THE BRAZOS BASIN:
DEEP BASEMENT STRUCTURE AND SEDIMENTARY FILL, CENTRAL EAST TEXAS

A Dissertation

by

ANDREW JOSEPH DAVIDOFF

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

May 1993

Major Subject: Geology

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Approved as to style and content by:

Robert R. Berg
(Chair of Committee)

John H Spang
John H. Spang
(Member)

Joel S Watkins
Joel S. Watkins
(Member)

Steven L Dorobek
Steven L. Dorobek
(Member)

Steven W Poston
Steven W. Poston
(Member)

John H Spang
John H. Spang
(Head of Department)

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ABSTRACT

The Brazos Basin: Deep Basement Structure and Sedimentary Fill, Central East Texas.
(May 1993)
Andrew Joseph Davidoff
B.S., Western Washington University;
M.S., University of Houston
Chair of Advisory Committee: Dr. Robert R. Berg

Detailed mapping of central eastern Texas using deep well log and seismic data indicate that the region is underlain by a thickened sedimentary section, referred to here as the Brazos basin. Recognition of this basin indicates that the East Texas region, which has traditionally been divided into two geologic provinces, is best described using a three basin model. The basins include, from north to south, the East Texas basin, Brazos basin, and Houston embayment. Basement structures which separate the basins include the Houston arch and the Angelina-Grimes terrace. The Houston arch is a present day structural feature which separates the East Texas and Brazos basin. Salt is absent, and Late Jurassic and Lower Cretaceous strata thin across the arch. The Angelina-Grimes terrace separates the Brazos basin and Houston embayment. The terrace is expressed as a flattening of regional dip in Lower Cretaceous and Upper Jurassic strata. However, prior to the Tertiary it was a northward-dipping paleo-monocline. Salt is interpreted to be absent, and Jurassic and Cretaceous strata thin across the terrace.

The Brazos basin appears to have formed as a large, complex half-graben between two transfer faults in association with Late Triassic through Middle Jurassic rifting that opened the Gulf of Mexico. The basin trends northeast-southwest, and is approximately 120 miles long and 50 miles wide. It existed as a unique structural unit from its inception until the end of the Early Cretaceous, accumulating 3,000 to 4,000 feet of Louann Salt, and

over 20,000 feet of post-rift sediments. Initial subsidence within the basin was rapid, and gradually diminished with time. By the end of the Early Cretaceous, differential subsidence within the basin had diminished to the point that it ceased to exist as a unique structural unit. During the Tertiary, the Angelina-Grimes terrace subsided and reversed the former northwest dip along the southeast flank of the Brazos basin. Present day structure across the Brazos basin is characterized by monoclinal southeast dip, the existence the Brazos basin indicated only by the stratigraphic thickening of Jurassic and Lower Cretaceous strata.

ACKNOWLEDGEMENTS

The successful completion of this dissertation has been possible due to the help of numerous people, organization, and companies. Among the organizations and companies that provided assistance, the American Association of Petroleum Geologists, Amoco Production Company, ARCO Oil & Gas Company, the Geological Society of America, the Gulf Coast Association of Geologic Societies, Mobil Exploration. & Producing. U.S. Inc., Shell Oil Company, the Society of Independent Professional Earth Scientists (SIPES), and Union Pacific Resource Company are all gratefully acknowledged for providing financial support. Amoco Production Company, Conoco Inc., Exxon U.S.A. Inc., Lometa Petroleum Company, Mobil Exploration. & Producing. U.S. Inc., Union Pacific Resource Company, and Westland Oil Company are all gratefully acknowledged for releasing and providing well logs, maps, and related data used in this study. Appreciation is expressed for Teledyne Exploration Company, which release over 1,100 miles of seismic data. Sierra Geophysical and GeoGraphix Inc. are gratefully acknowledged for providing access to software used in the analysis of seismic and well log data.

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The efforts and patience of the members of my advisory committee, Dr. Robert R Berg, Dr. John H. Spang, Dr. Joel S. Watkins, Dr. Steven L. Dorobek, and Dr. Steven W. Poston, all of whom spent may hours reviewing and discussing my research is gratefully acknowledged. The efforts of Dr. Dorobek to carefully review my dissertation manuscript are especially appreciated. Finally, Dr. Robert R. Berg, chairman of the advisory committee, is gratefully acknowledged for the hundreds of hours he spent instructing, advising, and encouraging, and for his continuous efforts to provide financial support.

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INTRODUCTION

The northern Gulf of Mexico province is composed of numerous basins, embayments, and uplifts (Figure 1). The east Texas region, which is part of the northern Gulf, has traditionally been divided into two major geologic provinces or basins, the East Texas or Tyler basin to the north and the Houston embayment or Houston Salt Diapir region to the south. Recent work by Davidoff (1989, 1990a, 1991 and 1992) has suggested that a three basin model may more accurately describe the structural and stratigraphic relationships of the the East Texas region. Identification of major basement structures which formed these basins, and the effect of these structures on the overlying sediments, has significant implications for both hydrocarbon exploration and the tectonic development of the east Texas region.

The three basin model for the East Texas region, as first proposed by Davidoff (1989), includes the East Texas basin and the Houston embayment. The third basin is located between these two traditional provinces and is referred to as the Brazos basin (Figure 2). Division of the region into three basins is based upon the distribution of Louann Salt, location of major basement structures, and the timing of initial sedimentation within each basin. Research upon which this dissertation is based has concentrated on the study of the structure and stratigraphy of the Brazos basin. The objective has been to delineate the boundaries of the Brazos basin, clarify the relationship of the Brazos basin to the East Texas basin and Houston embayment, study the implications of the Brazos basin for the tectonic development of the East Texas region, and define the potential of the Brazos basin for undiscovered hydrocarbons.

The Brazos basin formed in association with rifting that led to the opening of the Gulf of Mexico. The general morphology of the basin indicates that it originated as a large

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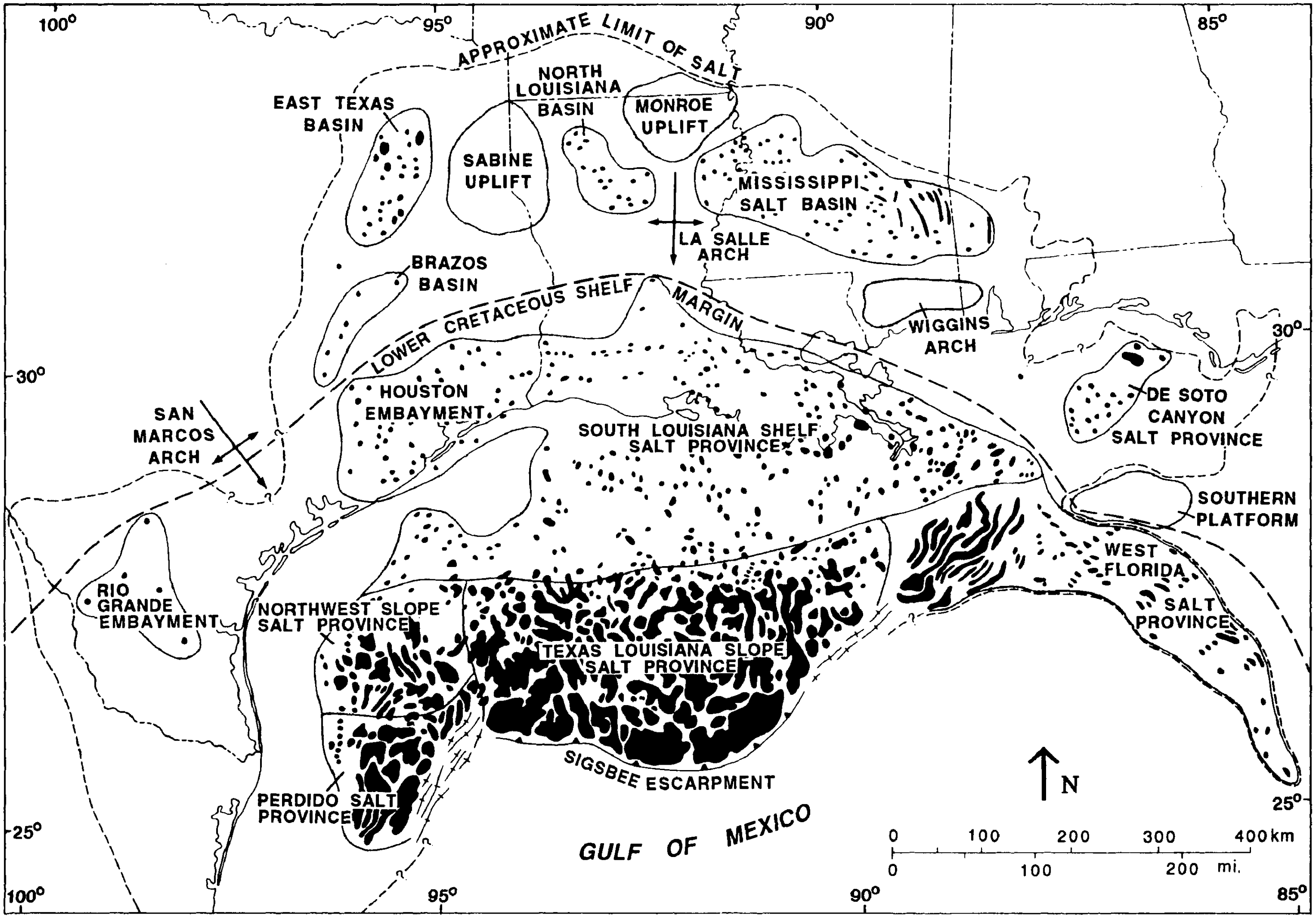

Figure 1 - Major basins, embayments and salt provinces of the northern Gulf of Mexico (modified from Ewing, 1991b). Also show are major uplifts, arches, platforms and other significant structural features. Salt diapirs, massifs and allochthonous sheets are shown in black.

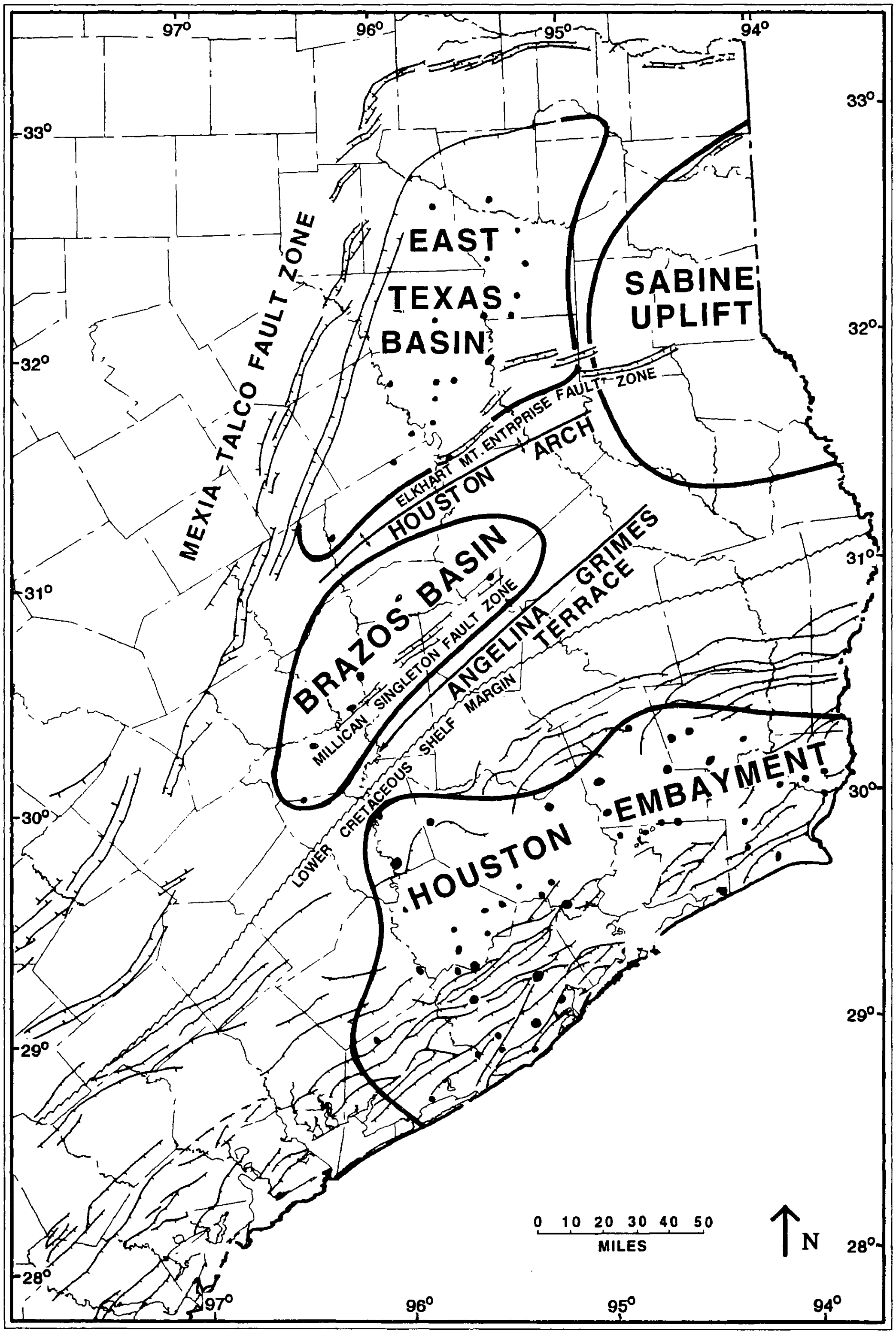

Figure 2 - Map of the east Texas region showing the general outline of the East Texas basin, Brazos basin and Houston Embayment. Also shown are major uplifts, arches and other structural features that bound the basins. The location of significant fault zones, salt diapirs (shown in black), and the position of the Lower Cretaceous shelf margin are modified from Hickey (1972).

complex half graben. The basin trends northeast-southwest, and is approximately 120 miles long and 50 miles wide. It extends from Houston and Trinity counties in the northeast to western Washington County in the southwest (Figure 3). It is bound by basement highs to the northwest and southeast. The basement high to the northeast is referred to as the Houston arch, and separates the Brazos basin from the East Texas basin. The structure to the southwest is referred to as the Angelina-Grimes terrace, and separates the Brazos basin from the Houston embayment. The axis of the basin is marked by an elongate grouping of six salt diapirs, and a relative thickening of the overlying Jurassic and Lower Cretaceous strata.

While the work by Davidoff (1989) was the first to study the Brazos basin as a unique structural unit, earlier studies have noted a thickening of the strata in the region occupied by the Brazos basin. The earliest such study was by Renick (1936) who identified a thickening of the Jackson Group (Late Eocene) and the Catahoula Formation (Early Oligocene) based on outcrop studies. He attributed the thickening to the development of a feature he referred to as the Brazos Valley syncline, the boundaries of which approximately correspond to the Brazos basin. It is from Renick's use of the name Brazos Valley syncline that the name Brazos basin was derived. Other studies that have shown a thickening of the strata within the region of the Brazos basin include those by Martin (1978) who showed a thickened interval of Louann Salt (Callovian), Bushaw (1968), who showed a thickening of the Travis Peak (Late Neocomian) through Pettet (Aptian) formations, Mosteller (1970), who showed a thickening of the Glen Rose (Early Albian) and Fredericksburg (Middle Albian) groups, and Stehli et al. (1972) and Porter (1987), who showed a thickening of the Woodbine (Middle Cenomanian) and Eagle Ford (Late Cenomanian through Turonian) groups. Later studies (those published after Davidoff, 1989) that have independently published maps showing a three basin model for the east Texas region included Ewing (1991a, 1991b), and Simmons (1992). Ewing

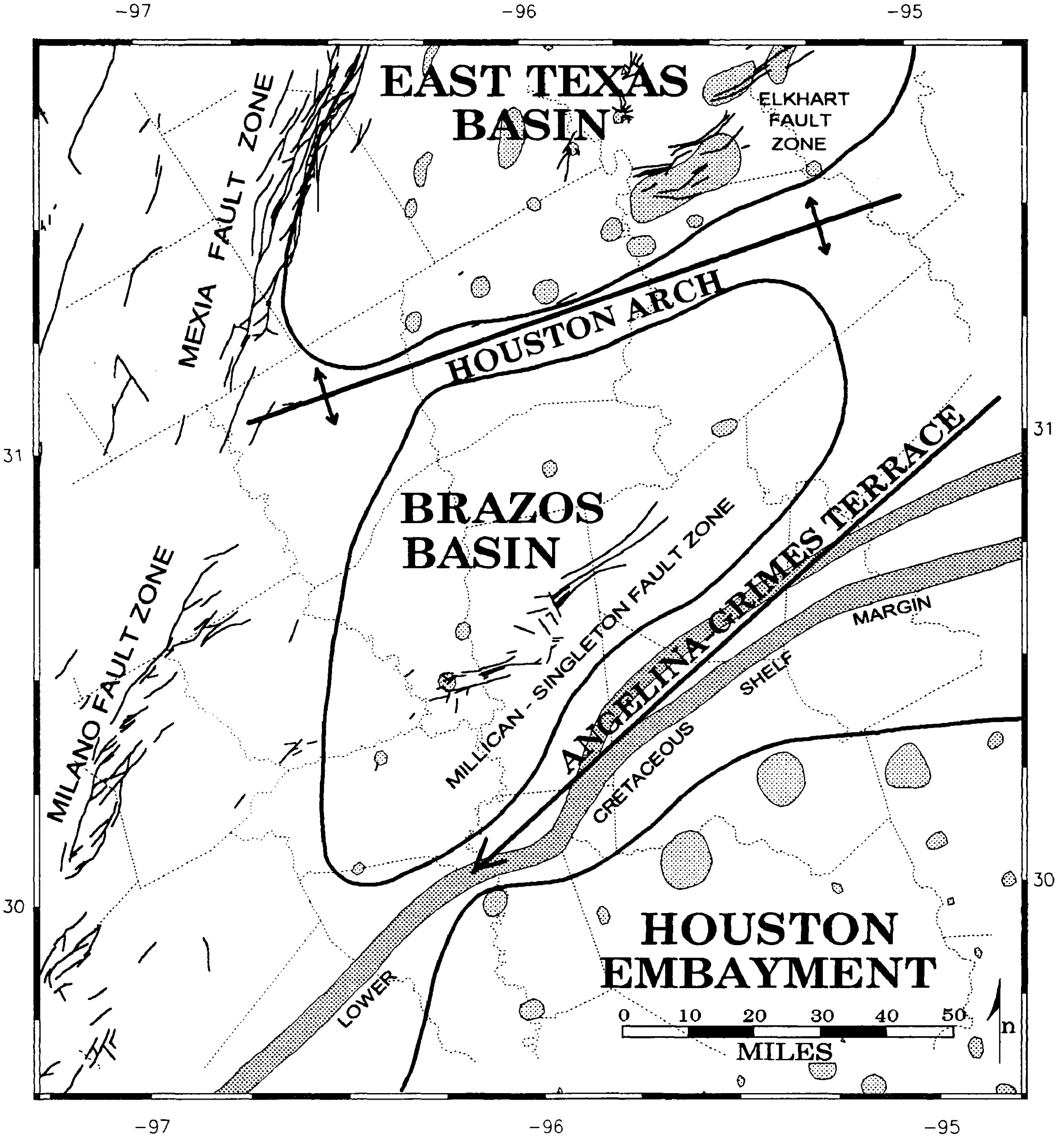

Figure 3 - Map of central East Texas showing the outline of the Brazos basin, and the relationship of the Brazos basin the East Texas basin and Houston embayment. Also shown are major structural features which separate the basins (the Houston arch and the Angelina-Grimes terrace), the distribution of salt diapirs (modified from Ewing (1991a), the location of significant surface faults (adapted from Barnes 1968a,b, 1970, 1974a,b; Pedrotti, 1958; Renick, 1936; Rolf 1958; Russell, 1957; Walton, 1959; and others), and the position of the Lower Cretaceous shelf edge.

(1991b) has suggested that the region referred to in this report as the Brazos basin may have formed as a graben between the East Texas basin and the Houston Embayment.

BACKGROUND

The East Texas region is part of the northern Gulf of Mexico (Figure 1). As such, it is part of, one of the world's largest and most intensely drilled petroleum provinces. Numerous studies have been published dealing with the geology of the Gulf of Mexico. The most recent compilation of the structure and stratigraphy of the region is by Salvador (1991a). Other recent summaries of significance for the Gulf of Mexico include those by Salvador (1987) for the Triassic and Jurassic, and Winker and Buffler (1988) for the Jurassic and Early Cretaceous. For the Tertiary, Galloway (1989) presented an excellent summary for the Texas portion of the Gulf coast. The most recent stratigraphic summary specific to the East Texas region is by Wood and Guevara (1981). Other significant studies of the eastern Texas include those by Kreitler at al. (1980, 1981), Nichols et al. (1968), Nichols (1964), and Eaton (1956). The following is a brief overview of the stratigraphy, structure and tectonics relevant to this study.

Regional stratigraphy

Over the years, the Gulf Coast region has developed a complex stratigraphic nomenclature. Most stratigraphic intervals have several different names, and in some cases the same name is used for different stratigraphic intervals. This report will follow as closely as is practical the nomenclature of Wood and Guevara (1981) for the Mesozoic section and that of Galloway (1989) for the Tertiary section. Correlation of groups and formations with European series and stages is based on Salvador (1991a), while age dates (Figure 4) are based on Palmer (1983).

The strata in and around the Gulf of Mexico may be divided into three broad categories; pre-rift, syn-rift and post-rift deposits. Little is known about the geology of the pre-rift and early syn-rift rocks. In the northern Gulf of Mexico pre-rift rocks are exposed

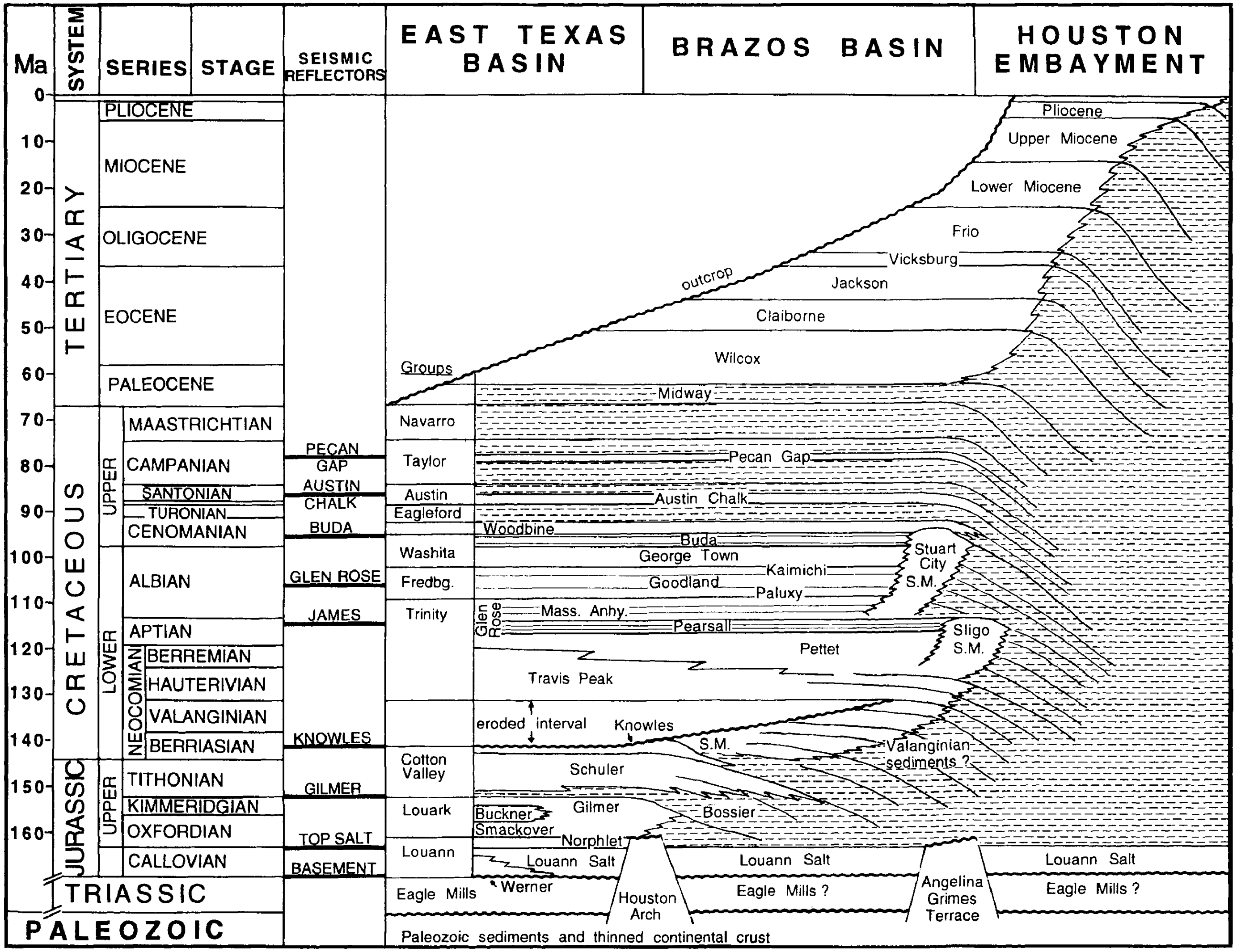

Figure 4 - Stratigraphic correlation charts for the East Texas basin, Houston embayment, and Brazos basin compiled from various sources (see text). Carbonate and siliciclastic units are unshaded, shale dominated units and deep basin shales are shaded, S.M. is used to denote carbonate shelf margins. Correlation of groups and formations with time scale are shown to the left. To the right correlation lines illustrate depositional topography and relationship to deep basement structure.

in only a few widely scattered outcrops, while the early syn-rift rocks are known only from subsurface data. Both rock groups have been penetrated by a limited number of boreholes.

The geology of the pre-rift rocks has been summarized by Woods and Addington (1973) and Woods et al. (1991). They indicated that pre-rift rocks across the northern Gulf of Mexico are primarily Paleozoic in age, although some Precambrian rocks are exposed around the margins of the basin. Based on limited bore hole penetrations, they have suggested that the East Texas region is underlain primarily by Pennsylvanian and Permian age sedimentary rocks. They also noted that some Devonian age rocks have been encountered along the western margin of the East Texas basin. Woods and Addington (1973) and Woods et al. (1991) have interpreted Pre-Pennsylvanian rocks to have been deposited on a Paleozoic passive margin. They further suggested that Pennsylvanian and Early Permian rocks were deposited in foredeep basin which developed in association with the impending Late Permian Ouachita orogeny. Late Permian through Middle Triassic rocks are notably absent from the northern Gulf of Mexico. During this time the region was part of the Pangean super-continent.

Early syn-rift rocks are represented by the Eagle Mills Formation. Their distribution and tectonic significance has been reviewed by Scott et al. (1961) and Salvador (1987, 1991b). Rocks of the Eagle Mills Formation are entirely non-marine, consisting of red sandstones, siltstones and conglomerates deposited by alluvial fans and braided streams in an arid environment. Distribution indicates that the Eagle Mills Formation was deposited in linear grabens and half grabens around the northern margins of the Gulf of Mexico. These grabens and half grabens developed in association with rifting that led to the opening of the Gulf of Mexico. Palynoflora indicate a Late Triassic (Carnian) age for the Eagle Mills Formation (Beju et al., 1986; Moy and Traverse, 1986).

The geology of the late syn-rift and post-rift rocks of the Gulf of Mexico is far better known than that of the pre-rift and early syn-rift rocks. They range in age from late Middle - Jurassic (Callovian) to Recent. The majority of these sediments were deposited in marine environments. Nearly continuous sedimentation over the last 160 million years has prograded the shelf edge hundreds of miles, and in the deeper parts of the Gulf of Mexico produced a sedimentary wedge 30,000 to 50,000 feet thick (Ewing, 1991b). Most stratigraphic intervals within the sequence produce hydrocarbons and have been the target of extensive exploration. One consequence of this exploration activity is that the stratigraphy and sediment distribution of the late syn-rift and post-rift rocks is reasonably well known.

Late syn-rift sediments consist of Late Jurassic (Callovian) evaporites, primarily halite, deposited unconformably on older Paleozoic and Triassic rocks (Salvador, 1987). They record the first incursion of the Jurassic seas into the developing Gulf of Mexico basin. These evaporites and associated deposits comprise the Louann Group. The group is composed of three formations; a basal unit known as the Werner Anhydrite which is conformably overlain by the Louann Salt, and an upper clastic unit known as the Norphlet Formation. The Louann Salt is the thickest of the three formations. Deposition appears to have been controlled by pre-existing topography, with thick salt accumulating in basins and embayments, while salt is thin or absent along arches and uplifts. In the deep Gulf of Mexico basin, original thickness for the Louann Salt has been estimated at 13,000 feet (Salvador, 1987). Farther to the north in the East Texas basin, the original thickness is estimated at 5,000 feet (Jackson and Seni, 1983). This thick salt, along with the overlying strata has been deformed into a large variety of structures, many of which have formed hydrocarbon traps.

The Norphlet Formation, which overlies the Louann Salt, is composed of conglomerates, sandstones, and shales deposited in an arid environment by fluvial and eolian processes (Hazzard et al, 1947; Bandon, 1975; Budd and Loucks, 1982). It is thickest in Mississippi, Alabama, and Florida where it may be over 700 feet (Marzano et al., 1988). In Texas and Louisiana maximum thickness is approximately 150 feet, and generally less than 100 feet (Jaffe, 1985). It appears to be absent in the Brazos basin (Davidoff, 1989).

The Late Jurassic (Oxfordian to Kimmeridgian) carbonates of the Louark Group were the first post-rift sediments deposited. They conformably overlie the Norphlet Formation, sandstone of the underlying Norphlet Formation shows evidence of marine reworking (Dixon et al, 1989). In eastern Texas the Louark Group is composed of the Smackover, Buckner, and Gilmer formations. The Smackover Formation was deposited as a carbonate ramp (Ahr, 1973), while the Gilmer Formation formed a carbonate platform (Moore, 1984). The Buckner Formation is an anhydrite unit that separates the Smackover and Gilmer formations. It is absent down dip where the section is simply referred to as the Louark Group (Forgotson and Forgotson, 1976). Still farther down dip in the Brazos basin, these shallow water carbonates are absent, and equivalent rocks appear to have been deposited in deep water environments (Davidoff, 1989).

The first incursion of clastic sediments into the northern Gulf of Mexico is represented by the Cotton Valley Group (Kreitler et al., 1980, 1981; McGowen and Harris, 1984). In Eastern Texas three formations are recognized, the Bossier Shale, Schuler Sandstone, and Knowles Limestone. The Bossier Shale is the lowest formation, composed primarily of prodelta sediments. It is overlain by, and time transgressive with, the Schuler Sandstone. Depositional environments for the Schuler Sandstone range from open marine to fluvial (McGowen and Harris, 1984). This regressive sequence is capped by the Knowles Limestone, a carbonate ramp deposit (Finneran et al., 1982) with localized patch reef development (Cregg and Ahr, 1983). Todd and Mitchum (1977), and Scott (1984) have shown that the Cotton Valley Group was deposited between the Late Jurassic (Tithonian) and Early Cretaceous (Berriasian). In the east Texas basin, the top of the Cotton Valley Group is marked by a major unconformity, with Valanginian age rocks missing (Todd and Mitchum, 1977). Down dip in the Brazos basin there is a wedge of sediments above the Knowles Limestone not present in the East Texas basin, and these may represent the missing Valanginian rocks of the East Texas basin (Davidoff, 1989).

The end of the Early Cretaceous (Valanginian), to the beginning of the Late Cretaceous (Cenomanian) was dominated by carbonate deposition. Siliciclastic sedimentation was gradually replaced by carbonate deposition between the Valanginian and the Barremian (McFarlan and Menes, 1991). The transition from clastic to carbonate deposition was associated with a gradual rise in sea-level (Scott et al., 1988). Carbonate deposition continued from the Barremian until the beginning of the Cenomanian, developing a carbonate platform that extended from Florida to the Yucatan and beyond (Winker and Buffler, 1988). In the northern Gulf these rocks form the Trinity, Fredericksburg, and Washita groups (Wood and Guevara, 1981; Winker and Buffler, 1988). Back-reef sediments are subdivided into numerous formations and members on the basis of shale and/or anhydrite units, while platform margin reefs are known as the Sligo and Stuart City. Topographic relief between the platform margin and the deep basin has been estimated at 5,000 feet (Winker and Buffler, 1988). Deep basin equivalents are unnamed.

Upper Cretaceous rocks deposited between the Late Cenomanian and Maastrichtian are composed primarily of shales and marls, with a few minor sandstone and chalks units. These rocks are separated from the underlying limestones deposited earlier in the Cretaceous by a regional unconformity (the Mid-Cretaceous unconformity of Winker and Buffler, 1988). In eastern Texas, Late Cenomanian through Turonian rocks are known as the Woodbine and Eagle Ford groups (Sohl et al., 1991). These are siliciclastic rocks, with depositional environments ranging from fluvial-deltaic (Oliver, 1971) to shallow shelf (Turner and Conger, 1981; and Berg and Leethem, 1985). These are overlain by Santonian through Maastrichtian marls, shales, and chalks of the of the Austin, Taylor and Navarro groups.

Tertiary rocks in the northern Gulf of Mexico are composed of siliciclastic sediments. Division of these strata into sand-dominated verses shale-dominated units form the basis for the placement of formation and group boundaries. Introduction of these clastic sediments into the northern Gulf is associated with tectonic developments to the west. Late Paleocene through Early Eocene sediments were sourced by Laramide uplifts. Middle Eocene through Oligocene sediments are associated with volcanism in West Texas and adjoining areas of Mexico and New Mexico, and formation of the Rio Grande rift. Miocene through Pliocene sediments are associated with Basin and Range uplift and extension (Galloway, 1989; and Galloway et al. 1991). Since the beginning of the Tertiary, these clastic sediments have caused the shelf edge to prograde approximately 200 miles (Winker, 1982). Erosion has removed post - Middle Eocene strata from the East Texas basin, and post - Early Miocene strata from the Brazos basin (Barnes, 1968a,b, 1970, 1974a,b).

Division of the East Texas region into three basins is based, in part, on the distribution of the Callovian Louann Salt, and on the timing of initial post - Callovian sedimentation within each basin. The Callovian age was a time of wide spread evaporite deposition. Distribution of these evaporites was controlled by the pre-existing topography, with thick salt accumulating in the basins, while thin or absent along uplifts and arches (Salvador, 1987). This pre-existing topography also appeared to have had a significant influence on subsequent sedimentary deposits. Within the East Texas region, the carbonates of the Louark Group were restricted to the East Texas basin and surrounding uplifts. Equivalent rocks deposited down dip in the Brazos basin and farther south are deep basin shales (Davidoff, 1989). The first significant volumes of sediment to reach the Brazos basin were the Late Jurassic through Early Cretaceous clastics of the Cotton Valley Group (Figure 4). While sedimentation within the East Texas and Brazos basins continued throughout the Cretaceous, the Houston embayment to the south was starved. The first significant volume of sediments to reach the Houston embayment occurred with the influx of Tertiary clastics.

Regional structure

The Gulf of Mexico basin is composed of numerous regions of enhanced and reduced subsidence. Regions of enhanced subsidence received a greater - than - average thickness of sediments and are referred to as basins or embayments. Regions of reduced subsidence received a thinner - than - average thickness of sediments, commonly contain numerous unconformities or surfaces of non-deposition, and are referred to as arches or uplifts (Ewing, 1991b). These basins or embayments may be classified as interior fracture to marginal sag basins using the classification of Kingston et al. (1983), or rift to passive margin basins using the classification of Bally (1980). Figure 1 shows some of the major uplifts and basins around the northern Gulf of Mexico. Basins of significance within the East Texas region include the East Texas basin, Brazos basin, and Houston embayment. Uplifts of regional significance within eastern Texas include the Sabine uplift, San Marcos arch, Houston arch, and Angelina-Grimes terrace (Figures 2 and 3).

Historical basin boundaries

Eastern Texas has traditionally been divided into two major geologic provinces or basins, the East Texas or Tyler basin, and the Houston embayment or Houston Salt Diapir province. Despite an extended history of research and publication, the boundaries of these two basins, and the relationship between them is still controversial. The simplest interpretations show the East Texas basin as an embayment-like extension of the deep Gulf of Mexico (Figure 5A). Where the two regions are separated, a variety of different criteria have been used to define their boundaries.

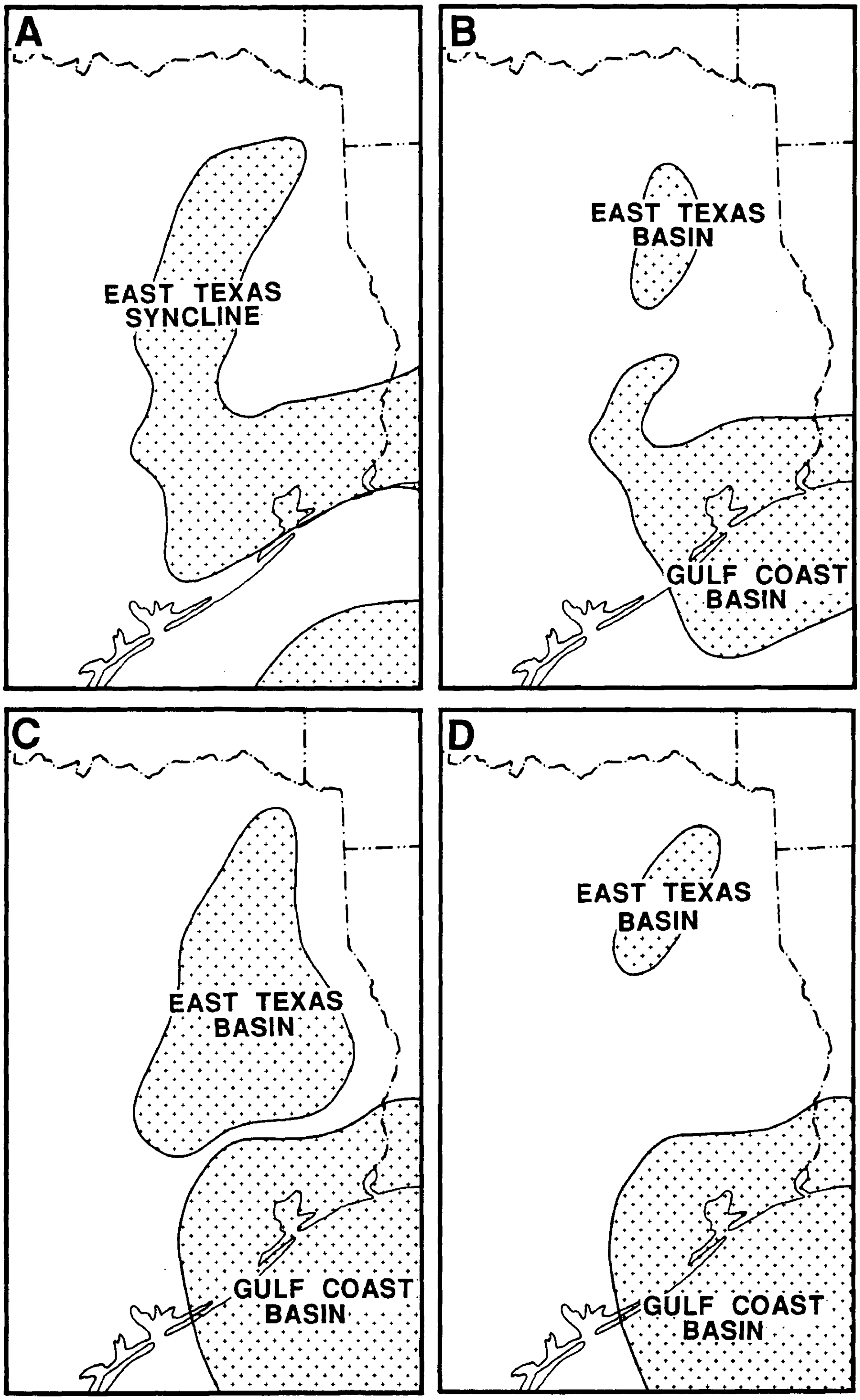

Figure 5 - Different interpretations for the boundaries of the East Texas basin and Houston embayment. A) Relationship of the East Texas basin and Houston embayment based on the distribution of thick salt after McGookey (1975). B) Boundaries of the East Texas basin and Houston Embayment based on the distribution of thick salt after Beall (1973). C) Boundaries of the East Texas basin and Houston Embayment as depicted by Petroleum Information (1983), and Geomap (1983). D) Boundaries of the East Texas basin and Houston embayment as shown by Petroleum information (1980).

The East Texas basin is the northern-most of the two structural provinces. Earlier studies delineated the boundaries of the basin by either outcrop patterns (Coon, 1956) or by county and state boundaries (Nichols, 1964). Recent studies have used geologic structures, and inferred distribution of salt to define the boundaries of the East Texas basin (Kreitler et at., 1980; Wood and Guevara, 1981; and Ewing, 1991a). The western and northern boundaries of the East Texas basin are placed along the Mexia - Talco fault zone. This fault system is associated with the updip pinch out of the Louann Salt (Jackson and Seni, 1983). The eastern boundary of the basin is placed along the western flank of the Sabine uplift, with salt thin to absent along the crest of the uplift (Ewing, 1991a). The southern boundary of the East Texas basin is most commonly placed along a feature known as the Angelina-Caldwell flexure. However, the nature and location of this feature is poorly defined in the literature, and varies between authors. As a result, several different geographic positions for the southern boundary may be found in the literature. The two most common are, either just updip from the lower Cretaceous shelf edge (Figure 5B), or approximately coincident with the Elkhart - Mt. Enterprise fault zone (Figure 5C and 5D).

The Houston embayment is located to the south of the East Texas basin. The province is continuous with the South Louisiana salt basin to the east. The western and southern boundaries of the embayment are defined by the limit of known diapiric salt structures (Ewing, 1983; Ewing, 1991a). The northern boundary of the Houston embayment is defined by either the Wilcox fault zone, or by the northern limit of diapiric salt structures south of the East Texas basin. Use of the Wilcox fault zone to define the northern boundary of the Houston embayment places that boundary just south of the Lower Cretaceous shelf edge (Figure 5C and 5D). Defining the boundary of the Houston embayment to include all diapiric salt structures south of the East Texas basin may extend the boundary of the embayment north of the Lower Cretaceous reef trend (Figure 5B).

The Angelina-Caldwell flexure and related structures.

The Angelina-Caldwell flexure has been noted in numerous publications as a significant structural feature of eastern Texas. It is often cited as defining the southern boundary of the East Texas basin (Kreitler et al., 1980; Wood and Guevera, 1981; and Ewing, 1991b). Despite the importance of this feature, there is considerable disagreement concerning the nature and location of the flexure. Critical review of the literature indicates that a minimum of four different features have been referred to as the Angelina-Caldwell flexure (Figure 6).

The earliest reference on the Angelina-Caldwell flexure known to the author occurs in a report by Veatch (1905) on ground water resources done for the Geological Survey of Louisiana. Based on surface outcrop data and shallow water wells he described the Angelina-Caldwell flexure as a monoclinal flexure "known to extend from Angelina County, Texas, through Louisiana, north of Natchitoches, Winnfield, and Columbia to the Mississippi River north of Vicksburg" (Veatch, 1905, p.67). The flexure was interpreted to have developed in the Oligocene, with strata north of the flexure horizontal and those south of the flexure dipping between 35 and 150 feet per mile.

Subsequent studies have extended use of the name to the subsurface of eastern Texas. Nichols (1964) showed the Angelina-Caldwell flexure as extending from Angelina County, Texas, westward through Walker and Grimes counties, Texas. He considered the feature to be a conspicuous arch during the Cretaceous and possibly Jurassic time. Stehli et al. (1972) showed the Angelina-Caldwell flexure as a feature several tens of miles wide extending from Angelina County westward across Houston, Trinity and Madison counties and then turning southwestward. They considered the feature to be a monocline that marked the edge of the Late Cretaceous shelf. Baumgardner (1987) showed the Angelina-Caldwell flexure as extending from Angelina County across northern Houston and Leon counties into Robertson County. Kreitler et al. (1980) referred to the flexure as a buried

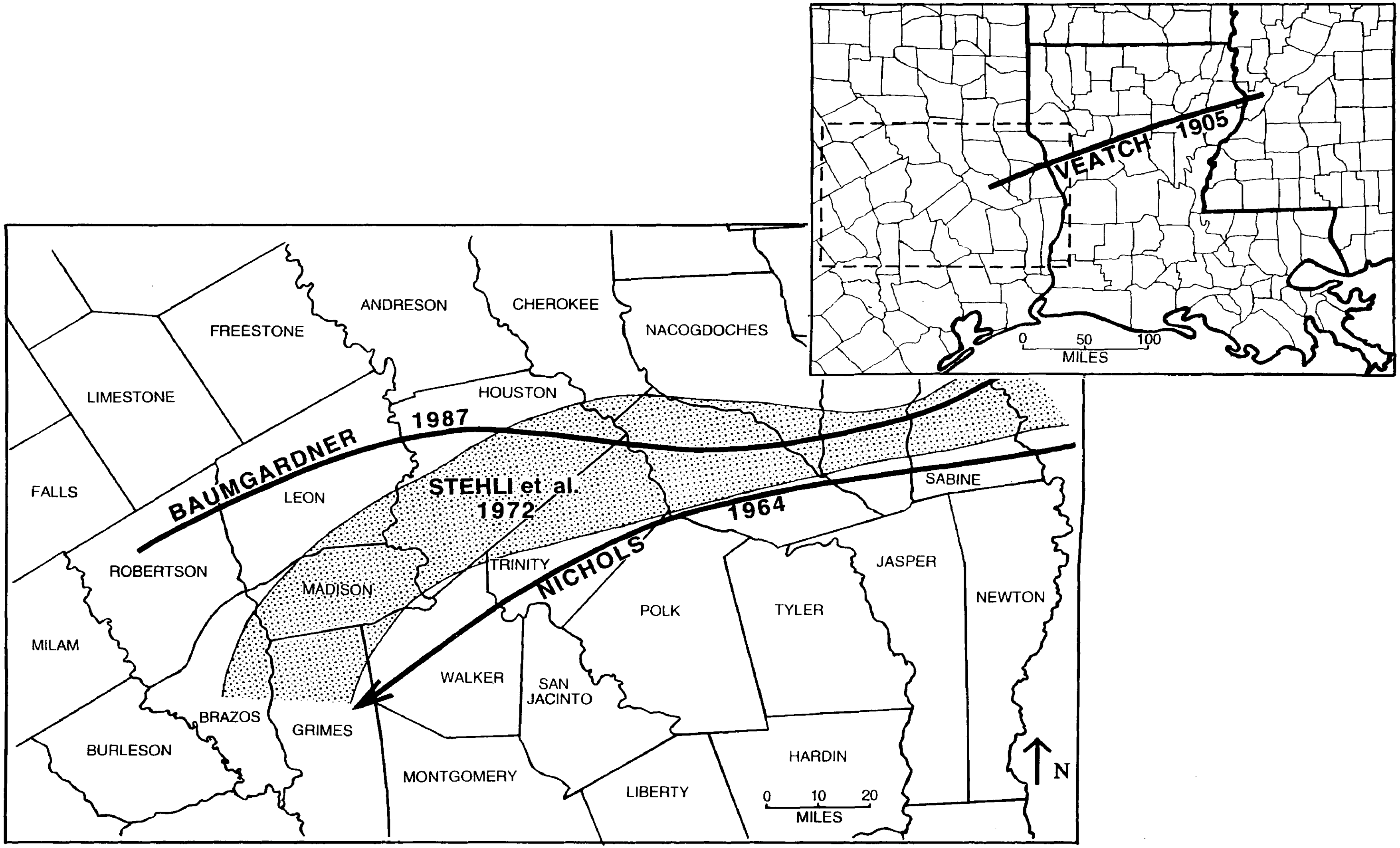

Figure 6 - Location of the Angelina-Caldwell flexure as described by different authors. Upper right shows the location of the Angelina-Caldwell flexure as described by Veatch (1905). Lower left shows extensions of the Angelina-Caldwell flexure into the subsurface of eastern Texas by Baumgardner, (1987), Nichols (1964), and Stehli et al. (1972, stippled pattern)

hinge line located a few miles south of the Elkhart - Mt. Enterprise fault zone. Jurassic and Cretaceous strata thicken north of this hinge line while Tertiary strata thicken southward. Numerous other reports have referred to the Angelina-Caldwell flexure without providing a detailed description of its location.

Differences in the geographic placement and structural interpretation of the Angelina-Caldwell flexure have significant implications for the size of the East Texas basin. Use of the Angelina-Caldwell flexure of Nichols (1964) to define the southern boundary of the East Texas basin will place that boundary just north of the Lower Cretaceous shelf margin reef trend, and result in a relatively large East Texas basin (Figure 5B). Acceptance of the flexure as described by Baumgardner (1987) and Kreitler et al. (1980) places the southern boundary approximately coincident with the Elkhart - Mt. Enterprise fault zone, and results in a relatively small East Texas basin (Figure 5C and 5D).

Davidoff (1990b) noted the definition problem described above and suggested that use of the name Angelina-Caldwell flexure be restricted to the surficial feature of northern Louisiana described by Veatch (1905). The feature shown by Baumgardner (1987) and described by Krietler et al. (1980) as the Angelina-Caldwell flexure should be referred to as the Houston Arch following the usage of Kieth and Pittman (1983). This arch is a present-day structure formed by an underlying basement high. It separates the Louann Salt of the East Texas basin from that of the Brazos basin to the south. Jurassic and Lower Cretaceous strata thin across the arch.

Davidoff (1990b) further recommended that the feature shown by Nicholes (1964) as the Angelina-Caldwell flexure be referred to as the Angelina-Grimes terrace. This feature is expressed as a present day reduction of regional dip in the Jurassic and Lower Cretaceous strata just north of the Lower Cretaceous shelf edge. Prior to the Tertiary, this feature was a northward dipping paleomonocline, formed by the rotation of a major basement fault block, and separated salt of the Brazos basin from that of the Houston Embayment to the south.

Tectonic origin

Development of the Gulf of Mexico was associated with Triassic to Jurassic rifting that lead to the breakup of the Pangean super-continent and opened the North Atlantic Ocean. Earlier plate reconstruction models closed the Gulf of Mexico with the northern edge of South America (Wood and Walper, 1974; Walper et al., 1979; Van Siclen, 1986), filled it with various Central American blocks (Dietz and Holden, 1970; White, 1980), or left it incompletely closed (Wilson, 1966; Cebull and Shurbet, 1980). Most researchers now agree that the Gulf opened by rifting of North America and the Yucatan (Moore and Castillo. 1974; Dunbar and Sawyer, 1987; Salvador, 1987), with later rifting separating the Yucatan and South America (Salvador and Green, 1980; Pindell, 1985; Ross and Scotese, 1988).

Rifting of the Gulf of Mexico began with the development of linear grabens and half grabens. These grabens were filled with continental red beds of the Eagle Mills Formation. A Triassic (Carnian) age for the formation constrains the onset of rifting (Beju et al., 1986; Moy and Traverse, 1986). Rifting and attenuation of continental crust continued until, at some point sea-floor spreading was initiated and a passive margin developed. Deposition of the Callovian Louann Salt marks the first significant incursion of marine waters into the Gulf of Mexico (Salvador, 1987). Restricted marine conditions associated with salt deposition was followed by the establishment of open marine conditions during the Oxfordian. The end of continental rifting and the onset of sea-floor spreading is therefore restricted to the Late Callovian (Salvador, 1987). Opening of the Gulf of Mexico is believed to have been rapid, achieving its present configuration by the end of the Jurassic, some time in the Tithonian (Pindell, 1985; Salvador, 1987; Ross and Scotese, 1988).

The rifting process which led to the opening of the Gulf of Mexico left a wide zone of extended and thinned continental crust. In the northern Gulf, this attenuated crust separates normal continental crust to the north from oceanic crust to the south. Along strike, there are significant variations in the amount of crustal extension, which have been attributed to variations in either original crustal composition, or to asymmetry of the rifting process itself (Buffler and Sawyer, 1985; Dunbar and Sawyer, 1987). Areas of relatively thick continental crust have become arches or uplifts, while areas of greater extension have subsided more than the surrounding region, and have became basins or embayments (Ewing 1991b). The Sabine uplift, San Marcos arch, Houston arch, and Angelina-Grimes terrace are all blocks of thicker continental material, while the East Texas basin and Brazos basin are underlain by relatively thin continental crust.

METHODS

Subsurface well log and multi-channel seismic data have been used to document the structure and stratigraphy of the Brazos basin. Distribution of well log data across the basin provides reasonable control to the top of the Lower Cretaceous, and good control through the Cretaceous across the northern flank and northeastern part of the basin. However, well log data alone does not provide adequate information on the Jurassic, with only a few bore holes penetrating the entire section. Industry seismic data across the Brazos basin is abundant, and provides good coverage. However, changes in rock velocities across the basin have a significant impact on structural and stratigraphic relationships when analyzed in time as opposed to depth. As a result, it has been necessary to integrate both seismic and well log data to develop a comprehensive picture of the Brazos basin.

Well log data

A total of 493 well logs were acquired across the Brazos basin (Figure 7, see Appendix I). Almost all of the wells penetrated the top of the Cretaceous, and a significant majority (339) penetrated the top of the Lower Cretaceous. A limited number of bore holes (29) penetrated the top of the Jurassic, and four wells penetrated the entire stratigraphic column reaching total depth in either salt or pre - Jurassic rock. Data acquired for most wells included a standard suite of resistivity, spontaneous potential, and gamma-ray logs. For deeper wells, or other wells of particular significance, additional logs such as formation density, neutron density, litho-density, sonic velocity, and well-cutting reports were acquired where possible.

Formation tops and marker beds were correlated across the basin. Criteria for identification of formation tops and other marker beds are based on regional studies of the East Texas basin by Kreitler et al. (1980, 1981). Well log data and other material used in

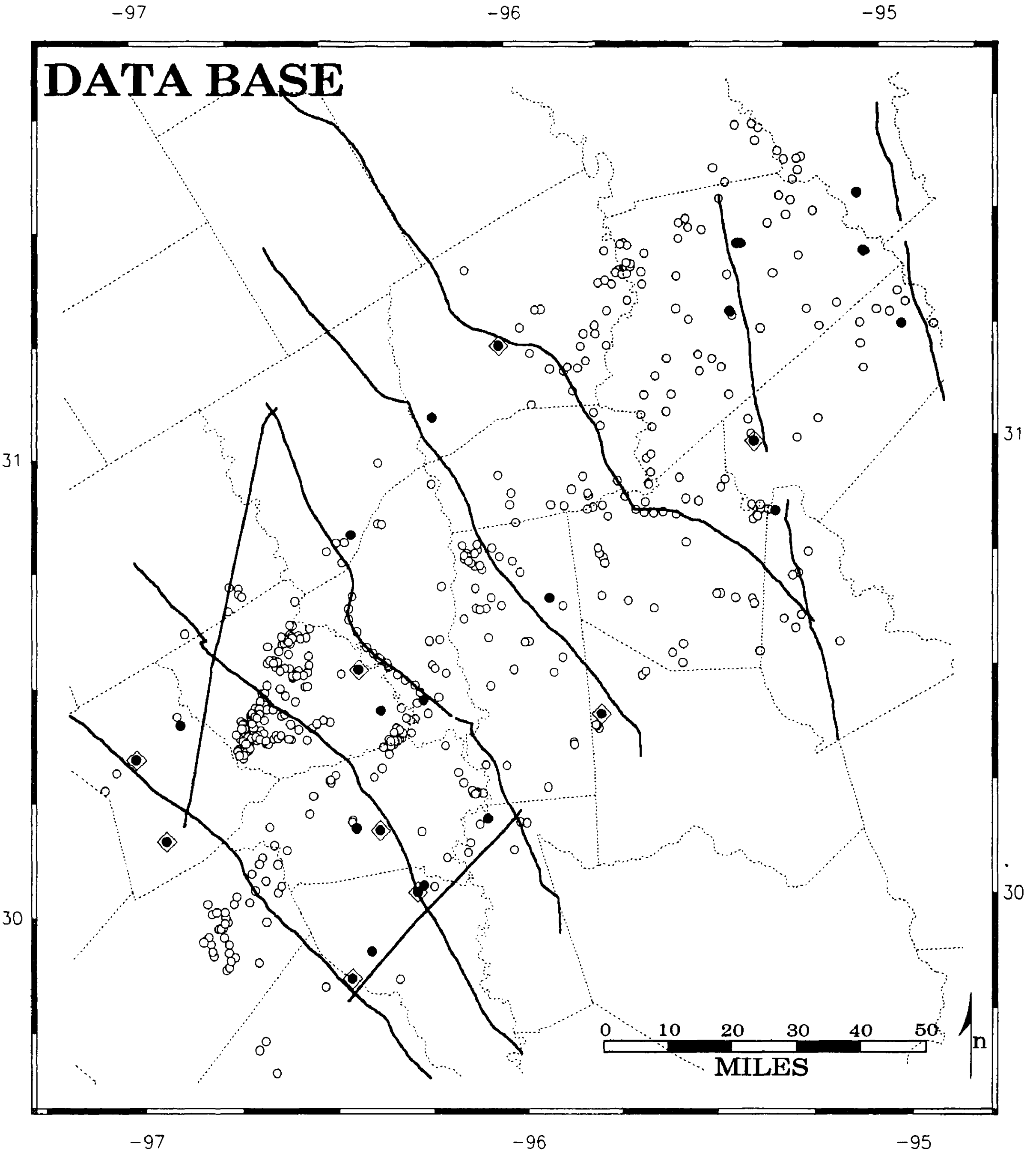

Figure 7 - Locations of well log and seismic data. Well log data is indicated by either open or solid circles. Solid circles indicate wells for which sonic logs were acquired and synthetics produced. Wells for which check shot data were also acquired are indicated by solid circles enclosed in diamonds. Solid lines indicate approximate location of seismic data provided by Teledyne Exploration. Some of the data released by Teledyne extended beyond the study area and are not shown.

these studies are on file and available for public inspection at the Bureau of Economic Geology in Austin, Texas. Over fifty horizons were correlated across the Brazos basin. The horizons were then evaluated for regional extent and correlation quality.

Seismic data

Over 1,000 line miles of six-fold migrated seismic data across the central East Texas region were provided by Teledyne Exploration Company Inc. (Figure 7, see Appendix II). The data were acquired between 1970 and 1978 and reprocessed between 1983 and 1984. The data set consists of seven regional dip lines and two strike lines. The strike lines connect only the southern part of the grid. Problems caused by a lack of strike lines to tie the grid together were over-come by the acquisition of a large number of synthetic seismograms (see below, Integration of well log and seismic data). Considering the fold and vintage of the data, quality is considered good to excellent. The data were analyzed for regional reflectors of chronostratigraphic significance using the methods and techniques described by Vail et al. (1977) and Vail (1987). A total of nine reflectors (see Figure 4) were identified and correlated across the region.

Integration of well log and seismic data

Integration of well log and seismic data involved the correlation of well log formation tops with regional seismic reflectors, and the conversion of seismic time to depth. Synthetic seismograms were used to correlate formation tops with seismic reflectors. Sonic logs from 25 wells, and check-shot surveys from nine wells were acquired (Figure 7, see Appendix III and IV). The well logs were digitized on an I.B.M.-compatible personal computer using Logdigi (software produced by The Logic Group, Austin, Texas). Synthetic seismograms were then produced from the digital data on a Sun, Sparc II work station using Quiklog (software produced by Sierra Geophysical Inc., Seattle, Washington). The resulting set of synthetics provided a good correlation between well log and seismic data, and insured a consistent interpretation between dip lines, where strike lines to tie the seismic grid were absent.

Conversion of seismic time to depth formed a crucial element in the structural and stratigraphic analysis of the region. Seismic velocities across the Brazos basin vary significantly. This variation is illustrated in Figure 8 using time-depth relationships derived from nine check-shot surveys across the basin. The general trend is for the average velocity to a given depth to decrease going from the northwest to the southeast flank of the basin. This decrease may be attributed to a southeast thickening of the Tertiary section, which is composed of relatively low velocity siliciclastic sediments. The result of this low velocity wedge is that time sections accentuate the apparent southeast dip of the strata, and obscure or even cause a reversal of low-angle northeast dip. It further complicates the time-depth conversion since simple velocity functions cannot be applied to the entire section.

Conversion of time to depth was accomplished by finding a time-depth function for each of the individual seismic horizons mapped across the region. The most updip and downdip wells for which check-shot data were available, were used to define a window of possible time-depth functions. A time-depth relationship to a given horizon, that fell within the window of possible time-depth functions, was then obtained using the available check-shot data. It was found that the for each seismic horizon, the time-depth data could be fitted to a third order polynomial with an R^2 coefficient of 0.997 or greater. Time-depth functions were then extrapolated to depth to account for areas where velocity control was lacking.

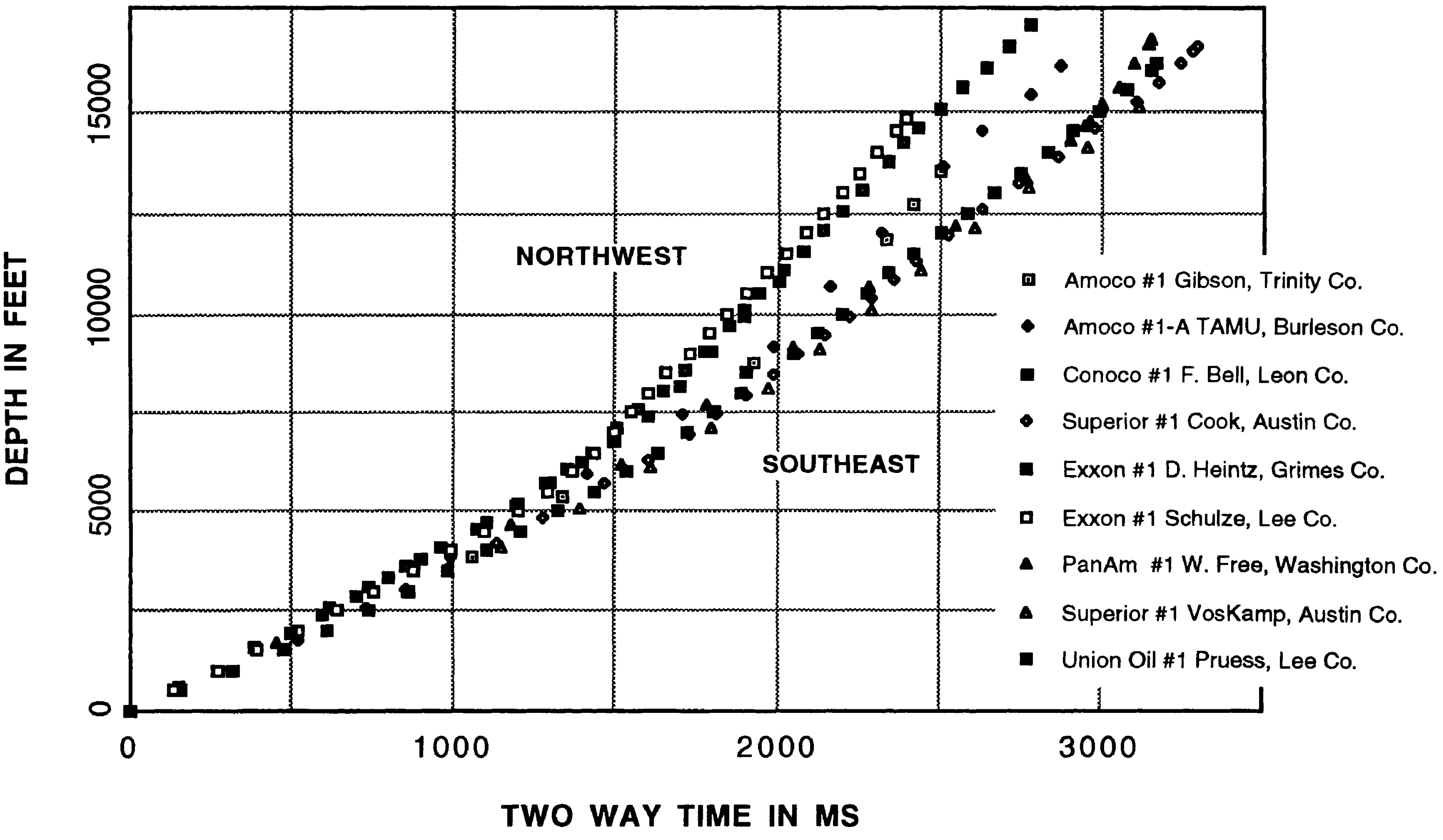

Figure 8 - Time-depth data obtained from nine wells across the study area. The data shows a well defined trend of decreasing average velocity for a given depth going from the northwest to southeast margin of the Brazos basin.

Map generation

The majority of structure and isopach maps presented have been contoured on an I.B.M.-compatible personal computer using the GeoGraphix Exploration System (GES, software produced by GeoGraphix Inc., Denver, Colorado). Well log formation tops and depths derived from seismic data were contoured using a coarse grid of approximately 11,200 feet squared, and an adaptive fitting algorithm. This algorithm, provided by GES, fits the data within a grid to a harmonic function, thus providing a smooth contour map. A relatively coarse grid was used to accentuated regional features, and minimize the effects of local anomalies associated with faults, salt structures, and errors in the time-depth conversion. Contours were further modified by hand to remove anomalies of a prospect specific nature and produce geologically reasonable maps.

BASIN STRUCTURE AND STRATIGRAPHY

Present day structure of the central east Texas region is characterized by monoclinal dip to the southeast. The structure is illustrated in Figure 9, a structure map contoured on the top of the Buda Formation (Lower Cenomanian). Deviations from regional dip are associated with salt structures and related faults. Present day structure of the region shows no evidence for differential subsidence associated with the development of the Brazos basin.

Evidence for the presence of the Brazos basin is provided primarily by stratigraphic thickening of the Late Jurassic and Early Cretaceous strata. This stratigraphic thickening is shown in Figure 10, an isopach map from the base of the Jurassic section (Callovian) to the top of the Buda Formation. Maximum basin subsidence occurred in Brazos, Grimes and Walker counties, with almost 25,000 feet of Late Jurassic and Lower Cretaceous sediments accumulating there.

General morphology suggests that the basin formed as a large half graben. Detailed sediment isopachs (discussed below) indicate that maximum basin subsidence occurred during the Late Jurassic and diminished throughout the Early Cretaceous. From the Oxfordian to the Kimmeridgian the basin was essentially starved of sediments. The first significant influx of sediments occurred in the Tithonian with the influx of the Cotton Valley clastics. By the end of the Early Cretaceous, differential subsidence within the Brazos basin had diminished to the point that it ceased to exist as a unique structural feature. The basin did, however, continue to have an influence on Late Cretaceous and Tertiary depositional patterns.

Major basement structures which bound the Brazos basin include the Angelina-Grimes terrace and the Houston Arch (Figures 2 and 3). The Angelina-Grimes terrace bounds the Brazos basin to the southeast and separates it from the Houston embayment. The terrace is expressed by a present day flattening or reduction of regional dip in the Buda

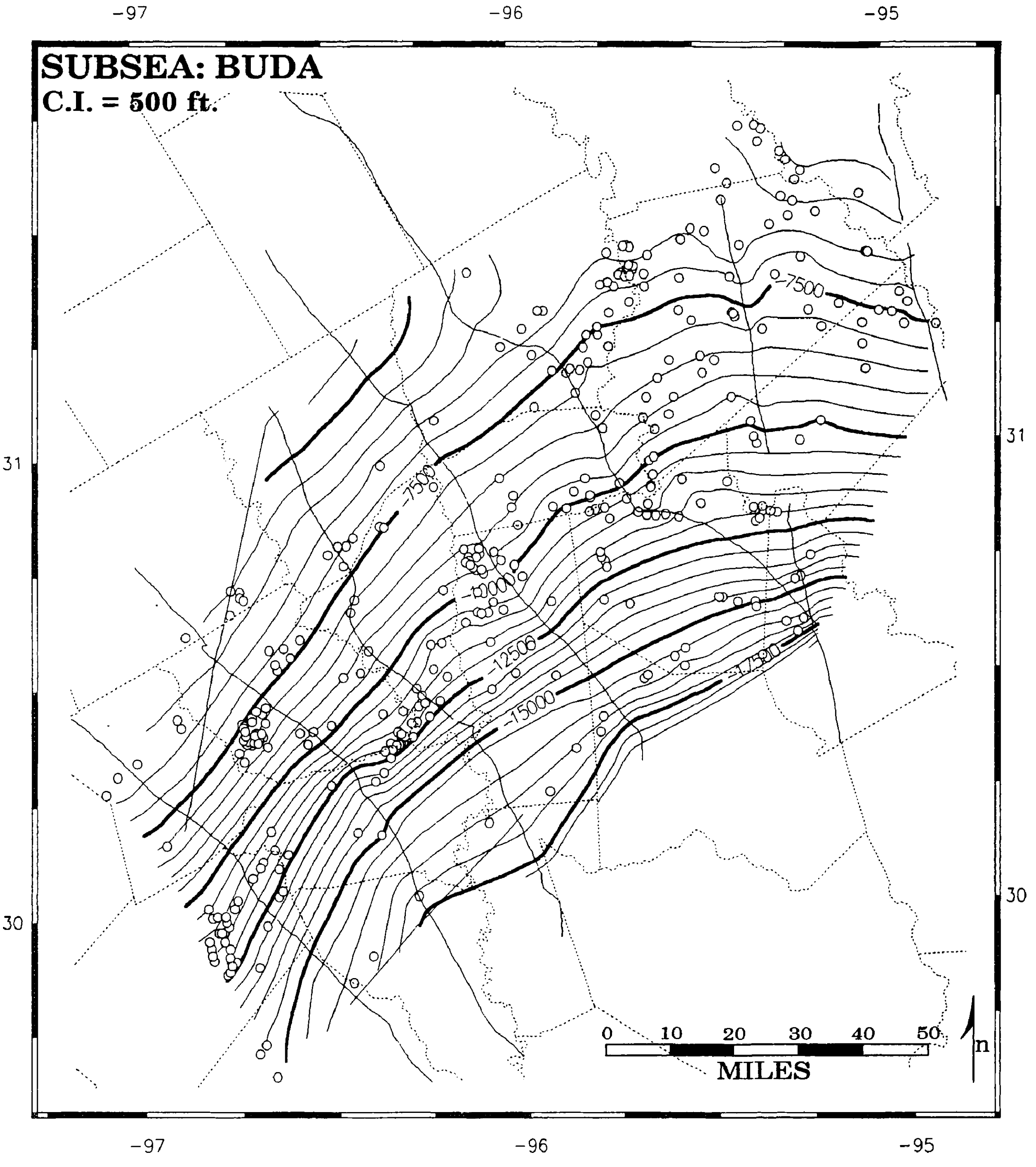

Figure 9 - Structure map showing elevation on top of the Buda Formation (Lower Cenomanian). Contour interval is 500 feet. Structure is characterized by monoclinal southeast dip, and shows no evidence for differential subsidence associated with development of the Brazos basin. Well logs penetrations of the Buda Formation are shown with open circles. Approximate location of seismic data provided by Teledyne Exploration are shown with solid lines. Contours produced by GES have been edited to remove anomalies associated with salt structures and faulting.

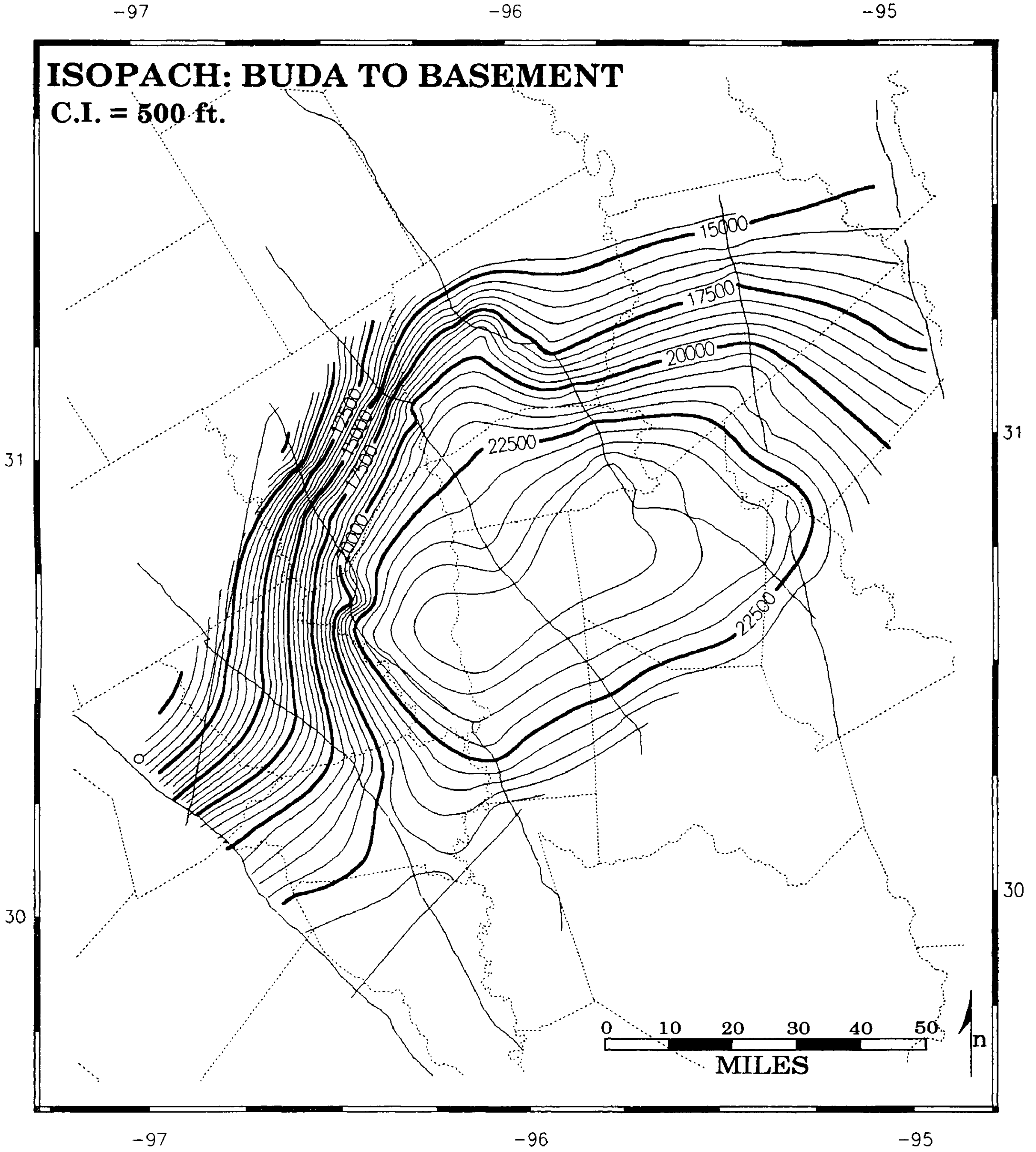

Figure 10 - Isopach map of sediments from the top of the Buda Formation (Lower Cenomanian) to the top of basement (base Callovian Louann Salt). Contour interval is 500 feet. Stratigraphic thickening of the section is associated with differential subsidence of the Brazos basin. Well log penetration of basement rocks shown with an open circle. Approximate location of seismic data provided by Teledyne Exploration are shown with solid lines. Contours produced by GES have been edited to remove anomalies associated with salt structures and faulting.

Formation (Figure 9). The aerial extent and degree of flattening increases downward through the Lower Cretaceous and Jurassic strata.

Prior to the Tertiary, sediment isopach maps (Figure 10) indicate that the Angelina-Grimes terrace was a northward dipping monocline. Jurassic and Cretaceous strata thin southward onto the flexure indicate that it was a structurally positive feature from its inception until the end of the Cretaceous. It formed a stable platform which localized Lower Cretaceous (Aptian and Albian) shelf margin reefs, and seismic and well log data indicate numerous unconformities along its length. Foundering of the Angelina-Grimes terrace occurred in the Tertiary, causing a reversal in the formerly northward dipping strata, and produced the present day structure.

The Houston arch, unlike the Angelina-Grimes terrace, is a present day structurally positive feature which separates the Brazos basin form the East Texas basin. The arch is underlain by a major basement high, interpreted to be a large, complex horst block formed in association with Triassic - Jurassic rifting. The general nature of the arch is shown in Figure 11, a structure map contoured on the top of the Massive Anhydrite Formation (Aptian). Seismic data show well developed pinch out of the Louann salt, and onlap of Jurassic reflectors onto presumed Paleozoic basement of the arch. Across the arch there is approximately 1,000 feet of structural relief, with thinning of Jurassic and Lower Cretaceous strata. Offset in the distribution of the Louann salt and Knowles Limestone shelf margin (see below) suggest that the arch is cut by a right lateral strike-slip fault.

Basement character and structure

The term basement is used in the sense of Buffler and Sawyer (1985) to refer to all pre - Jurassic rocks. The term includes rocks of the Triassic Eagle Mills Formation, as well as igneous, metamorphic, and sedimentary rocks of Paleozoic age. Within the study area, one well along the western margin of the Brazos basin reached total depth in basement

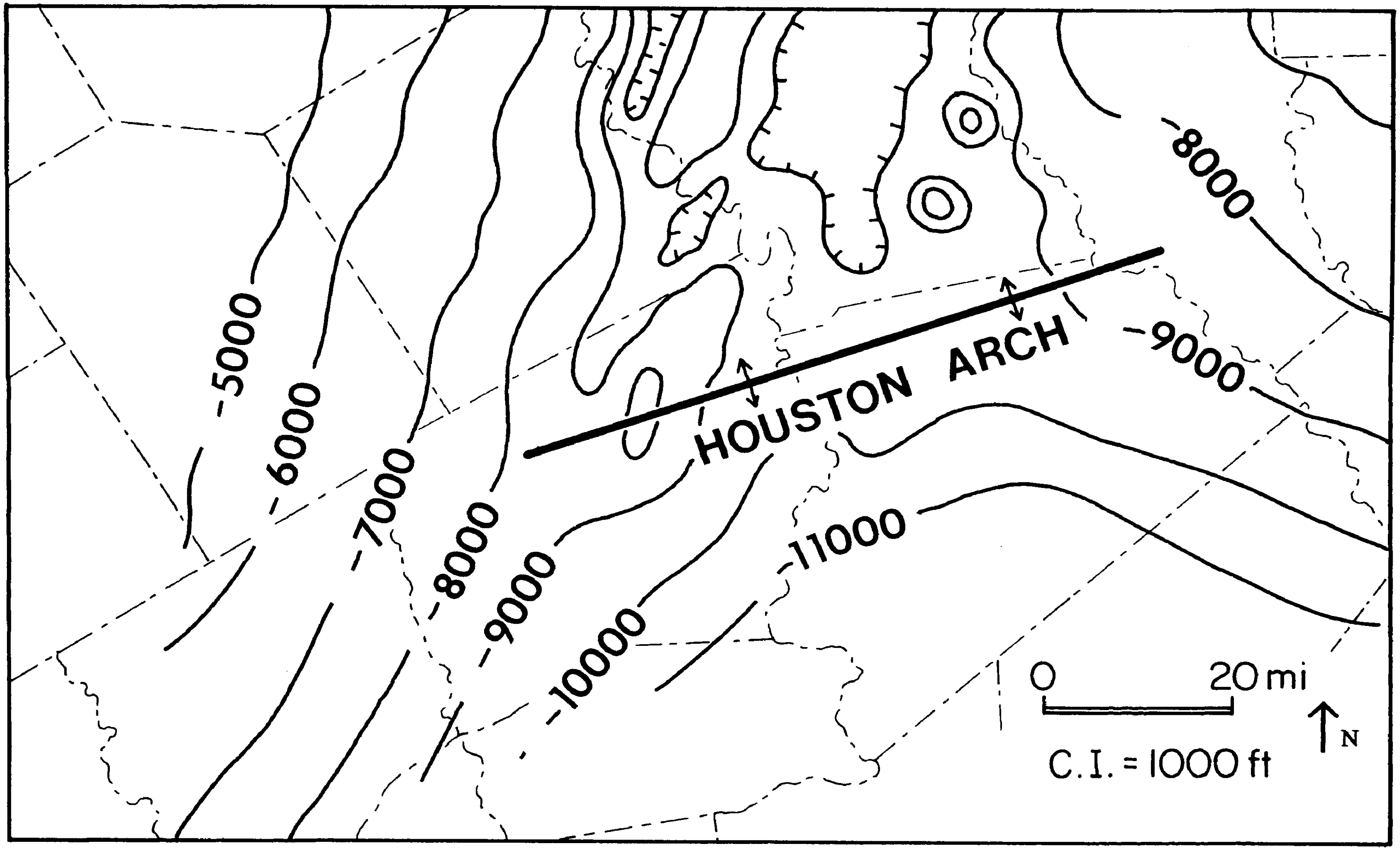

Figure 11 - Structure map of the Houston arch showing elevation on top of the Massive Anhydrite Formation of the Trinity Group (Aptian). The map shows about 1,000 feet of structural relief across the arch. Contours are modified from Coon (1956). Contour interval is 1,000 feet.

rock, penetrating approximately 70 feet of the Eagle Mills Formation. Synthetic seismograms generated for the well provided a good correlation to the seismic data, and allowed confident correlation of the basement reflector across the southwestern part of the study area. In the northeastern portion of the study area, where strike lines are not present, the basement reflector was identified on the basis of seismic character.

The general structure of the basement is shown in Figure 12, a structure map contoured on the basement reflector. Depth to basement ranges from less than 15,000, to an estimated 39,000 feet, and is generally characterized by monoclinal dip to the southeast. Structure contours along the southeast margin of the Brazos basin indicate a slight reversal of dip, suggesting that there may still be some structural relief along the Angelina-Grimes terrace. Southeast of the Angelina-Grimes terrace the basement is down dropped by faulting until it is below the limit of recorded data and is not observed in the Houston embayment.

The seismic profile presented in Figure 13 shows the general character of the basement reflector along the south flank of the Houston arch. The basement is indicated by the first strong, relatively continuous reflector below the Knowles reflector. Overlying Jurassic reflectors display strong onlap onto the basement surface indicating a significant unconformity, and further suggest that the region is salt free (see below, Callovian salt distribution and related structures) Sub-basement reflectors are weak and discontinuous, the basement reflector in this part of the study area representing the acoustic basement.

South of the Houston arch, and across most of the Brazos basin, the first significant reflector below the Knowles is interpreted as basement. North of the Houston arch in the East Texas basin, Oxfordian through Kimmeridgian sediments of the Louark Group are composed of shallow water carbonates and produce a prominent reflector (see Figure 4). In contrast, Louark Group sediments in the Brazos basin are composed of deep basin shales, which are in turn overlain by shales of the Bossier Formation (Tithonian). The contact between these two groups of sediments is therefore non-reflective.

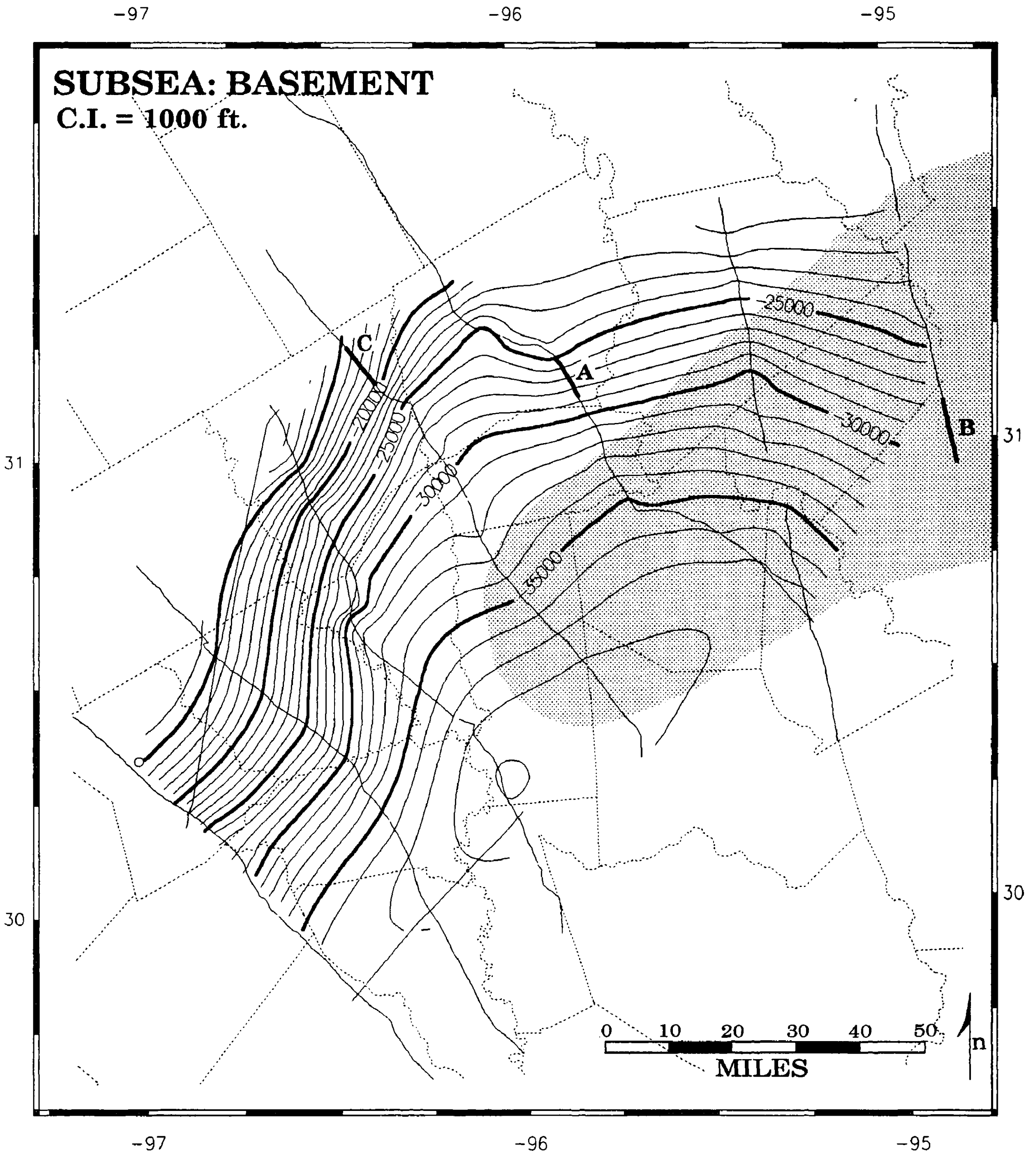

Figure 12 - Structure map showing elevation on top of basement (pre - Jurassic). Contour interval is 1,000 feet. Structure is characterized by monoclinal southeast dip, minor reversal of dip in the southeast is associated with the Angelina-Grimes terrace. Location of seaward dipping subbasement reflectors are shown in gray. Well log penetration of basement rocks is shown with an open circle. Approximate location of seismic data provided by Teledyne Exploration are shown with solid lines. A) Location of seismic profile in Figure 13. B) Location of seismic profile in Figure 14. C) Location of seismic profile shown in Figure 15. Contours produced by GES have been edited to remove anomalies associated with basement faulting.

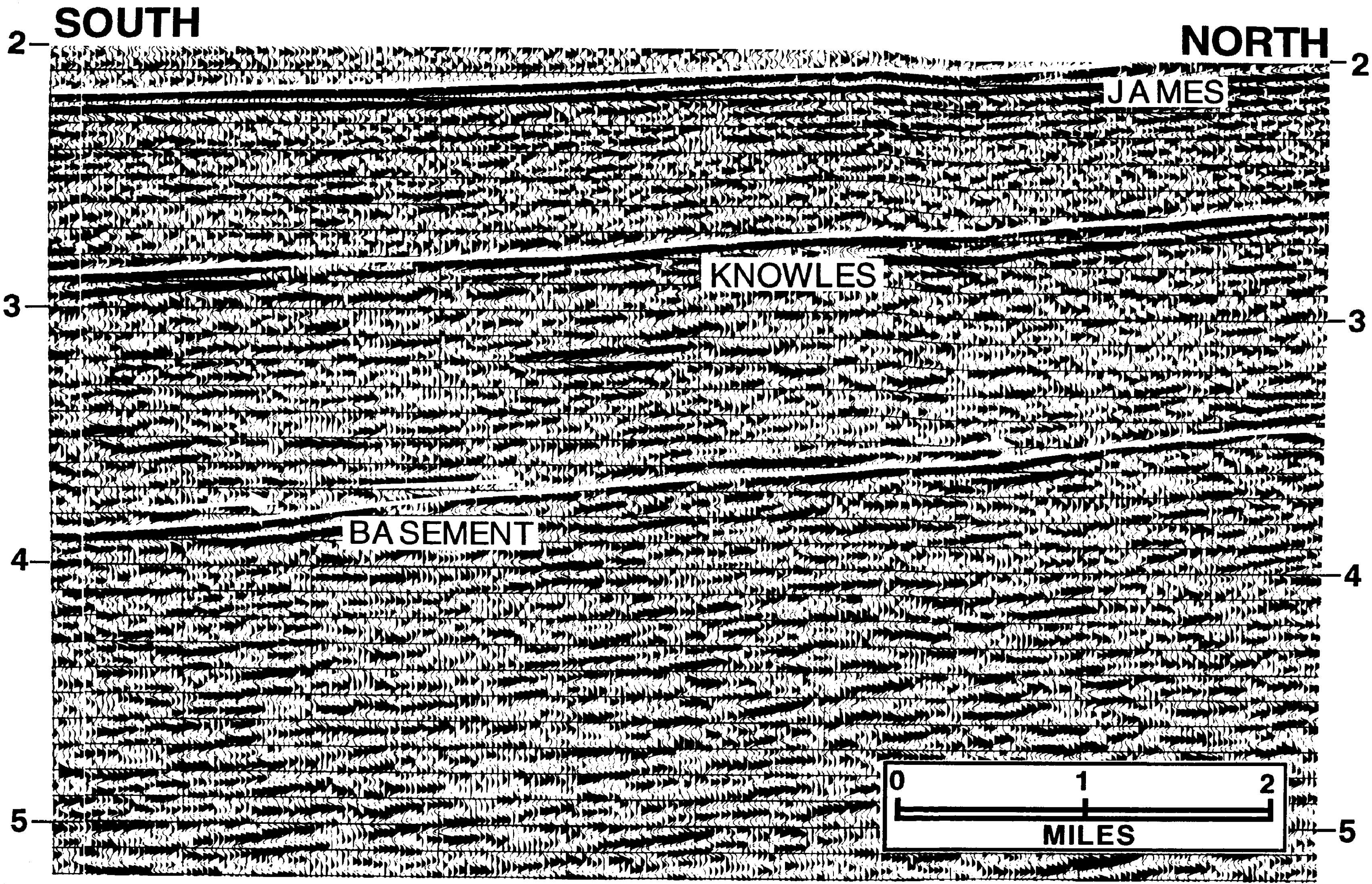

Figure 13 - Seismic profile showing character of the basement reflector along the south flank of the Houston arch. The basement surface is a relatively strong, continuous reflector, onlapped by overlying Jurassic strata. Subbasement reflectors are weak and discontinuous, interpreted as igneous or metamorphic rock of Paleozoic age. Location of seismic data shown in Figure 12 (line A).

Furthermore, within the Brazos basin, acoustic impedance of the Louann Salt and and the overlying shales are nearly identical and therefore, also non-reflective. The product of these factors is that, across most of the Brazos basin, the section between the top of the Cotton Valley Group and the basement produces few reflections.

Sub-basement reflectors across a large part of the study area are weak and discontinuous. In these areas the basement reflector is also the acoustic basement. Lack of sub-basement reflectors may be attributed to either data quality or composition of the basement rocks. While data quality may be a problem in some parts of the study area, where basement rocks are shallow, data quality is considered good, and lack of sub-basement reflectors is attributed to basement composition. In these areas basement rock is probably composed of non-reflective material such as Paleozoic igneous or metamorphic rock.

In other parts of the study area, the basement reflector is not the acoustic basement, and sub-basement reflectors may be observed. The distribution of these sub-basement reflectors are shown on Figure 12. The seismic profile shown if Figure 14 provides an example of the character of these sub-basement reflectors. The sub-basement reflectors shown are strong and relatively continuous. Across the entire area shown in Figure 12 they display an apparent south dip, have a strong angular relationship with, and are truncated by the overlying basement reflector, indicating a significant angular unconformity produced by uplift and subsequent erosion. These sub-basement reflectors are probably produced by either Paleozoic and Triassic sedimentary rocks, or by interbedded volcanic and volcano-clastic material.

The basement surface across the central East Texas region is characterized by numerous high-angle normal faults. These faults offset the basement and extend into the overlying sediments. South of the Houston arch, lack of significant reflectors between the basement and the Knowles Formation makes it difficult to determine the time of movement along these faults. An estimate for the timing of fault movement for basement faults in the

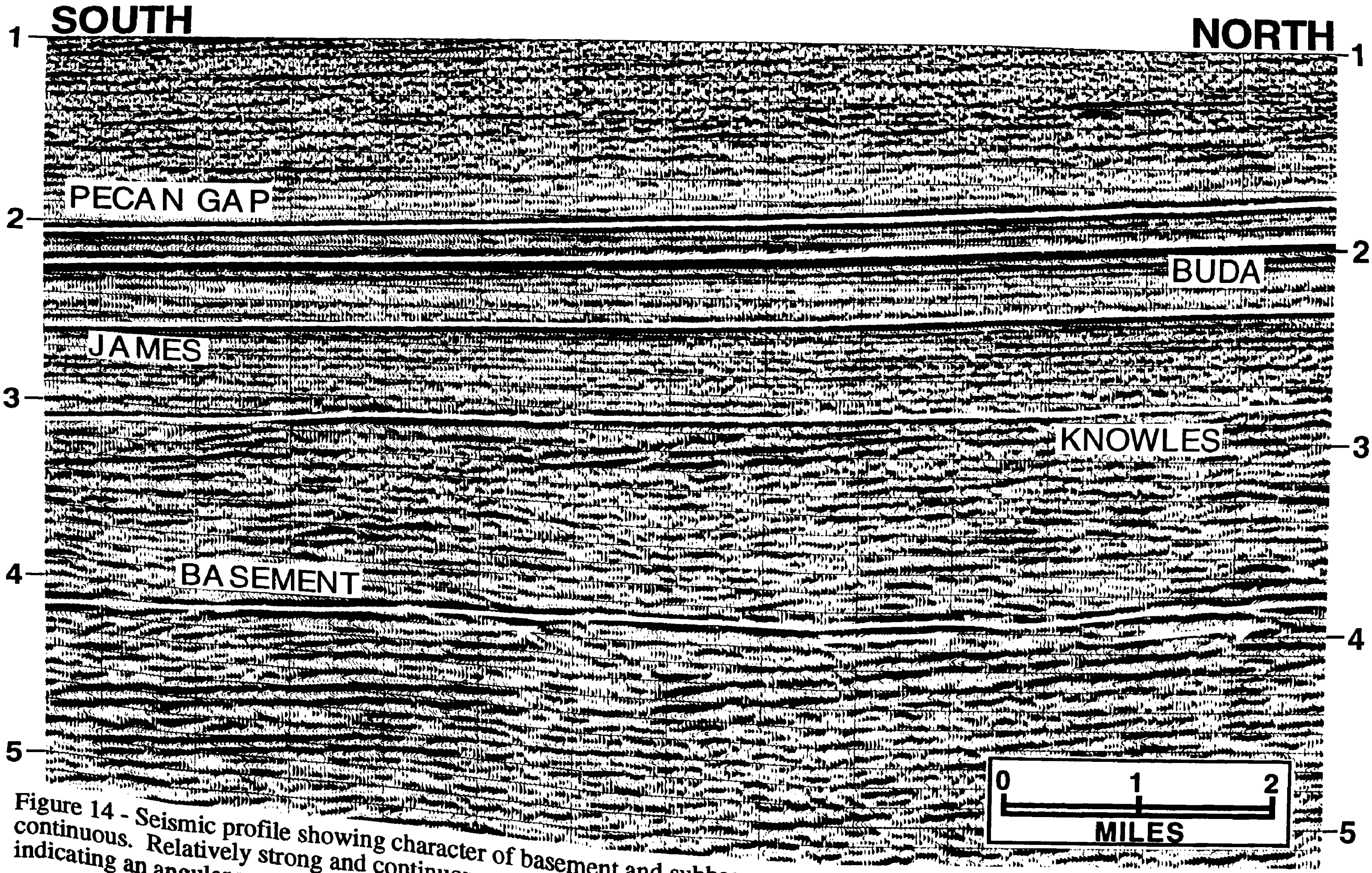

Figure 14 - Seismic profile showing character of basement and subbasement reflectors. The basement reflector is strong and continuous. Relatively strong and continuous subbasement reflectors are at an angle with, and truncated by the basement surface, indicating an angular unconformity associated with uplift and erosion. Location of seismic data shown in Figure 12 (line B).

Brazos basin can, however, be obtained from similar faults to the north, in the East Texas basin. A seismic profile from the southern margin of the East Texas basin displays well developed reflectors from both the top of salt and Louark Group (Figure 15). Faults shown on the profile offset the Louann Salt (Callovian), and Louark carbonates (Oxfordian to Kimmeridgian), extending up into sediments of the Cotton Valley Group (Tithonian to Berriasian). Jurassic strata offset by the faults, and Lower Cretaceous strata which overlie the faults, display thickening on the down thrown blocks. These stratigraphic thickness changes indicate that movement along the faults was continuous from Callovian to the end of the Jurassic, and may have continued into the Early Cretaceous.

Callovian salt distribution and related structures

The distribution of Louann Salt across the northern Gulf of Mexico is intimately associated with the regions topography at the time of deposition, with thick salt accumulating in various basin and embayments. Outside of these topographic lows, the Louann Salt is commonly believed to be thin but ubiquitous. The updip limit of the Louann salt is generally associated with a peripheral graben systems (see Figure 1). In eastern Texas the limit of salt is associated with the Mexia, Talco, and related fault systems (see Figure 2). Results of this study suggest that distribution of the Louann Salt may be more limited than previously recognized.

The distribution of Louann Salt in the central East Texas region is shown in Figure 16. The distribution is based on four wells which reached total depth in salt or basement rock, distribution of major salt structures (Ewing, 1991a), and location on seismic of observed or inferred salt pinch out. The presence of salt may be easily observed on seismic profiles across the East Texas basin, where it produces a prominent reflector. The top of salt produces a very poor reflector along the northern margins of the Brazos basin, and no reflector in the deeper parts of the basin. Lack of a reflector from the salt in the

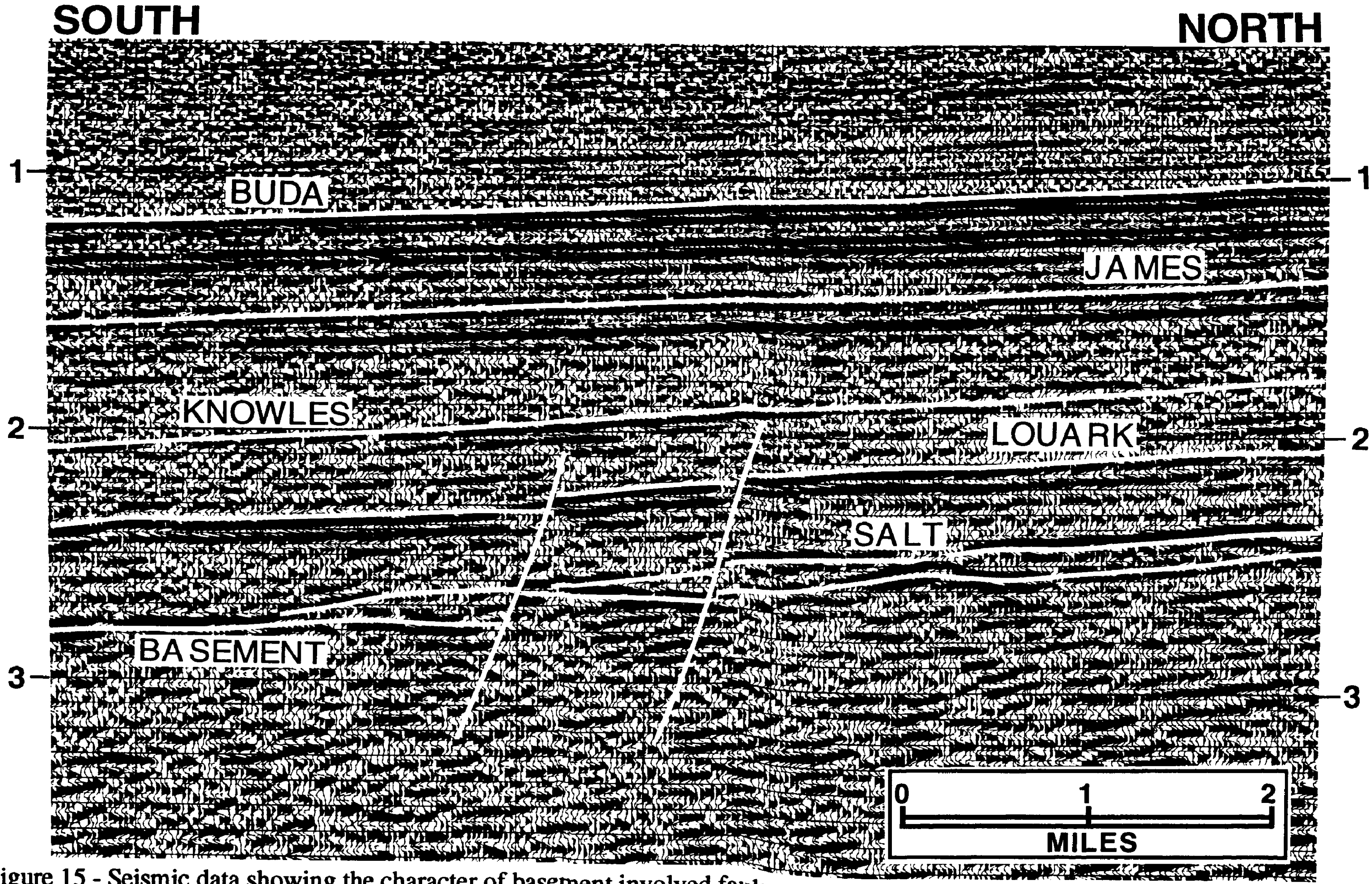

Figure 15 - Seismic data showing the character of basement involved faults. They are high-angle normal faults that offset reflectors associated with top basement , top Louann Salt (Callovian), and top Louark Group (Kimmeridgian). Stratigraphic thickening across the faults, and in overlying sediments indicate time of fault movement. Location of seismic data shown in Figure 12 (line C).

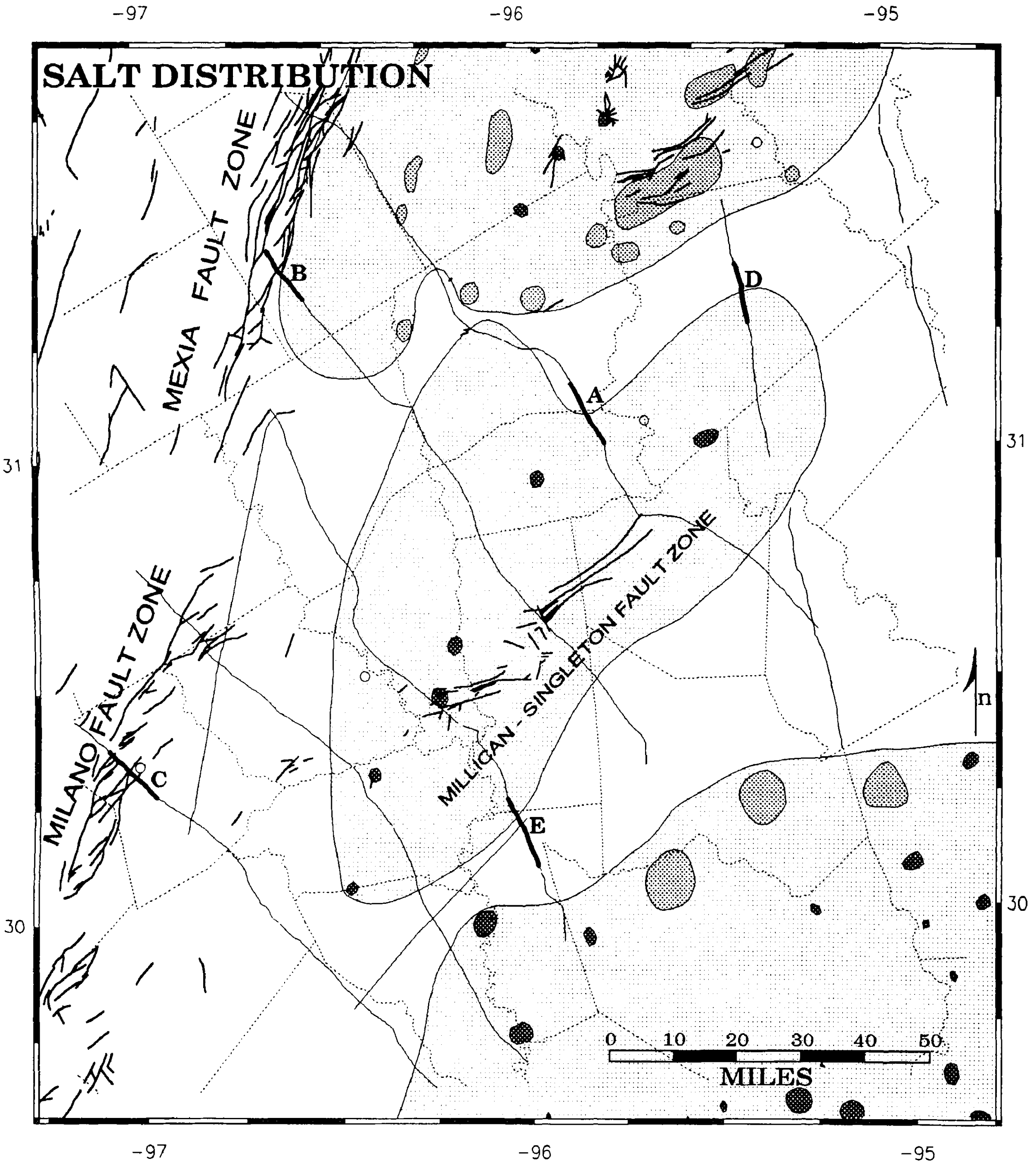

Figure 16 - Distribution of salt and salt related structures. Presence of salt is indicated by light gray shading, salt anticlines are shown with medium gray, and salt diapirs are shown with dark gray. Salt free regions are unshaded. Interpretation is based on well data, distribution of major salt structure (modified from Ewing, 1991a) and location of seismically observed or inferred salt pinch outs. Also shown are the location of major surface faults (see Figure 3 for sources). Well log penetrations of Louann salt or basement rock are shown with open circles. Approximate location of seismic data provided by Teledyne Exploration are shown with solid lines. A) Location of seismic profile shown in Figure 17. B) Location of seismic profile shown in Figure 18. C) Location of seismic profile shown in Figure 19. D) Location of seismic profile shown in Figure 20. E) Location of seismic profile shown in Figure 21.

Brazos basin is attributed to a lack of contrast in the acoustic impedance of the salt and overlying shales of the Louark and Cotton Valley groups. The presence of salt in the Brazos basin must therefore be inferred from deformation of the overlying sediments, and confirmed by well data. Distribution of salt in the Houston embayment is based on published distribution of major salt structures (Ewing, 1991a).

Analysis of sediment isopachs indicate original thickness of salt in the Brazos basin was between 3,000 and 4,000 feet. Distribution of the Louann Salt and overlying sediments within the Brazos basin are a function of the crustal structure imposed on the region during Late Triassic - Early Jurassic rifting, regions of greatest crustal attenuation receiving the largest volumes of both salt and sediments. Areas underlain by salt correlate with regions of enhanced Late Jurassic - Early Cretaceous subsidence as indicated by sediment isopach maps (compare Figures 10 and 16), and areas of thickest salt accumulation as indicated by the distribution of salt diapirs correlate to the area of greatest sediment accumulation. Furthermore, there is a reasonable correlation between the updip limit of salt in the Brazos basin interpreted from seismic data, and isopach contour lines. These relationships may be used to obtain an estimate of the original salt thickness in the basin.

Estimates of original salt thickness in the Brazos basin are significantly less than that of the East Texas basin (5,000 feet, Jackson and Seni, 1983; Seni and Jackson, 1983). This estimate is supported by a comparison of the number and morphology of salt diapirs in the two basins. The Brazos basin contains six salt diapirs, most of which are thin vertical stocks. The Kittrell salt dome on the border of Houston and Walker counties is a tear drop like structure detached form the mother salt (Pustejovsky, oral communication, 1988). In contrast, salt diapirs in the East Texas basin are more numerous, have greater radial extent, and are commonly capped by large mushroom like overhangs, indicating they were sourced by a larger volume of original salt.

Absence of salt along the Houston arch and western margin of the Brazos basin is based on the location of seismically defined salt pinch out, onlap of Jurassic reflectors onto the basement surface, lack structuring in the overlying sediment, and confirmed by well data. Pinch out of salt southward from the East Texas basin onto the Houston arch may be observed on seismic profiles (see Figure 15). Absence of salt along the southern flank of the Houston arch, and western margin of the Brazos basin is inferred where Jurassic reflectors onlap the basement surface (see Figure 13). If salt was present in these areas of onlap, minimum thickness of the salt would correspond to the amount of onlap. For the area shown in Figure 13 this would correspond to approximately 150 ms, or 2,250 feet (assuming salt velocity of 15,000 ft./sec.), a significant amount of salt which almost certainly would have deformed. Regions where Jurassic reflectors onlap the underlying basement are therefore interpreted to be salt free.

The location on seismic of observed salt pinch out and salt free regions, combined with published locations of major salt structures and diapirs (Ewing, 1991a) indicate a major offset in the Houston arch (Figure 16). This offset suggest that the arch is cut by a large northwest-southeast trending fault with significant right lateral movement. The data are not conclusive on the timing of fault movement. Movement along the fault may have occurred prior to salt deposition, creating topography that influenced subsequent salt emplacement, or may have offset salt deposits after deposition.

Stratigraphic data from the Late Jurassic and Cretaceous section suggest that the Angelina-Grimes terrace is probably salt free. Late Jurassic through Cretaceous strata thin significantly southward onto the terrace, and contain several documented unconformities or surfaces of non-deposition. The thinning and unconformities along the terrace indicate that it was a structurally positive feature, and suggest that it was topographically high during the deposition of the Louann Salt, and therefore salt free.

The character of the salt pinch out between the Brazos basin and Houston arch is shown on a seismic profile in Figure 17. The basement surface is cut by several fault

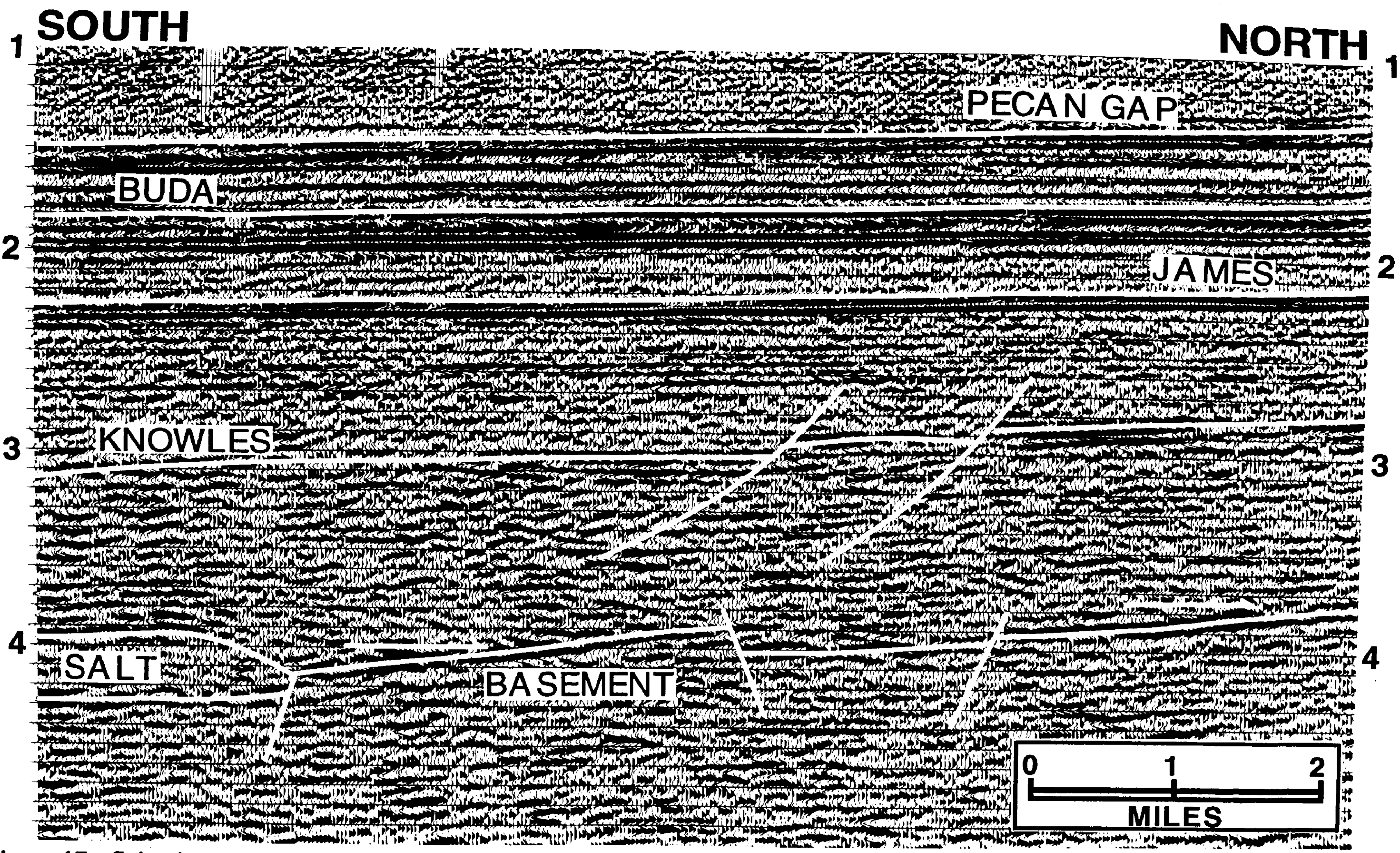

Figure 17 - Seismic profile showing pinch out of Louann Salt against the Houston arch. Basement surface is characterized by numerous faults producing horst and graben structure. Louann Salt to the south pinches out against an up thrown fault block, onlap of Jurassic reflectors on top of horst blocks indicate they are salt free. Location of seismic profile shown in Figure 16 (line A).

forming horst and graben topography. A salt swell is identified in the southern portion of the line by structuring of the overlying Cotton Valley sediments. The top of salt is placed between coherent reflectors associated with the overlying sediments and reflection free zone associated with salt. The salt pinches out against an up-thrown block, while Jurassic reflectors onlap the top of the horst block indicating it is salt free. A small graben to the north may contain some salt, however, farther to the north onlap of Jurassic reflectors onto the basement surface indicate the area is again salt free.

The Mexia and Talco fault zones, expressed at the outcrop as large graben systems, are associated with the updip limit of Louann Salt in the East Texas basin. Published reports (Jackson and Seni, 1983; Seni and Jackson, 1983) indicate that these grabens are formed at depth by large listric faults, the decollement of these faults developing along the updip limit of salt. The general character of the Mexia fault zone along the western side of the East Texas basin is shown on a seismic profile in Figure 18. The profile shows the Louann Salt thinning to a pinch out going north, toward the Mexia fault zone. The Mexia fault zone appears as a large listric fault with associated antithetic faults. The decollement of the main fault may be traced onto the basement surface just updip from the salt pinch out. The position of the fault appears to be related solely to the updip pinch out of the Louann Salt. The possibility of some basement influence on the location of the fault cannot, however, be ruled out due to degradation of data quality immediately below the fault.

The Milano fault zone occurs South of the East Texas basin, and west of the Brazos basin, on trend with the Mexia fault system. At the outcrop the two fault zones are separated by 25 miles of alluvium associated with the Brazos River (Barnes, 1970, 1974a). Tectonic maps for Texas (Ewing, 1991a) and the Gulf Coast (Hickey, 1972) show these two fault zones as continuous features, the Milano fault system also associated with the updip limit of salt (Ewing, 1991a). Data acquired for this study however, indicated that the

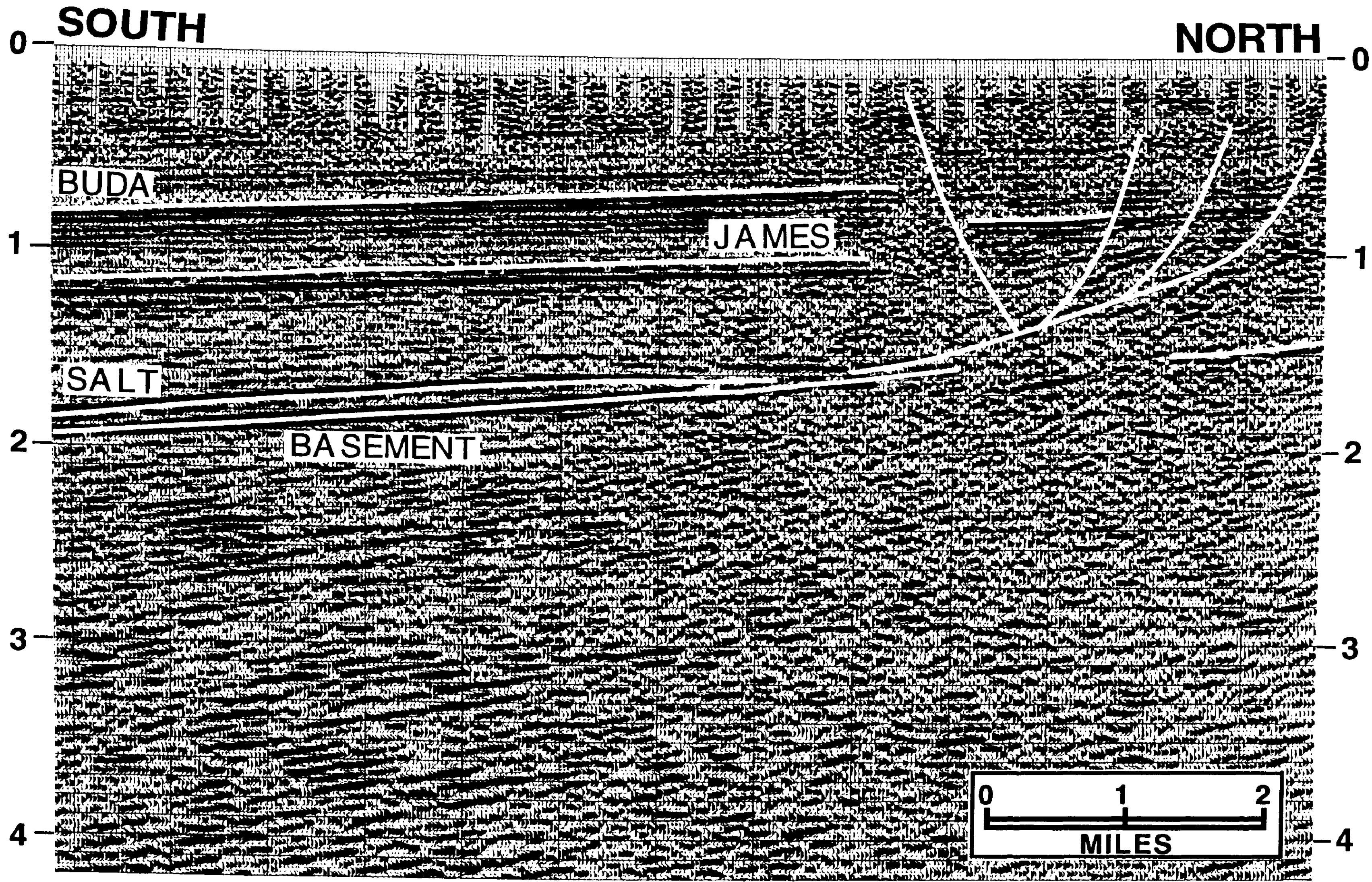

Figure 18 - Seismic profile showing structural and stratigraphic relationships of the Mexia fault zone. Louann Salt is shown thinning northward to a pinch out. Mexia fault occurs just updip from the salt pinch out, appearing as a large listric normal fault with the decollement in salt just above basement. Location of seismic profile shown in Figure 16 (line B).

character of the Milano fault system is significantly different from that of the Mexia fault system.

The Milano fault system is basement involved, and lacks a master fault with salt related decollement. The character of the fault zone is shown on a seismic profile in Figure 19. The basement surface south of the fault system is onlapped by Jurassic reflectors indicating it is salt free, an interpretation which is supported by well data. The well shown in Figure 19 reached total depth in the Eagle Mills Formation without encountering the Louann Salt. The Milano fault system shown is composed of several high angle normal fault, with a few antithetic faults. There is no evidence for a salt related decollement. Instead, the faults extend into basement to some undetermined depth.

Seismic data indicate that around the peripheries of the Brazos basin there are several major faults zone. These fault zones appear similar to the Mexia fault zone of the East Texas basin in that they are dominated by listric normal faults, intimately associated with pinch out of the Louann Salt, and have a decollement either within, or at the base of salt. The seismic profile show in Figure 20 provides an example of one of these faults from the northern edge of the Brazos basin where the Louann Salt pinches out against the Houston arch. Based on the deformation of the overlying strata, a salt pillow is interpreted to be present along the southern edge of the data. Just updip of the salt pillow is a graben which offsets the Knowles reflector. The graben is interpreted to have been formed by a down-to-the-south listric fault, and associated antithetic fault. Decollement of the listric fault is placed at the base of salt. Timing of initial fault movement is not constrained by the data, however, offset of the Knowles reflector and stratigraphic thickening of the Travis Peak and Pettet interval across the fault indicate that movement continued through Early Cretaceous, possibly as late as Aptian time. Just north of the fault zone are several smaller pods of salt.

A seismic profile from the southern edge of the Brazos basin (Figure 21) provide another example of these peripheral fault zone. Offsets in the Buda, James, and Knowles

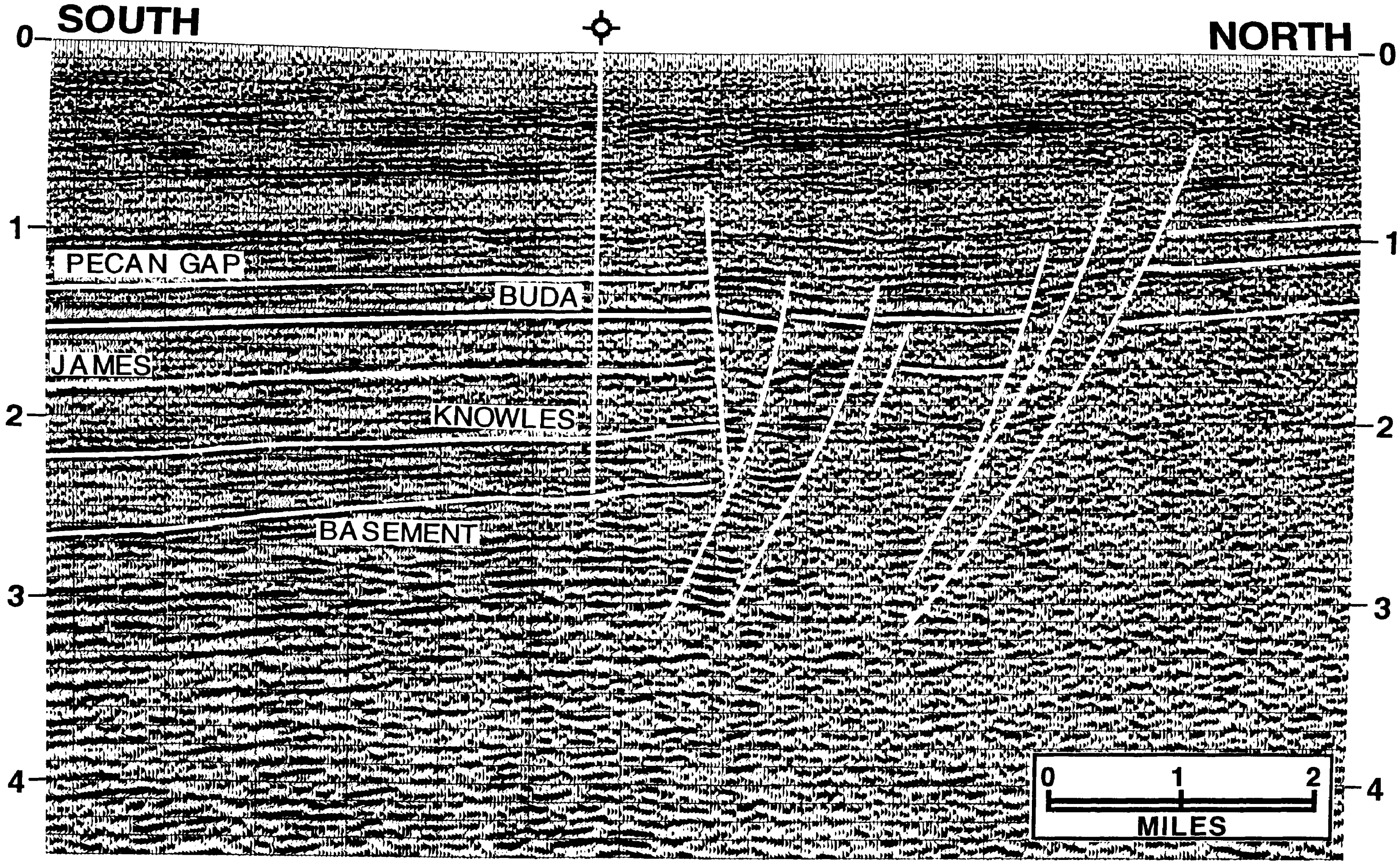

Figure 19 - Seismic profile showing structure of the Milano fault zone. Jurassic reflectors onlap the basement surface indicating it is salt free, an interpretation supported by well data. Milano faults zone just up dip from the well is characterized by high angle normal faults which cut basement as well as overlying sedimentary rocks. Location of seismic profile shown in Figure 16 (line C).

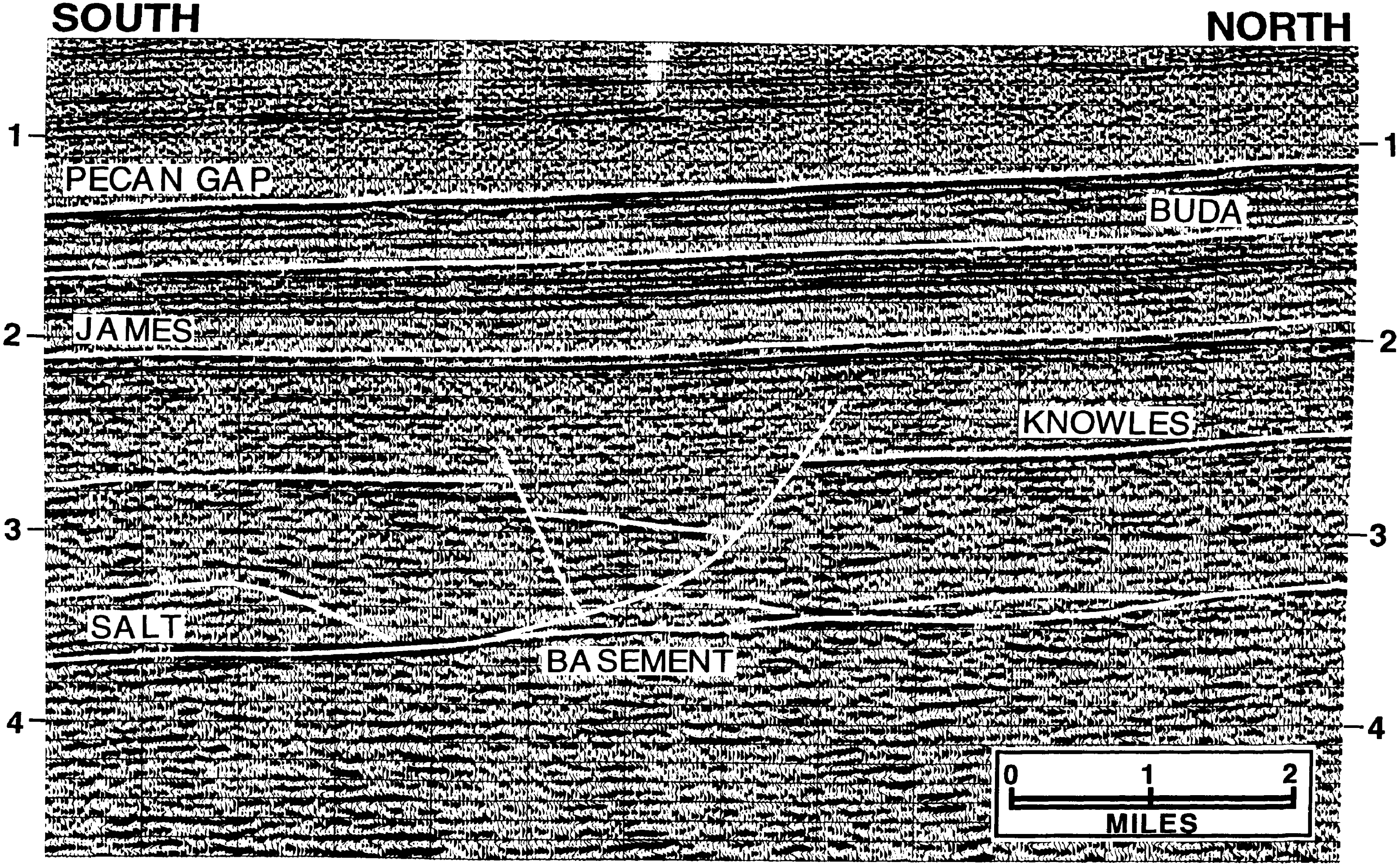

Figure 20 - Seismic profile showing listric fault associated with limit of salt along the northern margin of the Brazos basin. Fault shown displays a decollement just above basement, and is located just updip from a salt pillow to the south. Updip from the fault salt is thin, north of the data shown salt is absent. Location of seismic profile shown in Figure 16 (line D).

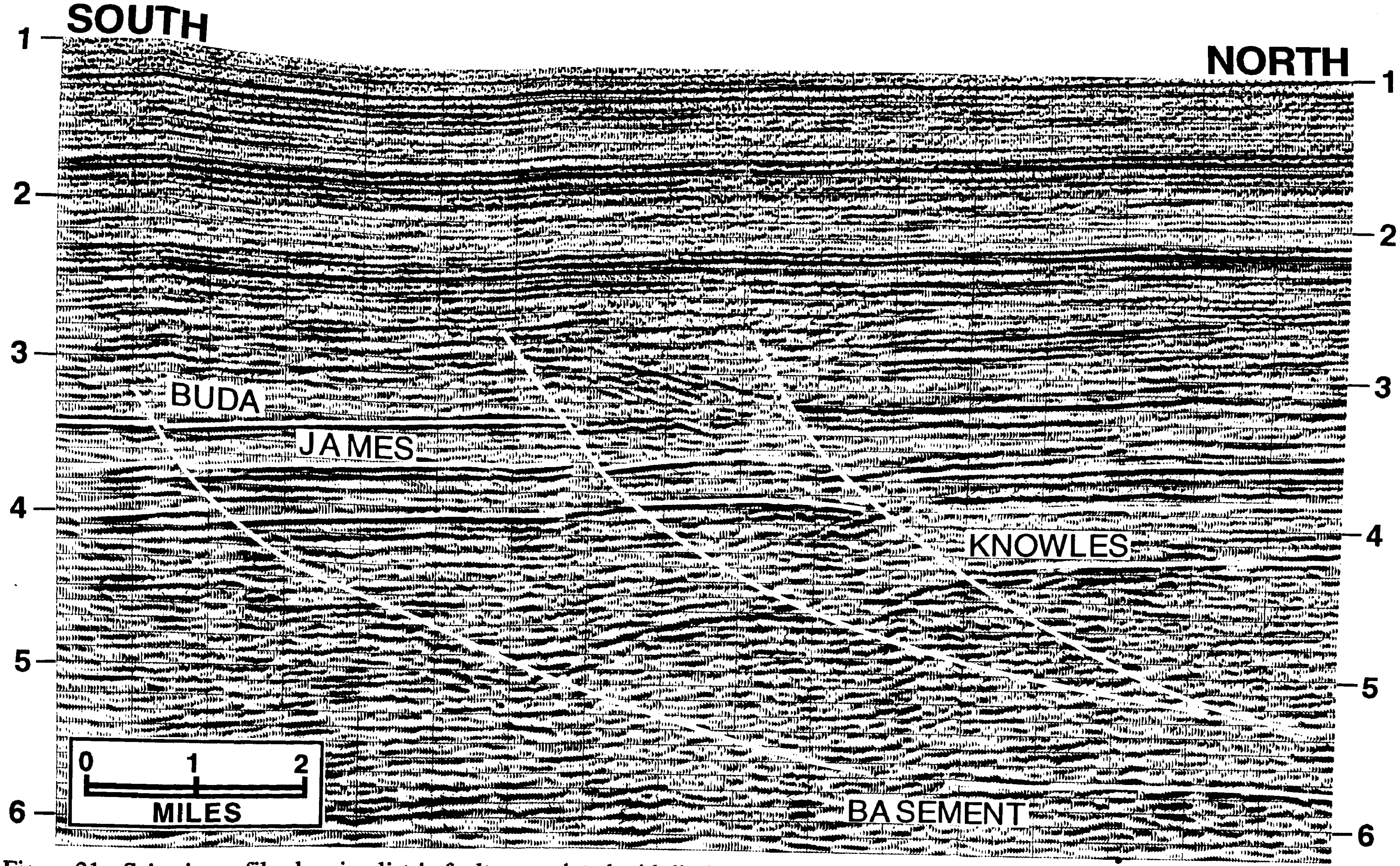

Figure 21 - Seismic profile showing listric faults associated with limit of salt along the southern margin of the Brazos basin. Faults offset Cretaceous reflectors, and are interpreted as down-to-the-north listric normal faults. Salt is not imaged on the data, however, faults are assumed to have their decollement within or at the base of salt. Location of seismic profile shown in Figure 16 (line E).

reflectors are interpreted to be caused by down-to-the-north listric normal faults. Salt is not imaged on the seismic data, but the faults are assumed to have a decollement either within, or at the base of the Louann. No significant changes in stratigraphic thickness are observed between the Buda, James and Knowles reflectors. Timing of initial fault movement is therefore Late Cretaceous, post - Middle Cenomanian. Stratigraphic thickening of the overlying Late Cretaceous and Early Tertiary sediments indicate that fault movement continued until Middle or possibly even Late Paleocene. The Millican and Singleton fault zones may be the outcrop expression of similar down-to-the-north listric faults. The location of seismic lines acquired for this study do not definitively address this question.

Oxfordian - Kimmeridgian

Oxfordian through Kimmeridgian sediments in the East Texas region are comprised of the Norphlet Formation of the Louann Group, and the Smackover through Gilmer formations of the Louark Group (see Figure 4). Eleven wells across the study area penetrated sediments of the Louark Group or their basinal equivalents (Figure 22). Four of these wells penetrated the entire Oxfordian - Kimmeridgian section to reach total depth in salt or basement rock. Only one well encountered sandstone of the Norphlet Formation.

Approximately 70 feet of Norphlet Formation sandstone was encountered in Anderson County in the East Texas basin. Two wells to the south, in the Brazos basin reached total depth in salt without encountering any equivalent sandstones. Absence of the Norphlet Formation in the Brazos basin is attributed to the Houston arch. The arch was probably a topographic high at this time, and blocked southward progradation of the Norphlet Formation.

The Houston arch also appears to have provided a stable platform for the development of Louark shelf margin. Generalized distribution of depositional

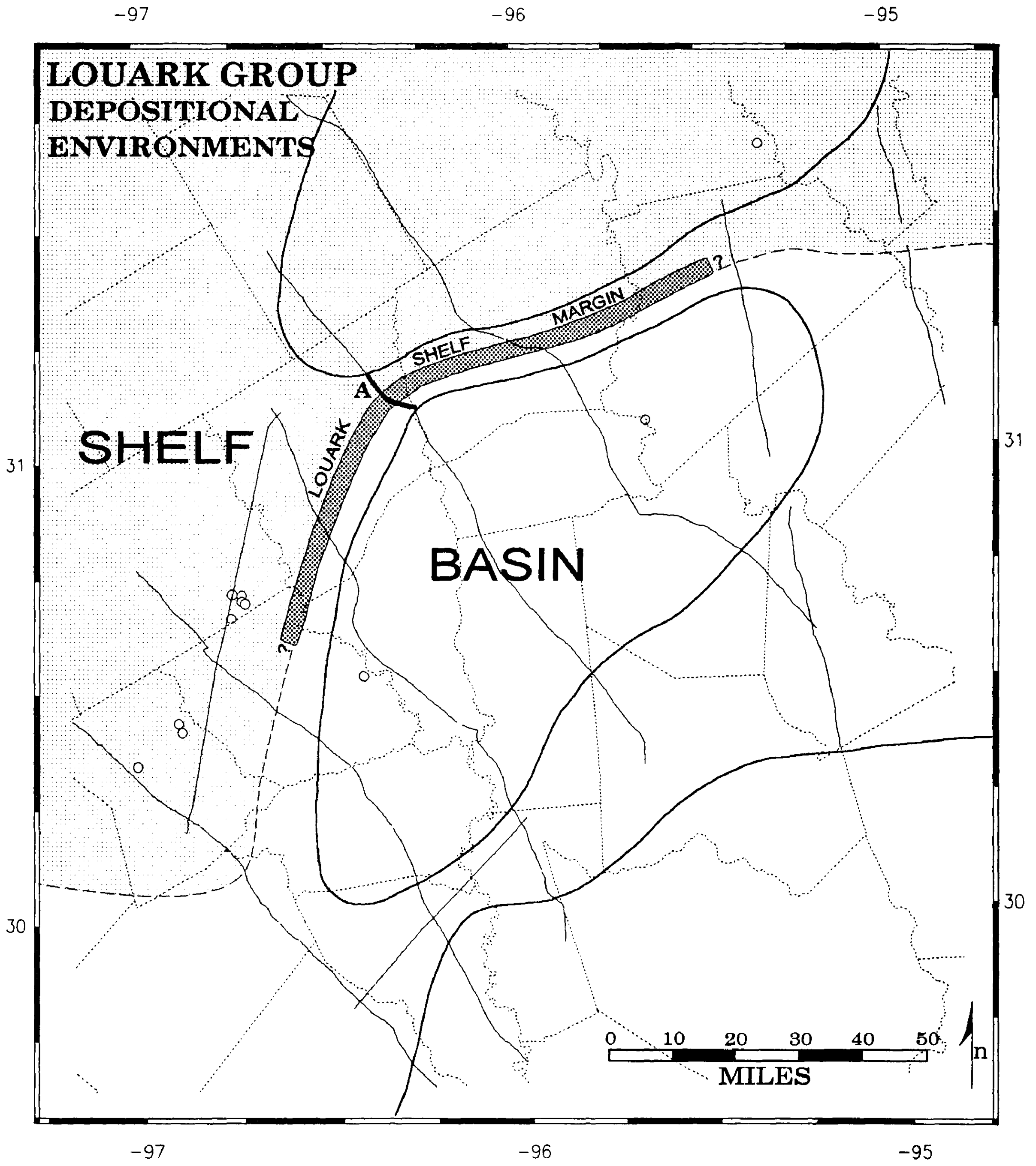

Figure 22 - Distribution of depositional environments for the Louark Group (Oxfordian to Kimmeridgian). Light gray indicates deposition in shallow shelf environment. Location of the Louark shelf margin is shown in dark gray, deep basin environments are unshaded. Interpretation is based on well logs, well cuttings reports, and seismically observed location of the Louark shelf margin. Well log penetrations of the Louark Group are shown with open circles. Approximate location of seismic data provided by Teledyne Exploration are shown with solid lines. A) Location of seismic profile shown in Figure 23.

environments for the Louark Group is shown on a map in Figure 22. North of the Houston arch, in the East Texas basin ,carbonate sediments were deposited in shallow water environments. Deposition of these shallow water carbonates generally kept pace with subsidence. The Brazos basin south of the arch was essentially sediment starved at this time. Louark Group equivalents in the Brazos basin are composed of deep water shales. Seismic data indicate that significant shelf-to-basin topography existed between the Houston arch and the Brazos basin.

West and north of the Brazos basin, well data acquired for this study indicate that the Louark Group ranges from 1,000 to 2,000 feet thick. Well cutting reports indicate that these carbonates were deposited in shallow water environments. Farther to the north in the East Texas basin, thickness of the Louark Group increases to over 3,000 feet (Rogers, 1967). Two wells to the south of the Houston arch, in the Brazos basin, reached total depth in the Louann salt without encountering any shallow water carbonates typical of the Louark Group. Well logs and cutting reports indicate that equivalent rocks immediately overlying the Louann Salt are composed of a relatively thin section of black, highly pyritic calcareous shales and shaley carbonates, suggesting a shelf and starved basin model for the Houston arch and Brazos basin.

Seismic profiles going from the crest of the Houston arch into the Brazos basin show significant shelf-to-basin topography for the Louark Group sediments (Figure 23). Both the top of basement and the top of the Louark Group produce prominent reflections along the crest of the arch where the Louark Group is over 400 ms thick. The Louark shelf margin is underlain by the structurally high Houston arch. Going from the crest of the arch southward into the Brazos basin the Louark Group thins to about 10 ms across a distance of only five miles before losing reflection character. Thinning of the Louark Group is accompanied by even greater thickening of the overlying Cotton Valley Group. Going from the crest of the Houston arch to the southern edge of the profile shown in Figure 23, the Cotton Valley Group (between the Knowles and Louark reflectors) goes from just over

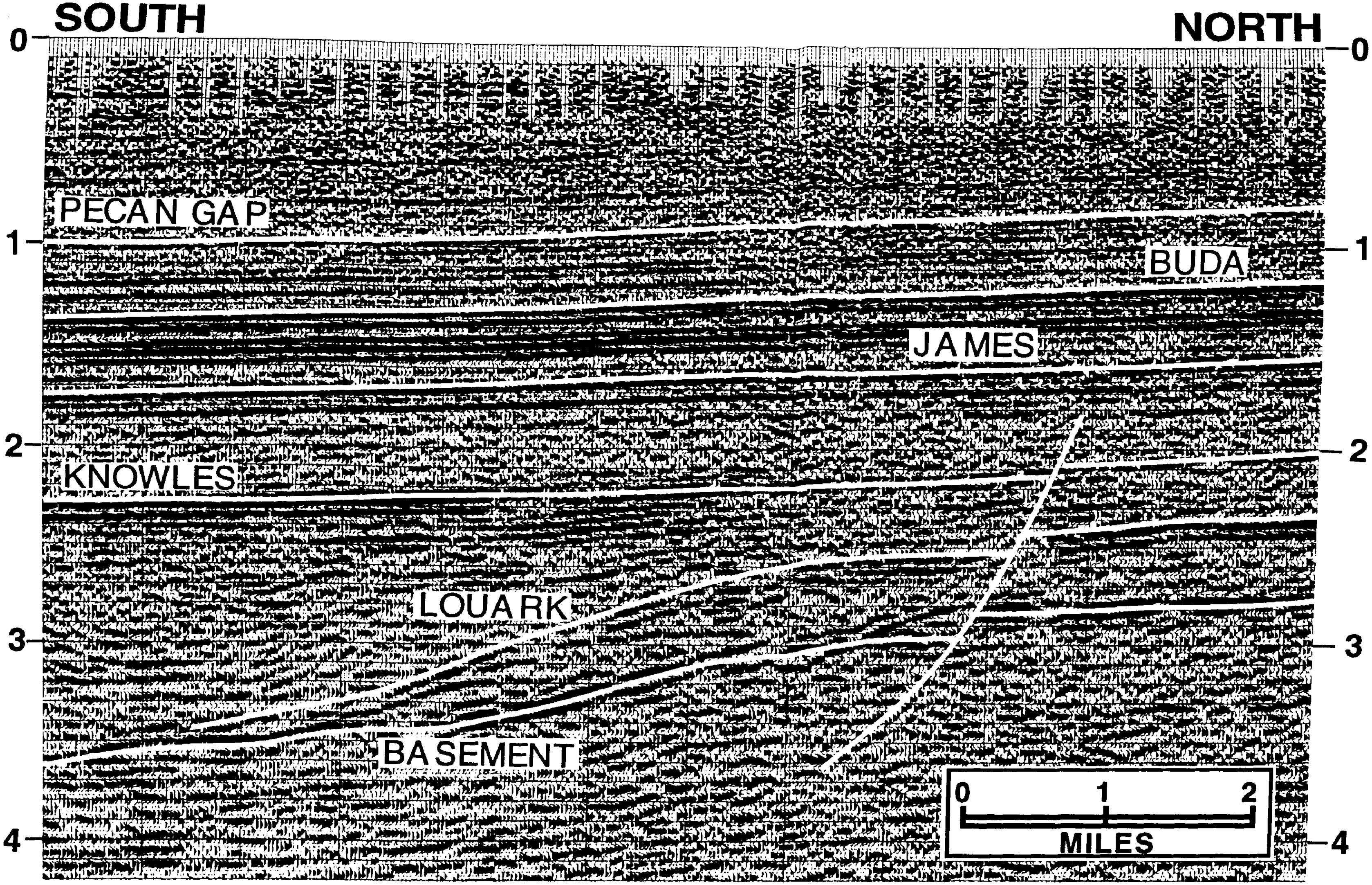

Figure 23 - Seismic profile showing character of the Louark shelf margin and associated shelf-to-basin topography. The Louark shelf margin is shown underlain by the structurally high Houston arch. Going from the arch southward into the Brazos basin, Louark Group sediment thin while overlying Cotton Valley Group strata thicken. Location of seismic profile shown in Figure 22 (line A).

300 ms, to more than 1000 ms thick. Interval velocities derived from check shot surveys indicate approximately 8,000 feet of depositional relief existed between the Louark shelf edge and the Brazos basin.

Tithonian - Valanginian

The sands and shales of the Cotton Valley Group represent the first significant influx of sediments into the Brazos basin. Prior to this, the Brazos basin was essentially starved of sediments. Deposition of the Cotton Valley group began in the Tithonian and continued into Early Berriasian (see figure 4). In the East Texas basin to the north, the Cotton Valley Group is overlain unconformably by Hauterivian age sediments of the Travis Peak Formation, and Valanginian rocks are absent. In the Brazos basin, seismic data indicates that the Cotton Valley Group is overlain by a large wedge of sediments not found in the East Texas basin. This wedge may represent part or all of the Valanginian sediments. The northern margin of the Houston embayment is rimmed by fault zones (see figure 2) which offset the Tithonian through Valanginian section. Equivalent rocks cannot be confidently identified south of this fault zone.

Thirty one wells across the study area penetrated rocks of the Cotton Valley Group. The wells are located around the western and northern edges of the Brazos basin. Eleven of these wells, mostly along the western margin of the Brazos basin, penetrated the entire Cotton Valley section reaching total depth in the Louark Group. Synthetic seismograms were produced for 14 wells, providing a good correlation between well log and seismic data.

Depositional environments for the sands and shales of the Cotton Valley Group include marginal marine to open shelf, and delta plain to prodelta (Figure 24). Davidoff (1989) analyzed well logs and well cutting reports from the northeastern portion of the study area (primarily Houston and Trinity counties). Results of his study indicated that in

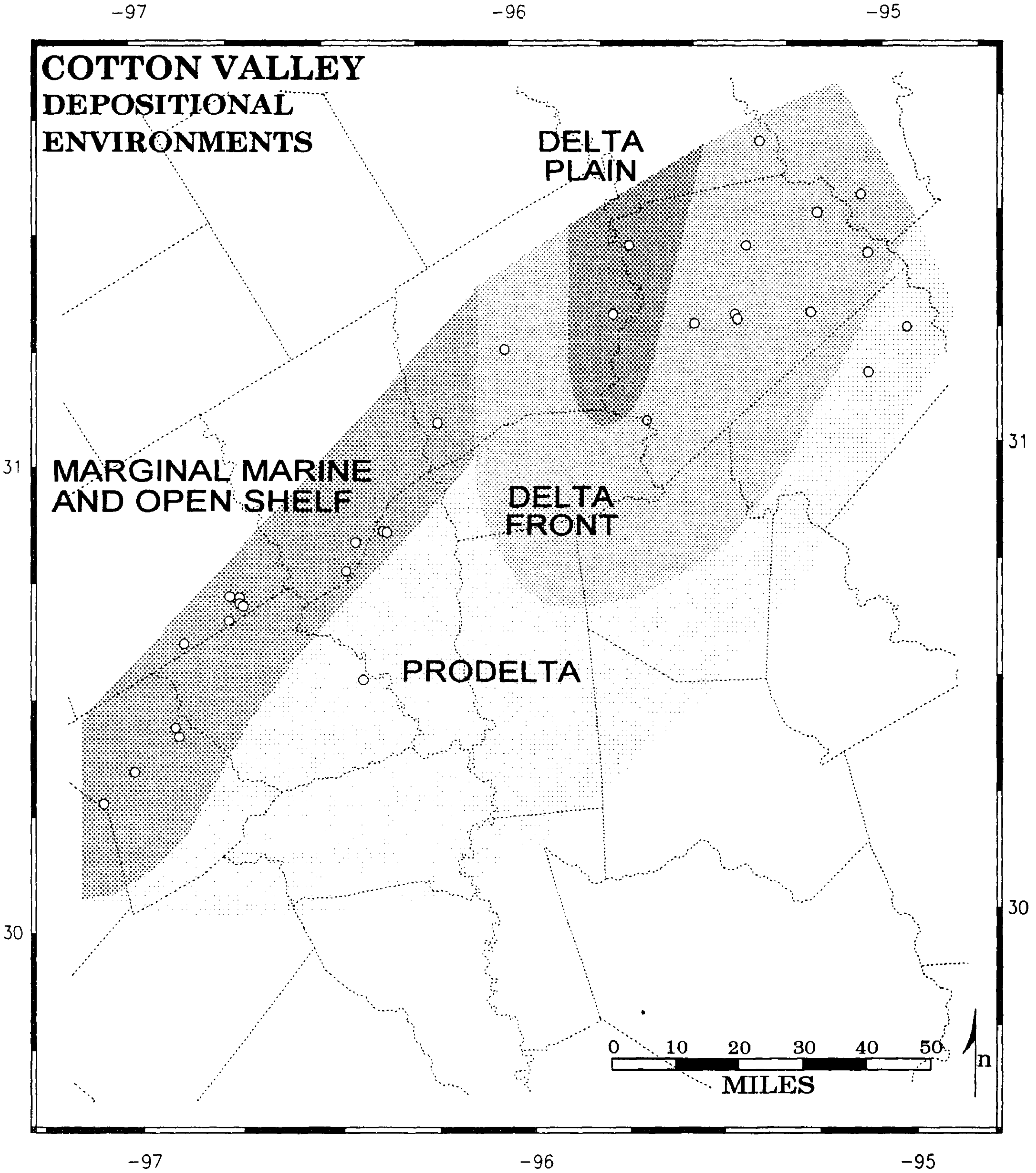

Figure 24 - Distribution of depositional environments for Cotton Valley Group siliciclastics (Tithonian to Berriasian), (modified from Davidoff, 1989). Depositional environments include; marginal to open marine, delta plain, delta front, and prodelta. Interpretation based on well log character and well cutting reports. Wells penetrations of the Cotton Valley Group are shown with open circles

this area, sediments of the Cotton Valley Group were deposited by a large prograding delta. Most wells in the northeast part of the study area reached total depth within the Cotton Valley section, with only one well penetrating the entire sequence. Gross thickness for sandstones deposited in the deltaic section ranges from a minimum of 2,500, to more than 4,500 feet. Well logs show the sands of the delta front to be arranged in coarsening-upward packages 100 to 200 feet thick.

Cotton Valley sediments along the western edge of the Brazos basin are underlain by the Louark shelf margin. Sandstone thickness in this area decreases abruptly. Electric logs indicate that individual sandstone units are generally less that 50 feet thick, separated by shale units of equal or greater thickness, suggesting deposition in marginal to open marine environments.Gross sandstone thickness ranges between 500 and 1,000 feet. Just down dip from this shelf setting, the well data indicates that sandstones associated with the Cotton Valley are absent.

Deposition of the Cotton Valley Group siliciclastics was interrupted by a brief transgression that led to the deposition of the Knowles Limestone Formation. Distribution of the limestone is shown in Figure 25, an isopach map of the formation. Northward thinning of the Knowles Limestone may be attributed to either updip facies changes or Valanginian erosion, or a combination of the two. Down dip thinning of the limestone appears depositional. Basinward the Knowles is overlain by shales and sands that are not related to the overlying Travis Peak Formation, and are not present in the East Texas basin to the north (Davidoff, 1989). These overlying sediments may represent Valanginian age deposition.

Location of the Knowles Limestone shelf margin is indicated by isopach thicks. Along the western portion of the study area, the Knowles shelf margin is approximately coincident with northwest margin of the Brazos basin, occurring just down dip from the Louark shelf margin. A significant offset in the trend of the shelf margin may be observed between Houston and Trinity counties. This offset may be related to right lateral strike slip

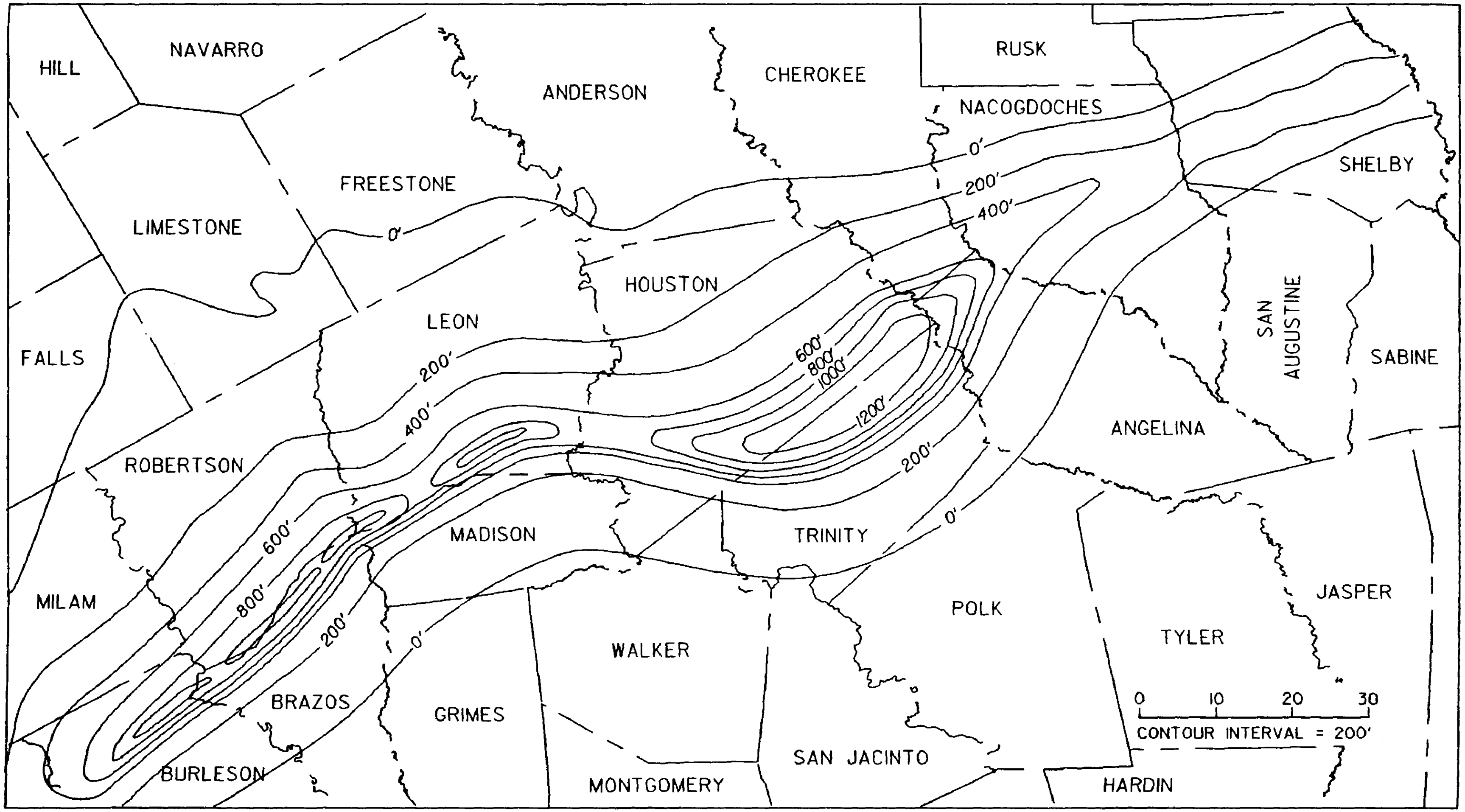

Figure 25 - Isopach map showing distribution for the Knowles Limestone of the Cotton Valley Group (from Davidoff, 1989), contour interval 200 feet. Isopach thicks are associated with the Knowles Limestone shelf margin. Offset of the shelf margin trend in Houston and Trinity counties may be related deep basement structure caused by earlier right-lateral, strike-slip movement.

movement in the underlying basement structure which offset salt deposits across the Houston arch (see above, Callovian salt and related structures).

Formations of the Cotton Valley Group are time transgressive and display rapid variations both laterally and down dip. Formational units therefore, do not provide an appropriate surface for regional mapping. There is however, a major unconformity above the Cotton Valley which spans the Valanginian and does provide an appropriate mapping surface (see Figure 4). Across the Houston arch and northward into the East Texas basin, the unconformity marks the top of the Cotton Valley Group. Where the Knowles Limestone is well developed the unconformity is indicated on seismic data by a prominent reflection (see Figure 13). To the north, where the Knowles Limestone is poorly developed or absent, reflection quality across the unconformity diminishes, but may still be identified as a prominent onlap surface (see Figure 15). Southward across the Brazos basin the unconformity climbs section to some undetermined extent, possibly through the Valanginian. Across this portion of the study area the unconformity surface is characterized by onlap and very pronounced toplap (see Figure 14). The amount of truncation, and the angle of the contact associated with this toplap surface increase southward onto the Angelina-Grimes terrace, suggesting uplift and erosion.

An isopach map from the top of the Valanginian unconformity to the top of basement is shown in Figure 26. The isopach interval includes rocks of the Louann, Louark and Cotton Valley groups, and unnamed sediments of probable Valanginian age. Maximum sediment thickness shown is over 16,500 feet, of which an estimated 3,000 to 4,000 feet is salt, and approximately 500 to 1,000 feet is Louark Group equivalents. The remaining 11,500 to 13,000 feet is composed of Cotton Valley and Valanginian sediments. Rocks included in the mapped interval represent the first major influx of sediments into the Brazos basin, and therefore provide the best picture of the basin's original structure. The isopach map indicates that the northern, western, and eastern flanks of the Brazos basin were very steep, while the floor of the basin was relatively flat, suggesting that the basin

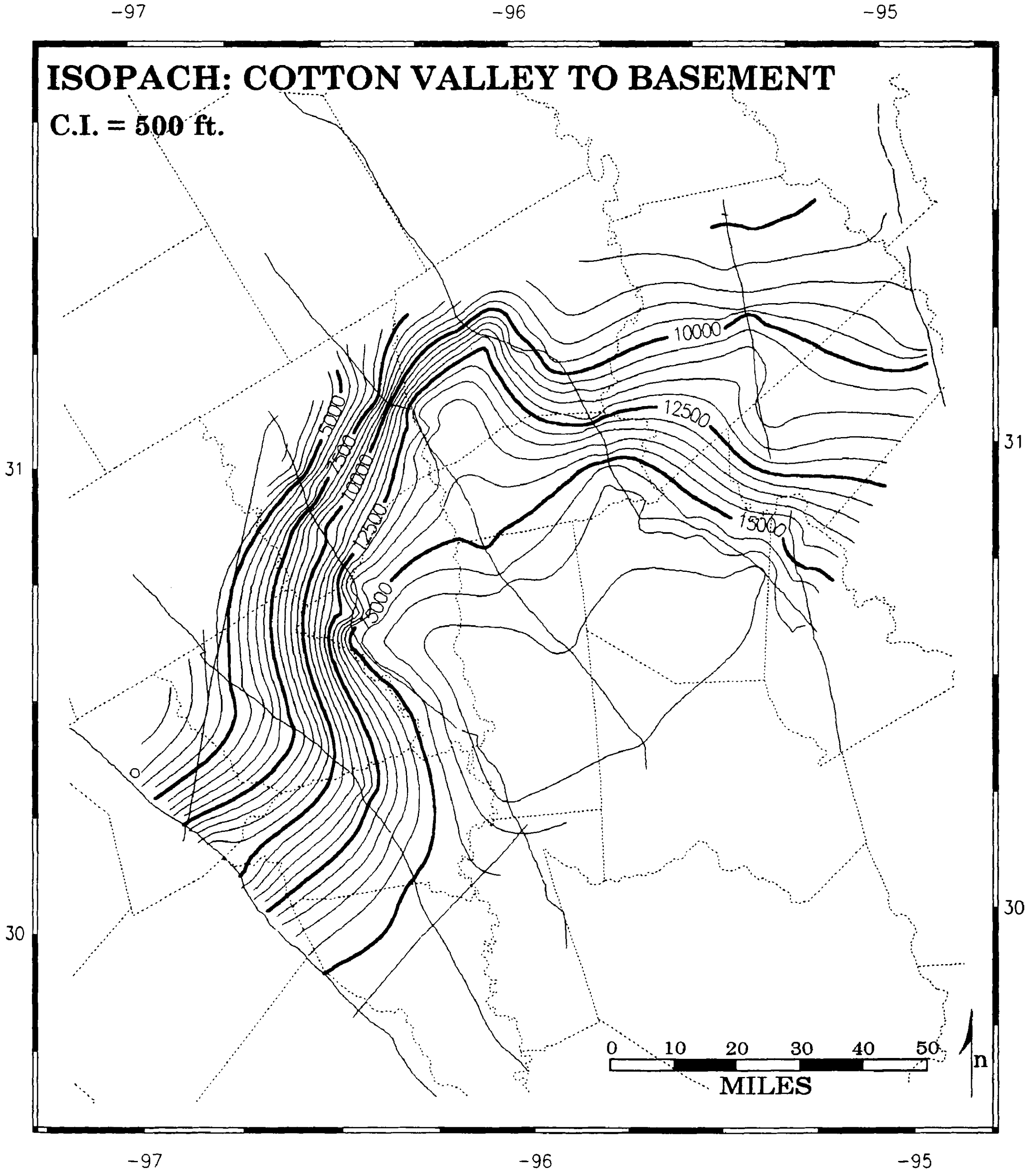

Figure 26 - Isopach map from the top of the Cotton Valley Group (Valanginian unconformity) to the top of basement (base Callovian Louann Salt). Contour interval is 500 feet. Stratigraphic thickening of the section is interpreted to reflect original post-rift basement structure. Rapid thickening of the section around the northern, western and eastern sides of the basin suggest that the basin formed as a fault bound graben. Well log penetration of basement rock is shown with an open circle. Approximate location of seismic data provided by Teledyne Exploration are shown with solid lines. Contours produced by GES have been edited to remove anomalies associated with salt structures and local faulting.

originated as a fault-bounded graben. The steep northeastern flank of the basin corresponds to offsets observed in the distribution of salt across the Houston arch, and in the Knowles limestone, which suggests that the basin is bounded in part by faults that have a significant strike-slip component. Details of the structure along the southeastern margin of the Brazos basin are obscured due to degradation in the quality of the basement reflector.

Hauterivian - Early Cenomanian

The Hauterivian through Early Cenomanian ages were dominated by carbonate deposition. Rocks deposited in the East Texas and Brazos basins during this time comprise the Trinity, Fredericksburg and Washita groups. These rocks form a second order stratigraphic sequence in the sense of Vail et al. (1977), bounded below by the Valanginian unconformity, and above by a Middle Cenomanian erosion surface. Across the study area 339 wells reached total depth in Early Cenomanian or older rocks, while 124 wells penetrated rocks of Aptian age and older. Synthetic seismograms were generated for 24 of these wells, providing an excellent correlation between seismic and well log data.

Generalized distribution of depositional environments for Hauterivian through Lower Cenomanian rocks are shown in Figure 27. Northwest of the Angelina-Grimes terrace, sediments were deposited in relatively shallow water, back reef environments. These back reef rocks are subdivided into Groups, Formations and Members on the basis of regional shale or anhydrite units which may be easily correlated across the entire study area. Well log and seismic data show that regions underlain by the Brazos and East Texas basins received a greater thickness of sediments, indicating that they subsided slightly faster than the surrounding area. The strata thin across the Houston arch and southward onto the Angelina-Grimes terrace, suggesting that these features were structurally positive throughout this time.

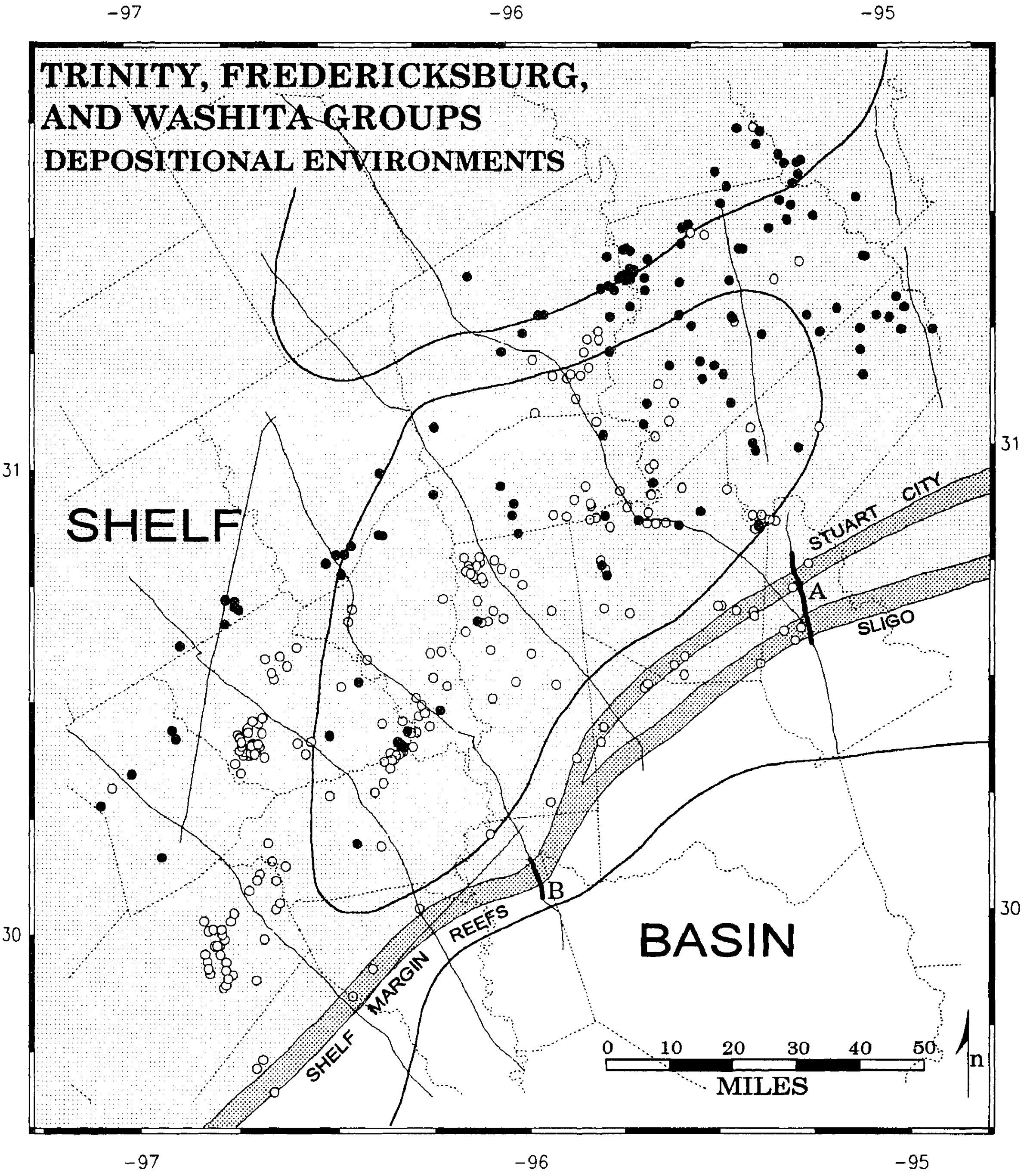

Figure 27 - Distribution of depositional environments for the Trinity, Fredericksburg, and Washita groups (Hauterivian through Lower Cenomanian). Light gray indicates deposition in shallow shelf environments. The location of the Sligo and Stuart City shelf margin reefs are shown in dark gray, deep basin environments are unshaded. Interpretation is based on well logs and seismically observed locations of shelf margin reefs. Well log penetrations of Aptian and older strata are shown with solid circles, penetrations of Lower Cenomanian and older rocks are shown with open circles. Approximate location of seismic data provided by Teledyne Exploration are shown with solid lines. A) Location of seismic profile shown in Figure 28. B) Location of seismic profile shown in Figure 29.

The Angelina-Grimes terrace provided a stable platform which localized Hauterivian through Lower Cenomanian shelf-margin reefs along the southeastern margin of the Brazos basin. These reefs are subdivided into the Sligo and Stuart City shelf margins. Development of the Sligo shelf-margin reefs began in the Hauterivian and continued into the Aptian. Shelf margin development was terminated by a series of rapid sea-level rises in Late Aptian which drowned the reefs (Scott et al., 1988). Development of the Stuart City shelf-margin reefs started at the beginning of the Albian and continued into the Early Cenomanian. The Stuart City and Sligo shelf-margin reefs overlie one another across the southwest part of the study area (Figure 27). In the eastern part of the study area the two reef trends bifurcate, the Stuart City shelf-margin reefs back stepping the underlying Sligo shelf margin. To the southeast, the Houston embayment was essentially starved of sediments.

The character of the Sligo and Stuart City shelf margins across the eastern half of the study area is shown on a seismic profile in Figure 28. The Valanginian unconformity surface at the base of the Hauterivian to Lower Cenomanian sequence is indicated by a well developed toplap pattern just below the Knowles reflector at the southern end of the profile. The top of the Sligo shelf-margin reefs and equivalent back reef strata is indicated by a strong continuous reflector from the top of the James Limestone Member of the Pearsall Formation (see Figure 4). The reflector above the James is from the Middle Cenomanian unconformity. It is a strong regional reflector produced from the top of the Buda Formation, and marks the top of the Hauterivian through Lower Cenomanian sequence.

The Sligo shelf margin is located at the southern end of the seismic profile in Figure 28, and is indicated by an increase in dip of the James reflector. Sligo shelf margin reefs are associated with the reflection free zone below the James reflector. The Stuart City shelf margin occurs at the northern end of the seismic profile, appearing as a rapid increase in dip of the Buda reflector. Stuart City shelf margin reefs are associated with the reflection

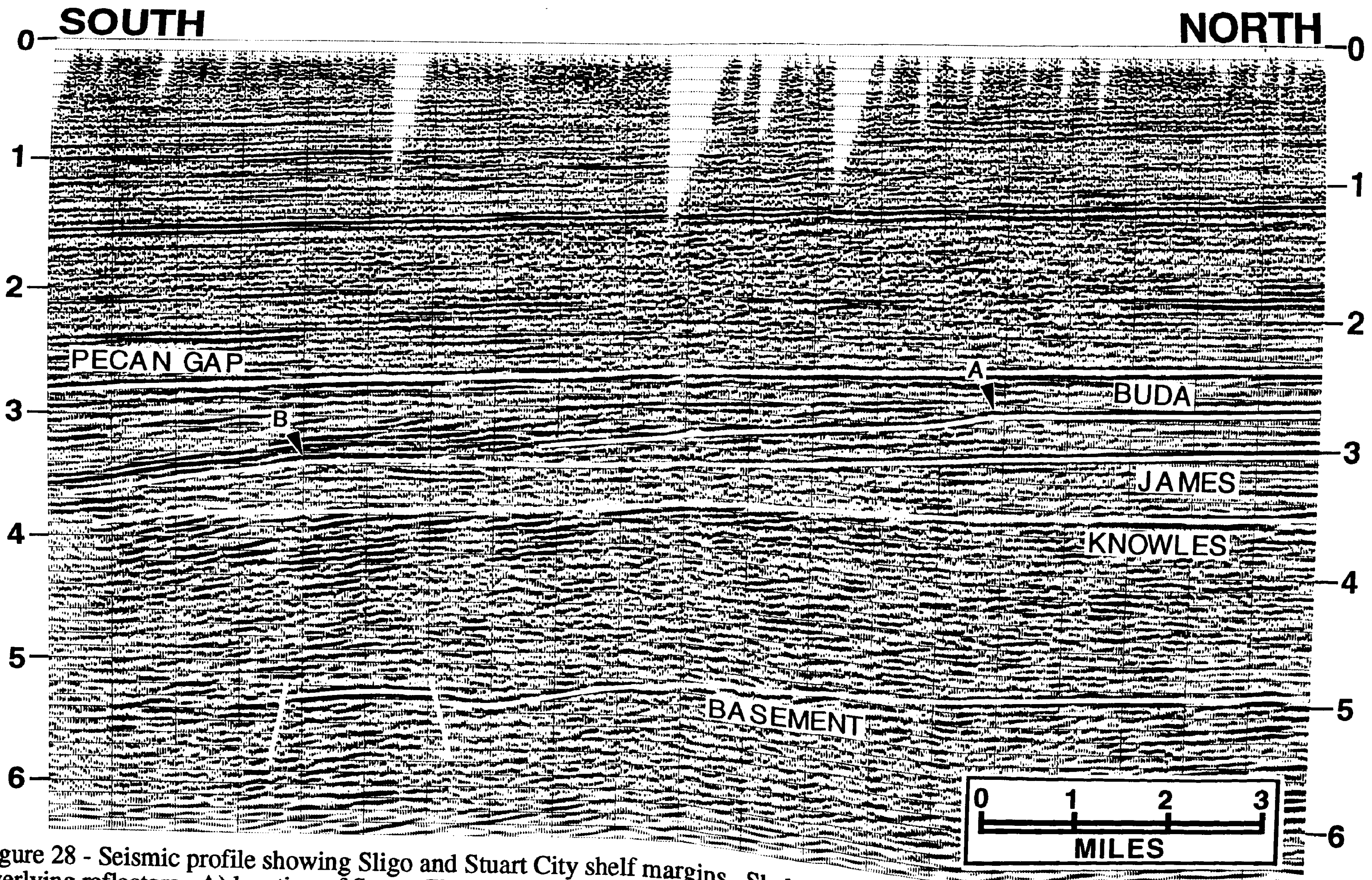

Figure 28 - Seismic profile showing Sligo and Stuart City shelf margins. Shelf margins are indicated by a distinct increase in dip of overlying reflectors. A) location of Stuart City shelf margin, B) location of Sligo shelf margin. Location of seismic profile shown in Figure 27 (line A)

free zone immediately below the Buda reflector. South of the Stuart City shelf margin, overlying Late Cretaceous strata onlap the Middle Cenomanian unconformity surface. Seismic and well log data indicate that depositional topography across the Stuart City shelf margin was approximately 1,200 feet. Depositional topography associated with the Sligo shelf margin could not be estimated due to faulting immediately south of the shelf edge.

The seismic profile presented in Figure 29 shows the character of the Stuart City shelf margin from the southwestern portion of the study area. The shelf margin is located in the center of the profile, and is indicated by a marked increase in the dip of the Buda reflector. Shelf-margin reefs below the Buda reflector are associated with mounded reflections immediately below the shelf edge. South of the shelf edge, overlying Upper Cretaceous strata onlap the Middle Cenomanian unconformity surface. The Sligo shelf margin could not be clearly identified on this profile, but is assumed to underlie the Stuart City shelf margin. Shelf-to-basin topography could not be estimated along this profile due to faulting immediately to the south. However, 400 ms of onlap shown on the data indicate that it was greater than 2,000 feet.

Distribution of Hauterivian through Aptian sediments is shown in Figure 30, an isopach from the top of the Valanginian unconformity to the top of the James Limestone. The map shows a distinct sediment thickening associated with the Brazos basin. Maximum sediment thickness for the mapped interval across the southwest and central parts of the basin is between 4,200 and 4,800 feet. Thickening of the sediments in these areas are attributed to differential subsidence within the Brazos basin. In the northeast corner of the basin, maximum sediment thickness reaches almost 7,000 feet. Seismic data suggest that this anomalous thickness is related to large scale salt movement during deposition. Sediments are also shown thinning northward onto the Houston arch, and towards the southeast onto the Angelina-Grimes terrace, indicating that these were both structurally positive features.

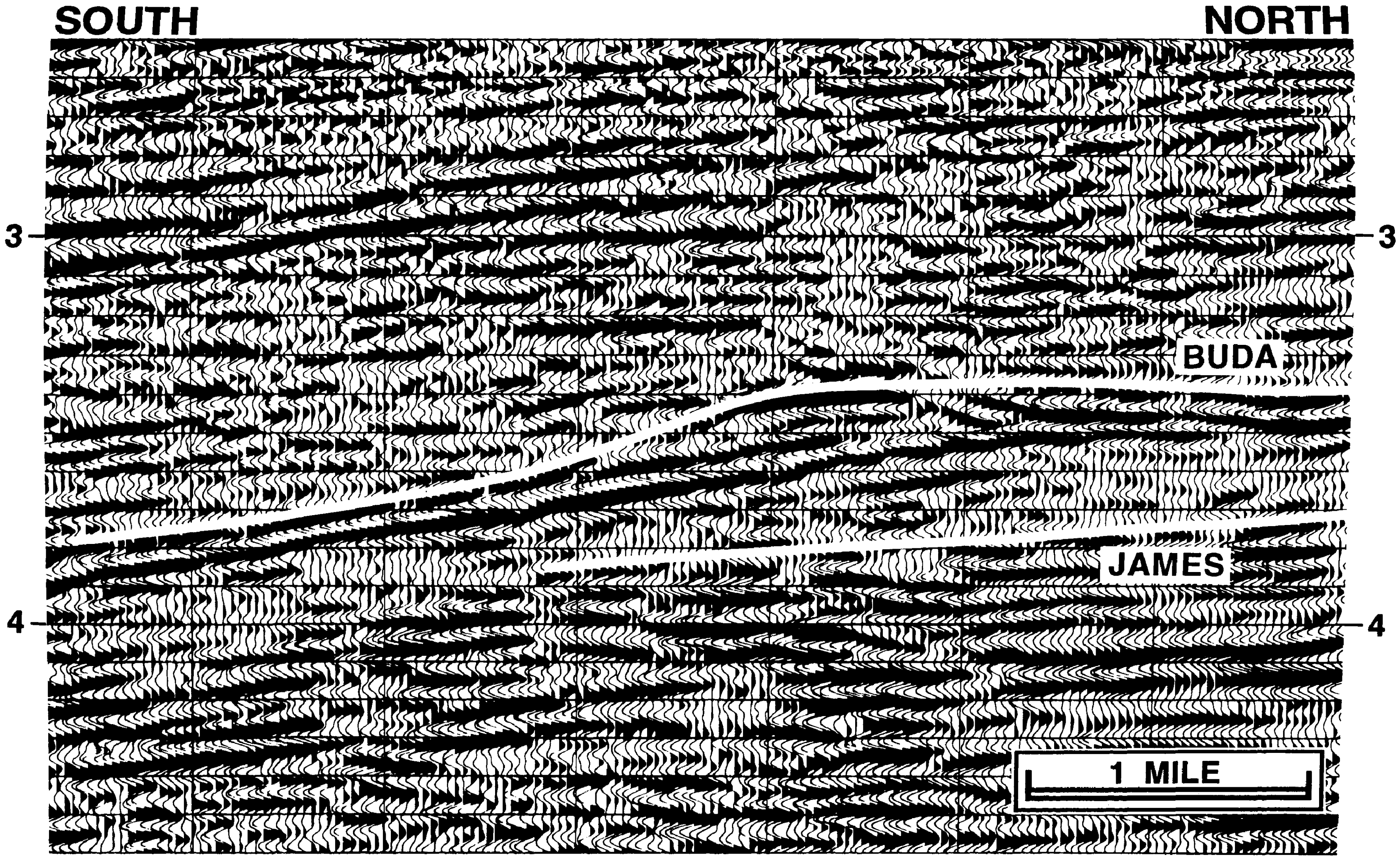

Figure 29 - Seismic profile showing Stuart City shelf margin. The shelf margin is indicated by a marked increase in dip of the Buda reflector. Underlying shelf margin reefs expressed as mounded reflectors. Sligo shelf margin is assumed to underlie the Stuart City margin, but is not clearly expressed on the profile. Location of seismic profile shown in Figure 27 (line B)

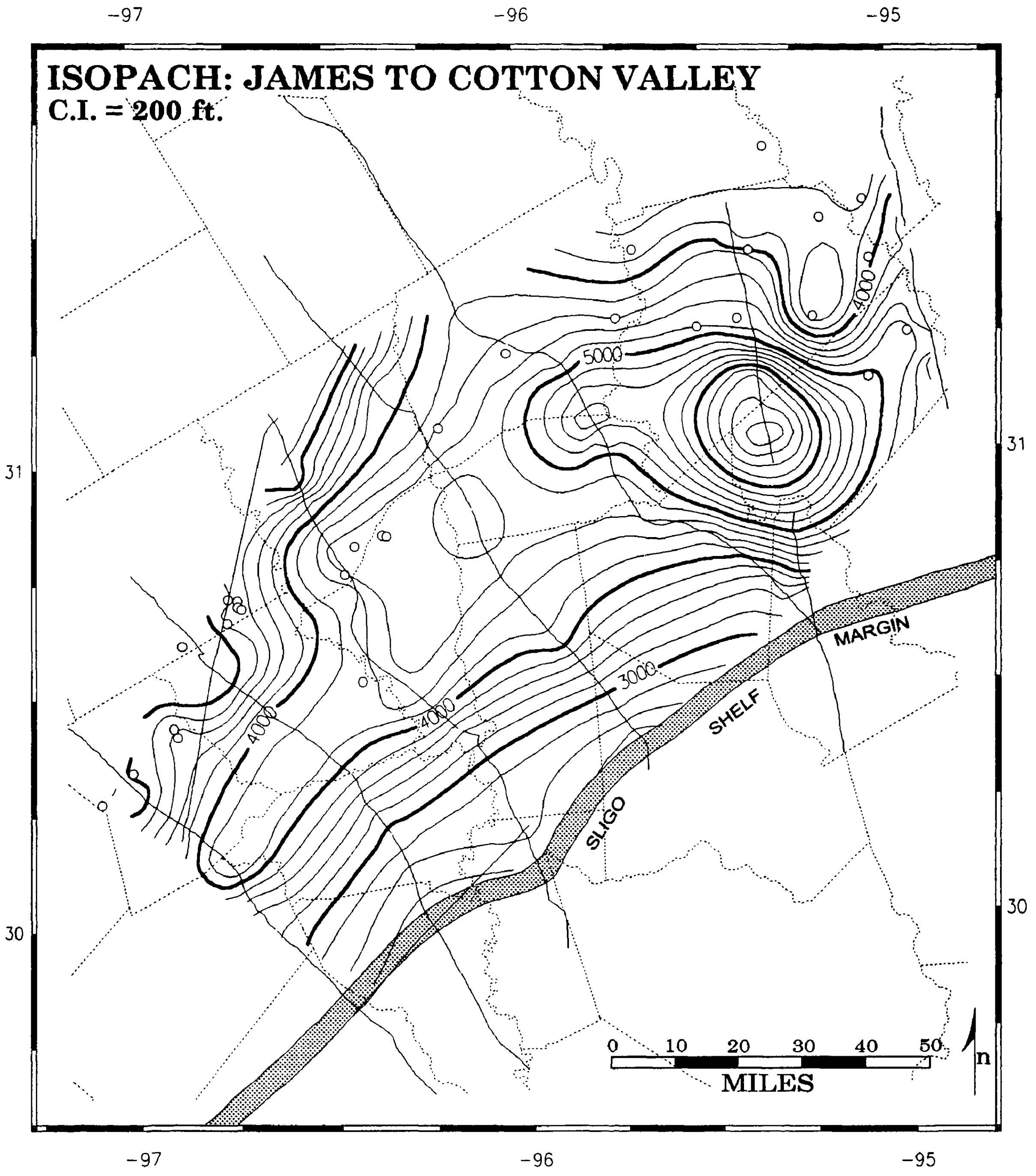

Figure 30 - Isopach map from the top of the Cotton Valley Group (Valanginian unconformity) to the top of the James Limestone (Aptian). Contour interval is 200 feet. Thickening of the section in the southwestern and central part of the basin is interpreted to be related to differential subsidence of the Brazos basin. Anomalous thickening of the section in the eastern part of the basin is probably related to large scale salt movement. Location of the Sligo shelf margin reefs are shown in gray. Well log penetration of the pre - Hauterivian rocks are shown with open circles. Approximate location of seismic data provided by Teledyne Exploration are shown with solid lines. Contours produced by GES have been edited to remove anomalies associated with local salt structures and related faulting.

Distribution of Albian through Early Cenomanian age rocks are similar to the underlying Hauterivian through Aptian strata. Distribution of these rocks are shown in Figure 31, an isopach from the top of the James Limestone to the top of the Buda Formation. Within the Brazos basin these sediments reach an average maximum thickness of 3,800 feet, significantly less than that which accumulated from the Hauterivian to the Aptian, suggesting that the rate of subsidence within the basin had diminished. Thinning of strata across the Houston arch is also less pronounced than that observed in older sections. The strata still display substantial thinning towards the southeast onto the Angelina-Grimes terrace, indicating that it was still a pronounced structural high.

Late Cenomanian - Maastrichtian (Late Cretaceous)

Late Cenomanian through Maastrichtian sediments are composed primarily of shales and marls. The presence of minor sandstone and limestone units forms the basis for subdividing the section into groups and formations. These sandstone and chalk units are highly variable both laterally and in a dip direction, with most lithostratigraphic units lacking the continuity necessary for regional mapping and stratigraphic analysis. Across the study area, 452 of the wells acquired penetrated rocks of Maastrichtian age and older. The well data indicate that only two chalk units maintain enough lateral continuity to be useful for regional mapping (see Figure 4). The youngest of these two chalk units is the Middle Campanian Pecan Gap Formation. This chalk unit ranges from 100 to 700 feet thick, is easily correlated on well logs across the study area, and produces a strong continuous reflector on seismic profiles. Maastrichtian through Early Paleocene strata that overlie the Pecan Gap are composed almost exclusively of shale, and generally appear on seismic profiles as a reflection free interval.

Sediments distribution for most of the Late Cretaceous interval is shown on an isopach map in Figure 32. The isopach interval is from the top of the Middle Cenomanian

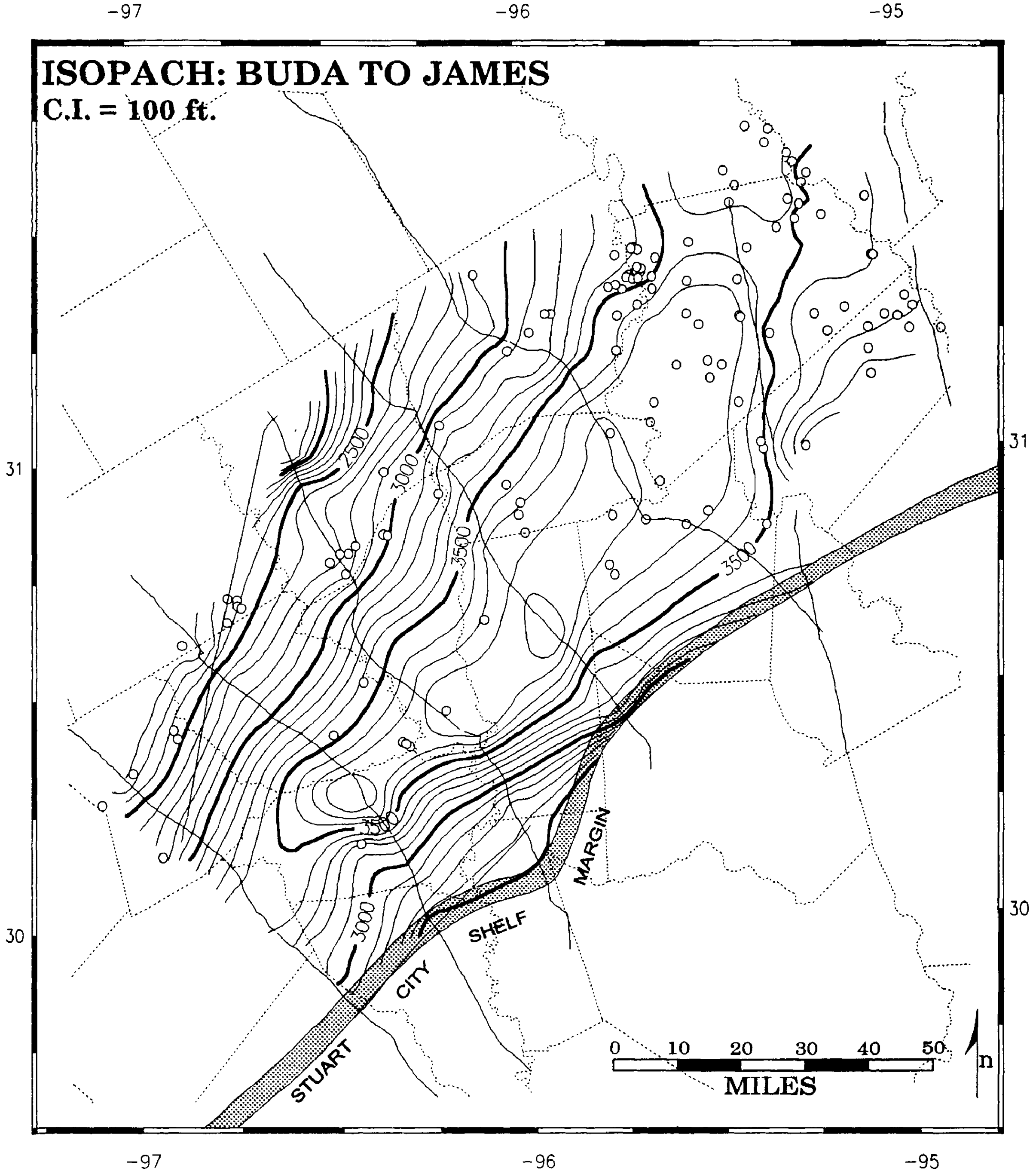

Figure 31 - Isopach map from the top of the James Limestone (Aptian) to the top of the Buda Formation (Middle Cenomanian unconformity). Contour interval is 100 feet. Thickening of the section is related to differential subsidence within the Brazos basin. Location of the Stuart City shelf margin reefs are shown in gray Well log penetration of Aptian age rocks are shown with open circles. Approximate location of seismic data provided by Teledyne Exploration are shown with solid lines. Contours produced by GES have been edited to remove anomalies associated with local salt structures and related faulting.

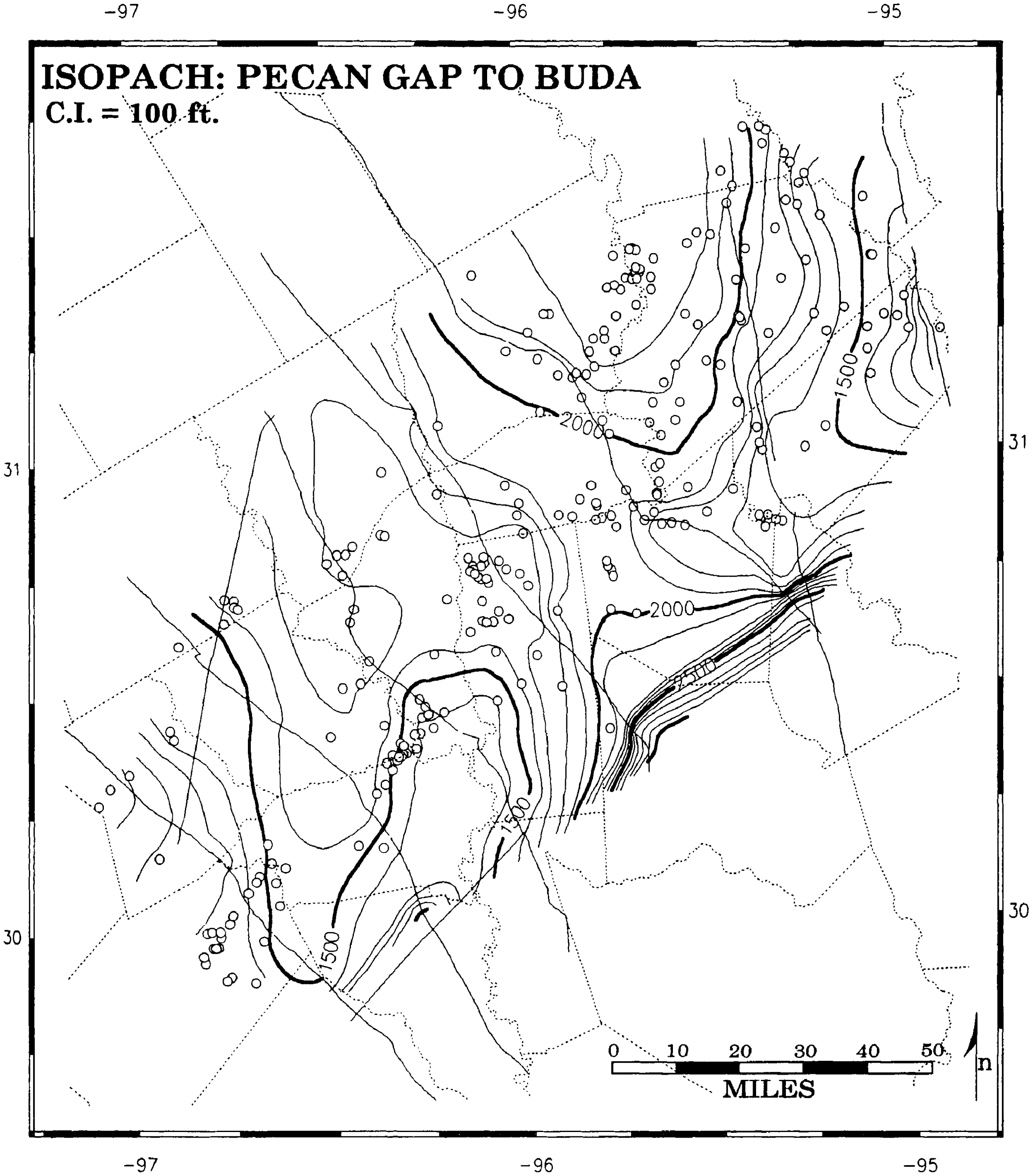

Figure 32 - Isopach map from the top of the Buda Formation (Middle Cenomanian unconformity) to the top of the Pecan Gap Formation (Campanian). Contour interval is 100 feet. Strata show a general thinning from the Houston arch southward onto the Angelina Grimes terrace, no thickening of the section associated with the Brazos basin is evident. Well log penetration of the Lower Cenomanian age rocks are shown with open circles. Approximate location of seismic data provided by Teledyne Exploration are shown with solid lines. Contours produced by GES have been edited to remove anomalies associated with local salt structures and related faulting.

erosion surface (top Buda Formation), to the top of the Campanian Pecan Gap Formation. The isopach map shows that the general trend is for sediments to thin southward onto the Angelina-Grimes terrace, and thicken northward across the Houston arch. South of the Stuart City shelf margin sediments thicken rapidly. The isopached interval could not be correlated with confidence south of the Sligo shelf margin due to faulting. Pronounced thickness variation observed in isopach maps of older sediments, and particularly thickening of the strata within the Brazos basin, are not observed in the Upper Cretaceous sediments.

The absence of stratigraphic thickening across the Brazos basin indicates that by the Late Cretaceous, differential subsidence within the basin had diminished to the point that it no longer existed as a unique structural unit. The Brazos basin apparently still influenced the location of depositional systems during the Late Cenomanian through Turonian. Net sand maps and cross sections for the Woodbine - Eagle Ford interval (Turner and Conger, 1981; and Porter, 1987) show a thickening of the Harris delta sands within the center of the Brazos basin, suggesting that the basin controlled the location of the delta. However, total sediment isopach for the same interval shows no significant thickening associated with the basin.

By Late Cretaceous the Houston arch was no longer impacting sediment distribution patterns. Thickening of the Upper Cretaceous strata across the arch suggests that the feature was subsiding at about the same rate as the rest of the central East Texas region. General thinning of the strata southward onto the Angelina-Grimes terrace indicates that it was still a structurally positive feature, although not as pronounced as it was during the Jurassic and Early Cretaceous. This is supported by well log data that show several unconformities present along the terrace. From northern Austin to southern Grimes counties the Woodbine and Eagle Ford intervals are absent, with the Austin Chalk resting unconformably on the Stuart City shelf margin, and in northern San Jacinto County the Austin Chalk interval is absent.

Tertiary

Siliciclastic Tertiary rocks represent the first major influx of sediments into the Houston embayment (see Figure 4). To the north across the East Texas basin, Tertiary strata are relatively thin, reaching an average maximum thickness of about 2,000 feet (Wood and Guevara, 1981). South of the Houston arch the Tertiary section starts to expand. In the Brazos basin these sediments reach a maximum thickness of about 10,000 feet in the southern part of the basin. The section expands rapidly across a regional growth fault trend just downdip from the Lower Cretaceous shelf margin reefs. Well data from the Houston embayment indicate the section there is in excess of 20,000 feet thick.

Tertiary strata thicken uniformly across the Brazos basin following regional dip, there is no evidence for significant thickening of the strata associated with the Brazos basin. There is also no apparent thinning of the strata across the Angelina-Grimes terrace, indicating it was no longer a structurally positive feature. Subsidence of the Angelina-Grimes terrace was probably the result of sediment loading to the south in the Houston embayment. This sediment loading resulted in flexural subsidence from a hinge line approximately coincident with the Houston arch southward across the Brazos basin, and reversed the former northward dip along the Angelina-Grimes terrace.

Although Brazos basin was no longer subsiding enough to be considered a distinct basin, it continued to have an influence on depositional systems. Maps of the lower Wilcox Rockdale delta system (Fisher and McGowen, 1967) show that individual deltas within the Brazos basin tend to be lobate and stack vertically, where as those outside the basin are more sinuous and are not stacked. Gross isopach maps of the Wilcox sands show that there is minor thickening of these sands within the Brazos basin. Outcrop studies have also shown that sand intervals across the Brazos basin tend to thicken slightly (Renick, 1936).

STRUCTURAL DEVELOPMENT AND GEOLOGIC HISTORY

The East Texas region is a product of Late Triassic through Middle Jurassic rifting that opened the Gulf of Mexico basin. Palynoflora found in syn-rift rocks (Eagle Mills Formation) indicate that rifting started in the Late Triassic, Carnian age (Beju et al., 1986; Moy and Traverse, 1986). The transition from rifting to sea-floor spreading is associated with the change from restricted marine evaporites of the Louann Group to open marine carbonates of the Louark Group, and placed at the beginning of the Late Jurassic, Oxfordian age (Salvador, 1987). Rifting processes operating throughout this time attenuated the pre - Mesozoic continental crust. The general trend is for attenuation to increase, and crustal thickness to decrease southward across eastern Texas (Sawyer et al., 1991). Compositional differences in the pre-rift basement, and/or irregularities in the rifting process, disrupted the regional trend, created zones of contrasting crustal thicknesses (Buffler and Sawyer, 1985; Dunbar and Sawyer, 1987), and produced the major basement structures of the East Texas region. The thicker stratigraphic sections in the East Texas basin, Brazos basin, and Houston embayment are attributed to greater structural attenuation in the underlying crustal rocks. Conversely, relatively thin stratigraphic sections over the Houston arch and Angelina-Grimes terrace are interpreted to be the result of underlying blocks of comparatively thick crustal material which subsided more slowly.

Simmons (1992) observed two northwest - southeast trending lineations in salt structures of the South Louisiana Shelf, and Texas - Louisiana Slope salt provinces (see Figure 1). He proposed that the lineations were related to major transfer faults formed during rifting of the Gulf, and extended the lineations northwest into eastern Texas where they formed the northeast and southwest boundaries of the Brazos basin. Results of this study strongly support this hypotheses, indicating that the Brazos basin formed between two transfer (strike slip) faults. Isopach maps of Middle Jurassic, Callovian through Early

Cretaceous, Valanginian rock (see Figure 26) suggest that the Brazos basin originated as a faulted depression, with bounding faults along the southwest, northwest, and northeast sides. The southwest and northeast bounding faults correspond to the transfer faults postulated by Simmons (1992). Offsets in the distribution of Louann Salt across the Houston arch (see Figure 16) and in the trend of the Knowles Limestone shelf margin (see Figure 25) indicate right-lateral, strike-slip movement along the northeast bounding fault. Nature of the motion along the southwest bounding fault is not clearly constrained by the data. However, offsets in the Lower Cretaceous shelf margin reefs suggest left-lateral, strike-slip movement (see Figure 27).

The general structure and geologic history of the Brazos basin is schematically illustrated in Figure 33. Regional morphology of the basin suggests that it originated as a large half-graben (Figure 33A). The primary bounding fault for the half-graben is proposed to occur along the south flank of the Houston arch, with dip-slip motion, downthrown to the southeast. Placement of this fault is based on shelf-to-basin topography along the Louark shelf edge (see Figure 22) and rapid thickening of Oxfordian through Valanginian strata (see Figure 26). The southeast margin of the Brazos basin and the Angelina-Grimes terrace, although cut by numerous small basement faults, lack evidence for large scale basement faulting, as indicated by rapid thickening of Callovian through Valanginian strata observed along the southwest, northwest, and northeast sides of the basin. South of the Angelina-Grimes terrace seismic data suggest another major basement fault (see above, Basement character and structure). These observations suggest that the south flank of the basin and the Angelina-Grimes terrace were formed by the northward rotation of a major basement fault block. Crustal material below the northwest end of the fault block was relatively thin and subsided, producing the Brazos basin. Crustal material along the southeastern edge of the fault block was relatively thick, subsided less than the surrounding region, and formed the Angelina-Grimes terrace.

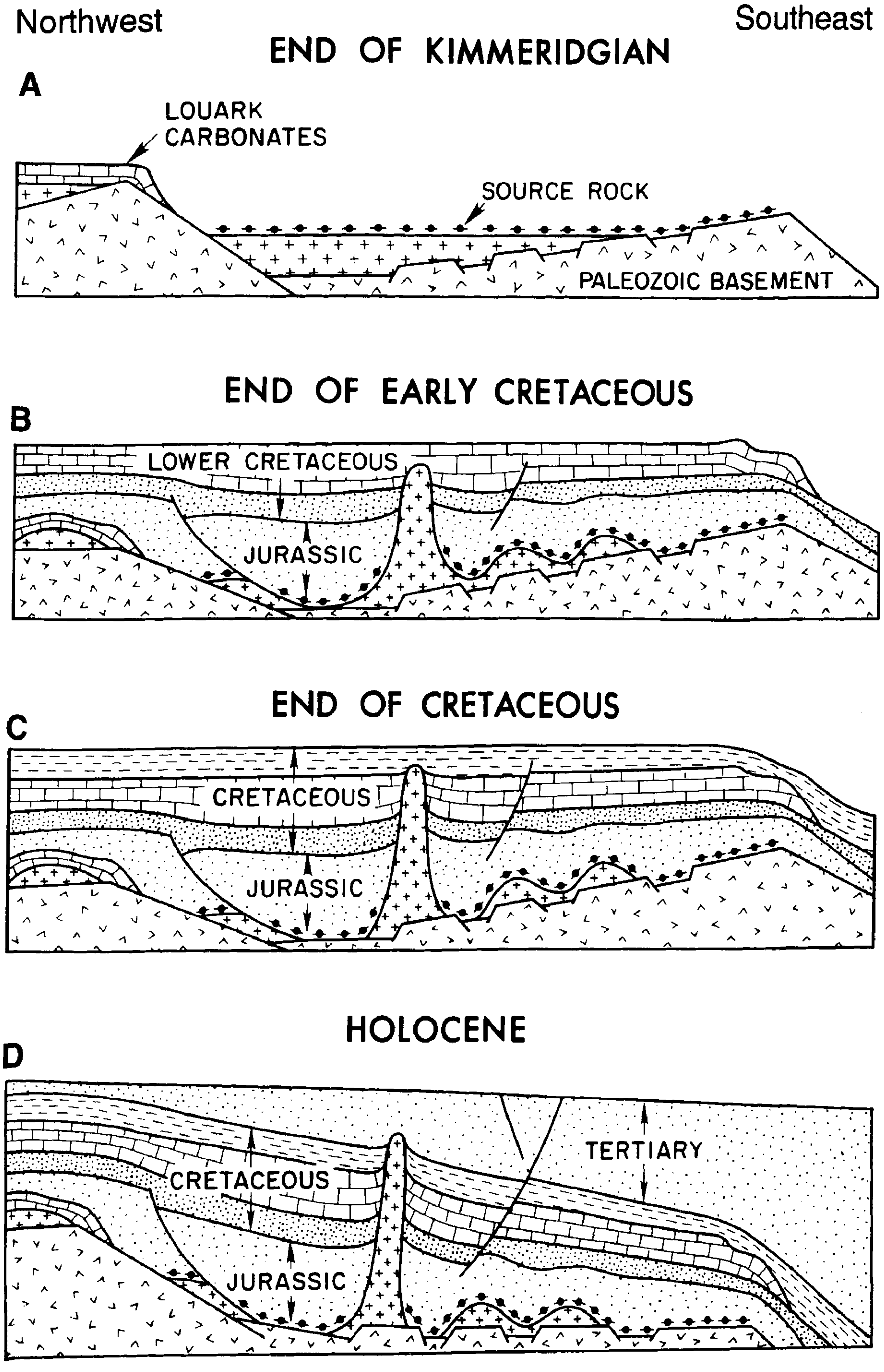

Figure 33 - Diagrammatic cross-sections of central East Texas showing the structural development and geologic history of the Brazos basin (not to scale). A) End of Kimmeridgian - The Brazos basin originated as a large half graben. Salt was deposited during the Callovian. Between Oxfordian and Kimmeridgian the basin was sediment starved. B) End of Early Cretaceous - Primary filling of the Brazos basin, and deformation of salt within the basin occurred during the Tithonian age and Early Cretaceous epoch. C) End of Late Cretaceous - During the Late Cretaceous differential subsidence within the Brazos basin had ceased to significantly influence depositional patterns. D) Tertiary - Influx of clastic sediments to the south caused the Angelina-Grimes terrace to subside producing the basins present day structure.

Initial incursion of marine waters into eastern Texas occurred at the very end of the rifting process, and is represented by Callovian evaporites of the Louann Group, primarily the Louann Salt. These evaporites were deposited and preserved in regions of enhanced crustal attenuation, the East Texas basin, Brazos basin, and Houston embayment. Maps of crustal attenuation published by Sawyer et al. (1991), and total sedimentary cover, indicate that crustal material is thickest below the East Texas basin, and thins progressively southward below the Brazos basin and Houston embayment. Assuming an isostatic response to crustal attenuation at the time of salt deposition, the depression created by crustal thinning should have been shallowest below the East Texas basin, deeper below the Brazos basin, and deepest below the Houston embayment. However, thickness of the Louann Salt within each of basin does not match the probable topography at the time of deposition. Estimates of original salt thickness indicate that the Louann Salt of the East Texas basin was of intermediate thickness (5,000 feet, Jackson and Seni, 1983; Seni and Jackson, 1983), thinnest in the Brazos basin (3,000 to 4,000 feet, see above, Callovian salt distribution and related structures), and thickest in the deep Gulf of Mexico basin (13,000 feet, Salvador, 1987). Clearly, depositional topography alone does not explain the distribution of salt in eastern Texas.

Thickness of the Louann salt was probably controlled by a combination of depositional topography, and gradual lowering relative sea-level in the Callovian Gulf Coast basin. The Louann Salt of the East Texas basin occurs in a stratigraphically similar, but structurally higher position than the Louann Salt of the Brazos basin (Figure 33A). These structural and stratigraphic relationships may be explained by initial deposition of salt in the East Texas basin, followed by a lowering of sea-level, and subsequent deposition of salt in the Brazos basin and Houston embayment. Topographic relief along the Houston arch may have provided a sill that produced restricted environments for deposition of the East Texas basin Louann Salt, and may have also controlled ultimate thickness of the evaporites (Figure 33A). Following deposition of the East Texas basin

Louann Salt, lowering of relative sea-level allowed progradation of the eolian Norphlet Sandstone. Sandstones equivalent to the Norphlet are not found in the Brazos basin. The southward progradation of these sandstones was probably blocked by the Houston arch.

Following deposition of salt in the East Texas basin, the Callovian seas regressed to a location just south of the Houston Arch, at which point salt deposition in the Brazos basin and Houston embayment began. The relationship of the salt deposits in the Brazos basin and Houston embayment is not entirely clear. The Angelina-Grimes terrace may have provided a sill behind which Louann Salt of the Brazos basin was deposited, with salt in the Houston embayment deposited later. Alternatively, salt deposition within the two basins may have been contemporaneous, with salt deposition in the Brazos basin terminating before that in the Houston embayment. In either event, thinning of the section overlying the Angelina-Grimes terrace, and numerous unconformities present within that section, strongly suggest that the terrace was a structurally high feature that separated salt deposits of the two basins.

Generalized structure and stratigraphy of the Brazos basin at the end of the Kimmeridgian is illustrated in Figure 33A. At the beginning of the Oxfordian age, continental rifting proceeded to sea-floor spreading, and open marine conditions were established across the Gulf of Mexico basin (Salvador, 1987). Carbonate sediments of the Louark Group (Oxfordian through Kimmeridgian) comprise the first major post-rift sequence deposited. To the north, in the East Texas basin, these sediments were deposited in shallow water environments, while the Brazos basin and Houston embayment to the south were essentially starved of sediments. The Louark shelf margin was established along the structurally high Houston arch, with an estimated 8,000 feet of relief between the shelf margin and Brazos basin.

Figure 33B illustrates diagrammatically the structure and stratigraphy across the Brazos basin at the end of the Early Cretaceous. The first significant volume of sediments to reach the Brazos basin were Tithonian and Berriasian age siliciclastics of the Cotton

Valley Group, and overlying sediments of probable Valanginian age. These siliciclastic rocks are in turn overlain by Hauterivian through Lower Cenomanian carbonates of the Trinity, Fredericksburg, and Washita groups. Isopach maps of these rocks (see Figure 10) demonstrate that the Brazos basin existed as a unique structural feature until the end of the Early Cretaceous. During the Tithonian age and Early Cretaceous epoch the East Texas and Brazos basins were separated by the Houston arch. The Angelina-Grimes terrace was also structurally positive throughout this time. The terrace separated the Brazos basin from the Houston embayment to the south, and localized the Lower Cretaceous shelf margin reef trend. The Houston embayment was still essentially sediment starved.

Factors which effected sediment distribution patterns in central East Texas during the Tithonian through Early Cretaceous include differential subsidence of the Brazos basin, and salt deformation within the basin. Studies of passive margins and rifted basins indicate that subsidence of these features is a combined response of isostatic compensation to crustal attenuation, thermal cooling of the lithosphere, and sediment loading (McKenzie, 1978; LePichon and Sibuet, 1981; and Bond and Kominz, 1988). Significant shelf to basin topography between the Louark shelf margin and the Brazos basin indicate rapid subsidence of the Brazos basin during the Late Jurassic. This initial subsidence was probably an isostatic response to crustal thinning. Isopach maps of Callovian through Valanginian age sediments (see Figure 26) are strongly influenced by in-filling of accommodation space created by this isostatic subsidence, and therefore reflect original rift related basement structure. Comparison of detailed isopach maps for the Upper Jurassic through Lower Cretaceous intervals (see Figures 26, 30, and 31) indicate that subsidence in the Brazos basin was rapid during the Late Jurassic, and gradually diminished through the Early Cretaceous, reflecting the influence of thermal lithospheric cooling which diminishes with time. These maps also indicate that as the rate of subsidence diminished, the region of enhanced subsidence increased, suggesting that subsidence related to thermal cooling effected a larger area than subsidence associated with crustal attenuation.

Deformation of the Louann Salt within the Brazos basin also had a significant, although local, effect on sediment distribution patterns (Figure 33B). Initial deformation of the Louann Salt was in response to loading by the Cotton Valley Group and Valanginian age sediments. Seismic profiles indicate that these sediments molded the underlying salt into a series of salt pillows. Profiles across the basin indicate that primary deformation in response to sediment loading continued through the Neocomian. The majority of salt related faults cut through Tithonian and Neocomian age strata, but rarely extend into Albian and younger rocks. The larger salt pillows continued to deform, eventually developing into salt diapirs. Isopach maps from well log data and faults associated with large salt structures and diapirs indicate that some of these structures continued to deform through the Eocene.

The general structure and stratigraphy of eastern Texas at the end of the Cretaceous is illustrated in Figure 33C. Although modest differential subsidence within the Brazos basin continued to influence depositional patterns through the Late Cretaceous and Tertiary, by the end of the Early Cretaceous, the Brazos basin had ceased to exist as a unique structural unit. Sediment isopach maps of the Late Cretaceous interval (see Figure 32) indicate that the general trend is for the strata to thin southward onto the Angelina-Grimes terrace, and thicken northward into the East Texas basin . Unconformities in the Upper Cretaceous section across the Angelina-Grimes terrace, and thinning of the section across the terrace demonstrate that this feature was still structurally positive, and functioned to separate the Houston embayment from the basin to the north. The Houston embayment was still essentially starved of sediment during this time.

The present day structure and stratigraphy of the Brazos basin is illustrated in Figure 33D. Starting in the Late Paleocene, large volumes of siliciclastic sediments were generated by tectonic events to the west (Galloway, 1989). The vast majority of these sediments by-passed the East Texas and Brazos basins, to be deposited in the Houston embayment. Deposition of these sediments in the Houston embayment induced flexural subsidence to the north, starting from a hinge line approximately coincident with the Houston arch (Kreitler et al., 1980), and increasing southward across the Brazos basin. This flexurally induced subsidence reversed the dip along the southern flank of the Brazos basin, and Angelina-Grimes terrace. Prior to the Tertiary, strata along the Angelina-Grimes terrace dipped to the northeast (Figure 33A, 33B, and 33C), by the end of the Eocene these strata were dipping to the southwest. The result of this dip reversal was to produce the present structure of the Brazos basin (Figure 33D), in which the rocks display relatively uniform southeast dip, and the former existence of the Brazos basin is expressed only by stratigraphic thickening of Upper Jurassic and Lower Cretaceous sediments.

The development of major post-rift depositional centers across eastern Texas through time is illustrated in Figure 34. The East Texas basin was the primary depositional center from Oxfordian through Kimmeridgian (Figure 34A). During this time shallow water carbonates of the Louark Group were deposited in the East Texas basin, reaching a thickness of over 3,000 feet, (Roger, 1967). The Houston arch was a structurally positive feature that separated the East Texas and Brazos basins, and provided a stable platform that localized the Louark shelf margin. The Angelina-Grimes terrace was also structurally high at this time, but apparently had little influence on depositional patterns. The Brazos basin and Houston embayment were essentially starved of sediments at this time.

The first significant volume of sediments to reach the Brazos basin occurred in the Tithonian with deposition of the Cotton Valley Group. From the Tithonian until the end of the Early Cretaceous both the East Texas and Brazos basins were major depositional centers (Figure 34B), both basins subsiding faster than the surrounding regions, and receiving a greater thickness of sediments. Throughout this time the Houston arch was a structurally positive feature that separated the two basin, with strata thinning significantly across the arch. The Angelina-Grimes terrace was also structurally positive at this time, separating the Brazos basin from the Houston embayment, and providing a stable platform

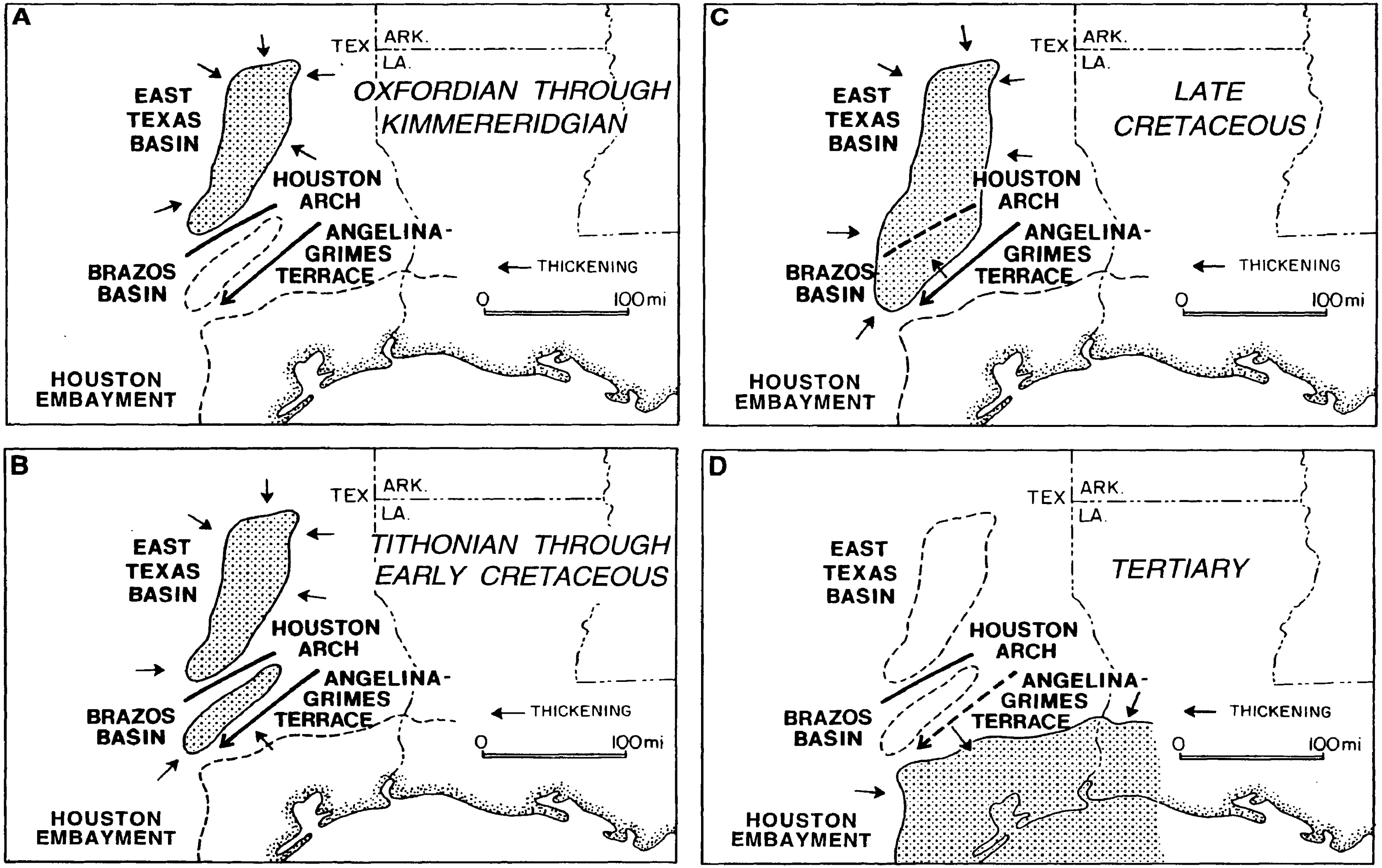

Figure 34 - Distribution of major depositional centers across eastern Texas through time. Active structures shown with solid lines. Inactive structures are shown with dashed lines. Major depositional centers are stippled. A) Oxfordian - Kimmeridgian, B) Tithonian - Early Cretaceous, C) Late Cretaceous, D) Tertiary.

that localized the Lower Cretaceous shelf margin reef trend. The Houston embayment, although a significant topographic depression, was still essentially starved of sediments.

During the Late Cretaceous, the regions underlain by the East Texas basin, Houston arch, and Brazos basin functioned as a single sedimentary basin (Figure 34C). Late Cretaceous strata display a general thickening trend northward across the Brazos basin into the East Texas basin, with no significant thinning across the Houston arch. Apparently, differences in the rate of subsidence between the Houston arch, and the East Texas and Brazos basins to the north and south, had diminished to the point that the Houston arch no longer separated the two basins. The Angelina-Grimes terrace was still structurally positive and separated this expanded Late Cretaceous basin from the Houston embayment to the south. Only minor quantities of sediments reached the Houston embayment during this time.

The Houston embayment did not become a major depositional center until the Tertiary period (Figure 34D). The first significant volumes of sediment to reach the Houston embayment occurred in the Late Paleocene and Early Eocene with deposition of the siliciclastic Wilcox Group. Since that time, siliciclastic sediments produced by tectonic events to the west have prograded the shelf margin approximately 200 miles (Winker, 1982). Sediment loading in the Houston embayment induced flexural subsidence to the north (Kreitler et al., 1980) across the Brazos basin. This flexural subsidence reactivated the Houston arch as a hinge-line, south of which Tertiary strata start to thicken. The flexurally induced subsidence also produced significant subsidence along the Angelina-Grimes terrace, reversing the former northwest dip along the terrace, and producing the present structure of the central East Texas region.

PETROLEUM GEOLOGY

The East Texas region has a long and prolific history of hydrocarbon exploration and production. Within the East Texas region (Texas Rail Road districts 3, 5, and 6) over 126,800 exploration and production wells have been drilled (Al Petry, written communication, 1991). The majority of these wells were drilled in either the East Texas basin or the Houston embayment. When compared to these provinces to the north and south, the Brazos basin is relatively underdrilled and contains relatively little production. Significant fields within the Brazos basin produce from the Woodbine Sandstones, and from the Upper Glen Rose Formation. The largest field is the Giddings Austin Chalk field, which produces from fractured reservoirs. The boundaries of this field as originally defined by vertical drilling lay on the northwest flank of the Brazos basin. The recent development of horizontal drilling has extended the productive limits of the Giddings field eastward into the Brazos basin. Aside from these three stratigraphic intervals, no other significant production has been established within the Brazos basin.

Davidoff (1991) presented a probable history of hydrocarbon generation and migration for the Brazos basin, and suggested that the basin still contains the potential for undiscovered hydrocarbon reservoirs. The Brazos basin contains an abundance of potential source rock, reservoir rock, and structures related to salt tectonism. Potential source rocks are scattered throughout the stratigraphic column. Probable timing of hydrocarbon generation and migration for these source rocks was determined from a burial history diagram, and calculation of time temperature indices (TTI) using the methods and values presented by Waples (1980). The burial history diagram was constructed using deep well data from eastern Madison and southwest Houston counties (Figure 35). Time temperature indices were calculated assuming a geothermal gradient of 1.8^{o} F/100 ft. Although changes in sediment thickness due to compaction and variations in temperature with time were not accounted for, the TTI values calculated provide a reasonable estimate

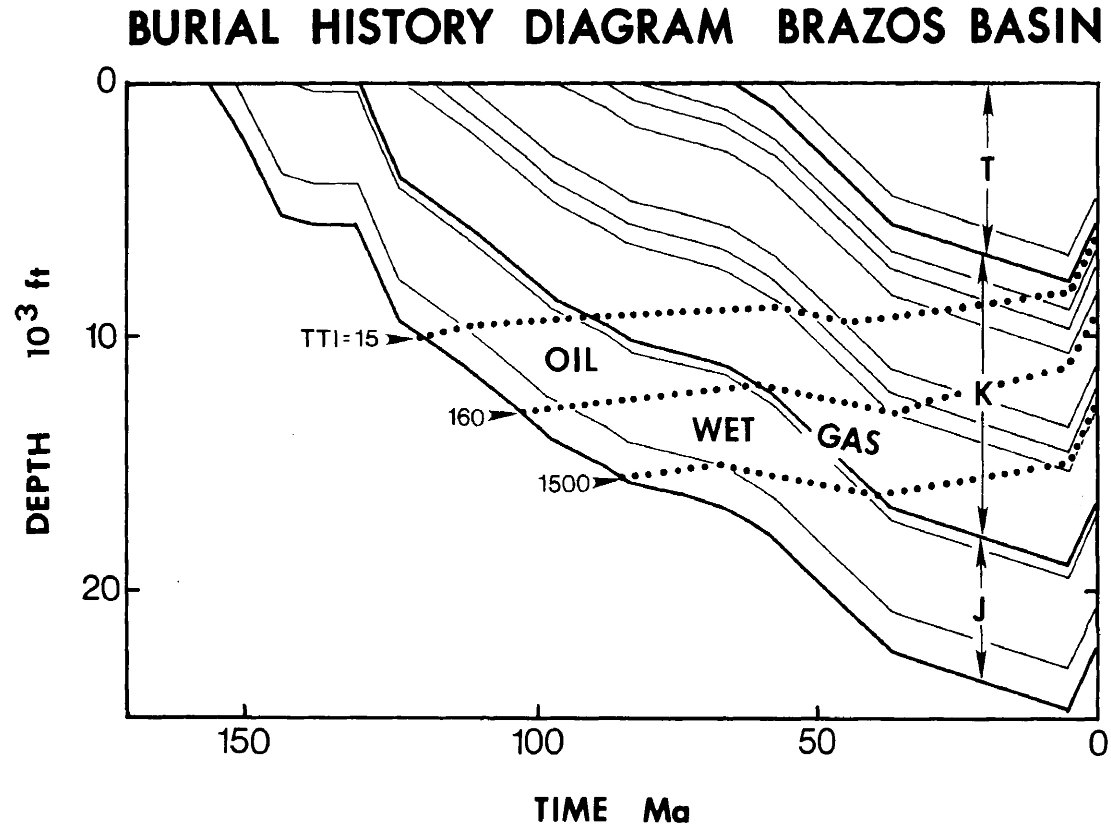

Figure 35 - Burial history diagram of major post-rift stratigraphic units in the Brazos Basin. J) Jurassic, K) Cretaceous, T) Tertiary. Also shown is the oil generation window between TTI = 15 and TTI = 160, and the limit of wet gas preservation TTI = 1,500. The diagram was prepared from deep well data in eastern Madison and southwestern Houston counties and has not been corrected for compaction. Time-temperature indices were calculated using a constant geothermal gradient of 1.8° F/100 ft (from Davidoff, 1991).

of the timing of hydrocarbon generation and migration. The results suggest that Upper Jurassic strata passed through the oil generation window during the later part of the Early Cretaceous and Late Cretaceous (Aptian through Maastrichtian), Lower Cretaceous strata passed through the oil generation window between the Late Cretaceous and Early Tertiary (Turonian through Oligocene), and Upper Cretaceous strata is still within the oil generation window (Figure 35).

Late Jurassic source rocks include the basinal carbonates of the Louark Group, and shales of the Bossier Formation of the Cotton Valley Group (see Figure 4). Calculation of TTI indicate that these source rocks passed through the oil generation window between the Aptian and Cenomanian ages. During this time period, strata across the southeastern part of the Brazos basins, and along the Angelina-Grimes terrace dipped to the northwest. The structural and stratigraphic relationships of these strata at the end of the Early Cretaceous are illustrated in Figure 36A (an enlargement of the southeast part of Figure 33B). Hydrocarbons generated at this time would have migrated up to the southeast. Primary deformation of the Louann Salt and related faulting occurred between the Tithonian age and Neocomian epoch, producing a variety of potential structural traps that could have been filled. The potential for the formation and filling of stratigraphic traps formed by the pinch-out of strata against the structurally high Angelina-Grimes terrace is also considered good.

The present day structure, and types of potential hydrocarbon traps across the southern flank of the Brazos basin and Angelina-Grimes terrace is illustrated is Figure 36B (an enlargement of the southeast part of Figure 33D). The Late Cretaceous was a period of relative stability across the Brazos basin. The rate of differential subsidence within the basins had diminished significantly, and only the largest of the salt structures continued to deform. During this time, basal and lateral diagenetic seals could have developed along hydrocarbon traps formed during the Aptian through Cenomanian ages. These diagenetic seals could have preserved the integrity of the traps when the Angelina-Grimes terrace subsided, and regional dip was reversed from northwest to southeast. Such hydrocarbon

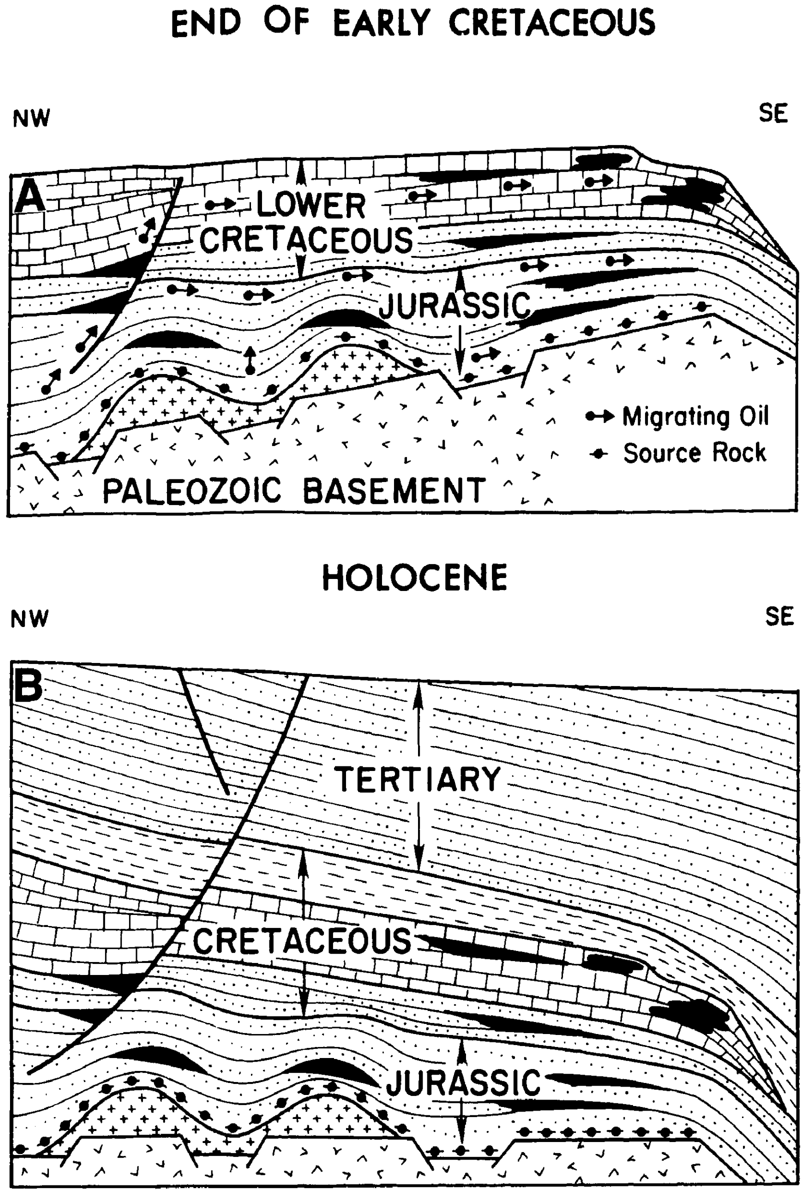

Figure 36 - Diagrammatic cross sections of the southern margin of the Brazos basin and Angelina-Grimes terrace, enlarged from portions of Figure 33 (not to scale). A) End of Early Cretaceous - Jurassic source rocks were generating hydrocarbons which migrated up to the southeast into a variety of structural and stratigraphic traps (potential hydrocarbon pools shown in black). B) Tertiary - The Angelina-Grimes terrace subsided, reversing the former northwest dip along the southeast margin of the Brazos basin. Diagenetic basal and lateral seals may have preserved the integrity of the hydrocarbon pools, and produced a variety of traps that have no obvious relationship to the regions present day structure.

traps, still in the dry gas preservation window, would have little relationship to the present day structure. Their identification would depend on the proper identification of Early Cretaceous structural and stratigraphic relationships. Stratigraphic traps formed by the pinch-out of strata southward against the previously high Angelina-Grimes terrace would now appear as downlap surfaces with no obvious hydrocarbon potential. Structural traps formed on the down-thrown side of fault blocks would also now appear non-prospective, and even hydrocarbons trapped above salt anticlines would be significantly offset from their original position. Considering the relatively few deep wells that have been drilled in the Brazos basin, there is still good potential for significant new discoveries.

CONCLUSIONS

The Brazos basin was a structural depression in the pre - Jurassic rocks of central East Texas, created by Late Triassic through Middle Jurassic rifting, and subsequently filled by a thickened section of Jurassic and Lower Cretaceous strata. This dissertation documents the structure and stratigraphy of the Brazos basin and demonstrates that the East Texas region is best described using a three basin model. The three basins include, from north to south, the East Texas basin, the Brazos basin, and the Houston embayment. Delineation of these three basins is based on the location of major basement structures, distribution of the Louann Salt, and timing of initial post-rift sedimentation within each of the basin.

The basins of eastern Texas were formed in association with Late Triassic through Middle Jurassic rifting that opened the Gulf of Mexico. The Brazos basin formed as a large northeast-southwest trending half-graben, bounded on the northeast and southwest by transfer faults. These transfer faults correlate with transfer faults interpreted to be present in the South Louisiana shelf and Texas - Louisiana slope salt provinces (Simmons, 1992) and strongly support a northwest-southeast opening direction for the Gulf of Mexico.

Basement structures which subdivide the East Texas region are the Houston arch and the Angelina-Grimes terrace. The Houston arch separates the Brazos and East Texas basins, while the Angelina-Grimes terrace separates the Brazos basin from the Houston embayment. Both of these features are salt free and suggest that distribution of salt across the region is more restricted that previously believed. The data also indicate that salt deposition across the region was diachronous, with salt deposited first in the East Texas basin, and later in the Brazos basin and Houston embayment.

The first major influx of post-rift sediments to reach the Brazos basin occurred in the Tithonian. Prior to this the Brazos basin was sediment starved, and the primary locus of deposition was to the north in the East Texas basin. Both the Brazos and East Texas basins existed as distinct structural units from their inception until the end of the Early Cretaceous. During the late Cretaceous the Houston arch subsided, and the two basins acted as a single sedimentary and structural unit. The first major influx of sediments to reach the Houston embayment occurred in the Tertiary. During this time the Angelina-Grimes terrace subsided, reversing the former northeast dip along the southern flank of the Brazos basin, and leaving the basin with its present structural configuration in which it is expressed only by the stratigraphic thickening of the Jurassic and Lower Cretaceous strata.

The presence of the Brazos basin was first proposed by Davidoff (1989), but only with the completion of this study has its structure and stratigraphy been documented. Furthermore, results of this study suggest that the basin contains the potential for undiscovered hydrocarbons. The ability to identify a new basin in one of the world's most intensely explored and highly drilled petroleum provinces suggests that there may be other basins with hydrocarbon potential in the onshore Gulf of Mexico that have yet to be identified.

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APPENDICES

APPENDIX I:

WELL LOG DATA

The following is a complete list of all wells for which geophysical logs were acquired and incorporated in the above described research. For most wells listed below a standard suite of resistivity, spontaneous potential and gamma ray logs were acquired. The wells are listed by county, operator and lease name. Also included for each well is the total depth drilled and the American Petroleum Institute (API) number. The location of wells listed are shown in Figure 7.

ANDERSON COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-001-30464	Amoco Prod.	1	Temple Industries /A/	11000
42-001-30885	Dallas Prod. & Pitts Oil	1	Temple East Texas	9516
42-001-31527	Hudson Resources	1	Temple EasTex	17525
42-001-30507	McCormick Oil & Gas	1	Chennault - Comte	11007
42-001-31550	Pitts Oil & Dallas Prod.	1	Boone	12000
42-001-01804	T.D. Humphrey Jr.	1	Billy Jack Chaffin	11467

ANGELINA COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-005-30013	Temple Industries Inc.	1	Temple Industries Inc.	12544

AUSTIN COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-015-30439	Placid Oil	1	George Prause	14400
42-015-30535	Superior Oil	1	Kemper-Byler et al.	17111
42-015-30503	Superior Oil	1	Robert E. Cook	16975
42-015-30444	Superior Oil	1	VosKamp G/U	16350
42-015-30463	Superior Oil	1	Woods Petroleum GU	16370
42-015-30459	Union Oil of Calif.	1	R.W. Woodley	15000

BRAZOS COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-041-30390	C.W. Williams	1	David S. Carrabba	18186
42-041-30653	C.W. Williams	1	J.W. McFarlane	12777
42-041-30722	C.W. Williams	2	J.W. McFarlane	12672
42-041-30360	Cayuga Expl.	1	C.S. Wooten	12350
42-041-30447	Champlin Pet. / Tipco	1	Charles C. Harter	16600
42-041-30422	Champlin Petroleum	1	J.M. Edwards et al.	13500
42-041-30448	Cities Service	1	D.C. Creagor /A/	12300
42-041-30629	Cities Service	1	M. Smith Unit	10346
42-041-30552	CRL Resources	1	M.P. Walker	12488
42-041-30527	Daleco Resources	1	Robert Moore	15120
42-041-30441	Daleco Resources	1	Tom J. Moore	14654
42-041-30570	Daleco Resources	1	W. Terrell	13740
42-041-00011	Hugh Goodrich	1	A. McCullough et al.	12292
42-041-31196	Inexco Oil	4	Conlee Brothers	9695

BRAZOS COUNTY (continued)

API	Operator	Well No.	Lease Name	Total Depth
42-041-31235	Inexco Oil	5	Conlee Brothers	9635
42-041-31254	Inexco Oil	1	P.K. Gamble	9975
42-041-31219	Inexco Oil	1	Valley Ridge	9917
42-041-31238	Inexco Oil	1	W.S. Pearson	9948
42-041-30708	Kieth D. Graham	1	Beal Unit	10700
42-041-30642	Kieth D. Graham	1	Texas Speedway	12004
42-041-30709	Kieth D. Graham	1-A	Texas Speedway	11454
42-041-30482	Langham Pet. Expl.	1	Willis B. Hicks	8170
42-041-31359	Lone Star Expl.	2	Sramek	8900
42-041-31080	Michael Pet.	1	Ennis Owens	8680
42-041-30987	North Central Oil	1	James Green	9755
42-041-31301	Paul J. Goldsmith	1	Crown Ranch	9545
42-041-30561	Peter Paul Pet. (QMG)	A-1	Wade	12553
42-041-00068	Phillips Petroleum	3	D.B. Schoeps	16655
42-041-30583	QMG Operations	1	William Johnson	12244
42-041-30494	Smith Prod	1	Conlee	9618
42-041-31261	T.D. Expl.	1	Dobrovolny /A	8648

BURLESON COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-051-30311	Amoco Prod.	1-A	Texas A&M	20021
42-051-31191	CAG Pet..	1	Rose	7538
42-051-31307	Champlin / C.W. Williams	2	F.W. Matcek	12250
42-051-31856	Champlin / C.W. Williams	1	Luke Kazmir	8523
42-051-31647	Champlin Pet. Co	1	M.R. Seymour	8762
42-051-31511	Champlin Pet. Co.	1	A. Hajovski Jr.	7480
42-051-32410	Champlin Pet. Co.	1	A.H. Tietjen	8038
42-051-32796	Champlin Pet. Co.	1-A	A.H. Tietjen	8112
42-051-31385	Champlin Pet. Co.	1	Adolph Hronek	7820
42-051-31318	Champlin Pet. Co.	1	Albert F. Faust	8050
42-051-31059	Champlin Pet. Co.	1	Albert Schultz	9270
42-051-30732	Champlin Pet. Co.	1	Albert Surovik	7752
42-051-31564	Champlin Pet. Co.	1-A	Alfonso Beran	8725
42-051-30637	Champlin Pet. Co.	1	Alfonso Beran	8137
42-051-32021	Champlin Pet. Co.	1	Alfred H. Roberts	7618
42-051-30869	Champlin Pet. Co.	1	Allan R. Raska	8432
42-051-31299	Champlin Pet. Co.	1	Allen Rhodes	10150
42-051-31747	Champlin Pet. Co.	1-A	Allen Rhodes	8600
42-051-30928	Champlin Pet. Co.	1	Alton Poehl	8642
42-051-31242	Champlin Pet. Co.	1	Alvin DRGAC	7797
42-051-31255	Champlin Pet. Co.	1	Alvin M. Paul	8842
42-051-31276	Champlin Pet. Co.	2	Alvin M. Paul	8280
42-051-31076	Champlin Pet. Co.	1	Andrew Loehr	11460
42-051-30868	Champlin Pet. Co.	1	Annie Vavra	8779
42-051-31519	Champlin Pet. Co.	1	Annie White	8060
42-051-31758	Champlin Pet. Co.	1	Anton F. Haisler	8841
42-051-31698	Champlin Pet. Co.	1	Anton Knesek	8460
42-051-31101	Champlin Pet. Co.	1	Bennie Hejl Un.	9070
42-051-30987	Champlin Pet. Co.	1	Bennie Supak	7780
42-051-30905	Champlin Pet. Co.	1	Bernice D. Williams	8330
42-051-30764	Champlin Pet. Co.	1	C.D. Henry	8040

BURLESON COUNTY (continued)

API	Operator	Well No.	Lease Name	Total Depth
42-051-32057	Champlin Pet. Co.	2	C.D. Henry	7790
42-051-31673	Champlin Pet. Co.	1	Carrie Payne	8000
42-051-31384	Champlin Pet. Co.	1	Carrie Polasek	7730
42-051-30655	Champlin Pet. Co.	1	Daniel Poehl	8219
42-051-30654	Champlin Pet. Co.	1	Delbert Zgabay	8703
42-051-31492	Champlin Pet. Co.	1	Dorothy Steck	8060
42-051-30754	Champlin Pet. Co.	1	E.M. Schuhmann	9129
42-051-31502	Champlin Pet. Co.	1	Earl Sebesta	10004
42-051-31259	Champlin Pet. Co.	1	Edd Drgac	7820
42-051-31734	Champlin Pet. Co.	1-D	Edwin Zgabay	8800
42-051-30912	Champlin Pet. Co.	1	Eldie Lee Koehler	8400
42-051-32502	Champlin Pet. Co.	2	Eldie Lee Koehler	8425
42-051-30753	Champlin Pet. Co.	1	Emagene R. Pitts	8300
42-051-31646	Champlin Pet. Co.	1	Ermma Green	8629
42-051-31355	Champlin Pet. Co.	1	Ervin B. Flencher	9460
42-051-32110	Champlin Pet. Co.	1-A	F.J. Krobot	7965
42-051-30936	Champlin Pet. Co.	1	Floyd T. Swonke	8220
42-051-31786	Champlin Pet. Co.	1	Floyd W. Moore	8456
42-051-32060	Champlin Pet. Co.	1	Frances Matcek	8214
42-051-30867	Champlin Pet. Co.	1	Gus Eberhardt	8375
42-051-31572	Champlin Pet. Co.	1	Helmus Loehr	7895
42-051-31555	Champlin Pet. Co.	2	Henery R. Zgabay	8481
42-051-31156	Champlin Pet. Co.	1	Henry R. Zgabay	8644
42-051-30697	Champlin Pet. Co.	2	J.F. Goodson	8301
42-051-30699	Champlin Pet. Co.	1	J.F. Goodson	8298
42-051-32817	Champlin Pet. Co.	3-A	J.F. Goodson	8070
42-051-30567	Champlin Pet. Co.	1	J.F. Krobot	8238
42-051-31458	Champlin Pet. Co.	1	J.L. Junek	8781
42-051-31472	Champlin Pet. Co.	1-A	Jack Cowen	8898
42-051-30726	Champlin Pet. Co.	1	James Sebesta	8065
42-051-31860	Champlin Pet. Co.	1	Jenkins Garrett	7620
42-051-31918	Champlin Pet. Co.	2	Joe F. Charanza	8930
42-051-31060	Champlin Pet. Co.	1	Joe F. Charanza	9321
42-051-30994	Champlin Pet. Co.	1-A	Joe J. Marek	8621
42-051-31091	Champlin Pet. Co.	1-X	Joe L. Lecour	8900
42-051-31001	Champlin Pet. Co.	1	Joe Marek	8765
42-051-30856	Champlin Pet. Co.	1	John W. Heine	8940
42-051-31457	Champlin Pet. Co.	2	John W. Heine	8928
42-051-32113	Champlin Pet. Co.	3	John W. Heine	8600
42-051-32183	Champlin Pet. Co.	2	John W. Springer	8554
42-051-30854	Champlin Pet. Co.	1	John W. Springer	8396
42-051-31759	Champlin Pet. Co.	2	Johnnie Knesek	8960
42-051-31760	Champlin Pet. Co.	3	Johnnie Knesek	8950
42-051-30999	Champlin Pet. Co.	1	Johnny Lyon	9610
42-051-30832	Champlin Pet. Co.	1	Jos Skrivanek Jr.	7830
42-051-31798	Champlin Pet. Co.	1-A	Junell Brinkman	8688
42-051-31524	Champlin Pet. Co.	1	L. Albright	7690
42-051-30612	Champlin Pet. Co.	1	L.J. Kocurek	8660
42-051-32520	Champlin Pet. Co.	4	L.J. Kocurek	8230
42-051-31527	Champlin Pet. Co.	2	L.J. Kocurek	8274
42-051-31146	Champlin Pet. Co.	1-A	L.W. Brinkman	8726

BURLESON COUNTY (continued)

API	Operator	Well No.	Lease Name	Total Depth
42-051-31956	Champlin Pet. Co.	2	L.W. Brinkman	8613
42-051-30603	Champlin Pet. Co.	1	Lancier Brinkman	8456
42-051-31032	Champlin Pet. Co.	1	Lenwood Wallace	9080
42-051-30748	Champlin Pet. Co.	1	Leon A. Krueger	9225
42-051-30792	Champlin Pet. Co.	1	Leroy Koehler	8732
42-051-31709	Champlin Pet. Co.	1-A	Leroy Koehler	8965
42-051-31518	Champlin Pet. Co.	1	Loss Warlick	8643
42-051-31434	Champlin Pet. Co.	1	Lottie Orsak	7880
42-051-30943	Champlin Pet. Co.	1	Louis Knesek	9351
42-051-31501	Champlin Pet. Co.	1	Louis Loehr	7918
42-051-31648	Champlin Pet. Co.	1	Lydia P. Rubach	10110
42-051-31050	Champlin Pet. Co.	2	Mabel D. Norman	8295
42-051-31741	Champlin Pet. Co.	1	Martin Knesek	9726
42-051-31607	Champlin Pet. Co.	1-A	Mary Ann Zgabay	8702
42-051-30656	Champlin Pet. Co.	1	Mary Ann Zgabay	8527
42-051-31999	Champlin Pet. Co.	1	Mary Gaas	8644
42-051-30833	Champlin Pet. Co.	1	Melvin M. Hronek	7958
42-051-31435	Champlin Pet. Co.	1	Melvin Skrabanek	7949
42-051-31233	Champlin Pet. Co.	1	Mildred Crnkovic	7770
42-051-31692	Champlin Pet. Co.	1	Mildred Mahlmann	8491
42-051-31785	Champlin Pet. Co.	1-A	Mildred Mahlmann	8720
42-051-31558	Champlin Pet. Co.	1	Peter B. Court	8493
42-051-30924	Champlin Pet. Co.	1	Raymond Zboril	8167
42-051-31902	Champlin Pet. Co.	2	T. L. Calvin	8621
42-051-31053	Champlin Pet. Co.	1	Theodore Weichert	8930
42-051-31319	Champlin Pet. Co.	1	Thomas A. Payne	7570
42-051-31464	Champlin Pet. Co.	1	Thomas L. Calvin	8649
42-051-31033	Champlin Pet. Co.	1	Tieman Dippel	9710
42-051-31505	Champlin Pet. Co.	1	Vaclav Hyvl	8276
42-051-30857	Champlin Pet. Co.	1	Vernon Brinkman	8485
42-051-30937	Champlin Pet. Co.	1	W.F. Eberhardt	8233
42-051-31260	Champlin Pet. Co.	1	W.F. Nowak	7850
42-051-30494	Champlin Pet. Co.	1	W.H. Easterwood	8360
42-051-32650	Champlin Pet. Co.	1	W.R. Fritcher	7860
42-051-31328	Champlin Pet. Co.	1	Walter Lightsey	7800
42-051-30903	Champlin Pet. Co.	1	Walter Schumacher	8375
42-051-31497	Champlin Pet. Co.	2	William A. Lange	8950
42-051-30842	Champlin Pet. Co.	1	William A. Lange	8550
42-051-31172	Champlin Pet. Co.	2	Willie F. Eberhardt	8250
42-051-31277	Champlin Pet. Co.	1	Willie Tracalek	8052
42-051-31258	Champlin Pet. Co.	1	Woodrow Worthington	7980
42-051-31217	Daleco Resources	4	Jesse B. Moore	12479
42-051-31493	Daleco Resources	5	Jesse B. Moore	12500
42-051-30950	Daleco Resources	3	Jesse B. Moore	15636
42-051-30767	Daleco Resources	2	Mabel Wilkins	11980
42-051-30437	Daleco Resources	1	Mabel Wilkins	15404
42-051-31538	Daleco Resources	4	Mabel Wilkins	15450
42-051-32915	Daleco Resources	2	McMillan	12030
42-051-32962	Daleco Resources	3	McMillan	12050
42-051-30610	Getty Oil	1	Rufus B. Lewis Un.	14001
42-051-30085	Hill Prod.	1	Jesse B. Moore	15728

BURLESON COUNTY (continued)

API	Operator	Well No.	Lease Name	Total Depth
42-051-30110	Hill Prod./ Daleco	2	Jesse Moore Est.	14810
42-051-31090	Martin Oil & Gas	2	Lightsey	9900
42-051-30705	Martin Oil &Gas	1	Fojt Un.	12307
42-051-31912	Martin Oil &Gas	1	John Fojt	9530
42-051-30666	Mosbacher-Transco	1-A	Robert Spearman	7676
42-051-31159	QMG Operations	1	Robert D. Leachman	12568
42-051-32978	Union Pacific Res.	2-A	A. Beran	8244

CHEROKEE COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-073-30394	Amoco Prod.	1	Temple EasTex /A/	12200
42-073-30064	Harry S. Phillips	1	New Birmingham Dev.	10138
42-073-30405	Herd Prod.	1	John M. Dixon	12215
42-073-30410	Hinton Prod.	2	Whiteman et al.	12443
42-073-01140	Placid Oil	1	Temple Industries /A/	10836
42-073-30010	Placid Oil	1	Temple Industries /B/	11114
42-073-30076	Texaco	1	J.I. Dean	18200

COLORADO COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-089-30963	Bradco Oil & Gas	1	Erwin H. Meyer	12300
42-089-31123	Exxon Corp.	1	Daisy Goode	15700
42-089-30650	Exxon Corp.	2	Oliver Wegenhoft	16200
42-089-31621	Superior Oil	1	Tillie Gartner	15120

FAYETTE COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-149-31097	Aero Coloma Pet.	1	Rudloff	13220
42-149-31399	C.W. Williams	1	Citzler-Tieman Un.	12366
42-149-31232	Coloma Pet.	1	A.A. Banik	13180
42-149-31126	Daleco Resources	1	Burnside	14000
42-149-31329	Daleco Resources	1	Halamicek	13550
42-149-32108	Endrex Expl.	1	Ella Un.	12174
42-149-32072	Endrex Expl.	1	Marian	12163
42-149-31303	Energetics Inc.	1	Edgea H. Schmidt	12025
42-149-31302	Energetics Inc.	1	Jack H. Schwecke	12352
42-149-32081	John H. Young	1	Eva Marie	13355
42-149-31212	John H. Young	1	Janssen	12044
42-149-32215	John H. Young	1	Joan Counts	12950
42-149-31161	John H. Young	1	Treybig	12370
42-149-31078	John H. Young	1	Voelkel Un.	12319
42-149-30936	Kaiser Oil LTD	1	John Quinn	12165
42-149-32130	Patterson Pet.	1	A.L.	12800
42-149-31666	Patterson Pet.	1	Fristch	12275
42-149-32021	Patterson Pet.	1	Lieb Scher	12143
42-149-31708	Patterson Pet.	1	Milton	12500
42-149-31694	Patterson Pet.	1	Reuter	12565
42-149-32080	Patterson Pet.	1	Schwarz	12075
42-149-31841	Patterson Pet.	1	Wessels	12560
42-149-31345	Prodeco Expl.	2	LCRA	12558
42-149-31385	Sage Energy	1	Catlett Un.	12673

FAYETTE COUNTY (continued)

API	Operator	Well No.	Lease Name	Total Depth
42-149-31455	Santa Fe Energy	1	Kiel	13003
42-149-31408	Santa Fe Energy	1	Lloyd Zwernemann	13379
42-149-31325	Santa Fe Energy	1	Salmanson	13200
42-149-00340	Sohio Pet.	1	M.L. Brisoc et al.	12075
42-149-00405	Texas Gulf Sulpher Co.	1	M.L. Brisoc et al.	12506
42-149-30784	Tipco	1	Bauer Un.	12240
42-149-31264	Tipco	1	Farmer Un.	12160
42-149-30755	Towner Pet.	1	Rose Un.	12526
42-149-31180	Union Dominion	1	Paul J. Battaglia Un.	13250
42-149-32250	United Oil & Minerals	1	Bohot	12960
42-149-32192	United Oil & Minerals	1	Norman Bain	13100

GRIMES COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-185-30214	Amoco Prod.	1	Geraldine Darby	12437
42-185-30384	Arco O&G	1	Apolonia	14824
42-185-30369	Arco O&G	1	Charlie Ashorn	14723
42-185-30395	Ballard Expl..	1	Carey & Corolla	20631
42-185-30226	Cashco Energy	1	Andess	12638
42-185-30219	Cashco Energy	1	Grant	11308
42-185-30218	Cashco Energy	1	Gressett	11467
42-185-30199	Cashco Energy	1	J.T. McDougald	11614
42-185-30231	Cashco Energy	2	Knotts	11112
42-185-30300	Cashco Energy	1	Leiber	13324
42-185-30252	Cashco Energy	1	McDuffie	10050
42-185-30234	Cashco Energy	1	Scamardo	9844
42-185-30225	Cashco Energy	1	Trant	12700
42-185-30260	Cashco Energy	1	Turner	10444
42-185-30222	Cashco Energy	1	W. Smith	15552
42-185-30216	Cashco Energy	1	W.O. Yeager	11450
42-185-30224	Cashco Energy	1	Williams	12693
42-185-30275	Cashco Oil	2	Gilpen	10720
42-185-30269	Cashco Oil	1	O'Conner-Goins	10077
42-185-30293	Cashco Oil	2	Scamardo	10070
42-185-30250	Cashco Oil	1	Yeager-Adams	10370
42-185-30304	Cashco Oil	2	Yeager-Adams	10050
42-185-30204	Cayuga Expl..	1	Coneley-Galbreath	13472
42-185-30058	Cities Service Co	1	Butler /B/	13013
42-185-30423	Columbia Gas Dev.	1	Union Fee	14300
42-185-30205	Damson Oil	1	Beula M. Yeager	10988
42-185-30062	Damson Oil	1	W.H. Knotts	9150
42-185-30342	Exxon Corp.	1	Doyle Glen Slaten	13350
42-185-30373	Exxon Corp.	1	William Bushman	12350
42-185-30011	Gulf Oil	1	Fannie Upchurch	12127
42-185-30271	Louisiana Land & Expl..	1	J.C. Howard et al.	12600
42-185-30064	Moran Corp.	3	Fannie Upchurch	13000
42-185-00085	R. Olsen Oil Co.	1	E.L. Harris	10520
42-185-30305	Tenneco Oil Co.	1	L.R. Fuqua	14100
42-185-30291	Tenneco Oil Co.	1	Ross L. Jarvis	12000
42-185-30007	Texaco	1	Garrett	13350
42-185-30066	Ustace Corp.	1	D.M. Wright	12075

GRIMES COUNTY (continued)

API	Operator	Well No.	Lease Name	Total Depth
42-185-30410	W.A. Moncrief	1	Butler	17201
42-185-30043	William E. Andrau	1	Homer F. Leifeste	10013

HOUSTON COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-225-30357	Alcorn Prod	1	C.N. Sullivan	12000
42-225-30346	Alta/Bonanza Pet.	1	King	13045
42-225-30479	Amerada Hess	1	Temple EasTex	17905
42-225-30085	Amoco Prod.	1	Shaw Gas Un.	10500
42-225-30160	Amoco Prod.	1	Pete W. Youngblood	13010
42-225-30067	Basin Oper.	1	Dailey-Pridgen	11303
42-225-30073	Basin Oper.	1	Streetman	11183
42-225-00456	Brewster & Bartle	1	T.G. Adams	12200
42-225-30340	Chevron	1	J.C. Smith	19548
42-225-30344	Conoco Inc.	1	Louis Cook	18896
42-225-30438	Conoco Inc.	2	Louis Cook	18541
42-225-00488	Delhi-Taylor	1	D.E. Hart	12950
42-225-00485	Glen Rose Corp	1	G.E. Kelly	12629
42-225-30132	Glen Rose Corp.	1	I.J. Young	13467
42-225-30108	Gulf Oil	1	Louis Cook	12511
42-225-00699	Humble Oil & Ref.	6	H.H. Dailey	13677
42-225-00389	Humble Oil & Ref.	1	J.T. Wilcox	12095
42-225-00268	Humble Oil & Ref.	3	Nell H. Rhea	10575
42-225-30538	Inexco	1	C.W. Brown	10000
42-225-30149	Inexco	2	Davy Crockett Fed.	11496
42-225-30338	Inexco	1	Herman Beazley Est.	12331
42-225-30137	Inexco	1	KLB VI Davy Crockett Fed.	11511
42-225-30543	Inexco	1	Wolf	10120
42-225-30100	Kirby Pet.	1	Dorthula Williams	12695
42-225-00621	M.B. Rudman & Star Oil	1	Ellis Estate	11515
42-225-00505	Mobil	1	Dan Hartt	15008
42-225-30455	Mobil	1	East Crockett Fed.	18300
42-225-30333	Mobil	1	Tom Fenley	12700
42-225-30378	Mobil	1	USA-NM-A19767	12189
42-225-30395	Moore McCormack	1	A.E. Murray	11554
42-225-30466	Moore McCormack	2	A.E. Murray	11500
42-225-30539	Moore McCormack	4	A.E. Murray	11050
42-225-30414	Moore McCormack	1	Moody Est.	11400
42-225-30018	Moran Corp.	1	Crowley Stubblefield	13100
42-225-30294	Natomas North America	1	J.S. Strong	13000
42-225-30297	Northshore Expl.	1	Johnie Perkins	11348
42-225-00451	Pure Oil	1	E.P. Adams	12200
42-225-00461	Pure Oil	29-2	Ft. Trinidad Up Glen Rose	11350
42-225-00496	Pure Oil & Union of Calif	1	W.H. La Rue	12609
42-225-30433	Santa Fe Energy	1	Eastham State Farm	13967
42-225-30463	Santa Fe Energy	2	Eastham State Farm	12800
42-225-30503	Santa Fe Energy	3	Eastham State Farm	12150
42-225-00312	Sun Oil	4	R.S. Dailey	10058
42-225-30072	Sun Oil	1	Warner Gas Un.	10200
42-225-30156	Supron Energy	1	Murray et al.	11699
42-225-30099	Texas Crude	1	E.M. Decker	10750

HOUSTON COUNTY (continued)

API	Operator	Well No.	Lease Name	Total Depth
42-225-30094	Texas Crude	1	Temple Industries /B/	10700
42-225-30360	Wessely Energy	1	Wilcox	11648
42-225-30596	Westland Oil	1	C. Richards Estate	20500
42-225-30529	Westland Oil	1	E.D. Moore	19550
42-225-30678	Westland Oil	1	G.H. Scarborough	12500
42-225-30666	Westland Oil	1	Rosine McFaddin	13200
42-225-30653	Westland Oil	1	T.W. Tyer	13005

LEE COUNTY CONTINUED

API	Operator	Well No.	Lease Name	Total Depth
42-287-30012	Amoco Prod.	1	S.P. Peebles	16000
42-287-31293	Energetics Inc.	1	H.E. Wolf	13834
42-287-31546	Exxon Corp.	1	Gilbert Schulze	15334
42-287-00091	Pan Am	1	Willie Matejcek	16441
42-287-30034	Union Oil of Calif.	1	L.E. Wells	12821
42-287-00087	Union Prod.	1	E.M. Preuss	12206

LEON COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-289-00568	Cauble Enterprises	1	Irva B. Mitchell Est.	11350
42-289-30432	Conoco Inc.	1	Frank Bell Un.	17500
42-289-30400	E.B. Germany & sons	1	J.R. Montgomery G.U.	10610
42-289-30774	First Energy Corp.	1	T.A. Sullivan	11000
42-289-30422	Hunt Oil	1	Challacombe Ranch	11900
42-289-30502	Hunt Oil	2	Challacombe Ranch	11925
42-289-30466	Inexco Oil	1	Swift Subdivision	17519
42-289-30599	Kalos Corp.	1	H.E. Wells	10300
42-289-30511	Lake Ronel Oil	1	Balden-Hall	10180
42-289-30446	Lake Ronel Oil	1	Epps et al.	10420
42-289-30678	Mitchell Energy	1	J.B. Richardson	10400
42-289-30714	Mitchell Energy	2	Largent Heirs	10510
42-289-30618	Mitchell Energy	1	Robert E. Gresham	9500
42-289-00118	Mrs I.M. Lemon	1	Swift Ranch	11130
42-289-30553	Murphy H. Baxter	1	Leathers	12338
42-289-30706	Palmer Pet.	1	Gordon B. Sullivan	10400
42-289-30532	Pitts Oil & Dallas Prod.	1	Irwin /A/	12360
42-289-30547	Pitts Oil & Dallas Prod.	1	Story	11200
42-289-30543	Shar-Alan Oil	1	Forrest Buie et al.	10165
42-289-30807	Shar-Alan Oil	1	Joe Lee Thomason	9831
42-289-30766	Shar-Alan Oil	1	Rogers Max	9906
42-289-30560	Texas Crude Expl..	1	Edell Price	11500
42-289-30493	Tipco	1	Hilltop Lake Resort /A/	18000
42-289-30611	Union Oil of Calif.	1	J.D. Wilson et al.	12002
42-289-30319	Universal Res/ Basin Oper.	1	Brown	10700
42-289-30458	Wessely Energy Corp.	1	Kennedy	11500
42-289-30851	Wisenbaker Prod.	1	Greer Estate	9810
42-289-30654	Wisenbaker Prod.	1	Lois Vaughn	10315

MADISON COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-313-30372	Allco Expl..	1	Corrie	12657
42-313-30035	Anadarko Prod Co.	1	Hightower /A/	13000
42-313-00045	Associated Oil & Gas	1	L.A. Wakefield	12100
42-313-30232	Dorchester Expl.	1	Ory D. Heath	12600
42-313-30291	Dorchester Expl.	1	S.C. Wilson Jr. et al.	13000
42-313-00229	G. Mitchell & Assoc.	1	J.S. Stewart	12225
42-313-00279	Glen Rose Corp.	1	Wilson Heirs	12500
42-313-00226	Lone Star Prod.	1	Olin Farris	11950
42-313-00230	Lone Star Prod.	1	Ory D. Heath	12850
42-313-00068	Moran Corp.	B-1	Wakefield & Harrison	21227
42-313-00162	R.A. Johnston	1	P.M. Ringo Jr.	12368
42-313-30042	Schneider et al.	1	Pearl H. Tyler	13019
42-313-30307	TXO Prod.	1	Jones /FF/	14001
42-313-00094	West Prod. Co.	1	H.M. Boring	12517
42-313-00086	Woodley Pet. et al.	1	M.E. McWhorter et al.	13314

MILAM COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-331-00781	Genral Crude	1	P.H. Perry Jr. et al.	12670
42-331-00786	Shell Oil	1	Adove Estate	14431
42-331-00837	Shell Oil	2	Adove Estate	14600
42-331-30949	Shell Oil	1	G.A. Finn	14519
42-331-00785	Shell Oil	1	Nell Ross	15187
42-331-30864	Shell Oil	1	W.R. Newton	14855

MONTGOMERY COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-339-30487	Burnett Oil et al.	1	Henery Lawrence	12046
42-339-30504	Burnett Oil et al.	1	Linda Groninger	12462
42-339-30441	Cities Service	1	D. J. Heintz	17456
42-339-30722	Exxon Corp.	1	Dolly Heintz	16600
42-339-30533	HNG Fossil Fuels	1	Central Coal & Coke	12500
42-339-00006	Phillips Pet.	1	Central Coal & Coke /A/	16762

ROBERTSON COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-395-30223	Amoco Prod.	1	Robert H. Seale	16200
42-395-30029	Belco Pet Corp.	1	R.H. Seale	10413
42-395-00147	Charles H. Wacker III	1	A.A. Towler	10514
42-395-00162	Glen H. McCarthy	1	Frank B. Seale	10979
42-395-30221	Inexco Oil	1	R.H. Seale	16005
42-395-30269	Southern Plains Energy	1	V.C. Sanders	10320

SAN JACINTO COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-407-30414	Amoco Prod.	1	Horizon Prop.	12700
42-407-30424	Amoco Prod.	2	Horizon Prop.	12507
42-407-30043	Glen Rose Corp	1-A	Central Coal & Coke	16470
42-407-30033	Glen Rose Corp.	1	Carey Heirs	18098
42-407-30059	Glen Rose Corp.	1-C	Central Coal & Coke	17425
42-407-00012	Humble Oil & Ref.	1	Ben Ogletree	15497

SAN JACINTO COUNTY (continued)

API	Operator	Well No.	Lease Name	Total Depth
42-407-30097	Mitchell Energy	1	Sun Mineral Fee	14880
42-407-30069	North Central Oil Corp.	1	Carey Heirs Inc.	15030
42-407-30397	South Louisiana Prod.	1	Foster Minerals	18007

TRINITY COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-455-30009	Amoco Prod.	1	G.G. Gibson	14100
42-455-30328	Goldking Prod.	1	Joyce Foundation	12500
42-455-30296	HNG Oil Co.	1	Temple	12200
42-455-30297	HNG Oil Co.	2	Temple	12387
42-455-30025	HNG Oil Co.	1	W.C. Odom	12616
42-455-00060	Humble Oil & Ref.	1	Thompson Bros.	12005
42-455-30023	Hunt Oil	1	Hoyt Moore	18890
42-455-00037	Pauley - McCulloch	1	Cameron Heirs	15012
42-455-00022	Shell Oil	1	Southern Pines Lumber	13006
42-455-30007	Shell Oil	1	Temple Industries	19468
42-455-30347	Shield Resources	1	J.W. Bell	12281
42-455-00005	Socony Mobil	1	Southland Paper Mills	12000
42-455-00010	Tenneco et al.	1	Southern Pines Lumber Co.	12200
42-455-00061	Wallace Enterprises	1	Southland Paper Mills /B/	13501

WALKER COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-471-30203	Adobe Oil & Gas CORP	2	Gibbs Gas Unit	15559
42-471-30025	Adobe Oil Co.	1	Gibbs Bros. & Co.	13780
42-471-30252	Amerada Hess	1	E. Keisler	13280
42-471-30251	Amerada Hess	1	S. L. Riley	15560
42-471-30256	Exxon Corp.	1	Gibbs Bros. & Co.	14206
42-471-30232	Getty Oil	1	T. W. Keeland	20827
42-471-00077	Hawkins & Hawkins	1	Earl Morris	14300
42-471-00079	Humble Oil & Ref.	1	Gibbs Bros. & Co.	15556
42-471-00097	Humble Oil & Ref.	2	Gibbs Bros. & Co.	13000
42-471-00075	Humble Oil & Ref.	1	Gibbs Bros. & Co. /C/	14550
42-471-00076	Humble Oil & Ref.	1	Gibbs Bros. & Co. /D/	12000
42-471-00073	Humble Oil & Ref.	1	M. B. McAdams	13754
42-471-00072	Humble Oil & Ref.	1	Mossy Grove Gas Un. 2	13805
42-471-00074	Humble Oil & Ref.	1	W. D. McAdams	14600
42-471-00180	M. H. Marr	1	Katie Ward	14365
42-471-00183	M. H. Marr & Moran	3	Gibbs Bros. Co.	15402
42-471-30245	McMoran Expl..	1	Gibbs Bros.	17028
42-471-30201	McMoran Expl..	1	W. L. Smithers	14487
42-471-30206	Moran Corp	E-1	Gibbs Bros.	11957
42-471-30021	Moran Corp.	11	Central Coal & Coke	17860
42-471-00191	Moran Corp.	G-2	Central Coal & Coke	15860
42-471-00186	Moran Corp.	G-4	Central Coal & Coke	18803
42-471-00190	Moran Corp.	1	Gibbs Bros. & Co.	12492
42-471-30022	Moran Corp.	B-1	Gibbs Bros. Un.	14500
42-471-30023	Moran Corp.	C-1	Gibbs Bros. Un.	15467
42-471-30024	Moran Corp.	C-2	Gibbs Bros. Un.	15215
42-471-30003	Moran Corp.	1	J. W. McAdams	12515
42-471-30238	Northern Mich. Expl..	1	Eastman	12686

WALKER COUNTY (continued)

API	Operator	Well No.	Lease Name	Total Depth
42-471-30008	Placid Oil Co.	1	Gibbs Bros. & Co.	16929
42-471-30011	Placid Oil Co.	2	Gibbs Bros. & Co.	22430
42-471-30231	Shield Resources	1	Gibbs Bros. & Co.	12503
42-471-30243	Shield Resources	1	J. H. Painter	12185
42-471-30247	Shield Resources	1	Smithers	11162
42-471-00093	Skelly Oil Co.	1	Gibbs /A/	15972
42-471-30225	Tenroc Corp.	C-1	Gibbs Bros.	13801
42-471-30224	Tenroc Corp.	A-4	Gibbs Bros.	12543
42-471-00169	Tidewater	1	A. D. Newman	13807
42-471-30199	Tipco	A-1	Gibbs Bros.	15100
42-471-00014	Union Prod.	1	Smithers	13500

WALLER COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-473-30430	Atapco	1	Keenan	13060
42-473-00007	Dan J. Harrison Jr.	1	Abbie K. Gaines	10605
42-473-30329	Getty Oil	1	W.J. Look	13000
42-473-00314	Pan America	1	C. A. O'Connor	12006
42-473-00005	Shell Oil	1	G. A. Chapman	20800
42-473-00009	Sinclair Oil & Gas	1	R. C. McDade	10982
42-473-00024	Sun & Indiola Oil Co.	1	Von Blucher	11968

WASHINGTON COUNTY

API	Operator	Well No.	Lease Name	Total Depth
42-477-30422	Ada Oil Expl..	1	Hogan	12027
42-477-30398	Anderson Prod./ Ada	1	Harding Harmel	12719
42-477-30293	Bradco Oil & Gas	1	F.A. Liddell	12850
42-477-30562	C.W. Williams	1-A	Ashorn-Bentke Un.	12500
42-477-30544	C.W. Williams	1	David Wolff	12600
42-477-30589	C.W. Williams	1	Fred Heineke	12029
42-477-30549	C.W. Williams	1	W.M. Hutchings Est.	13670
42-477-30481	Cenergy Expl..	1	Sadie R. Schaer	12000
42-477-30528	Daleco Resources	1	Olson	13400
42-477-30485	Geosouthern Energy	1	Monique	12730
42-477-30052	Goldking Prod.	1	Anderson-Free Un.	14621
42-477-00256	Gulf Coast Lease Holds	1	G.W. Tate et ux.	9800
42-477-30405	Gus Edward	1	Landgraft	12622
42-477-00229	H.A. Potter / Pure	1	H.F. Schroeder	14251
42-477-00260	John Deering	1	H.C. Buck	7729
42-477-30593	Kimball Prod.	1	Ashorn	12475
42-477-30468	Kimball Prod.	1	Clay Gas Un.	12615
42-477-30474	Kimball Prod.	2	Clay Gas Un.	12450
42-477-30497	Kimball Prod.	3	Clay Gas Un.	12425
42-477-30577	Kimball Prod.	1	Hahn-Ashorn	12331
42-477-30030	Millican Oil Co.	1	T.J. Moore Land Co.	10880
42-477-30033	Millican Oil Co.	2	T.J. Moore Land Co.	11000
42-477-30005	Pan Am	1	Woodrow Free	18898
42-477-30463	Penn Resources	2	Richardson Un.	12743
42-477-30420	Penn Resources	1	Richardson Un.	11900
42-477-30633	Petrus Oper. / Adams	1	O'Malley	12034
42-477-30021	Prairie Prod. & H. Hurt	1	T.J. Moore Land Co.	10510

WASHINGTON COUNTY (continued)

API	Operator	Well No.	Lease Name	Total Depth
42-477-00264	Ray J. McDermott	1	Mary H. Lott	10518
42-477-30379	Retamco Inc. (S.Gose)	1	Fuchs	12850
42-477-30382	Retamco Inc.(S.Gose)	1	Kunkel-Muller Inc.	12500
42-477-00291	Shell Oil	1	C.W. Jackson	18500
42-477-00263	Sinclair Oil & Gas	1	Bess Henery	11513
42-477-00262	Sinclair Oil & Gas	2	Bess Henery	10745
42-477-30448	Traverse Oil	1	Lugene Lohmeyer	10520
42-477-30411	US Operating	1	Hinze Un.	12214

APPENDIX II:

SEISMIC DATA

The following is a list seismic lines released by Teledyne Exploration and incorporated in the above described research. Included in the list are the line numbers, acquisition date, processing date, and line miles. Those portions of the released seismic data that cross the study area are shown in Figure 7.

Line Number	Acquisition	Date	Processing	Date	Line Miles
8ET1	July	1978	March	1984	40.5
8ET2	July	1978	May	1984	51.6
8ET3	June	1978	June	1984	68.0
7T01	March	1974	April	1984	35.0
7T02	April	1973	April	1984	35.9
7T03	May	1973	May	1984	49.3
ET1E	August	1973	July	1984	62.4
ET1W	November	1973	August	1984	44.8
ET4E	September	1978	September	1984	50.0
ET4W	September	1978	September	1984	54.5
3W	November	1969	December	1983	56.9
3J	January	1970	September	1984	40.3
4W	November	1969	January	1984	59.7
4J	January	1970	October	1984	59.8
5W	May	1970	February	1984	69.9
5J	June	1970	September	1984	59.8
6W	April	1970	January	1984	74.1
6J	May	1970	December	1984	105.2
			Total Miles		1017.7

APPENDIX III:

VELOCITY LOG DATA

The following is a list of all wells for which velocity logs were acquired and used to produce synthetic seismograms for the correlation of well log and seismic data. The wells are listed by operator and lease name. Also included for each well is the total depth drilled and the American Petroleum Institute (API) number. The location of the wells listed are shown in Figure 7, and an example of a synthetic seismograms is shown in Figure 37.

API	Operator	Well No.	Lease Name	Total Depth
42-395-30223	Amoco Prod.	1	Robert H. Seale	16200
42-407-30414	Amoco Prod.	1	Horizon Prop.	12700
42-455-30009	Amoco Prod.	1	G.G. Gibson	14100
42-051-30311	Amoco Prod.	1-A	Texas A&M	20021
42-225-30340	Chevron	1	J.C. Smith	19548
42-185-30423	Columbia Gas Dev.	1	Union Fee	14300
42-289-30432	Conoco Inc.	1	Frank Bell Un.	17500
42-225-30344	Conoco Inc.	1	Louis Cook	18896
42-041-30653	C.W. Williams	1	J.W. McFarlane	12777
42-339-30722	Exxon Corp.	1	Dolly Heintz	16600
42-287-31546	Exxon Corp.	1	Gilbert Schulze	15334
42-051-31912	Martin Oil &Gas	1	John Fojt	9530
42-287-00091	Pan Am	1	Willie Matejcek	16441
42-477-30005	Pan Am	1	Woodrow Free	18898
42-477-00291	Shell Oil	1	C.W. Jackson	18500
42-473-00005	Shell Oil	1	G. A. Chapman	20800
42-455-30007	Shell Oil	1	Temple Industries	19468
42-015-30535	Superior Oil	1	Kemper-Byler et al.	17111
42-015-30503	Superior Oil	1	Robert E. Cook	16975
42-015-30444	Superior Oil	1	VosKamp G/U	16350
42-015-30463	Superior Oil	1	Woods Petroleum GU	16370
42-073-30076	Texaco	1	J.I. Dean	18200
42-289-30493	Tipco	1	Hilltop Lake Resort /A/	18000
42-225-30529	Westland Oil	1	E.D. Moore	19550
42-225-30653	Westland Oil	1	T.W. Tyer	13005

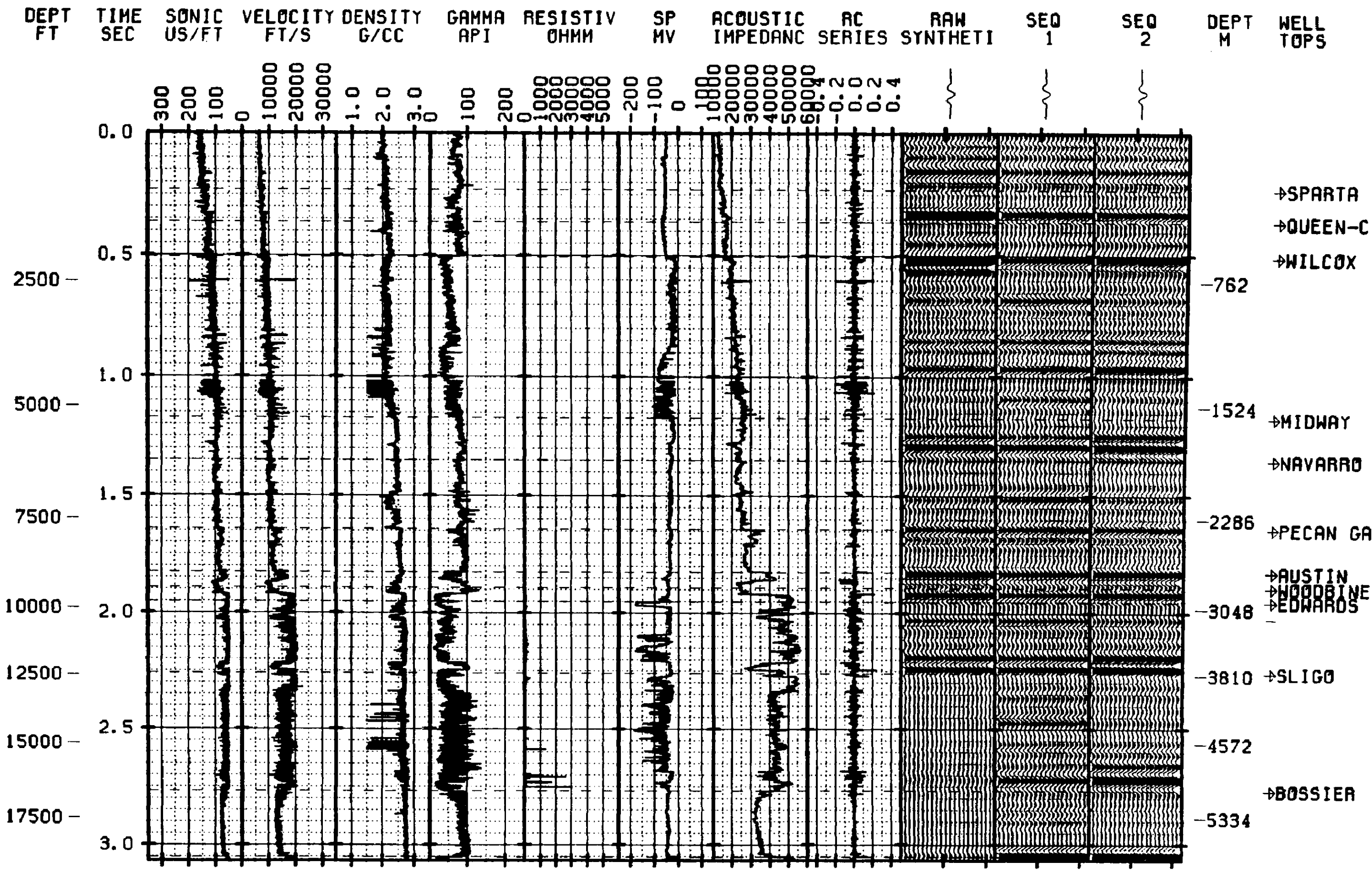

Figure 37 - Example of a synthetic seismogram used in the correlation of well log and seismic data. The example shown was produced from velocity and density logs run in the Amoco Production Co., #1-A, Texas A&M University well in Burleson County.

APPENDIX IV:

CHECK SHOT DATA

The following is a list of wells for which check shot survey data were acquired and used for the conversion of seismic times to depths. The wells are listed by operator and lease name. Also included for each well is the total depth drilled and the American Petroleum Institute (API) number. The location of the wells listed are shown in Figure 7, and the time depth data is displayed in Figure 8.

API	Operator	Well No.	Lease Name	Total Depth
42-455-30009	Amoco Prod.	1	G.G. Gibson	14100
42-051-30311	Amoco Prod.	1-A	Texas A&M	20021
42-289-30432	Conoco Inc.	1	Frank Bell Un.	17500
42-339-30722	Exxon Corp.	1	Dolly Heintz	16600
42-287-31546	Exxon Corp.	1	Gilbert Schulze	15334
42-477-30005	Pan Am	1	Woodrow Free	18898
42-015-30535	Superior Oil	1	Kemper-Byler et al.	17111
42-015-30503	Superior Oil	1	Robert E. Cook	16975
42-287-00087	Union Prod.	1	E.M. Preuss	12206