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Depositional History and Stratigraphic Framework of Upper Cretaceous (Campanian to Maastrichtian) Strata in the Minerva-Rockdale Oil Field of Milam County and Adjacent Counties, Texas.

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fulfillment of the requirements for the degree of
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by

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ABSTRACT

First discovered in 1921, the Minerva-Rockdale Oil Field (MROF) has experienced a recent resurgence of drilling. The targeted Navarro Group is Upper Cretaceous (Maastrichtian) in age and ranges in depth from approximately 100 to 3000+ ft. (subsea). Several thin elongated sandy zones within the Kemp clay of the Corsicana (Navarro) Formation are the current targets for oil production. These sandy zones are informally divided into the Navarro ‘A’ and ‘B’ and their depositional morphology is described by the shelf plume model, as proposed by Patterson (1983).

Despite the mature nature of the MROF and surrounding area, only a small number of published studies regarding the local strata exist. The purpose of this study is to: (1) produce a regional stratigraphic framework for the Eagle Ford though Navarro Group strata within Milam and surrounding counties, (2) document the sequence-stratigraphic framework for Campanian to Mastrichtian aged strata, (3) recreate and test the depositional shelf plume model developed by Patterson (1983).

Donated well logs and one sidewall core report from a current operator in the Minerva-Rockdale Oil Field as well as raster logs obtained from the Drillinginfo.com aided in reconstructing and testing the shelf plume model. Findings from the correlation of 274 well logs and analysis of the modern sidewall core report challenge depositional proximity of the elongated sand bodies to a deltaic depocenter.

ACKNOWLEDGEMENTS

Firstly, I would like to express much gratitude to Dustin Price of Price Land and Energy for the generous donation of data which formed the foundation of this project.

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A special thanks is extended to all of the friends I made during this process. Their support and advice helped me complete the needed classwork and my thesis in a timely manner.

Finally, I would like to acknowledge the endless appreciation I have for my family and their continued encouragement throughout my college career.

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1. INTRODUCTION AND GEOLOGIC BACKGROUND

1.1 INTRODUCTION

First discovered in 1921, The Minerva-Rockdale Oil Field (MROF) is located in south central Milam County, Texas (Figure 1). The first producing well in the Minerva-Rockdale Oil Field was drilled on February 17, 1921 by Okla-Bell Oil Company, at a depth of 627 feet with an initial production of 8 barrels (Brown and Hanger, 1924). At that time the field was known as the Minerva shallow pool and it was not until 1922 that the field began to see greater interest. By November 1, 1923 there were 153 producing oil wells, one gas well, and 18 dry holes (Brown and Hager, 1924). The Minerva-Rockdale Oil Field has produced over seven million barrels of oil to date.

Currently the field covers approximately 70 square miles and due to recent development is growing in size and well density. Although not an area of prolific drilling for major companies, the shallow nature of this field paired with the low but sustained production has proven to be economic for smaller independent operators. Due to low drilling costs and the relatively high price of oil, a recent resurgence has sparked academic and industrial interest within the field.

The targeted Navarro Group is Upper Cretaceous (Maastrichtian) in age and ranges in depth from approximately 100 to 3000+ ft. (subsea). Several thin elongated sandy zones within the Kemp clay of the Corsicana (Navarro) Formation, are the current targets for oil production. These sandy zones are informally divided into the Navarro ‘A’ and ‘B’ and are described as clean to dirty sandstone bodies separated by varying numbers and thickness of shale partings (Patterson, 1983; Brown and Hager, 1924; Hencey and Tucker, 1987).

Despite the recent increase in drilling activity, few studies have been published regarding the stratigraphic framework and depositional history within the MROF. Patterson (1983) conducted the only known study regarding the depositional processes of the sandstone bodies within the Navarro Group. Although very detailed in nature, Patterson's study did not provide a regional stratigraphic framework and lacked the use of modern well logs.

The study conducted by Patterson (1983) served as the intial guide for constraining my study area and research methods. The acquisition of more data expanded the study area and provided greater detail for containing a sequence stratigraphic framework. The subsurface interpretations presented in this study are based on well log analysis from approximately 270+ well logs across 5 counties (Milam, Lee, Burleson, Robertson, and Williamson).

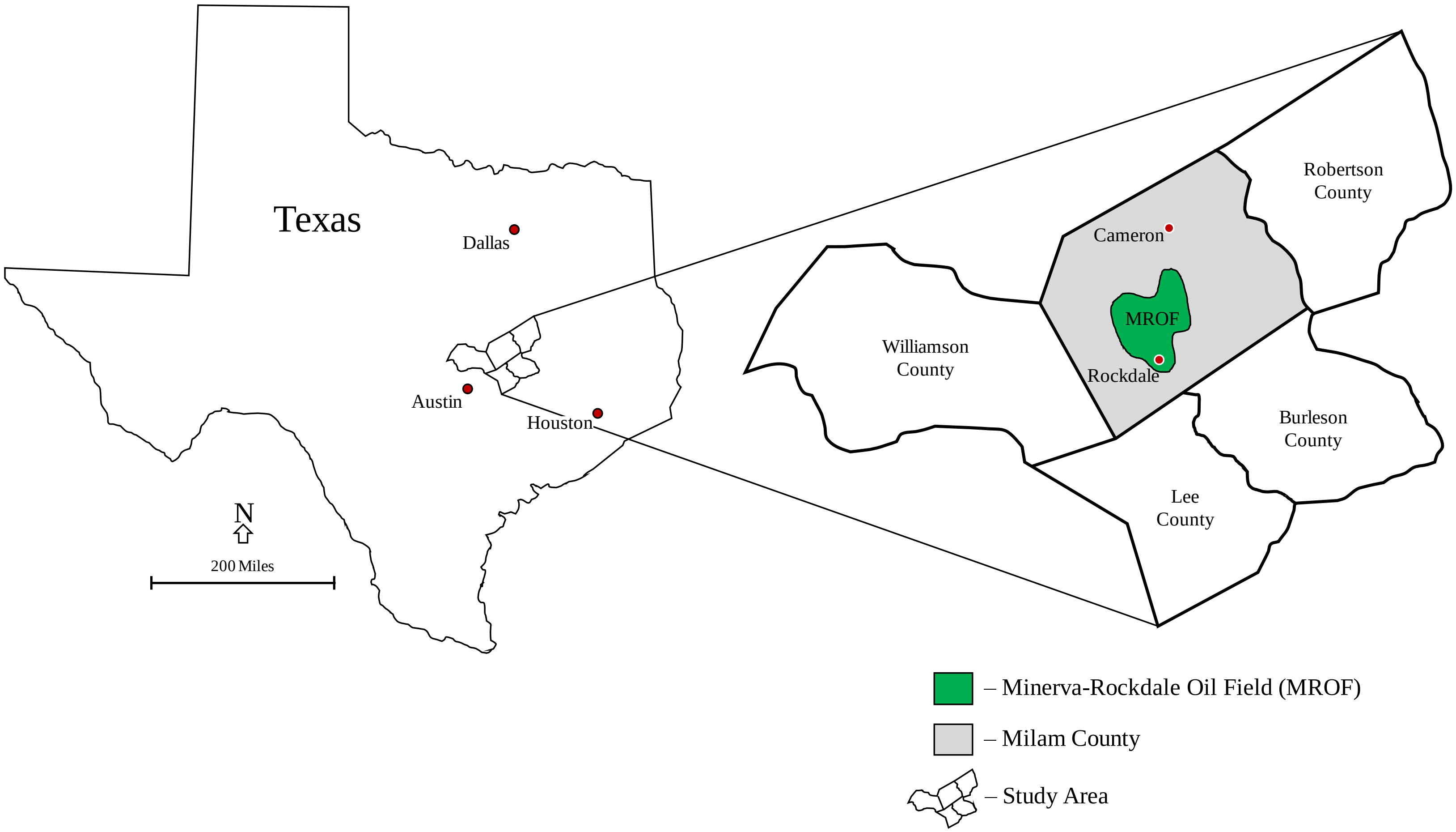


Figure 1: Location map of study area and Minerva-Rockdale Oil Field (MROF).

Previous Work

Despite the mature nature of the MROF and surrounding area, only a small number of published studies regarding the local strata exist. Brown and Hanger (1924) first introduced the Minerva Oil Field, now known as the Minerva-Rockdale Oil Field. This study focused primarily on providing general information about the location, initial production, well cuttings, and subsurface structure. Other early works focused on age determination by faunal characterization of the Navarro Group (Plummer, 1926; Dane and Stephenson, 1928; Stephenson, 1941; Pessagno, 1969).

Few studies have addressed the local stratigraphy or depositional framework within the Minerva-Rockdale Field and surrounding area. An outcrop study by Lopez and McGowen (1983) in Northeast Texas and Southwest Arkansas focused on depositional systems of the Nacatoch Formation within the Navarro Group. Although deposited before the Navarro ‘A’ and ‘B’, the detailed outcrop analysis of the Nacatoch sandstone provides suggestive insight into possible depositional trends between the Nacatoch and Navarro ‘A’ and ‘B’ (Figure 2).

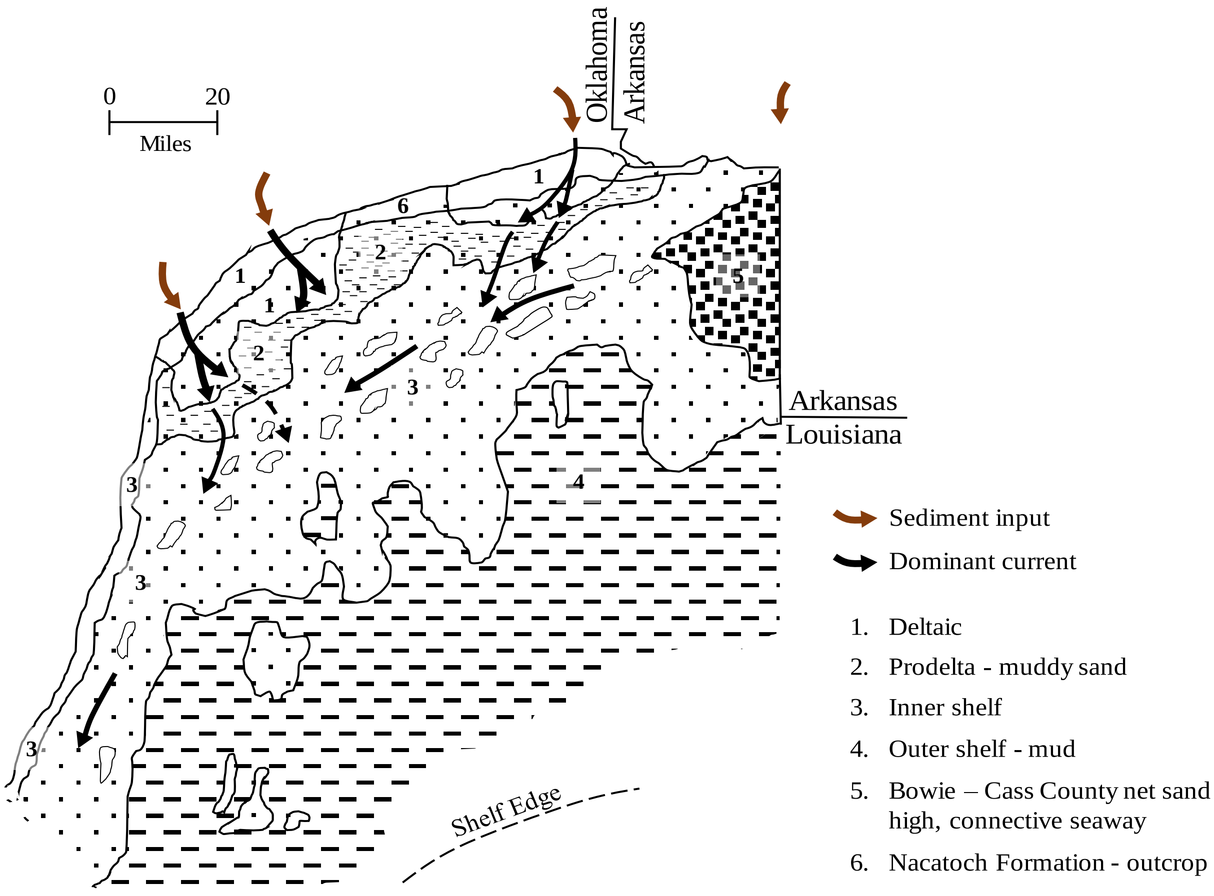


Figure 2: Depositional model and facies distribution map of the Nacatoch Formation within the East Texas Basin (modified from Lopez and McGowen, 1983).

Adjacent to the study area (Figure 1), in Bastrop County, subsurface work was performed by Hencey and Tucker (1987) which looked at Buda through Wilcox strata. This study focused heavily on interpreting “mini-shelf” packages in the basal Bergstrom (Upper Taylor), and found the Navarro to show rapid deposition by relatively strong currents across a mud rich, sand poor shelf. This study did not provide a sequence stratigraphic framework, but did constrain nearby structural elements and depositional trends.

The most recently published work that directly addresses the Minerva-Rockdale Field or local strata, is an oil and gas assessment of the Western Gulf Province of Texas published by the U.S. Geological Survey (Condon and Dyman, 2003). This study provides generalized geologic information regarding the undivided Navarro and Taylor Groups, and their total petroleum system. Despite the very detailed and descriptive nature of this study, little stratigraphic interpretation within my study area is presented.

Shelf Plume Model

The modern analogue for the shelf sand-plume model originates from Coleman et al. (1981) who studied the Damietta branch of the Nile River delta, describing long east-west oriented arcuate sand bodies (5 to 20 km wide) deposited down current by deflected currents off the Damietta promontory. These deflected currents produce an entrapped eddy current with a high-speed outer limb allowing for the down current deposition of highly mobile sand bodies (Coleman et al., 1981). The authors provide wind and ocean current velocity data from different recording stations, paired with detailed side-scan sonar surveys to prove the existence of an eddy system produced from the deflected pervasive current off the Damietta promontory. The authors conclude that: (1) a seaward-directed jet of high-speed current 4-8 km across forms off the Damietta promontory and shoots out northeasterly against the prevailing wind. (2) A broad, slow return flow to the northwest forms in the shallower waters along the coast. This return flow is highly influenced by local winds. (3) These two zones are elements of a mesoscale (~50 km) eddy trapped in the lee of the promontory. (4) The spatial and velocity characteristics of the eddy are consistent with a composite model of eddies induced by flow separation based on analytical, numerical, and experimental studies. (5) Detailed side-scan sonar surveys of bottom morphology indicate that the eddy is underlain by a highly coherent, mobile sand belt that extends about 50 km down current.

Soon after the publication of Coleman et al. (1981), a number of authors used it as a modern analogue for various Upper Cretaceous sandstones deposited within the Western Interior seaway (Gaynor and Scheihing, 1991). These studies developed and elaborated on the shelf sand-plume model based on the conclusions from Coleman et al. (1981) (Barratt, 1982; Patterson, 1983; Thompson et al., 1986; Gaynor and Scheihing, 1991).

The first study to implement the depositional model from Colman et al. (1981) was Barratt (1982), who conducted an investigation of the Late Cretaceous (Campanian) aged Fales Sandstone Member of the Mesaverda Formation in the West Poison Sider Field in Natrona Count, Wyoming. Based on the analysis of several cores, Barratt (1982) interpreted detailed lithofacies relationships and delineated multiple genetic subdivisions within the Fales Sandstone. These interpretations allowed for inferred lithofacies correlations between the Nile River delta sandstone bodies and those of the Fales Member.

The Nile River delta analogue was again used to construct a detailed depositional model (the shelf sand-plume model) for fine-grained sandstones within the Upper Cretaceous (Maastrichtian), Kemp clay of the Navarro Group in east central Texas by Patterson (1983). This shelf sand-plume model was documented in great detail and utilized both subsurface well log correlation and core analysis to determine three depositional variations within the plume model: (1) a rapidly deposited, immature shelf sandstone-plume which is high in shale content and number of shale breaks due to insufficient current-winnowing, (2) an abandoned, current-reworked shelf sandstone plume which has a complex depositional history due to shifts in the depositional axis and current modification of the original plume deposits, and (3) a transgressed shelf sandstone-plume which exhibits morphologic and lithologic variations as the results of storm reworking and transgressive marine processes. In summary, this study showed geometric correlation between the sand bodies within the Navarro Group and the Nile River delta, implying both have similar depositional origins.

Patterson's depositional model explains how the large arcuate sandstone bodies within the Navarro Group were deposited on a mud rich shelf by deflected long shore currents (Figure 3). He included these attributes in his model: (1) increased stratigraphic isolation of sandstone bodies down-paleocurrent, (2) increased numbers and thickness of shale partings in the distal portion of the plume, (3) stratigraphic climbing of the migrating shelf-bars onshore and down-paleocurrent from the deltaic depocenter and (4) interfingering and pinchout of plume sandstone up-dip into the mud seal of the entrapped eddy system (Patterson, 1983). He also performed a detailed internal subdivision of the shelf sandstone-plume based on geometry and lithology characteristics, and assigned exploration potentials to these subdivisions.

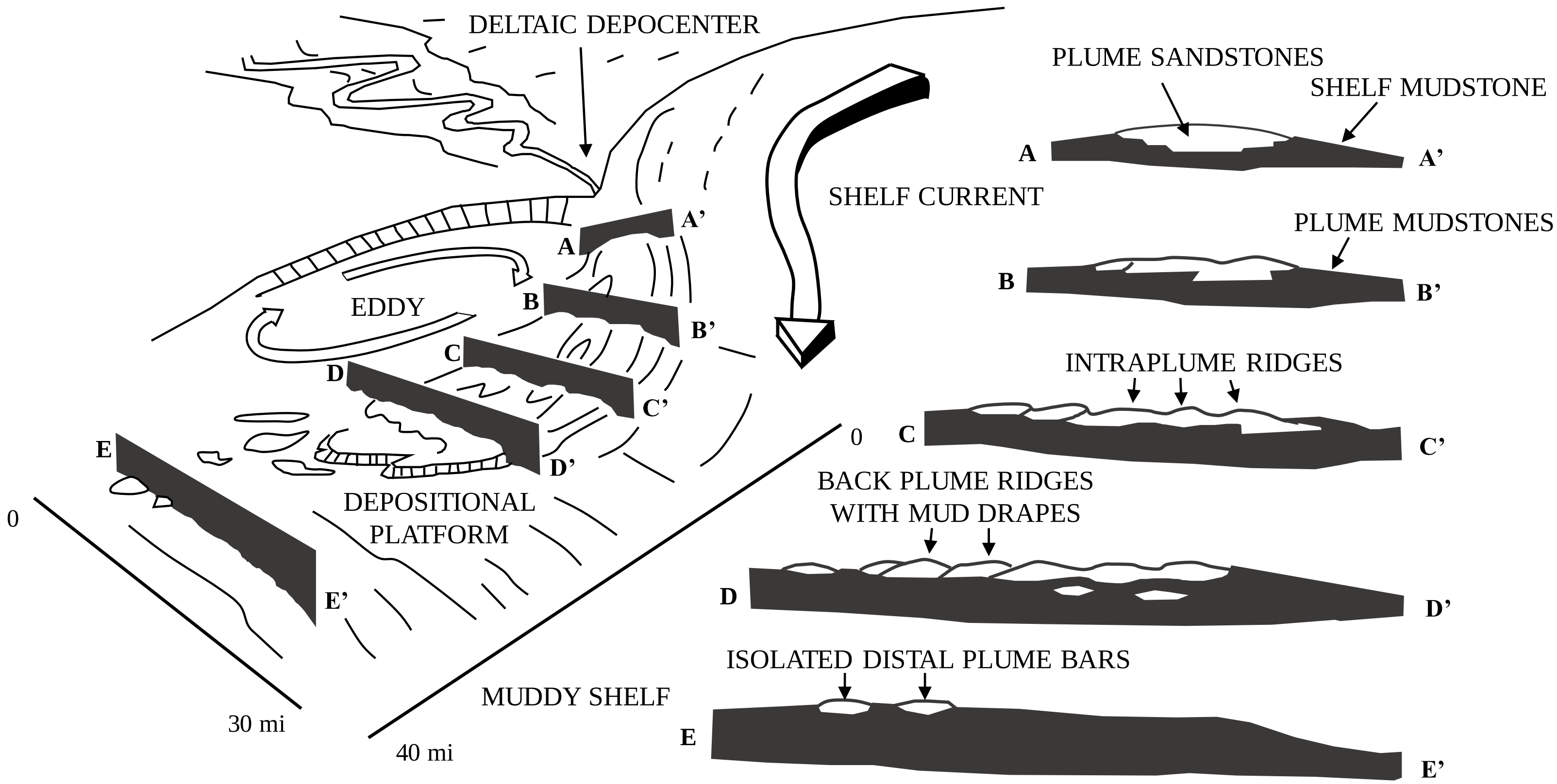


Figure 3: Depositional model developed by Patterson (1983) depicting the shelf sand-plume morphology. The model illustrates how a long shore current deflected off the head of a deltaic depocenter can produce arcuate, elongated sand bodies on a muddy shelf (digitized from Patterson, 1983).

Palmer and Scott (1984) studied on the Upper Cretaceous (Campanian), La Ventana Tongue of the Cliff House Sandstone in the San Juan Basin. Their work incorporated detailed subsurface well log interpretation with outcrop analysis to: (1) accurately subdivide the La Ventana Tongue into genetic subunits, (2) develop depositional models for the subunits, and (3) apply hydrocarbon production to the depositional models. The author's found that the analogous nature of the La Ventana Tongue to the modern Nile delta are based on similarities between the lithofacies and inferred depositional processes, but differ in deltaic size, coastline geometry, and tectonic history.

Thompson et al. (1986) preformed an in depth study of the Upper Cretaceous (Turonian), Ferron Sandstone Member of the Mancos Shale, central Utah. Using five cores, parallel and approximately a mile from their outcrop, a dip line was created through a thinning deltaic influenced clastic wedge. Each core's sedimentary structures, facies, and inferred depositional processes were integrated with subsurface and outcrop data to create a depositional model which features shelf sand-plumes from two different deltaic sources.

Purpose of the Study

The purpose of this study is to: (1) produce a regional stratigraphic framework for the Eagle Ford though Navarro Group strata within Milam and surrounding counties, (2) document the sequence-stratigraphic framework for Campanian to Mastrichtian aged strata, (3) recreate and test the depositional shelf plume model developed by Patterson (1983).

Significance of the Study

The current work fills an important gap in understanding the nature and depositional environment of the Navarro Group within the MROF and surrounding area, the first significant attempt in over 20 years. Renewed petroleum interest in the area has provided new subsurface data that has the potential to more accurately clarify stratigraphic relationships and expand on previous studies.

1.2 GEOLOGICAL SETTING

Structural Geology

The Minerva-Rockdale Oil Field is located approximately 50 miles northeast of Austin, Texas in Milam County (Figure 1). The northeast-southwest trending Mexia fault zone bounds the southern portion of the Minerva-Rockdale Field, while to the northeast of the field is the margin of the East Texas Basin. To the southwest lies the San Marcos Arch, the structural flexure which separates the East Texas Basin from the Rio Grande Embayment (Patterson, 1983).

The Mexia fault system is a complex zone of *en echelon* grabens striking at approximately 15° to 30° east that intersects the Balcones and Luling fault zone to the southwest and the Talco fault zone to the northeast (Rodgers, 1980). The downthrown sides of the faults are on the southeast and northwest with the resulting grabens varying in width (Week, 1945). The approximate age of movement along the Mexia fault zone is reported from Late Jurassic to Oligocene (Paleogene) (Rodgers, 1980; Weeks, 1945; Hencey and Tucker, 1987; Jackson, 1982). The opening of the Gulf of Mexico in the Early Jurassic is the probable cause of initial movement with some of the post-Jurassic sporadic movement resulting from the mobilization of the Jurassic Louann Salt and wedge-out zones of lower strata (Hencey and Tucker, 1987; Jackson, 1982; Rodgers, 1980).

Week (1945) states that movement most likely occurred in the Oligocene or early Miocene based on exposed faulted Eocene strata and notes that any evidence of movement in earlier (Cretaceous) sediment shows the same amount of displacement as Eocene aged strata; thereby making the age of movement the same as the youngest displaced strata. It is beyond the scope of this study to determine the time of the movement of faulted strata within the Mexia fault zone, or related fault zones; so a general adoption of movement ranging from the Jurassic to Paleogene will be used henceforth.

To the northeast of the Minerva-Rockdale Field is the East Texas Basin, which is a north-northeast-trending extensional salt basin (Mondelli, 2011). Similar to the Mexia fault system, The East Texas Basin is part of the Gulf of Mexico tectono-stratigraphic province, making it a product of the opening of the Gulf of Mexio, in which it underwent rifting during the Middle and Upper Jurassic (Mondelli, 2011; Jackson, 1982; Rodgers, 1980). Substantial progradation of terrigenous clastics occurred during the end of the Jurassic and beginning of the Cretaceous, when crustal cooling allowed significant subsidence (Mondelli, 2011). This rapid sedimentation caused shared stratigraphic relationships with the East Texas Basin and surrounding areas.

1.3 DEPOSITIONAL EPISODES

Upper Cretaceous sediments within the Texas margin that are addressed within this study, consist of the Eagle Ford Group, Austin Group, Taylor Group, and Navarro Group. Spanning a time of approximately 30 million years, each group was affected by progradation and flooding events which created the Upper Cretaceous stratigraphic sucession (Figure 4) and defined the Northern Gulf of Mexico basin architectire (Galloway, 2008). Each depositional episode can be generalized based on a carbonate-dominted or siliciclastic-dominated system (Figure 5).

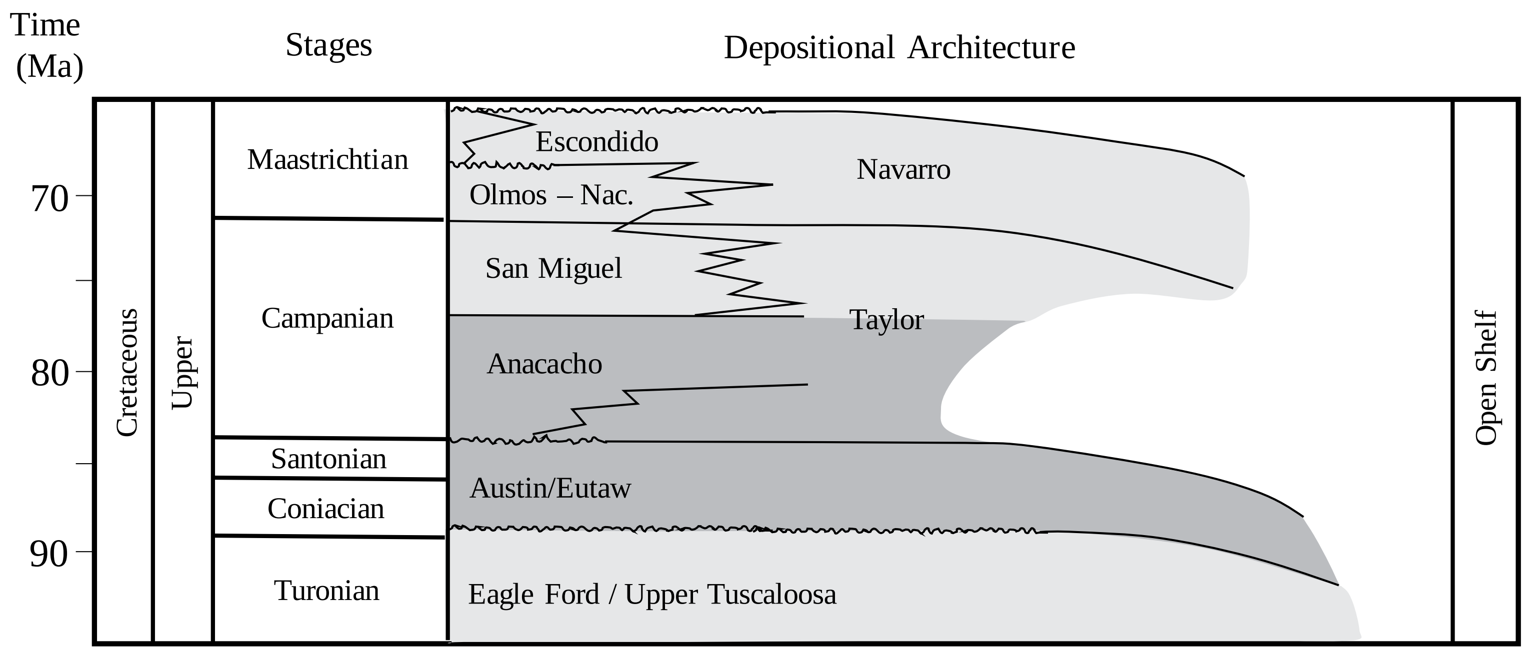


Figure 4: Generalized depositional architecture representing the major sedimentary pluses and stratigraphic succession of Upper Cretaceous sediments (modified from Galloway, 2008).

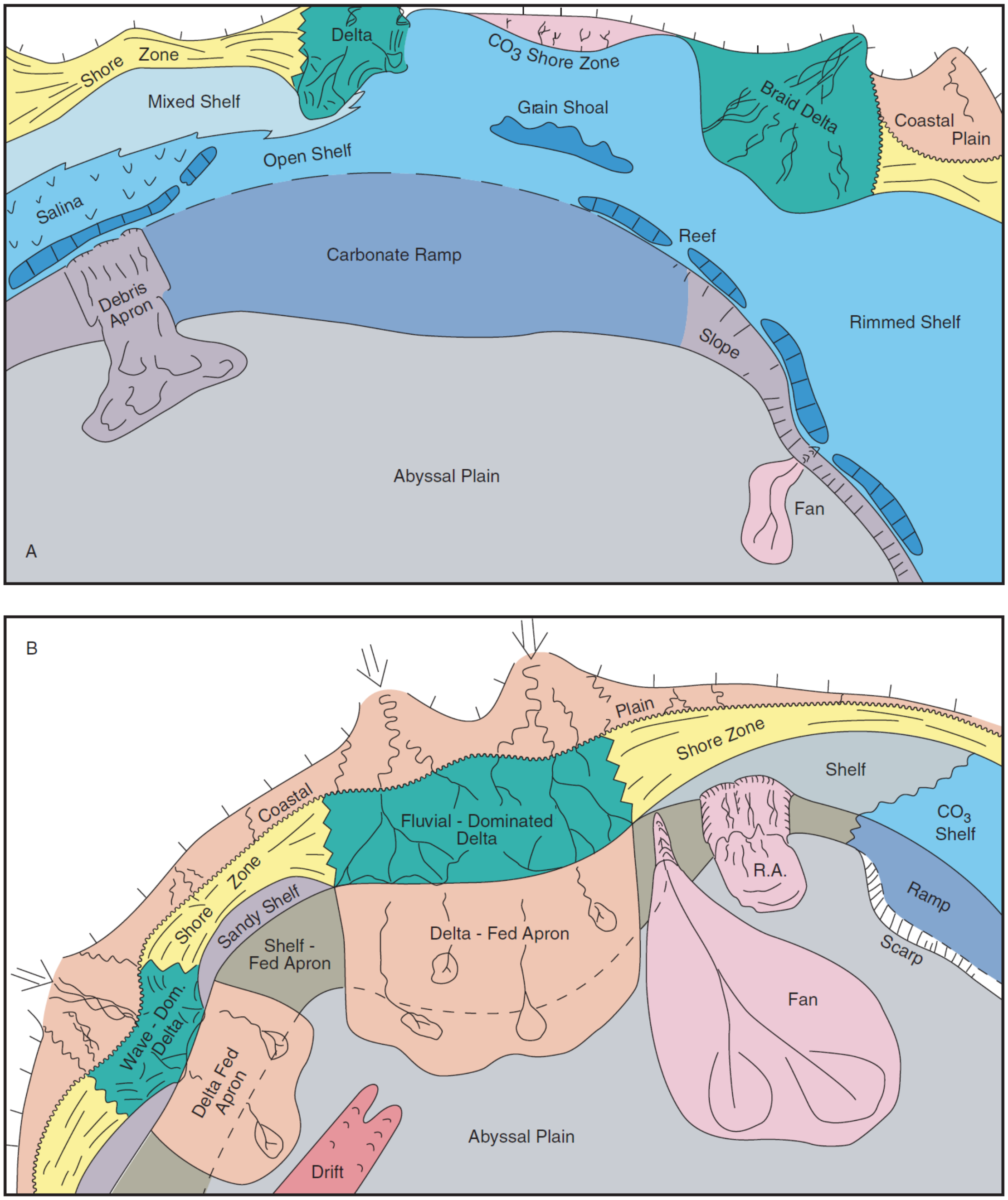
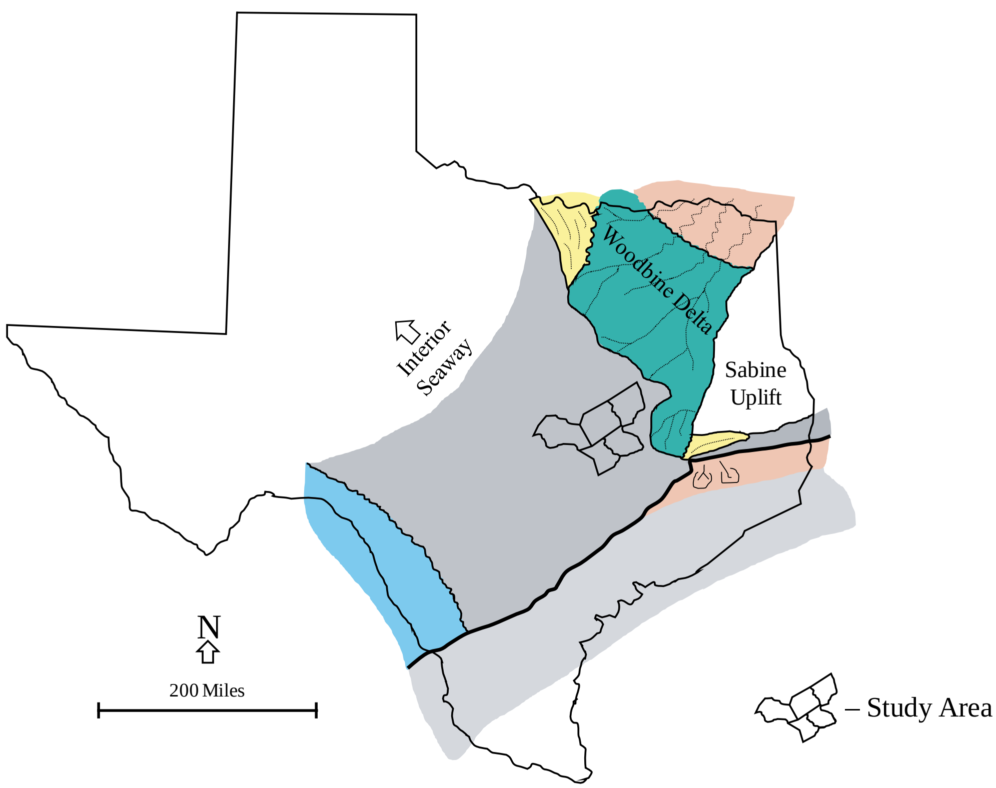


Figure 5: Illustration of the generalized palegeographies of a (A) carbonate-dominated and (B) siliciclastic-dominated within the northern Gulf of Mexico. Depositional zones shown correspond to those in depositional episodes shown later (from Galloway, 2008).

Woodbine/Eagle Ford Episode

The Woodbine depositional episode (Figure 6) records a large scale progradational deltaic system that moved into the East Texas Basin (Galloway, 2008). In central Texas widespread deposition of the Eagle Ford Shale occurred on a muddy shelf that was contemporaneous with the deltaic progradation (Galloway, 2008). A condensed interval is reported in the lower Turonian, recording sea level rise after the progradation the of Woodbine deltaic system (Dawson, 2000). Subsequent regression followed in the Middle and Upper Turonian, coinciding with the regressive facies of the Eagle Ford described by Dawson (2000). Condensation and/or erosion defines the contact between the Eagle Ford and Austin Groups



across much of south Texas and over inferred paleo-highs (Galloway, 2008; Young, 1986).

Figure 6: Generalized depositional episode for the Woodbine/Eagle Ford. Widespread deposition of the Eagle Ford Shale spans across central Texas, while extensive progradation of the Woodbine delta spills abundant siliciclastics into the region (adapted from Galloway, 2008).

Austin Episode

The Upper Cretaceous Austin episode (Figure 7) is characterized by accumulation of open-shelf carbonates and shoaling cycles bounded by periods of relatively deep water across the northwest Gulf (Galloway, 2005). Similar to modern Florida, the San Marcos Arch was active during the Austin depositional episode with only one period of inundation recorded during Lower Campanian (Young, 1986).

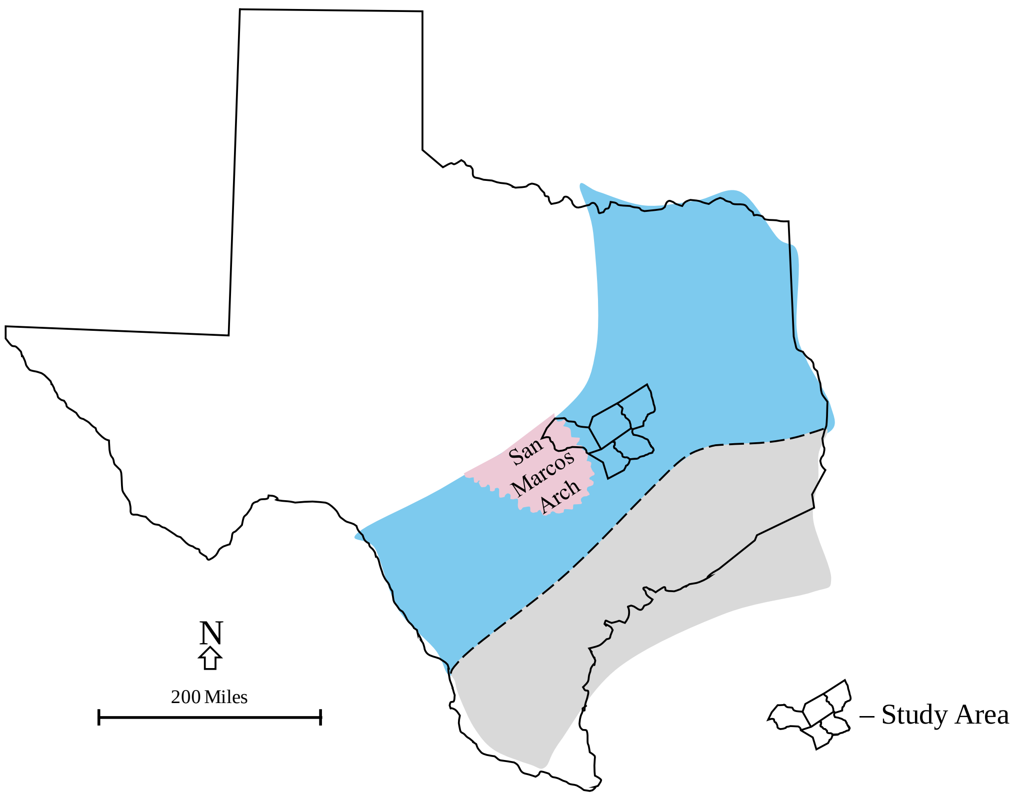


Figure 7: Generalized depositional episode for the Austin Chalk. Thick accumulations of open-shelf carbonates dominate this time period, with deposition being largely effected by the active San Marcos Platform (adapted from Galloway, 2008).

Taylor Episode

The next inundation, which covered the San Marcos Arch, occurred during the Middle Campanian allowing for the deposition of the Pecan Gap and genetically related chalks and limestone of the Taylor Group (Young, 1986). After the deepening event in the Middle Campanian, a renewed sandy terrigenous sediment influx occurred and by the Late Campanian the wave-dominated San Miguel delta system began to fill the Rio Grande embayment. Although a majority of the siliciclastics were sourced by the San Miguel delta system, additional material was locally provided by numerous volcanic cones that spread across the Rio Grande embayment and San Marcos Arch. Despite multiple recorded fluctuations, sea level remained relatively high during the deposition of the Taylor Group with a majority of the sediments being shallow shelf, shoreface, and transgressive marine in origin (Galloway, 2008).

Navarro Episode

Due to the Olmos delta and Nacatoch clastic system, significant siliciclastic progradation (Figure 8) occurred during the Upper Cretaceous Navarro depositional episode, (Galloway, 2008). The Nacatoch delta and shore-zone system provided a clastic pulse to north-east Texas, south-west Arkansas and North-west Louisiana, while the larger Olmos delta prograded across the Rio Grande embayment from Laramide uplands in northern Mexico (Lopez and McGowen, 1983; Tyler and Ambrose, 1986; Galloway, 2008).

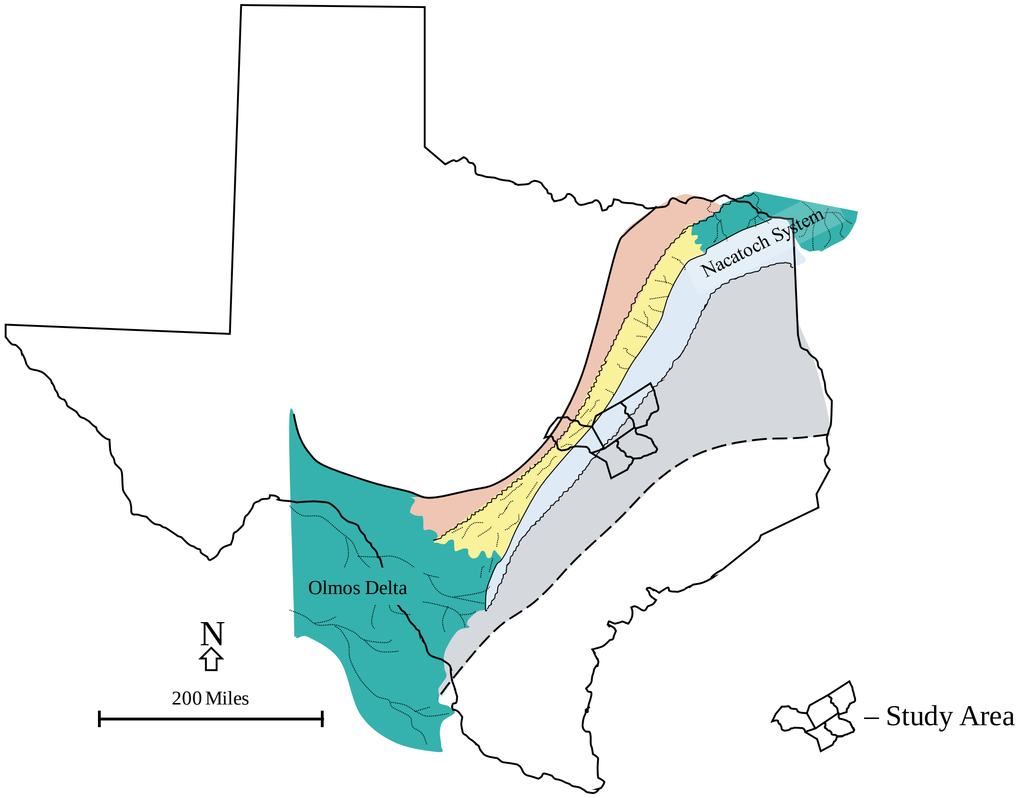


Figure 8: Generalized depositional episode of the Navarro. Early progradation of delta systems from the northeast and southwest deposited extensive siliciclastic sediment, while shelf and shore zone deposits collect the distal influences of the delta systems (adapted from Galloway, 2008).

2. STRATIGRAPHY

2.1 STRATIGRAPHIC NOMENCLATURE

The generalized lithostratigraphic framework of Upper Cretaceous strata within the Gulf Coast province is illustrated in Figure 9. Due to the study area falling between major structural features (East Texas Embayment, San Marcos Arch and East Texas Basin), it does not fit a single stratigraphic column. Moving northeastward away from the San Marcos Arch and central Texas across the Minvera-Rockdale Field (towards the East Texas Basin) there is a shift in stratigraphic nomenclature, perhaps due to facies shift in outcrop as well as legacy formation picks from producing oil and gas fields across the area (Brown and Hager, 1924; Blackburn, 1935; Hamman, 1951; Lopez and McGowen, 1983; Hencey and Tucker, 1987; Condon and Dyman, 2006).

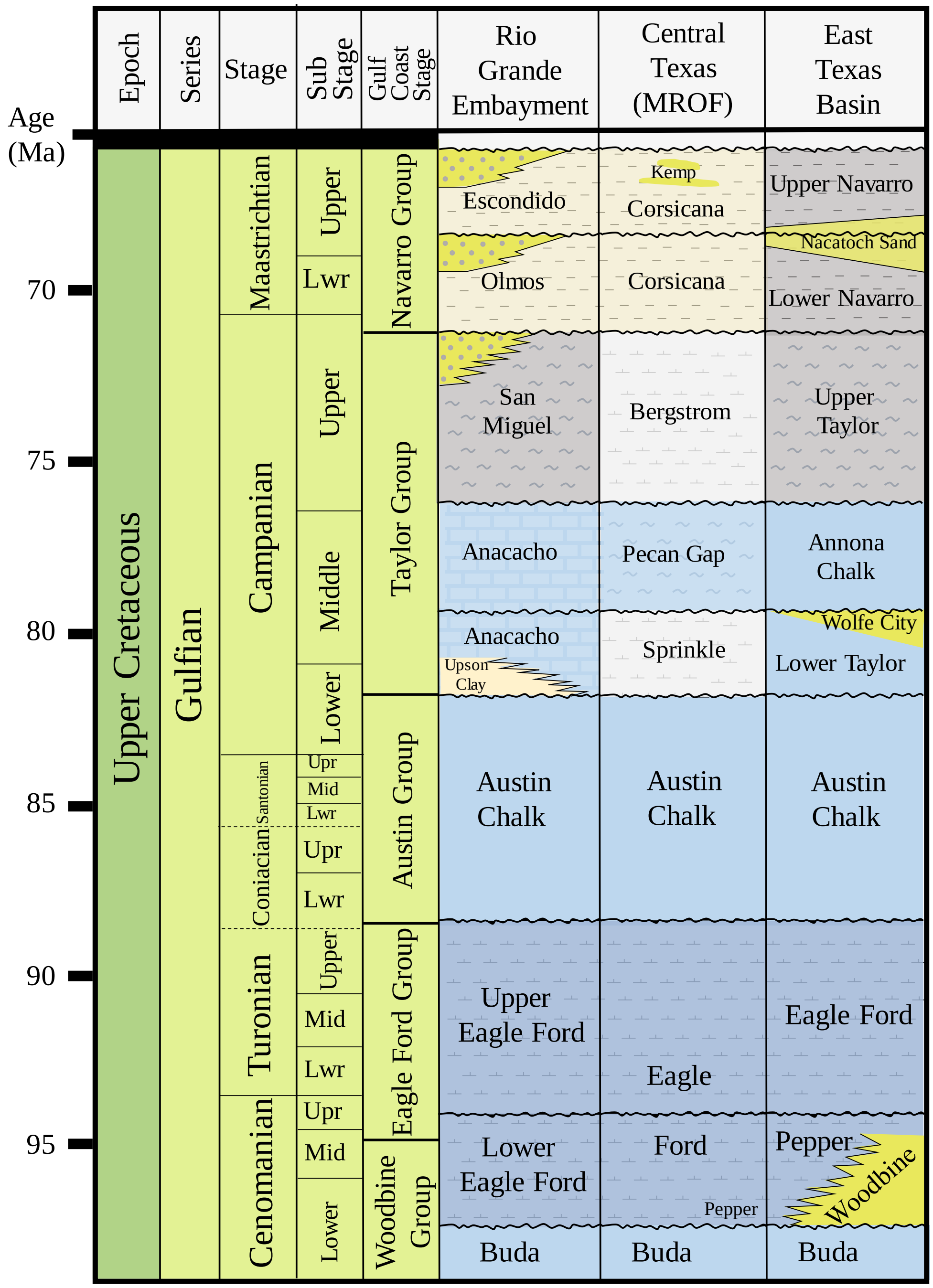


Figure 9: Lithostratigraphic column of Upper Cretaceous strata for the Texas Gulf Coast region. (Stratigraphic nomenclature, relationships, and geologic time adopted and synthesized from: Stephenson, 1937; Rouse, 1944; Hamman, 1951; Patterson, 1983; Chimene and Maddocks, 1984; Young, 1986; Baker, 1994; Dawson, 2000; Mancini and Puckett, 2005; Condon and Dyman, 2006; Mancini et al., 2008).

During the initial phases of literature review and stratal correlation there was much confusion regarding the correct stratigraphic nomenclature to use within the study area. Early nomenclature comes from outcrop studies and formations were named from local landmarks near type localities (Ellisor and Teague, 1934; Stephenson, 1937; Stephenson, 1941; Rouse, 1944; Young, 1965; Maxwell et al., 1967; Pessagno, 1969; Chimeme and Maddocks 1984). Many of the names assigned to formations seen in outcrop do not extend into the subsurface or are misused. A synthesized outcrop cross section, correlating undivided Austin, and Taylor strata across the Upper Cretaceous outcrop belt in Texas was created to remedy the confusion in nomenclature (Figure 10).

To constrain the stratigraphic relationships and nomenclature within Navarro and Taylor strata Figure 11 was created. Figure 11 is a modification to the subdivisions defined by Patterson (1983) (Figure 12), which brings updated terminology and stratigraphic relationships to his original model. Both of the newly created figures show the transition from the Rio Grande Embayment in southwest Texas across the study area and the MROF into the East Texas Basin. The creation of these figures required diligent investigation into all relevant literature. A merger of these studies was then conducted and it was this merger that helped correctly constrain the stratigraphic terminology for this study.

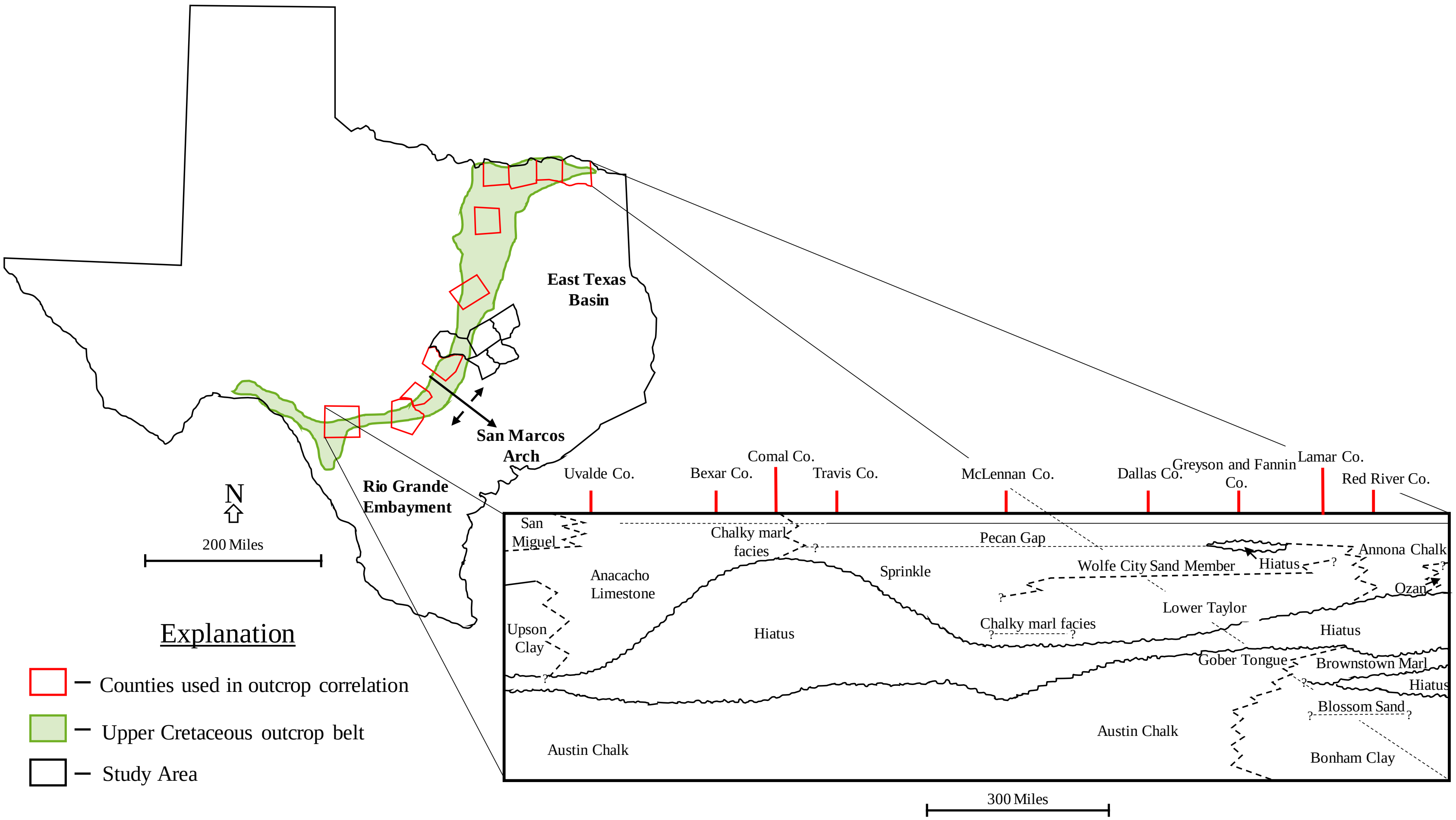


Figure 10: Synthesized outcrop cross section with updated stratigraphic nomenclature. Correlation spans across 10 counties within the Upper Cretaceous outcrop belt. Stratigraphic correlation helps show the transition of depositional trends and nomenclature across the Texas Gulf Coast region. Vertical scale is greatly exaggerated and is not proportional to thickness (modified from Stephenson, 1937).

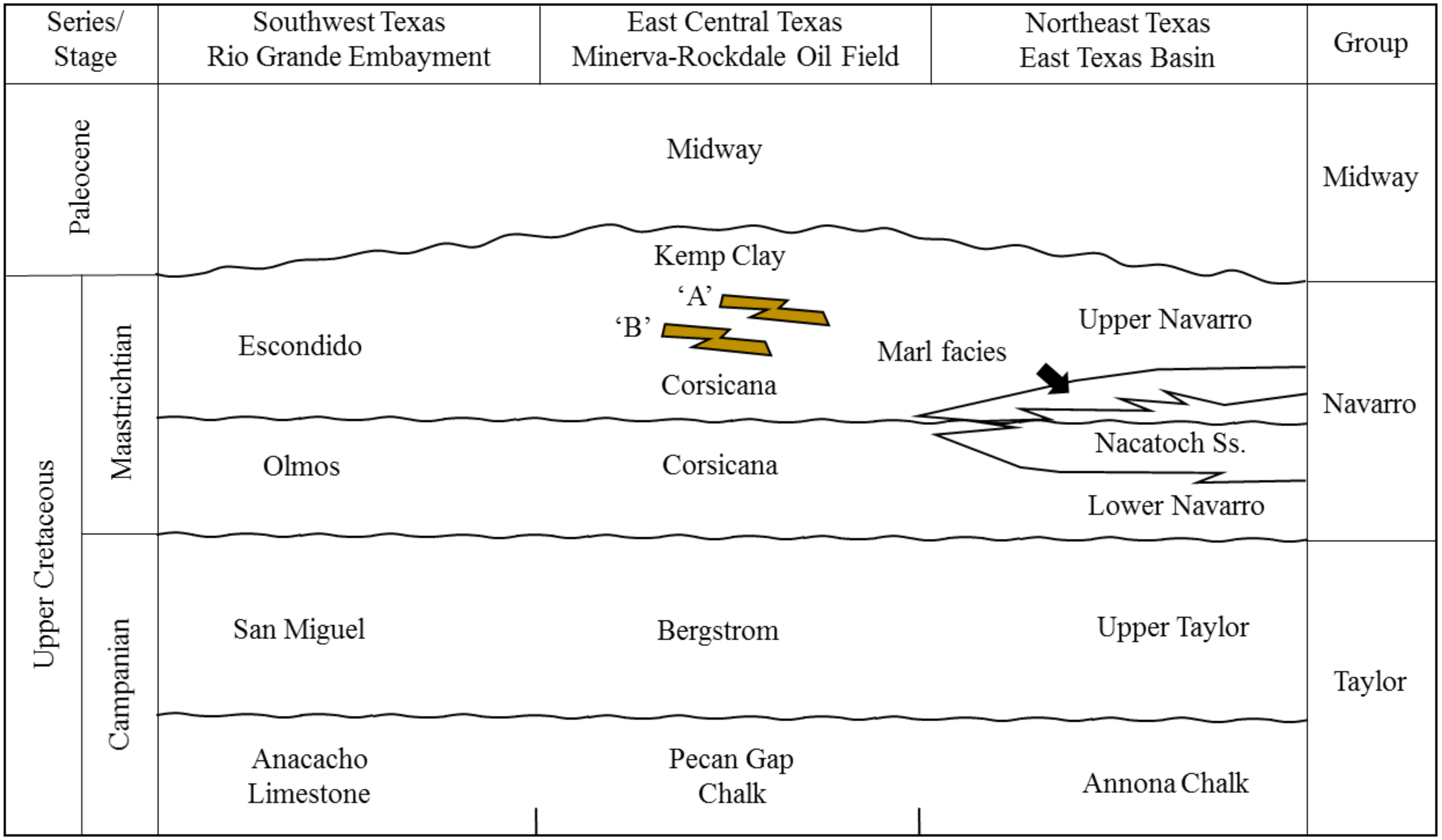


Figure 11: Generalized stratigraphic columns showing the placement of the Navarro 'A' and 'B' sandstone bodies within the Kemp clay of the Navarro Group (modified from Patterson, 1983).

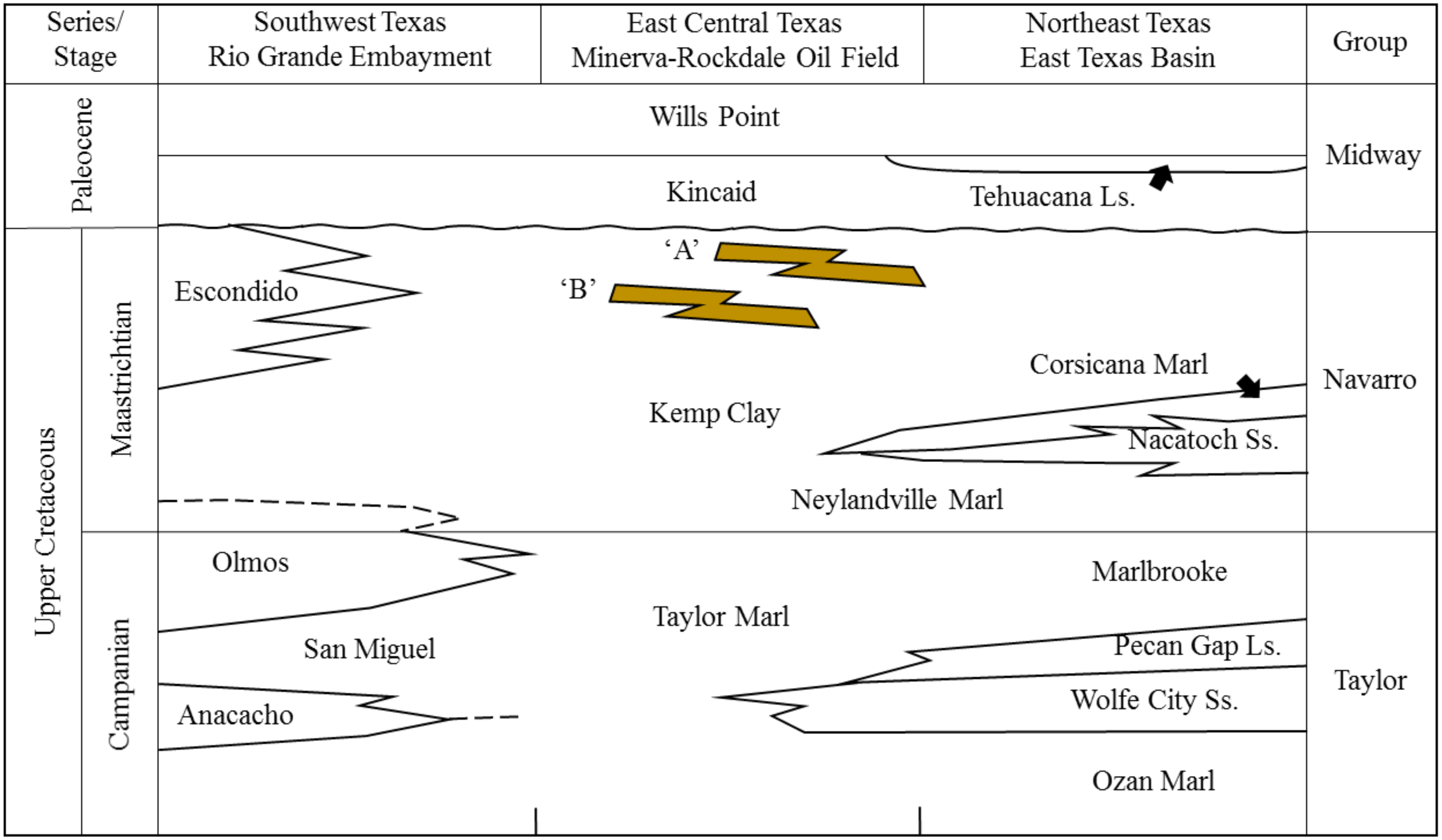


Figure 12: Original stratigraphic column developed by Patterson (1983), showing stratigraphic relationships of strata within the MROF and surrounding area (digitized from Patterson, 1983).

2.2 LITHOSTRATIGRAPHY

Within central Texas, the Late Cretaceous was a time of relatively high sea level, with abundant limestone, chalk, marls, and other marginal marine sediments. (Vail, et al., 1977; Condon and Dyman, 2006; Galloway, 2008; Mancini, 2008).-Figure 13 depicts the transgressive nature of the Cretaceous shifting into the regression of the Tertiary (Paleogene). It is important to note that within the study area many of the lithostratigraphic zonations come from outcrop studies and might not resemble the true subsurface units. It is also known that multiple members within the Eagle Ford Group and Austin Group exist; however, it is outside the scope of this study to differentiate the subdivisions/members within those formations and they will be known as the Eagle Ford and Austin Chalk, respectively.

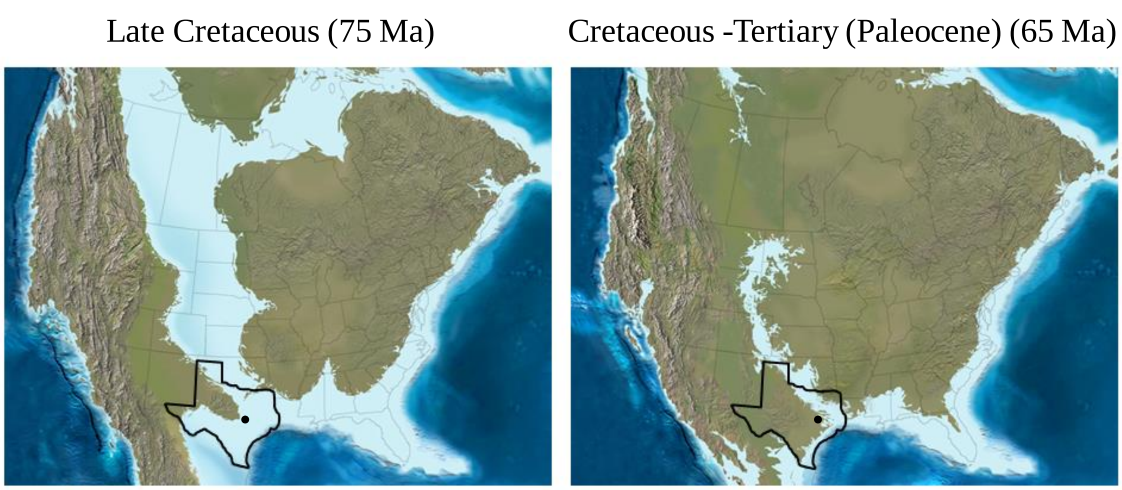


Figure 13: Paleogeography map showing the locations of Texas and the relative location of the MROF during the Late Cretaceous into the early Tertiary (Paleocene) (modified from Blakey, 2011).

Eagle Ford (Upper Cenomanian-Turonian)

The Eagle Ford Group is generally described as a mixed siliciclastic and carbonate unit with the lower (transgressive) portion dominated by dark well-laminated shales; and the upper (regressive) part composed of thinly interstratified shales, limestones, and carbonaceous quartzous siltstones (Condon and Dyman, 2006; Dawson, 2000). The Eagle Ford Group is a known source rock for many producing formations within the area and the organic-rich facies, generally in the lower (transgressive) portion, is said to have the highest hydrocarbons potential as well as the most oil-prone (Condon and Dyman, 2006; Dawson, 2000).

Austin Chalk (Coniacian-Lower Campanian)

The Eagle Ford unconformably overlies the Austin Chalk and forms the Turonian-Coniacian boundary (Dawson, 2000). The Austin Chalk consists of low-energy, shallow to open marine, chalks, marls and shales; it is generally described as a fractured carbonate reservoir with respect to petroleum production (Hencey and Tucker, 1987; Condon and Dyman, 2006). Although the Eagle Ford Group is considered a more prolific source rock, it has been shown that hydrocarbon generation within the Austin Group can occur with sufficient burial (Grabowski, 1981).

Taylor Group (Campanian)

Within the study the Taylor Group consists of three formations: the Sprinkle (Lower Taylor), the Pecan Gap and the Bergstrom (Upper Taylor) Formations.

The Sprinkle Formation (Lower Taylor) disconformably overlies the Austin Group and in outcrop is described as a green-gray to brownish-gray, calcareous montmorillonitic claystone with the calcium carbonate content increasing towards the base (Young, 1965; Tucker and

Hencey, 1987). Outcrops descriptions of the Sprinkle in Travis County, note that it is lithologically very homogeneous with an undulating contact with the Austin Chalk (Lungquist, 2000). Tucker and Hencey (1987) described the Sprinkle Formation in the subsurface in Bastrop County as a platform shale and soft chalk sequence of uniformly stratified key bed packages, with the possibility of a small disconformity or condensed zone occurring in the upper third of the formation. Basal Taylor strata in Arkansas contain abundant glauconite, phostphorite, shark teeth, and shells, typical of a marine condensed and shelf deflation horizon (Galloway, 2008).

Moving east, toward the East Texas Basin, the Sprinkle grades conformably into the overlying Wolfe City Sand Member (Pessagno, 1969). The Wolfe City Sand shows much heterogeneity in outcrop and its facies can vary from an arenaceous clay, marl, to sandy chalk (Rouse, 1944; Pessagno, 1969). The Wolfe City Sand is only present in the eastern portion of the study area and pinches out near the eastern limits of the MROF.

The Pecan Gap Formation lies disconformably on the Sprinkle. At its type locality in White Cliffs, Arkansas the bulk of the Pecan Gap is described as a creamy-white chalk, with thin partings of slightly laminated chalk; thinner sections of it range from a bluish-white siliceous chalk to very siliceous chalk and argillaceous chalk marl (Ellisor and Teague, 1934). Outcrops in Travis and Williamson County show the Pecan Gap as varying from a calcareous claystone to an argillaceous marl, with carbonate content ranging from 25 to 75 percent (Young, 1977; Chimene and Maddocks, 1984).

The Bergstrom Formation sits disconformably above the Pecan Gap. In Travis and Williamson County, Chimene and Maddocks (1984) described outcrops of the Bergstrom Formation as a blue-black, jointed, smectitic claystone that lies gradationally above the Pecan Gap. The same study found that fauna within the Bergstrom (Upper Taylor) and Pecan Gap probably lived on a soft substrate in warm, quite water with shale, normal-marine salinity, deeper than 250 ft. and distant from shore (Chimene and Maddocks, 1984).

Few current operators in the Minerva-Rockdale Field report tops for the Sprinkle or Bergstrom as most wells do not extend beyond the producing sands within the Navarro. If a well does extend beyond the Navarro formation only the more distinguishable formations tops (Corsicana (Navarro), Pecan Gap, and Austin Chalk) are typically reported.

Navarro Group (Upper Campanian-Maastrichtian)

The Navarro Group disconformably overlies the Bergstrom Formation; it is regionally undivided, considered to be deposited in a shallow water, marginal marine setting and is comprised of interbedded sequences of sandstone, mudstone, and marls (Patterson, 1983; Hencey and Tucker, 1987; Condon and Dyman, 2006).

Within the MROF the Navarro Group is divided into the Corsicana (Navarro) Formation and the Kemp Clay. The Corsicana Formation is a greenish to dark-gray, gaulconitic, fosiliferous, calcareous mudstone (Pessagno, 1969). Dane and Stephenson (1928) described outcrops of the basal Corsicana, within Milam County, to be a gray sandy marl, overlain by a richly glauconitic green marly sand; above the rich glauconitic bed is a pure white chalky marl, approximately five feet thick. Based on paleontology evidence from outcrops in Milam County, showing the co-mingling of different age assemblages, suggestions have been made that the boundary between the Corsicana and Bergstrom is transitional, lacking an unconforable surface seen elsewhere (Dane and Stephenson, 1928).

The Kemp Clay describes the upper most part of the Corsicana in central Texas and is partly equivalent to the Upper Navarro in the East Texas Basin (Pessagno, 1969; Lopez and McGowen, 1983). Outcrop investigations of the Kemp Clay concluded that it is a greenish, gray glauconitic, silty calcareous mudstone (Pessagno, 1969). According to Patterson (1983) the Navarro ‘A’ and ‘B’ sand bodies are found within the Kemp Clay.

The Navarro ‘A’ and ‘B’ sand bodies are described as deltaic shelf “sand-plumes” which were deposited on a muddy shelf. They form in arcuate belts with a thickness of 3 to 20 feet, lateral extent of 17 to 20 miles, extend 27 to 30 miles down drift, and stretch 21 to 40 miles into the basin (Patterson, 1983).

3. DATA AND METHODS

3.1 WORKFLOW

This study followed the workflow of Figure 14. Due to the lack of legacy data, the initial stages of development focused heavily on literature review and data acquisition. The beginning phase of literature review was challenging due to anonymity of the MROF. Once sufficient background information was known about the MROF and surrounding area, the acquisition of all available well logs and related data became the next objective. After the data acquisition stage, the project progressed and circled back until a viable fully interpreted and thought-out conclusion was reached.

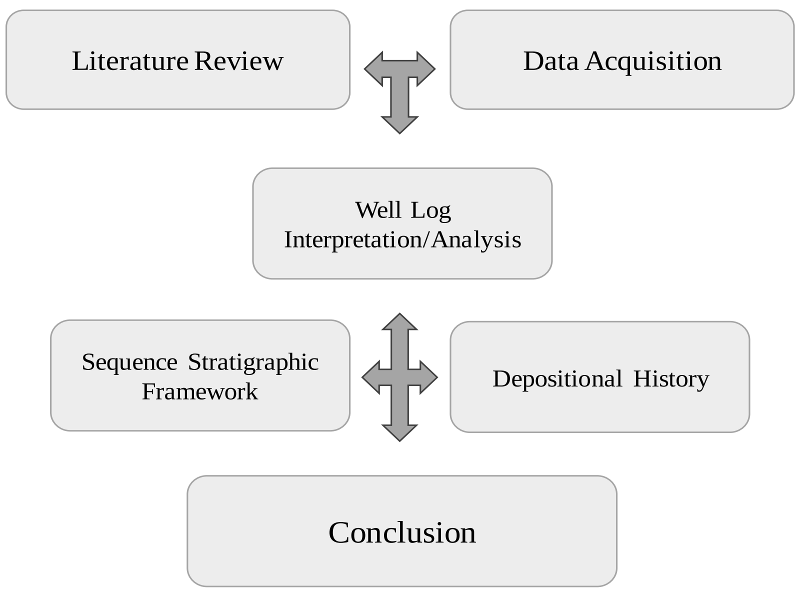


Figure 14: Workflow utilized for achieving the goals of this thesis.

3.2 DATASET DESCRIPTION

The study area is regionally located in East-Central Texas within five counties: Milam, Lee, Burleson, Robertson, and Williamson (Figure 1). A majority of the current exploration and production takes place in central Milam, where the Navarro Group is very shallow (300 to 800 ft. subsea) and wells prove to be economic. Due to current drilling efforts being concentrated within a small area the distribution of modern logs is clustered. Also to keep well costs low many wells are quickly and poorly logged, resulting in poor quality of well logs that are inadequate for use in this study. My work benefitted greatly from the generous donation of multiple well logs from Price Land and Energy. As a new operator within the MROF, Price Land and Energy had no previously interpreted geologic information, making the project a “wildcatter” situation.

The dataset for this thesis consists of 274 wells within the MROF and surrounding area (Figure 15). All of the well logs used in the study were either donated from current operators or downloaded from the online database Drilling Information Incorporated (Drillinginfo.com). The study area is a mature province in regards to historical exploration and production, and therefore has an abundant supply of well locations. However, logs were not available for all wells in the area, and many existing logs were of poor quality or too shallow. Finding wells with decent quality logs at the appropriate depths proved to be an arduous task. Many logs were missing scales, elevation datums, or large depth intervals, inhibiting the ability to perform interpretations.

If wells were missing an elevation datum, the exact position of each well was found from its latitude and longitude in Google Earth and then the ground-level elevation was recorded and used as the datum. To check the accuracy of the elevation from Google earth, the reported ground-level from nearby wells were compared. This method proved to be accurate with little variation between elevations from Google Earth and reported elevations from nearby well log headers.

Of the 274 well logs used, a majority were in raster (not digital) format. A Tagged Image File Format (TIFF), is a common raster image file format for well logs. All non-digital well logs acquired from Drilling Information Incorporated were available for free in TIFF format but varied in quality. If the well log image was of good quality (e.g., scanned correctly) it was imported into the geologic software Petra, depth calibrated, and digitized if necessary.

To perform any kind of statistical log curve analysis a digital version of the log is needed. This requires a user to manually digitize individual raster log curves to extract the log values at depth. All raster image logs used for gross- or net-sandstone calculations had to be manually digitized. Many of the logs used in regional and local cross sections were digitized for improved accuracy in stratal correlation and increased aesthetics.

The standard file format for digital a well log is Log ASCII Standard (LAS). A LAS file contains values for each individual log at regular depth intervals, is easily imported into Petra and doesn’t require depth calibration or manual digitization. LAS is the preferred format when gathering data and preforming subsurface interpretations.

230 raster well logs downloaded from Drillinginfo.com were imported into Petra and depth calibrated (Appendix A); 102 of the 230 raster files were manually digitized after depth calibration (Appendix B). Only 7 digital well logs were downloaded from Drillinginfo.com while, 17 digital files were donated by Price Land and Energy. An additional 20 raster well logs were also donated from Price Land and Energy, but were not digitized because they did not meet data quality standards. In total, 274 well logs were obtained and merged into this dataset.

In addition to the format and log quality issues, many of the available wells within the MROF would only touch the top of the pay interval, not fully penetrating or logging the Navarro Group. Interpretations given here are based only on wells that fully penetrated the Navarro Group and had associated logs of adequate quality.

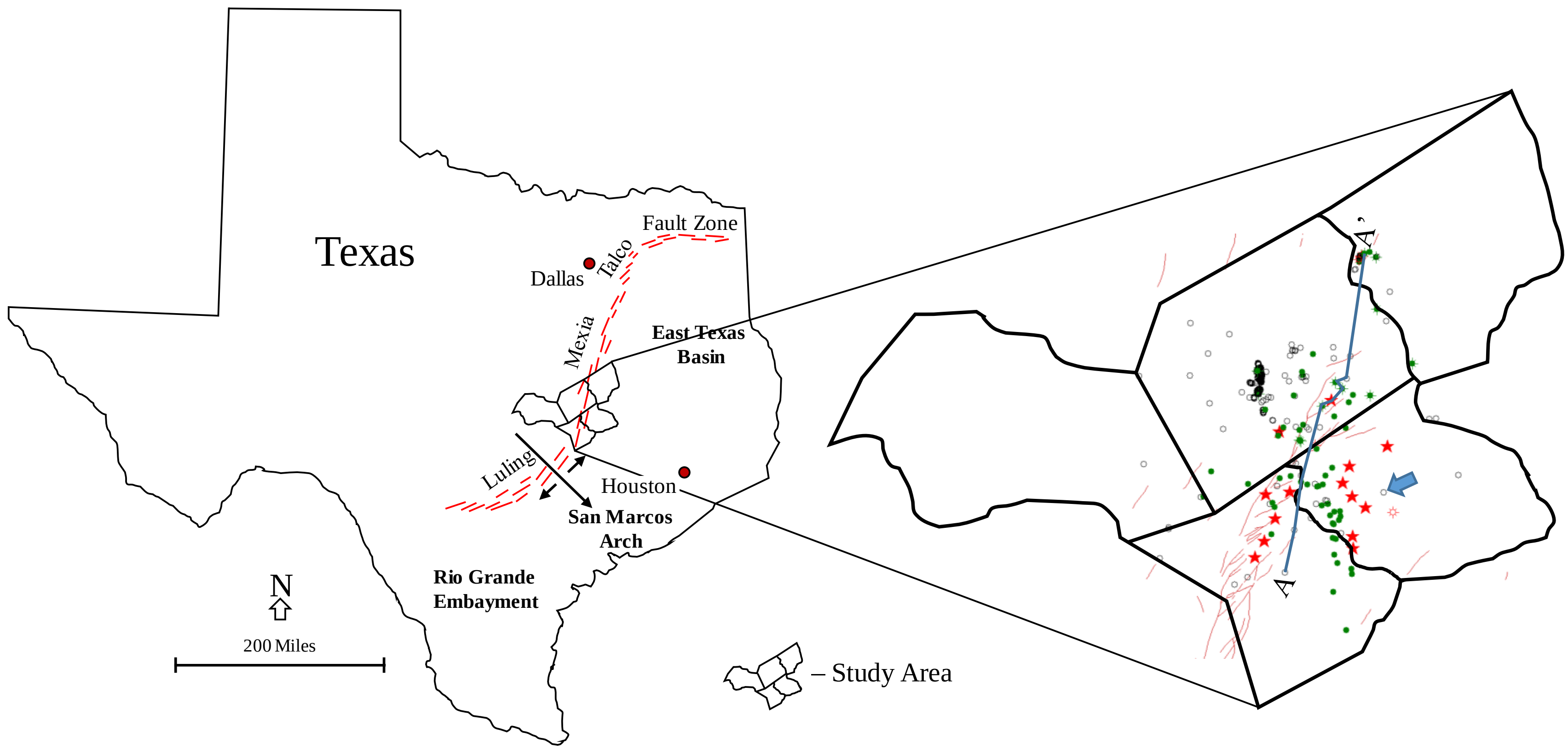


Figure 15: Location map of study area, structural features, and well control. Faults shown in study area are mapped faults from the USGS. Blue arrow indicates location of regional type log. Line of cross section indicated by blue line and A – A’. Well symbols are arbitrary and should be disregarded.

3.3 WELL LOG INTERPRETATION

The primary well logs used in this study are: gamma ray (GR), deep conductivity (CILD), and deep resistivity (ILD), although other logs were occasionally used.

The GR log measures natural formation radioactivity from the elements thorium (Th), potassium (K), and uranium (U) and can be used for identifying differing lithologies, stratal correlation, and distinguish depositional trends (Selley, 1998; Asquith and Krygowski, 2004). The GR log is measured in API (American Petroleum Institute) units and is typically plotted on a scale of 0-150 (Selley, 1998). Lithologies rich in clay minerals will normally contain more of the radioactive elements and therefore will have a higher GR value indicating clay rich versus sandy zones (Asquith and Krygowski 2004). This inferred relationship was used to identify the Navarro 'A' and 'B' sand bodies within the mud/clay rich Navarro Group. Prominent chronostratigraphic surfaces, such as marine flooding surfaces and unconformities are indicated by sharp or dramatic shifts in gamma ray signature.

The CILD and ILD logs are both induction logs that measure formation electrical conductivity. Formation conductivity is inversely related to resistivity by (Asquith and Krygowski, 2004):

$$C = \frac{1000}{R}$$

Where:

$C =$ Conductivty (mmho)

$R =$ Resistivity (ohm-m)

The grains or matrix of a rock are considered nonconductive, as are hydrocarbons. Therefore the resistivity of a rock is a function of saturation and salinity of water in the pore space. Higher hydrocarbon saturation implies decreasing water saturation which will increase the resistivity of the formation (Asquith and Krygowski, 2004). Knowing the resistivity of a formation can help determine hydrocarbon-bearing versus water-bearing zones, indicate permeable zones, and also can be used to estimate porosity (Selley, 1998; Asquith and Krygowski, 2004). Within this study the conductivity and resistivity logs were very useful in determining limestone or chalk units (low conductivity or high resistivity), if gamma ray was absent.

The current work includes strata from Eagle Ford through the Navarro Group as the stratigraphic framework. The Eagle Ford Formation is the lower most viable source rock within the study area and therefore represents the basal constraint for the stratigraphic framework (Condon and Dyman, 2006). The upper limit is represented by the glauconitic marker or "Green Sand" as described by Hagar and Brown (1924) and Patterson (1983). Figure 16 is a type log which illustrates the correlations and general well log signatures for each unit defined within the studied interval. Stratal relationships were based on individual well log motifs and correlated across the study area. The gamma ray log was mostly used for stratal correlation and lithologic interpretations.

To expand on the depositional history proposed by previous authors, a sequence-stratigraphic framework was developed for Taylor and Navarro aged strata. The top of the Austin Chalk is recognized as the basal chronostratigraphic surface for the sequence-stratigraphic framework. The boundary between the Austin Chalk and Taylor Group shows a transition from carbonates to siliciclastics. The analysis of regional well log cross sections delineated depositional trends through Taylor aged strata into the deposition of the Navarro

Group concluding with the glauconitic marker. After well log correlation, isopach and structure maps were created to aid in the depositional interpretation.

To recreate and test the depositional model proposed by Patterson (1983), the Navarro 'A' and 'B' were subdivided into mappable units based on Patterson's detailed type log. The GR, ILD, and CILD logs were used to recreate the subdivision as accurately as possible. Strike and dip cross sections were created and interpreted for depositional trends, along with net-sand, isopach, and structure maps. All of the results from this study were compared to the findings of Patterson (1983) to see if his depositional model is consistent with the data.

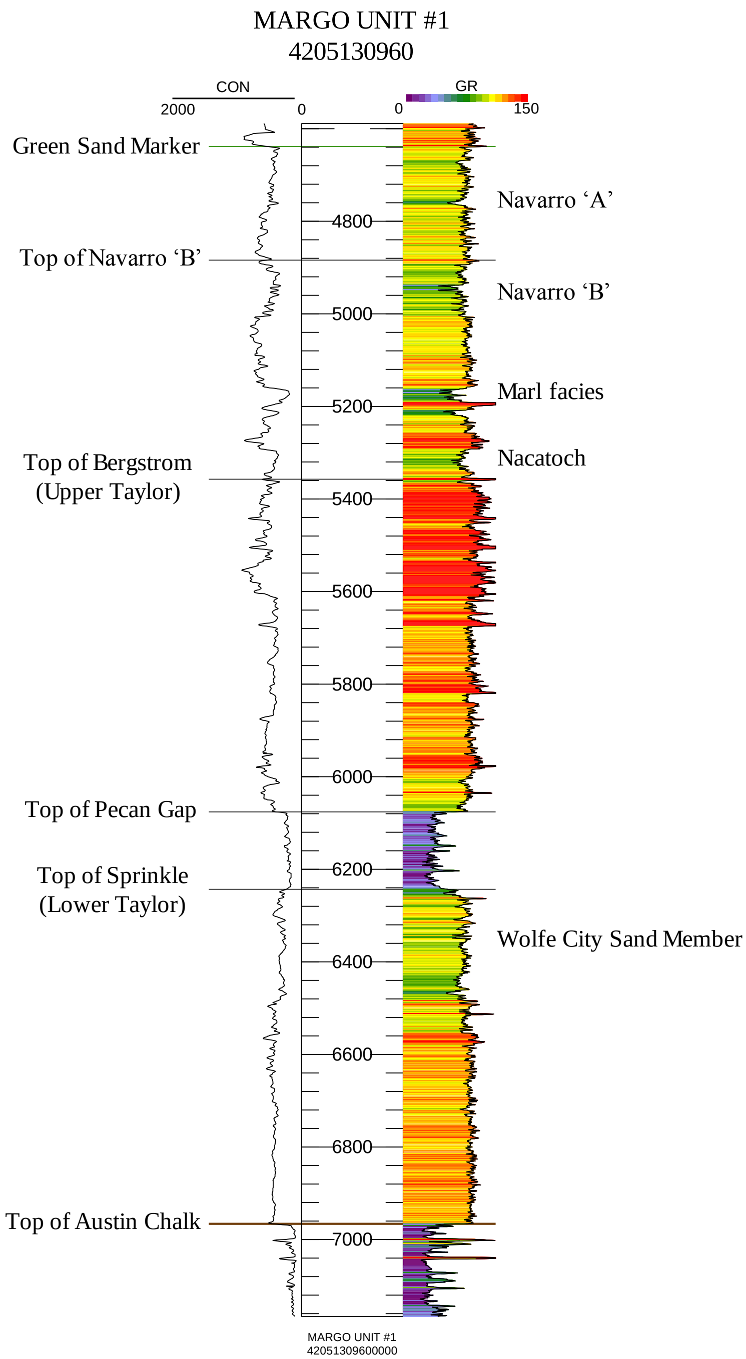


Figure 16: Type log showing the stratigraphic relationships and general log characteristics. Location of type log is shown in Figure 15.

4. SEQUENCE STRATIGRAPHIC FRAMEWORK

4.1 CAMPANIAN STAGE

The Campanian Stage is characterized by a time of relatively little siliciclastic influx and minimal changes in relative sea level based on the dominance of marls, chalks and claystones within the stage (Mancini et al., 2008).

Lower to Middle Campanian

The upper portion of the Austin Chalk marks the basal Campanian Stage and lies disconformably under the Sprinkle (Lower Taylor). The upper portion of the Austin Chalk was deposited during a highstand with abundant chalk production and little siliciclastic input (Young, 1965). The top of the Austin Chalk was correlated based on its lower gamma ray character juxtaposed to the higher signature of the Sprinkle (Figure 16). In Travis and Williamson County, Lundquist (2000) notes an undulating contact between the Austin Chalk and Sprinkle with a semi-gradational boundary and insignificant microfaunal change. This relationship indicates an increased input of fine clastics, rather than the cessation of chalk production, to produce the facies change from marly chalk of the Austin Chalk to claystone of the Sprinkle (Lundquist, 2000).

In well logs, the Austin Chalk show a much lower gamma ray signature than the overlaying Sprinkle. The boundary between the Austin Chalk and Sprinkle transitions from a sharp boundary in the eastern portion of the study area to more gradational in the west. This gradational boundary in the western portion corresponds with the westward thinning of the

Sprinkle (Figure 17), suggesting a more distal environment in the southwest, supported by faunal studies showing an abundance of open ocean forms throughout the Sprinkle in Travis and Williamson County (Lundquist, 2000).

The well log characteristics of the Sprinkle Formation shows a homogeneous lithology until it grades conformably into the over lying Wolfe City Sand Member in the eastern portion of the study area (Figure 17). The Wolfe City shows a reduction in gamma ray values and southwesterly thinning and wedging out; suggesting an east to northeasterly influx of ‘cleaner’ sand, cause by a regression throughout the Sprinkle and Wolfe City. Mancini and Puckett (2005) propose that a reduction in accommodation and increase in siliciclastic sediment supply occurred during the Middle to Lower Campanian, agreeing with the transition of the Sprinkle (Lower Taylor) into the conformable Wolfe City. The top of the Sprinkle (Lower Taylor) and the conformable Wolfe City, in the eastern portion of the study area, represent a sequence boundary or end of the regression.

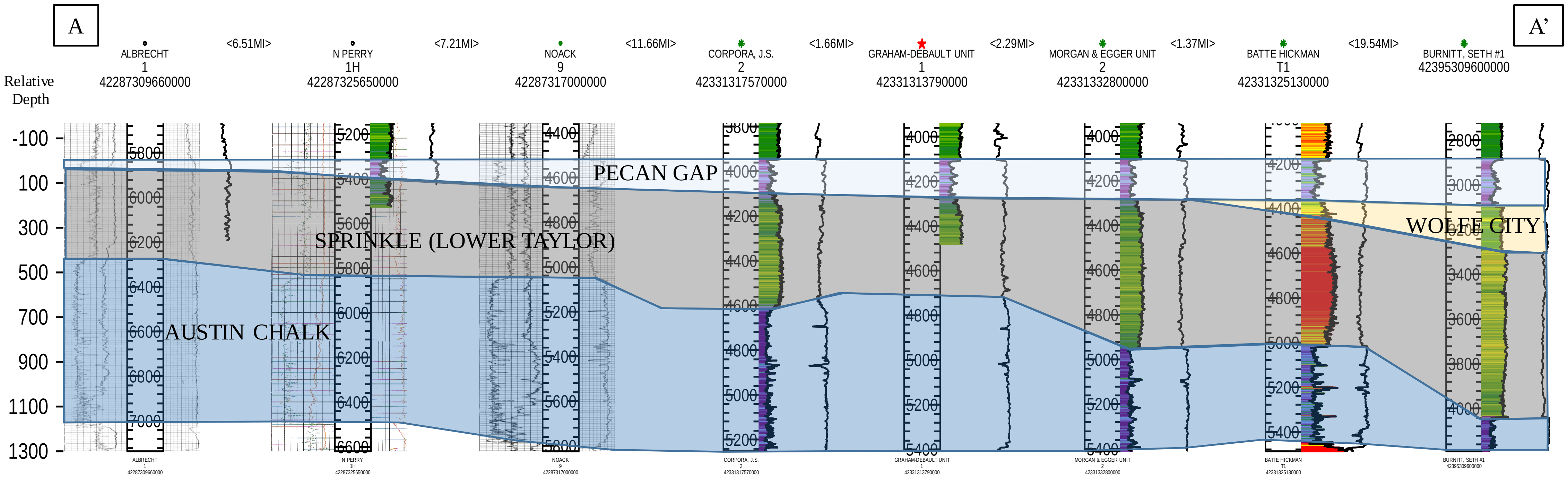


Figure 17: Line of section A – A’, showing the west/southwestward thinning of the Sprinkle (Lower Taylor) and Pecan Gap. The Wolfe City Sand Member of the Sprinkle (Lower Taylor) is present in the east/northeast, indicating maximum regression/progradation during its deposition. It is inferred that the thinner sections of both the Sprinkle (Lower Taylor) and the Pecan Gap represent deeper and/or more distal depositional environments. Conversely, the thicker portions represent more shoreward, proximal, environments. Datum is the top of the Pecan Gap, location of cross section shown on Figure 15.

Middle Campanian

The lower portion of the Pecan Gap is representative of a transgressive deposit with an inferred maximum flooding surface/condensed interval in the middle (Young, 1986; Mancini and Puckett, 2005; Mancini et al., 2008). The upper Sprinkle and Pecan Gap were deposited in relative deeper water, documented where the Wolfe City is absent, than the lower sections of the Sprinkle based on a higher planktic to benthic foraminifera (P/B) ratio (Lundquist, 2000). This relationship is documented in samples from the Travis and Williamson County which again, would have the highest correspondence with the western part of this study area. The boundary between the Sprinkle and Pecan Gap in the western portion of the study area has a gradational transition as the Pecan Gap thins in that direction (Figure 17). This thinning of the Pecan Gap and gradational boundary implies a more distal depositional environment in the west, this distal environment in the west also confirms how the upper portion of the Sprinkle and Pecan Gap share similar depositional environments as reported by Lundquist (2000). Conversely, where the Pecan Gap is thicker, in the eastern portion of the study area, it represents shallower water deposition and maximum carbonate production.

In the middle of the Pecan Gap, gamma ray values increase to a maximum and then fall (Figure 16 and 17). Tucker and Hencey (1987) describe a condensed zone in the upper Sprinkle which corresponds to the placement of the Pecan Gap, which is not differentiated within their study. Also, Chimene and Maddocks (1984) note abundant microfossils and macrofossils including (fish teeth and gastropods) within the Pecan Gap, which are typical of marine condensed intervals (Galloway, 2008). Pairing the observed gamma ray motif with literature documenting a possible condensed interval, a maximum flooding interval is interpreted within the middle of the Pecan Gap. This would imply that the lower portion of the Pecan Gap is transgressive while the upper is regressive, agreeing with the timing of a marine inundation recorded by Young (1986) as well as reported flooding events (Mancini, 2005; Mancini et al., 2008)

Middle to Upper Campanian

Following the deposition of the Pecan Gap there was a cessation in chalk production, resulting in the Bergstrom. The boundary between the Pecan Gap and Bergstrom marks a transition from higher carbonate (chalk) formation, to a more argillaceous one. The Bergstrom (Upper Taylor) is a smectitic claystone with carbonate content ranging up to 25 percent (Chimene and Maddocks, 1984). The higher carbonate content is mainly constrained to the lower portion when the boundary is gradational with the underlying Pecan Gap. The lower portion of the Bergstrom shows a uniform gamma ray motif, implying a relatively homogeneous lithology (Figure 16). However, gamma ray patterns within the upper portion of the Bergstrom show cyclic spikes (high gamma values) varying in spacing and count. These spikes have almost no distinct pattern, making them very difficult to correlate.

My initial Bergstrom top came from Patterson's (1983) regional type log (Figure 18). This type log does not indicate what well logs were used, but from analyzing log characteristics, it is speculated that it uses the SP and two induction (deep and shallow resistivity) logs. The top of the Bergstrom (Upper Taylor) is placed in what appears to be a leftward (assumed decreasing value) deflection in resistivity (assumed shallow resistivity). This formation pick proves to be inconclusive when trying to correlate across the study area. The supplementation of Bergstrom Formation top picks from Drillinginfo.com did not provided a clear or consistent correlation either. In the current study, the top of the Bergstrom is picked on an inferred genetically related marker that correlates across the study area.

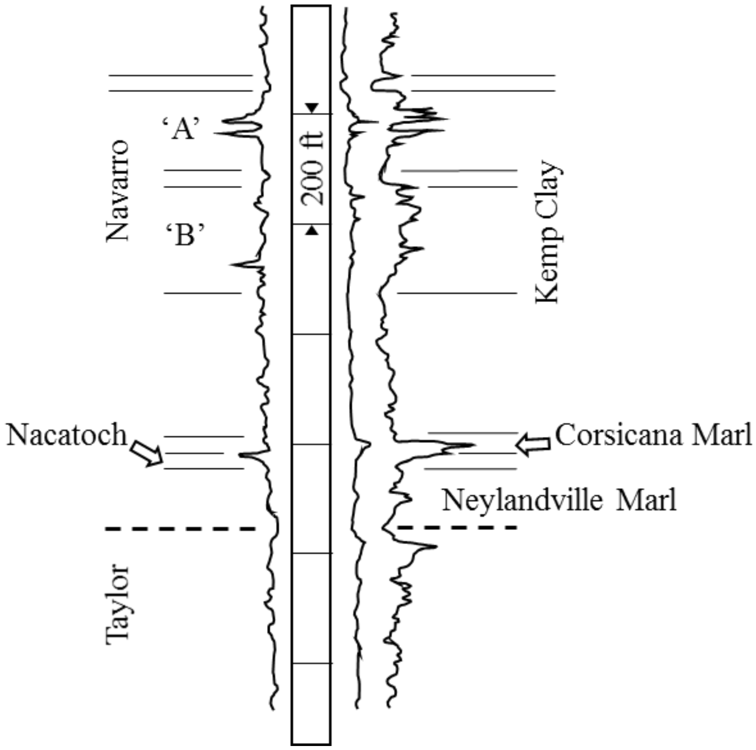
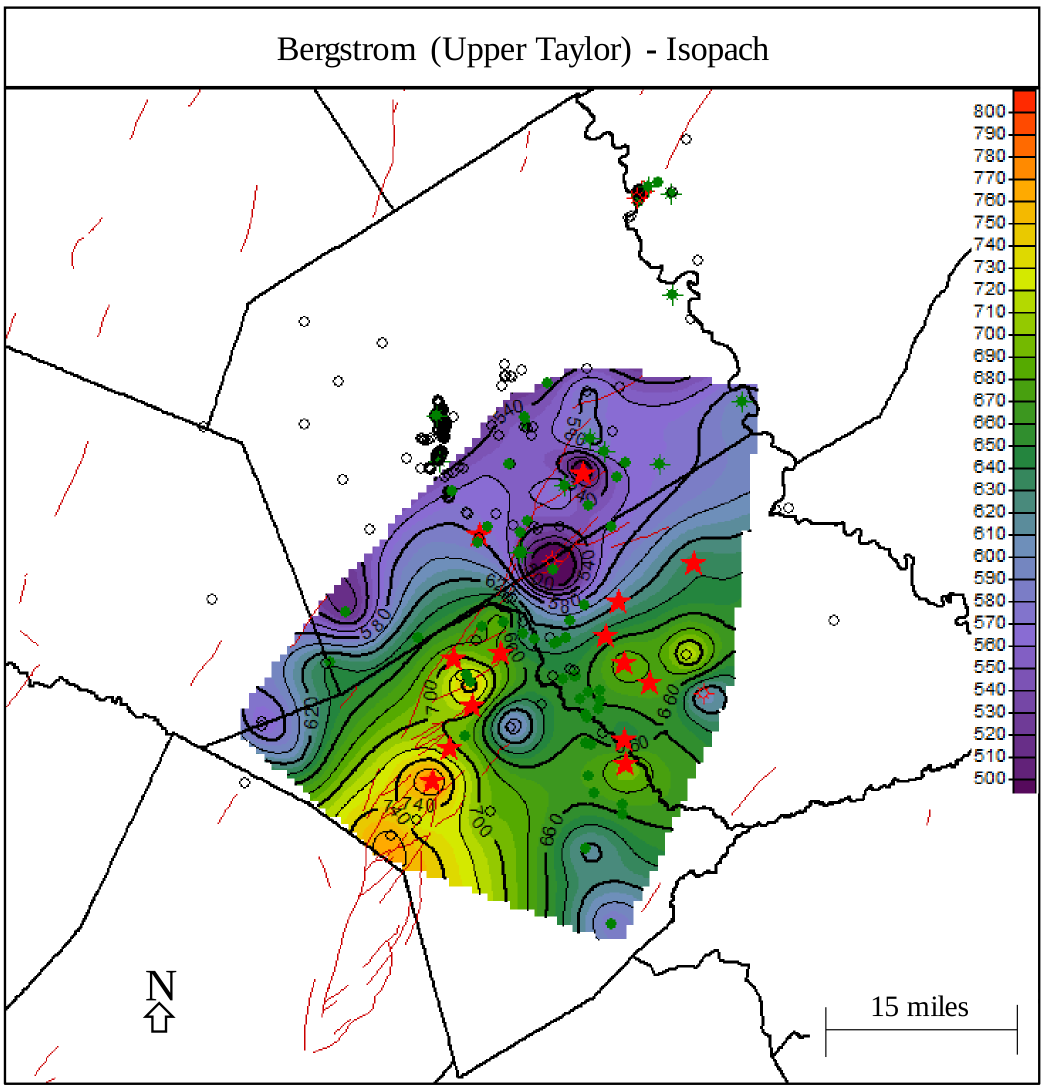


Figure 18: Regional type log from Patterson (1983). There are no scales or identification of the different logs used. This type log uses the original formational terminology from Patterson (1983) and the Taylor top, Bergstrom (Upper Taylor) as referred in my study, does not correlate well across the study area (digitized from Patterson, 1983).

The Bergstrom isopach map depicts a semi-lobate pattern, indicative of an outer-shelf environment, distal from the sediment source influenced primarily by storm-driven currents (Figure 19). The cyclic high gamma ray spikes approaching the top of the Bergstrom are interpreted as possible condensed intervals from shifting deltas and/or sea level changes. It is more likely the cyclic nature of the spikes are due to the shifting and/or abandonment of distal



sediment sources, marking a time of maximum sea level.

Figure 19: Isopach map of the Bergstrom (Upper Taylor) showing characteristics indicating a distal outer-shelf environment. Irregular thickening in the southwest could suggest structural control on deposition. 39 wells were used in the creation of this isopach map.

The disconformable basal boundary of the Bergstrom and inferred subsequent transgression into a period of maximum sea level, indicates that the upper portion was deposited during a regression (Hencey and Tucker, 1987). The irregular thickening pattern in the southwestern portion of the study area (Figure 19) agree with Bergstrom isopach maps produced by Hencey and Tucker (1987) in adjacent Bastrop County. The thickening in Bastrop County is attributed to the Paige fault, a listric fault with complicated antithetic faults, rollover structures, suggested mega-slide features, and possibly movement at the beginning of the Late Cretaceous (~100 Ma) (Hencey and Tucker, 1987). It is possible that a feature similar or equal to the Paige trough, as define by Hencey and Tucker (1987), continues into Lee County and effected deposition of the Bergstrom. However, due to lack of well control within that area, it is only suggested and further interpretation would be required to validate syndepositional movement.

4.2 MAASTRICHTIAN STAGE

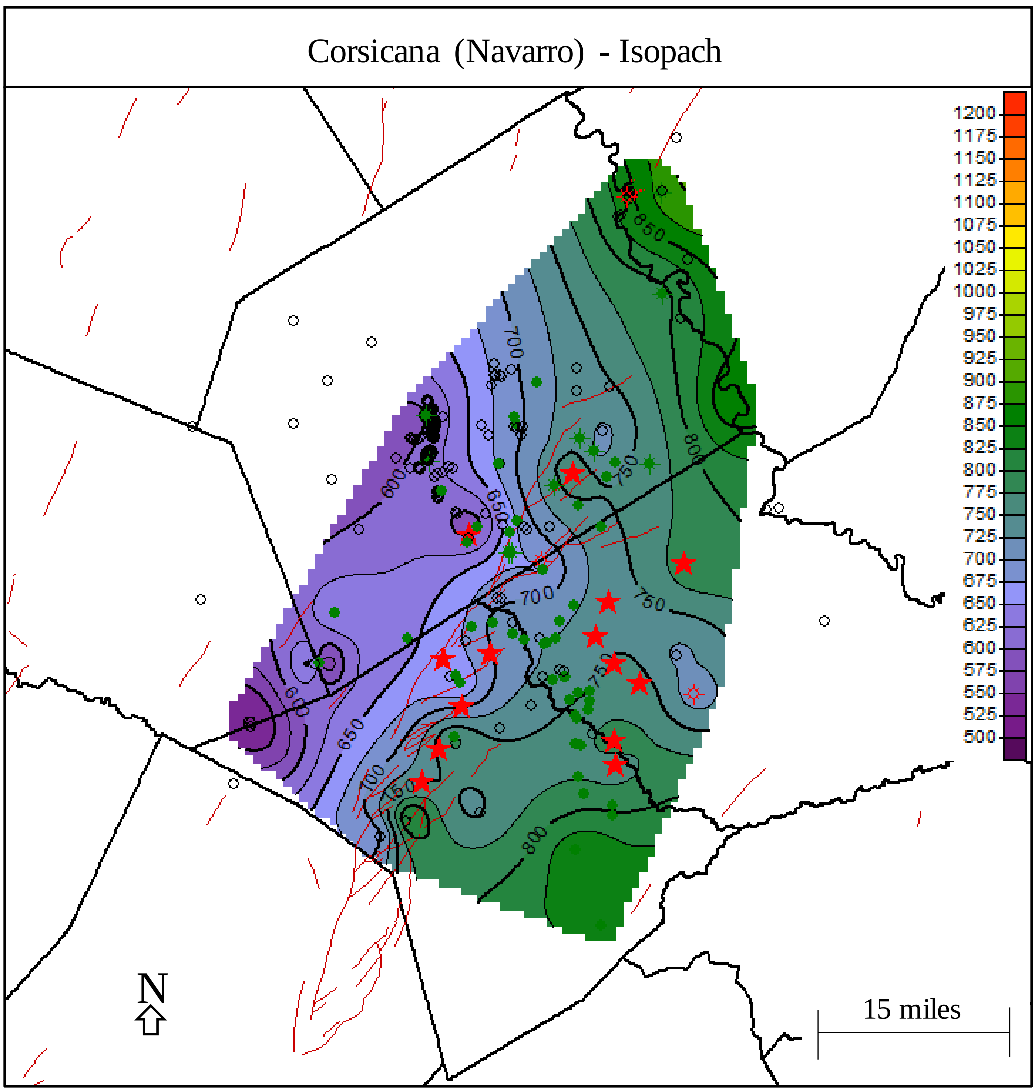
Upper Campanian to Lower Maastrichtian

The regressive nature of the Upper Campanian continued into the Lower Maastrichtian and marked the progradation of clastic systems from the northeast and southwest (Figure 8). The deposition of the Nacatoch Formation reached its maximum limit of progradation within the East Texas Basin during this time of regression (Lopez and McGowen, 1983; Mancini and Puckett, 2005). A very thin portion of the Nacatoch is recognized in the eastern portion of the study area, located near the base of the Corsicana Formation (Figure 16). An unconformity atop the Nacatoch due to regression is reported (Mancini and Puckett, 2005; Mancini et al., 2008), but no evidence of this is seen from well logs in my study area.

Following the regression throughout the lower part of the Maastrichtian, transgressive conditions developed (Young, 1986; Mancini and puckett, 2005). This flooding event was relatively quick and peaked during in late Lower Maastrichtian. The marl facies of the Corsicana are suggested to be deposited during this time of maximum transgression, when clastic progradation had been diminished (Smith and Pessagno, 1973; Mancini and Puckett, 2005). In well logs this marl facies of the Corsicana is identified above the thin Nacatoch (Figure 16), but neither are continuous enough to fully correlate or map. After the inferred flooding event, allowing for the deposition marl, a subsequent regression occurred. Deposition of the Corsicana continued through the regression with little evidence of prograding siliciclastic influence, until the presence of the Navarro ‘A’ and ‘B’ sand bodies within the Kemp Clay (Figure 16). The shelf plume model developed by Patterson (1983) for the suggested deltaic influenced Navarro ‘A’ and ‘B’ sand bodies could be the product of this regression.

5. SHELF PLUME MODEL

The isopach map of the Corsicana showing a band of thickening starting in the north/northeast and swinging down in an arcuate shape (Figure 20). This shape mimics the net-sand geometry of the Navarro ‘A’ and ‘B’ described by Patterson (1983). There is also a thinning of the Corsicana in the west/northwest, possibly due to sediment bypass or lack of



accommodation.

Figure 20: Isopach map of the Corsicana (Navarro) showing a broad arcuate band of thickening trending along southeast, truncated by thinning in the west/northwest. 41 wells were used in the creation of this isopach map.

Implementing the shelf plume model (Figure 2) could help describe some of the depositional patterns seen in the Corsicana isopach. The thinning in the west/northwest might be an example of the large scale eddy system deflecting deltaic sediment down current. Conversely, the northeast/southwest trending arcuate shaped thicker portion could constitute the band of deflected sediment, thinning basinward. Despite the similarities between the isopach of the Coriscana (Figure 20) and shelf plume model (Figure 2), location of the deltaic headland or source of sediment is still in question.

According to Patterson (1983), there are two deltaic depocenters, one in northeast Milam County, and one in central Milam (Figure 21). If there were two deltaic depocenters one would expect pronounced deltaic deposits. A well log from the central Milam depocenter (Figure 22) shows little evidence of a deltaic depocenter, with only two relatively thin coarsening upward packages within the Corsicana. The location of the well is outside the 32 foot contour on Patterson's (1983) net-sand map (Figure 21). A gamma ray cutoof (65 API) was applied to the log, resulting in a net-sand calculation of approximately 20 feet. Although the net-sand footage falls just short Patterson's, the well log lacks the assumed succession of deltaic deposits inferred with a deltaic depocenter.

A sidewall core report from Landcastle, No. 1 (Figure 23), also indicates very little evidence of a proximal deltaic depocenter in central Milam. The report was created July 18, 2012 and describes pro-deltaic or distal deposits, noting: fine to very fine grained sand, silty laminated calcareous shale, and very shaley limestone (marl).

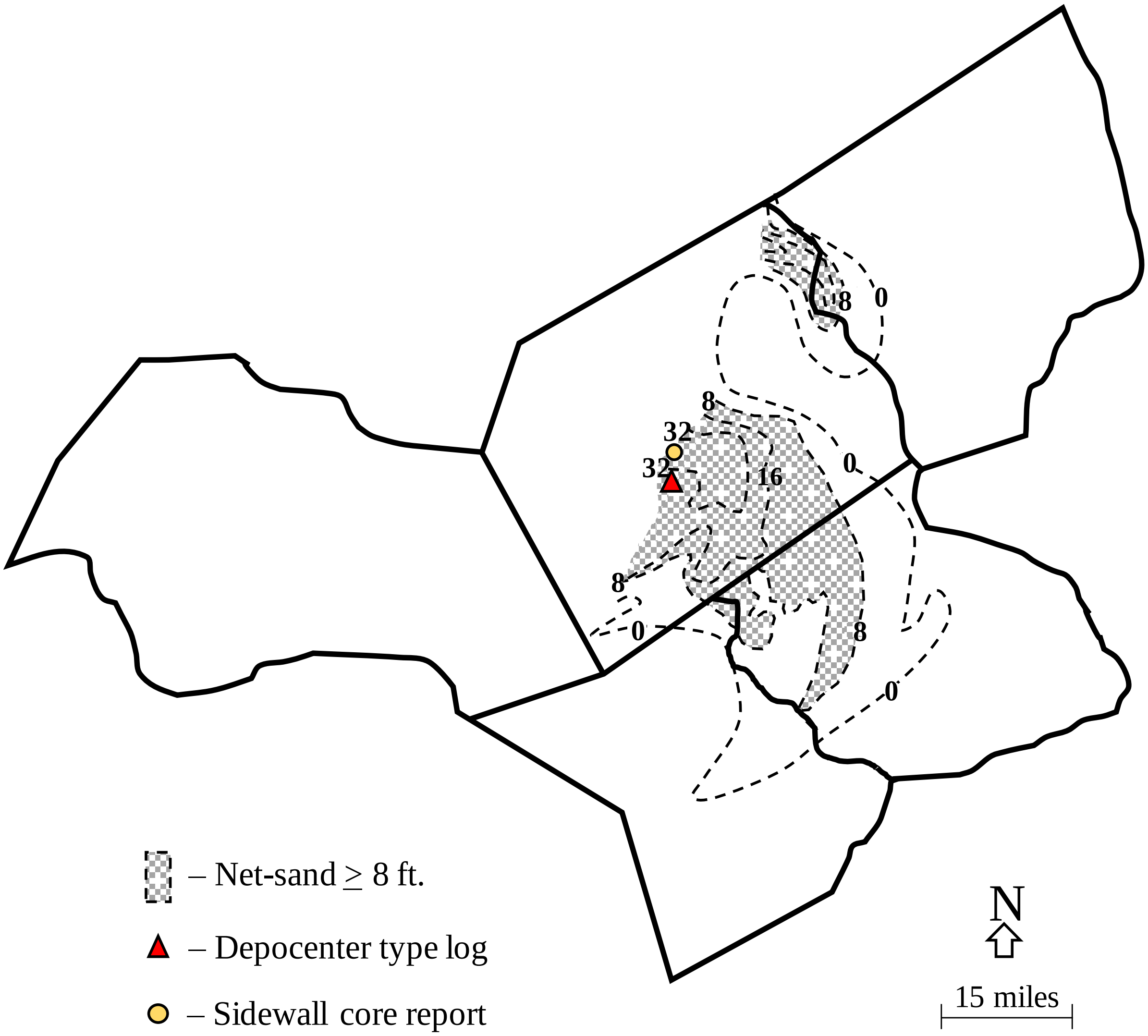


Figure 21: Location map of the two depocenters documented by Patterson (1983). Location of depocenter type log and well with sidewall core report shown (adapted from Patterson, 1983).

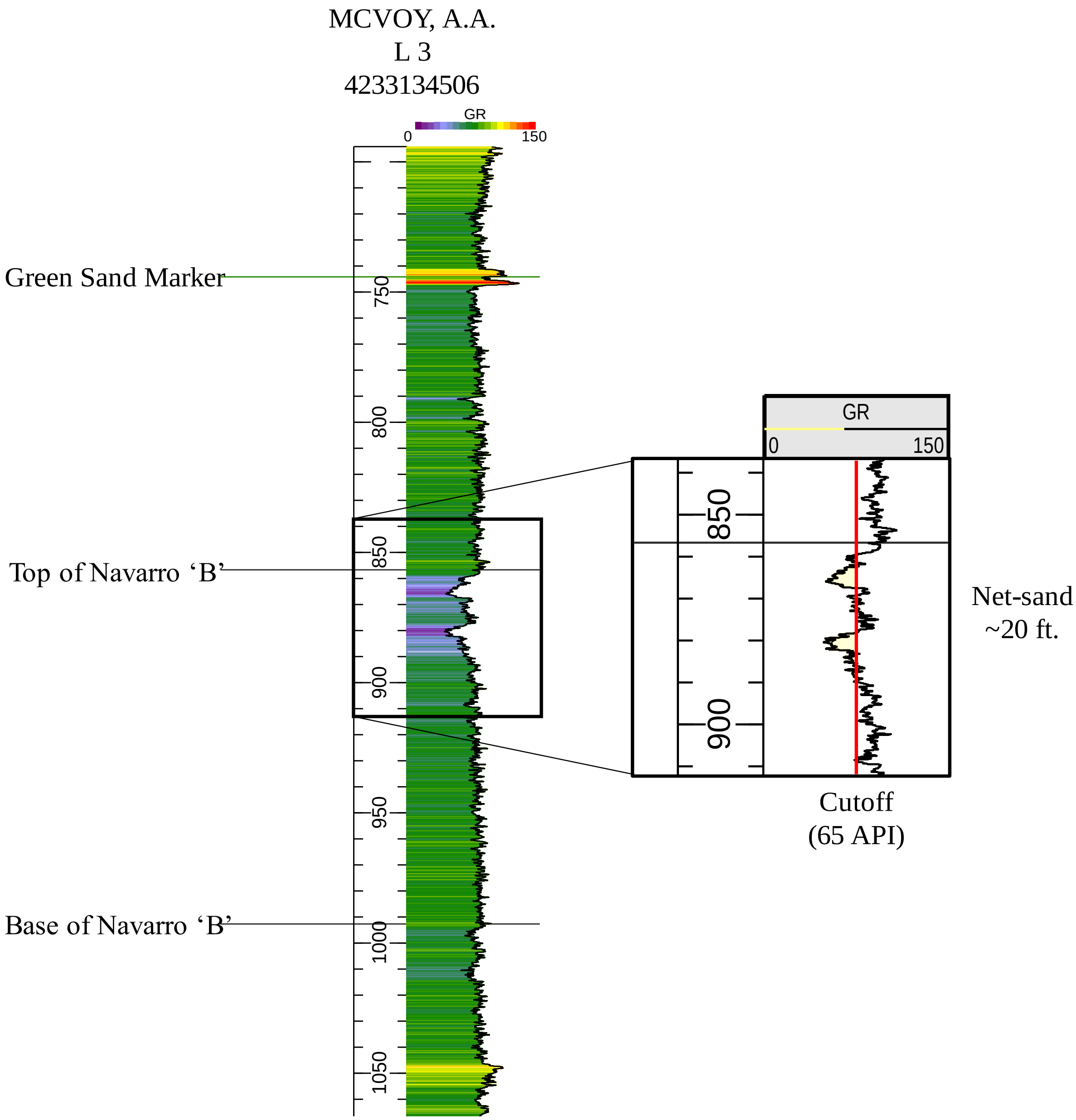


Figure 22: 300+ foot succession of the Corsicana (Navarro) from central Milam, County. Log character shows little evidence of a deltaic depocenter, only two small coarsening upward sequences in the Navarro 'B'. Location of well shown in Figure 21.

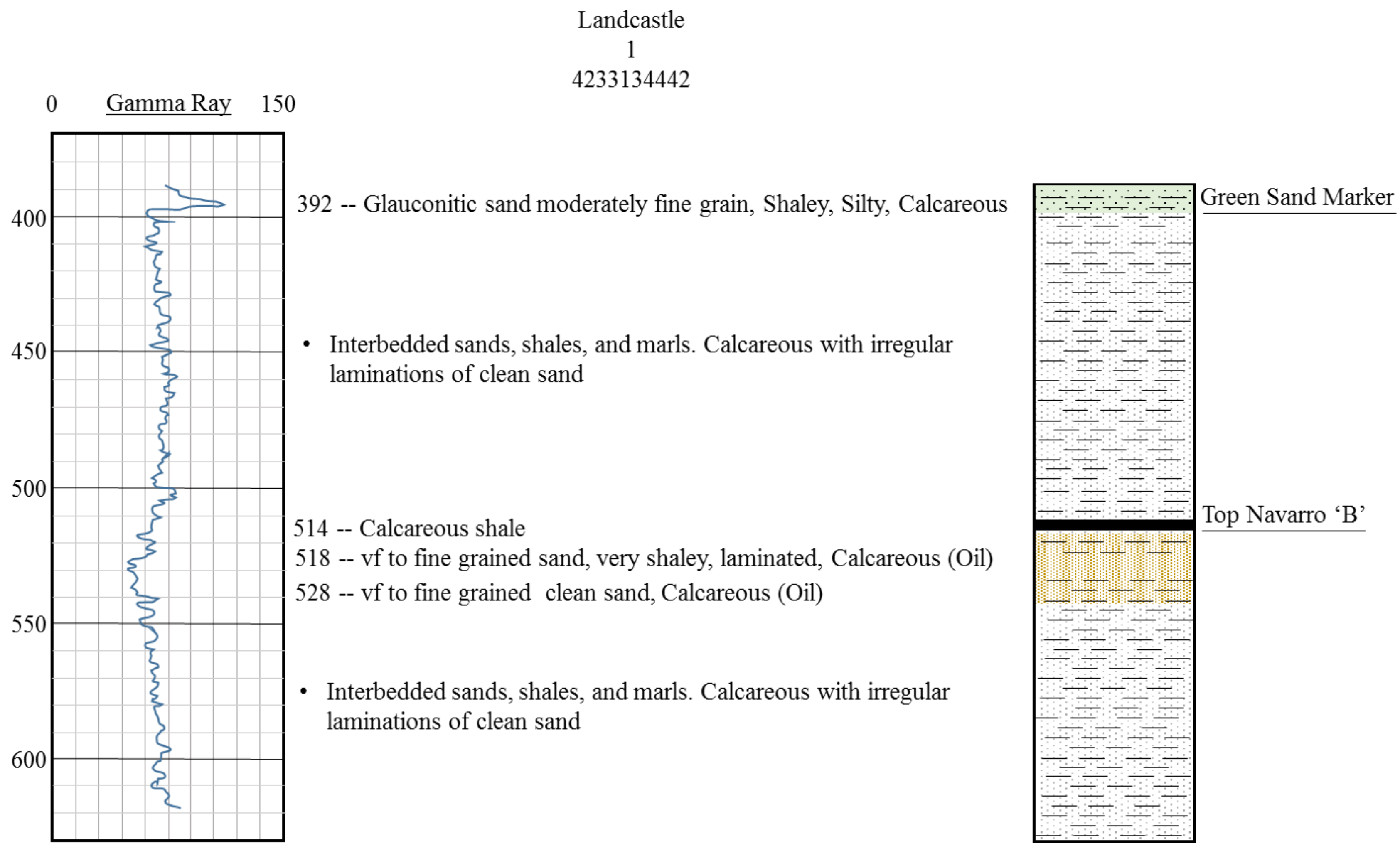


Figure 23: Sidewall core report for Landcastle No. 1. Lithology shows a dominance of very fine grain sand and calcareous shales; indicative of pro-deltaic deposits. Location of well shown in Figure 21.

6. CONCLUSION

This study was conduct to expand upon previous studies within and adjacent to a revitalized shallow, conventional oil field (MROF) with respect to reservoir and drilling techniques. With the boom of oil and gas shale plays, this study was intended to show that there was still vitality in interpreting conventional datasets. First a revision of stratigraphic nomenclature for the MROF and surrounding area was updated for modern formational identification. A sequence stratigraphic framework was then established to show implications on the depositional history for Upper Cretaceous (Campanian to Maastrichitian) strata. This sequence stratigraphic framework was then used in conjunction with a previously developed depositional model to improve on past interpretations. Conclusions regarding these results are provided below.

5.1 STRATIGRAPHIC NOMENTCLATURE

- ❖ Although members and intraformational divisions of the Austin Chalk are known to be recognized within the MROF and study area, the undivided formation name 'Austin Chalk' proves to be the correct terminology for this study.
- ❖ The Taylor Group (Campanian) strata should be divided into these formations: the (1) Sprinkle (Lower Taylor), (2) Pecan Gap, and (3) Bergstrom (Upper Taylor). The Wolfe City Sand Member of the Sprinkle (Lower Taylor) is also recognized, but thins and pinches out on the eastern limits of the MROF.
- ❖ The Navarro Group (Maastrichtian) strata is composed of the Corsicana (Navarro), with the Kemp clay constituting the upper portion and housing the Navarro 'A" and 'B' sand bodies. The Nacatoch Formation and marl facies of the

Corsicana (Navarro) are located in the basal portion, but exhibit unmappable continuity.

5.2 SEQUENCE STRATIGRPHIC FRAMEWORK

- Campanian to Maastrichtian aged strata constitutes the basal and top constraints for the sequence stratigraphic framework, respectively.
- The upper portion of the Austin Chalk (Lower Campanian) was deposited in a period of highstand, sitting disconformably below the Sprinkle. Subsequent regressive conditions developed, depositing the Sprinkle, reaching a maximum after the deposition of the Wolfe City.
- The western to southwestern portion of the study area was a distal and likely deep water environment throughout deposition of the Sprinkle. Conversely, the eastern to northeastern area is likely shallower water and more proximal based on the thicker deposits of the Sprinkle and presence of the conformable Wolfe City Sand Member.
- The top of the Sprinkle and basal Pecan Gap, represents a sequence boundary or time of maximum regression. A subsequent flooding event throughout the lower Pecan Gap diminished the siliciclastic influx of the Wolfe City, allowing for carbonate (chalk) accumulations. The easterly thickening of the Pecan Gap suggests a transition from deeper to shallower water.
- Transgressive conditions reached a maximum in the middle of the Pecan Gap, followed by regressive conditions that continued into the lower Bergstrom.

- ❖ The Bergstrom represents deposition on a distal outer shelf environment. A condensed zone near the top represents a maximum flooding interval, followed by regressive conditions.
- ❖ Regression continued into Lower Maastrichtian time and allowing for the progradation of the Nacatoch delta system. Trangressive conditions developed and the abandonment of the Nacatoch system ensued. Following this abandonment, marl facies of the Corsicana were deposited.
- ❖ Regressive conditions represent the remainder of the Corsicana and allowed for the deposition of the deltaic influenced Navarro ‘A’ and ‘B’ sand bodies.

5.3 SHELF PLUME MODEL

- ❖ Although very detailed in nature, Patterson’s (1983) suggestion of two different deltaic depocenters within the Corsicana (Navarro) Formation in Milam County seems unlikely.
- ❖ The lack of a pronounced succession of deltaic deposits and the indication of primarily pro-deltaic fine grained sediment, rules out a proximal delta source.
- ❖ The correlation between the isopach map of the Corsicana and the geometry of the Navarro ‘A’ and ‘B’ is curiously similar; however, the available data obtained for this study did not supply enough information to fully conclude on the accuracy of the shelf plume model.

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APPENDIX A.

Raster Well Logs Downloaded From Drillininfo.com				
API#	**County**	**Operator**	**TD (ft.)**	**Abstract**
42-491-30436	Williamson	PATTON EXPLORATION, INC.	3,006	479
42-491-30434	Williamson	M. A. MUELLER CONST. CO., INC.	2,177	286
42-491-30426	Williamson	CHART - X CORPORATION	1,532	59
42-395-31685	Robertson	XTO ENERGY INC.	13,732	331
42-395-31071	Robertson	HOUSTON PETROLEUM CO	2,750	51
42-395-30960	Robertson	ARBOL RESOURCES, INC.	5,000	51
42-395-30747	Robertson	ARBOL RESOURCES, INC.	4,600	22
42-395-30355	Robertson	OERTLI OPERATING COMPANY	3,298	48
42-395-30354	Robertson	OERTLI OPERATING COMPANY	2,288	48
42-331-34489	Milam	PRICE OPERATING, LLC	650	30
42-331-34488	Milam	PRICE OPERATING, LLC	660	30
42-331-34485	Milam	PRICE OPERATING, LLC	660	30
42-331-34484	Milam	PRICE OPERATING, LLC	685	30
42-331-34483	Milam	PRICE OPERATING, LLC	660	30
42-331-34481	Milam	PRICE OPERATING, LLC	685	30
42-331-34480	Milam	PRICE OPERATING, LLC	685	30
42-331-34457	Milam	PRICE OPERATING, LLC	685	30
42-331-34456	Milam	PRICE OPERATING, LLC	685	30
42-331-34455	Milam	PRICE OPERATING, LLC	685	30
42-331-34454	Milam	PRICE OPERATING, LLC	685	30
42-331-34453	Milam	PRICE OPERATING, LLC	685	30
42-331-34446	Milam	PROEX ENERGY MANAGEMENT	685	30
42-331-34445	Milam	PROEX ENERGY MANAGEMENT	685	30
42-331-34444	Milam	PROEX ENERGY MANAGEMENT	685	30
42-331-34443	Milam	PROEX ENERGY MANAGEMENT	685	30
42-331-34442	Milam	PROEX ENERGY MANAGEMENT	685	30
42-331-33979	Milam	OMNI OIL & GAS, INC.	955	7
42-331-33978	Milam	OMNI OIL & GAS, INC.	966	7
42-331-33977	Milam	OMNI OIL & GAS, INC.	959	7
42-331-33976	Milam	OMNI OIL & GAS, INC.	953	7
42-331-33975	Milam	OMNI OIL & GAS, INC.	944	7
42-331-33974	Milam	OMNI OIL & GAS, INC.	925	7
42-331-33973	Milam	OMNI OIL & GAS, INC.	921	7
42-331-33972	Milam	OMNI OIL & GAS, INC.	985	7
42-331-33971	Milam	OMNI OIL & GAS, INC.	948	7
42-331-33965	Milam	OMNI OIL & GAS, INC.	888	7
42-331-33964	Milam	OMNI OIL & GAS, INC.	897	7

Raster Well Logs Downloaded From Drillininfo.com (CONT.)				
API#	**County**	**Operator**	**TD (ft.)**	**Abstract**
42-331-33963	Milam	OMNI OIL & GAS, INC.	937	7
42-331-33962	Milam	OMNI OIL & GAS, INC.	942	7
42-331-33957	Milam	OMNI OIL & GAS, INC.	728	87
42-331-33951	Milam	OMNI OIL & GAS, INC.	750	87
42-331-33949	Milam	OMNI OIL & GAS, INC.	755	87
42-331-33936	Milam	OMNI OIL & GAS, INC.	900	7
42-331-33935	Milam	OMNI OIL & GAS, INC.	891	7
42-331-33893	Milam	TEXAS SECONDARY OIL	1,500	398
42-331-33841	Milam	OMNI OIL & GAS, INC.	777	87
42-331-33840	Milam	OMNI OIL & GAS, INC.	841	87
42-331-33816	Milam	RESACA RESOURCES, L.L.C.	1,788	318
42-331-33812	Milam	RESACA RESOURCES, L.L.C.	1,761	29
42-331-33805	Milam	WM C RAYMOND OIL AND GAS	1,400	7
42-331-33770	Milam	OMNI OIL & GAS, INC.	984	7
42-331-33765	Milam	OMNI OIL & GAS, INC.	801	7
42-331-33744	Milam	OMNI OIL & GAS, INC.	790	7
42-331-33743	Milam	OMNI OIL & GAS, INC.	805	7
42-331-33741	Milam	OMNI OIL & GAS, INC.	760	7
42-331-33740	Milam	OMNI OIL & GAS, INC.	785	7
42-331-33664	Milam	EXPLORATION TECHNIQUES	2,800	130
42-331-33658	Milam	BETRO, INC.	991	29
42-331-33648	Milam	OMNI E & P, INC.	530	52
42-331-33638	Milam	ENTEGER USA LLC	5,919	304
42-331-33635	Milam	M. A. MUELLER CONST. CO., INC.	2,985	198
42-331-33620	Milam	XTO ENERGY INC.	14,852	9
42-331-33560	Milam	CARR RESOURCES, INC.	6,000	21
42-331-33549	Milam	GEOSTRAT INC.	1,999	43
42-331-33517	Milam	LASER EXPLORATION, INC.	5,133	1
42-331-33513	Milam	RAYMOND, WM. C.	1,275	74
42-331-33508	Milam	UNION PACIFIC RESOURCES	9,700	53
42-331-33490	Milam	WADI PETROLEUM, INC.	3,700	146
42-331-33489	Milam	RAYMOND, WM. C.	1,385	74
42-331-33453	Milam	TARGET DRILLING INC.	1,256	7
42-331-33425	Milam	PENROD OIL COMPANY	1,000	7
42-331-33414	Milam	PENROD OIL COMPANY	1,400	7
42-331-33413	Milam	R.E.O. ENERGY, INC.	1,370	7
42-331-33404	Milam	FERGUSON-BURNS LEASING CO.	1,973	288
42-331-33382	Milam	R.E.O. ENERGY, INC.	1,008	7
42-331-33380	Milam	R.E.O. ENERGY, INC.	1,060	7

Raster Well Logs Downloaded From Drillininfo.com (CONT.)				
API#	**County**	**Operator**	**TD (ft.)**	**Abstract**
42-331-33379	Milam	R.E.O. ENERGY, INC.	1,040	7
42-331-33377	Milam	R.E.O. ENERGY, INC.	1,045	7
42-331-33362	Milam	RESERVOIR ENHANCE. & OP CO	1,171	7
42-331-33358	Milam	RESERVOIR ENHANCE. & OP CO	1,000	7
42-331-33350	Milam	RESERVOIR ENHANCE. & OP CO	761	7
42-331-33341	Milam	RESERVOIR ENHANCE. & OP CO	798	7
42-331-33334	Milam	PROSPECT MINERALS, INC.	1,745	318
42-331-33325	Milam	SHALE OPERATING CO.	2,520	191
42-331-33321	Milam	STILES ENERGY CORPORATION	1,067	230
42-331-33318	Milam	STILES ENERGY CORPORATION	1,062	230
42-331-33304	Milam	VOSKAMP EXPLORATION, INC.	1,850	189
42-331-33302	Milam	NAVARRO PRODUCTION CO.	1,630	29
42-331-33297	Milam	NAVARRO PRODUCTION CO.	1,750	29
42-331-33291	Milam	MCADAMS, WILLIAM A.-LTD	1,905	288
42-331-33283	Milam	MCADAMS, WILLIAM A.-LTD	1,900	288
42-331-33282	Milam	STILES ENERGY CORPORATION	974	29
42-331-33280	Milam	HOUSTON PETROLEUM CO.	6,100	328
42-331-33276	Milam	HEARTLAND RESOURCES, INC.	2,410	191
42-331-33261	Milam	EILAND, MELVIN C	1,000	1
42-331-33243	Milam	MCCRARY OIL COMPANY	2,200	58
42-331-33218	Milam	STEDMAN OIL & GAS CO.	1,000	29
42-331-33199	Milam	MCCRARY OIL COMPANY	2,330	58
42-331-33198	Milam	MCCRARY OIL COMPANY	2,324	58
42-331-33194	Milam	MCCRARY OIL COMPANY	2,310	58
42-331-33177	Milam	MCCRARY OIL COMPANY	2,180	58
42-331-33176	Milam	MCCRARY OIL COMPANY	2,190	58
42-331-33174	Milam	RIATA	1,320	74
42-331-33167	Milam	NAVARRO EXPLORATION CO.	600	30
42-331-33166	Milam	NAVARRO EXPLORATION CO.	620	30
42-331-33162	Milam	NAVARRO EXPLORATION CO.	620	30
42-331-33161	Milam	NAVARRO EXPLORATION CO.	600	30
42-331-33154	Milam	NAVARRO EXPLORATION CO.	600	30
42-331-33143	Milam	MCCRARY OIL COMPANY	2,158	58
42-331-33137	Milam	WILHITE-WELPETCO JV	860	335
42-331-33125	Milam	MCCRARY OIL COMPANY	2,121	58
42-331-33124	Milam	MCCRARY OIL COMPANY	2,130	58
42-331-33116	Milam	NAVARRO EXPLORATION CO.	600	30
42-331-33114	Milam	MCCRARY OIL COMPANY	2,130	58
42-331-33109	Milam	NAVARRO EXPLORATION CO.	600	30

Raster Well Logs Downloaded From Drillininfo.com (CONT.)				
API#	**County**	**Operator**	**TD (ft.)**	**Abstract**
42-331-33106	Milam	NAVARRO EXPLORATION CO.	620	30
42-331-33104	Milam	MCCRARY OIL COMPANY	2,100	58
42-331-33102	Milam	MCCRARY OIL COMPANY	2,145	58
42-331-33100	Milam	MCCRARY OIL COMPANY	2,145	58
42-331-33082	Milam	NAVARRO EXPLORATION CO.	620	30
42-331-33069	Milam	HOUSTON PETROLEUM CO.	6,118	317
42-331-33065	Milam	HEARTLAND RESOURCES, INC.	3,073	317
42-331-33059	Milam	NELSON-DEAN ENERGY CORP.	1,610	29
42-331-33057	Milam	MCCRARY OIL COMPANY	2,172	58
42-331-33056	Milam	MCCRARY OIL COMPANY	2,140	58
42-331-33050	Milam	Y OIL COMPANY	1,030	137
42-331-33041	Milam	LEONARD, J. A.	2,700	191
42-331-33039	Milam	MCCRARY OIL COMPANY	2,120	58
42-331-33038	Milam	HARVARD RESOURCES	3,650	43
42-331-33027	Milam	LEONARD, J. A.	2,600	191
42-331-33008	Milam	NELSON-DEAN ENERGY CORP.	588	187
42-331-33007	Milam	NELSON-DEAN ENERGY CORP.	573	187
42-331-32999	Milam	MUELLER ENGINEERING CORP.	2,700	355
42-331-32993	Milam	NELSON-DEAN ENERGY CORP.	581	187
42-331-32982	Milam	RODEL OIL & GAS COMPANY	3,253	391
42-331-32974	Milam	MCCRARY OIL COMPANY	2,100	58
42-331-32956	Milam	NELSON-DEAN ENERGY CORP.	590	187
42-331-32954	Milam	HEARTLAND RESOURCES, INC.	3,110	317
42-331-32953	Milam	CORTEZ ENERGY INC.	1,270	29
42-331-32888	Milam	GIBRALTAR MINERALS, INC.	550	187
42-331-32881	Milam	ERNEST OIL COMPANY	3,617	328
42-331-32821	Milam	WILSON SERVICE COMPANY	1,301	29
42-331-32759	Milam	NELSON-DEAN ENERGY	519	187
42-331-32758	Milam	NELSON-DEAN ENERGY	522	187
42-331-32757	Milam	NELSON-DEAN ENERGY	606	187
42-331-32756	Milam	MARGO, INC.	1,760	29
42-331-32607	Milam	MCCRARY OIL COMPANY	2,225	58
42-331-32603	Milam	B & B DRILLING CO.	3,500	153
42-331-32513	Milam	TEXAS ONSHORE ENERGY, INC.	6,000	183
42-331-31892	Milam	B & B DRILLING CO.	1,263	143
42-331-31805	Milam	C. & O. OIL CO.	824	52
42-331-31757	Milam	HOUSTON PETROLEUM CO.	6,090	344
42-331-31683	Milam	DOSS, THOMAS C. OIL & GAS	1,700	199
42-331-31533	Milam	OAKLAND PETROLEUM OPER.	3,200	55

Raster Well Logs Downloaded From Drillininfo.com (CONT.)				
API#	**County**	**Operator**	**TD (ft.)**	**Abstract**
42-331-31418	Milam	PEMBERTON, WAYNE	8,000	249
42-331-31379	Milam	LAMPLEY OIL COMPANY INC.	5,827	344
42-331-31298	Milam	SEAGULL OPERATING CO., INC.	2,900	288
42-331-31195	Milam	PEMBERTON, W. C.	7,000	249
42-331-31193	Milam	ATOPP OIL	1,200	29
42-331-31127	Milam	ARIES OIL CORP.	1,200	7
42-331-31036	Milam	LULING OIL & GAS COMPANY	3,804	140
42-331-30932	Milam	DAVIS, CHUCK	1,654	398
42-331-30889	Milam	SCAFFOLDING INC	6,730	39
42-331-30731	Milam	CADDO OIL CO.-CALDWELL	5,810	353
42-331-00725	Milam	DAVIS, CHUCK	1,536	398
42-287-32578	Lee	FOREST OIL CORPORATION	5,362	334
42-287-32576	Lee	FOREST OIL CORPORATION	7,049	85
42-287-32573	Lee	FOREST OIL CORPORATION	8,128	211
42-287-32571	Lee	GEOSOUTHERN ENERGY CORP	10,112	108
42-287-32569	Lee	GEOSOUTHERN ENERGY CORP	8,341	38
42-287-32565	Lee	BRAMMER ENGINEERING, INC.	7,298	65
42-287-32557	Lee	PATTON EXPLORATION, INC.	3,090	246
42-287-32554	Lee	NESTEX ENERGY, LLC	4,980	1
42-287-32552	Lee	NESTEX ENERGY, LLC	5,114	1
42-287-32533	Lee	HOUSTON PETROLEUM CO	3,266	211
42-287-32527	Lee	HOUSTON PETROLEUM CO	3,244	108
42-287-32511	Lee	BAR-MAC INVESTMENTS INC.	2,600	365
42-287-32509	Lee	BAR-MAC INVESTMENTS INC.	5,000	220
42-287-32409	Lee	WCS OIL AND GAS CORP	5,965	22
42-287-32300	Lee	GEMINI EXPLORATION CO	9,065	149
42-287-32297	Lee	UNITED OIL & MINERALS, INC.	6,500	120
42-287-32290	Lee	HECI EXPLORATION COMPANY	6,000	22
42-287-32265	Lee	CRESCENT EXPLORATION CO	4,785	138
42-287-32250	Lee	HOUSTON PETROLEUM CO	6,139	158
42-287-31939	Lee	HOLLUB, LAMBERT DRILLING	4,665	220
42-287-31903	Lee	TXO PRODUCTION CORP.	4,500	153
42-287-31899	Lee	ROUSSEAU, GEORGE L.	3,931	174
42-287-31871	Lee	ERNEST OIL COMPANY	4,975	289
42-287-31844	Lee	U. S. OPERATING, INC.	9,396	114
42-287-31838	Lee	ERNEST OIL COMPANY	3,450	106
42-287-31769	Lee	GLENCO OIL & GAS COMPANY	5,100	138
42-287-31700	Lee	ERNEST OIL COMPANY	4,000	250
42-287-31401	Lee	DOBOS, JAMES D. CORP	4,722	108

Raster Well Logs Downloaded From Drillininfo.com (CONT.)				
API#	**County**	**Operator**	**TD (ft.)**	**Abstract**
42-287-31229	Lee	HALAMICEK, F. A. ENTERPRISES	7,959	1
42-287-31121	Lee	CONVEST ENERGY CORP	7,192	289
42-287-30991	Lee	ENERGETICS, INC.	3,815	211
42-287-30966	Lee	TAMARACK PETROLEUM CO	7,656	182
42-051-33628	Burleson	INTEGRAS OPERATING, LLC	3,760	114
42-051-33626	Burleson	INTEGRAS OPERATING, LLC	3,850	114
42-051-33623	Burleson	INTEGRAS OPERATING, LLC	3,950	114
42-051-33603	Burleson	BAR-MAC INVESTMENTS INC.	4,300	171
42-051-33571	Burleson	BAR-MAC INVESTMENTS INC.	4,450	171
42-051-33464	Burleson	BAR-MAC INVESTMENTS INC.	4,300	124
42-051-33344	Burleson	BAR-MAC INVESTMENTS INC.	4,500	82
42-051-33072	Burleson	CRESCENT EXPLORATION CO	4,200	60
42-051-33054	Burleson	CRESCENT EXPLORATION CO	4,250	60
42-051-32991	Burleson	H&K OIL FIELD SERVICES, INC.	4,100	60
42-051-32967	Burleson	LEONARD, J. A.	3,786	159
42-051-32955	Burleson	CENTRAL TEXAS OIL & GAS	3,975	168
42-051-32947	Burleson	CJD EXPLORATION INC.	8,000	2
42-051-32908	Burleson	MID-GULF, INC.	4,500	82
42-051-32905	Burleson	MID-GULF, INC.	4,457	82
42-051-32896	Burleson	CRESCENT EXPLORATION CO	4,000	245
42-051-32736	Burleson	PESETAS EXPLORATION CO	4,400	53
42-051-32693	Burleson	ERNEST OIL COMPANY	3,650	114
42-051-32663	Burleson	DOILCO EXPLORATION	3,800	52
42-051-32630	Burleson	ERNEST OIL COMPANY	4,500	123
42-051-32578	Burleson	EAST TEXAS EXPLORATION	4,100	168
42-051-32487	Burleson	CRESCENT EXPLORATION CO	4,000	245
42-051-32067	Burleson	GEO EXPL. INC.	4,500	230
42-051-32009	Burleson	GRAHAM, KEITH D.	7,950	64
42-051-31774	Burleson	ENERGETICS, INC.	6,122	210
42-051-31679	Burleson	MARSHALL EXPL. INC.	7,823	26
42-051-31353	Burleson	DRILLCO ENERGY CORP	7,006	167
42-051-31279	Burleson	HARKEN OIL & GAS, INC	8,000	95
42-051-30960	Burleson	U. S. OPERATING, INC.	7,871	58
42-041-31403	Brazos	T. M. ENERGY, INC.	7,465	18
42-041-31394	Brazos	T. M. ENERGY, INC.	7,578	18
42-027-30135	Bell	OIL CREEK PRODUCTION CO	2,000	8
42-021-31581	Bastrop	PATTON EXPLORATION, INC.	3,500	189

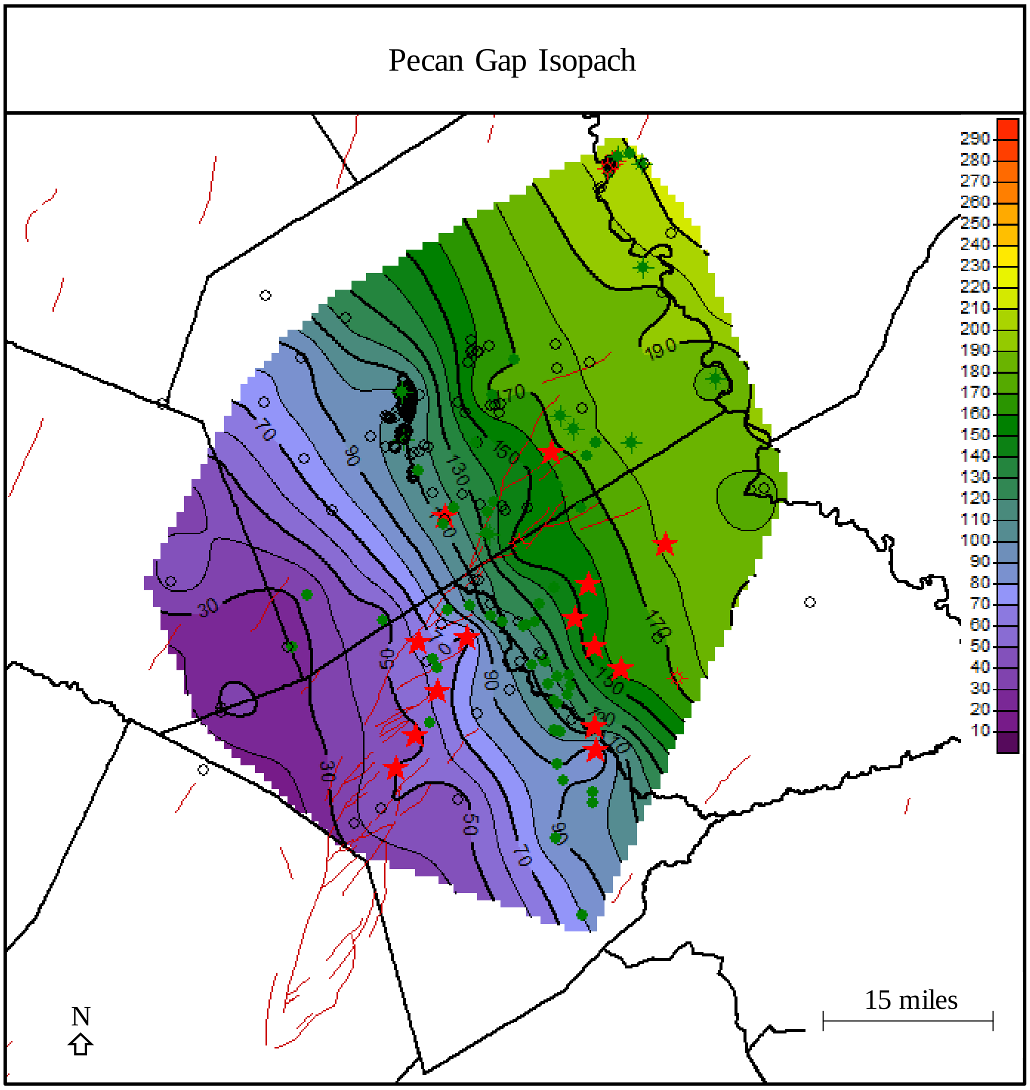
APPENDIX B.

Well Logs Manually Digitized				
API#	**County**	**Operator**	**TD (ft.)**	**Abstract**
42-051-30960	Burleson	U.S. OPRG INC	7871	58
42-051-31279	Burleson	HARKEN O&G INC	8000	95
42-051-31353	Burleson	DRILLCO	7006	167
42-051-31679	Burleson	MARSHALL EXPL INC	7823	26
42-051-31774	Burleson	ENERGETICS INC	6122	210
42-051-32009	Burleson	KEITH GRAHAM	7950	64
42-051-32067	Burleson	GEO EXPL ET AL	4500	230
42-051-32487	Burleson	CRESENT EXPL CO	4000	245
42-051-32578	Burleson	EAST TEXAS EXPL	4100	168
42-051-32630	Burleson	ERNEST OIL CO	4500	123
42-051-32663	Burleson	DOILCO EXPL	3800	52
42-051-32693	Burleson	ERNEST OPRG	3650	114
42-051-32736	Burleson	PESETAS EXPL CO	4400	53
42-051-32896	Burleson	CRESCENT EXPL CO	4000	245
42-051-32905	Burleson	MID GULF INC	4457	82
42-051-32908	Burleson	MID GULF INC	4500	82
42-051-32947	Burleson	C J D EXPL	8000	2
42-051-32955	Burleson	CENTRAL TX O&G PROD	3975	168
42-051-32967	Burleson	BURLESON	3786	159
42-051-33054	Burleson	CRESCENT EXPL CO	4250	60
42-051-33072	Burleson	CRESENT EXPL CO	4200	60
42-051-33344	Burleson	BAR MAC INVESTMENTS	4500	82
42-051-33464	Burleson	BAR MAC INVESTMENTS	4300	171
42-051-33603	Burleson	BAR-MAC INVESTMENTS INC.	4300	171
42-051-33623	Burleson	INTEGRAS OPERATING, LLC	3950	114
42-051-33626	Burleson	INTEGRAS OPERATING, LLC	3850	114
42-051-33628	Burleson	INTEGRAS OPERATING, LLC	3760	114
42-287-30966	Lee	TAMARACK PETRO CO INC	7656	182
42-287-30991	Lee	ENERGETICS INC	3815	211
42-287-31121	Lee	CONVEST ENERGY	7192	289
42-287-31229	Lee	TOMLINSON, THOMAS K.	7959	1
42-287-31401	Lee	DOBOS, JIM CORP	4722	108
42-287-31700	Lee	ERNEST OPRG CO	4000	250
42-287-31769	Lee	WARNCKE, ROGER ET AL	5100	138
42-287-31838	Lee	ERNEST OPRG CO	3450	106

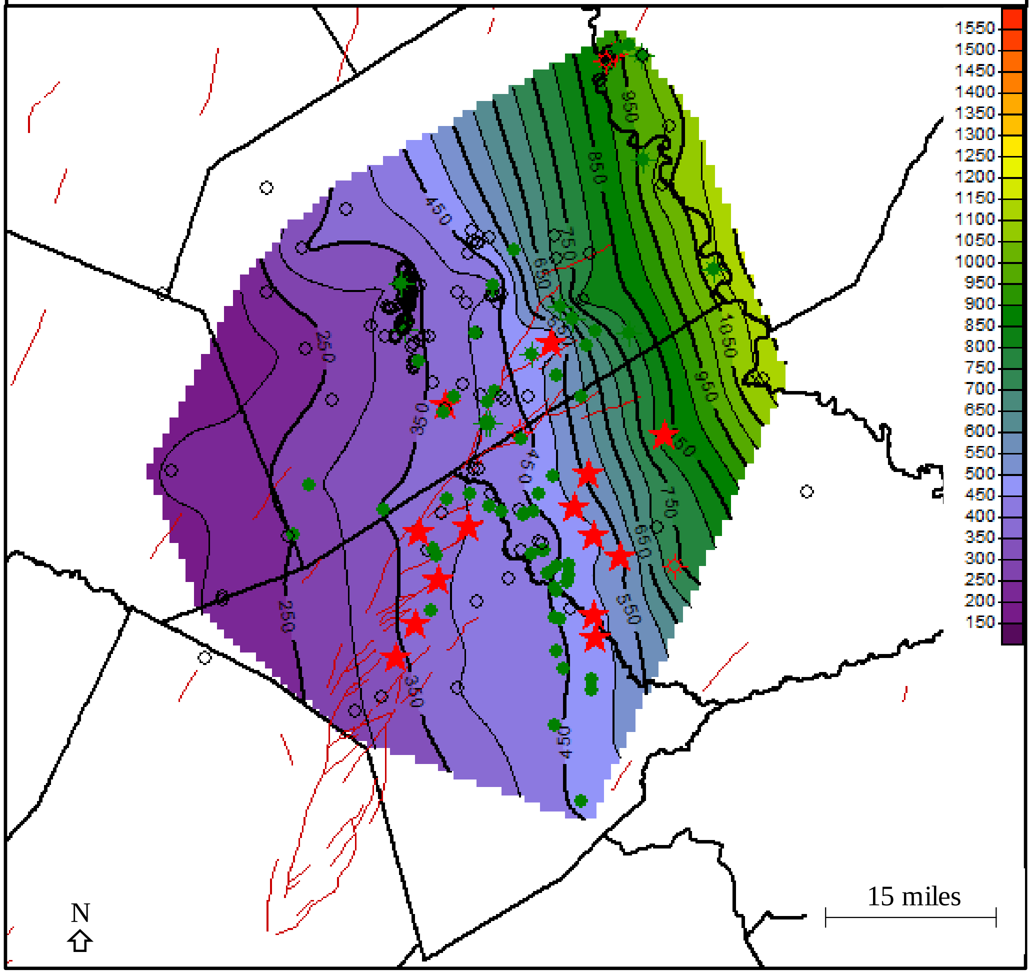
Well Logs Manually Digitized (CONT.)				
API#	**County**	**Operator**	**TD (ft.)**	**Abstract**
42-287-31844	Lee	U S OPRG INC	9396	114
42-287-31871	Lee	ERNEST OIL	4975	289
42-287-31899	Lee	ROUSSEAU, GOERGE L.	3931	174
42-287-31903	Lee	TXO PRODUCTION CORP.	4500	153
42-287-31939	Lee	CRESCENT EXPL CO	4665	220
42-287-32250	Lee	B & B DRLG CO	6139	158
42-287-32265	Lee	CRESENT EXPL CO	4785	138
42-287-32290	Lee	ESTATE O&G CORP	6000	22
42-287-32297	Lee	UNITED OIL & MINERALS INC	6500	120
42-287-32300	Lee	GEMINI EXPL CO	9065	149
42-287-32409	Lee	WCS O&G CORP	5965	22
42-287-32509	Lee	BAR MAC INVESTMENTS	5000	220
42-287-32533	Lee	HOUSTON PETROLEUM CO.	3266	211
42-287-32552	Lee	NESTEX ENERGY LLC	5114	1
42-287-32554	Lee	NESTEX ENERGY LLC	4980	1
42-287-32557	Lee	PATTON EXPLORATION INC	3086	246
42-287-32565	Lee	BRAMMER ENGINEERING INC	7300	65
42-287-32569	Lee	GEOSOUTHERN ENERGY CORP.	6834	38
42-287-32571	Lee	GEOSOUTHERN ENERGY CORP.	5833	108
42-287-32573	Lee	FOREST OIL CORPORATION	6516	211
42-331-30731	Milam	CADDO OIL CO. INC.	5810	353
42-331-30889	Milam	SCAFFOLDING & RENTAL INC	6730	39
42-331-31036	Milam	LULING O&G INC	3804	140
42-331-31195	Milam	PEMBERTON, WAYEN C.	7000	249
42-331-31298	Milam	SEAGULL OPRG CO INC	2900	288
42-331-31379	Milam	EXPLORATION TECHNIQUES	5797	344
42-331-31418	Milam	PEMBERTON, WAYNE C.	8000	249
42-331-31683	Milam	LANDMARK EXPL	1700	191
42-331-31757	Milam	HOUSTON PETRO CO	6090	344
42-331-31892	Milam	B & B DRLG CO	1263	142
42-331-32513	Milam	TEXAS ONSHORE ENERGY INC	6000	183
42-331-32603	Milam	B & B DRLG CO	3500	152
42-331-32756	Milam	MARGO INC	1760	29
42-331-32881	Milam	ERNEST OPRG CO	3617	328
42-331-32954	Milam	HEARTLAND RES INC	3110	317
42-331-32974	Milam	MCCRARY OIL CO	2100	58
42-331-32982	Milam	RODELL O&G CO	3253	391

Well Logs Manually Digitized (CONT.)				
API#	**County**	**Operator**	**TD (ft.)**	**Abstract**
42-331-32999	Milam	MUELLER ENG CORP	2700	355
42-331-33027	Milam	LEONARD, J. A.	2600	191
42-331-33041	Milam	LEONARD, J. A.	2700	191
42-331-33065	Milam	HEARTLAND RES INC	3073	317
42-331-33069	Milam	EXPL TECHNIQUES INC	6118	317
42-331-33102	Milam	MCCRARY OIL CO	2145	58
42-331-33198	Milam	MCCRARY OIL CO	2324	58
42-331-33280	Milam	HOUSTON PETRO CO	6100	328
42-331-33283	Milam	W M MCADAMS LTD	1900	288
42-331-33291	Milam	WILLIAM MCADAMS LTD	1905	288
42-331-33297	Milam	NAVARRO PRODUCTS CO INC	1750	29
42-331-33302	Milam	NAVARRO PROD CO	1630	29
42-331-33304	Milam	VOSKAMP EXPL	1850	189
42-331-33404	Milam	FERGUSON BURNS LEASING	1973	288
42-331-33453	Milam	TARGET DRLG INC	1256	7
42-331-33490	Milam	WADI PETRO INC	3700	146
42-331-33508	Milam	UNION PACIFIC RESOURCES	9700	53
42-331-33517	Milam	LASER EXPLORATION, INC.	5133	1
42-331-33560	Milam	CARR RESOURCES, INC.	6000	21
42-331-33635	Milam	M A MUELLER CONST CO INC	2944	286
42-331-33638	Milam	ENTEGER USA LLC	5000	304
42-331-33664	Milam	EXPLORATION TECHNIQUES	2802	130
42-331-33805	Milam	WM C RAYMOND OIL AND GAS	1406	7
42-395-30354	Robertson	OERTLI OPRG CO INC	2288	48
42-395-30747	Robertson	ARBOL RESOURCES	4600	22
42-395-30960	Robertson	ARBOL RESOURCES, INC.	5000	51
42-395-31071	Robertson	HOUSTON PETROLEUM CO.	2750	51
42-491-30426	Williamson	PANAMERICAN OPERATING	1532	59
42-491-30434	Williamson	M. A. MUELLER CONST. CO.	2177	286
42-491-30436	Williamson	PATTON EXPLORATION INC	3006	479

APPENDIX C.


Pecan Gap Isopach
290
280
270
260
250
240
230
220
210
200
190
180
170
160
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
190
170
150
130
90
70
30
50
15 miles
N

Sprinkle (Lower Taylor) Isopach



APPENDIX D.

Relative sea level for the Upper Cretaceous (modified from Lowell Waite, Pioneer Natural Resources, Dallas, Texas, 2002 version, complied from Sloss, 1963).