An Unproven Unconventional Seven Billion Barrel Oil Resource - the Tuscaloosa Marine Shale

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Abstract

The Gulf Coast region of the United States is considered a mature producing province. In order to maintain and/or increase future hydrocarbon production, future trends must include the research and evaluation of untested ideas about non-conventional hydrocarbon occurrences. Many studies have been conducted on hydrocarbon production associated with shale formations e.g. the Bakken Shale, Williston Basin; Antrim Shale, Michigan Basin; etc. However, no published information is available relative to the lithological characteristics or existence of hydrocarbons in the Tuscaloosa marine shale.

The marine shale section lies between sands of the upper and lower Tuscaloosa sections and varies in thickness from 500 ft (152.4 m) in southwestern Mississippi to more than 800 ft (243.8 m) in the southern part of the Florida Parishes, southeastern Louisiana. The primary zone of interest , a high log resistivity (5 ohms) zone at the base of the above referenced shale section, varies in thickness from zero to 325 ft (99 m) over the area and is found at the shallowest depth of approximately 10,000 ft (3048 m) in the study area. Two wells are known to have produced from the marine shale in southeastern Louisiana with one having produced over 20,000 barrels of oil in the last nineteen years. Preliminary evaluations indicate that the Tuscaloosa marine shale may contain a potential reserve of about 7 billion barrels of oil. Horizontal drilling could maximize production and minimize environmental impacts.

Introduction

The Gulf Coast region of the United States is considered a mature producing province. In order to maintain and/or increase hydrocarbon production, future industry trends should include research and evaluation of potential non-conventional hydrocarbon resources. Though oil production from fractured self sourced shales occurs in many areas, the magnitude and resource potential of such unconventional hydrocarbon sources is not well defined. Many studies have been conducted and published on hydrocarbon production associated with shale formations. However there is no published information on the Tuscaloosa marine shale as regards its potential as a significant hydrocarbon resource.

The locations of the shale basins of the United States are shown in Figure 1. Summary descriptions of some of these basins and current drilling activity information is provided by Reeves et al., 1996. Published literature information available on hydrocarbon production from such basins include the upper Devonian - lower Mississippian age Bakken Shale of the Williston basin (Meissner, 1991a; Hansen, 1991; LeFever, 1991; Price and LeFever, 1992); the Cane Creek Shale of the Pennsylvanian Paradox basin, Utah (Morgan, 1992; Morgan et al., 1992); the Woodford Shale in the Anadarko Basin of Oklahoma (Hester, Schmoker and Sahl, 1990a, 1990b; Fertl and Chilingarian, 1990; Comer, 1992); the Mississippian - Devonian New Albany Shale of the Illinois Basin (Cluff and Dickerson, 1982;Comer et al., 1993; Minihan and Buzzard, 1995, 1996); Antrim Shale of the Michigan Basin; the Ohio Shale occupying the Appalachian Basin area; the Miocene Monterey Shale of California, the Mississippian Barnett Shale, Fort Worth Basin (Lancaster et al., 1993) and the upper Cretaceous Niobrara Shale Formation of northwestern Colorado (Vincelette and Foster, 1992; Pollastro, 1992).

Stratigraphy

Sands and shales of the Tuscaloosa Group are over 1,000 ft. (305 m) thick (Howe, 1962) and represent a complete depositional cycle (Spooner, 1964). A generalized stratigraphic column of the study area is shown in Figure 2. The study area comprises the Florida Parishes (St. Helena, East & West Feliciana, East Baton Rouge, Livingston, Tangipahoa, Washington and St. Tammany), the counties of southwest Mississippi (Amite, Wilkinson, Adams, Franklin, Pike, and Walthall) and extends westwards through central Louisiana (Avoyelles, Catahoula, Concordia, Pointe Coupee, Rapides, Vernon, Allen, St. Landry, Beauregard, Grant and Evangeline Parishes) to the Texas border (Figure 3). It is generally located between the Cretaceous and Wilcox production in north Louisiana and in south Mississippi, and the Miocene production to the south in south Louisiana (Howe, 1962). The Tuscaloosa in this area also represents the lowest formation of the Gulfian Cretaceous series (Forgotson, 1958).

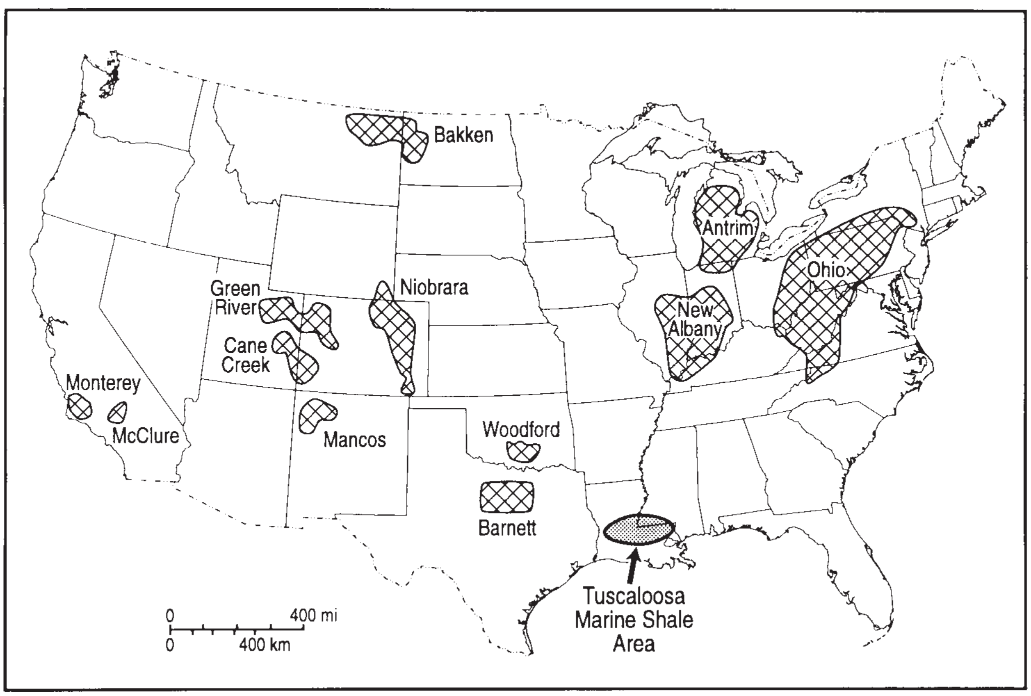

Figure 1. Map showing the locations of shale basins in the United States (modified from Reeves et al., 1996)

The Tuscaloosa Group is comprised of three units. The lower Tuscaloosa represents a transgressive stage of the depositional cycle (Spooner, 1964) and consists of an arenaceous and argillaceous lower unit which is represented on the stratigraphic chart (Figure 2) as the massive sand and the stringer sands. The marine shale forms the middle Tuscaloosa unit and represents the inundated phase of the depositional cycle. The marine shale is mostly gray to black, fissile and sandy at some locations thickening downdip. In the McComb Field (Pike County Mississippi) the marine shale is 500 ft (152.4 m) thick increasing to 800 ft (24m) in the south-central area of Washington Parish, Louisiana. The upper Tuscaloosa sands and clays represent the regressive phase of the depositional cycle. It is difficult to distinguish the upper Tuscaloosa from the overlying Eutaw Formation due to their lithologic similarity (Howe, 1962).

Previous Work

The purpose of this paper is to bring industry attention to what may be a very significant potential reserve of hydrocarbons contained in the Tuscaloosa marine shale (TMS) underlying a large area of southwestern Mississippi and southern Louisiana. While it has long been known by operators and drillers in the area that the TMS in the study area (Figure 3) contained oil and gas under sufficient pressure to release oil and gas into the mud and/or on to the pits, occasionally with attention- getting pressure, not much progress has been made or much interest shown by industry in evaluating and testing the TMS.

One of the earliest geoscientists who noted the hydrocarbon potential of the TMS was the late Mr. Alfred C. Moore (Dwight “Clint” Moore, 1997, personal communication) who wrote in his unpublished notes in 1969 that the TMS was believed to be the “source bed” for most of the underlying lower Tuscaloosa oil trapped in sand bars draped over and around structural highs between the Brookhaven (Lincoln County) and Gillsburg Oil Fields (Amite Co., Mississippi). Moore evaluated over 50 dry wells drilled in the general area and concluded that the TMS was fractured and that the fractures were interconnected. He also stated that there was significant fracturing of the TMS probably by pressure increases from oil generation. Meissner (1991b) believed that overpressuring from oil generation in the Bakken Shale is related to the vertical fracturing. Unpublished records from Mr. Alfred C. Moore which were provided to us by his son, Dwight “Clint” Moore, also contained core information from the Callon Petroleum #2 Cutrer well (Section 55-TIS-R7E) Tangipahoa Parish, Louisiana. The analysis of 110 section plugs from the cored interval 11,550 ft - 11,653 ft (3520 m - 3552 m) showed a range of figures from lowest to highest, as follows: _permeability_ - from less than 0.01 to 0.06 millidarcies; _porosity_ - from 2.3 to 8.0%; oil - from 0.7 to 4.3% (vol.); _gas_ - from 0.2 to 1.3% (vol.); and, _water_ - from 31.8 to 88.2%. While the permeability and porosity figures appear to be quite low, this is the well that produced some 2,500 barrels of oil from the TMS from perforations between 11,584 ft - 11,644 ft (3531 m - 3549 m). The cores were predominantly described as silty shale and sometimes calcareous.

The information also contained lithologic descriptions of cores from the Sun #1 Spinks well (Section 7, T2N-R7E) Pike Co., Mississippi in the TMS section over the interval 10,750 ft - 11,067 ft (3277 m - 3373 m). The upper 120 ft (36.5 m) of the core was described as shale, with the section below being shale and siltstone withcross-bedding and fracturing, with oil shows. On December 1, 1971, Mr. Moore (unpublished notes) wrote:

“Visible fractures containing live oil are apparent in the diamond cores commencing at 10,940 ft. Frequency of the fractures increases steadily with depth and are most extensive between 11,000 ft and 11,055 ft (40% of diamond core lengths contain visible fractures).”

This information would indicate some enhanced porosities and permeabilities in areas where fracturing may be present. Obviously, more fracturing would be expected in areas of stress where folding, faulting, or movement of the shale may have occurred. It would appear that none of the wells produced or tested are located on proven structures, so it is suggested that locations at or near the apex of structure may have considerably greater fracturing.

Moore (1970-1974, unpublished notes) observed from his evaluation of wells in the area penetrating the TMS that they generally had an abnormal pressure of 6200 psi in the TMS whereas the normal pressure for the upper and lower Tuscaloosa in the area ranged from 4400 to 5200 psi. Drillers of wells in the area increased mud weights to create a hydrostatic pressure equal to 6200 psi while drilling through the TMS section in order to prevent blowouts. Moore was of the opinion that wells completed in the TMS would be capable of commercial oil production. He estimated that the geographic area commencing in western Washington Parish and extending through northern Tangipahoa, southern Pike, northern St. Helena, southern Amite, northeast Feliciana

SYSTEM	SERIES	GROUP	FORMATION		DESCRIPTION
TERTIARY	NEOGENE		POST-ANAHUAC (UNDIFF.)		MASSIVE SANDS WITH SHALE
TERTIARY	NEOGENE		ANAHUAC		PREDOMINANTLY LIMESTONE
TERTIARY	NEOGENE		FRIO		SANDS AND SHALES
TERTIARY	OLIG.	VICKSBG.	UNDIFFERENTIATED		CLAY, CALCAREOUS SAND
TERTIARY	EOCENE	JACKSON	YAZOO CLAY		GRAY MARINE CLAY
TERTIARY	EOCENE	JACKSON	MOODYS BRANCH		FOSSILIFEROUS MARL
TERTIARY	EOCENE	CLAIBORNE	COCKFIELD		SAND AND SHALE
TERTIARY	EOCENE	CLAIBORNE	COOK MOUNTAIN	SHALE MEMBER "LIME" MEMBER	SHALE MASSIVE LIMESTONE
TERTIARY	EOCENE	CLAIBORNE	SPARTA		REGRESSIVE SANDS AND SHALES
TERTIARY	EOCENE	CLAIBORNE	CANE RIVER	SHALE MEMBER (ZILPHA) MARL MEMBER (WINONA)	SHALE GLAUCONITIC MARL
TERTIARY	EOCENE / PALEOC.	WILCOX	UNDIFFERENTIATED	(OVERLYING TALLAHATTA INCLUDED)	DELTAIC SANDS AND SHALES
TERTIARY	PALEOC.	MIDWAY	PORTERS CREEK		DARK GRAY MARINE SHALES
TERTIARY	PALEOC.	MIDWAY	CLAYTON		CHALK
CRETACEOUS	GULF	SELMA	SELMA CHALK (UNDIFF.)		CHALK
CRETACEOUS	GULF	EUTAW	EUTAW (EAGLEFORD)		GRAY SHALE AND BASAL SAND
CRETACEOUS	GULF	TUSCALOOSA	UPPER TUSCALOOSA		SANDS AND SHALES
CRETACEOUS	GULF	TUSCALOOSA	MARINE SHALE		DARK GRAY MARINE SHALE
CRETACEOUS	GULF	TUSCALOOSA	LOWER TUSCALOOSA	STRINGER MASSIVE SAND	LENTICULAR SANDS AND SHALES WHITE, COARSE-GRAINED
CRETACEOUS	COMANCHE	WASHITA-FREDSBG.	DANTZLER		SANDS AND SHALES
CRETACEOUS	COMANCHE	WASHITA-FREDSBG.	UNDIFFERENTIATED		PREDOMINANTLY LIMESTONE
CRETACEOUS	COMANCHE	TRINITY	PALUXY		VARIABLY COLORED SANDS AND SHALES

Figure 2. Generalized stratigraphic chart of the study area (modified from Howe, 1962).

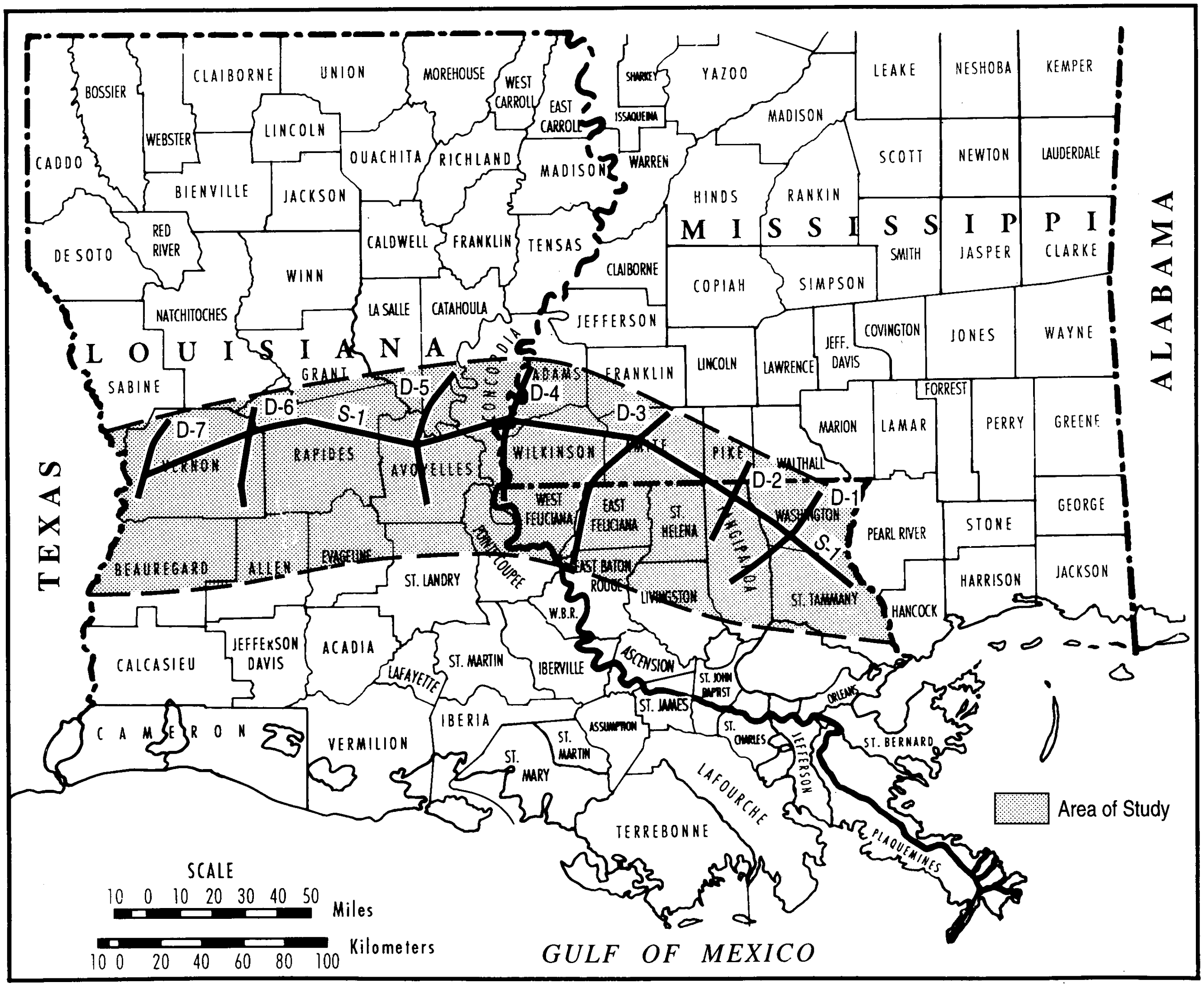

Figure 3. Index map showing the study area and locations of cross sections compiled for this investigation.

and southern Wilkinson was underlain by the TMS "Fracture Fairway" covering an area of approximately 750,000 acres , based on isopach and subsurface studies. In 1974 Moore estimated the recoverable reserves from the TMS to range from 3-10 billion barrels of oil. Later, in 1978, he revised and increased his estimate of acreage to be over one million acres. In his calculations he used an average thickness of saturated rock of 160 ft (49 m) which computed to 160 million acre feet. He also used a oil in place estimate of 300 barrels of oil per acre foot which computed to 48 billion barrels of oil in place reserves in the TMS. He believed that at least 5% of oil in place could be recovered by present and near future technology.

Jones and Moncrief (co-authors of this paper) had also carried out preliminary investigations of the occurrence of hydrocarbons in the TMS zone prior to becoming knowledgeable of Moore's earlier work. They determined that the overall shale interval between sands of the upper Tuscaloosa and these of the lower Tuscaloosa section varies from approximately 500 ft (152.4 m) at McComb field in Pike County, Mississippi, to more than 800 ft (244 m) in Central Tangipahoa Parish, Louisiana. The primary zone of interest bears high log resistivity (5+ ohms), a fact also noted by Moore, and lies at the base of the above referenced shale section and varies from zero to 325 ft (99 m) in thickness over the prospective area of interest. Both these investigations (i.e. Moore as well as Jones & Moncrief) of the TMS independently confirm the resource potential of the TMS and the viability of commercial production from it. Schmoker and Hester (1990) studied log formation resistivities in the upper Devonian-lower Mississippian Bakken Formation of the Williston Basin, North Dakota. They concluded that an abrupt resistivity increase on the electrical logs was an indication of oil generation and was not due to change in the physical properties of the shale.

Tuscaloosa Marine Shale

In this study the writers have attempted to generally delineate the location and depth of the TMS within the study area (Figure 3) and determine more specifically areas where the shale shows electrical log characteristics (higher resistivity) that make it of potential commercial value.

In order to accomplish this task in the study area, hundreds of electric logs from the simplest (1940's vintage) to the sophisticated logs available today have been examined and correlated. From the inception of this study, it was evident that the zones with the greatest potential were those of the greatest resistivity in the lower part of the TMS and that these zones would not cover the entire region. Since there has been no significant "commercial" production from the TMS much consideration was given to what guidelines or parameters should be used to determine which were the potentially productive zones. The type log and standard used for this study was from the Texas Pacific Oil Company, #1 Winfred Blades well in Tangipahoa Parish Louisiana (Figure 4). At present this is the only well producing oil from the TMS. It has produced over 20,000 bbls of oil with no water from perforations in many different places between 11,073 ft - 11,644 ft (3375 m - 3549 m) since its completion in 1978. Schlumberger log analysts believe the oil is primarily coming from the higher resistive section from 11,460 ft - 11,645 ft (3493 m - 3549 m). Current owners of this well, informed us that this well is presently producing about 1.2 - 2 barrels of oil per day with no water. The second well to have some production from the TMS is the Callon #2 Cutrer well located in Sec. 55-T1S-R7E, about 7 miles (11.2 km) northwest of the Texas Pacific #1 Blades well and about 7 miles (11.2 km) east-southeast of Gillsburg Field, Amite County, Mississippi. It encountered the top of the TMS at a measured depth of 11,520 ft (351 m) and was perforated over the interval 11,544 ft - 11,678 ft (3519 m - 3559.5 m). This well produced about 2,500 barrels of oil from the TMS before being plugged and abandoned in 1991.

Our discussions with Schlumberger log analysts on several logs have led us to believe that the criteria we have established for delineating the potential areal extent of the TMS resistive zone are reasonable and valid. High resistivity (generally 5 ohms or more) or a dramatic increase in resistivity (3.5 ohms or more) required consideration. Obviously, vintage or type of logging device, drilling mud characteristics (logging tool environments, resistivity) etc. are factors in determining 'high' resistivity log readings. In determining net thicknesses, high resistive sections that were not separated by more than 20 ft (6 m) of low resistive shales were counted. Smaller resistive sections separated by 20 ft (6 m) or more of shale were omitted for the count. Fairly high resistive zones with more than one ohm of separation between the short normal resistive curve reading and the lower long normal resistive or conductivity reciprocal were considered to be questionably potential, in which case surrounding wells were checked and influenced decisions. In some cases, instinct or "feel" might have been a factor in determining net section thickness. There seems to be little doubt that the highly resistive section of the TMS is hydrocarbon laden. It is also obvious that some permeability and porosity exists, but how much of each would be of great importance in dealing with economic aspects. Unfortunately, little is known about porosity and permeability of the TMS. Basically our knowledge is limited to knowing that two wells produced enough volume of oil to warrant attention, and the information available from well logs or cores.

To determine the regional extent of the TMS an east-west, basically a strike section (S-1) was constructed (Figure 5). This cross section graphically demonstrates the lateral extent of the resistive TMS section. It also demonstrates the overall loss of the resistive TMS section west of Avoyelles Parish, Louisiana, as well as its thinning to the east in Washington and St. Tammany Parishes of Louisiana. Seven north-south dip sections (D-1 to D-7) were also compiled crossing the strike section as shown in Figure 3. The eastern most dip cross section (D-1, Figure 6) reflects the regional updip thinning of the resistive TMS in the northern portion of Washington Parish, Louisiana, its downdip thickening 100 ft (30.5 m) towards the south in Washington Parish and then a regional downdip fading of the section further to the south in Tangipahoa Parish, Louisiana. The D-2 dip section (Figure 7) extends from just west of McComb, Mississippi, in Pike County to north of Amite in Tangipahoa Parish, Louisiana. It goes through the Texas Pacific Oil Company Winfred Blades #1 well, which represents the

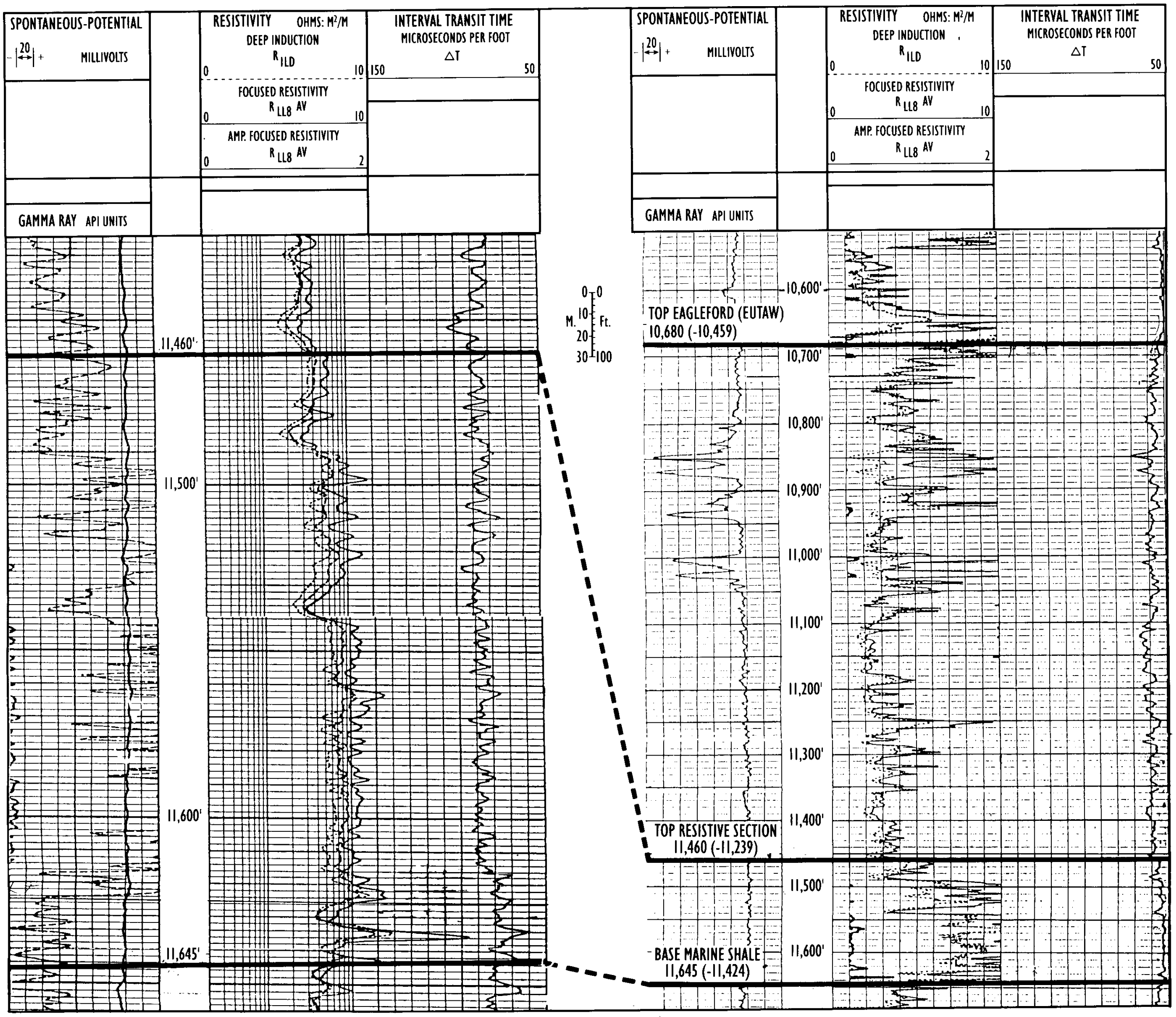

Figure 4. Type log of the marine shale section from the Texas Pacific Oil Company, #1 Winfred Blades, Tangipahoa Parish, Louisiana. The 1" log of the resistive section is shown on the right side and the 5" log is shown on the left side of the figure.

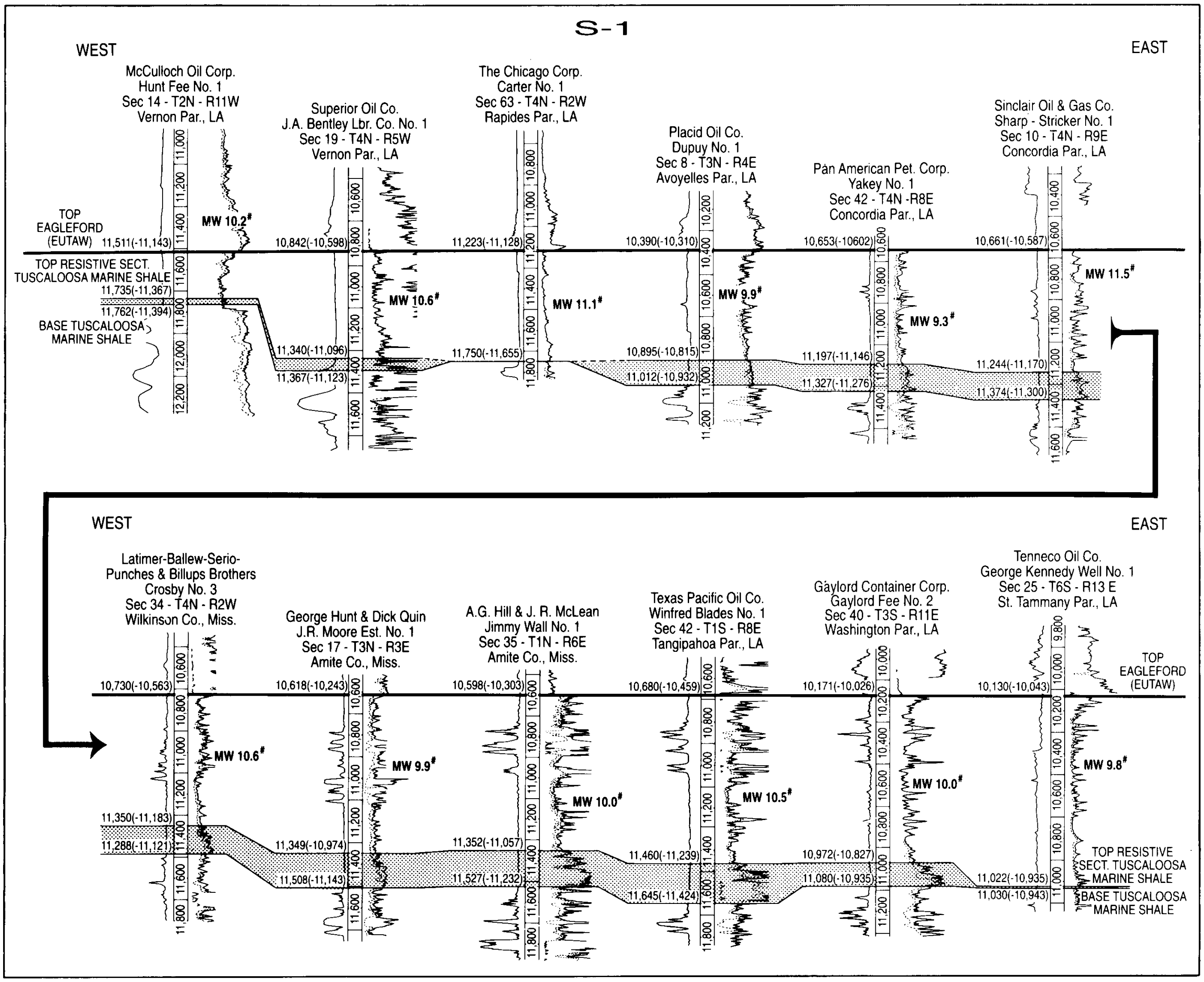

Figure 5. East-west strike section (S-1) across the study area from St. Tammany Parish, Louisiana through southwest Mississippi to Vernon Parish Louisiana.

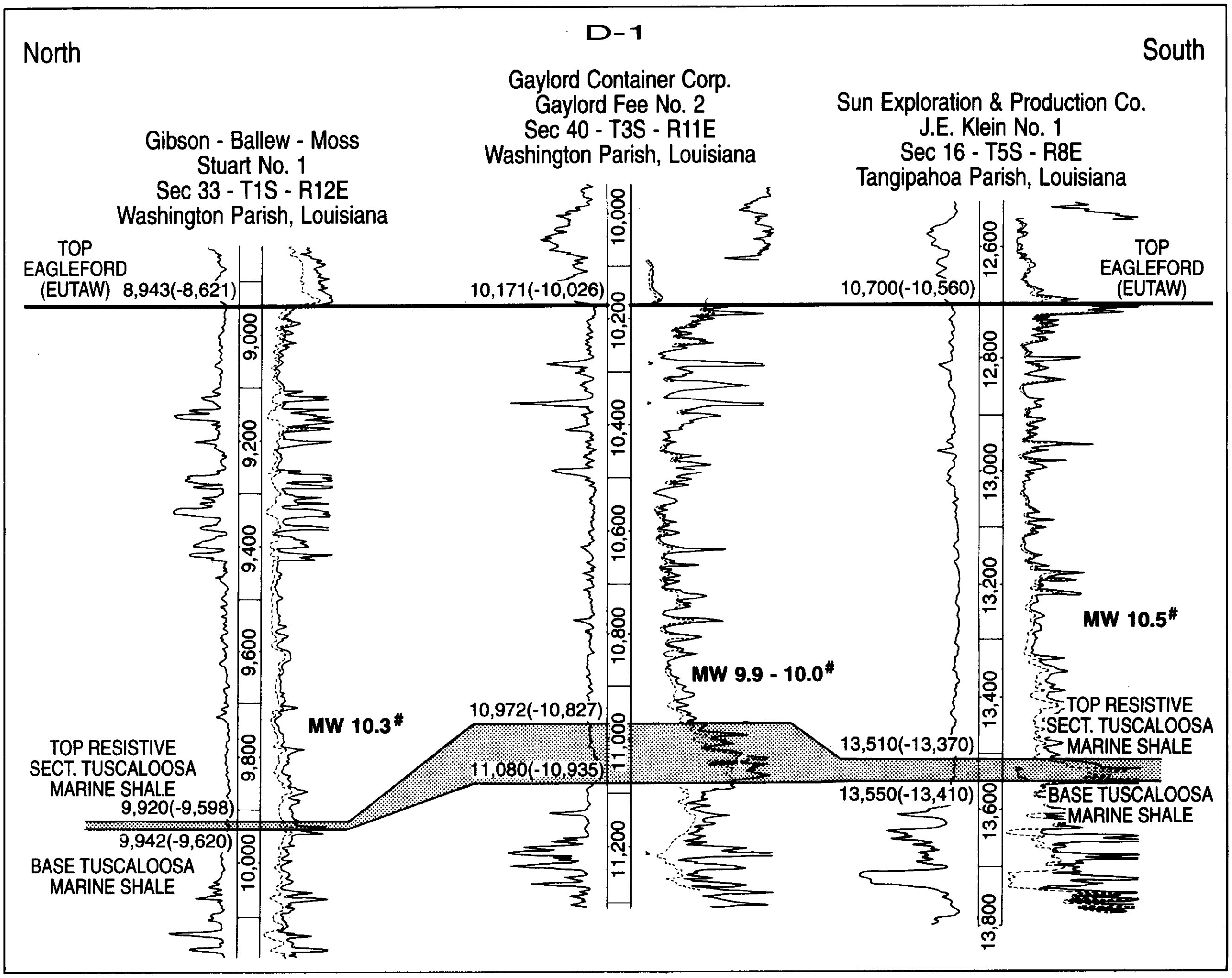

Figure 6. North-south dip section (D-1) across the eastern part of the study area from Washington Parish to Tangipahoa Parish, Louisiana.

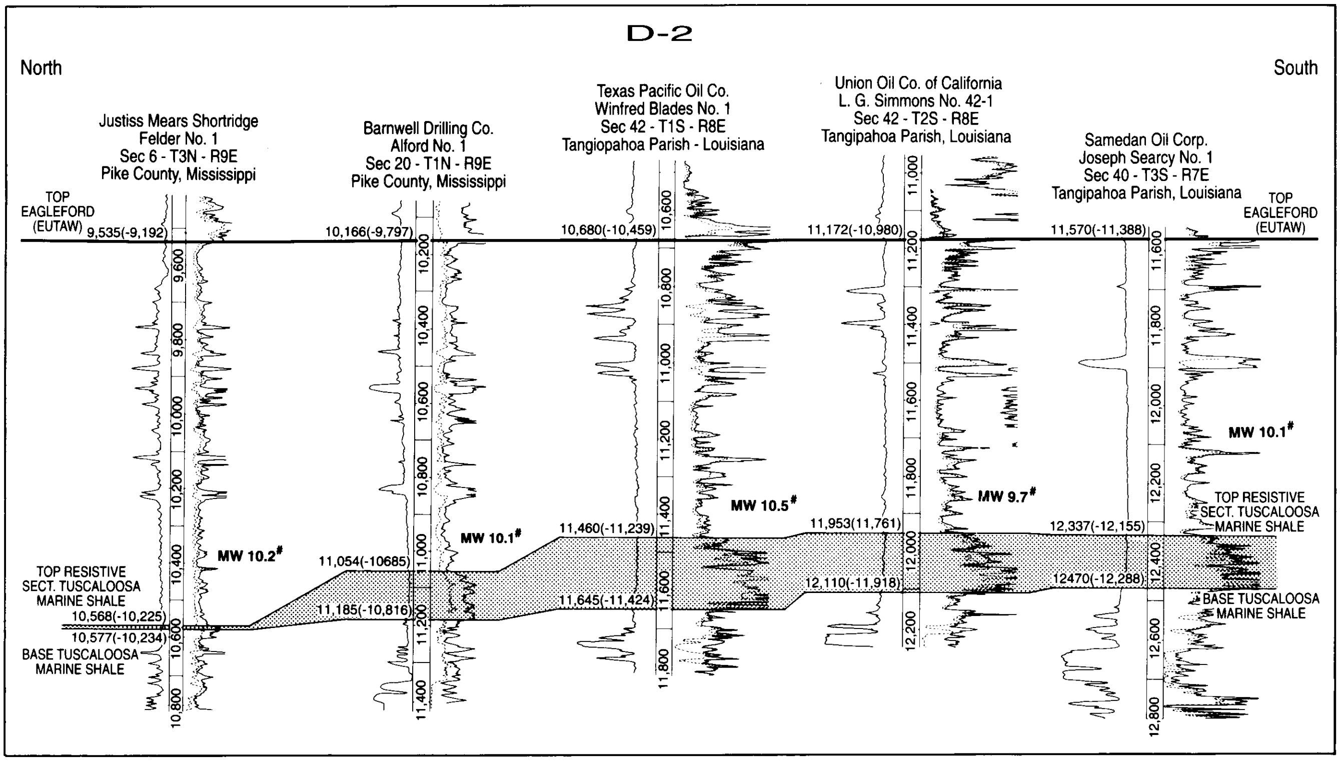

Figure 7. North-south dip section across the eastern part of the study area from Pike County, Mississippi to Tangipahoa Parish highlighting the resistive marine shalesection. See figure 3 for the line of cross section (D-2). The Texas Pacific Oil Co., Winfred Blades No. 1 well, located in the center of this cross section is the only known well currently producing oil from the Tuscaloosa marine shale.

standard or type log used for this study, and is the only well producing from the TMS. The lower resistive TMS section has a maximum thickness of 185 ft (56.4 m) in the southwestern portion in Tangipahoa Parish, Louisiana and thins to 9 ft (2.7 m) to the northeast in Pike County Mississippi. The TMS section also dips from 10,225 ft (3116.5 m) in Pike County, Mississippi to a depth of 12,155 ft (3705 m) in Tangipahoa Parish, Louisiana. Figure 8 shows the D-3 cross section which is the longest dip section in the study area traversing what may be considered "the heart of the potentially productive area". The thinnest part of the TMS section here is about 65 ft (19.8 m) and is found at the north end of the cross section in Amite County, Mississippi and it thickens to more than 220 ft (67 m) to the South as seen in the Amoco, Corona No. 1 well located in East Baton Rouge Parish, Louisiana. The D-4 dip cross section (Figure 9) is located in the central part of the study area more or less along the Louisiana - Mississippi border. This cross section traverses the "golden trend" of good thick resistive TMS section. The Humble Oil & Ref. Company well in Adams County, Mississippi shown at the north end of this cross section (Figure 9) encountered a thick 135 ft (41 m) resistive TMS section at a depth of 10,100 ft (3078 m) which is shallower than in most other areas. The thickest resistive TMS section of 305 ft (93 m) is seen in the Pennzoil Laborde No. 1 well located at the southern end of the cross section in Point Coupee Parish, Louisiana at a depth of 16,190 ft (4935 m).

The D-5 cross section (Figure 10) fairly well demonstrates our belief that shale encountered above 10,000 - 10,500 ft (3048 - 3200 m) does not have resistivity necessary to indicate hydrocarbon content in the study area. As shown on the cross section, the resistive TMS section thins towards the north end, but thickens towards the south. The thickest TMS section of 166 ft (50.5 m) on this cross section is seen in the Shell Oil Company, Edwin Barbin No. 1 well located in Avoyelles Parish, Louisiana, and is found at a depth of 12,060 ft (3676 m). The D-6 cross section (Figure 11) shows the beginning of the overall thinning of the Eagle Ford - TMS section in the western part of the study area. The resistive TMS section is completely missing (not developed) in some wells on this cross section. The D-7 dip cross section constructed at the western end of the study area (Figure 12) again shows the thinning of the overall interval of

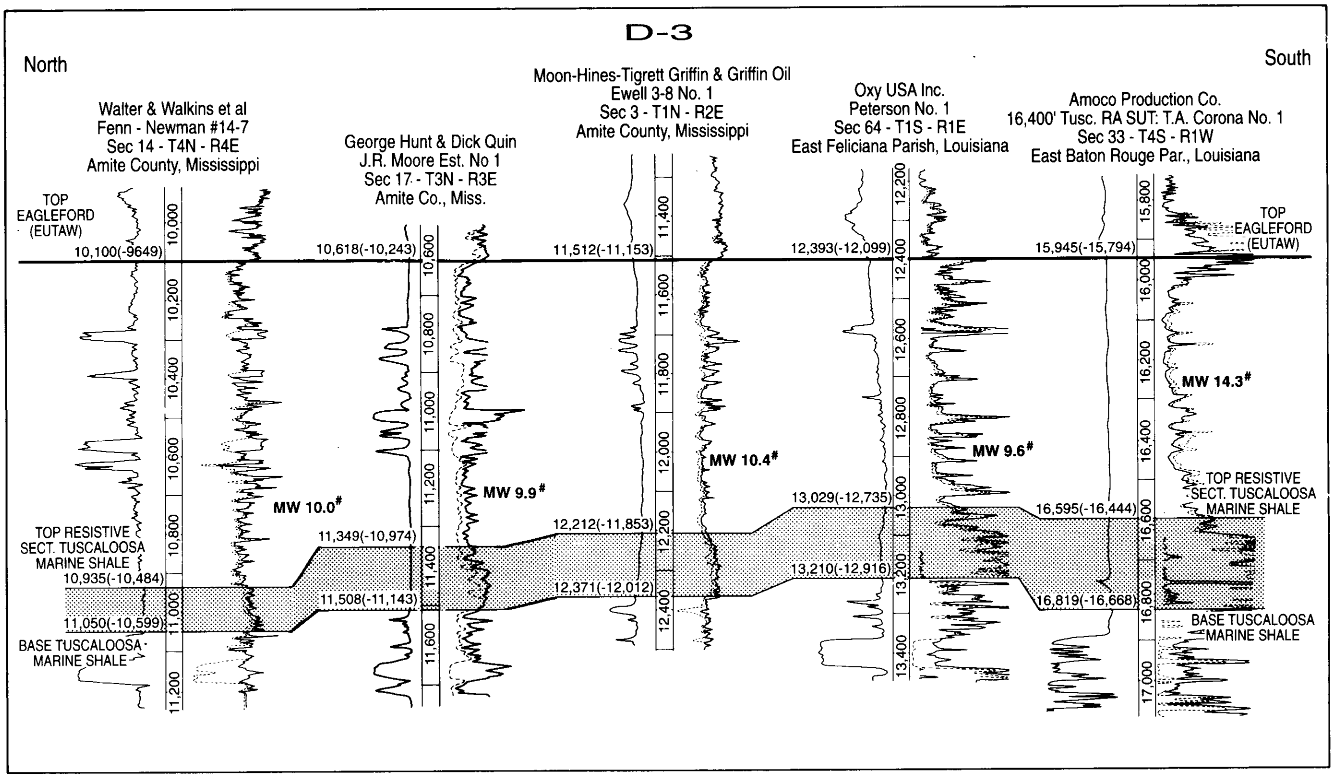

Figure 8. North-south dip cross section across the central part of the study area from Amite County, Mississippi to East Baton Rouge Parish, Louisiana. The resistive marine shale section is highlighted on this cross section. The line of cross section (D-3) is shown in figure 3.

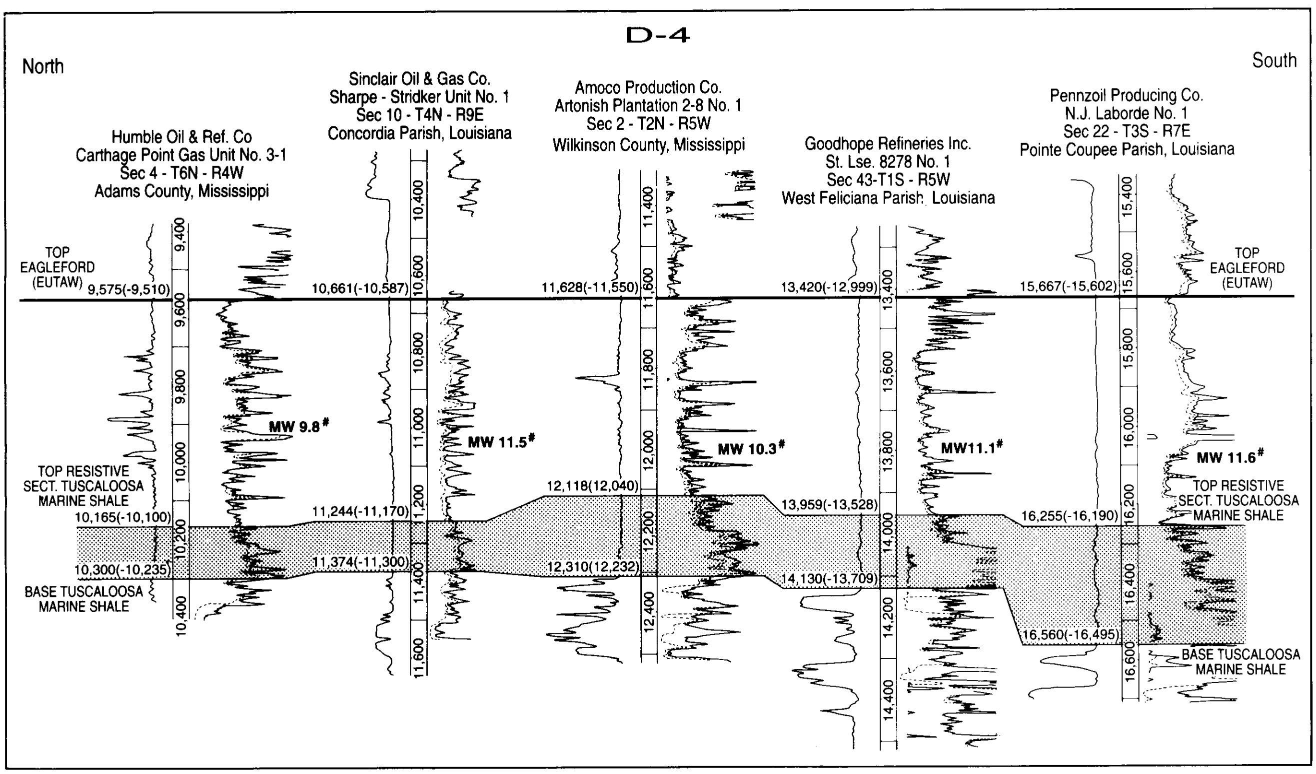

Figure 9. North-south dip cross section across the central part of the study area running more or less along the Louisiana - Mississippi State boundary from Adams County, Mississippi to Pointe Coupee Parish, Louisiana highlighting the resistive marine shale section. The location of this cross section (D-4) can be seen in figure 3.

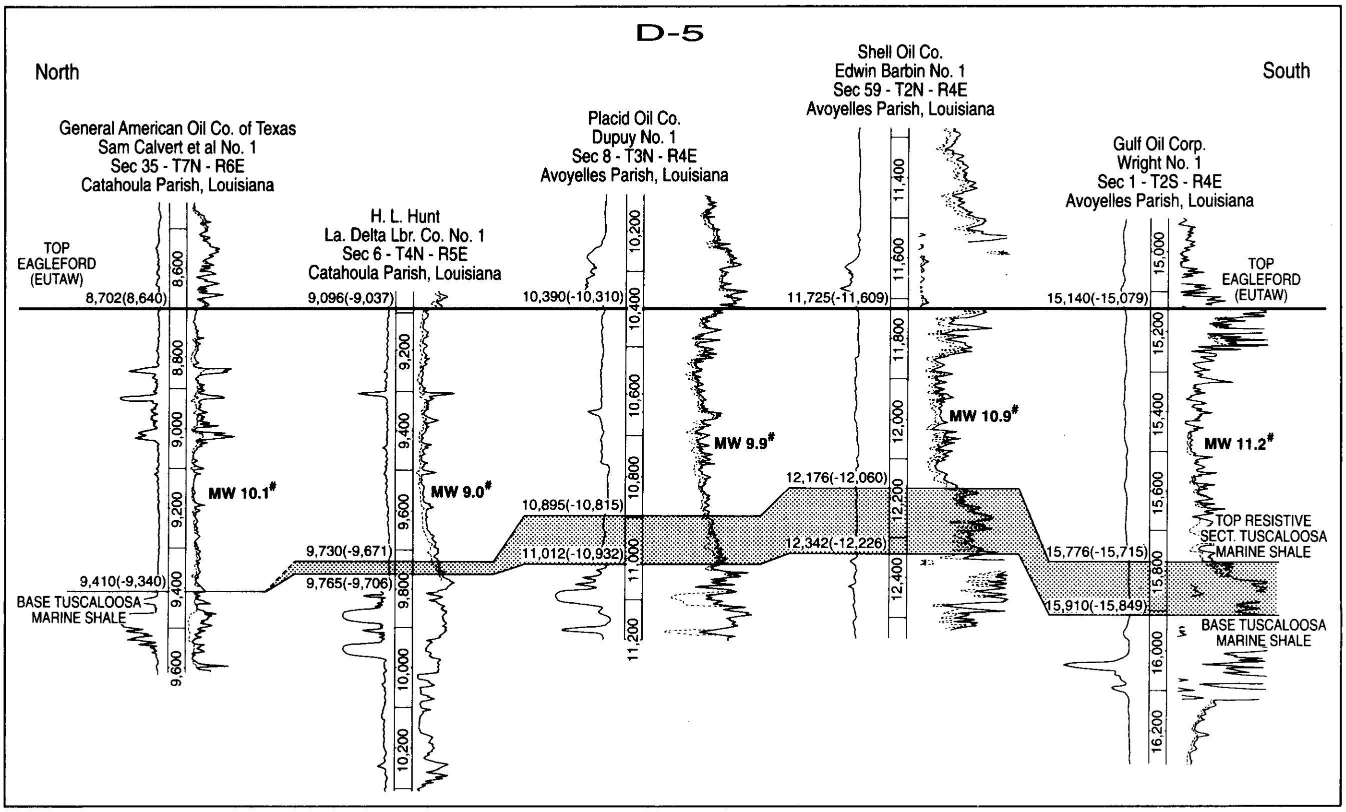

Figure 10. North-south dip cross section across the central part of the study area from Catahoula Parish to Avoyelles Parish. The resistive marine shale section is highlighted. See figure 3 for cross section location (D-5).

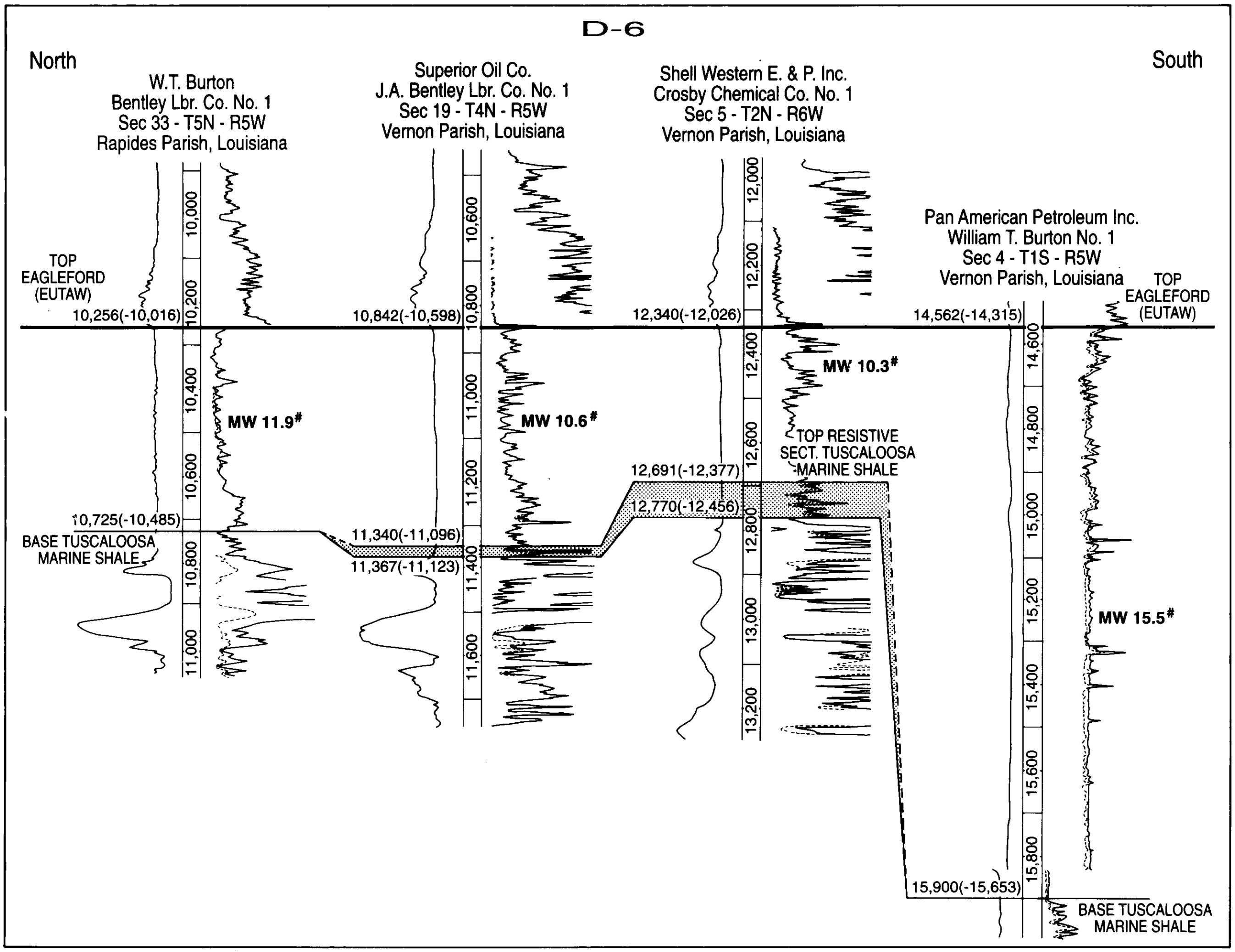

Figure 11. North-south dip cross section across the western part of the study area from Rapides Parish to Vernon Parish showing the resistive marine shale. See figure 3 for the location of this cross section (D-6).

the Eagle Ford to the TMS section, possibly influenced by the Sabine uplift to the north. Another notable factor is the lower resistivity demonstrated at the base of the section in comparison with wells farther east in the study area.

Structure maps were made on several horizons along with isopachous maps of the in-between intervals. All the maps were made using the GeoGraphix computer software which is commercially available.

Figure's 13 and 14 reflect the general structural configuration on top of the Eagle Ford Formation and base of Tuscaloosa marine shale respectively, through out the study area. There are only slight differences in strike and dip rates between these structures and other structure maps previously published on well known geological horizons. An isopach map from the top of Eagle Ford - base of Tuscaloosa marine shale interval (Figure 15) shows the thickening to the northeast and the thinning of section northwestward. Major thickening to the southwest is based on minimum well control and may not reflect the complete picture. The regional structural nature of the resistive Tuscaloosa marine shale section is shown in Figure 16. Again this regional structure is similar to other regional maps of this area with only slight differences in strike and dip rates between structural maps in this study and those previously published. It is noteworthy that even on this scale some small undulations are noted in northeastern Rapides Parish (Big Island Field), Gillsburg Field at the Louisiana - Mississippi border in Amite County, Mississippi, and at Lockhart Crossing Field in Livingston Parish, Louisiana. Also note the very sparse control below 12,500 ft. (3810 m) in parishes to the west of Rapides Parish, Louisiana. A three dimensional view of this structure is shown in Figure 17.

Figure 18 is an isopach map of the resistive Tuscaloosa marine shale on a 20 ft.(6.1 m) contour interval. The "heart" or thickest zone is located from Avoyelles Parish on the west to Washington Parish to the east. A net isopach of this resistive Tuscaloosa marine shale section (Figure 19) is contoured on a 10 ft. (3 m) interval and shows the most attractive areas for potential production. Figure 20 is provided to reflect these "hot spots" or maximum net thickness of resistive Tuscaloosa marine shale in relationship to the depth one

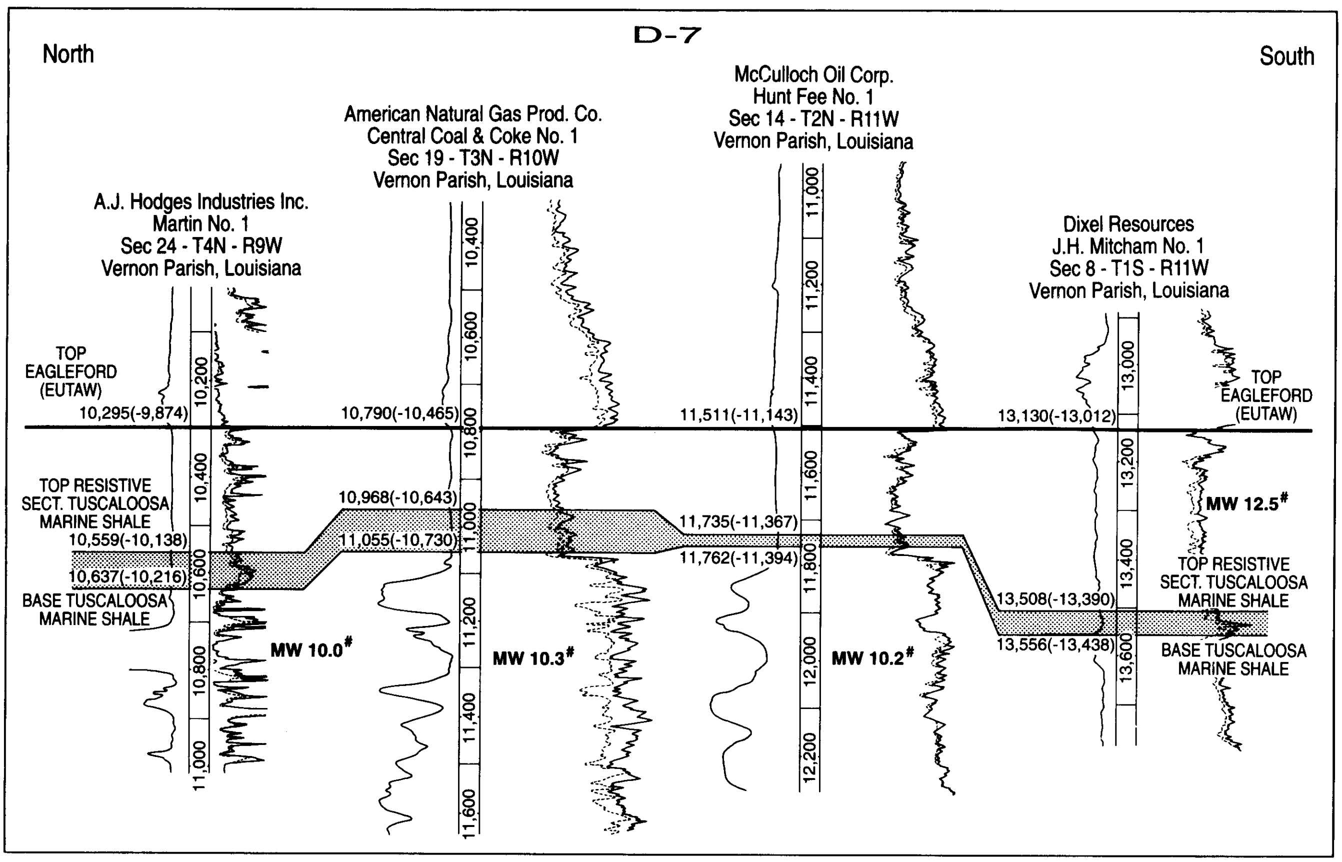

Figure 12. North-south dip cross section across the western most part of the study area in Vernon Parish, Louisiana highlighting the resistive marine shale section. The location of this cross section (D-7) is indicated in figure 3.

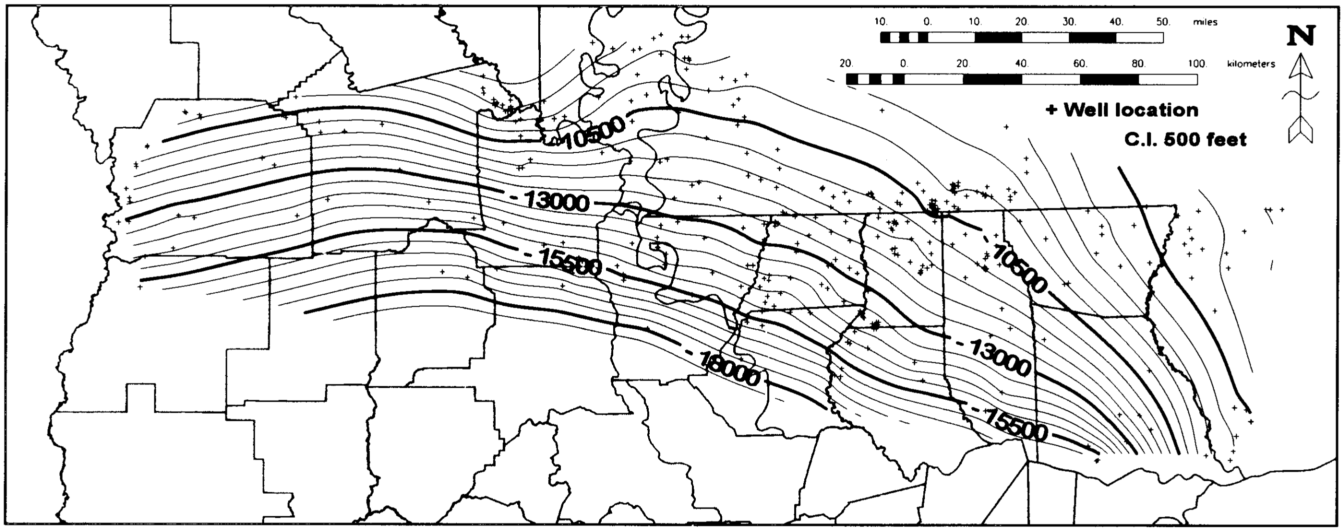

Figure 13. Structure map of the study area on top of the Eagle Ford Formation.

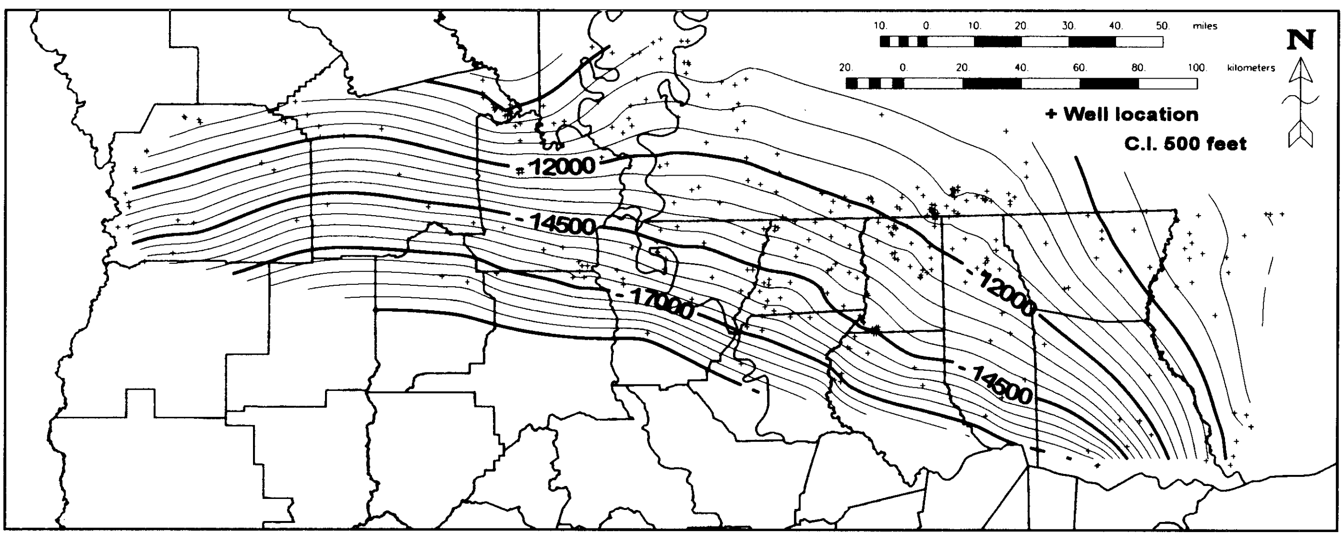

Figure 14. Structure map of the study area drawn at the base of the marine shale.

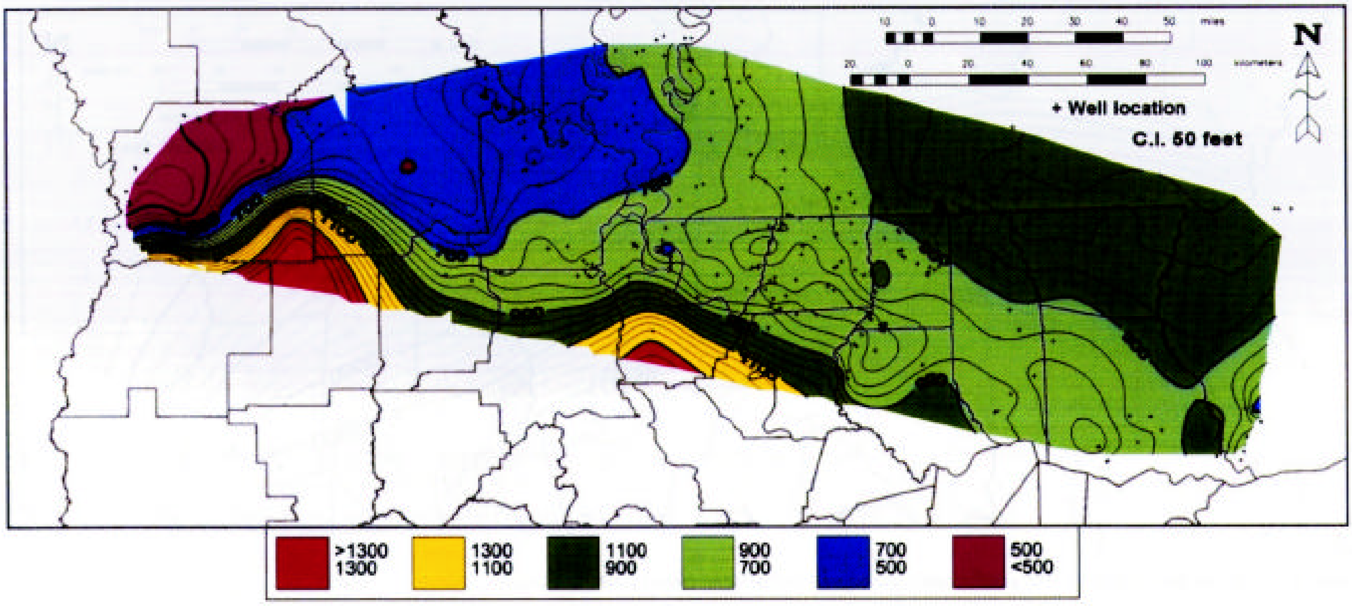

Figure 15. Isopach map showing the overall thickness from the top of the Eagle Ford to the base of the marine shale in the study area.

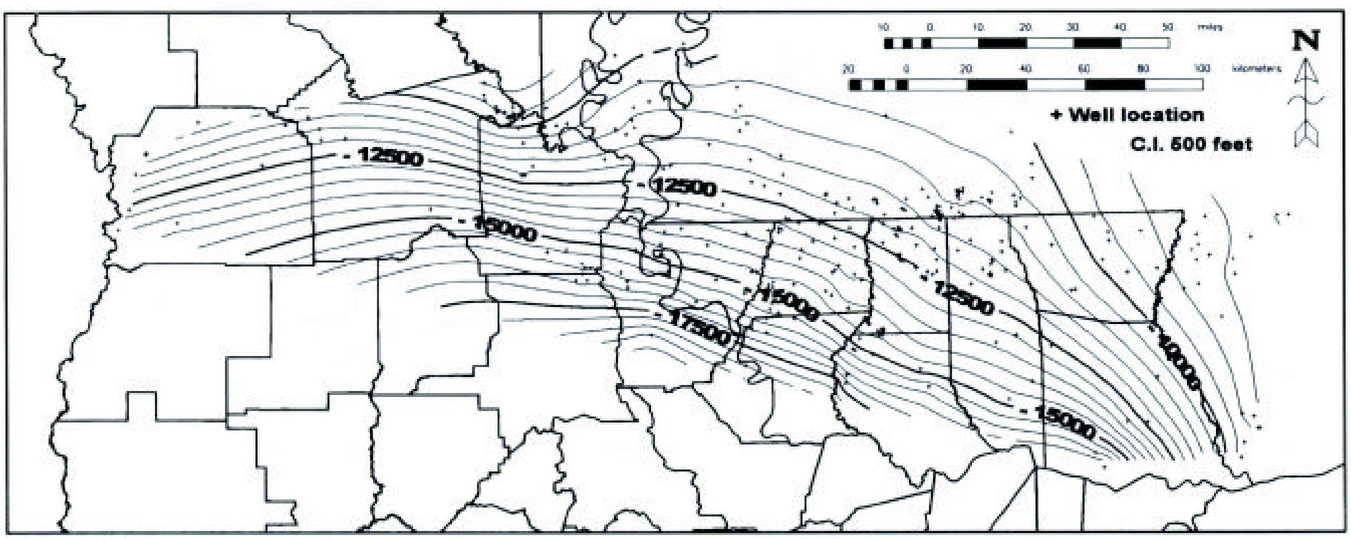

Figure 16. Structure map drawn on top of the resistive section of the Tuscaloosa marine shale.

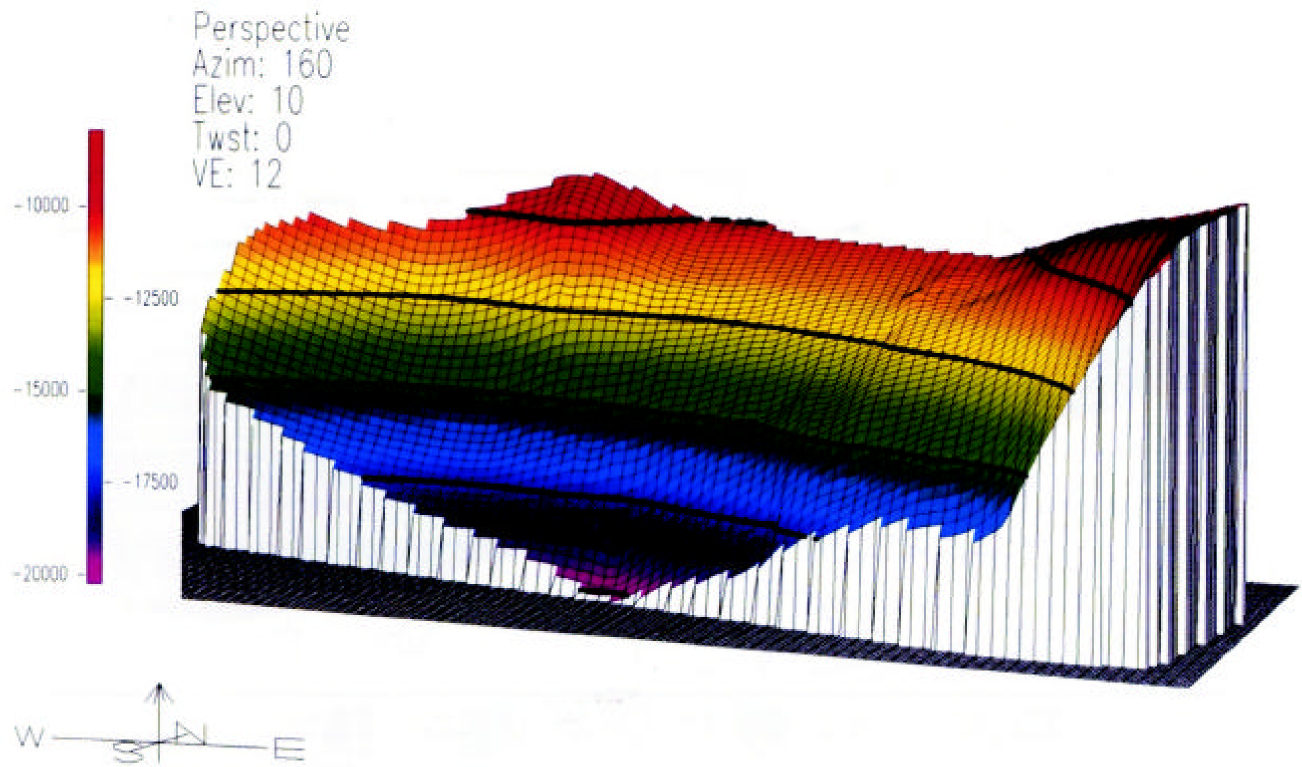

Figure 17. Three dimensional representation of the structure map on top of the Tuscaloosa marine shale resistive section.

would encounter the prospective zone. The net isopach is color coded to reveal the maximum areas of thickness. To further illustrate this depth - net thickness relationships a three dimensional view is found in Figure 21.

The TMS has for many years and by many geologists been thought to be the "source rock" for the production from the Tuscaloosa sand reservoirs. This has been substantiated by a geochemical analyses of oil from two wells in the study area: the Canadian Delta (formerly Norcen) #A-1 Calhoun (upper Tuscaloosa sand) at Gillsburg Field in Amite County, Mississippi, and the Long Leaf (formerly Texas Pacific) #1 Blades well in Tangipahoa Parish, La. (Silvercreek Field). These analyses were performed by DGSI, Houston, for The Basin Research Institute, Louisiana State University. A more detailed discussion of the geochemical analyses results of the oil samples from these two wells is provided by Echols (1997) in the technical note immediately following this paper.

Reserve Potential

Well logs have shown an average section thickness of 93 ft (28.3 m) of prospective TMS section within the 50 ft (15.2 m) net resistive TMS contour. If this figure is used as a lower average thickness limit of the shale and if even only 40% of the resistive TMS section has fracture induced porosity and permeability, then there would still be a net effective section of approximately 37 ft (11.3 m) which could potentially yield hydrocarbons. If fracturing is not widespread and/or if porosities are low, then a conservative figure of 50 barrels of oil per acre foot could probably be assumed. Since the shale section within the 50 ft (15.2 m) thickness contour covers an area of about 5900 square miles or 3,776,000 acres (15,281 square km) it potentially could produce approximately 7 billion barrels of oil.

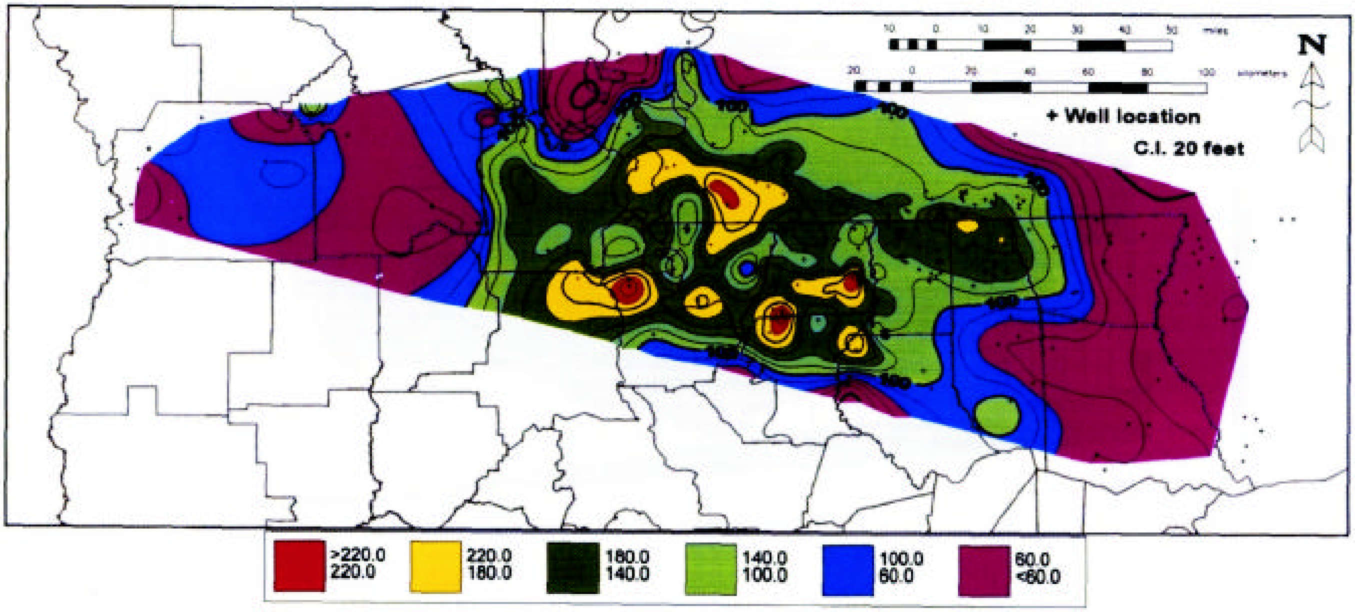

Figure 18. Isopach map of the Tuscaloosa marine shale resistive section.

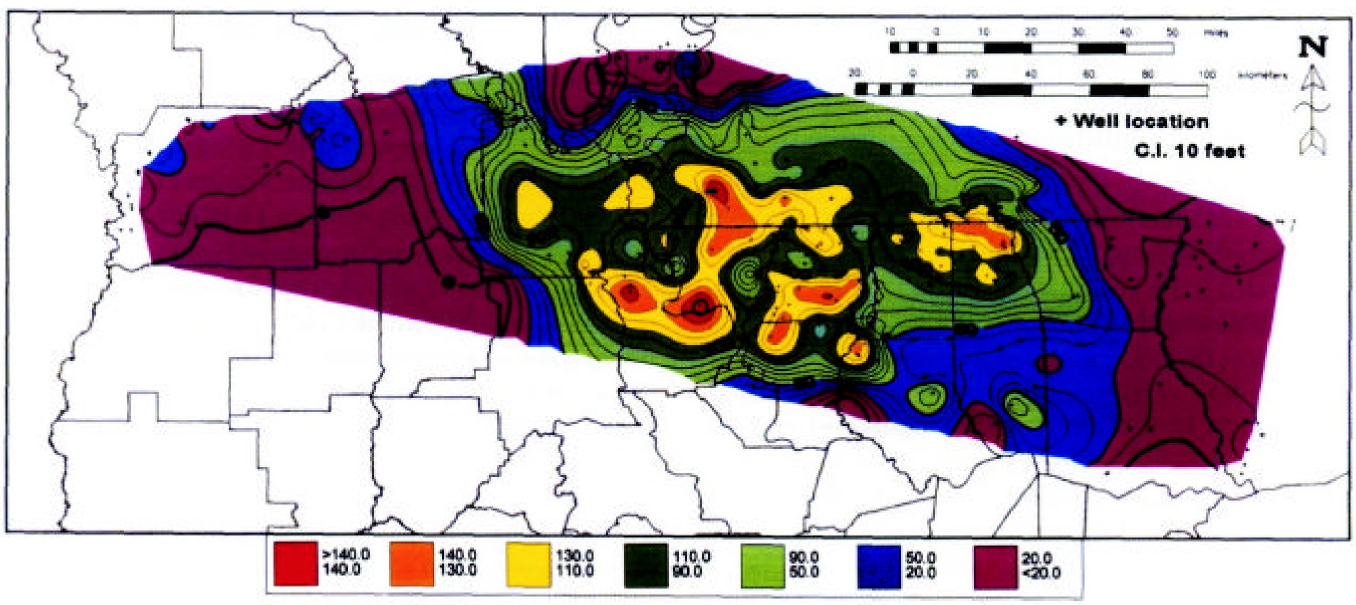

Figure 19. Net isopach map of the resistive Tuscaloosa marine shale section.

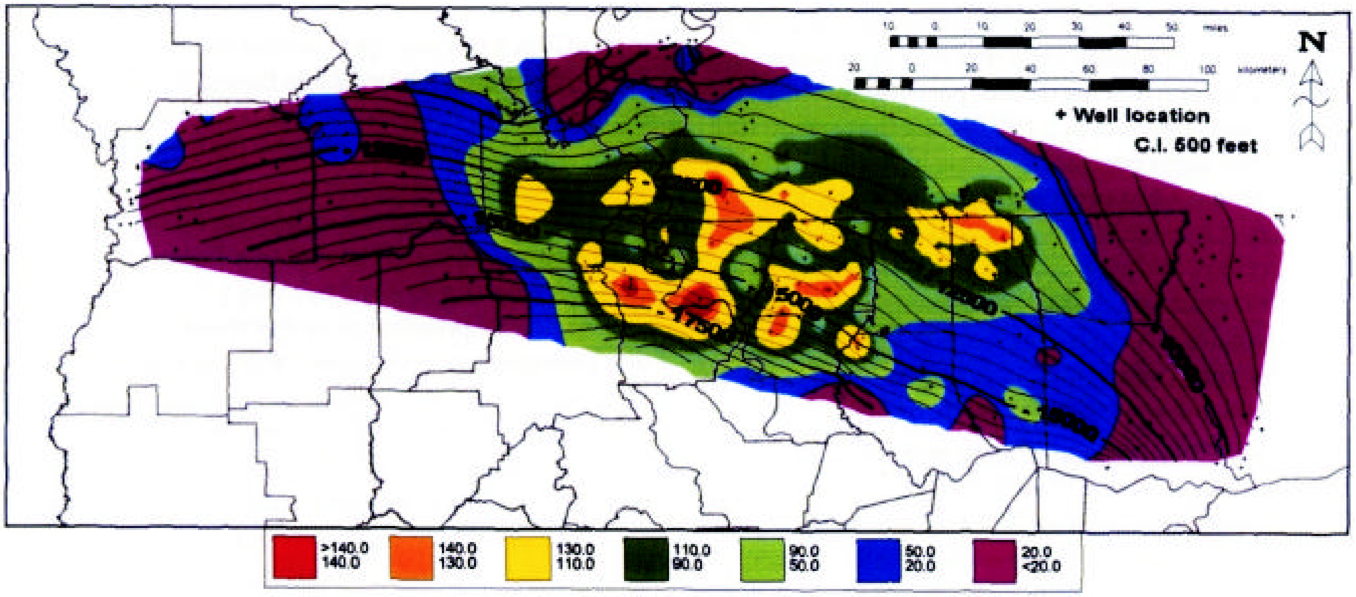

Figure 20. Resistive Tuscaloosa marine shale net isopach superimposed on structure map of resistive Tuscaloosa marine shale section.

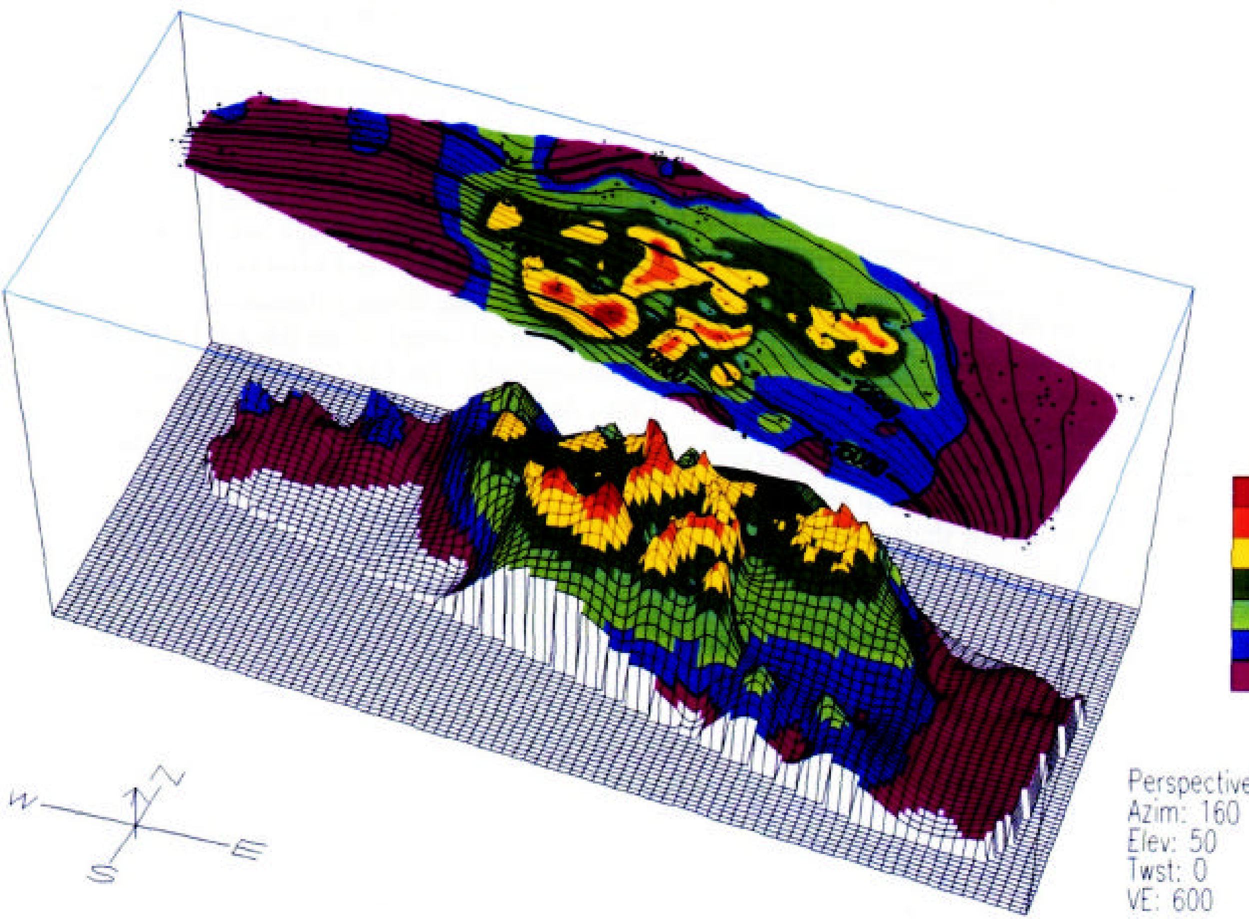

Figure 21. Three dimensional representation of the Tuscaloosa marine shale net isopach with superimposed structure on top of the resistive section.

Horizontal Drilling

Horizontal drilling technology has significantly advanced in recent years in so much as deep horizontal wells are currently being drilled, particularly in the Austin Chalk. Deskins et al.,(1995) state that about 1000 horizontal wells per year are now being drilled in the United States. Most of these are in the Austin Chalk play of Texas - Louisiana (79%), the Bakken Shale in North Dakota (5%), Niobrara in Colorado-Wyoming (2%) and in other formations (14%). Most horizontal wells in the U.S. are being drilled in intersecting fractured formations for improved production and also in some cases for minimizing water and/or gas coning.

Using the horizontal drilling technology available today it probably would be feasible to drill a carefully planned horizontal well in the TMS section. Such a well would increase the possibility of commercial production from the TMS and result in a significant increase in the recoverable reserves which could not have been technically or economically obtained with traditional vertical well technology. Preliminary evaluations point to the strong possibility that the TMS may contain significant hydrocarbon reserves. This now awaits confirmation by the drill bit using horizontal drilling technology to maximize production and minimize environmental impacts.

Summary

The lower resistive section of the Tuscaloosa marine shale is a potentially significant commercial oil reservoir under a large area straddling the Mississippi - Louisiana boundary south of McComb, Mississippi and covering the Florida Parishes of Louisiana, the southwestern counties in Mississippi and extending westward through central Louisiana to the Texas border. The most prospective section covers an area of approximately 5900 sq. miles (15,281 sq. km) and has potential reserves of 7 billion barrels of oil. The marine shale section lies between the sands of the upper and lower Tuscaloosa sections and varies in thickness from 500 ft. (152.4 m) in southwestern Mississippi to more than 800 ft. (244 m) in the southern part of the Florida Parishes, southeastern Louisiana. The primary zone of interest, a high log resistivity (5+ ohms) zone is located at the base of the Tuscaloosa marine shale section and is found at the shallowest depth of approximately 10,000 ft. (3048 m). Production from this section by conventional drilling and production methods has been established by the Texas Pacific Oil Company, #1 Blades well (Sec. 42, T1S, R8E) located in the Tangipahoa Parish of southeastern Louisiana. This well has produced over 20,000 barrels of oil with no water at a rate of 1-2 barrels per day for the last nineteen years. There are a number of reports of oil shows in mud logs from wells penetrating the section throughout the study area. The mud logs have generally described the shale as being light to dark gray or brown, splintery, brittle, micaceous, calcareous silty shale with occasional stringers of white to light gray sand that, in most cases, has a yellow fluorescence indicating oil in the sample. Horizontal drilling of the resistive Tuscaloosa marine shale section is proposed because it is the most up to date technique presently available to maximize production and minimize environmental impacts. These features are especially important since production from a single well (vertical completion) may not yield commercially economic quantities of oil. If proved economically, the Tuscaloosa marine shale oil would be a huge addition to the domestic United States oil reserves. It will also lead to the further possibility of opening up exploration and exploitation of similar deep fractured shale resources throughout the country and other areas of the world.

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