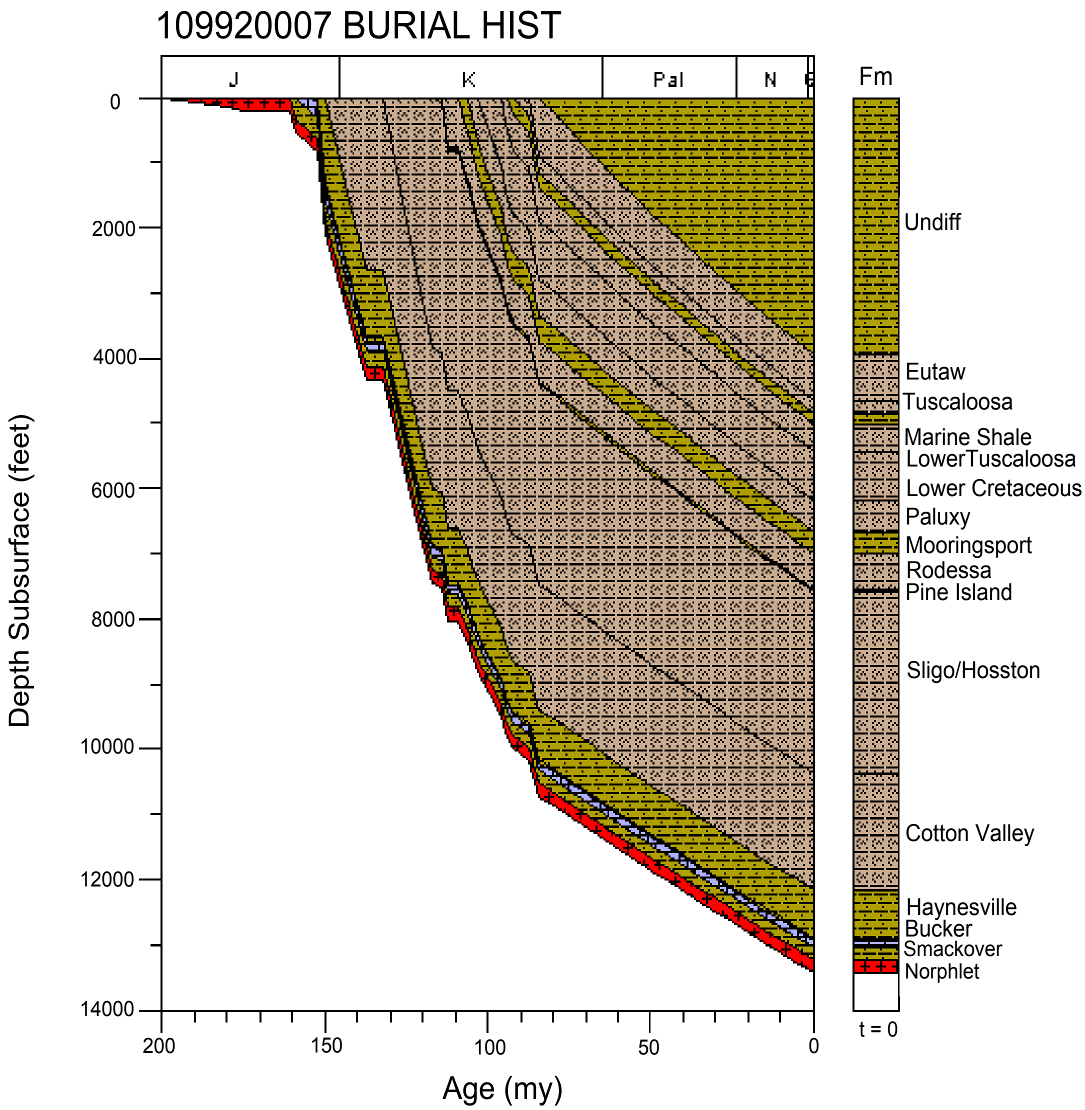

Figure 20. Burial history for well 109920007, Manila Subbasin.

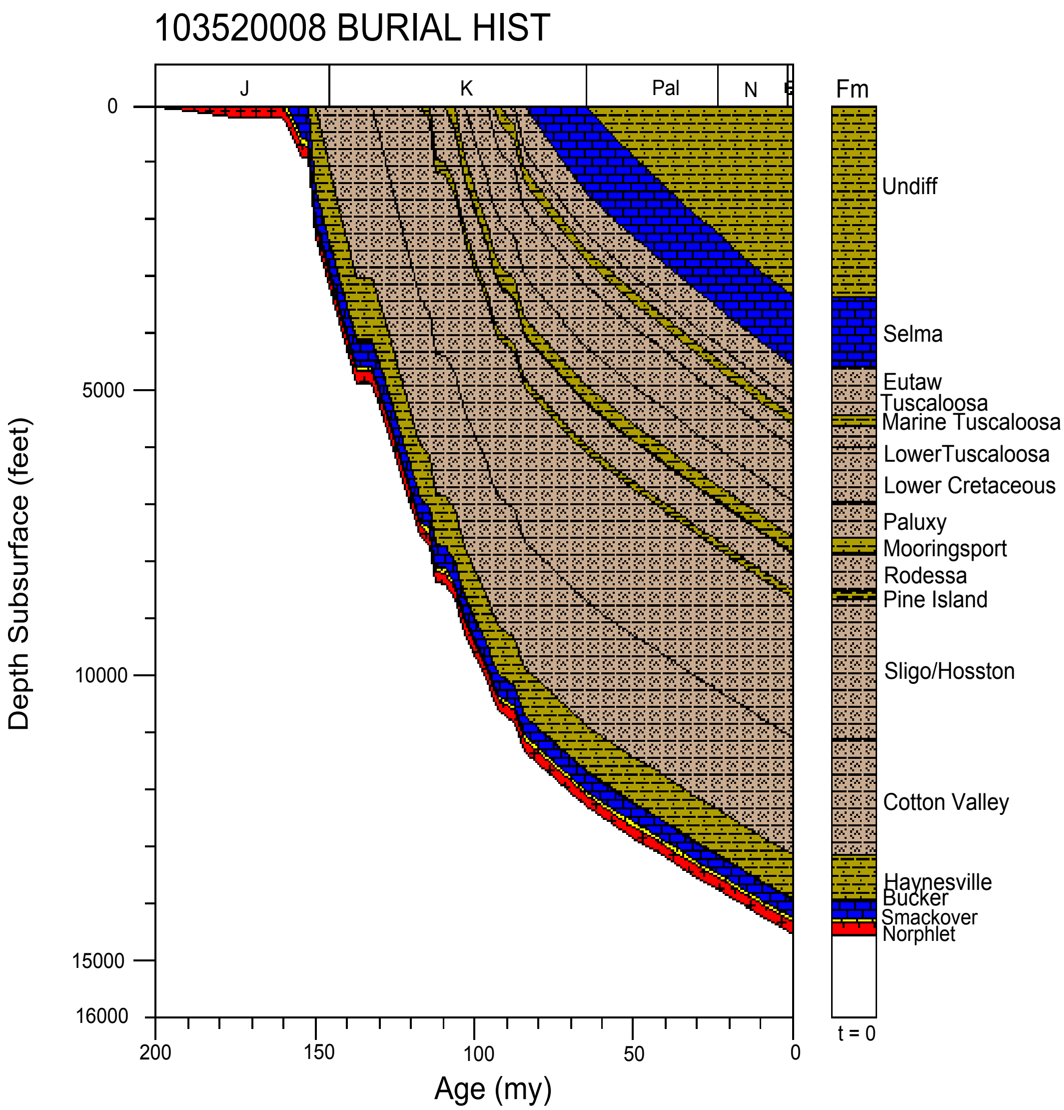

Figure 21. Burial history for well 103520008, Conecuh Subbasin.

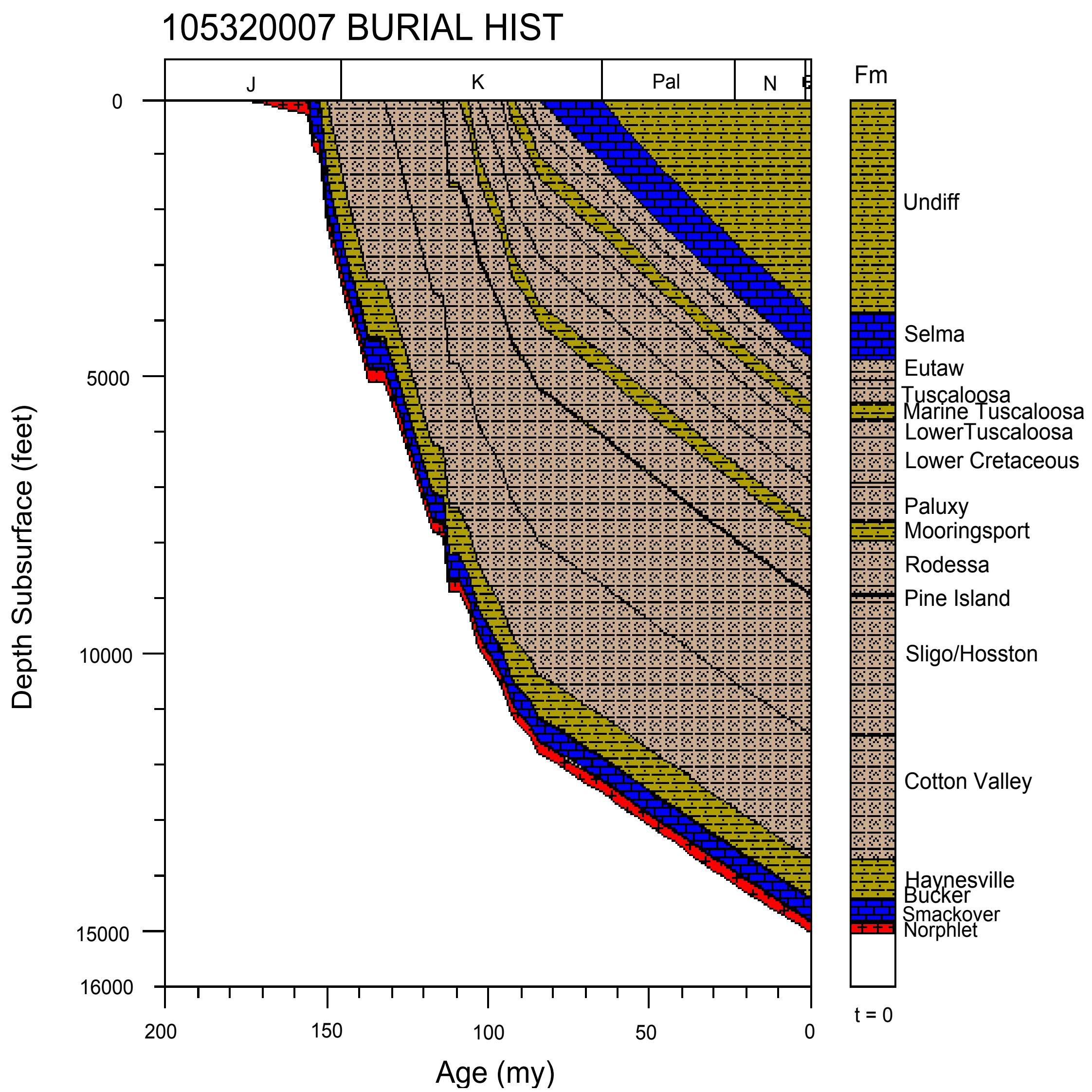

Figure 22. Burial history for well 105320007, Conecuh Subbasin.

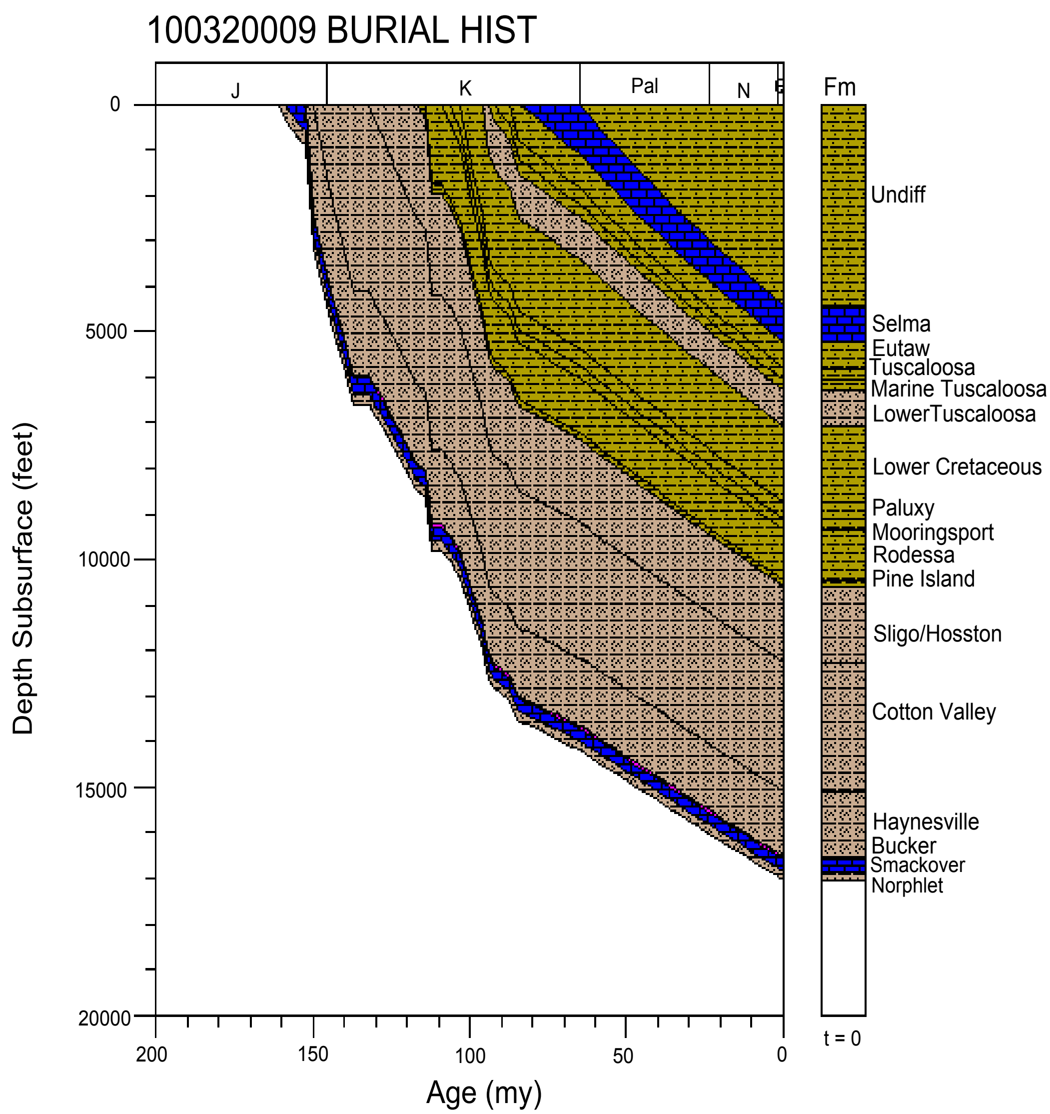

Figure 23. Burial history for well 100320009, Conecuh Subbasin.

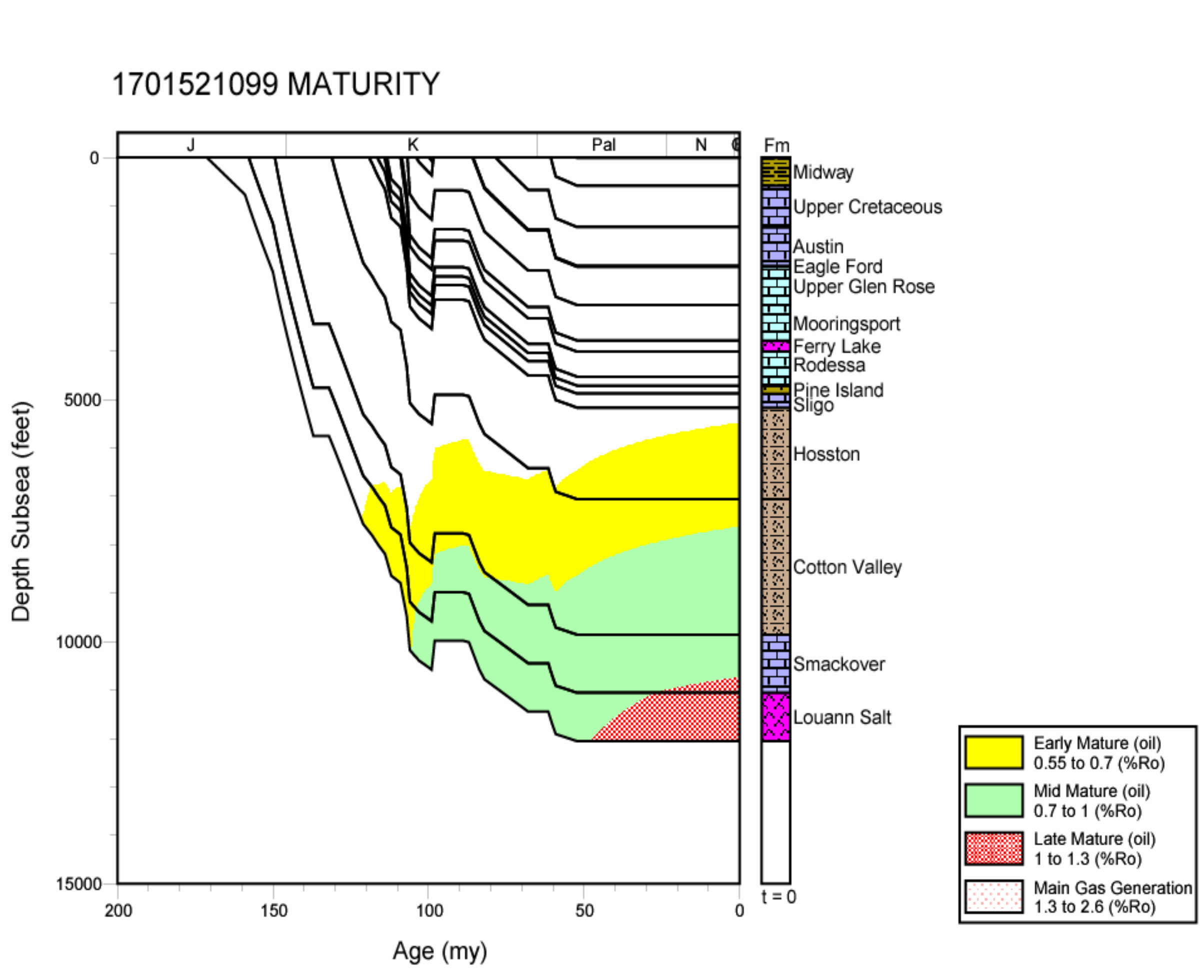

Figure 24. Thermal maturation profile for well 1701521099, North Louisiana Salt Basin.

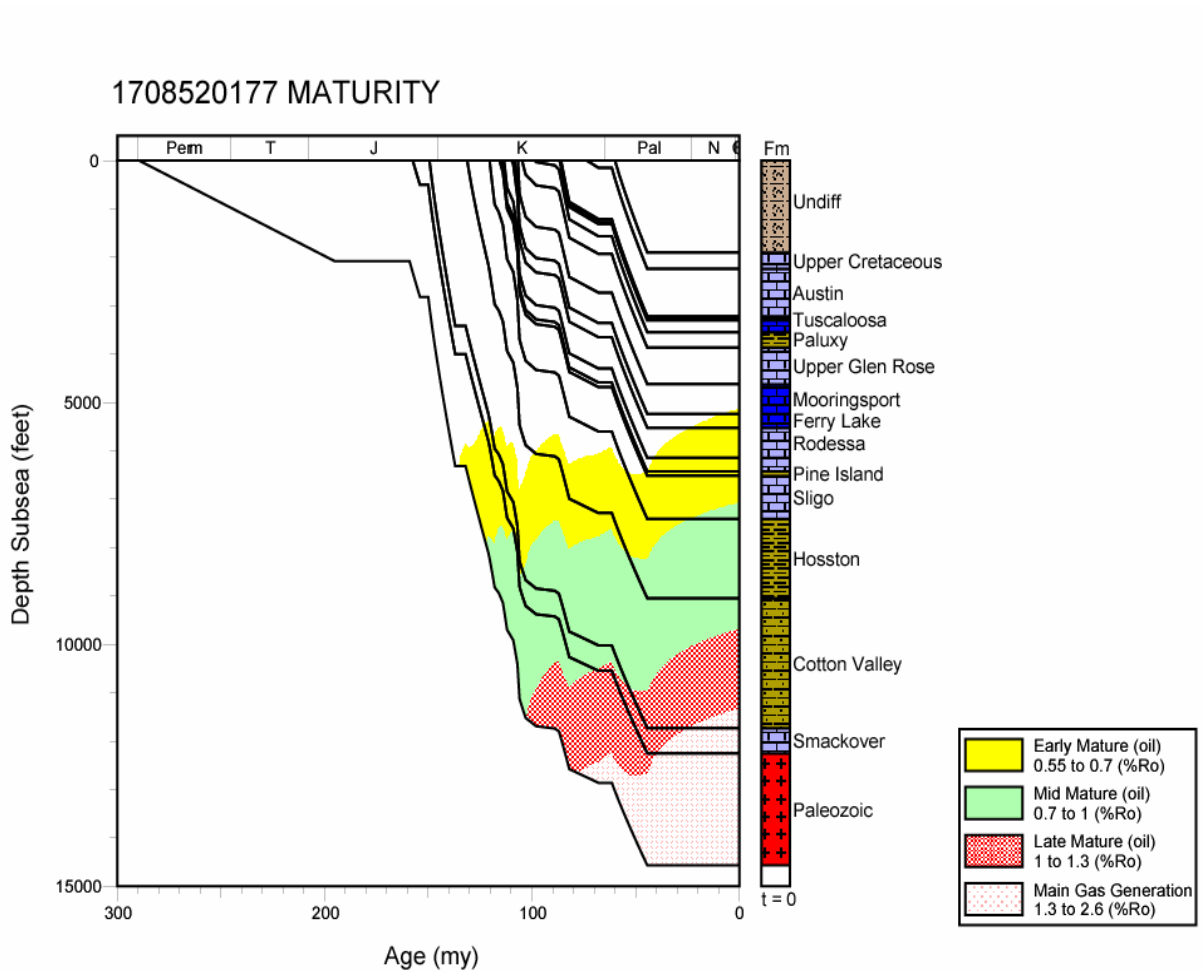

Figure 25. Thermal maturation profile for well 1708520177, North Louisiana Salt Basin.

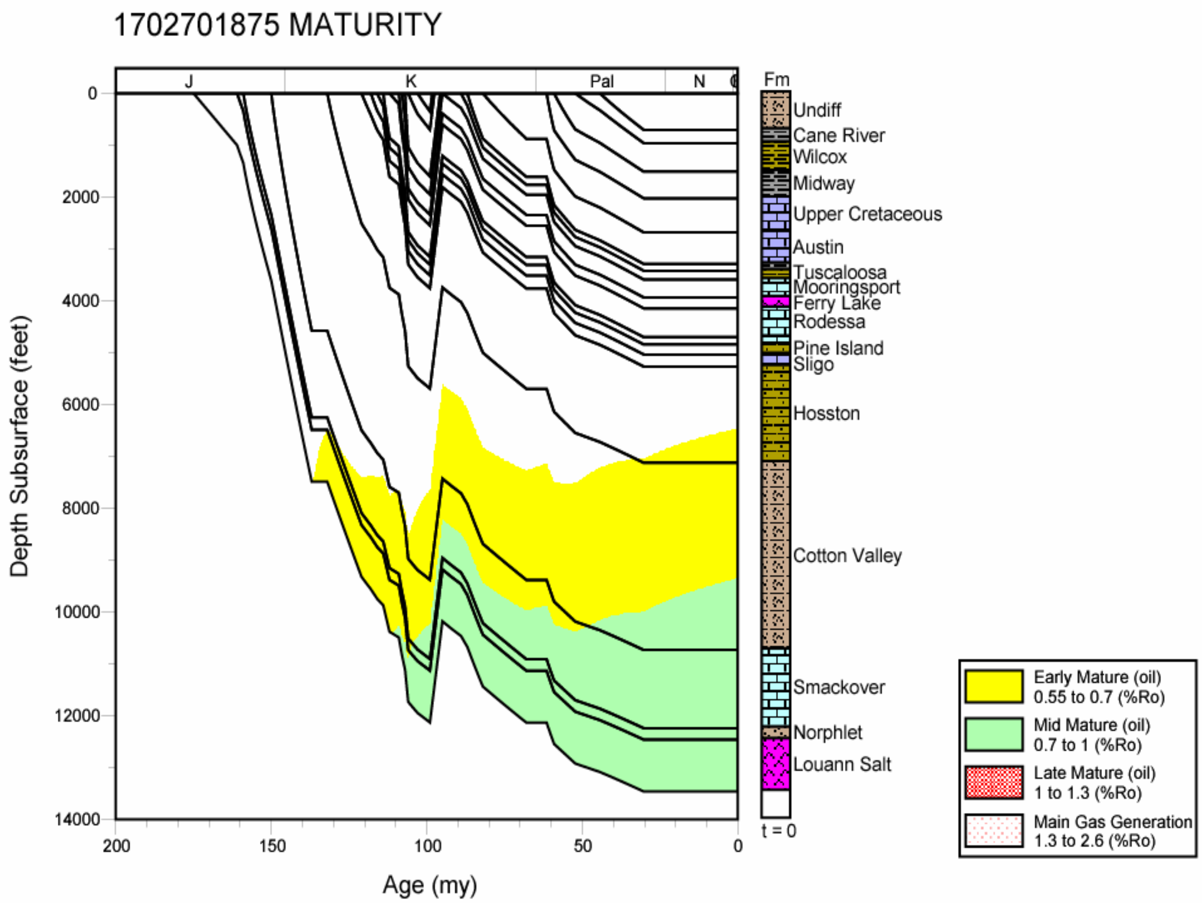

Figure 26. Thermal maturation profile for well 1702701875, North Louisiana Salt Basin.

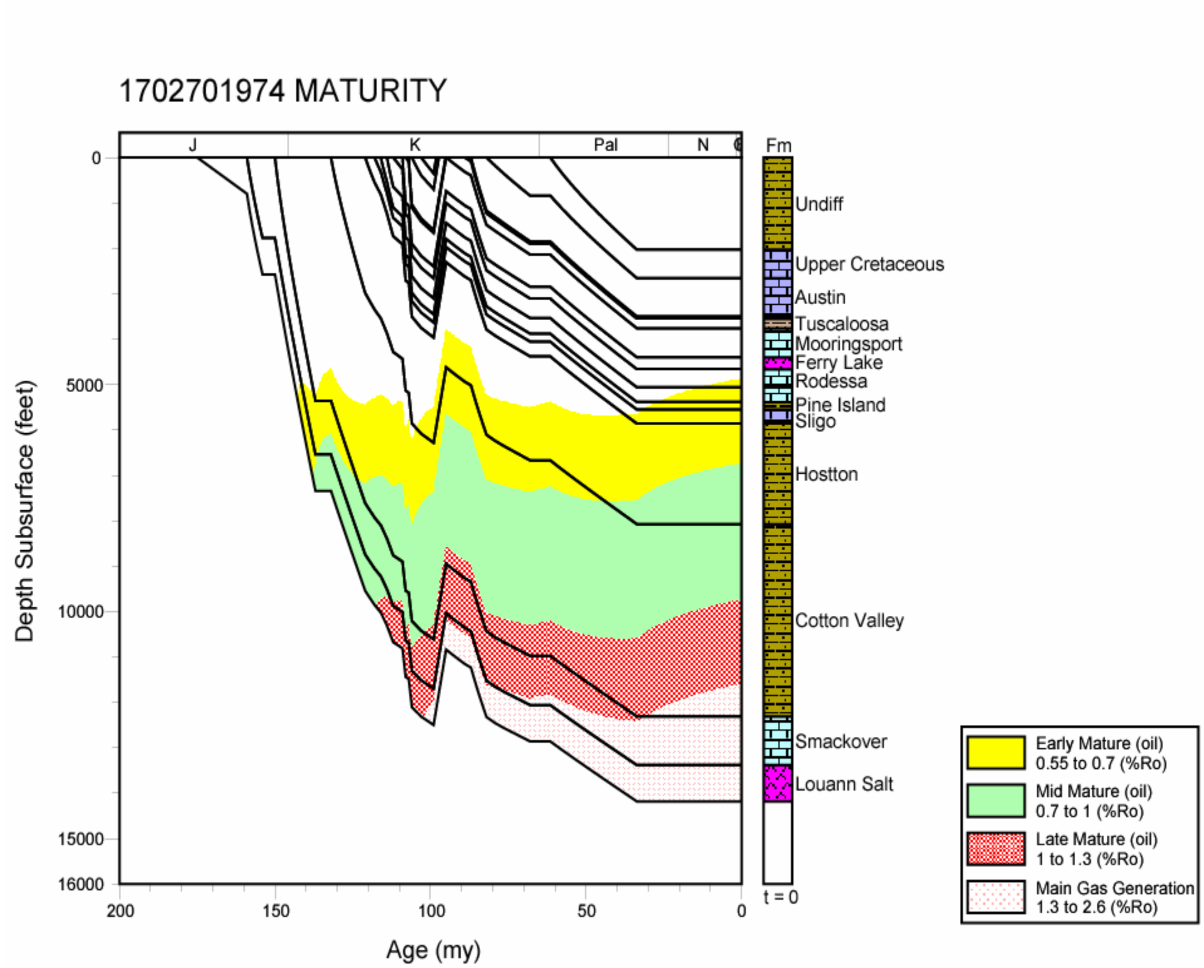

Figure 27. Thermal maturation profile for well 1702701875, North Louisiana Salt Basin.

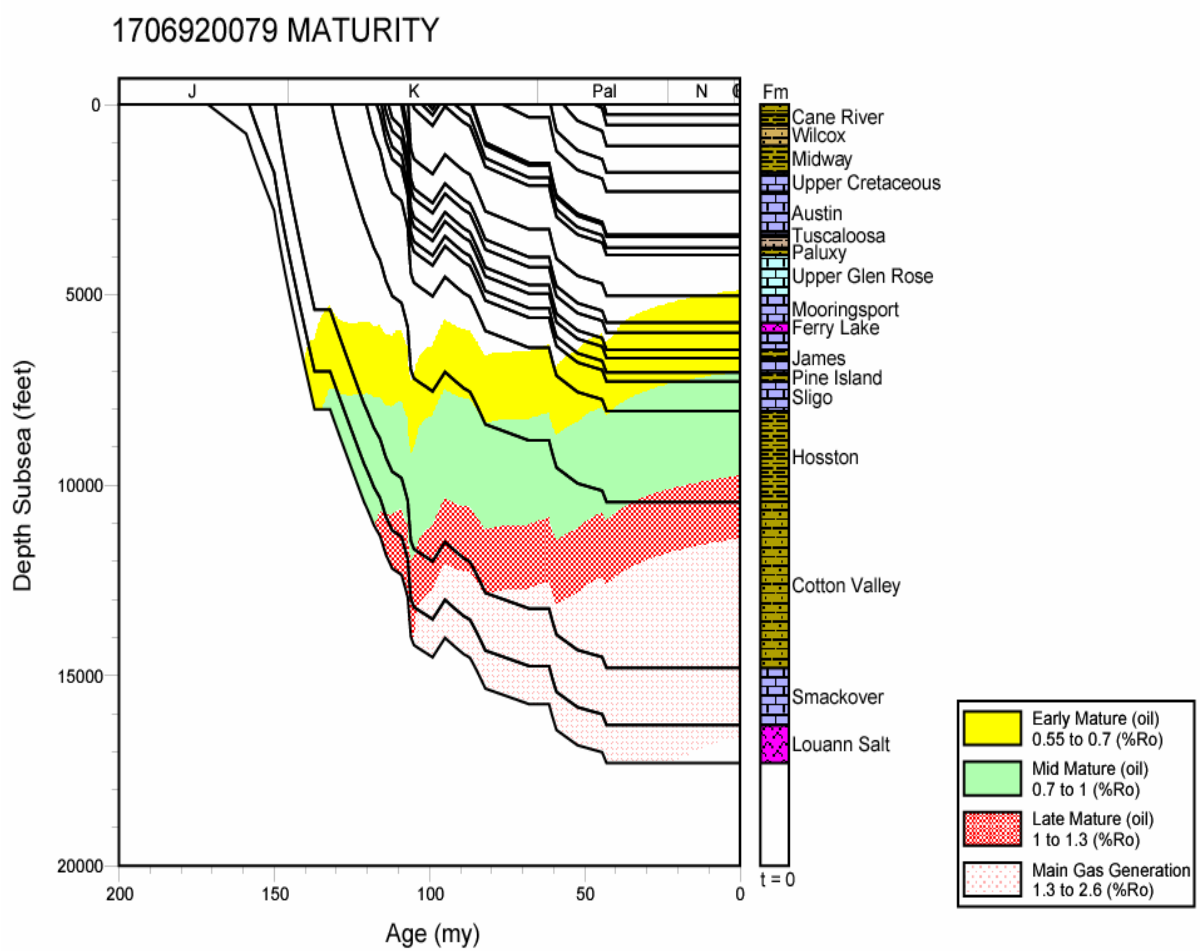

Figure 28. Thermal maturation profile for well 1706920079, North Louisiana Salt Basin.

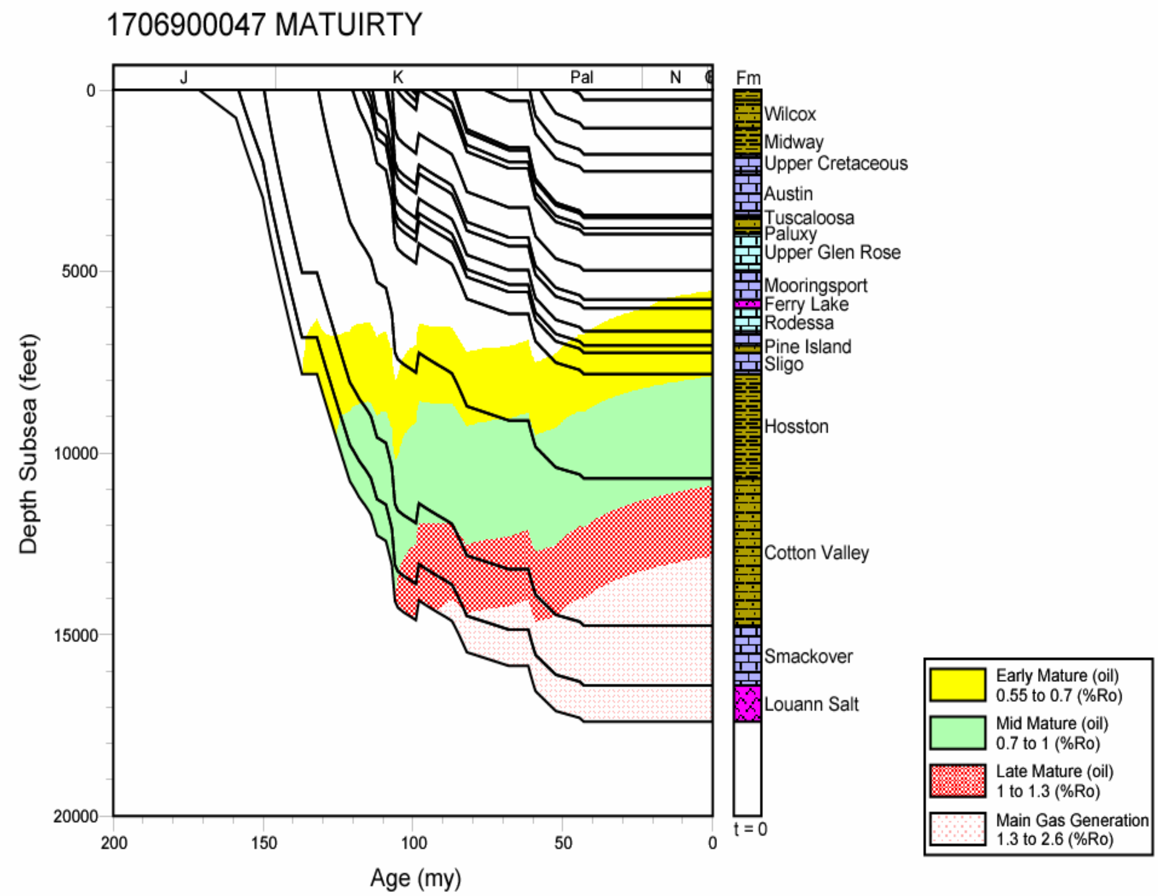

Figure 29. Thermal maturation profile for well 1706900047, North Louisiana Salt Basin.

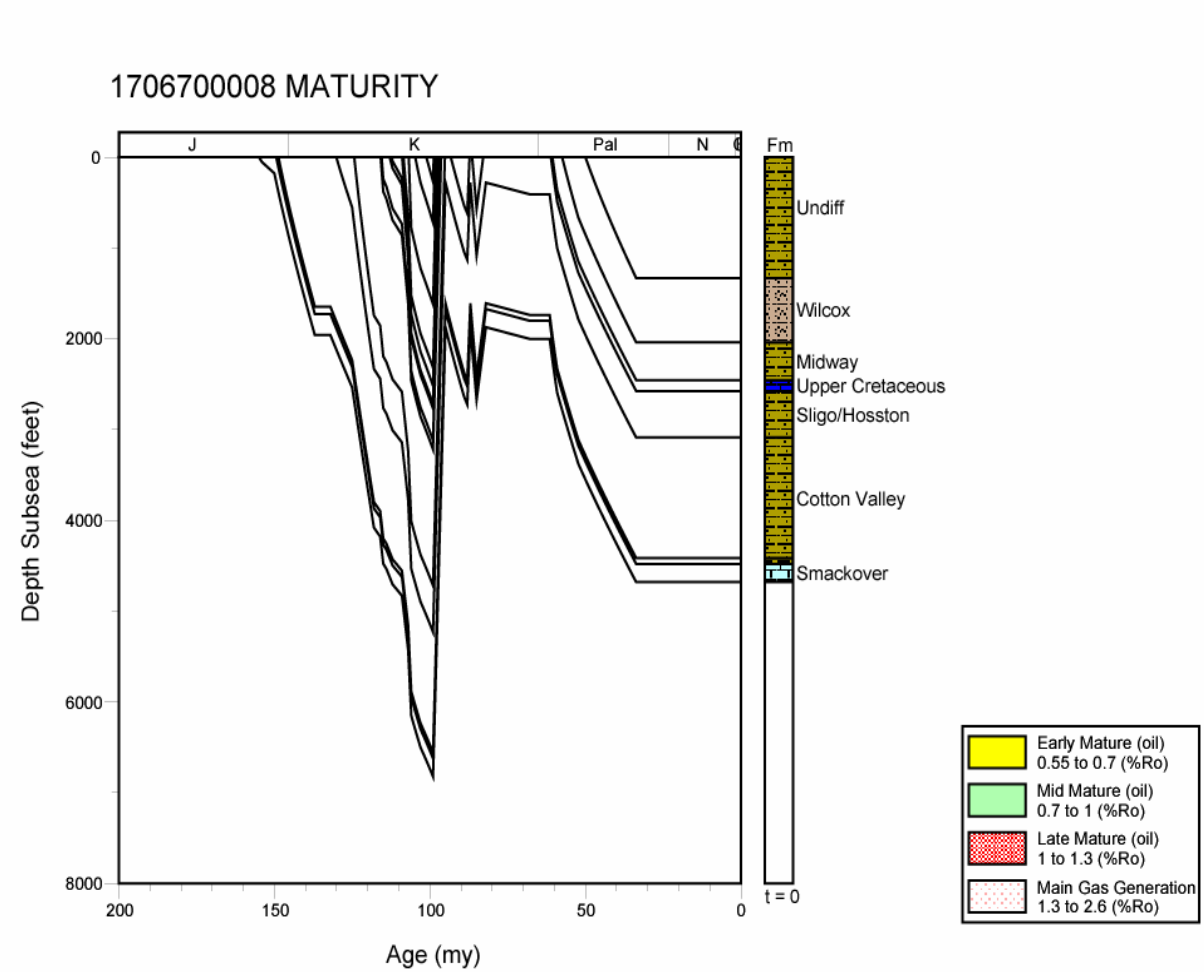

Figure 30. Thermal maturation profile for well 1706700008, North Louisiana Salt Basin.

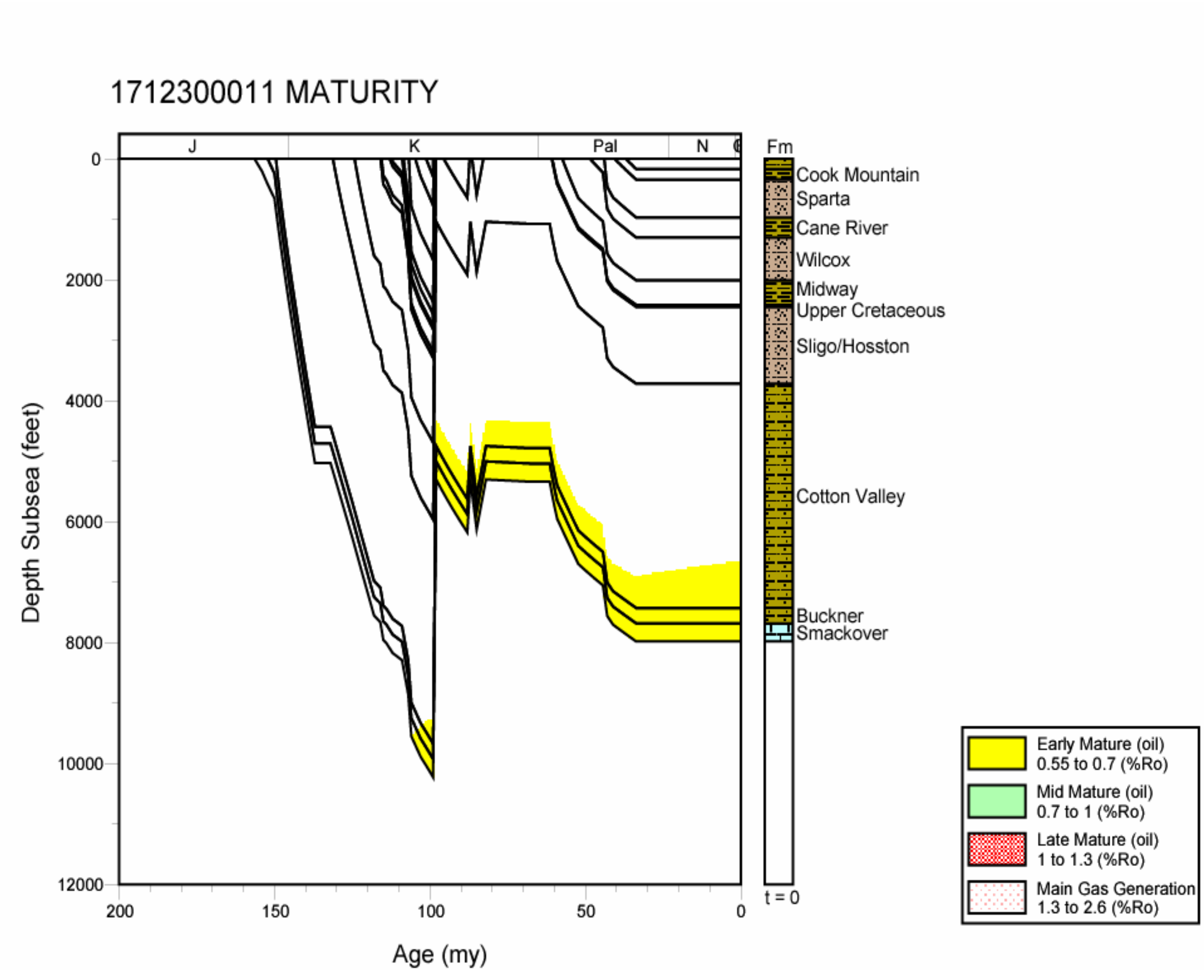

Figure 31. Thermal maturation profile for well 1712300011, North Louisiana Salt Basin.

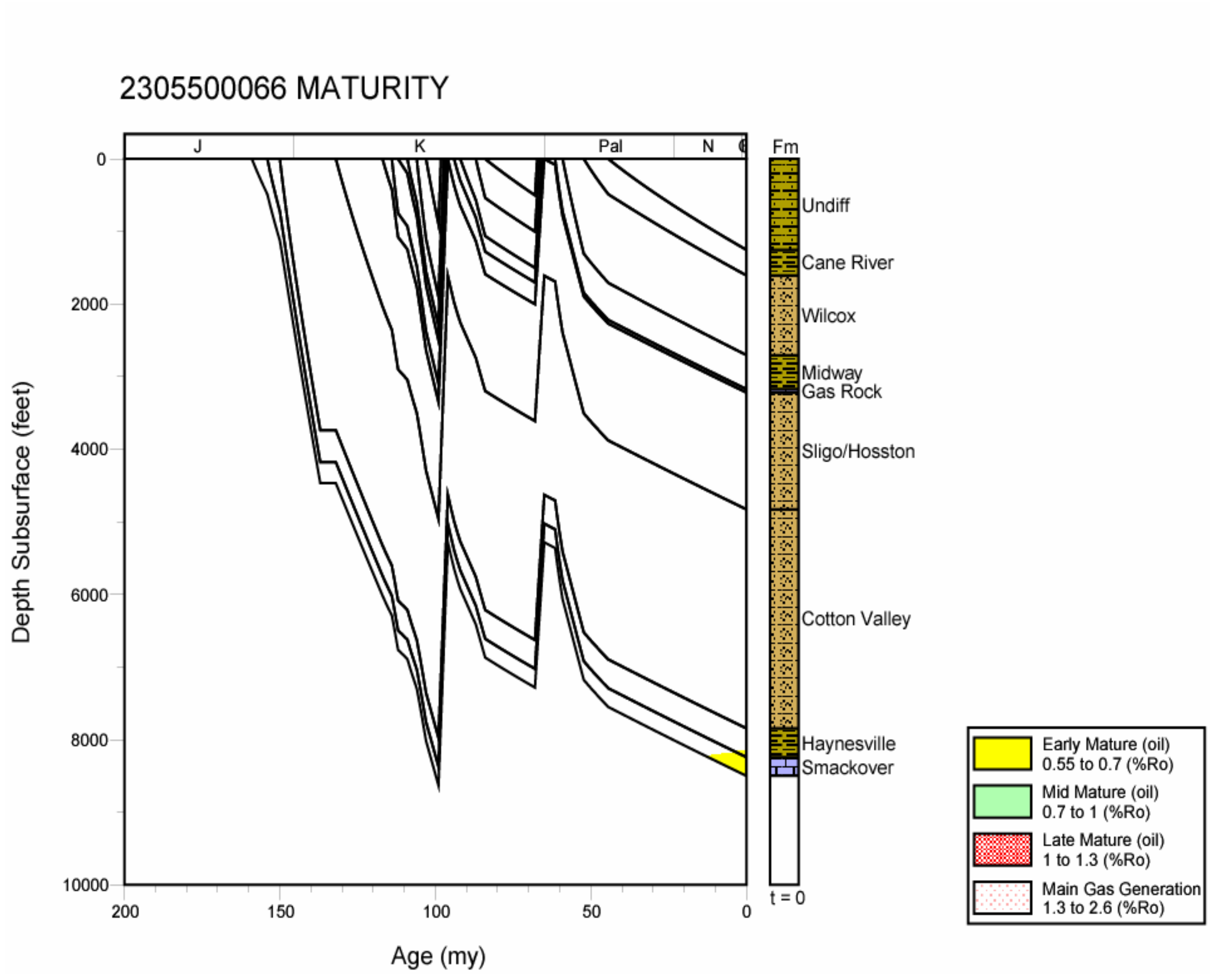

Figure 32. Thermal maturation profile for well 2305500066, Mississippi Interior Salt Basin.

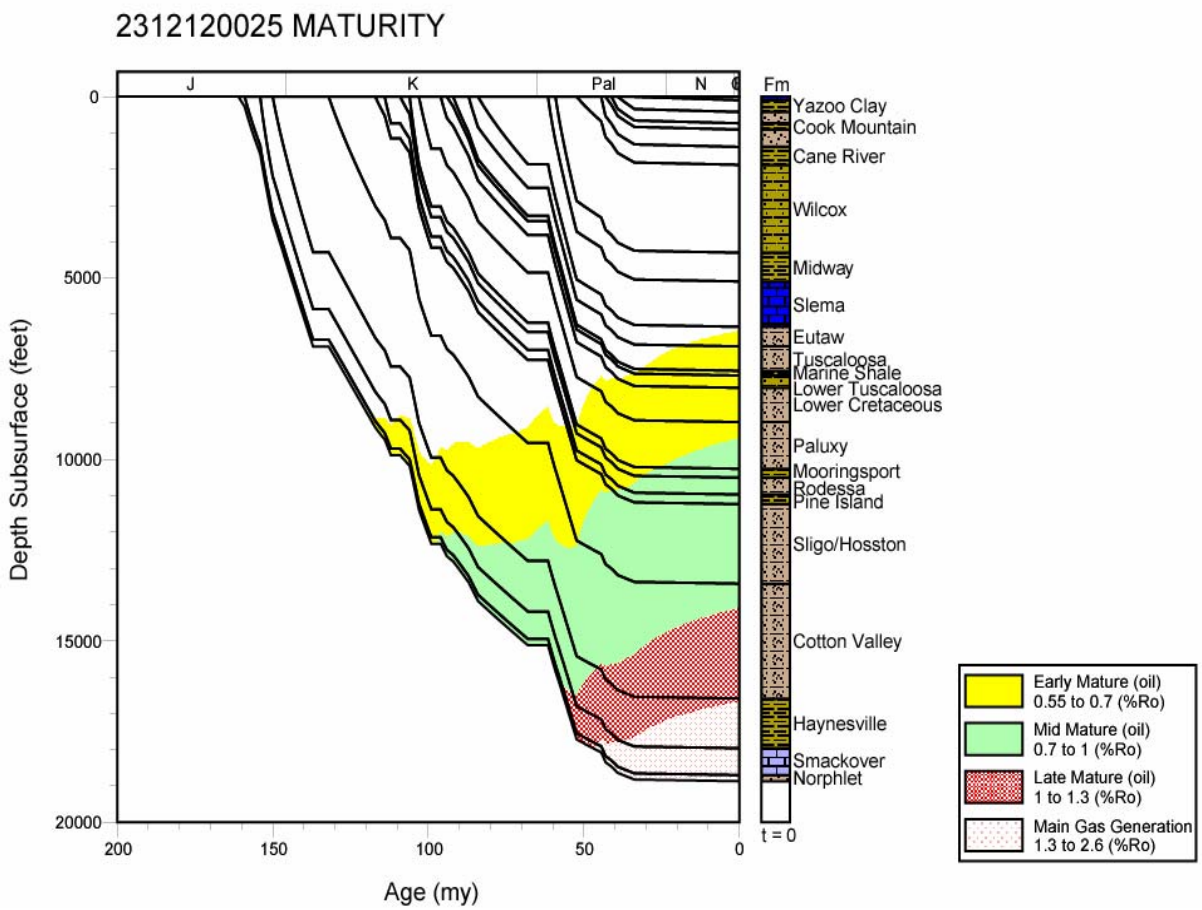

Figure 33. Thermal maturation profile for well 2312120025, Mississippi Interior Salt Basin.

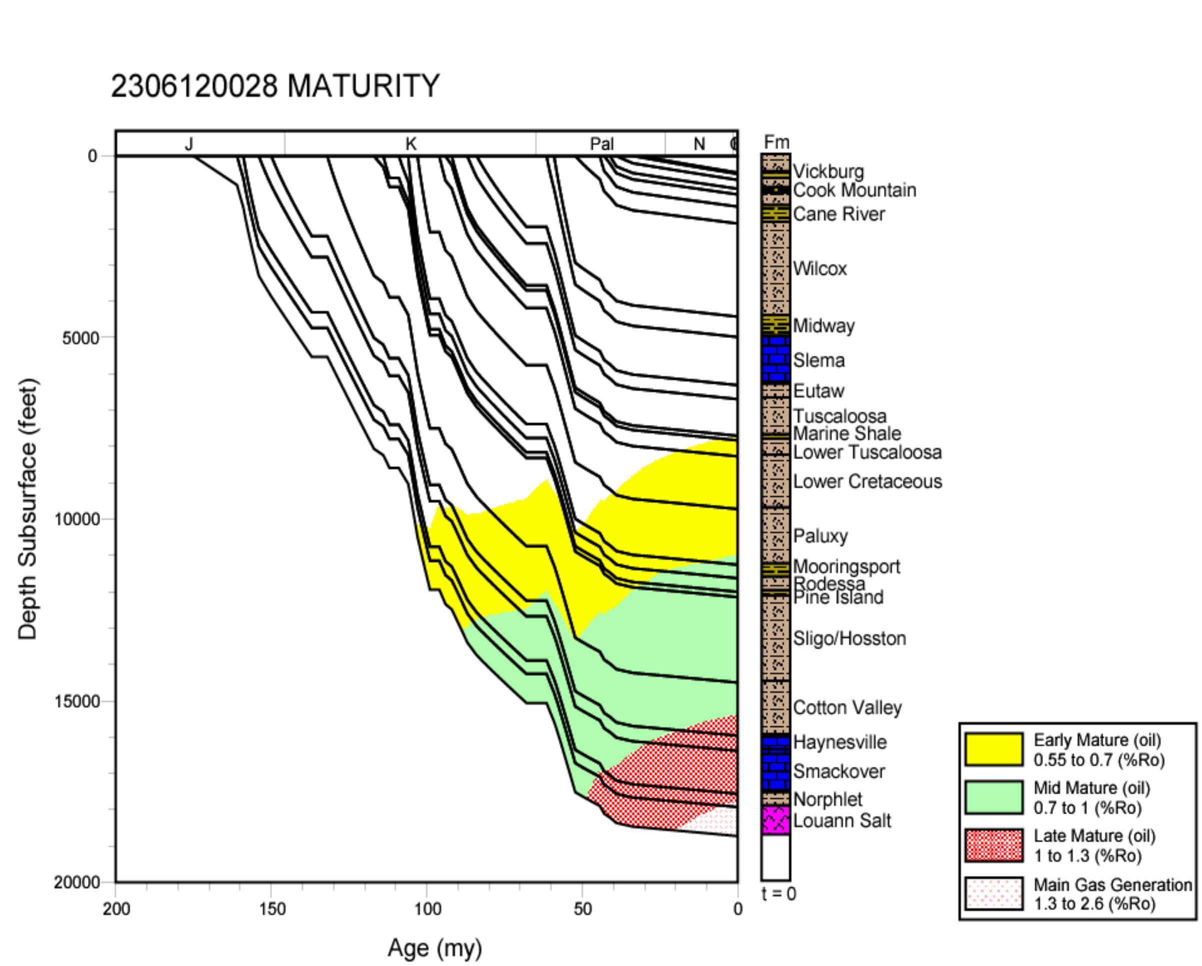

Figure 34. Thermal maturation profile for well 2306120028, Mississippi Interior Salt Basin.

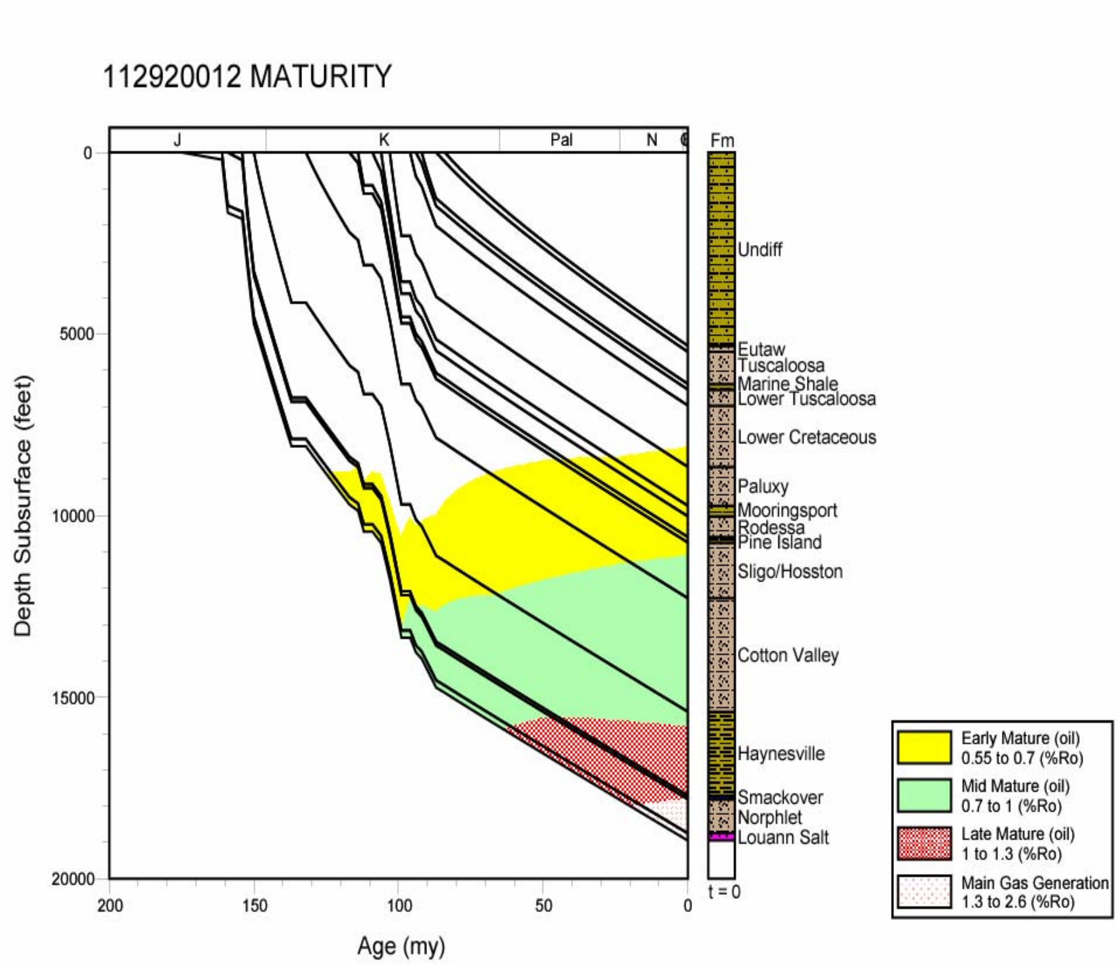

Figure 35. Thermal maturation profile for well 112920012, Mississippi Interior Salt Basin.

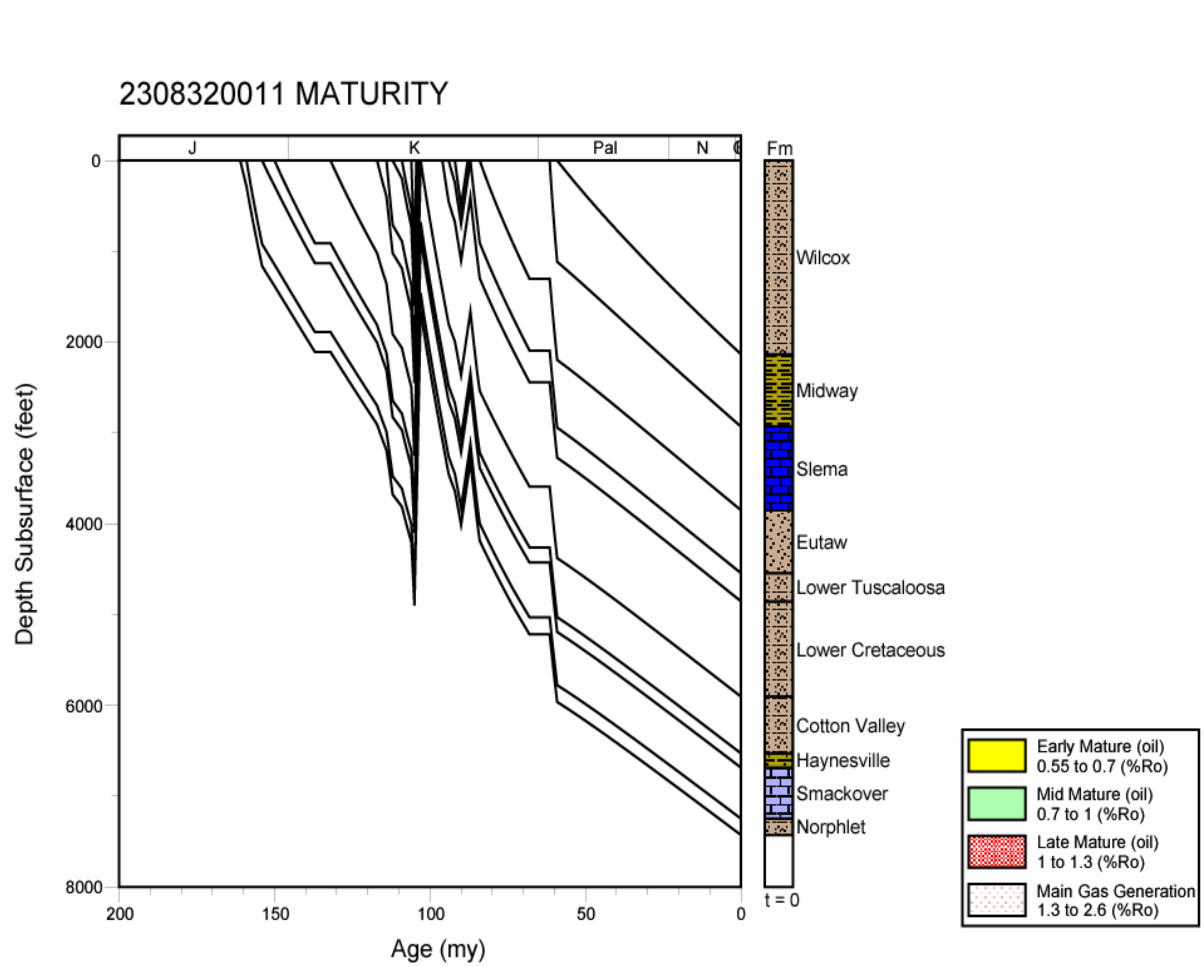

Figure 36. Thermal maturation profile for well 2308320011, Mississippi Interior Salt Basin.

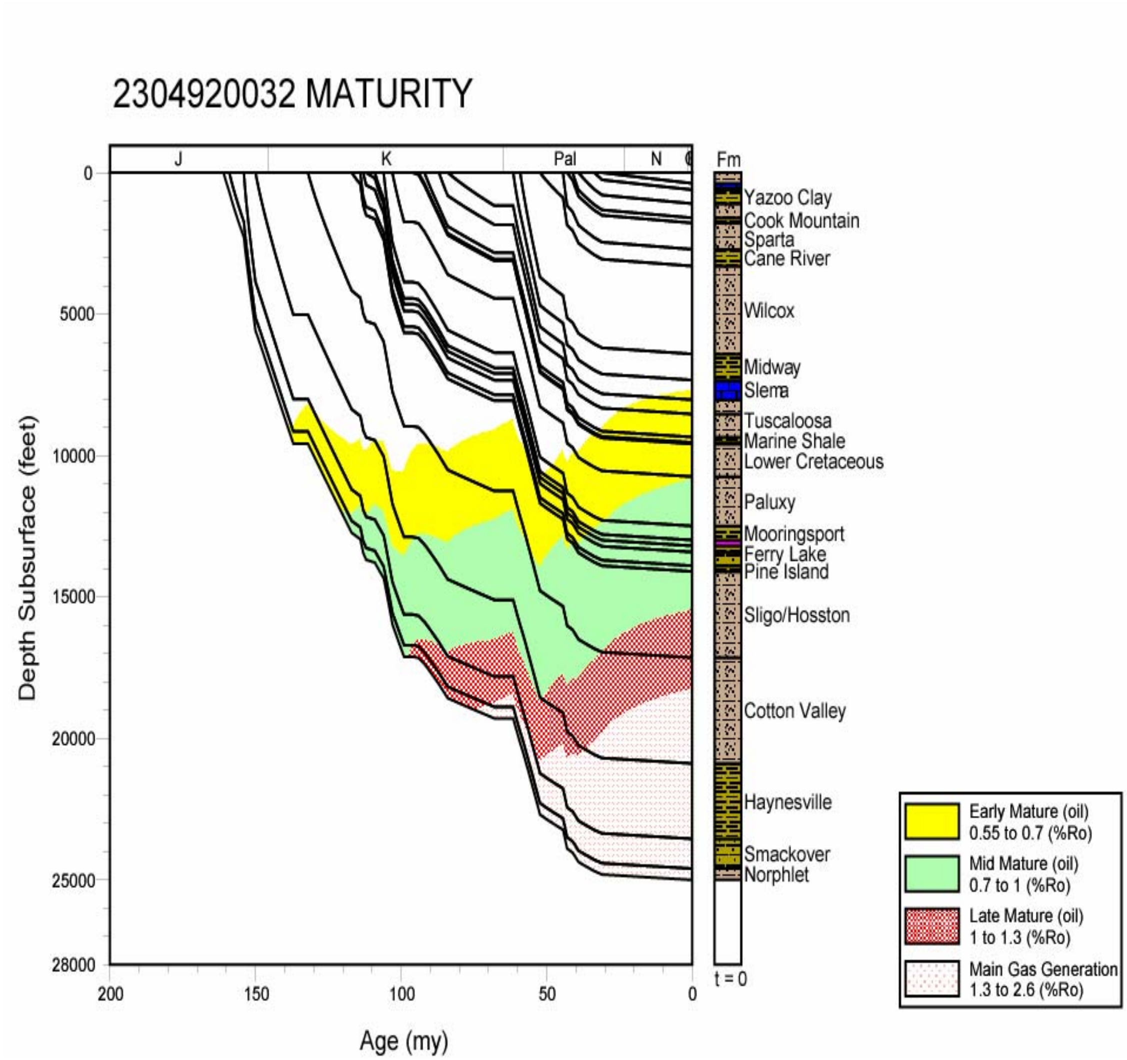

Figure 37. Thermal maturation profile for well 2304920032, Mississippi Interior Salt Basin.

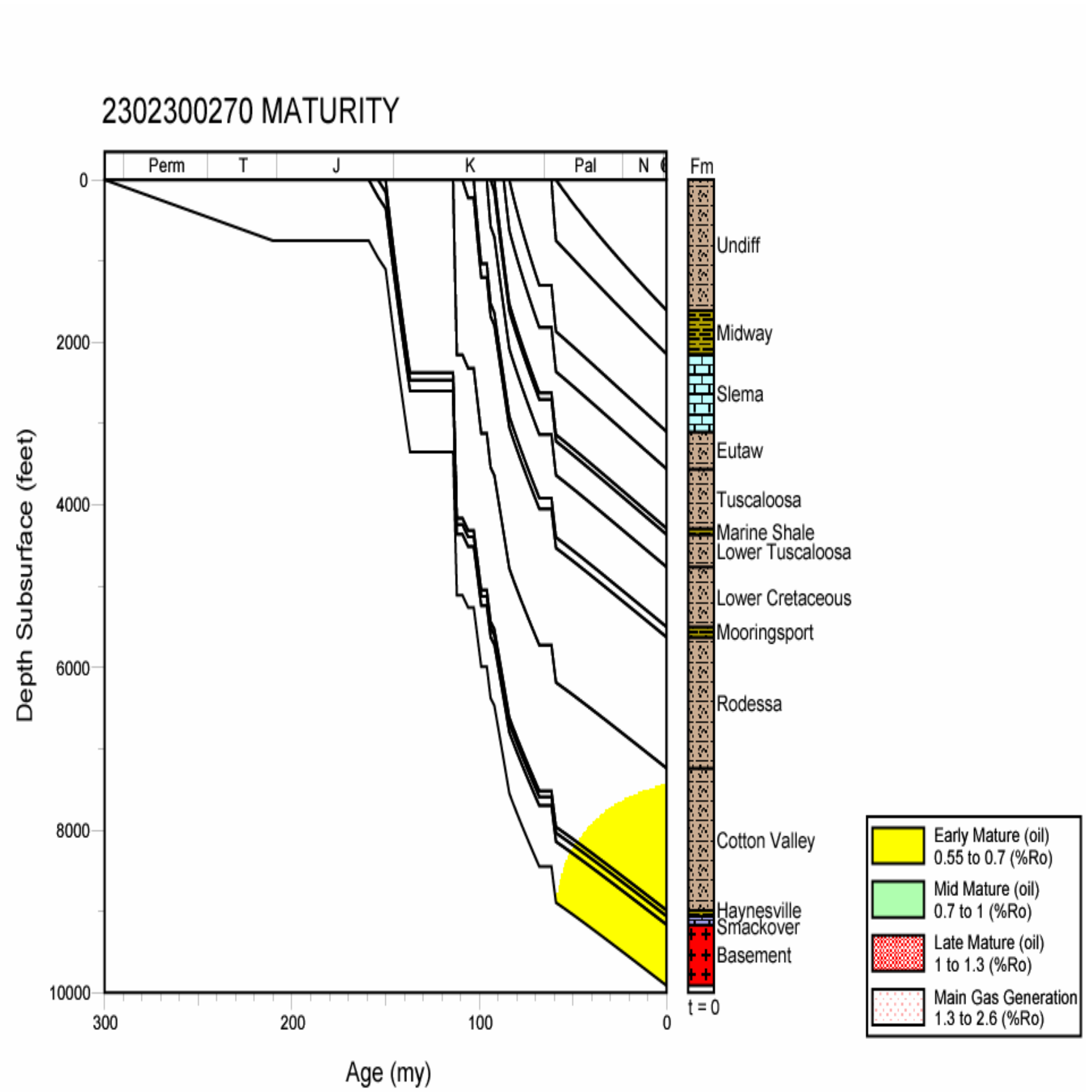

Figure 38. Thermal maturation profile for well 2302300270, Mississippi Interior Salt Basin.

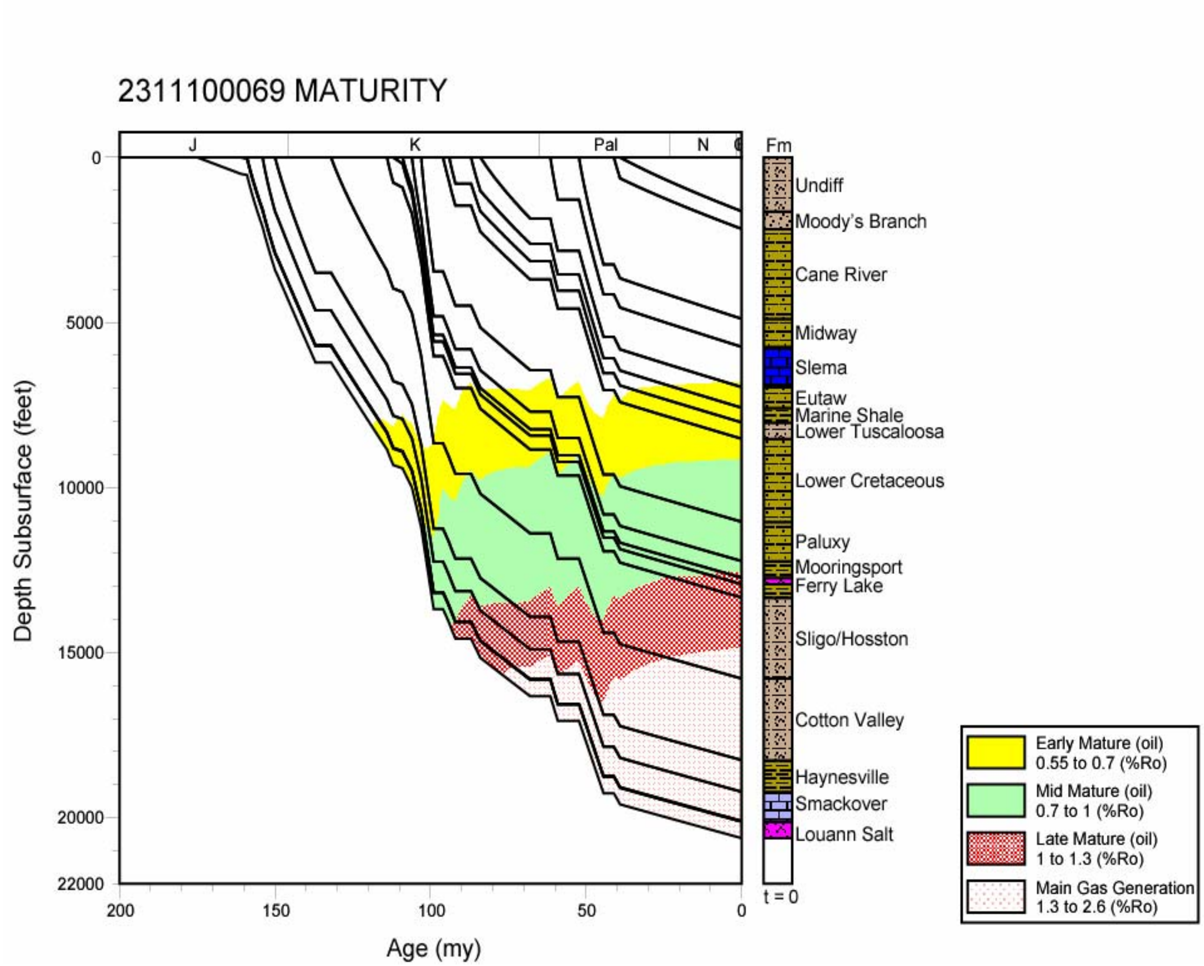

Figure 39. Thermal maturation profile for well 2311100069, Mississippi Interior Salt Basin.

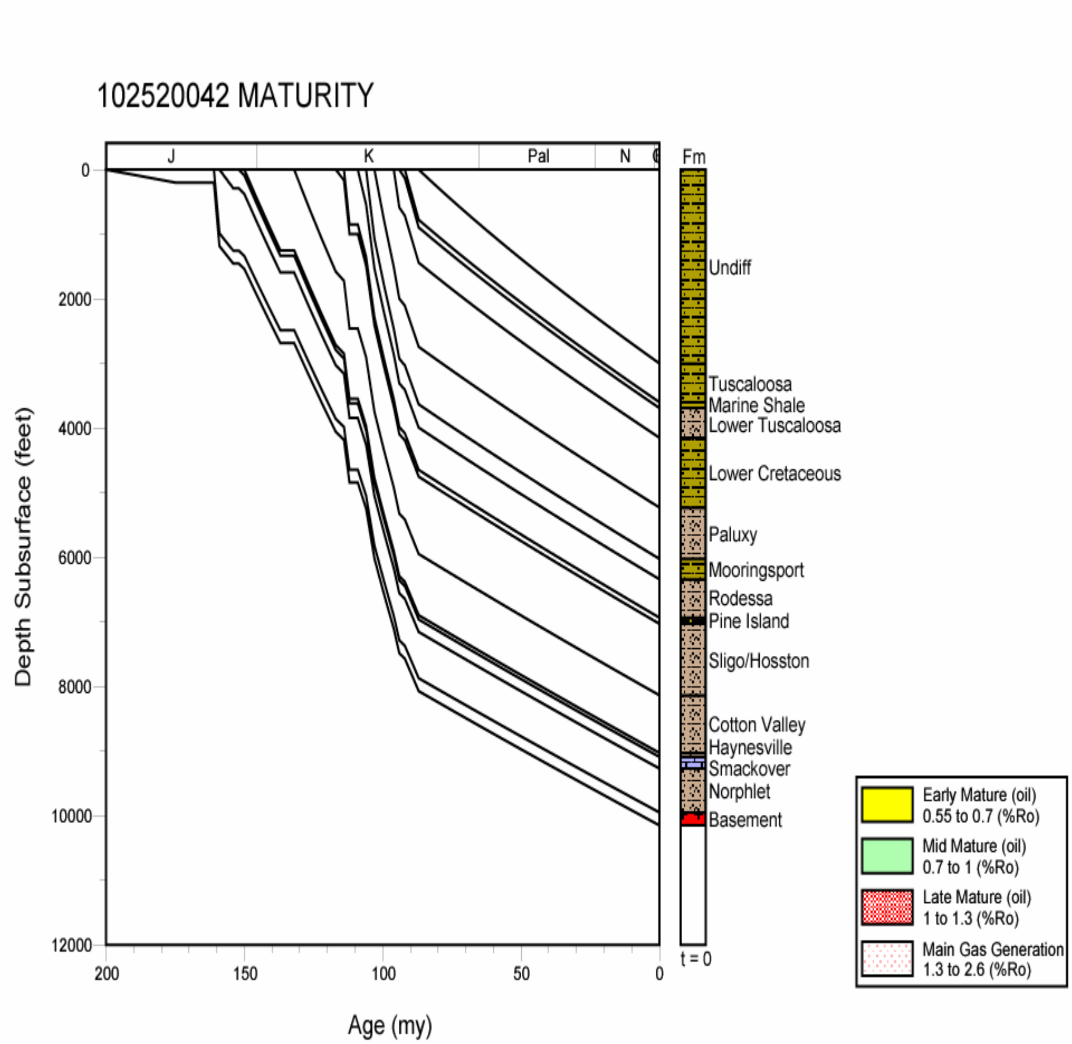

Figure 40. Thermal maturation profile for well 102520042, Manila Subbasin.

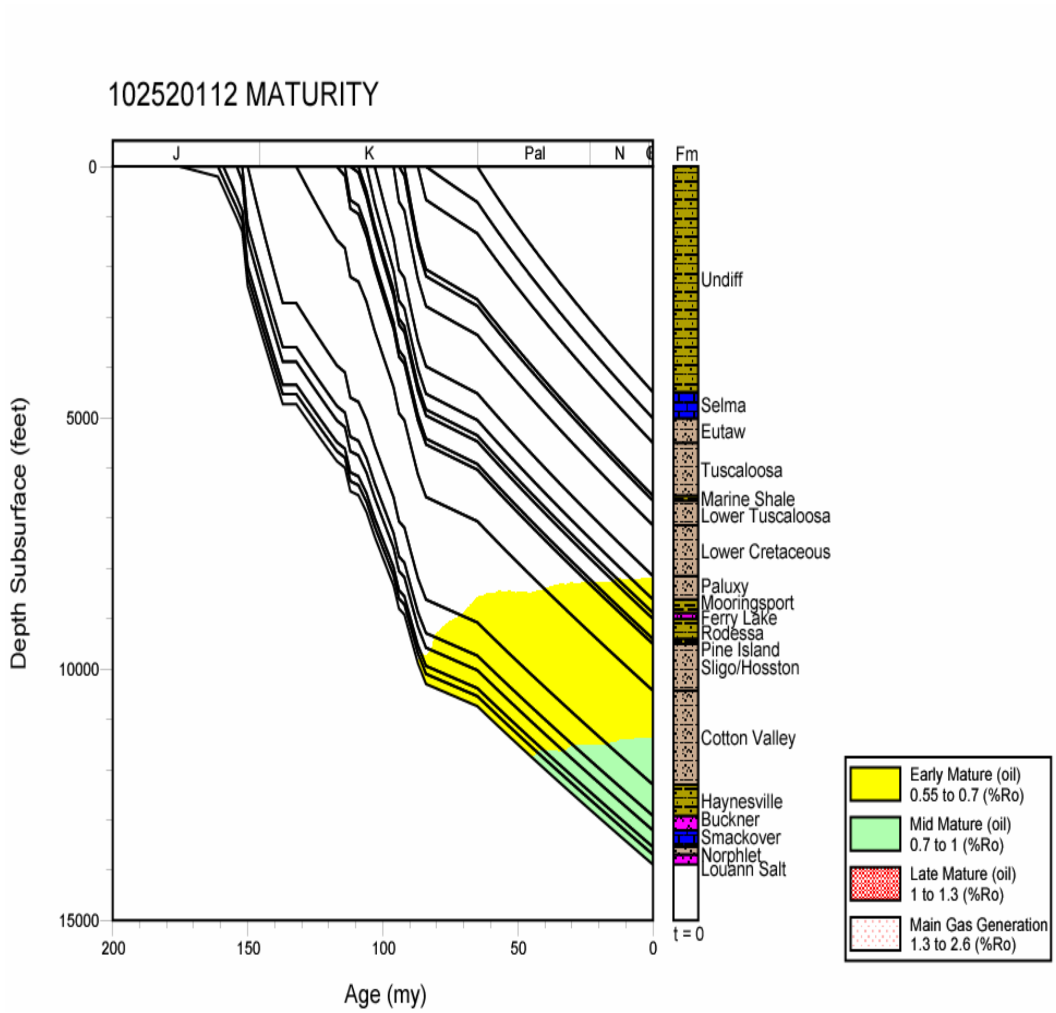

Figure 41. Thermal maturation profile for well 102520112, Manila Subbasin.

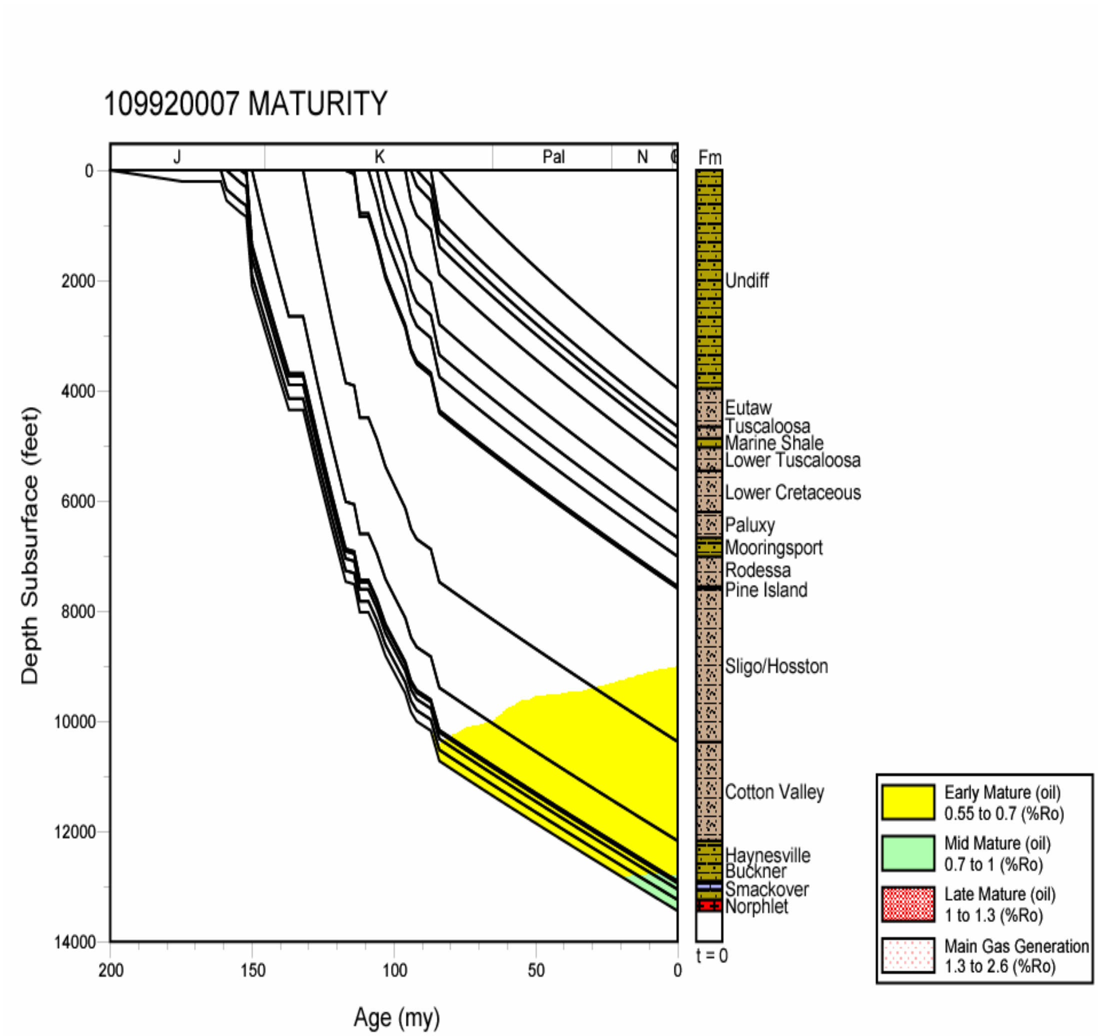

Figure 42. Thermal maturation profile for well 109920007, Manila Subbasin.

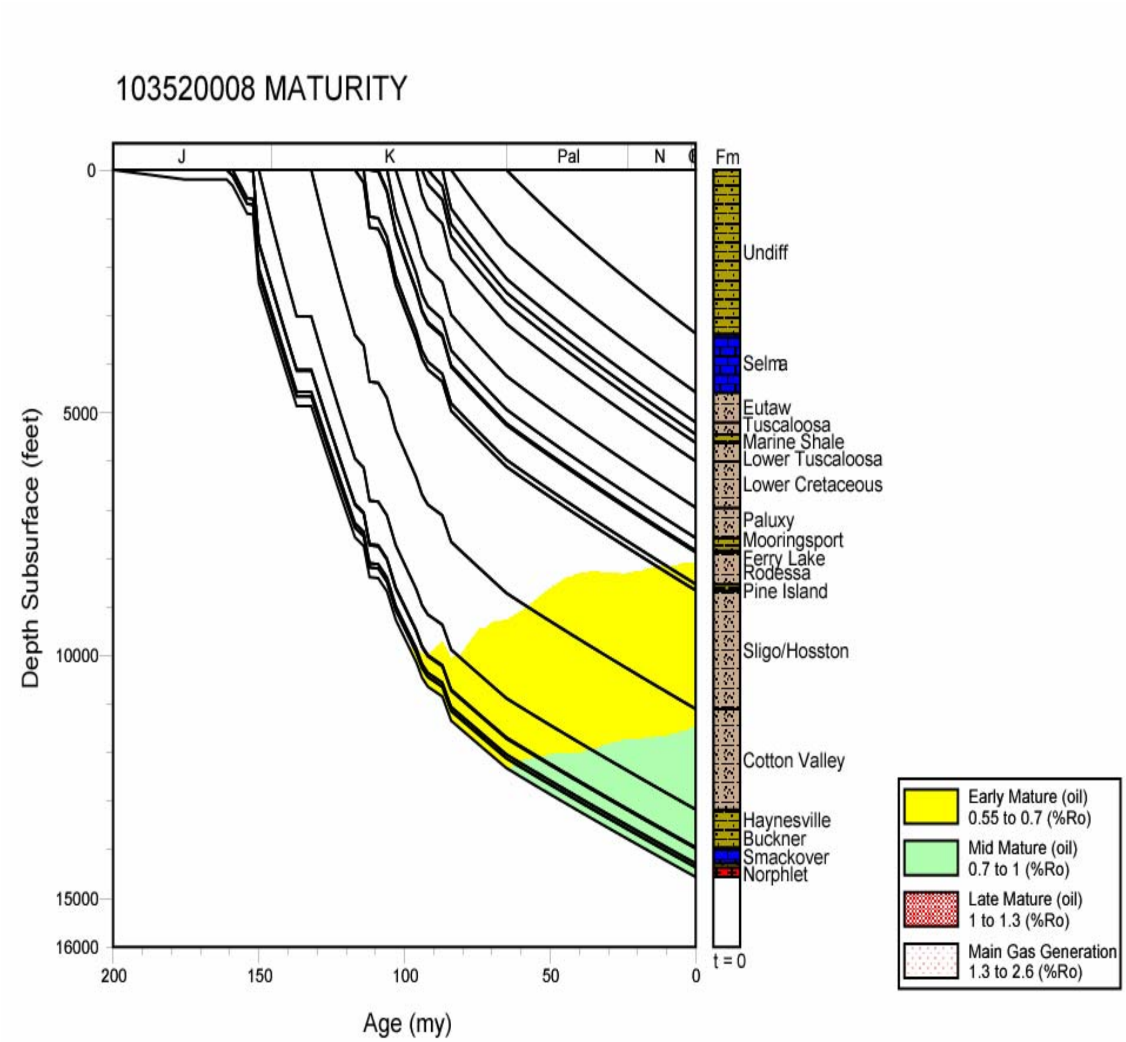

Figure 43. Thermal maturation profile for well 103520008, Conecuh Subbasin.

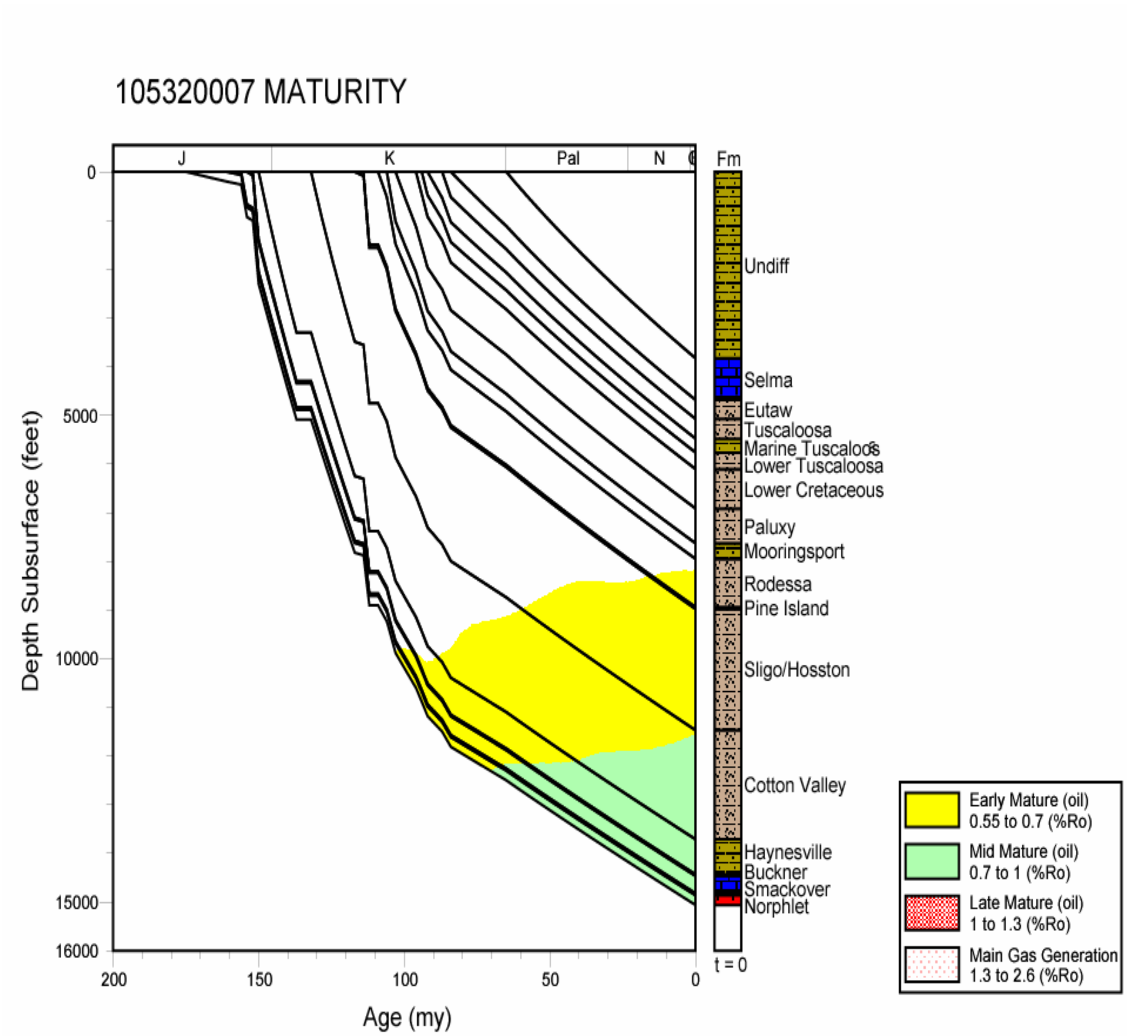

Figure 44. Thermal maturation profile for well 105320007, Conecuh Subbasin.

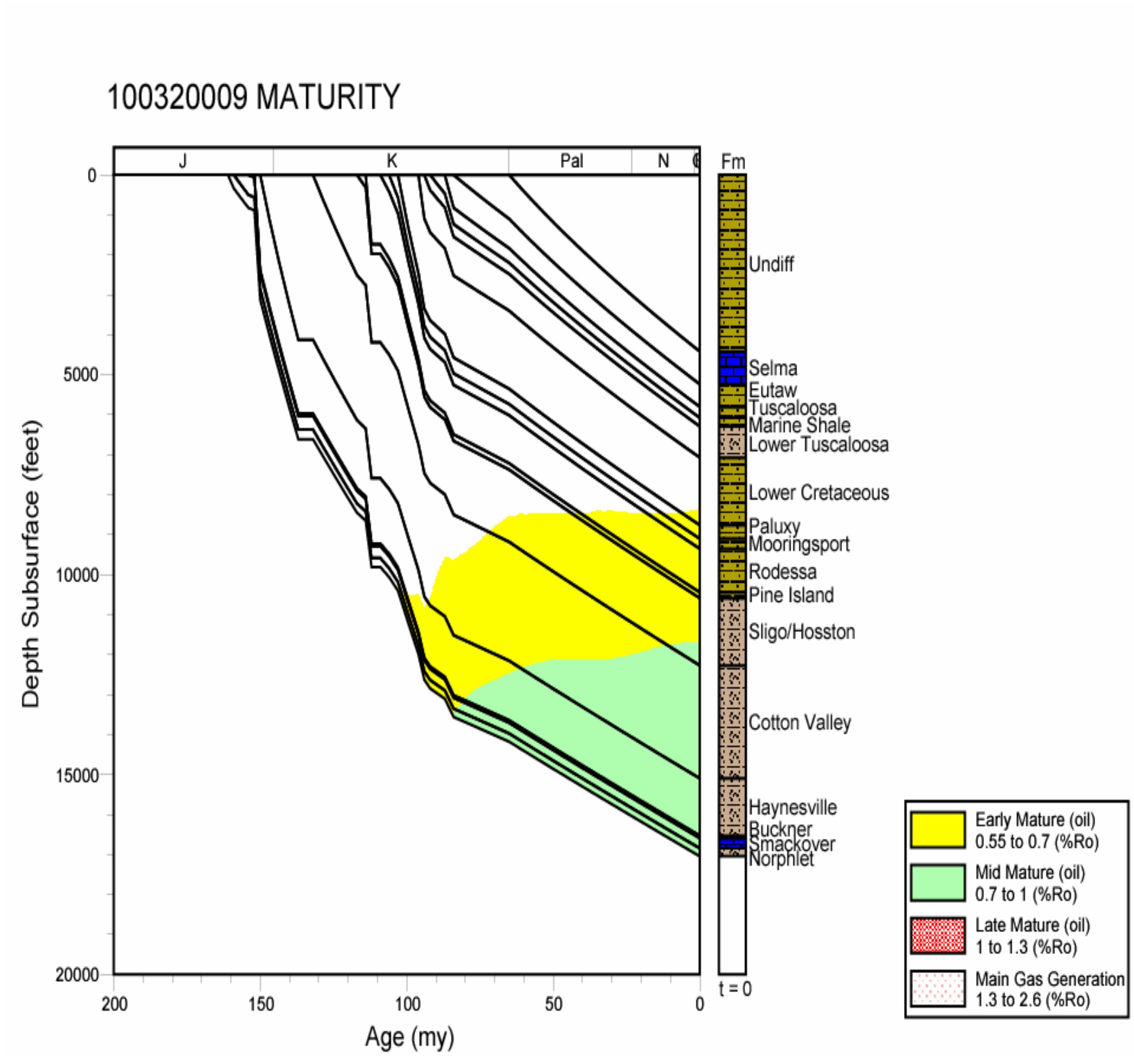

Figure 45. Thermal maturation profile for well 1003220009, Conecuh Subbasin.

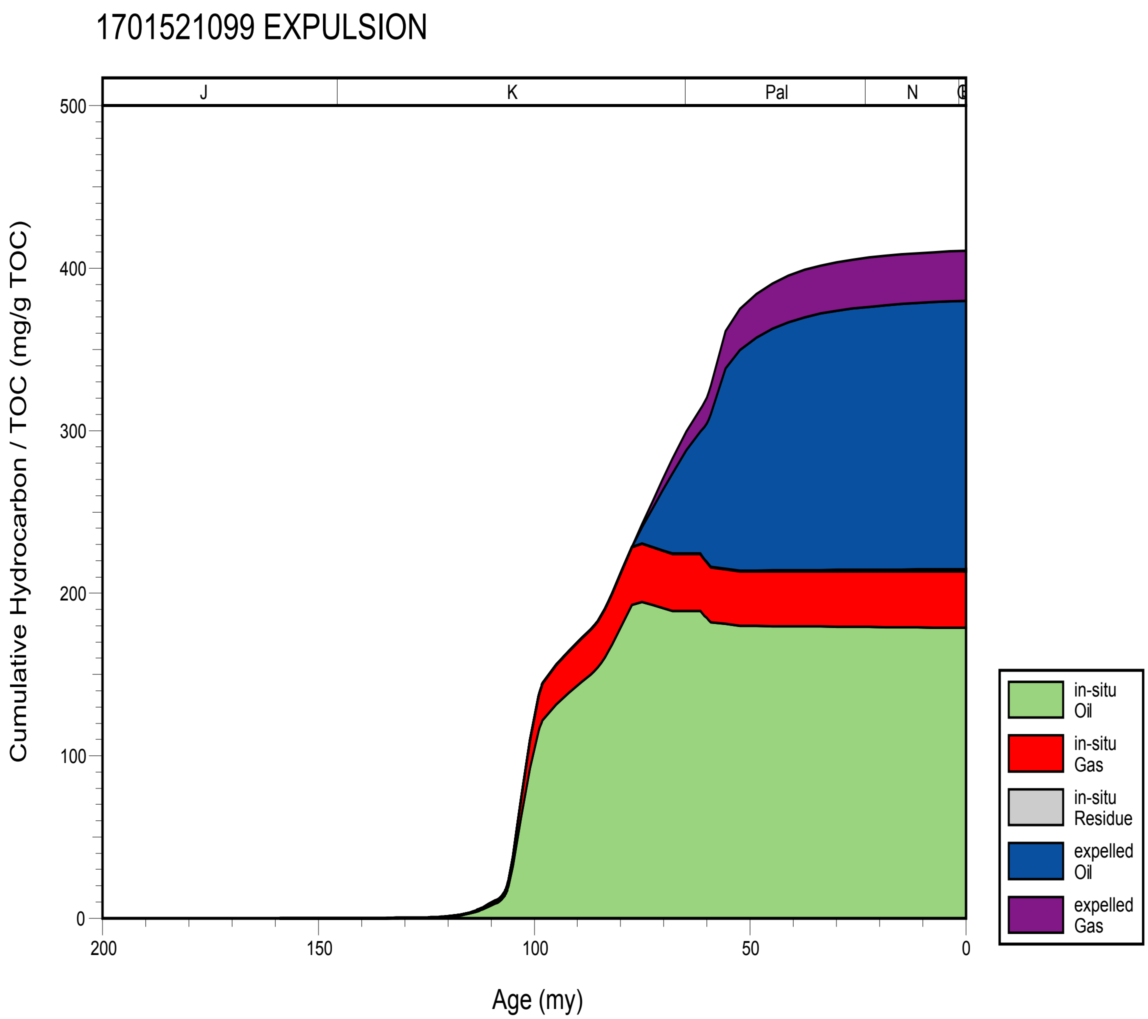

Figure 46. Hydrocarbon expulsion plot for well 1701521099, North Louisiana Salt Basin.

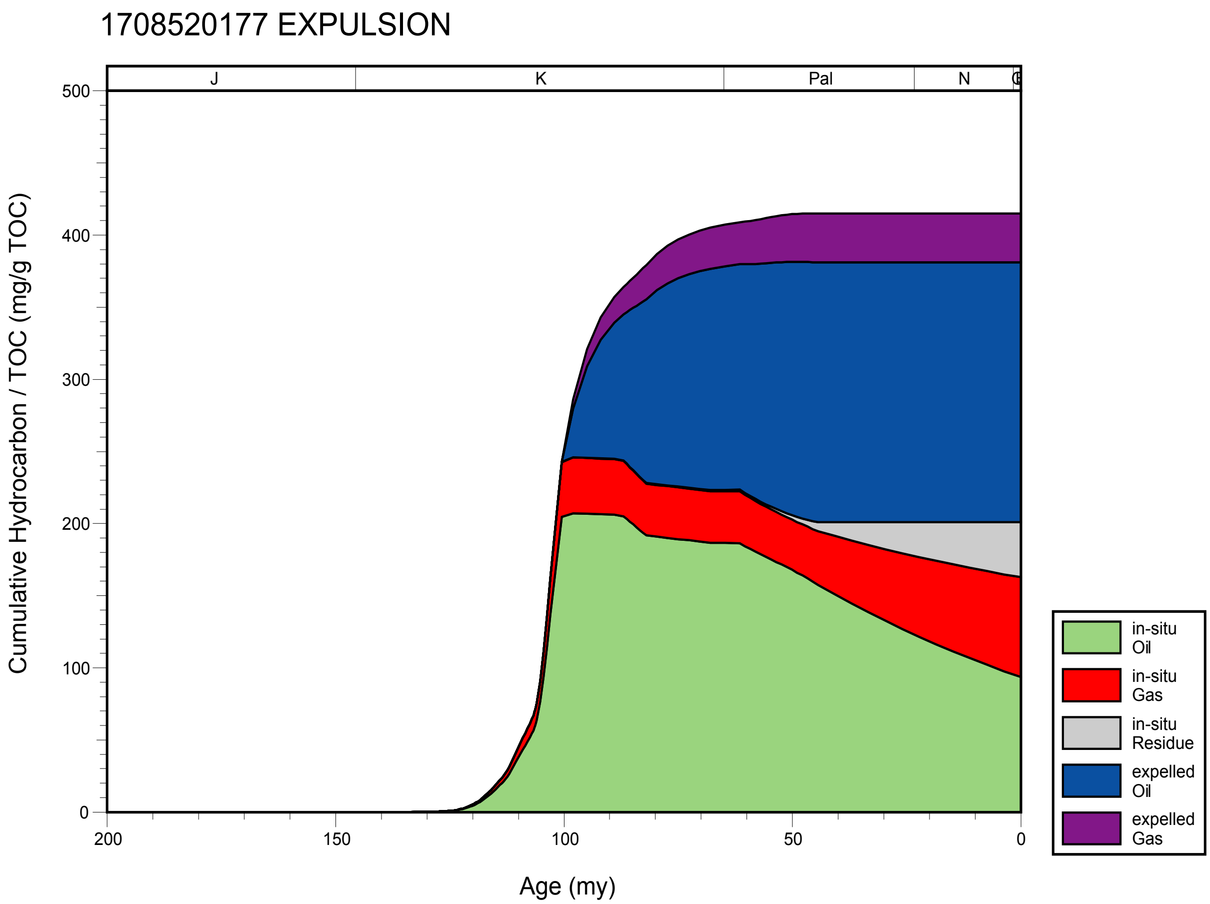

Figure 47. Hydrocarbon expulsion plot for well 1708520177, North Louisiana Salt Basin.

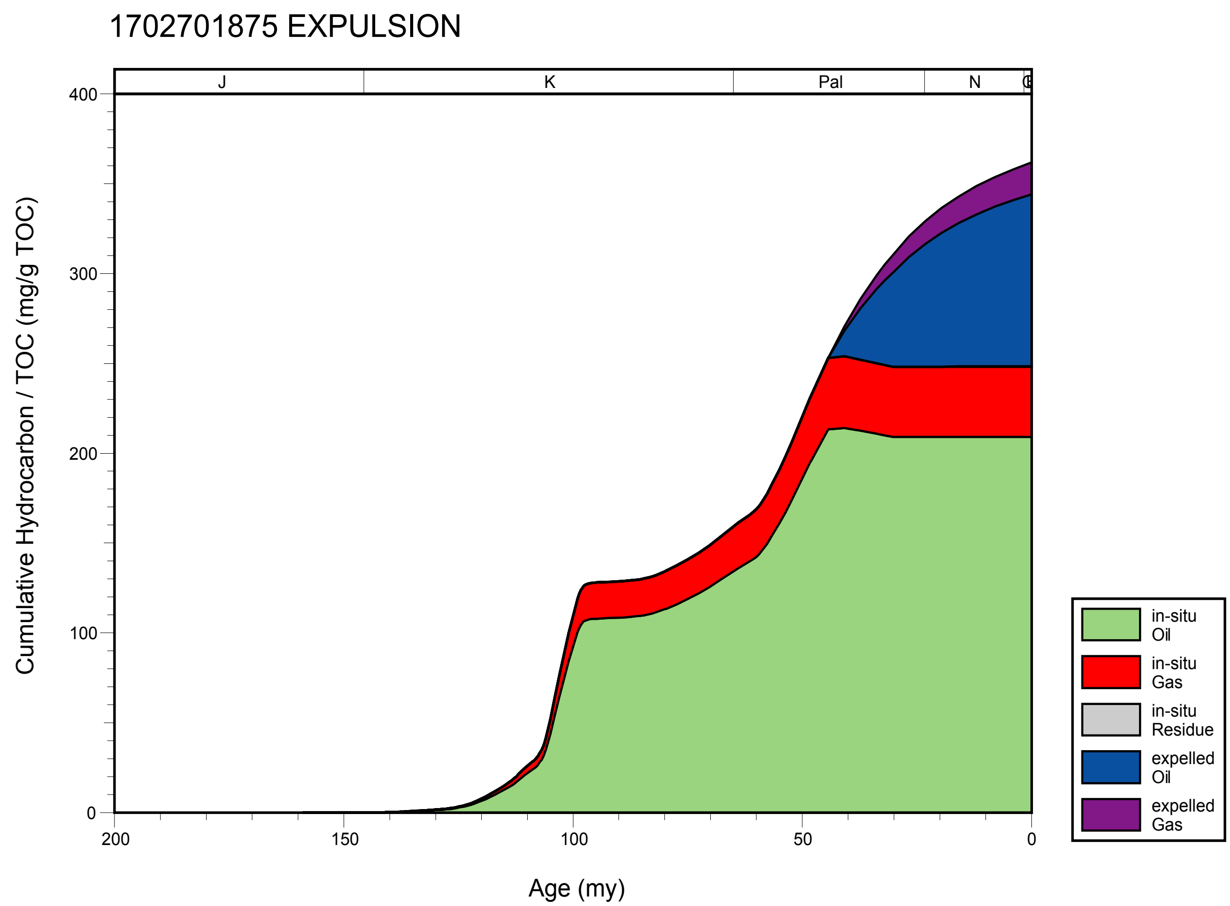

Figure 48. Hydrocarbon expulsion plot for well 1702701875, North Louisiana Salt Basin.

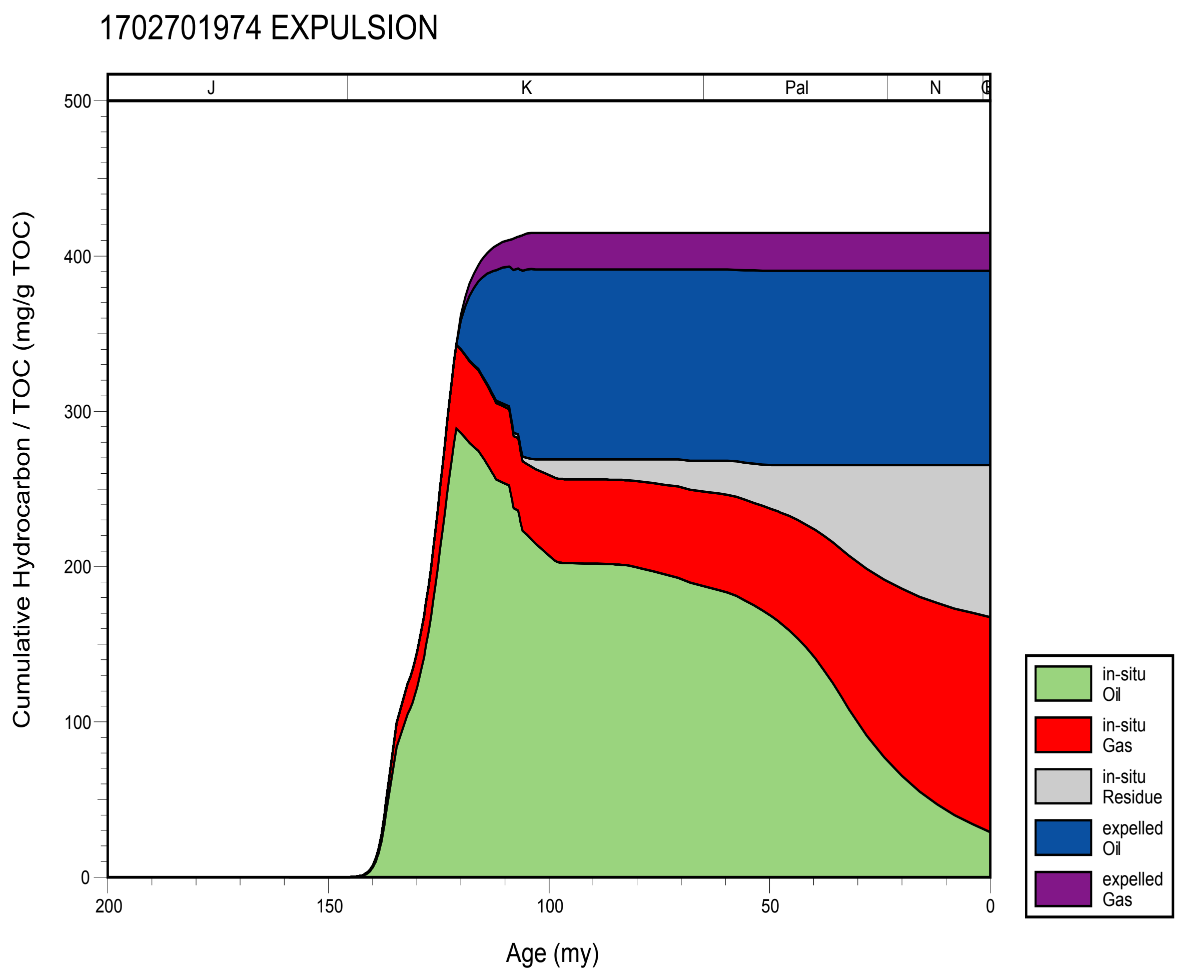

Figure 49. Hydrocarbon expulsion plot for well 1702701974, North Louisiana Salt Basin.

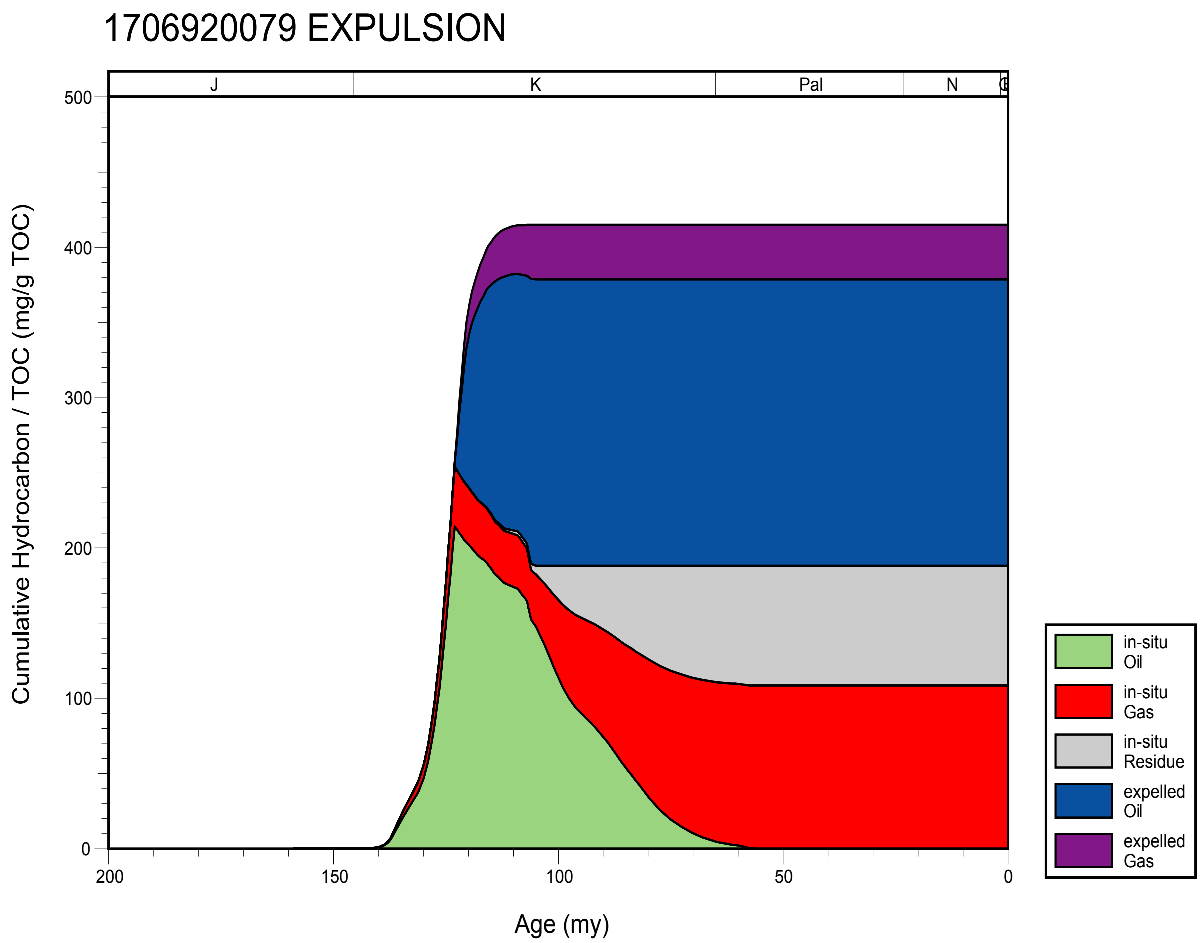

Figure 50. Hydrocarbon expulsion plot for well 1706920079, North Louisiana Salt Basin.

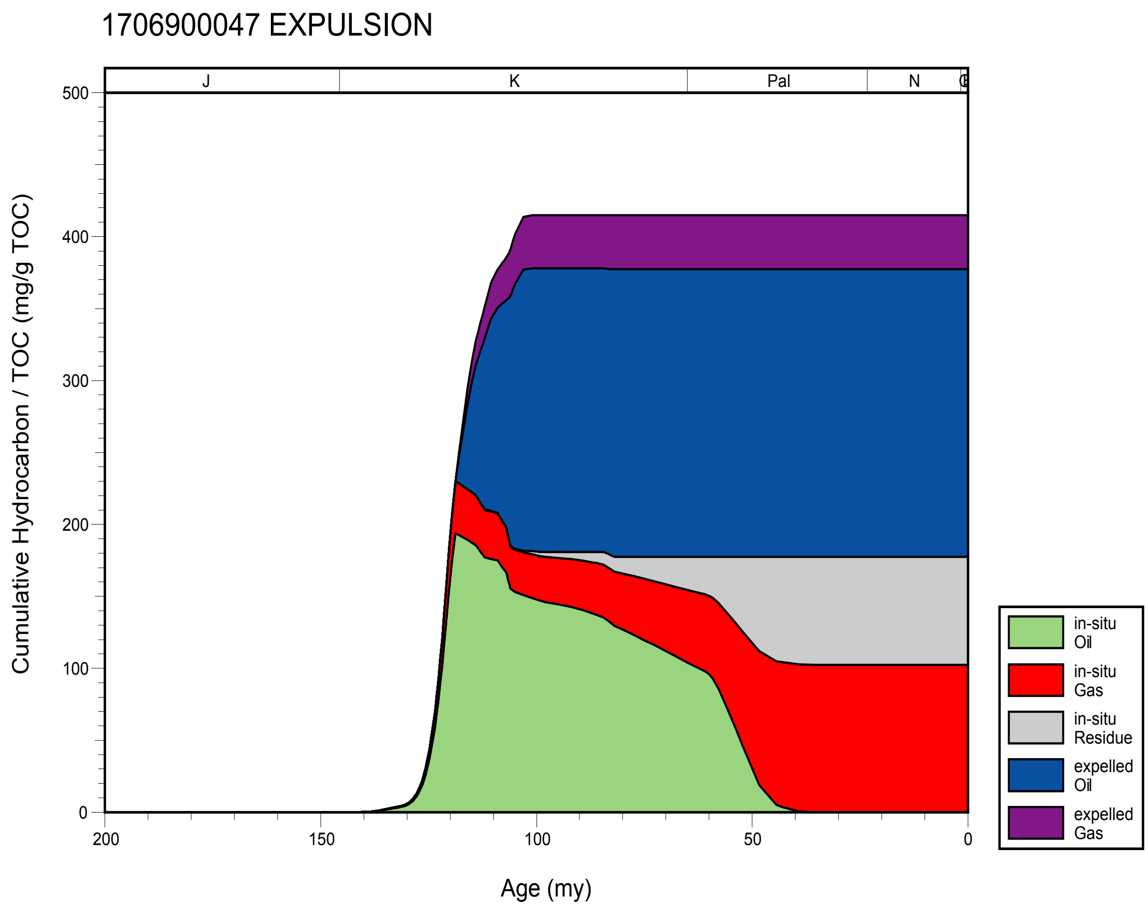

Figure 51. Hydrocarbon expulsion plot for well 1706900047, North Louisiana Salt Basin.

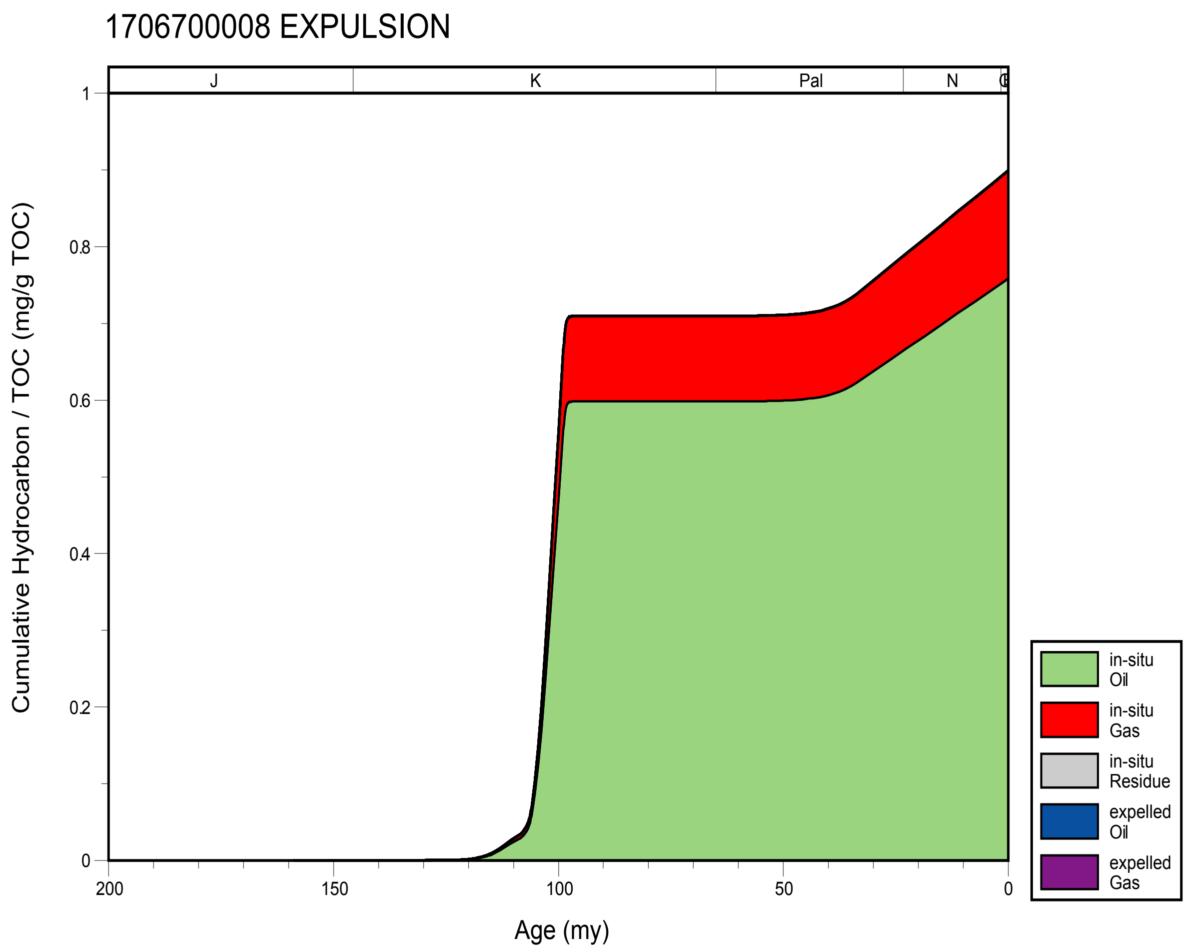

Figure 52. Hydrocarbon expulsion plot for well 1706700008, North Louisiana Salt Basin.

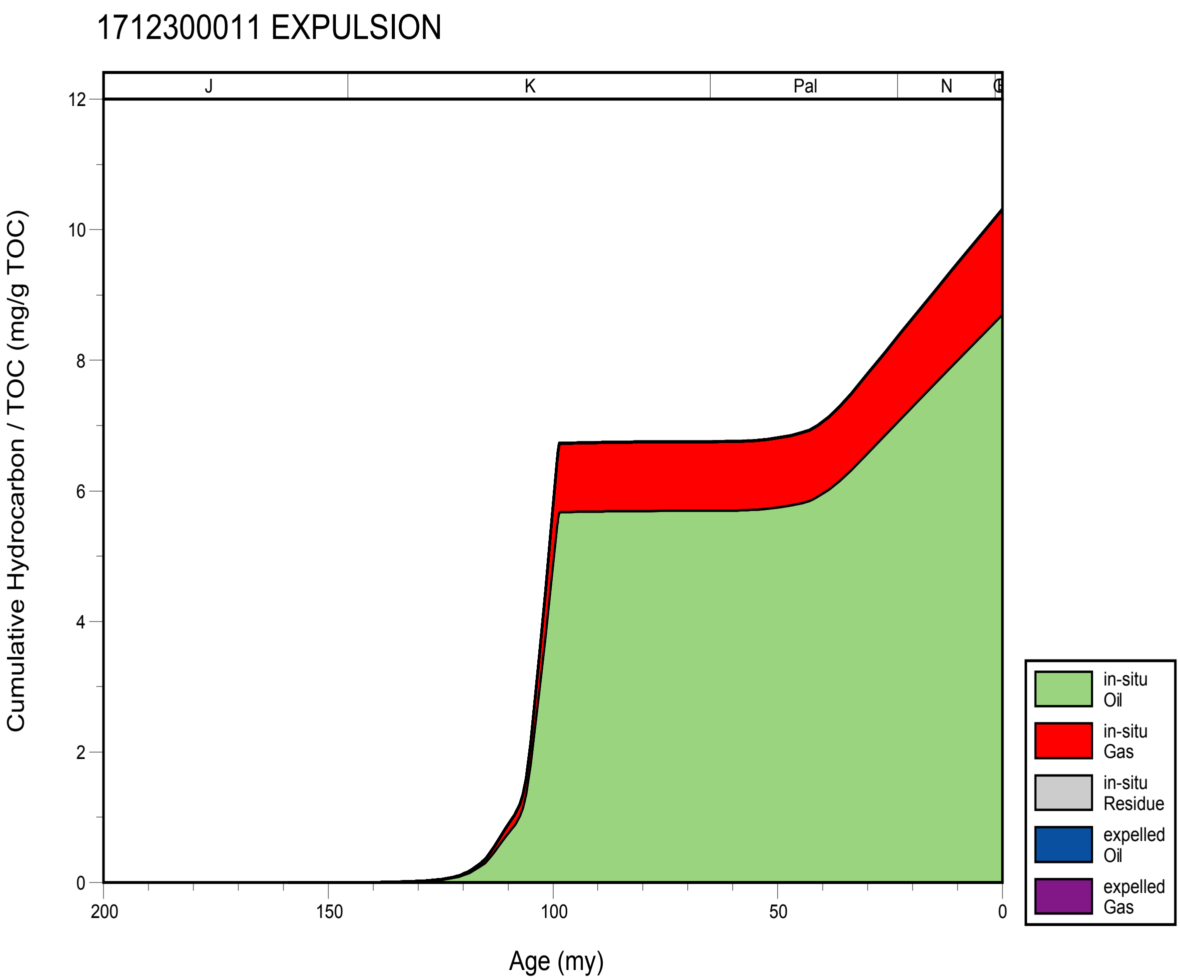

Figure 53. Hydrocarbon expulsion plot for well 1712300011, North Louisiana Salt Basin.

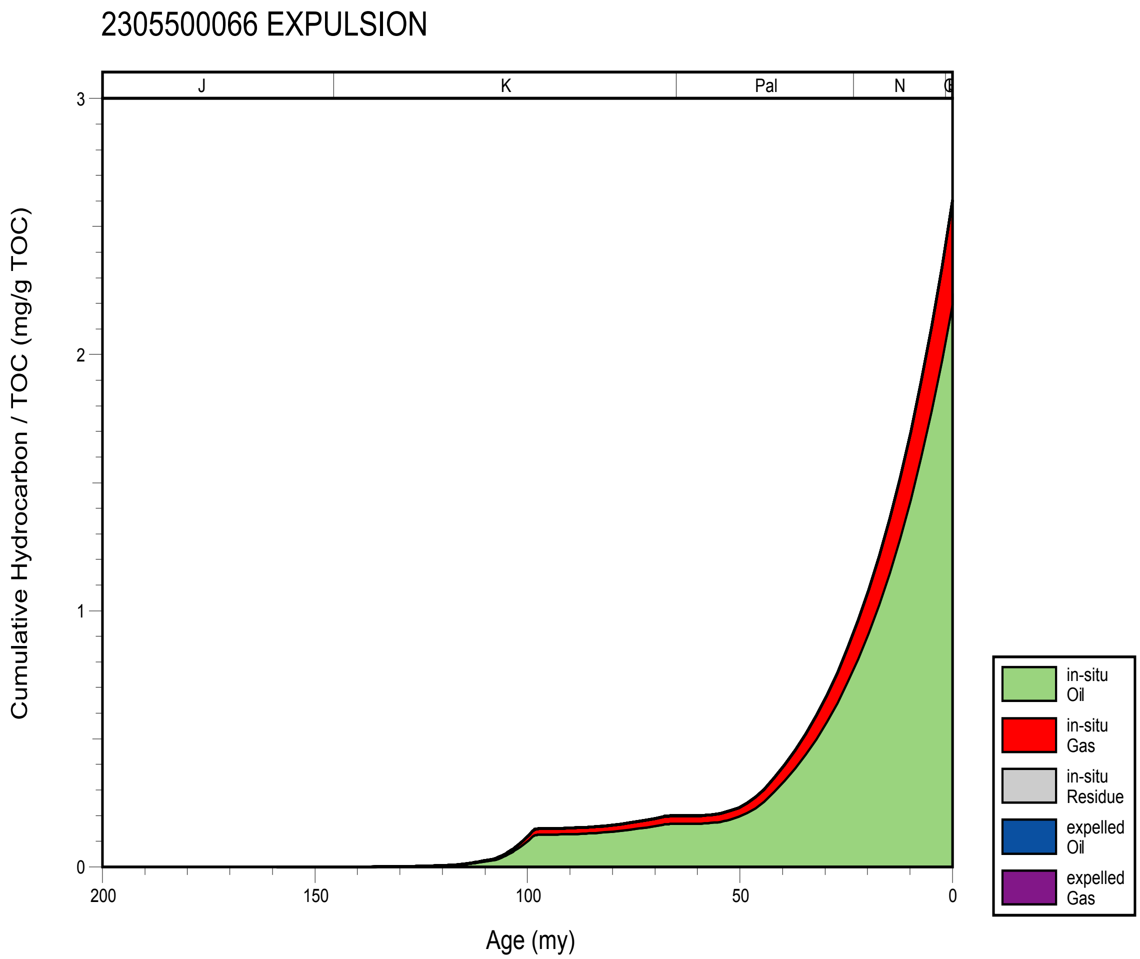

Figure 54. Hydrocarbon expulsion plot for well 2305500066, Mississippi Interior Salt Basin.

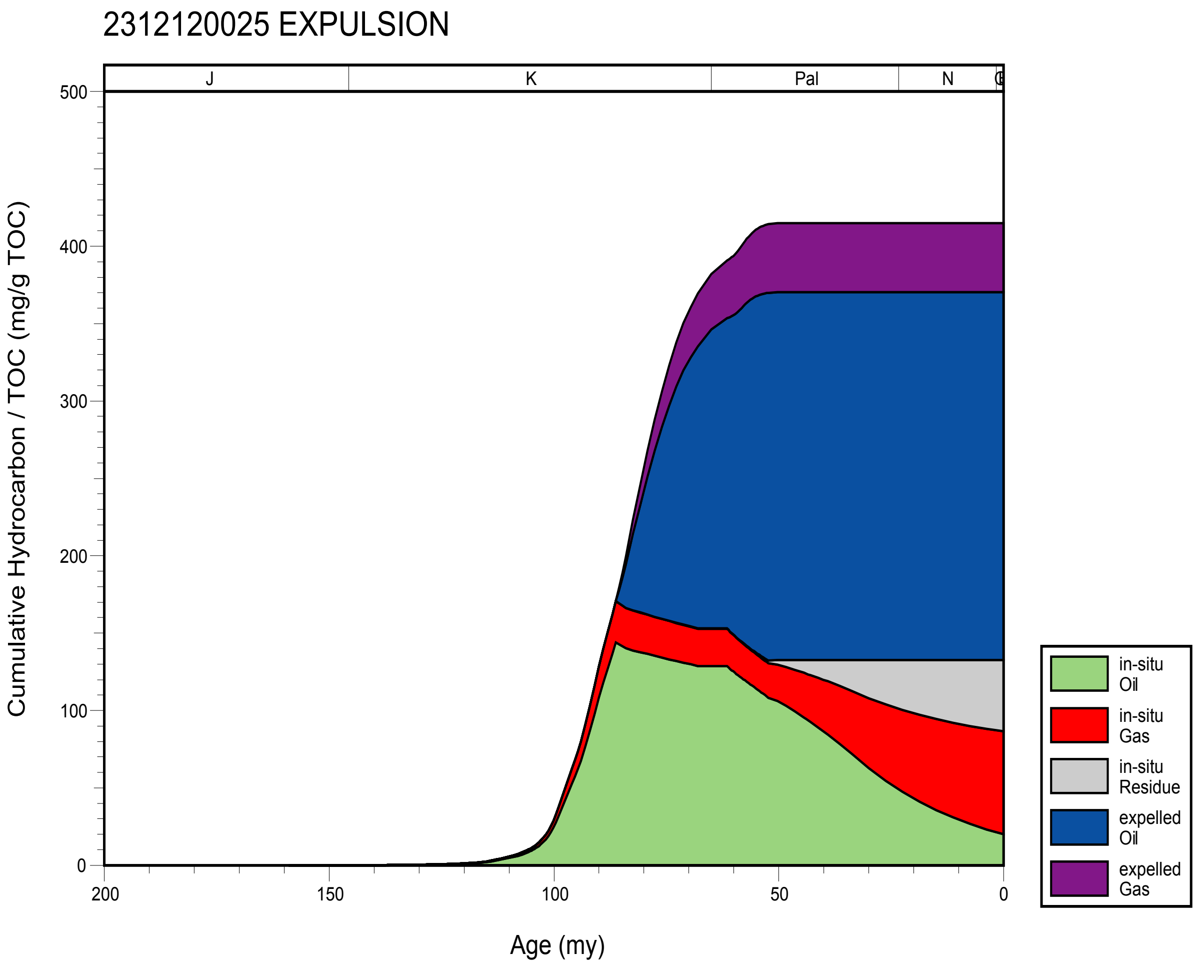

Figure 55. Hydrocarbon expulsion plot for well 2312120025, Mississippi Interior Salt Basin.

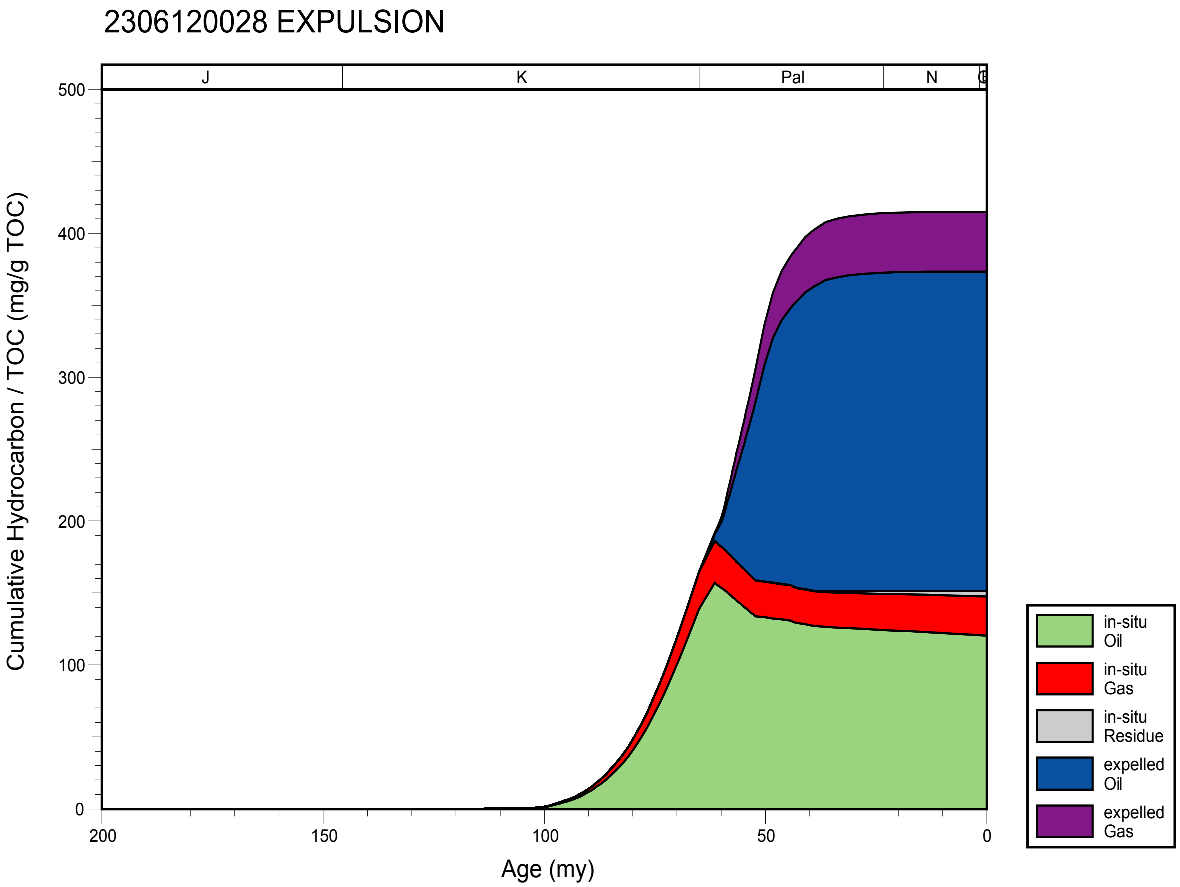

Figure 56. Hydrocarbon expulsion plot for well 2306120028, Mississippi Interior Salt Basin.

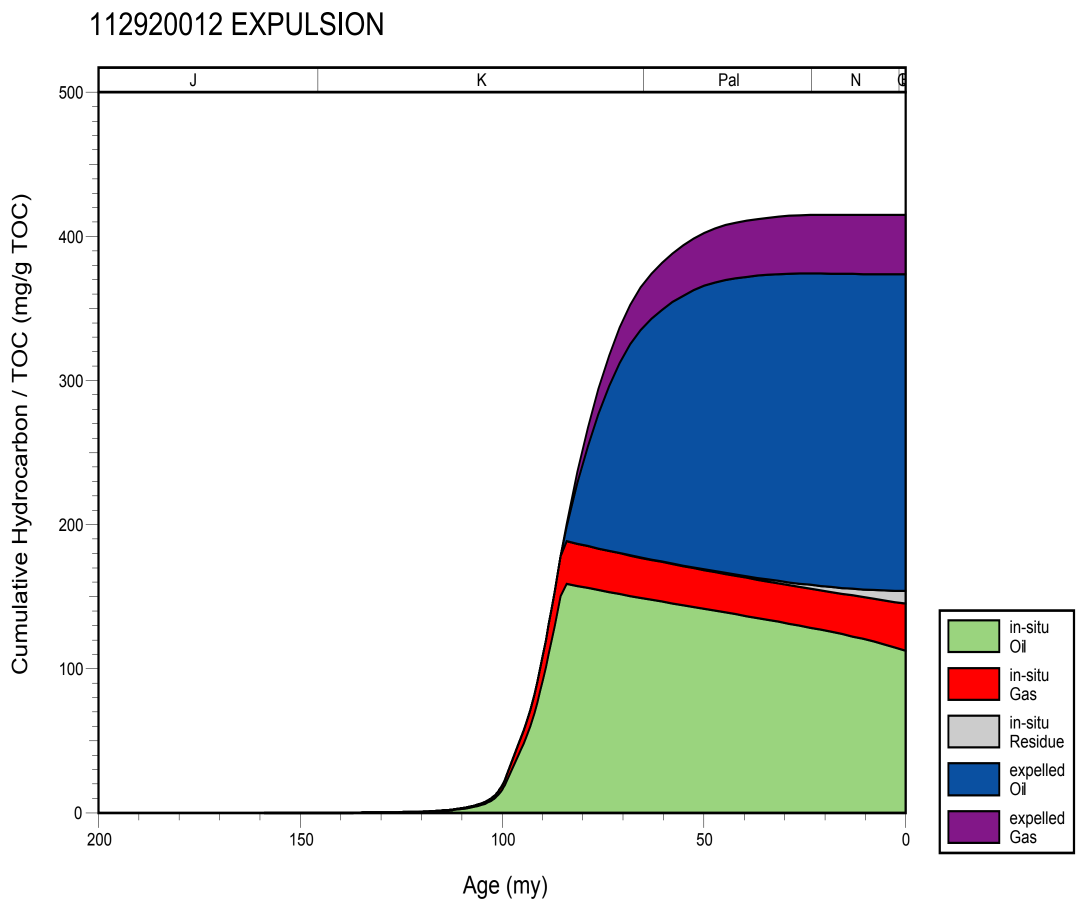

Figure 57. Hydrocarbon expulsion plot for well 112920012, Mississippi Interior Salt Basin.

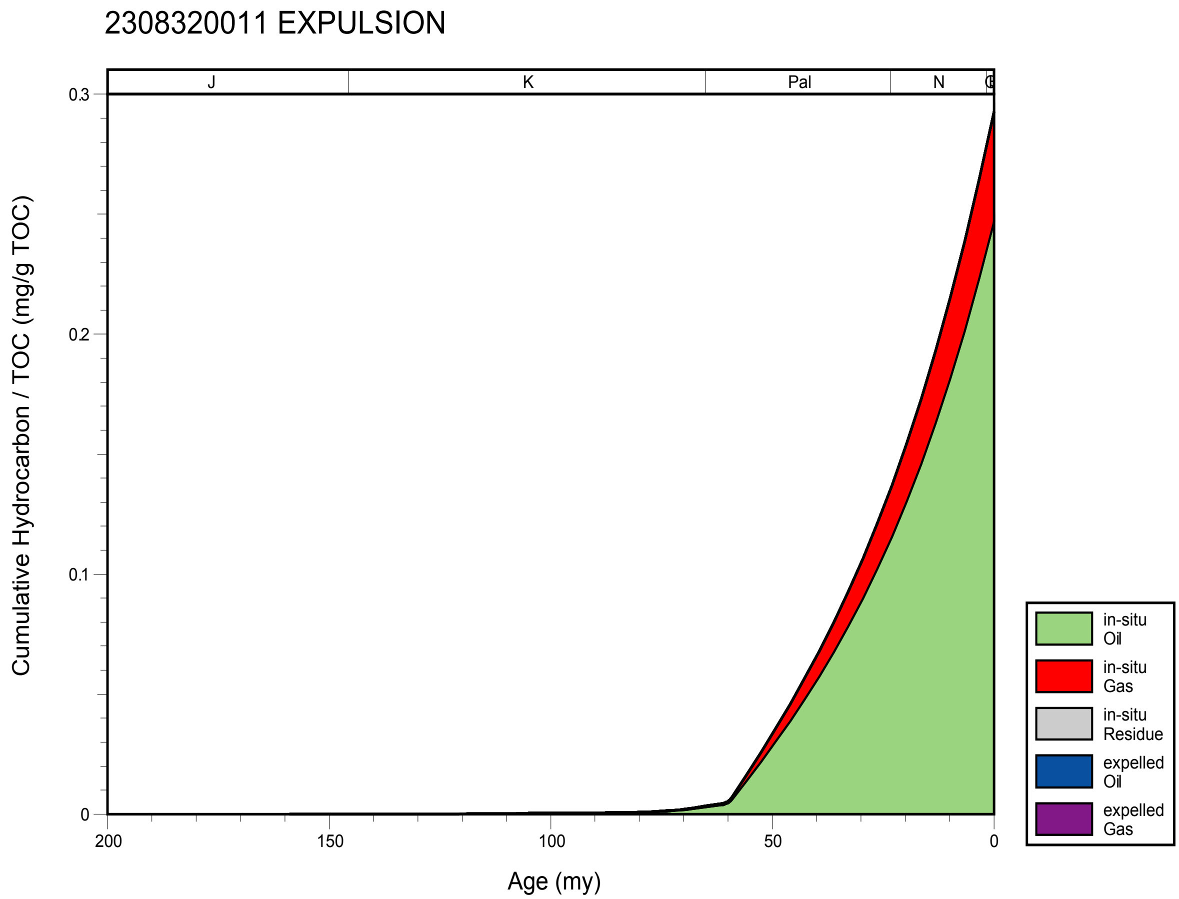

Figure 58. Hydrocarbon expulsion plot for well 2308320011, Mississippi Interior Salt Basin.

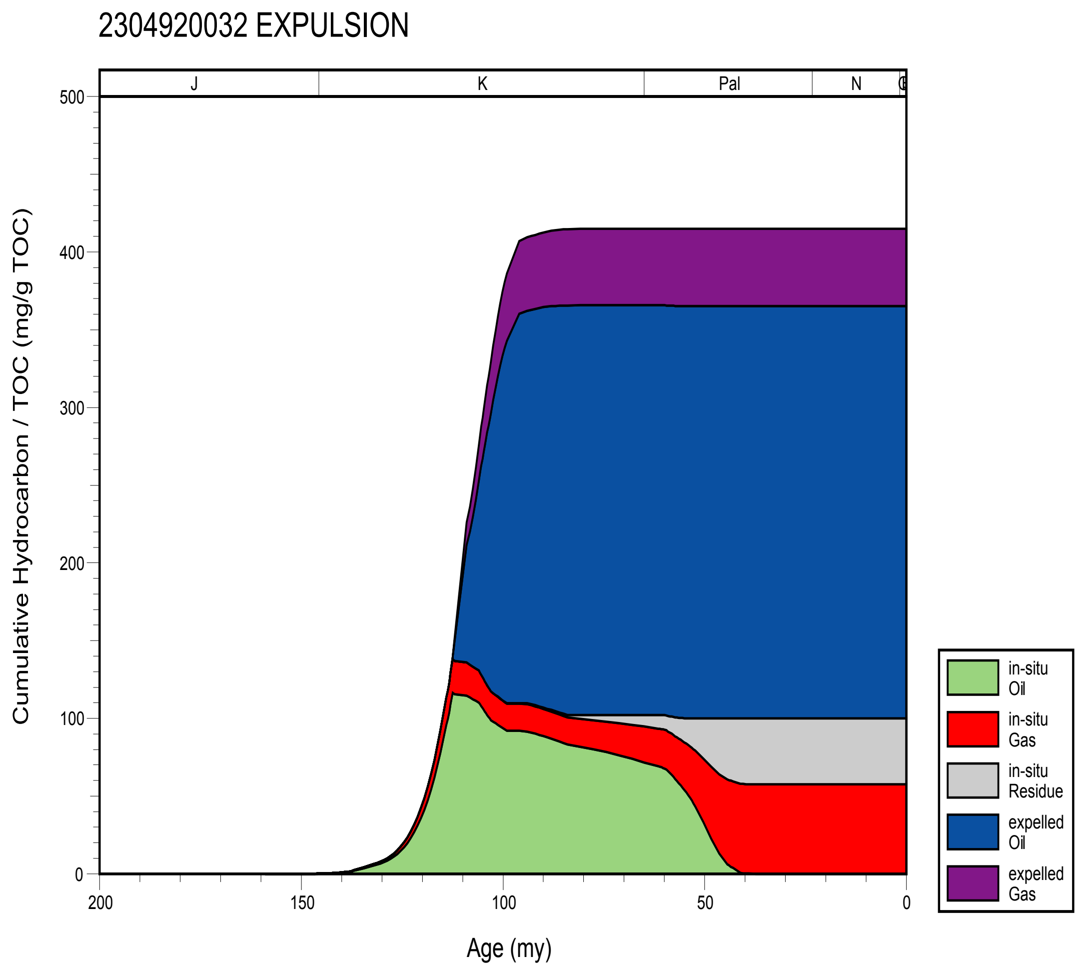

Figure 59. Hydrocarbon expulsion plot for well 2304920032, Mississippi Interior Salt Basin.

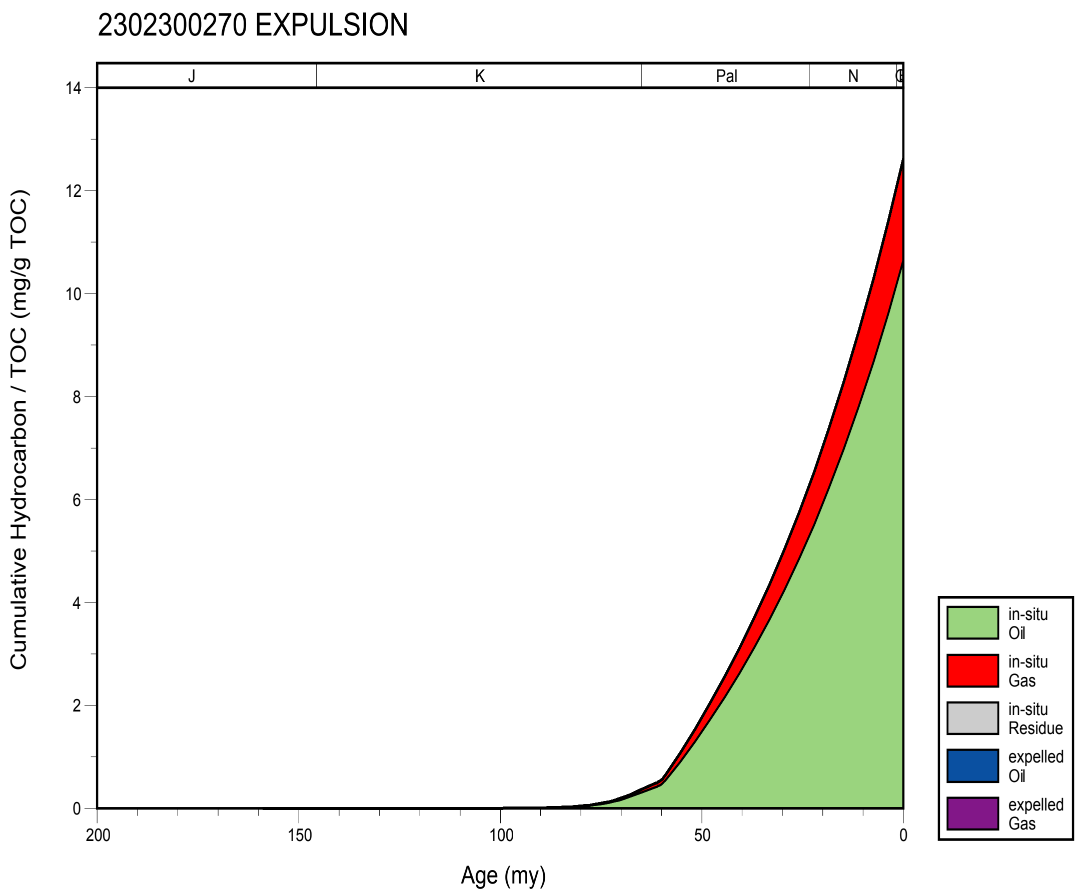

Figure 60. Hydrocarbon expulsion plot for well 2302300270, Mississippi Interior Salt Basin.

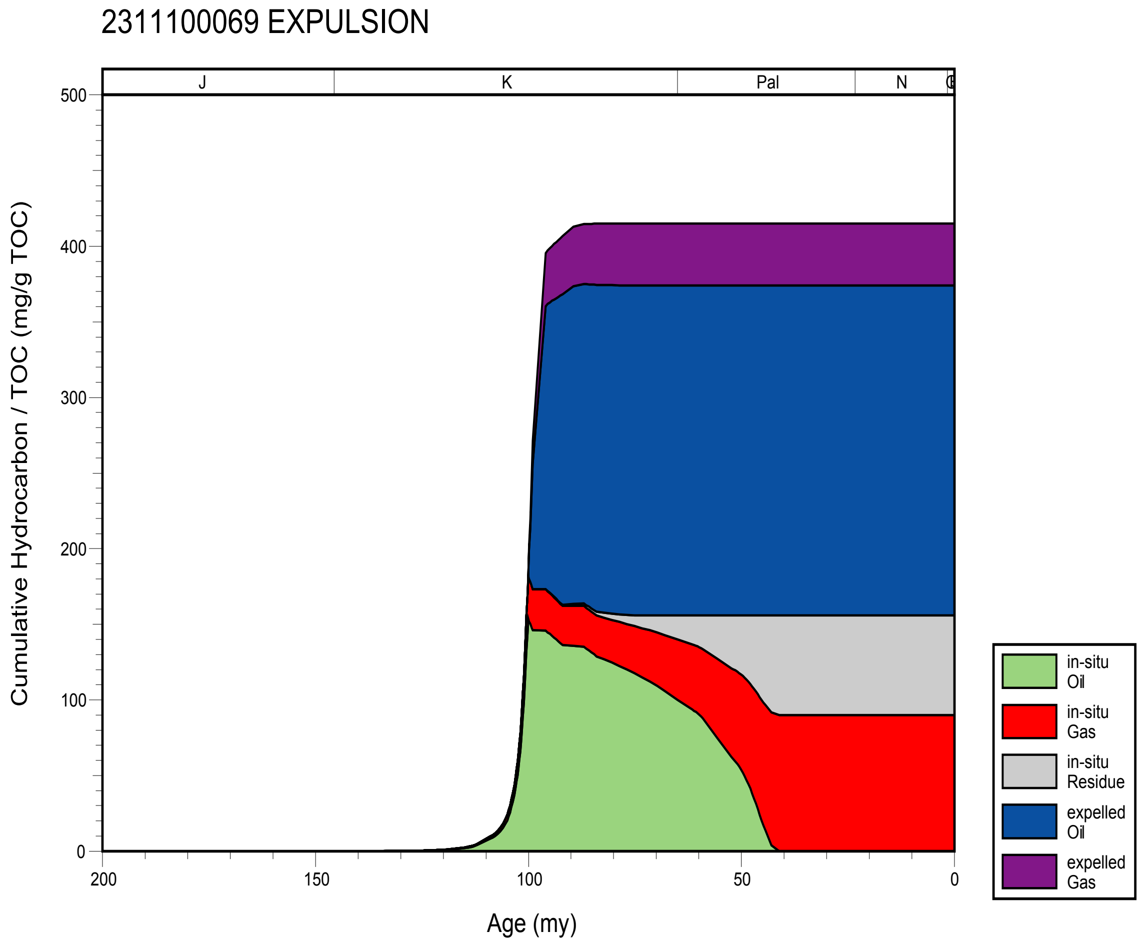

Figure 61. Hydrocarbon expulsion plot for well 2311100069, Mississippi Interior Salt Basin.

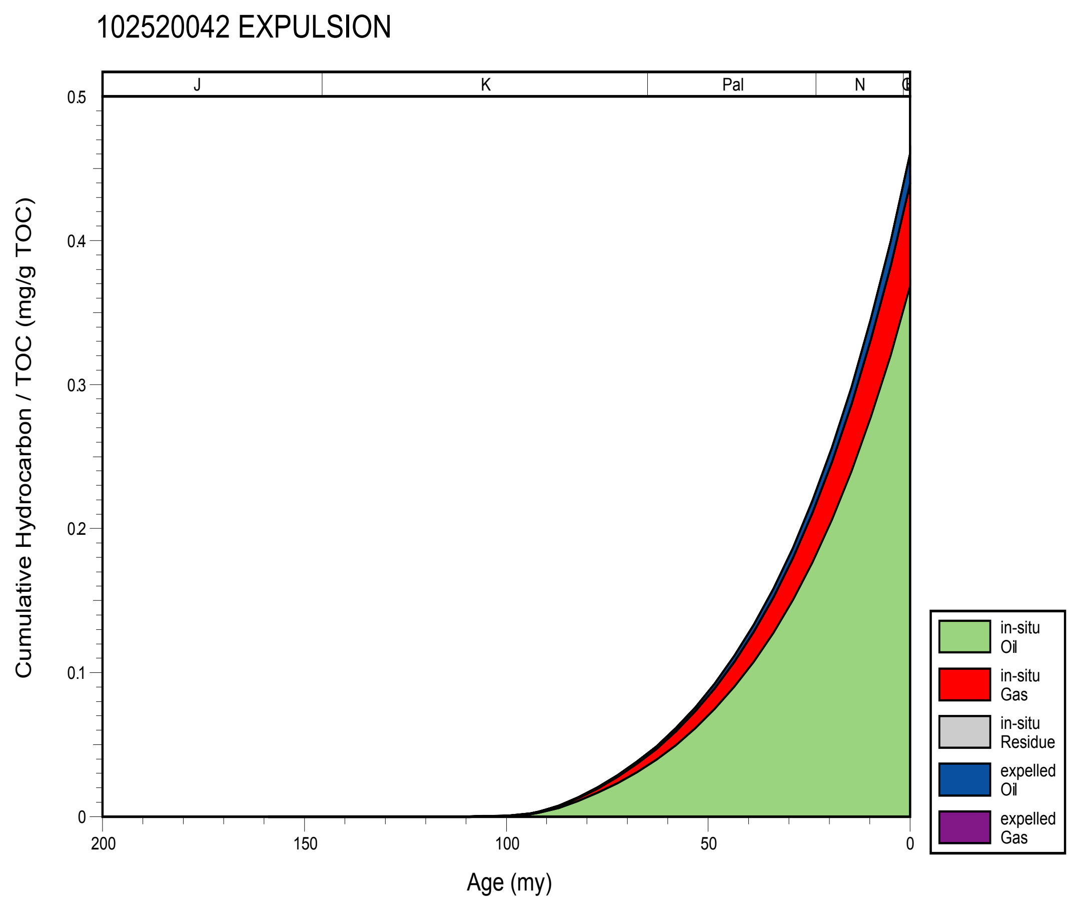

Figure 62. Hydrocarbon expulsion plot for well 102520042, Manila Subbasin.

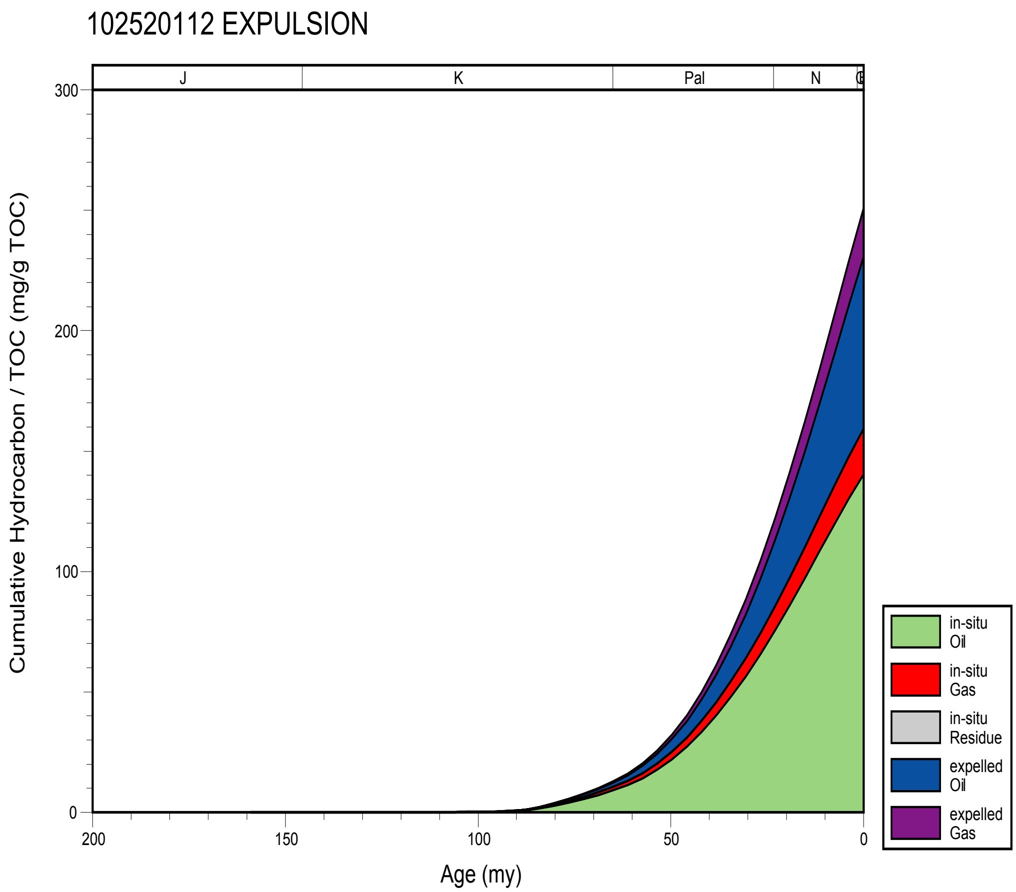

Figure 63. Hydrocarbon expulsion plot for well 102520112, Manila Subbasin.

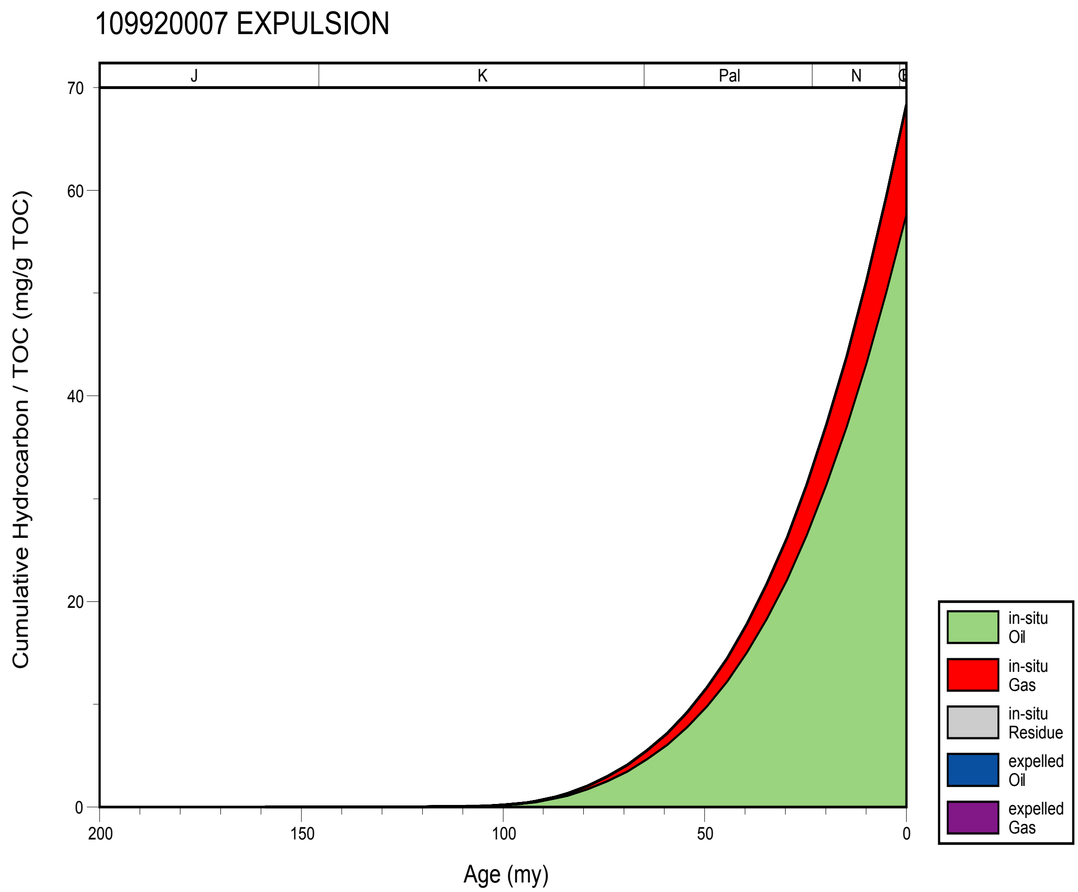

Figure 64. Hydrocarbon expulsion plot for well 109920007, Manila Subbasin.

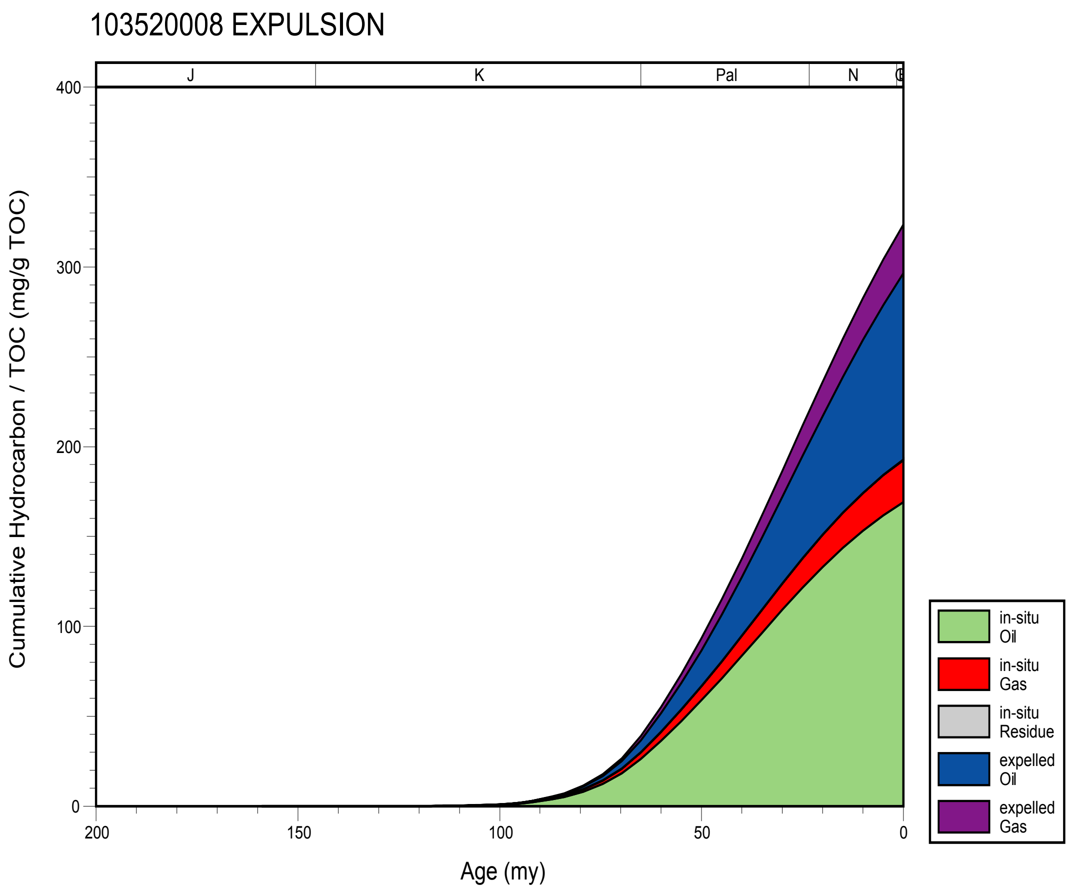

Figure 65. Hydrocarbon expulsion plot for well 103520008, Conecuh Subbasin.

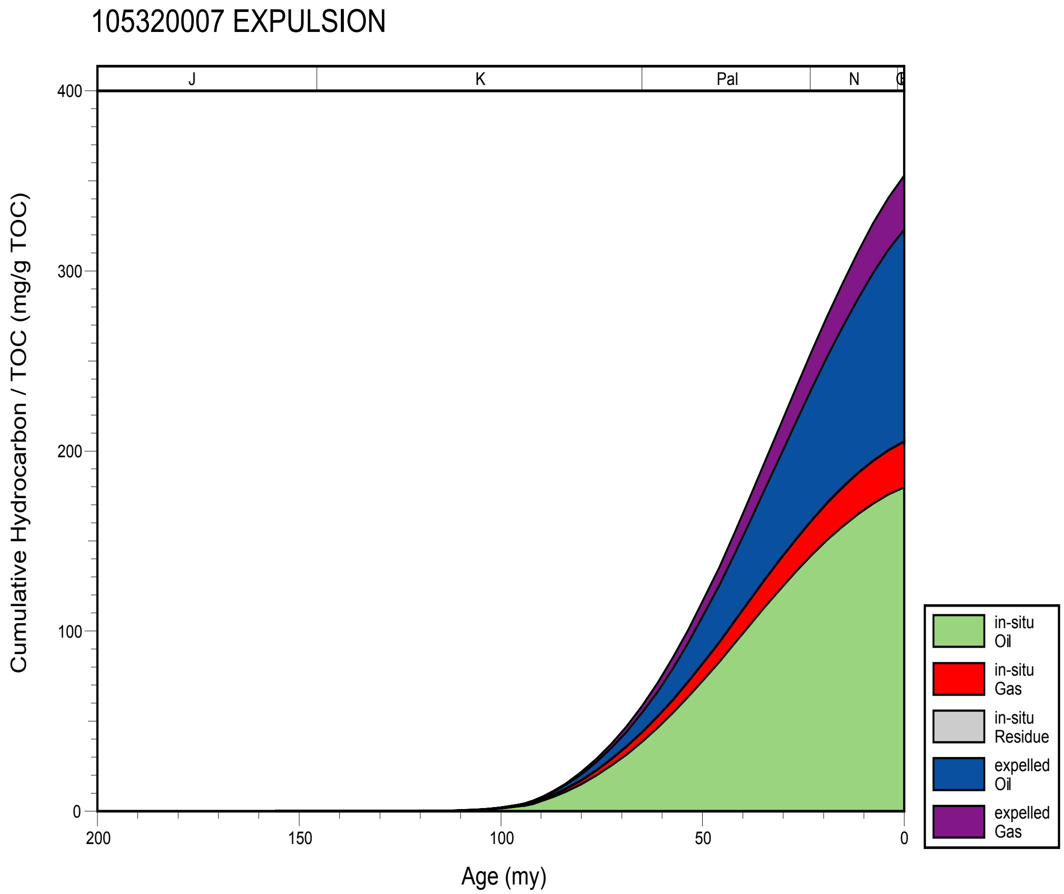

Figure 66. Hydrocarbon expulsion plot for well 105320007, Conecuh Subbasin.

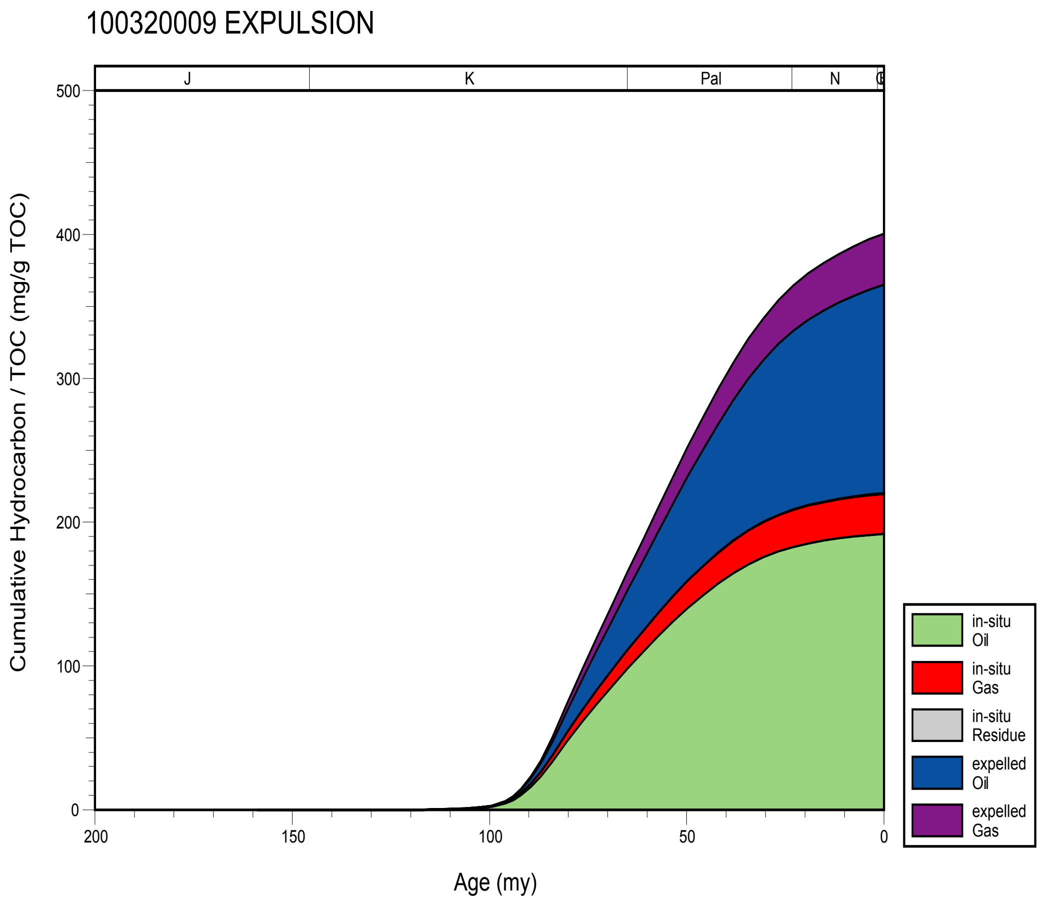

Figure 67. Hydrocarbon expulsion plot for well 100320009, Conecuh Subbasin.

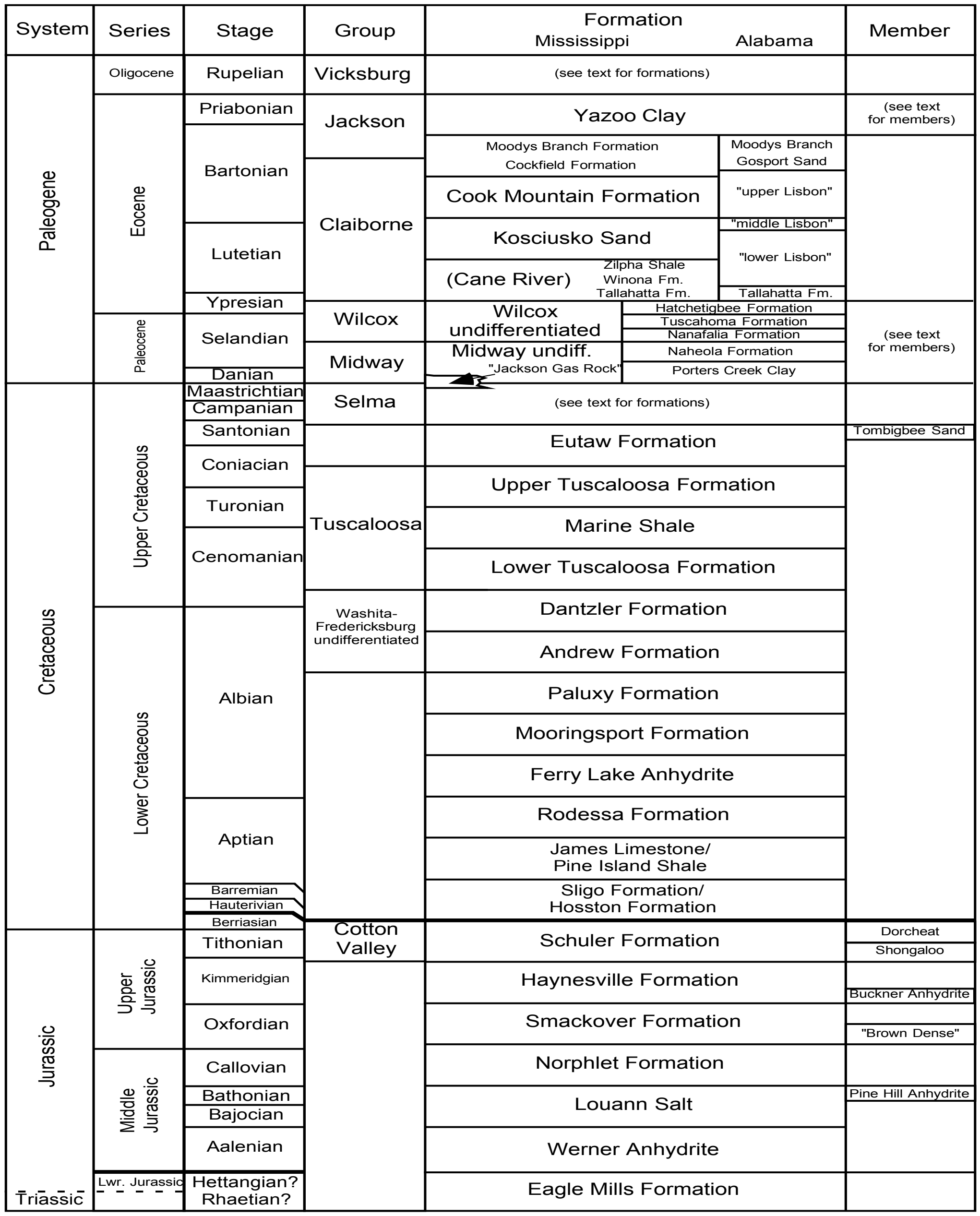

Figure 68. Stratigraphy for the north central and northeastern Gulf of Mexico area.

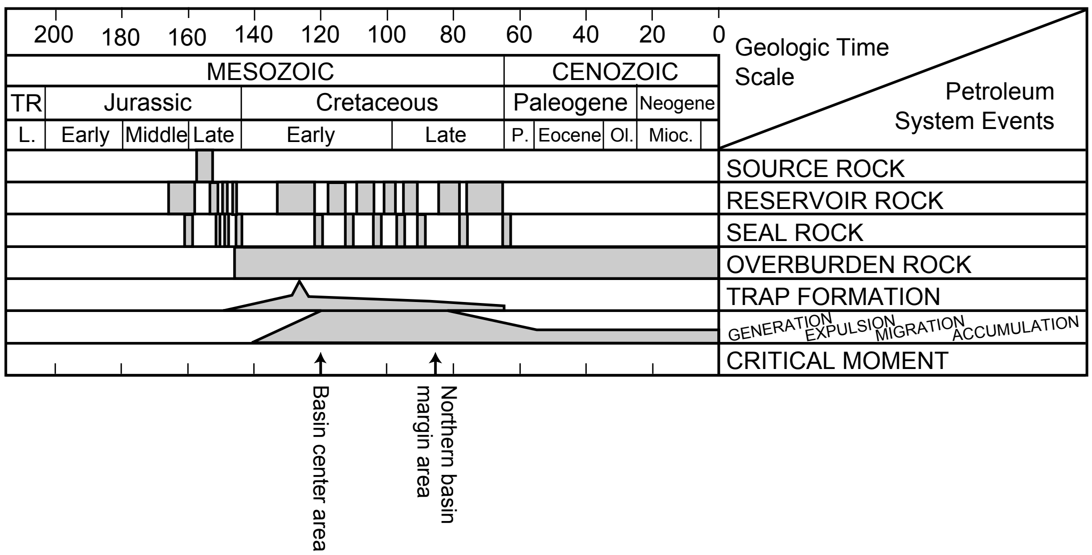

Figure 69. Event chart for Smackover petroleum system, North Louisiana and Mississippi Interior Salt Basins.

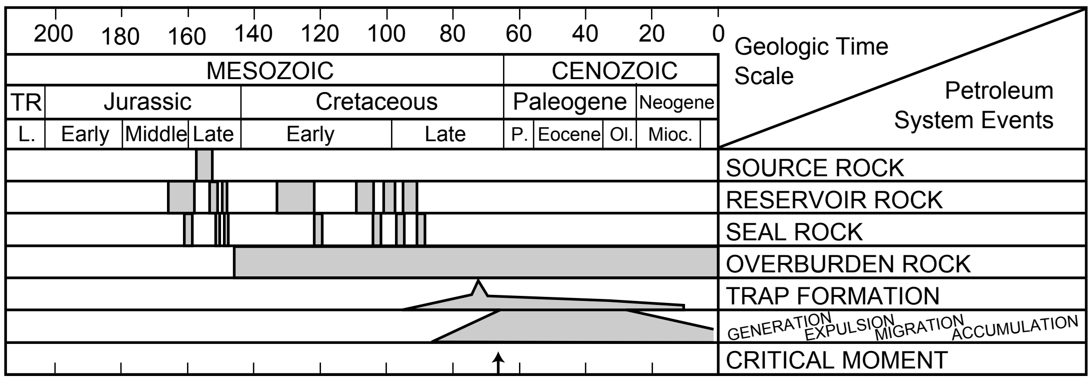

Figure 70. Event chart for Smackover petroleum system, Manila and Conecuh Subbasins.

Table 3. North Louisiana Oil and Gas Production.

Reservoir	Oil (Bbls)	Gas (Mcf)
Total	2,133,342,497	26,239,552,096

Table 4. Mississippi Oil and Gas Production.

Reservoir	Oil (Bbls)	Gas (Mcf)
Wilcox/Tertiary	273,753,647	198,084,956
Selma	37,047,952	224,393,889
Eutaw	289,094,337	1,754,500,527
Tuscaloosa	628,095,348	1,824,391,605
Upper Cretaceous	40,140,601	35,078,117
Cretaceous	138,339,338	112,019,949
Dantzler	783,201	72,450,931
Washita-Fredericksburg	56,943,318	255,821,157
Paluxy	56,544,588	568,991,732
Mooringsport	11,633,767	215,885,662
Ferry Lake	7,381	8,175
Rodessa	67,170,316	326,133,535
Pine Island	543,856	676,027
Sligo	30,927,220	157,859,597
James	902,320	80,356,905
Hosston	54,887,990	995,065,210
Lower Cretaceous	57,685,226	250,089,321
Cotton Valley	106,461,276	146,163,240
Haynesville	6,363,237	349,782,029
Smackover	158,901,664	1,048,396,779
Norphlet	12,491,968	329,591,578
Others	52,964,607	46,502,819
Total	2,081,683,158	8,992,243,740

Table 5. Alabama Oil and Gas Production.

Reservoir	Oil (Bbls)	Gas (Mcf)
Miocene	0	140,049,784
Selma	2,145,085	0
Eutaw	12,620,913	5,745
Tuscaloosa	30,187,182	851,222
Lower Cretaceous	1,424	136
Rodessa	167,426,752	15,142,921
Dantzler	176,036	7,245
Washington/Fredrick	1,820,140	78,263
Paluxy	167,463	243
Hosston	849,150	67,232
Cotton Valley	1,015,955	0
Haynesville	27,212,560	39,200,467
Smakover	306,760,497	1,788,681,246
Smakover/Norphlet	77,124,095	422,223,389
Norphlet	20,079,623	2,710,652,138
Total	647,586,875	5,116,960,031

Table 6. Florida Oil and Gas Production.

Reservoir	Oil (Bbls)	Gas (Mcf)
Smackover	414,233,000	548,713,000
Norphlet/Smackover	58,135,000	60,843,000
Total	472,368,000	609,556,000

<u>Work Planned (Table 7)</u>

***In-Place Resource Assessment*—**This task is designed to volumetrically calculate the total estimated in-place hydrocarbon resource generated and the potential amount of resource that is classified as deep (>15,000 ft) gas in the North Louisiana Salt Basin, the Mississippi Interior Salt Basin, the Manila Subbasin, and the Conecuh Subbasin. This was initiated in Year 2 and will be completed as part of the work effort for Year 3.

***Potentially Recoverable Deep Gas Volume*—**The volume of the generated total hydrocarbon resource and of the deep gas resource in the onshore interior salt basins and subbasins that was expelled and migrated will be estimated.

***Oil Converted to Gas Assessment*—**The potential volume of gas in deeply buried reservoirs as a result of the thermal cracking of entrapped liquid hydrocarbons being converted in the reservoirs will be calculated.

***Identification of Deep Gas Resources*—**The areas in the onshore interior salt basins and subbasins with high potential for the recovery of commercial quantities of the deep gas resource will be identified.

Results and Discussion

<u>Overburden Rocks</u>

The underburden and overburden rocks in these basins and subbasins are a product of their rift-related geohistory. The underburden rocks include pre-rift Paleozoic rocks; syn-rift Triassic graben fill redbeds of the Eagle Mills Formation and Jurassic evaporite deposits of the Werner Formation and Louann Salt; and post-rift nonmarine and marine siliciclastic sediments of the Norphlet Formation. The overburden rocks are Jurassic, Cretaceous and Tertiary post-rift nonmarine and marine siliciclastic, carbonate and evaporite deposits.

<u>Petroleum Source Rocks (Smackover Lime Mudstone)</u>

Upper Jurassic organic rich and laminated Smackover lime mudstone beds are the

Table 7

Milestone Chart—Year 3

	O	N	D	J	F	M	A	M	J	J	A	S
In-Place Resource Assessment												
Recoverable Deep Gas Volume												
Oil Converted to Gas Assessment												
Identification of Deep Gas Resources												

Work Planned	
Work Completed	

petroleum source rocks for most of the oils in these onshore interior salt basins and subbasins (Oehler, 1984; Sassen et al., 1987; Mancini and Claypool, 1989; Mancini et al., 2003). Organic geochemical analyses of the Smackover source beds indicate that the Jurassic oils and many of the Cretaceous oils originated from the organic matter associated with the Smackover lime mudstone beds. Our work confirms that Smackover lime mudstone is the major petroleum source rock in the onshore interior salt basins and subbasins. To validate this observation, Paul Aharon at the University of Alabama plans to perform additional geochemical and isotopic analysis on Smackover lime mudstone samples and selected Jurassic and Cretaceous oils from these basins and subbasins.

From burial history and thermal maturation history profiles for wells in the North Louisiana Salt Basin, Mississippi Interior Salt Basin and Manila and Conecuh Subbasins, hydrocarbon generation and maturation trends have been observed. In wells in much of the North Louisiana Salt Basin, the generation of hydrocarbons from Smackover lime mudstone was initiated at 1,829 to 2,896 m (6,000 to 9,500 ft) during the Early Cretaceous and continued into the Tertiary. In wells in much of the Mississippi Interior Salt Basin, the generation of hydrocarbons from Smackover lime mudstone was initiated at 2,438 to 3,353 m (8,000 to 11,000 ft) during the Early Cretaceous and continued into the Tertiary. In wells in much of the Manila and Conecuh Subbasins, the generation of hydrocarbons from Smackover lime mudstone was initiated at 2,591 to 3,811 m (8,500 to 12,500 ft) during the Late Cretaceous and continued into the Tertiary. The thermal maturation profiles for wells located updip or along the updip margins of the basins and subbasins indicate that the Smackover source rocks in this area are thermally immature to mature and did not generate significant quantities of oil throughout much of this area, whereas, wells located in the centers of the basins and subbasins are late mature to overmature.

Hydrocarbon expulsion from Smackover source rocks in the North Louisiana Salt Basin and the Mississippi Interior Salt Basin commenced during the Early Cretaceous and continued into the Tertiary. Initiation of oil expulsion began first in the central portion of the basin in Early Cretaceous and peaked in mid Early Cretaceous in this area. Hydrocarbon expulsion from Smackover source rock in the Manila and Conecuh Subbasins commenced during the Late Cretaceous and continued into the Tertiary. The hydrocarbon expulsion profiles for the wells are in agreement with the thermal maturation profiles. The timing of commencement of oil expulsion is consistent with the tectonic, depositional, burial and thermal histories of the basins and subbasins. The Smackover hydrocarbon expulsion profiles support an intermediate range (80 km or 50 mi) migration model for Smackover crude oil in that the thermal maturity and hydrocarbon expulsion profiles for wells located in fields producing low gravity crude oil show that the local Smackover source beds, to date, have not reached the thermal maturity level to expel Smackover oil. Smackover hydrocarbon migration into overlying strata was facilitated by vertical migration along faults. Evans (1987), Sassen (1990) and Zimmerman and Sassen (1993) also published information in support of combined long range and vertical hydrocarbon migration in this area.

Petroleum Reservoir Rocks

Petroleum reservoir rocks of the North Louisiana Salt Basin, Mississippi Interior Salt Basin, Manila Subbasin and Conecuh Subbasin include Jurassic, Cretaceous and Tertiary siliciclastic and carbonate strata.

Petroleum reservoir rocks in the North Louisiana Salt Basin include the Upper Jurassic Smackover limestone, Haynesville (Buckner) sandstone and limestone, and Cotton Valley (Schuler) sandstone and limestone; the Lower Cretaceous Hosston sandstone, Sligo limestone, Pine Island sandstone, James limestone, Rodessa limestone, Ferry Lake limestone, Mooringsport limestone, and Washita-Fredericksburg limestone; the Upper Cretaceous Tuscaloosa sandstone, Austin sandstone and chalk, Taylor chalk and sandstone, Navarro sandstone and Monroe gas rock chalk; and Lower Tertiary Wilcox sandstone. The petroleum reservoirs in the Mississippi Interior Salt Basin include the Upper Jurassic Norphlet sandstone, Smackover limestone and dolostone, Haynesville sandstone, and Cotton Valley (Schuler) sandstone; the Lower Cretaceous Hosston sandstone, Sligo sandstone, James limestone, Rodessa sandstone, Mooringsport sandstone, Paluxy sandstone, and Dantzler sandstone; the Upper Cretaceous Tuscaloosa sandstone, Eutaw sandstone, Selma chalk, and Jackson gas rock; and Lower Tertiary Wilcox sandstone. The petroleum reservoirs in the Conecuh Subbasin include the Upper Jurassic Norphlet sandstone, Smackover limestone and dolostone and Haynesville sandstone; Lower Cretaceous Hosston sandstone, Fredericksburg-Washita sandstone and Dantzler sandstone; and Upper Cretaceous Tuscaloosa sandstone. The petroleum reservoirs in the Manila Subbasin include the Upper Jurassic Norphlet sandstone, Smackover limestone and dolostone and Haynesville sandstone and Upper Cretaceous Tuscaloosa sandstone.

Petroleum Seal Rocks

Petroleum seal rocks in the North Louisiana Salt Basin, Mississippi Interior Salt Basin, Manila Subbasin and Conecuh Subbasin include Jurassic, Cretaceous, and Tertiary anhydrite and shale beds.

Petroleum seal rocks in the North Louisiana Salt Basin include the Upper Jurassic Buckner anhydrite and Cotton Valley (Bossier) shale; the Lower Cretaceous Pine Island shale, Bexar shale, Ferry Lake anhydrite, and Paluxy shale; the Upper Cretaceous Eagle Ford Shale; and the Lower Tertiary Midway shale. Petroleum seal rocks in the Mississippi Interior Salt Basin include Upper Jurassic Smackover limestone, Buckner anhydrite, Haynesville shale and Cotton Valley shale; Lower Cretaceous Pine Island shale, Bexar shale, Ferry Lake anhydrite, Mooringsport shale, and Dantzler shale; Upper Cretaceous Tuscaloosa shale, Eutaw shale and Selma chalk; and Lower Tertiary Midway shale. Petroleum seal rocks in the Manila Subbasin and Conecuh Subbasin include Upper Jurassic Smackover limestone, Buckner anhydrite, Haynesville shale and Upper Cretaceous Tuscaloosa shale and Eutaw shale.

Petroleum Traps

Structural or combination traps characterize the North Louisiana Salt Basin, Mississippi Interior Salt Basin, Manila Subbasin and Conecuh Subbasin. Movement of the Jurassic Louann Salt has produced a complex array of structures. These structures include peripheral salt ridges; low relief salt pillows, salt anticlines and turtle structures; and piercement domes. These features form the majority of the petroleum traps in these basins and subbasins. Anticlinal structures associated with basement paleotopographic highs are also present.

Conclusions

The principal research effort for Year 2 of the project has been petroleum system characterization and modeling. Understanding the burial and thermal maturation histories of the strata in the onshore interior salt basins and subbasins of the North Central and Northeastern Gulf of Mexico areas is critical in hydrocarbon resource assessment. The underburden and overburden rocks in these basins and subbasins are a product of their rift-related geohistory.

Petroleum source rock analysis and thermal maturation and hydrocarbon expulsion modeling have shown that the Upper Jurassic Smackover Formation served as an effective regional petroleum source rock in the North Louisiana Salt Basin, Mississippi Interior Salt Basin, Manila Subbasin and Conecuh Subbasin. Also, previous studies have indicated that Upper Cretaceous Tuscaloosa shale was an effective local petroleum source rock in the Mississippi Interior Salt Basin and a possible local source bed in the North Louisiana Salt Basin given the proper organic facies; that Lower Cretaceous lime mudstone was an effective local petroleum source rock in the South Florida Basin, and a possible local source bed in the North Louisiana Salt Basin and Mississippi Interior Salt Basin given the proper organic facies; that uppermost Jurassic strata were effective petroleum source rocks in Mexico and were possible local source beds in the North Louisiana Salt Basin given the proper organic facies; and that lower Tertiary shale and lignite were petroleum source rocks in south

Louisiana and southwestern Mississippi. These lower Tertiary beds have not been subjected to favorable burial and thermal maturation histories required for petroleum generation in the North Louisiana Salt Basin, Mississippi Interior Salt Basin, Manila Subbasin and Conecuh Subbasin.

Petroleum reservoir rocks in the North Louisiana Salt Basin, Mississippi Interior Salt Basin, Manila Subbasin and Conecuh Subbasin include Jurassic, Cretaceous and Tertiary siliciclastic and carbonate strata. These reservoir rocks include Upper Jurassic Norphlet, Smackover, Haynesville, and Cotton Valley units, Lower Cretaceous Hosston, Sligo, James, Rodessa, Mooringsport, Paluxy, and Fredericksburg-Washita units, the Upper Cretaceous Tuscaloosa, Eutaw-Austin, Selma-Taylor/Navarro, and Jackson gas rock-Monroe gas rock units, and the Lower Tertiary Wilcox unit.

Petroleum seal rocks in these basins and subbasins include Upper Jurassic Smackover lime mudstone, Buckner anhydrite, Haynesville shale, and Cotton Valley shale beds, Lower Cretaceous Pine Island shale, Ferry Lake anhydrite, Mooringsport shale, and Fredericksburg-Washita shale beds, Upper Cretaceous Tuscaloosa shale, Eagle Ford shale, and Selma Chalk beds, and Lower Tertiary Midway shale beds.

Petroleum traps include structural and combination traps in these basins and subbasins. Halokinesis is the principal process that formed these traps producing a complex array of salt structures. These structures include peripheral salt ridges, low relief salt pillows, salt anticlines and turtle structures, and piercement domes. Structures associated with basement paleotopographic highs are also present.

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