GEOMETRY OF THE SOUTHERN PART OF THE CARTER-KNOX STRUCTURE, ANADARKO BASIN, SOUTHERN OKLAHOMA

By

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"But do not forget this one thing, dear friends: With the Lord a day is like a thousand years, and a thousand years are like a day. The Lord is not slow in keeping his promise, as some understand slowness. He is patient with you, not wanting anyone to perish, but everyone to come to repentance." 2 Peter 3: 8-9

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INTRODUCTION

STATEMENT OF PURPOSE

The Anadarko basin is a deep sedimentary basin that extends in a southeast-northwest direction from south-central Oklahoma to northern Texas (Figure 1) The Carter-Knox structure is located in the southeastern end of the Anadarko Basin in northeastern Stephens County and southeastern Grady County, Oklahoma (Figure 2). The basin, as well as the study area, is considered to have had a long and complex geologic evolution from Early Cambrian to Permian.

The main purpose of this study is to investigate the structural evolution of the southern part of the Carter-Knox structure, located in the southeastern end of the Anadarko basin (Plate I and Figure 3). Special emphasis was given to provide time constraints on the structural events, such as formation of folds and faults The subsurface structure of the southern end of Carter-Knox was studied to provide a better understanding of the geometry of structural features within the Carter-Knox structure. In order to achieve this, the main objectives were to determine.

(1) the subsurface structural geometry of the southeast end of the Carter-Knox structure

(2) types and numbers of major faults within the southeast end of the Carter-Knox structure.

(3) if possible, the type and extent of displacement along the faults, by using wire-line well log data and seismic data provided by Marathon Oil Company.

LOCATION OF THE STUDY AREA

The study area is in the southeastern end of the Anadarko basin (Figure 1). It includes parts of Grady and Stephens counties, Oklahoma (Figure 2). The Carter-Knox structure is an oil field approximately 11 miles long and 1.5 miles wide (Reedy and Sykes, 1958); however, the study concentrated on the southern 6 miles of the structure. This includes all of T 2N., R.5W. and sections 19 through 36 in T.3N., R.5W. (Figure 3 and Plate 1). The Carter-Knox structure is also north of the Doyle field and south of Chitwood and Bradley fields (Figure 4).

METHODS OF INVESTIGATION

Necessary to the main objectives, the study utilized the following information:

(1) The electric logs Spontaneous Potential (SP), induction, gamma ray, conductivity, and resistivity were examined to locate the tops and bottoms of

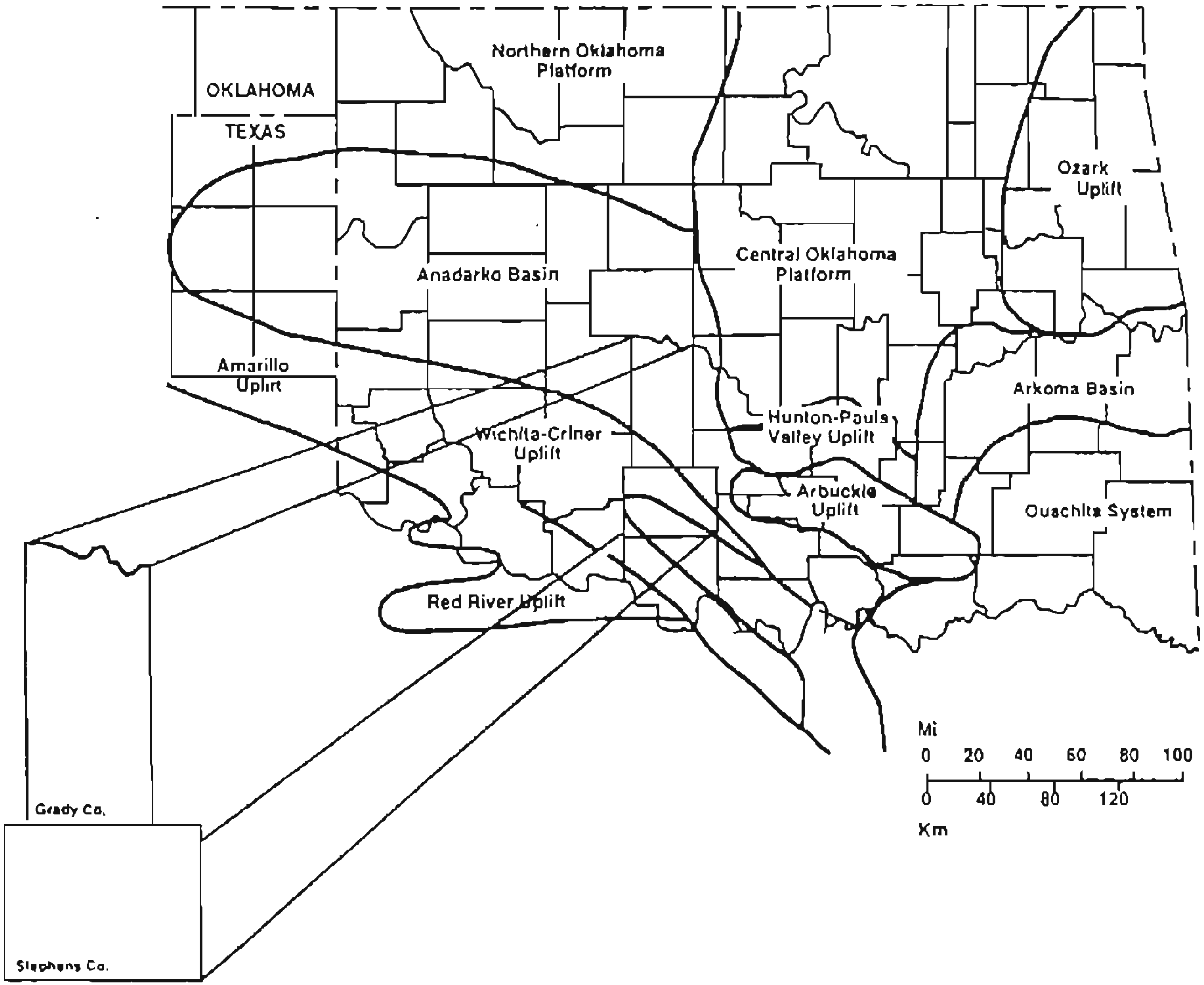


Figure 1. Tectonic Province map of Oklahoma.

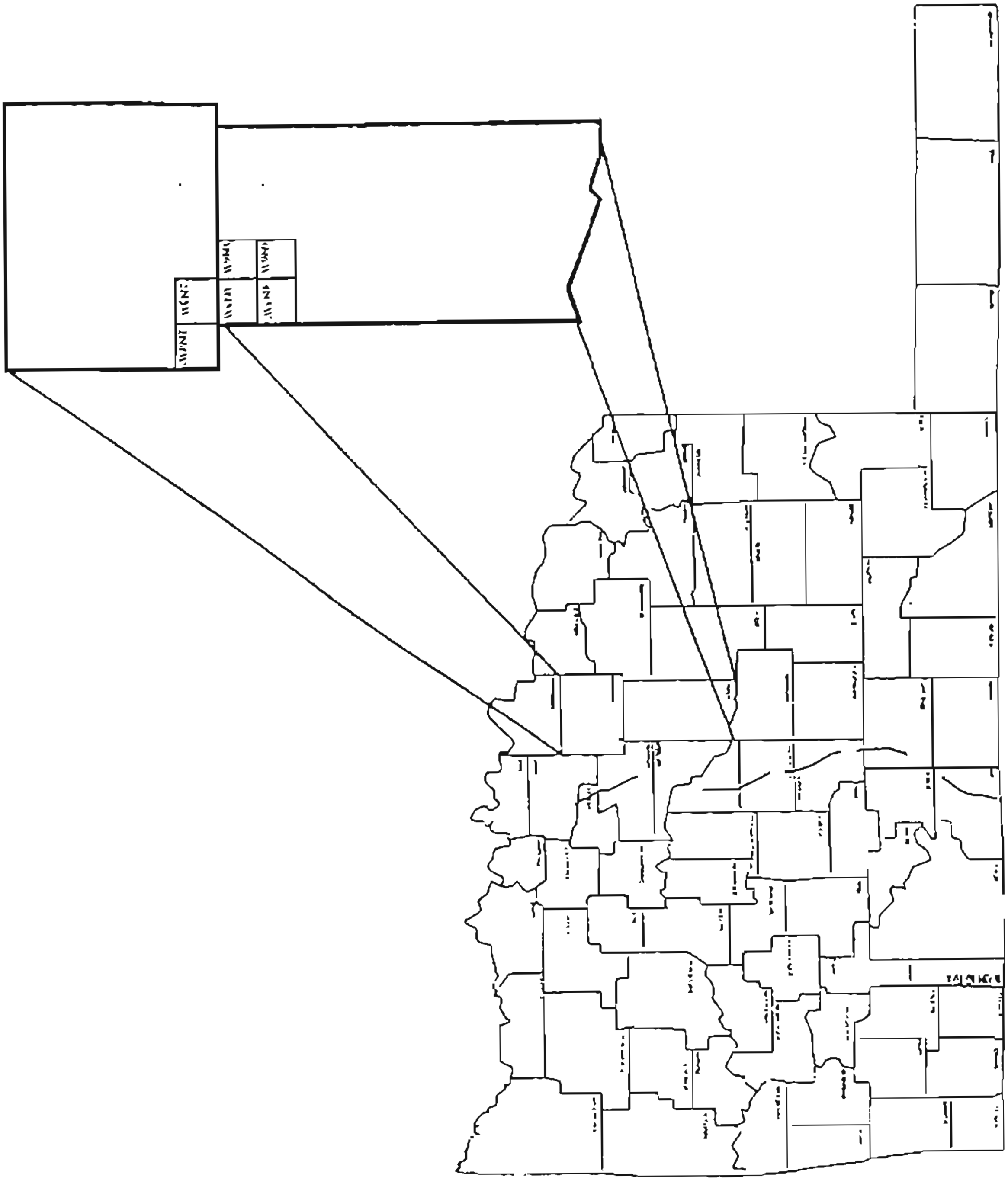


Figure 2. Location of Carter-Knox in Oklahoma.

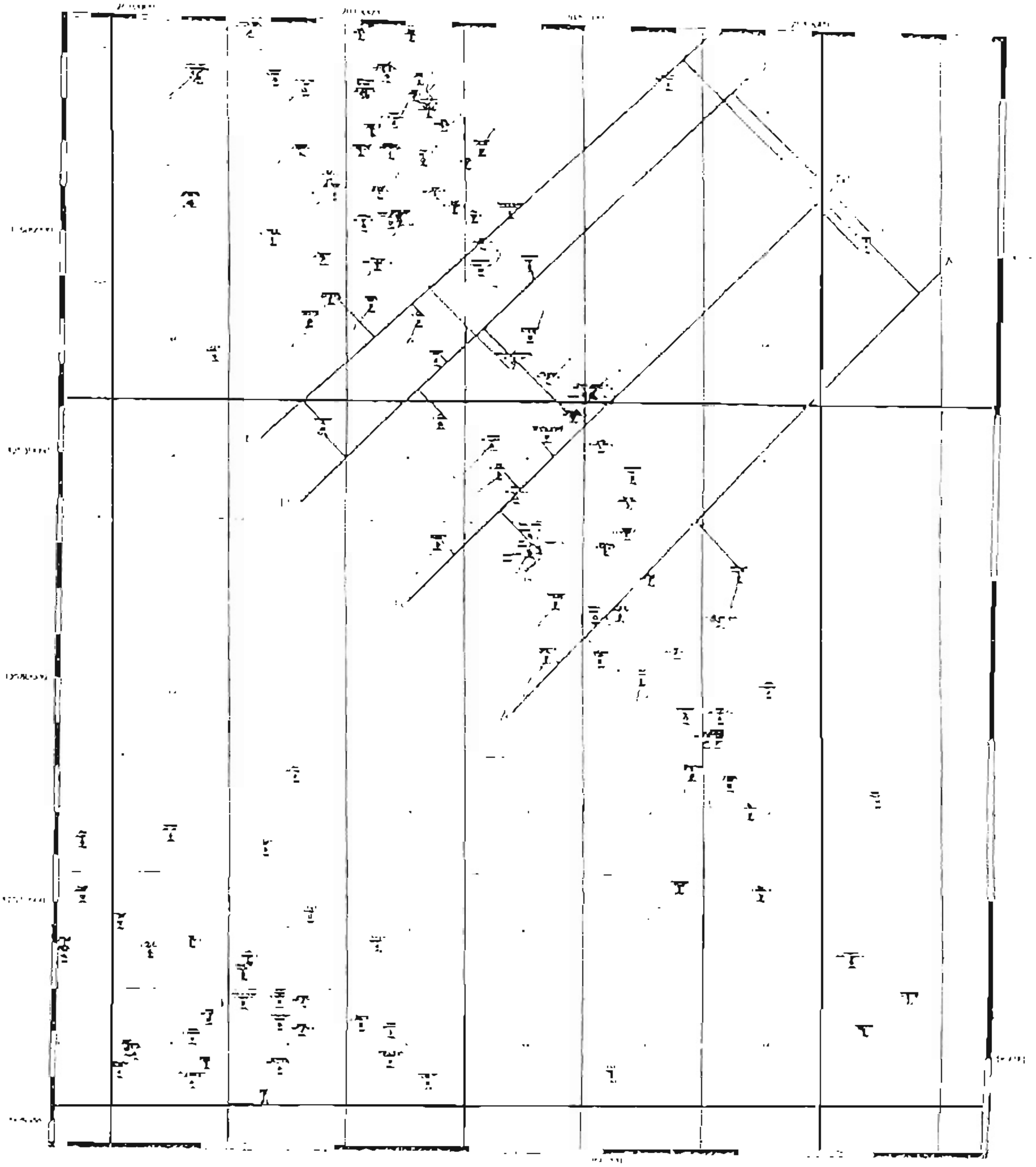


Figure 3. Location of study area of the southern part of the Carter-Knox structure

the Morrow Series, Springeran Series, Caney Shale, Sycamore Limestone, Woodford Shale, Hunton Group, Sylvan Shale, Viola Limestone, and an informal marker referred as the "Boat Marker" within T.2N., R.5W. and T.3N., R.5W. All electric logs were provided by Marathon Oil Company.

(2) Three seismic profiles provided by Marathon Oil Company were examined to interpret the subsurface structural features in the area.

(3) Four structural cross-sections and two structural contour maps were constructed to delineate the subsurface geometry of the southern part of the Carter-Knox structure.

All structural cross-sections were constructed at or close to perpendicular with the subsurface structure, in order to reveal the most accurate structural geometry within the study area. The sedimentary units used to construct the structural cross-sections include the tops of the: Morrow Series, Springeran Series, Caney Shale, Woodford Shale, Hunton Group, Viola Limestone, and the Boat Marker. Figures 11-15 illustrate wire-line well log signatures that represent the beds within the structural cross-section.

PREVIOUS INVESTIGATIONS

The geologic evolution of the Anadarko Basin and surrounding areas has been discussed in numerous publications. Although a complete discussion of the voluminous literature is beyond the scope of this study, a brief summary is provided. For a more nearly complete discussion, the reader is referred to Ham (1954), Tanner (1967), Ham (1964), Wickham (1978), and Gilbert (1983).

Tectonics of the Anadarko Basin

The Anadarko Basin, along with the Ardmore Basin and Wichita-Arbuckle uplift, is long recognized as part of the Southern Oklahoma Aulacogen. This aulacogen evolved in three main stages (Figure 5): (1) the stage of rifting, (2) the stage of subsidence (or sagging), and the stage of (3) deformation (or transcurrent stage) (Hoffman and others, 1974).

Hoffman, Dewey, and Burke (1974) explained the origin of an aulacogen by the concept of hot spots and plate tectonics. The rifting stage of an aulacogen begins with a series of hot spots that expand and uplift the lithosphere (Figure 5a). Continued uplift produces fracturing of the lithosphere and a rift-rift-rift triple junction (Figure 5b). Igneous activity is associated with early rifting. As rifting continues, igneous activity ceases, and a broad basin forms, representing one of the failed arms of the rift-rift-rift system (Figure 5c). This failed arm, now an intracratonic basin, subsides at a rate greater than that of the surrounding craton. As the basin subsides, it accumulates a thick sequence of sediments consisting of carbonate material and marine and nonmarine sandstones and shales (Figure 6b and 6c).

The Southern Oklahoma Aulacogen is also explained as having gone through these stages (Wickham, 1978). Beginning in the Precambrian, with crustal consolidation representing its pre-rifting stage, dikes were emplaced; they trend about N. 60 W.

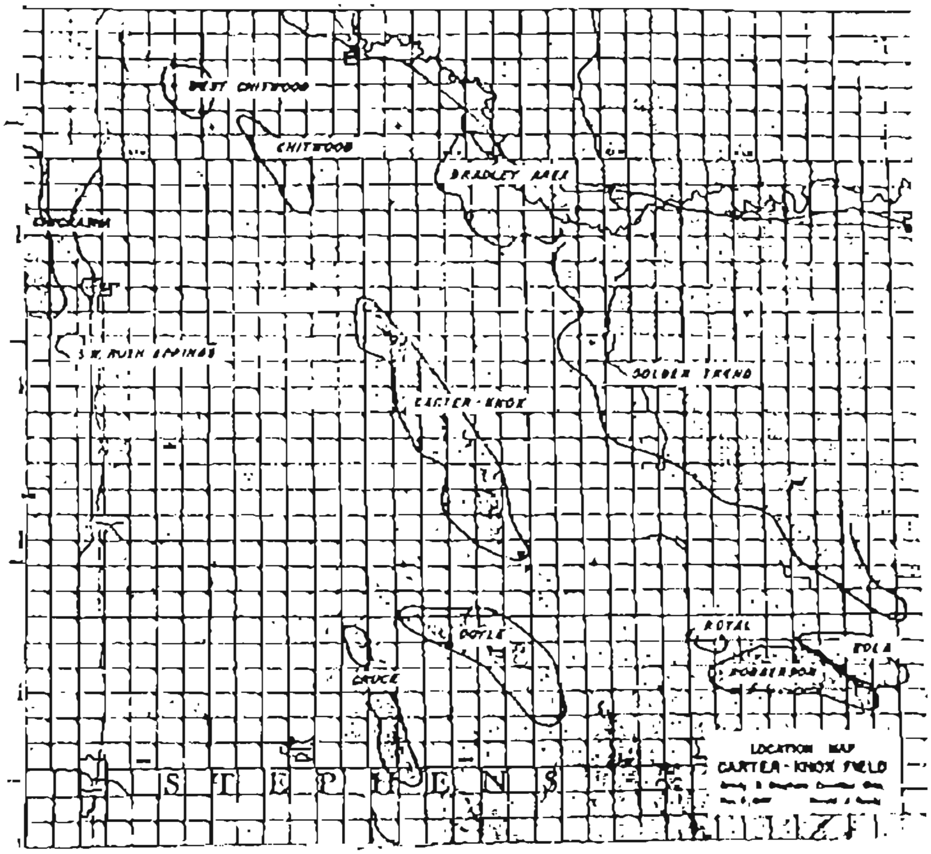


Figure 4. Location of Carter-Knox and other oil fields (from Reedy and Sykes, 1958)

(Denison, 1982). This crustal consolidation probably was accompanied by steep basement faults that bound the rift-valley structure (Webster, 1980).

During the stage of early rifting in Late Precambrian to Early Cambrian, grabens were formed and both extrusive and shallow intrusive rocks were emplaced (Figure 6a) These rocks are represented by the Carlton Rhyolite and have been dated at 500-550 million years old (Brown and others, 1985)

During the subsidence stage, from Late Cambrian through Mississippian, a passive continental margin developed (Brown and others, 1985). During this time marine transgression as well as subsidence took place within the Southern Oklahoma Aulacogen (Figure 6b and 6c). The beginning of the subsidence stage maybe represented by the deposition of the Upper Cambrian Reagan Formation (Wickham, 1978) Soon after the deposition of the Reagan Formation carbonate sediment deposition became dominant within the aulacogen and surrounding areas. Deposition of terrigenous clasitic sediment became dominant in Pennsylvanian due to a combination of subsidence and orogenic activity (Brown and others, 1985). Wickham (1978), suggests that subsidence of the aulacogen is accommodated by displacements of major faults that were initiated in the rifting stage Displacement of these faults probably continued throughout the subsidence stage due to sedimentation. However, Wickham (1978), does say that there is "little evidence to indicate active faults during sedimentation".

The deformational stage of the aulacogen began in Pennsylvanian and is represented by several orogenic conglomerates (Brown and others, 1985 and Pybas, Cemen, and Al-

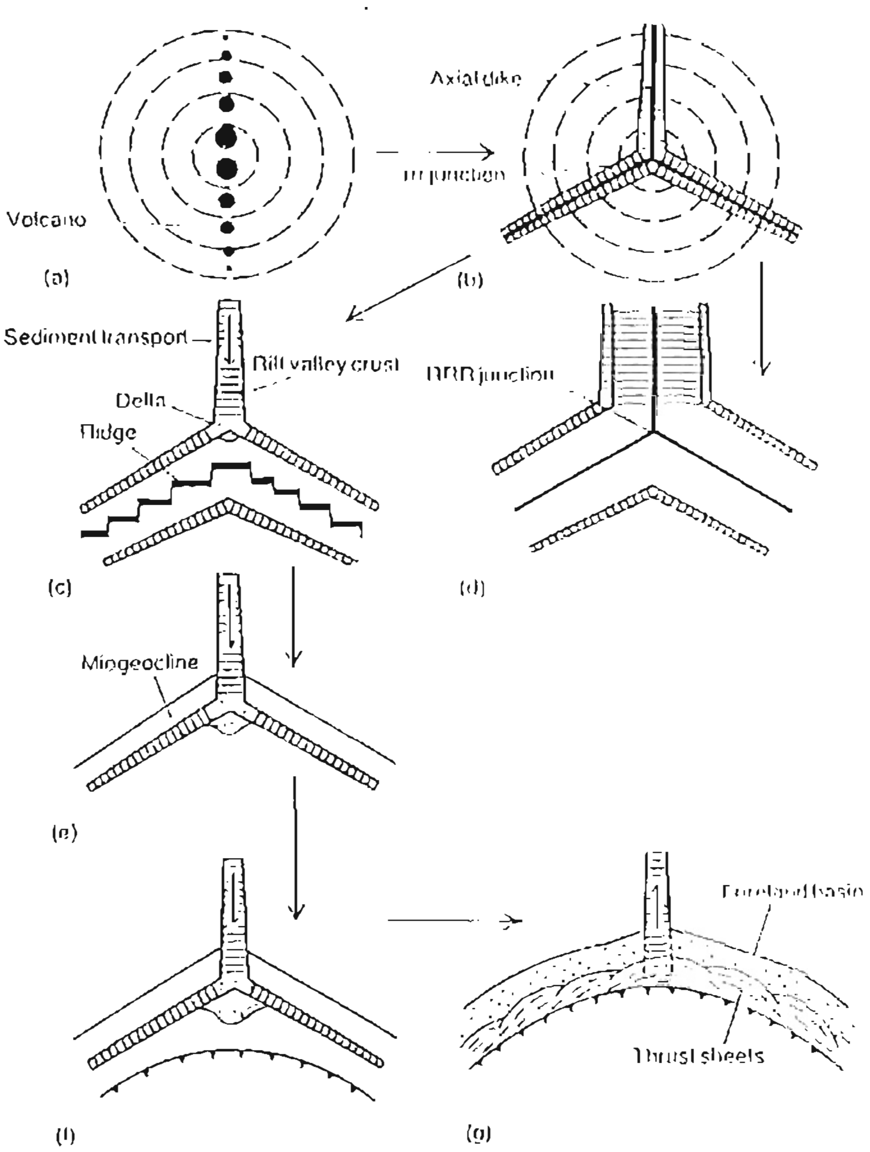


Figure 5 Schematic origin and evolution of plume-generated triple junctions (redrawn from Burke and Dewey, 1973).

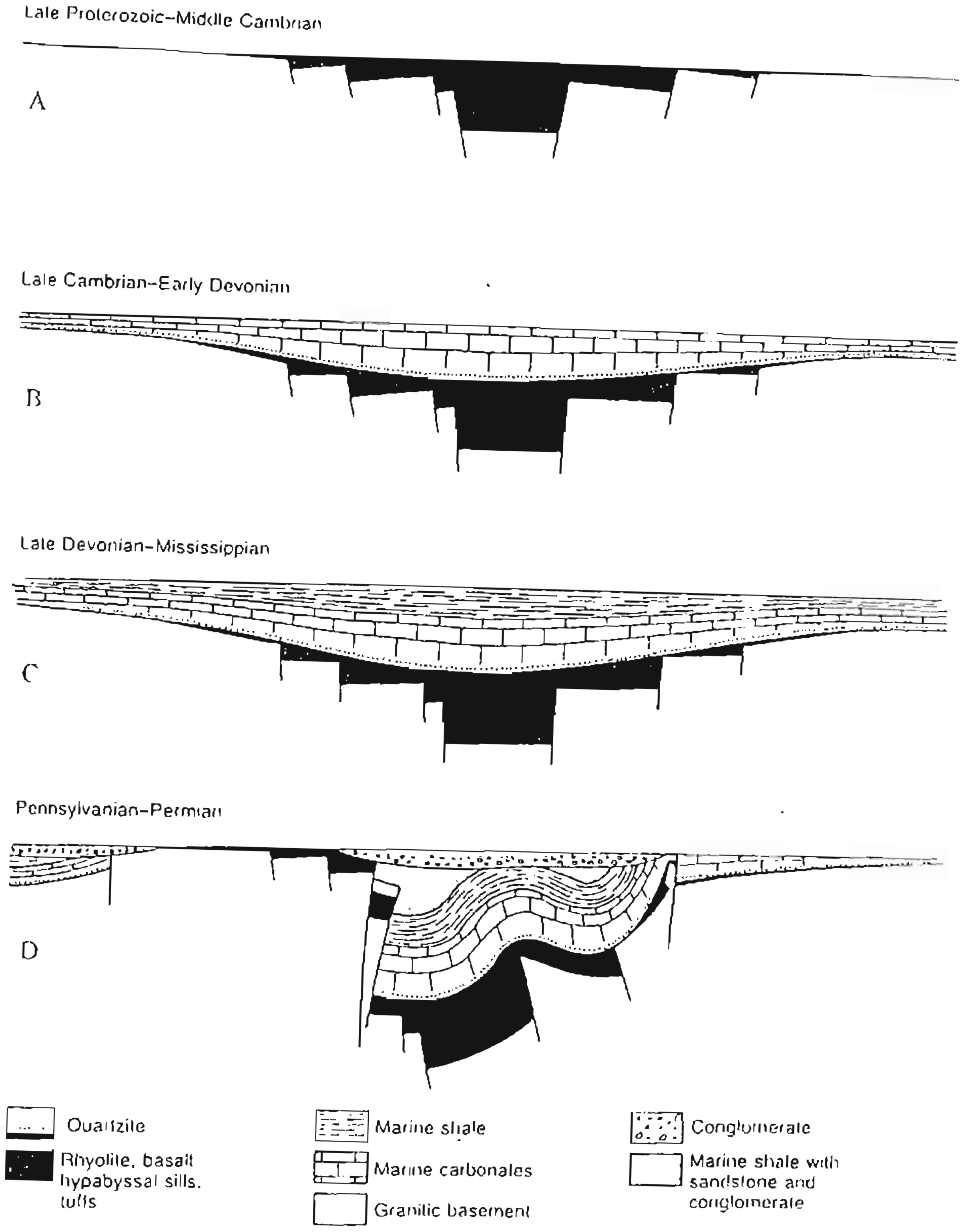


Figure 6. Schematic cross-sections showing the evolution of an aulacogen (from Hoffman, Dewey, and Burke, 1974).

Shaieb, 1995). During this phase, there was reactivation of faults (structural inversion), which probably originated as Cambrian normal faults, during the initial rifting stage(Figure 6d) These faults were high-angle faults with large displacements that produced major deformation within the aulacogen (Wickham, 1978) This deformational stage of the Southern Oklahoma Aulacogen is thought to have been brought about by a major collision between the North American plate and either the South American plate or some other microplate (Perry, 1989). Convergence of the North American plate with the South American plate continued into Late Mississippian (probably Chesterian) time (Perry, 1989), forming the Ouachita Mountains and other tectonic provinces in Oklahoma (Figure 1). The continued convergence is also thought to have deformed the south-central part of the Anadarko Basin, producing several thrust-cored, en-echelon anticlines (Perry, 1989). This deformation is explained as strike-slip or wrench fault tectonics (Tanner, 1967; Wickham, 1978; Harding, 1985, Pybas, Cemen, and Al-Shaieb, 1995) or as compressional tectonics (Dott, 1934, Denison, 1982; Brown and Grayson, 1985). Evidence from the study area suggests that these thrust-cored, en-echelon anticlines would have been caused by transpressional forces produced by wrench fault tectonics during the deformational stage of the aulacogen.

McBee (1995) suggested that the Anadarko Basin, along with other tectonic provinces in Oklahoma, was formed by a megashear. He explained the entire Southern Oklahoma Aulacogen as being the Oklahoma Megashear (OM). Therefore, he

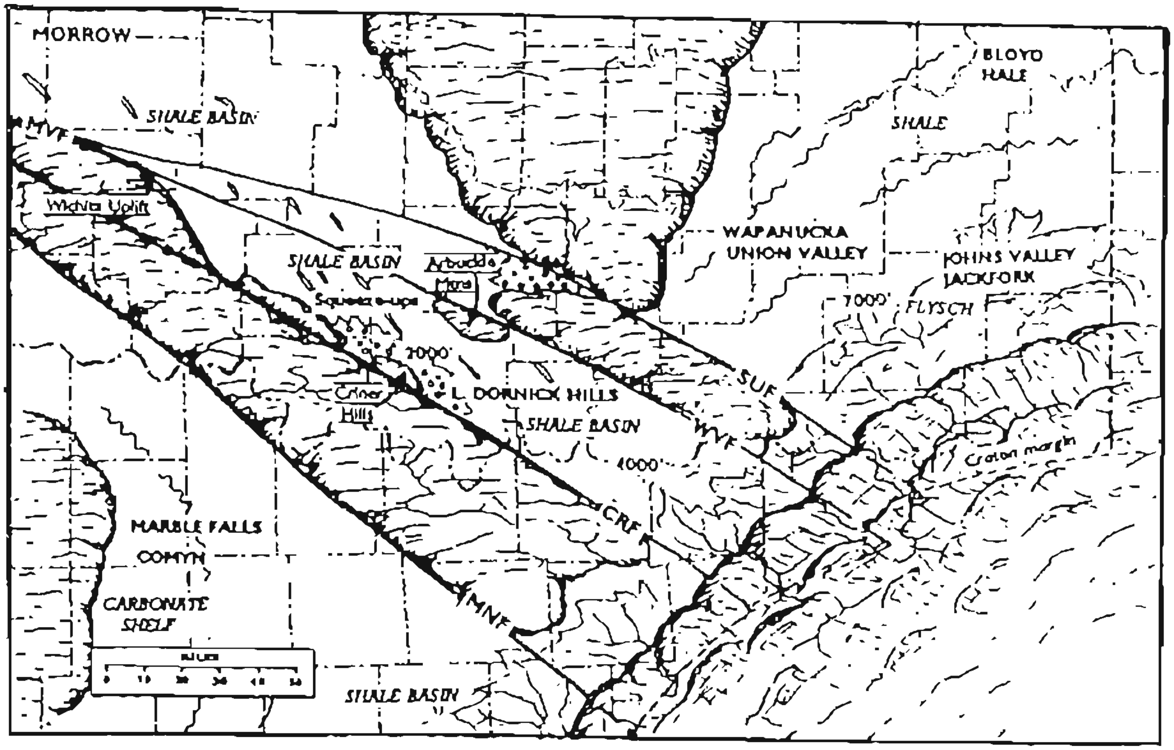


Figure 7. The relative position of the Ouachita thrust front as it approached the OM and encroached onto the North American plates (Laurentia) southern margin. Craton margin represents the North American plate boundary. The OM consists of the Sulphur Fault (SUF), Washita Valley Fault (WVF), Criner Fault (CRF) and, Muenster Fault (MNF) as well as the other uplifts and basins. Wavy lines show boundaries between lithofacies. (McBee 1995)

stipulated that wrench-fault tectonics were active throughout the evolution of the aulacogen. He proposed that the OM was a part of a "long-lived, transcratonic, convergent shear-fault (wrench) system." This OM system was formed bycompressional shear fractures, forming a basin that was deformed over geologic time by several episodes of east-and-west orogenic stresses (McBee, 1995).

McBee (1995) suggested that during Early Pennsylvanian, two orogenic events occurred. To the southeast, the South American Plate collided with the North American plate (Laurentia), an episode that lasted from Middle Mississippian to Middle Pennsylvanian. This episode is believed to have created the Ouachita fold-thrust belt to the south of the OM (Figure 7). However, McBee (1995) suggested that the continued Ouachita Orogeny into Middle Pennsylvanian had no effect on the OM. Instead an early Pennsylvanian east-west compressional stress regime termed "*Alleghenian*" (McBee, 1995) produced very intense tectonic events, which were manifested by a great deal of left-lateral strike-slip movement on the Muenster Fault (MNF) and Washita Valley Fault (WVF) (Figure 7) which in turn created the tectonic provinces of Oklahoma (Figure 1).

Regardless of the origin of the Pennsylvanian strike-slip movement, there is an agreement that basins and uplifts in the area of the Southern Oklahoma Aulacogen were produced by strong strike-slip deformation. The aulacogen hypothesis prefers the interpretation that the formation of the Ouachita Mountains affected the aulacogen and was responsible for its deformational stage. However, McBee (1995) argued that the Ouachita Orogeny did not affect the areas to the west of the Anadarko Basin. He proposed that reactivation of the older faults was owing to the *Alleghenian* compressional-stress regime

Carter-Knox structure

Geologic studies of the Carter-Knox area started in 1916, when surface geologic work was done for the A.T. and S.F. Railway Company by Clyde T. Griswold, who mapped the southern portions of the anticline in Grady County. In 1921, Absher mapped the northern portion of Carter-Knox anticline for the Goldeline Oil Corporation and Guy H. Cox mapped it for the Jersey Oil Company. By 1923, the entire Carter-Knox area had been mapped, and several wells had been drilled by the previously mentioned companies. Oil production in the area started in 1923, and by 1947 several other oil companies had claims within the area (Reedy and Sykes, 1958).

Through the years, data accumulated in the form of surface mapping and wire-line well-log data, and seismic profiles have helped in the interpretation of the Carter-Knox area. However, the only literature on the area is by Reedy and Sykes (1958), and they interpreted Carter-Knox as having three separate structural features formed in pre-Pennsylvanian, Pennsylvanian, and Permian time.

Reedy and Sykes (1958) delineated the pre-Pennsylvanian structure as an anticlinal fold, approximately one mile west of the Pennsylvanian structure (Figure 8). They believed that the thrust faults in Pennsylvanian beds were confined to Pennsylvanian, and do not distort the pre-Pennsylvanian structure

Reedy and Sykes (1958) delineated the Pennsylvanian structure as an elongated, northwest-southeast trending fold that is faulted on the northeast limb (Figure 8). They interpreted the faults as fold-thrust faults with dips of 50-60 degrees which flatten to the southeast within the Springer.

Reedy and Sykes (1958) delineated the Permian structures as two normal faults that flank the Pennsylvanian structure (Figure 8).

Many companies in the oil industry followed this train of thought by Reedy and Sykes (1958), because this was the only well-recognized published paper that described the Carter-Knox structure. However, based on the interpretation of recent data, this study suggests that the Carter-Knox structure is a transpressional structure that formed a positive flower structure.

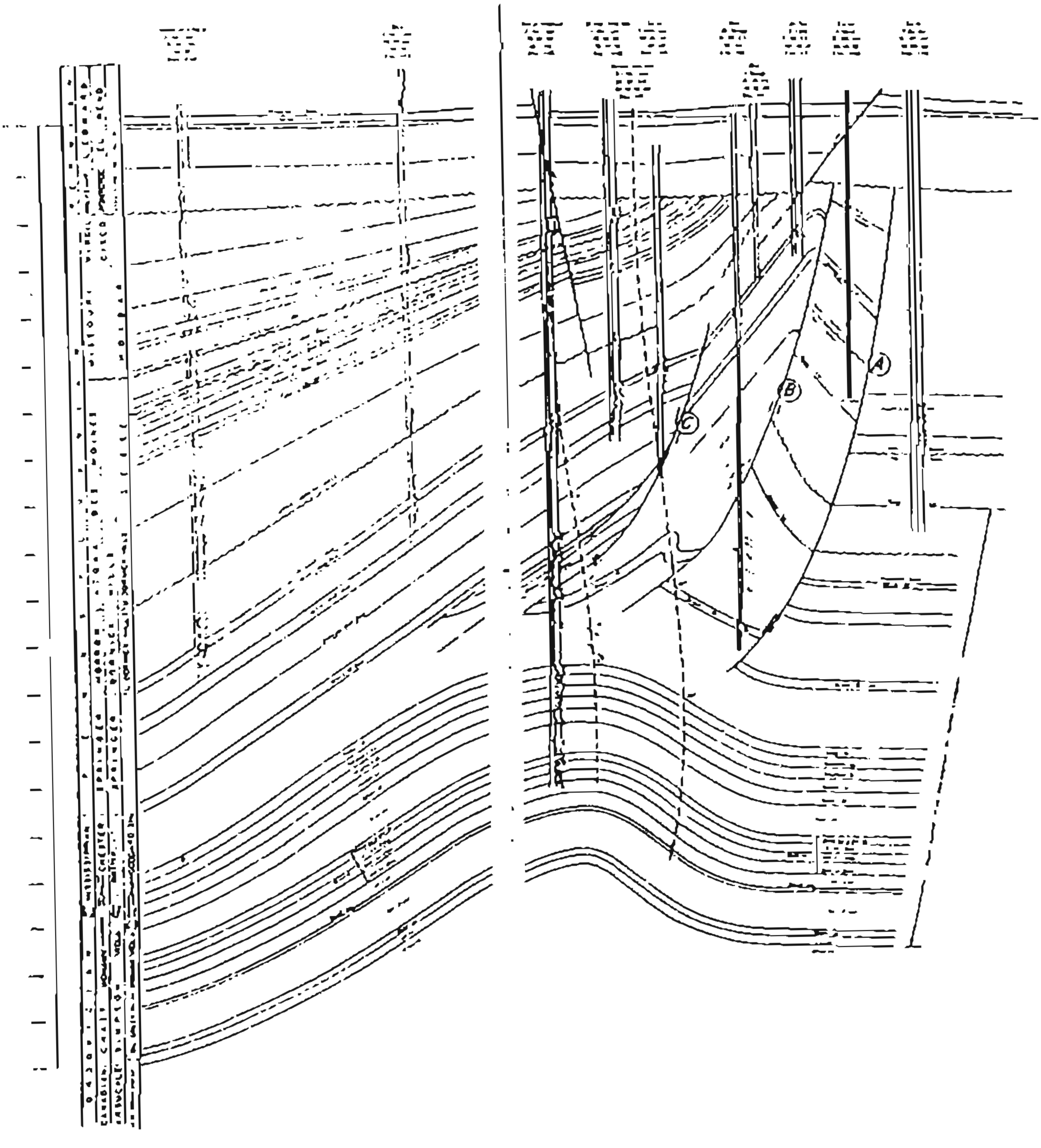


Figure 8. Cross-section showing interpretation of Carter-Knox by Reedy and Sykes, 1958.

CHAPTER II

STRATIGRAPHY OF THE ANADARKO BASIN

The Anadarko Basin contains a thick sequence of sedimentary rocks; however, the study only utilizes rocks from Ordovician to Middle Pennsylvanian (Figure 9). The Ordovician to Middle Pennsylvanian sedimentary units were used to construct the structural cross-sections of the study area; therefore, these strata will be discussed in detail. However, a brief description of the Pre Ordovician rock units of the Anadarko basin also is included. Figure 10 is a stratigraphic chart which shows the pre-Ordovician rocks and can be used to correlate the Anadarko Basin rock units with other areas.

PRE-ORDOVICIAN ROCK UNITS

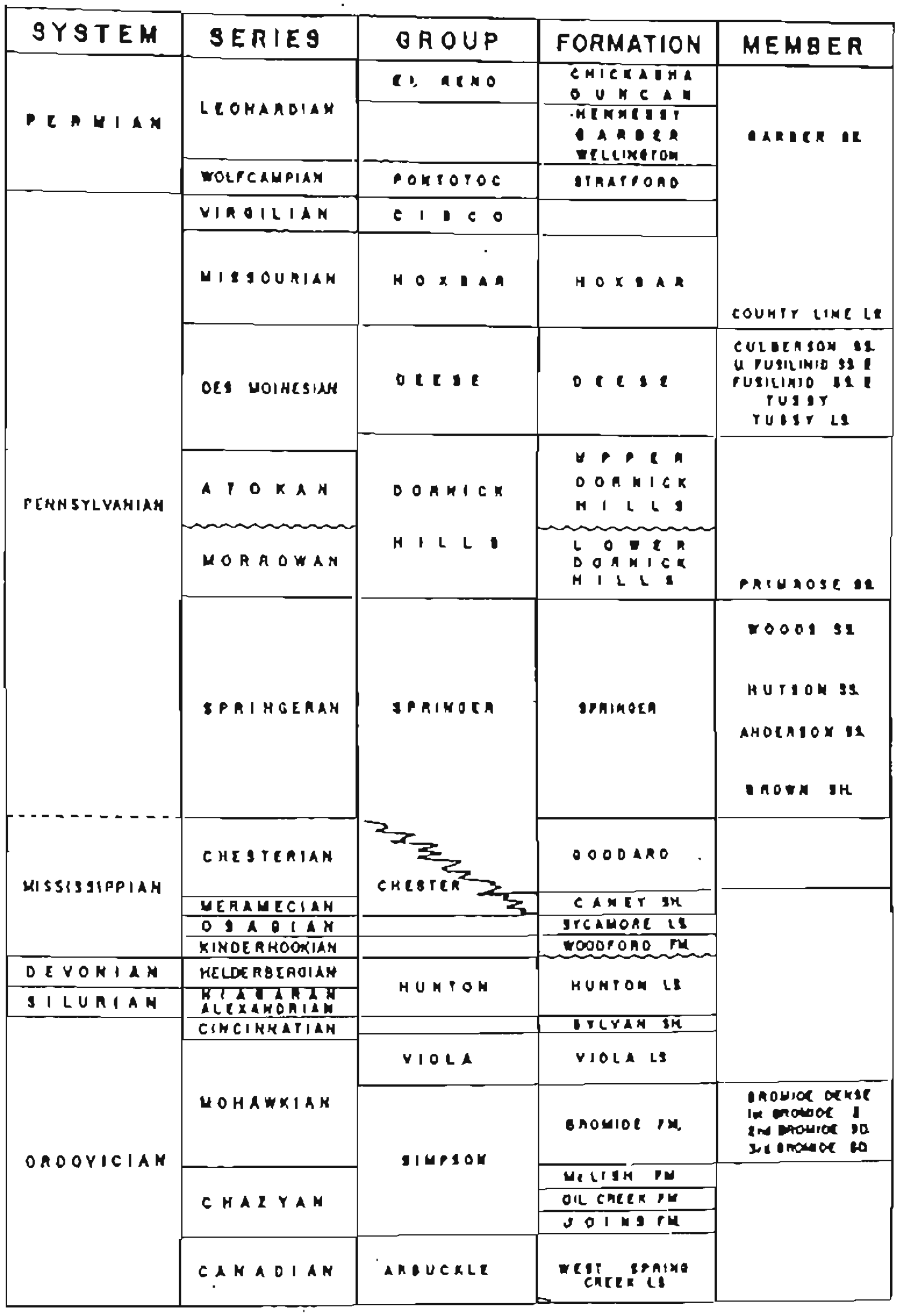
The oldest sedimentary rock unit in the Anadarko basin is the Upper Cambrian Timbered Hills Group (Honey Creek Limestone and underlying Reagan Sandstone), which uncomformable overlie the Carlton Rhyolite (Perry, 1989) (Figure 10). The Reagan Sandstone is a transgressive basal sandstone which underlies the Honey Creek Limestone (Figure 10) which is a fossiliferous limestone (Ham, 1973)

The Arbuckle Group is composed of shallow-water marine sediments and conformable overlies the Timbered Hills Group (Figure 10). The Arbuckle is divided into the lower Arbuckle of Cambrian age and upper Arbuckle of Ordovician age. The lower Arbuckle consists of the Fort Sill Limestone, Royer Dolomite, and the Signal Mountain Formation. The upper Arbuckle consists of the Butterly Dolomite, McKenzie, Cool Creek, Kindblade and West Spring Creek Formations (Johnson, 1991) (Figure 10)

ORDOVICIAN-PENNSYLVANIAN ROCK UNITS

The Simpson Group uncomformable overlies the Arbuckle Group. The Simpson, from oldest to youngest, is composed of the Joins, Oil Creek, McLish, Tulip Creek, and Bromide Formations (Figure 10). The Joins Formation is mostly limestone. The Oil Creek Formation is composed of a basal limestone overlain by interbedded shale and fossiliferous limestone units. The McLish, Tulip Creek, and Bromide Formations also have basal sandstones; however, the formations are overlain by skeletal calcarenites (Ham, 1978).

Overlying the Simpson Group is the Viola Limestone of Middle Ordovician age (Figure 9). The Viola Limestone is shown in structural cross-sections B-B', C-C', and D-D' (Figures 25-27 and Plates IV-VI). In the study area, the Viola Limestone is 650 feet thick, on the average, and is composed of "mottled gray, fine to coarsely crystalline, and tan to brown, finely crystalline with tan to brown chert" (Reedy and Sykes, 1958).



SYSTEM	SERIES	GROUP	FORMATION	MEMBER
PERMIAN	LEONARDIAN	EL RENO	CHICKASHA DUNCAN	GARBER SS
			HENNESSEY GARBER WELLINGTON	
	WOLFCAMPIAN	PONTOTOC	STRATFORD	
PENNSYLVANIAN	VIRGILIAN	CISCO		
	MISSOURIAN	HOXBAR	HOXBAR	COUNTY LINE LS
	DES MOINESIAN	DEESE	DEESE	CULBERSON SS U FUSILINID SS E FUSILINID SS E TUSSY TUSSY LS
	ATOKAN	DORNICK HILLS	UPPER DORNICK HILLS	
	MORROWAN		LOWER DORNICK HILLS	PRIMROSE SS
	SPRINGERAN	SPRINGER	SPRINGER	WOODS SS HUTSON SS ANDERSON SS BROWN SH
MISSISSIPPIAN	CHESTERIAN	CHESTER	GODDARD	
	MERAMECIAN		CANEY SH	
	OSAGIAN		SYCAMORE LS	
	KINDERHOOKIAN		WOODFORD FM	
DEVONIAN	HELDERBERGIAN	HUNTON	HUNTON LS	
SILURIAN	NIAGARAN ALEXANDRIAN			
ORDOVICIAN	CINCINNATIAN		SYLVAN SH	
	MOHAWKIAN	VIOLA	VIOLA LS	
		SIMPSON	BROMIDE FM	BROMIDE DENSE 1st BROMIDE S 2nd BROMIDE SD 3rd BROMIDE SD
	CHAZYAN		McLISH FM	
			OIL CREEK FM	
			JOINS FM	
	CANADIAN	ARBUCKLE	WEST SPRING CREEK LS	

Figure 9. Stratigraphic chart of the Carter-Knox field (from Reedy and Sykes, 1958).

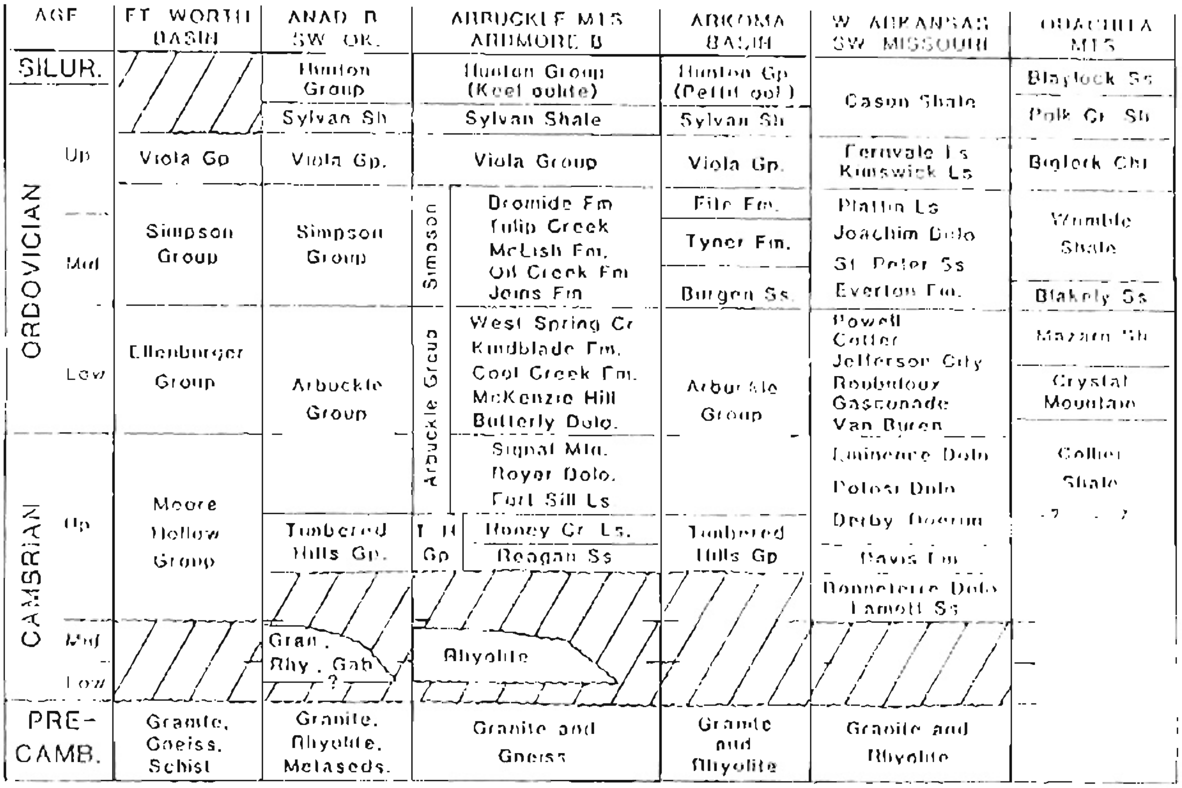


Figure 10. Correlation chart for Cambrian and Ordovician rocks of Oklahoma and adjacent areas. (Hills and Kottlowski, 1983; Mankin, 1987).

Log characteristics used to distinguish the Viola are: (1) conductivity close to 0 (MMHO), (2) gamma ray of ~ 30 (gAPI) or less, and (3) shallow and deep induction of ~ 40 (ohm-m) or more (Figure 11).

Conformable above the Viola is the Sylvan Shale of Late Ordovician age (Figure 9). The Sylvan shale is 280 feet thick, on the average, and is composed of a "greenish gray, pyritic shale" (Reedy and Sykes, 1958). Log characteristics used to distinguish the Sylvan are: (1) conductivity ~ 100 (MMHO), (2) gamma ray of ~ 120 (gAPI), and (3) shallow and deep induction of 10-20 (ohm-m) (Figure 11).

Conformable above the Sylvan Shale is the Hunton Group of Silurian to Devonian age (Figure 9). The Hunton Group is shown in structural cross-section A-A' (Figure 24). The Hunton Group is composed, from oldest to youngest, of the Chimneyhill Subgroup, consisting of the Keel, Cochrane, and Clarita Formations, and the Henryhouse, Haragan-Bois d'Arc, and Frisco Formations. Within the Chimneyhill Subgroup, the Keel Formation is an oolitic limestone. The Cochrane is composed of fossiliferous mudstone/wackestone and fossiliferous packstone/grainstone The Clarita Formation is composed of glauconitic pelematazoan packstone/grainstone. The Henryhouse Formation is composed of marlstone, with some calcareous shale beds in the lower part. The Haragan-Bois d'Arc Formation consists of marlstone grading upward into packstone/grainstone The Frisco Formation is composed of bioclastic packstone/grainstone, which has abundant crinodal fragments (Al-Shaieb and others, 1993). The Hunton, within the study area, lies unconformable below the Woodford Shale (Reedy and Sykes, 1958) The Hunton has been seen in the study area as thin as

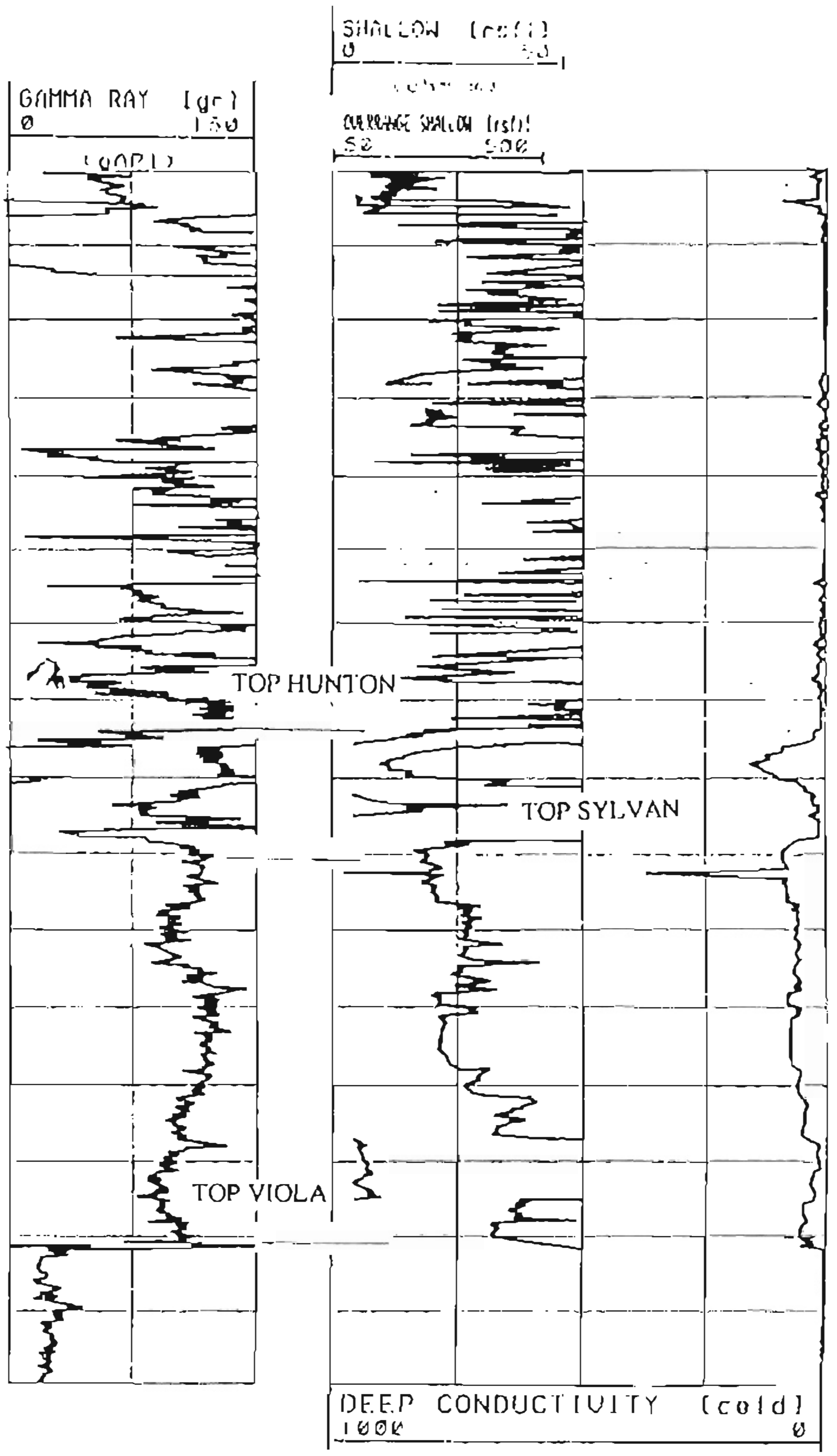


Figure 11 Representative well log signatures of the Viola, Sylvan, and Hunton (from the Ledbetter well in Sec 12, T 2N , R.5W., operator Chesapeake)

20 feet at the axis of the Baker anticline and as thick as 330 feet on the limbs of the Baker anticline. Log characteristics used to distinguish the top of the Hunton are: (1) conductivity around to 200 (MMHO) after the Woodford Shale then settling to near 0 (MMHO), (2) shallow and deep induction of 15 ohm-m , and (3) gamma ray decreasing to 100 (gAPI) after the Woodford Shale (Figure 11).

Unconformable above the Hunton Group is the Woodford Shale (Figure 9) of Late Devonian to Early Mississippian age. The Woodford Shale is shown in all four structural cross-sections (Figures 24-27 and Plates III-VI). The Woodford Shale is characterized as black, highly organic shale, and is the primary source rock for hydrocarbons (Al-Shaieb and others, 1993). Throughout the study area the Woodford Shale is about 350 feet thick (Reedy and Sykes, 1958). Log characteristics used to distinguish the Woodford are: (1) conductivity close to 0 (MMHO), (2) shallow and deep induction of 10 (ohm-m) and less, and (3) a gamma ray of 270 (gAPI) plus (Figure 12).

Conformable above the Woodford Shale is the Sycamore Limestone of Middle Mississippian age (Figure 9). The Sycamore is about 200-250 feet thick within the study area, and is composed of "gray to tan, siliceous, argilaceous limestone"(Reedy and Sykes, 1958). Log characteristics used to distinguish the Sycamore are: (1) conductivity near 0 (MMHO) with the lower quarter half having a conductivity of 50 (MMHO), (2) gamma ray of ~ 30 (gAPI), and (3) shallow and deep induction varying from 10 - 50 (ohm-m) (Figure 12).

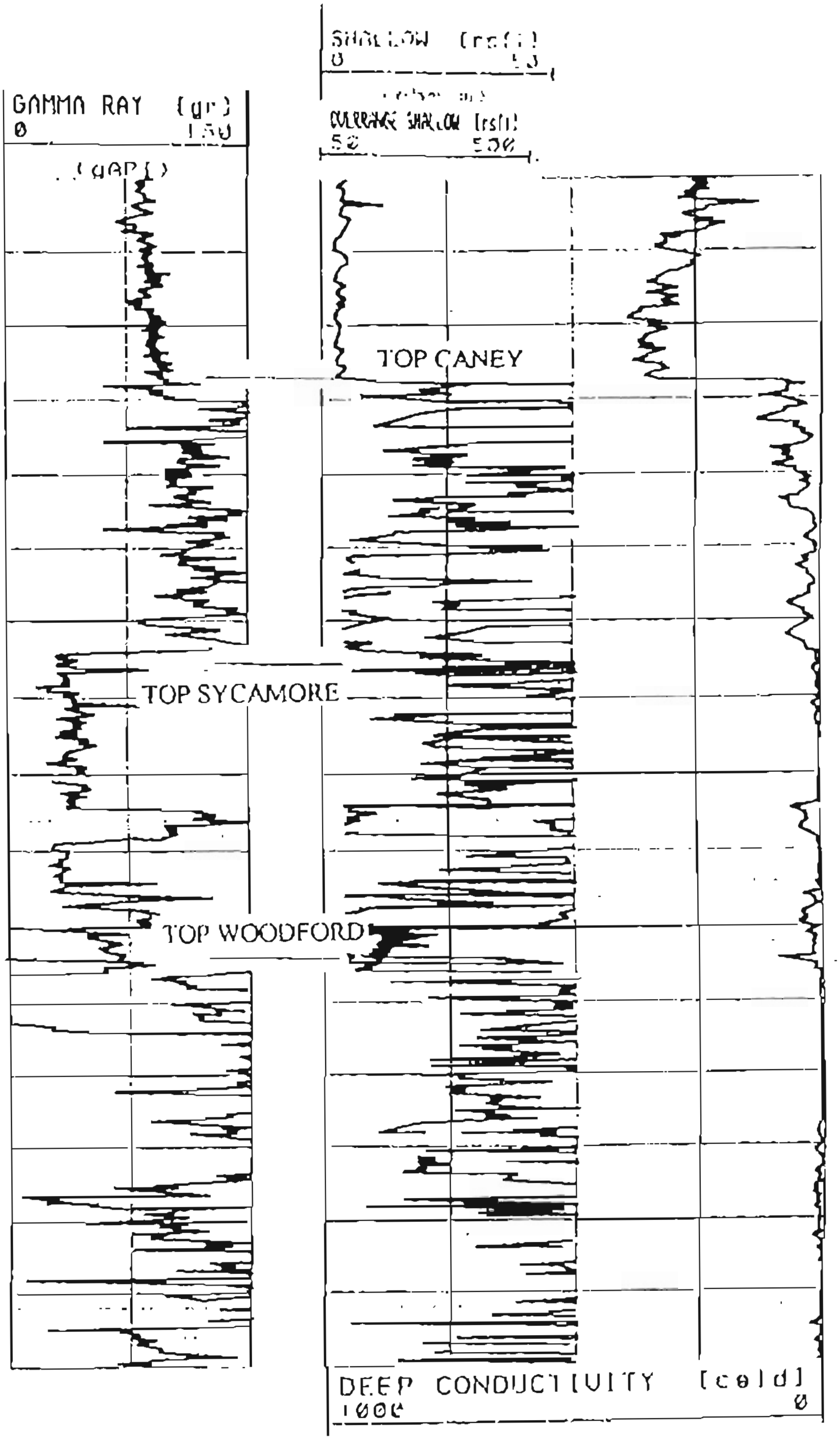


Figure 12. Representative well log signatures of the Woodford, Sycamore, and Caney (from the Ledbetter well in Sec. 12, T.2N., R.5W., operator Chesapeake).

Conformable above the Sycamore Limestone is the Caney Shale (Figure 9) of Middle Mississippian age. The Caney is shown in all four structural cross-sections (Figures 24-27 and Plates III-VI). The Caney is about 200 feet thick throughout the study area, and is composed of "dark gray to brown shale" (Reedy and Sykes, 1958). Log characteristics used to distinguish the Caney are: (1) decrease in conductivity to 100 (MMHO), (2) an increase in shallow and deep induction of 30 (ohm-m) plus, and (3) gamma ray increasing to ~120 (gAPI) (Figure 12).

Comformable on the Caney Shale is the Goddard Shale (Figure 9) of Late Mississippian age. The Goddard is a gray to dark gray shale with sparse nodules of siderite. The Goddard is about 1000 feet thick in the study area (Reedy and Sykes, 1958). The Goddard has not been distinguished using log characteristics, due to uncertainty about the boundary between the Goddard and the Springeran Series.

Above the Goddard is an informal marker named the "Boat". The Boat Marker is useful in distinguishing possible faults within the study area. This marker is detectable only by log characteristics. The Boat Marker is shown in all the structural cross-sections (Figures 24-27 and Plates III-VI) because it is very prominent within all wells in the study area. The Boat Marker is a black shale having an average thickness of about 100 feet in the study area. Its log characteristics are: (1) drop in conductivity to near 0 (MMHO) and (2) an increase in shallow and deep induction to 50 (ohm-m) (Figure 13).

Conformable overlying the Goddard Shale is the Springeran Series of Early Pennsylvanian age (Figure 9). The Springer consists of the Woods, Hutson and

Anderson Sandstones, and the Brown Shale. However, only the uppermost part of the Springeran Series is shown in the four structural cross-sections, in order to maintain legible cross-sections (Figures 24-27 and Plates III-VI). The Woods and Hutson are glauconitic sandstones whereas the Anderson is characterized as a fine grained, tightly cemented sandstone. The Brown Shale is dark gray to brown (Reedy and Sykes, 1958). Thickness of the Springer-Caney interval varies due to faulting and/or compression of the Goddard Shale. The Ledbetter well operated by Chesapeake (Sec. 12, T.2N., R.5W.) was used as the control well to determine the actual thickness in the study area. The control well shows the thickness between the top of the Springer-Caney interval at about 2900 feet. Log characteristics used to distinguish the top of the Springer Series are: (1) conductivity around 400 (MMHO) and (2) a shallow and deep induction around 5 (ohm-m) (Figure 14).

The Morrowan Series is comformable above the Springeran Series (Figure 9) and is shown in all four structural cross-sections. In order to simplify the structural cross-sections, only the uppermost part of the Morrowan Series is used (Figures 24-27 and Plates III-VI). The Morrowan Series is divided into the lower and upper Dornick Hills Group The lower Dornick Hills Group is composed of a micaceous shale with occasional thin glauconitic limestone beds (Reedy and Sykes, 1958). The Primrose Sandstone is within the lower Dornick Hills Group and is characterized as semi-crystalline sandstone with interbedded shales (Tomlinson, 1959). Log characteristics used to distinguish the top of the Morrowan Series are (1) conductivity around 50

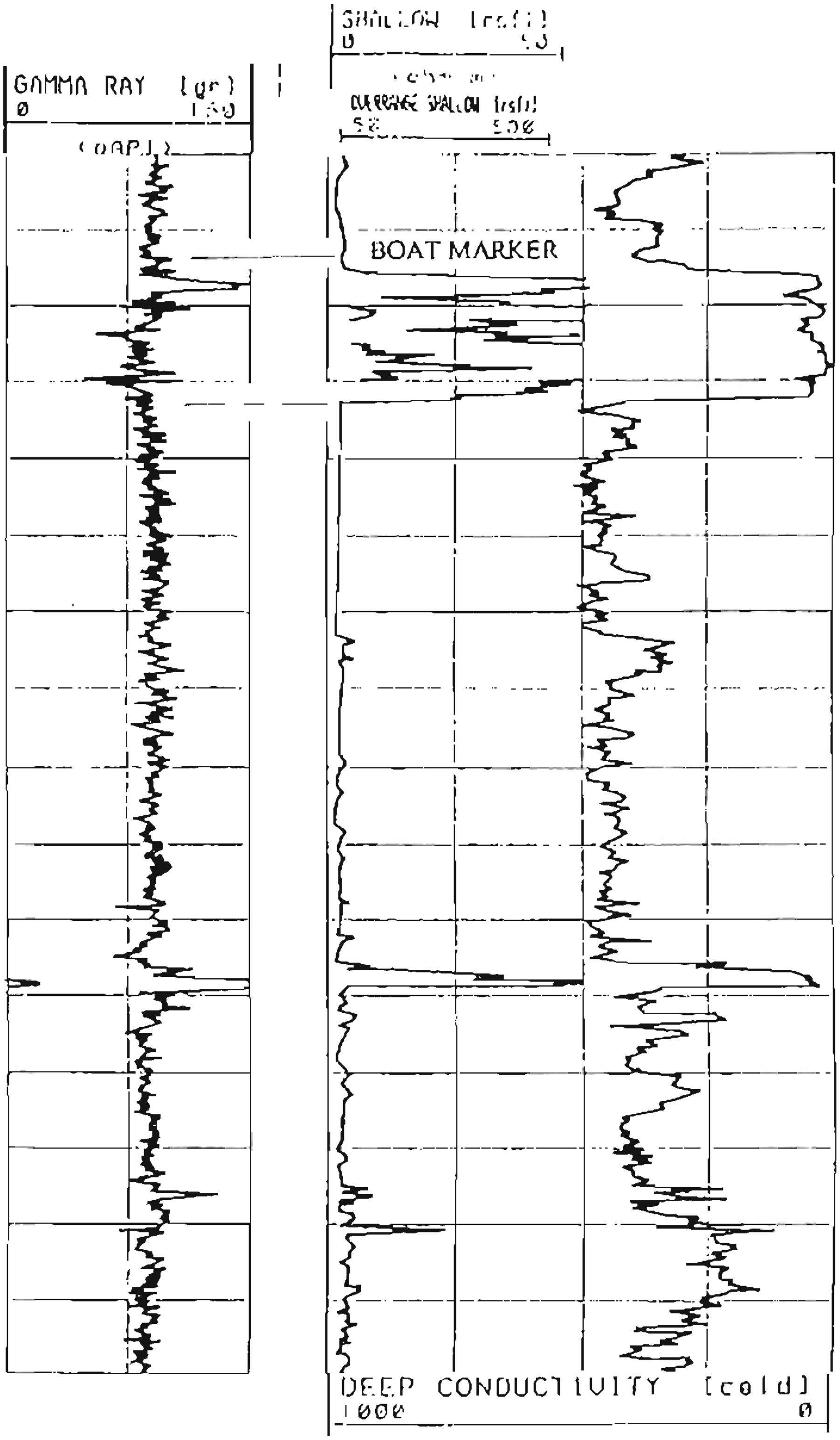


Figure 13 Representative well log signature of the Boat Marker (from the Ledbetter well in Sec. 12, T.2N., R 5W., operator Chesapeake).

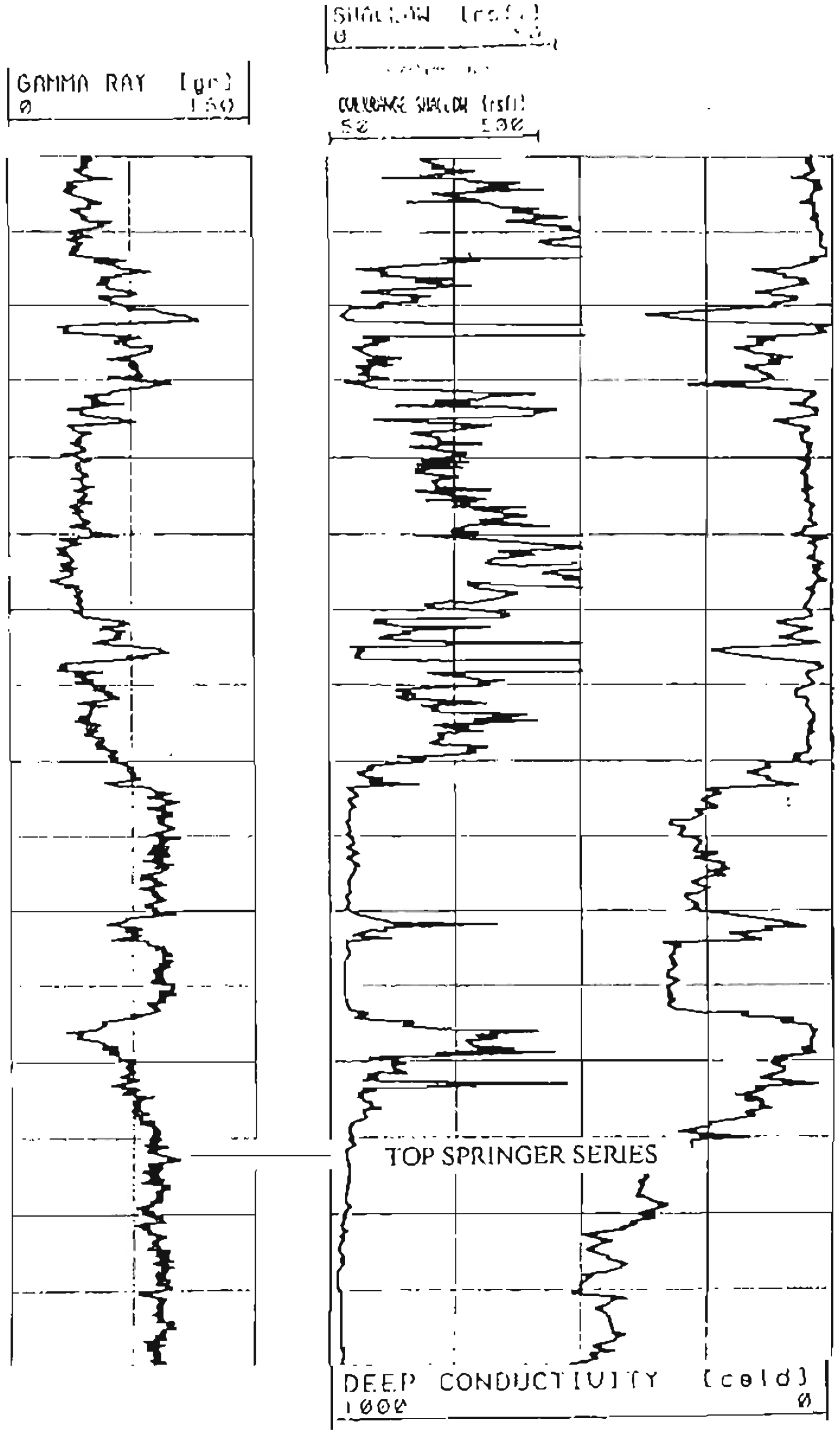


Figure 14. Representative well log signature of the Springer Series (from the Ledbetter well in Sec. 12, T.2N., R.5W., operator Chesapeake)

(MMHO), (2) increase in shallow and deep induction to 25 (ohm-m) plus, (3) a decrease in the gamma ray to 45 (gAPI) and (4) directly below this thin bed, about 100 feet, is a thicker bed of about 50 feet with similar log characteristics (Figure 15).

There are several other rock-stratigraphic units above the Morrowan Series (Figure 9), but they are not shown in the structural cross-sections. This is done in order to simplify the four structural cross-sections. Other Ordovician-Pennsylvanian units penetrated by wells but not used in the structural cross-sections are the Sylvan Formation and Sycamore Formation. This is also done in order to simplify the four structural cross-sections. The pre-Ordovician rock units (Timbered Hills Group, Arbuckle Group, and Simpson Group) are not used in the structural cross-sections due to the lack of wells penetrating to this depth.

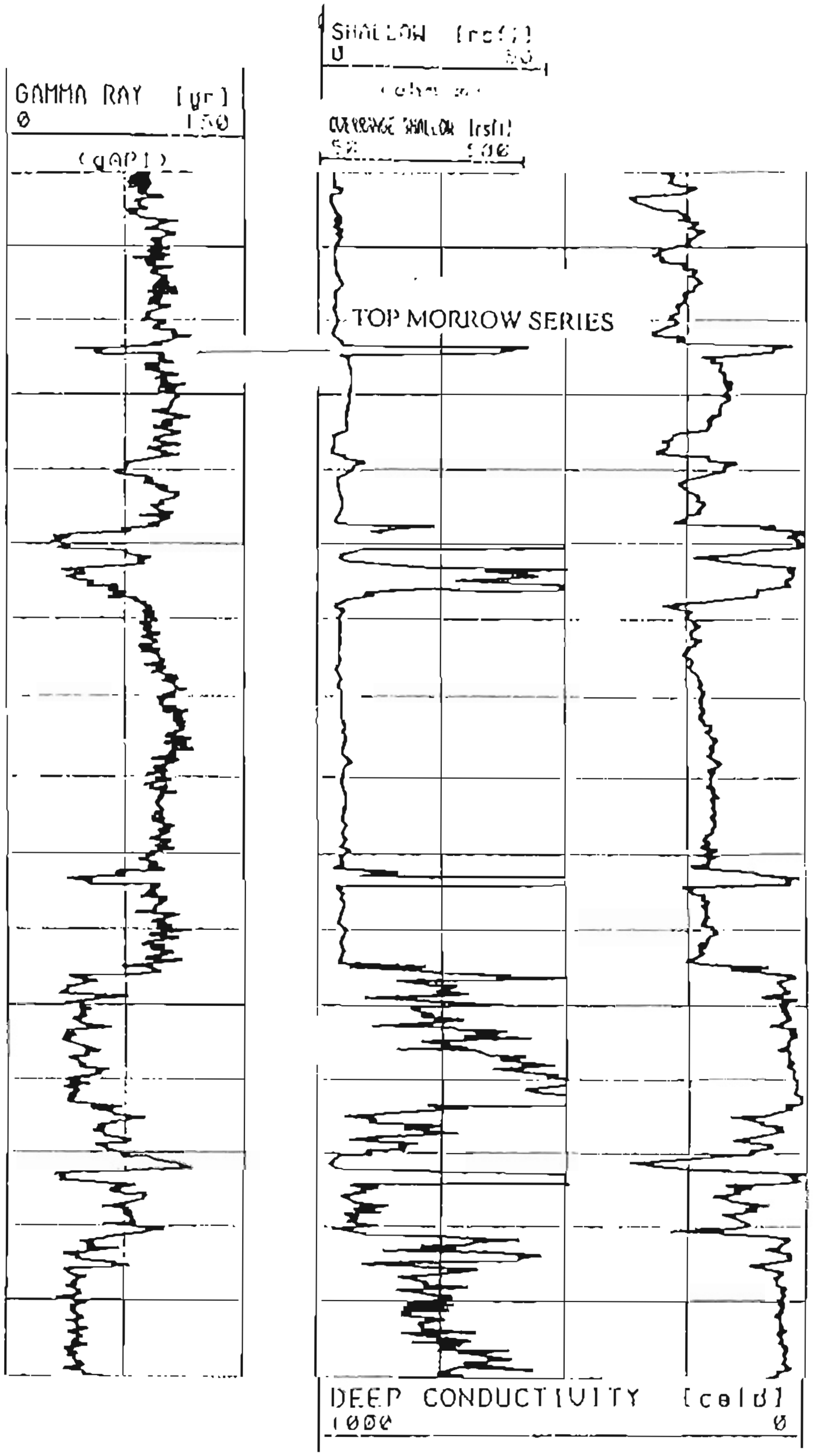


Figure 15 Representative well log signature of the Morrowan Series (from the Ledbetter well in Sec 12, T.2N , R.5W., operator Chesapeake)

CHAPTER III

STRIKE-SLIP FAULTS

Strike-slip faults are high-angle faults which usually involve the basement extending tens to hundreds of miles in a straight to slightly curved trace on the Earth's surface (i.e. San Andres Fault). The strike-slip faults which form lithospheric plate boundaries are called Transform faults, and the strike-slip faults which are within continental crust maybe termed Transcurrent faults (Sylvester, 1988) Through laboratory studies by Wilcox, Harding, and Seely, (1973) and Tchlanko, (1970) a mechanical understanding of strike-slip faults has been obtained which has produced the concepts of pure shear and simple shear. Pure shear strike-slip faults are usually associated with conjugate sets of strike-slip faults located along the strike of convergent orogenic belts. Simple shear is usually associated with major strike-slip faults forming in regional belts, typically parallel to orogenic belts (Sylvester, 1988)

When these faults move parallel to one another there is no addition or subtraction of crust in any one place along the trace of the fault. However, there can be convergence or divergence within a strike-slip fault depending on the bending along the fault (Figure 16). Divergence along a strike-slip fault may produce an elongate basin which can range in size depending on the amount of displacement. This type of occurrence is termed pull-apart basin. Convergence along a strike-slip fault may produce an elongated uplift which can also range in size from small hills to mountain ranges depending on the amount of displacement. Both of these occurrences produce a feature called a wrench fault which produce flower structures within the subsurface (Sylvester, 1988, Wilcox, Harding, and Seely, 1973).

MECHANICS

Pure shear and simple shear are the types of mechanics which produce strike-slip faulting. Pure shear produces conjugate sets of sinistral and dextral strike-slip faults. Strike-slip faults which are produced by pure shear do not produce large displacement, due to the fact that they are located within large crustal masses (Sylvester, 1988) such as the tear faults seen in fold-thrust belts.

Simple shear produces major strike-slip faults around the world which can have displacement measuring in hundreds of kilometers Wilcox, Harding, and Seely, (1973) recreated the evolution of a strike-slip environment using simple shear mechanics (Figures 17 and 18). An earlier experiment by Tchlanko using simple shear, (1970), also proposed five sets of fractures which are seen in strike-slip zones of different magnitudes (Figure 19): (1) Riedel (R) shears or "synthetic", (2) Conjugate Riedel (R') shears or "antithetic", (3) secondary synthetic strike-slip faults, (4) extension fractures at 45 degrees to the zone of displacement, and (5) faults which are parallel to the zone of

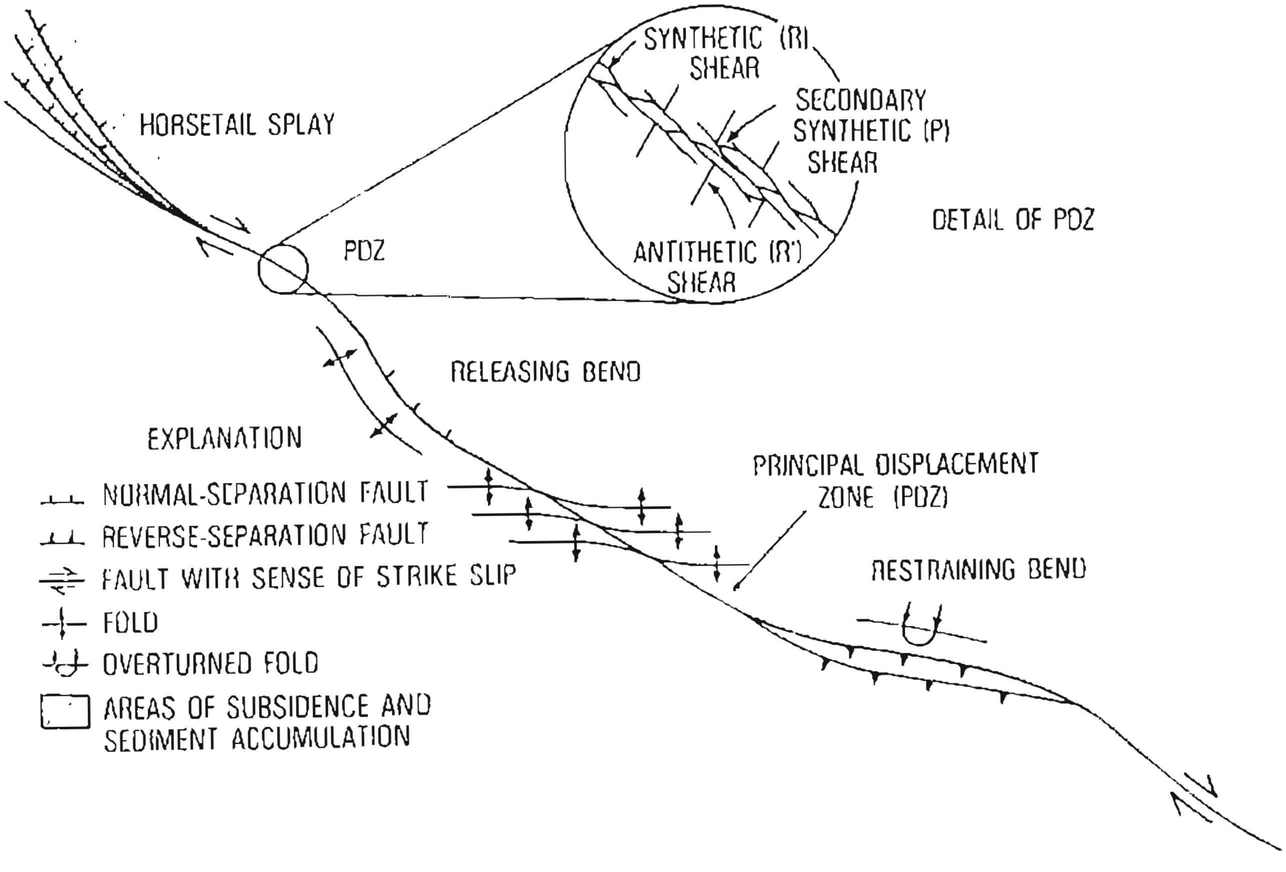


Figure 16. Characteristic map features of a strike-slip fault (from Christie-Blick and Biddle, 1985)

displacement. The evolution of the strike-slip environment recreated in the laboratory by Wilcox, Harding, and Seely (1973), and Tchalanko (1970) provide supporting evidence that strike-slip faults can form using simple shear mechanics.

CHARACTERISTICS

Strike-slip faults are recognized by physiographic features, geologic features, and/or the use of subsurface data in the form of well logs and seismic profiles. If the strike-slip fault is active, the use of focal mechanisms could also be used to help place the strike-slip fault within the subsurface (Sylvester, 1988). Since this study deals mostly with subsurface structural features, only subsurface characteristics of the strike-slip faults will be discussed.

Seismic characteristics of strike-slip faults

Seismic profiles, which were used in the study area, may be the most useful mechanism for identifying a strike-slip fault within the subsurface. When looking at a seismic profile, certain characteristics should be present to validate the presence of a strike-slip fault. The following are important criteria when identifing a wrench fault (Harding, 1990):

(1) The presence of a steeply dipping single or master fault which cuts all sedimentary units down to the basement.

(2) A narrow zone of deformation , which may have steeply dipping faults

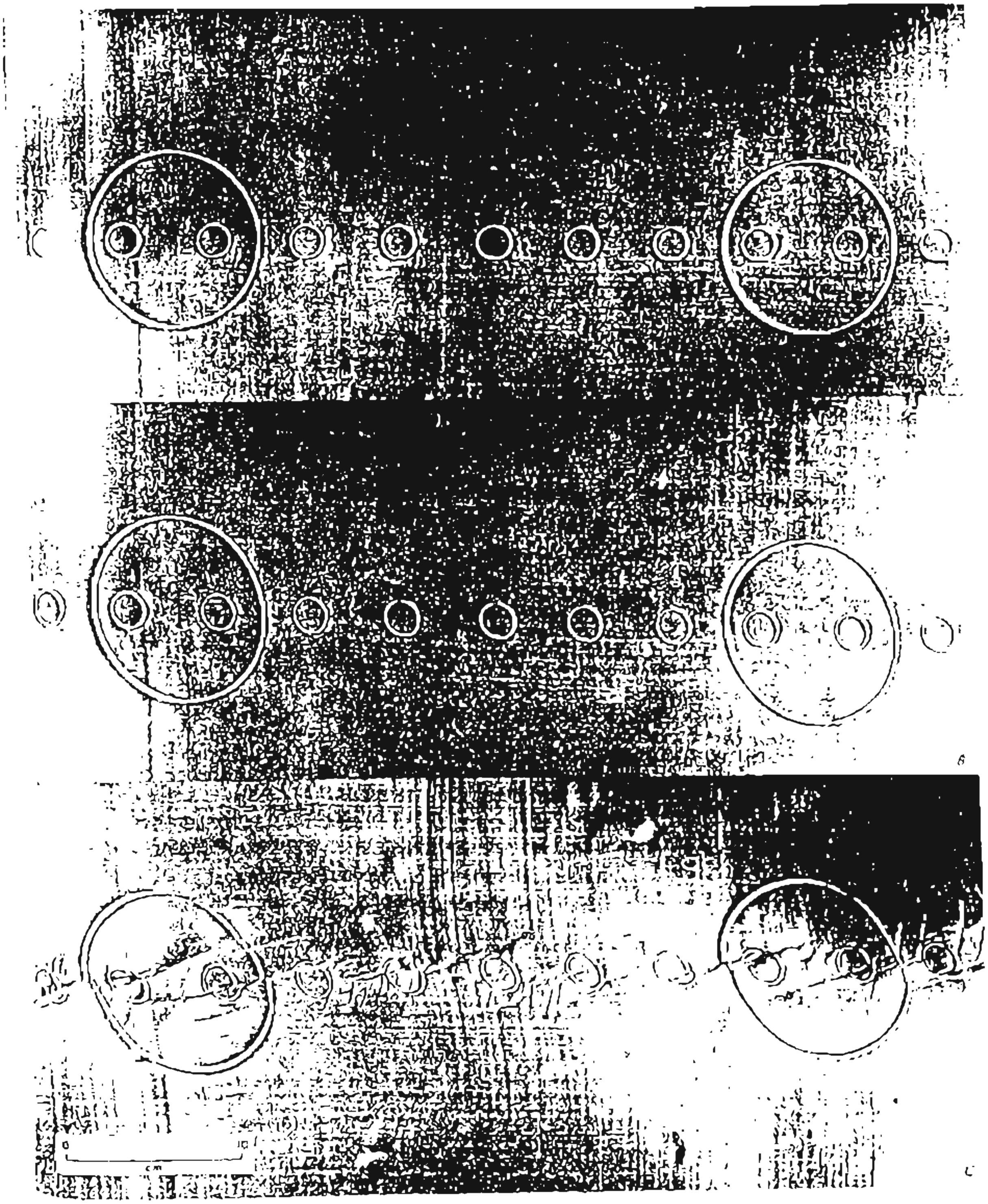


Figure 17. Clay model of parallel left-lateral wrenching showing stages of deformation with increase in simple shear (from Wilcox, Harding, and Seely, 1973).

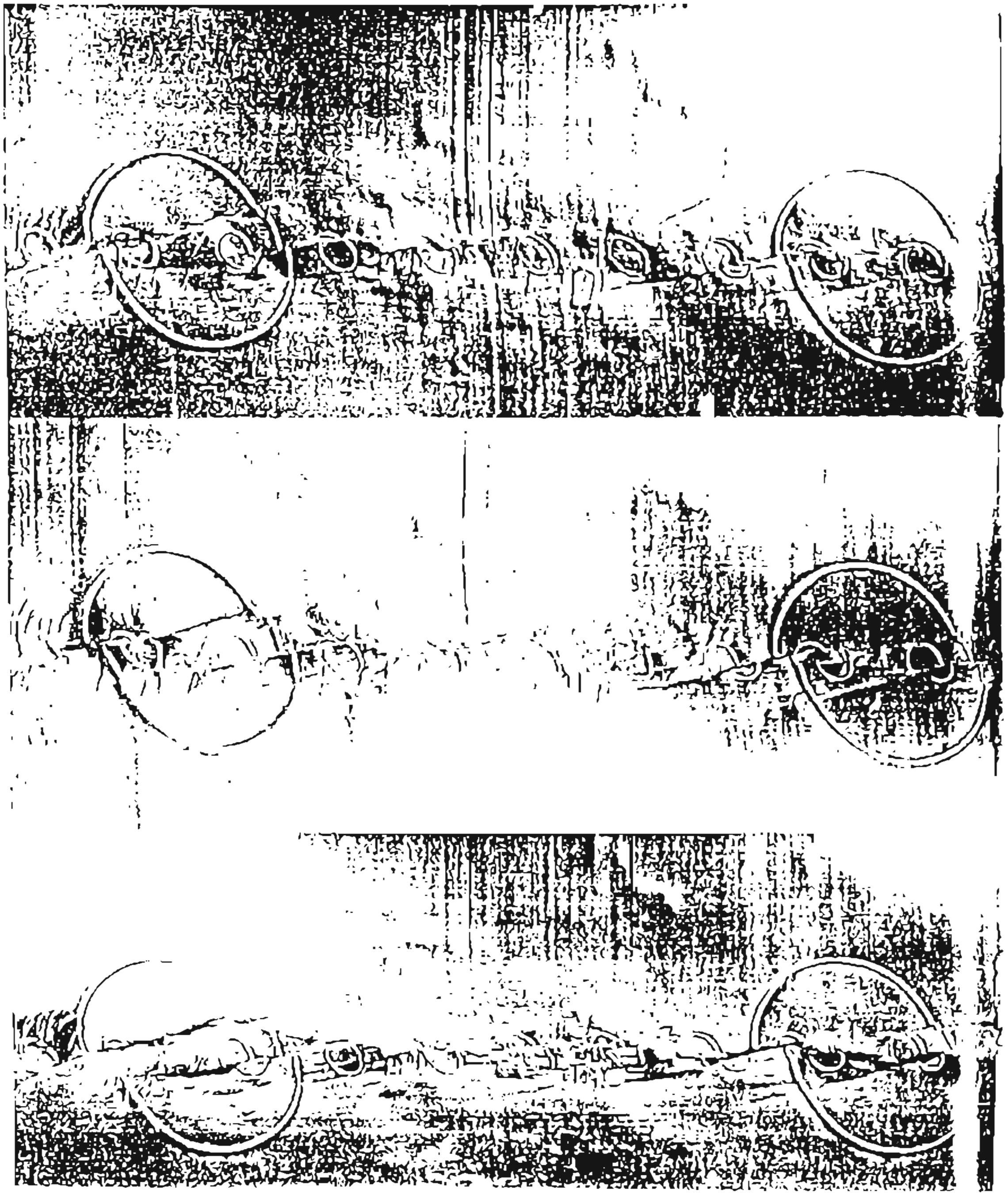


Figure 18. Clay model of parallel left-lateral wrenching showing stages of deformation with increase in simple shear (from Wilcox, Harding, and Seely, 1973)

converging with the master fault at depth. These faults can be seen on one or both sides of the master fault and have reverse or normal separation forming flower structures. The presence of these faults form a symmetrical antiform (Figure 20) or synform (Figure 21) on a seismic profile

(3) The presence of juxtaposed dissimilar strata thickness or stratigraphic successions.

(4) The presence of anomalous faults or folds which cannot be explained using fold geometries.

Of these four characteristics, the most important is the presence of a master fault. Strike-slip faults are most commonly recognized by the master fault due to its length and tectonic dominance. On a sequence of parallel seismic lines, normal to the main structures, the master fault will be thoroughgoing and undisrupted along its trace (Figure 22) if it truly is a strike-slip fault (Harding, 1990).

GEOMETRIES

When a strike-slip fault bends, it either converges or diverges depending on which direction the fault bends (Figure 16). Convergence occurs when the strike-slip movement is inhibited by restraining bends which produce crustal shortening and uplifts (Figure 16) Divergence occurs when the strike-slip movement is uninhibited by releasing bends (Figure 16), producing crustal extension, and pull-apart basins (Sylvester, 1988).

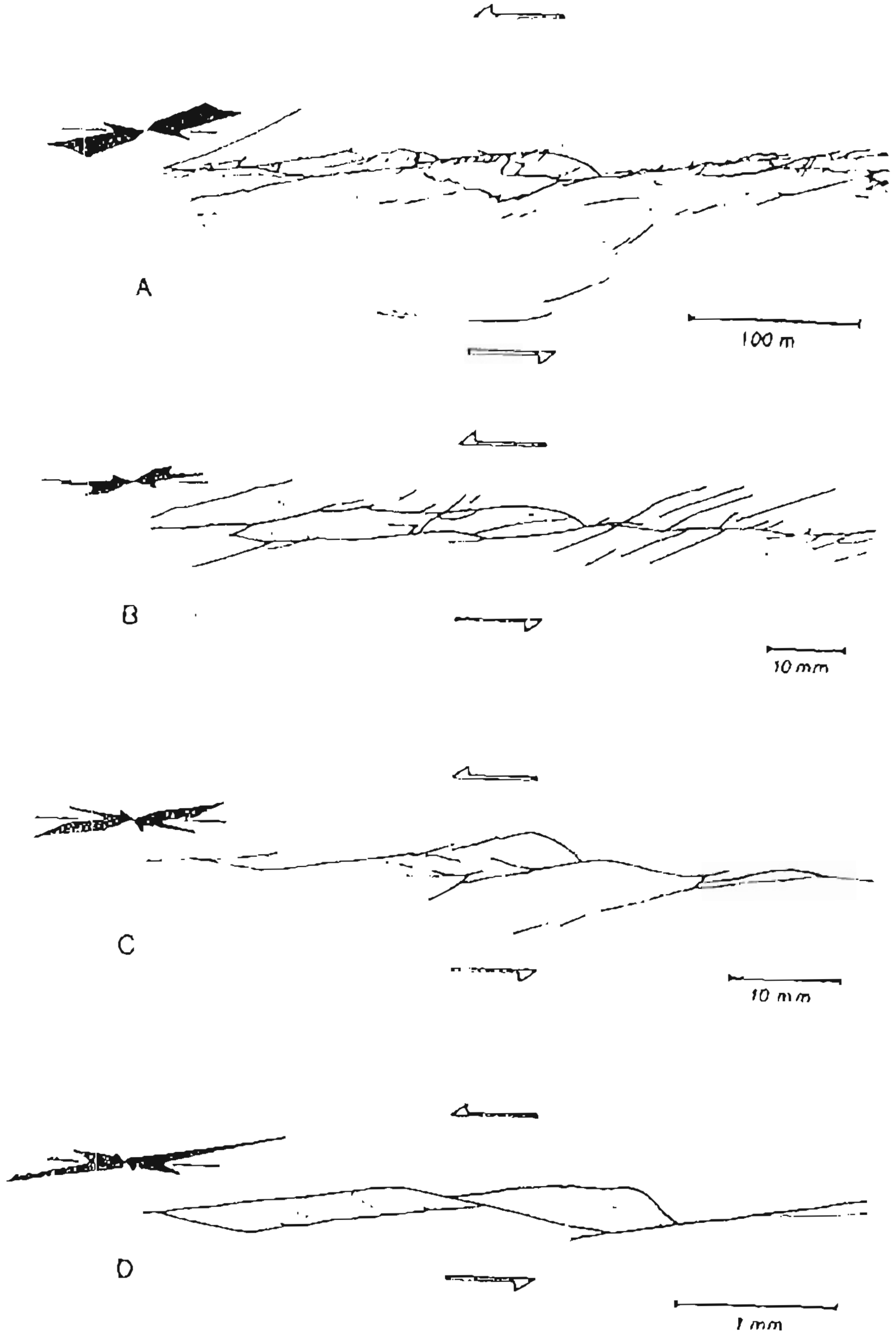


Figure 19. Comparison of conjugate Riedel (R') shears and Riedel (R) shears of different magnitudes (from Tchalanko, 1970)

Releasing bends will produce a negative flower structure in the subsurface (Figure 21), and restraining bends will produce a positive flower structure in the subsurface (Figure 20). When using seismic profiles certain criteria are used to distinguish between a negative flower structure and a positive flower structure.

First, the splays which diverge from the master fault differ in type of displacement. The individual splays in a negative flower structure (Figure 21) have normal separation (Harding, 1985) due to fault blocks diverging from one another. The splays within a positive flower structure (Figure 20) have reverse separation (Harding, 1985) which is due to fault blocks converging toward one another.

A negative flower structure (Figure 21) has fault blocks which diverge from one another. This produces normal separation of the blocks giving the fault slices a graben like appearance (Figure 21). This creates a synform appearance on seismic (Harding, 1985). A positive flower structure (Figure 20), has fault blocks converging toward one another. This produces reverse seperation of the blocks, which creates an antiform appearance on a seismic profile (Harding, 1985).

Positive flower structures can be divided into "squeeze-up" structures or "pop-up" structures (Harding, 1983). "Squeeze-up" structures (Figure 23a) are usually formed in basins or grabens which have a thick sequence of shale, much like the Mississippian strata in the study area. If transpressional forces are applied to this shale, a deformation of plastic flow occures forming rootless, faulted, and tightly folded en-echelon anticlines

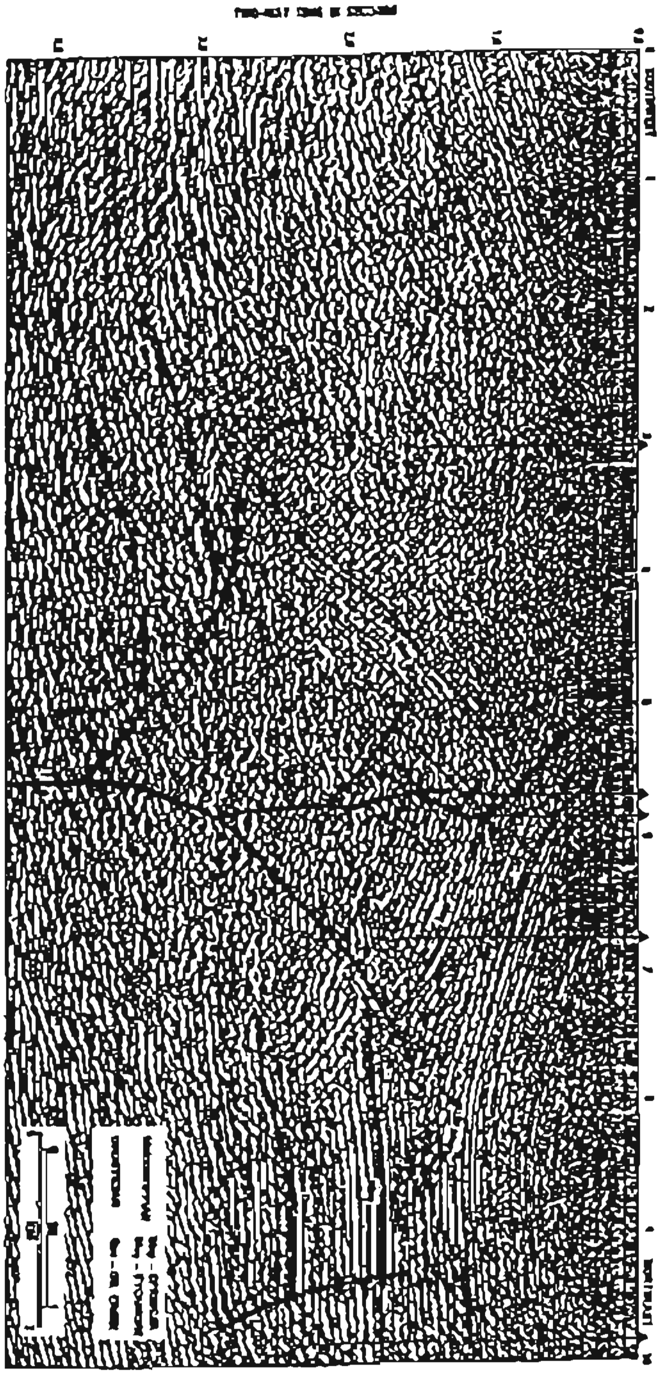


Figure 20. Seismic profile showing a positive flower structure (from Harding, 1983).

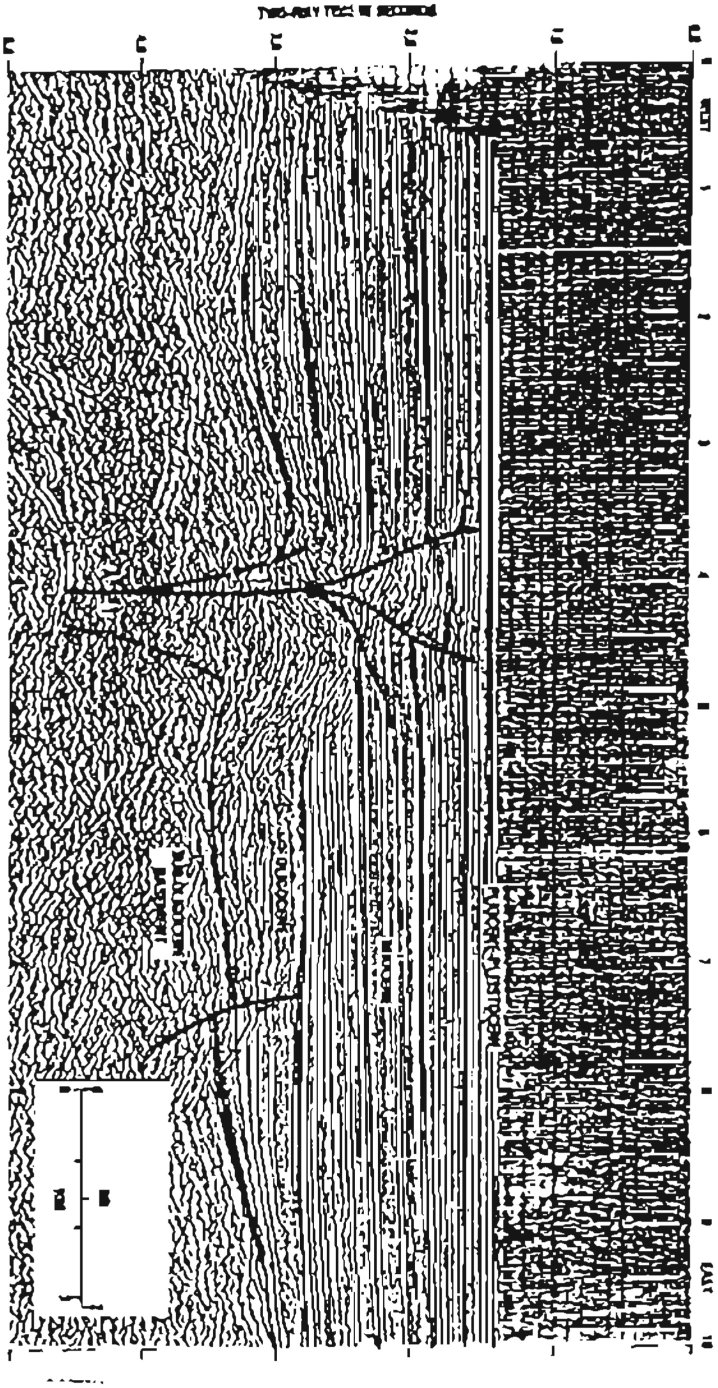


Figure 21. Seismic profile showing a negative flower structure (from Harding, 1983).

with upward diverging splays. These structures, on seismic profiles, have an appearance which displays a great amount of horizontal shortening where in fact there is little if any shortening at the basement level. With increase in strata depth comes a decrease in deformation with the "squeeze-up" structure (Harding, 1983).

"Pop-up" structures are formed where two large thoroughgoing strike-slip faults join forming a graben like uplift (Figure 23b). These structures form in intricate shear fault systems with rigid strata (Harding, 1983).

The splays, which create the blocks, on a positive flower structure can have steep upthrust to shallow dipping thrusts that merge with depth to the master fault. These splays flank the overall structure and have a linear antiform appearance on a seismic profile (Harding, 1985). The splays that come off the main fault can diverge to one or both sides of the structure. Splays can also diverge upward in a wide to narrow spreading zone. This in turn will produce a wide or narrow zone of deformation (Hardening, 1985)

PITFALLS

There is also evidence which refutes the presence of a strike-slip fault and flower structures. As explained by Harding (1985), evidence which can refute the presence of a master fault in a strike-slip tectonic environment are as follows:

(1) The master fault does not displace the top of the basement.

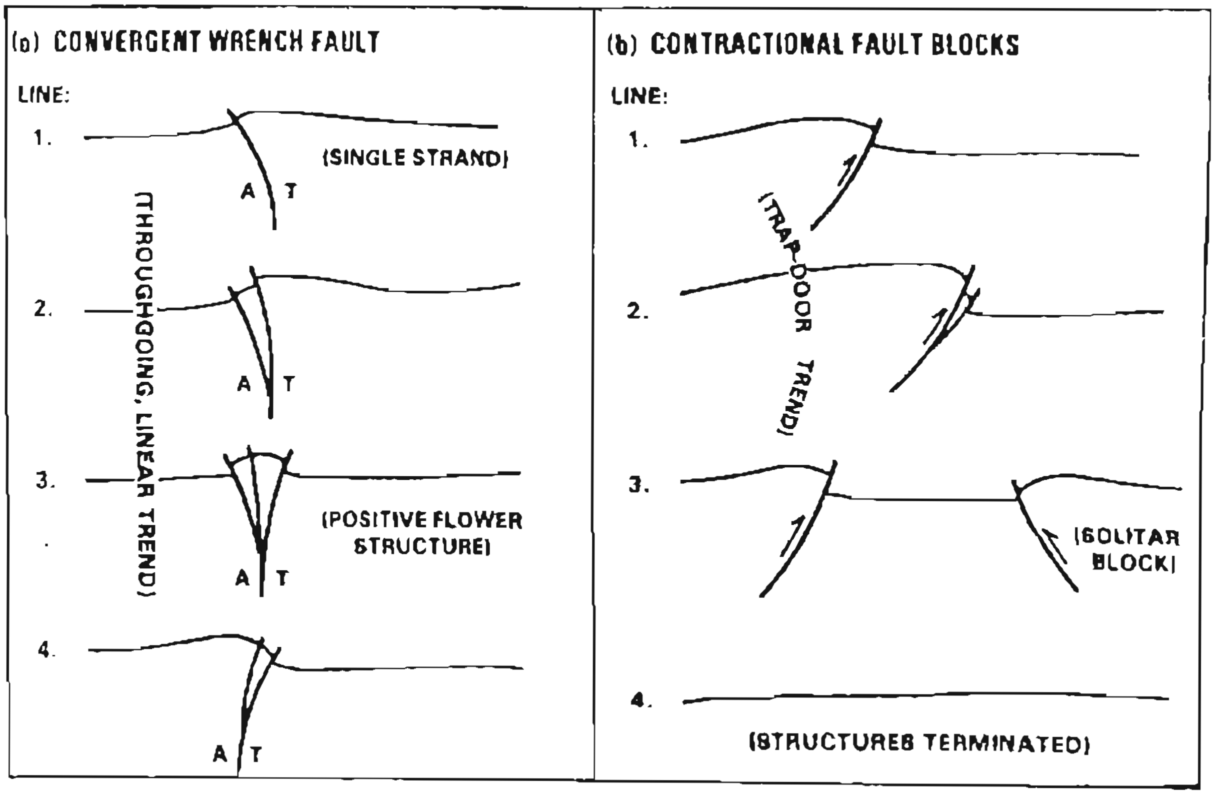


Figure 22. Cross-sections from hypothetical parallel seismic profiles showing an idealized master fault (from Harding, 1990)

(2) In a succession of parallel seismic profiles perpendicular to the subsurface structure, the master fault is not thoroughgoing or linear.

(3) The master fault is just one fault in a group of closely spaced faults with similar structural appearances.

As explained by Harding (1985), pitfalls which can cause the misidentification of a wrench fault producing a flower structure are as follows:

(1) The use of a single seismic profile for interpretation.

(2) The strike-slip zone has only one splay and is asymmetric.

(3) Geometries within the core of the structure are not clear in seismic due to a loss in reflection continuity.

(4) The contact with the master fault to basement is lost due to deterioration of the seismic profile with increase in time

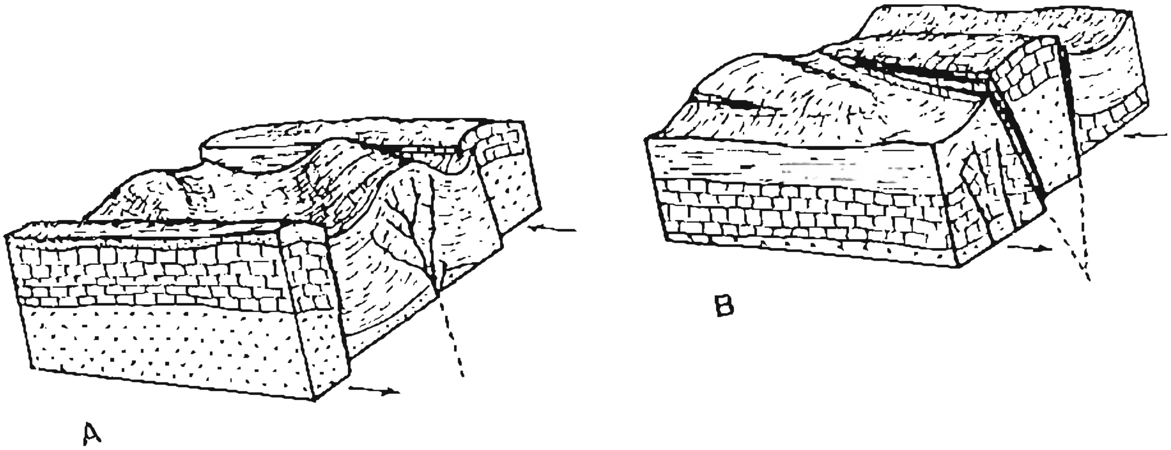


Figure 23. (A) "Squeeze-up" wrench fault structure (B) "Pop-up" wrench fault structure (from Harding, 1983)

CHAPTER IV

STRUCTURAL GEOLOGY

The structural geometry of the study area is delineated by constructing four structural cross-sections (Figures 24-27, Plates III-VI) and two structural contour maps (Figures 28 and 29, Plates VII and VIII) using wire-line well-log data and seismic profiles donated by Marathon Oil Company. The markers shown in the cross-sections are the tops of the Morrow and Springer Series, as well as the Caney, Woodford, Hunton, and Viola Formations Also shown in the cross-sections is a bed termed the "Boat Marker", which is used to determine types of faults and differentiate the thickness between it and the Caney Shale using the Ledbetter (Sec 12, T.2N., R 5W , operator Chesapeake) as the control well.

Plate II is a base map showing the locations of the cross-sections within the study area. The base map also shows locations of the oil-wells used in the construction of the structural cross-sections. Appendix I includes the information obtained from the oil- wells used for the construction of the structural cross-sections. Structural contour maps were also prepared on top of the Springer series (Figure 28 and Plate VII) and Hunton (figure 29 and Plate VIII) Formation The cross-sections, as well as the structural contour maps, show interpretations of the subsurface geometry within the study area.

The four structural cross-sections (Figures 24-27, Plates III-VI), as well as the seismic profiles (Figures 30 and 32, Plates IX and X), show a prominent anticline This anticline is informally named the "Baker Anticline". It involves the Caney, Sycamore, Woodford, Hunton, Sylvan, and Viola Formations.

The faults within the study are informally named, because they have not been previously named; although several of them have been known by oil-industry workers for many years. The faults in the study were determined using by wire-line well-log data and/or seismic data. The main fault cuts the northeast limb of the Baker anticline and trends northwest (Figures 30 and 32). This fault is interpreted as the master fault of a wrench fault system and is named "Knox fault".

Another fault cutting the northeastern limb of the Baker anticline is seen southwest of Knox fault in the cross-sections (Figures 24-27, Plates III-VI), and in seismic (Figures 30 and 32, Plates IX and X). The fault is named the Brickle fault and is interpreted as a splay joining the Knox fault at depth. The interpretation of a splay is due to the fact that the fault is seen diping toward the Knox fault in seismic (Figure 30 and 32, Plates IX and X). If this dip remains constant with increase in depth, it may eventually join Knox fault. The Brickle fault also trends northwest. The fault is well recognized in the Brickle well (Sec. 4, T.2N., T.5W., operator British Amer. Oil Prod. Co.) using wire-line well log data by a repeat of the Boat Marker. This repeat, due to the Brickle fault, is also seen in well HPC (Sec. 14, T.2N., R.5W., operator

Chesapeake), P. Diane No. 1 (Sec. 24, T 2N , R.5W. operator N A.), J. Kaye No 1 (Sec. 3, T.3N., R 5W., operator N.A.) and J. W. Baker No. 1 (Sec. 33, T.3N., R 5W operator British Amer. Oil Prod. Co.).

A third fault named "Carter fault" is located to the northeast of Knox fault. This fault could be a splay joining the Knox fault at depth, or a fault parallel to the Knox (Figures 24-27, Plates III-VI) The fault is interpreted as having reverse separation and parallel to the Knox This interpretation of the fault being a reverse fault parallel to the Knox fault is based on the interpretation of seismic, which shows a similar dip direction as Knox fault (Figure 32 and Plate X). Therefore, the Carter fault may not be joining the Knox fault at depth. The fault is interpreted on seismic profiles trending northwest, but is difficult to see in wire-line well-log data due to its almost vertical dip on the seismic profiles (Figures 30 and 32, Plates IX and X).

Marathon Oil Company donated two 2-D seismic profiles which were used for structural interpretation of the study area. One of the seismic profiles (Figure 32 and Plate X) is located in the northern part of the study area and is used in conjunction with wire-line well-log data to construct the four structural cross-sections (Figures 24-27, Plates III-VI). The second seismic profile (Figure 30 and Plate IX) is located in the southern part of the study area and is used for the interpretation of the trends of the Brickle and Knox faults. Between the northern and southern profiles is a gap which makes it difficult to correctly interpret what is happening to the trend of the faults between the seismic profiles. The seismic profiles are interpreted and are shown

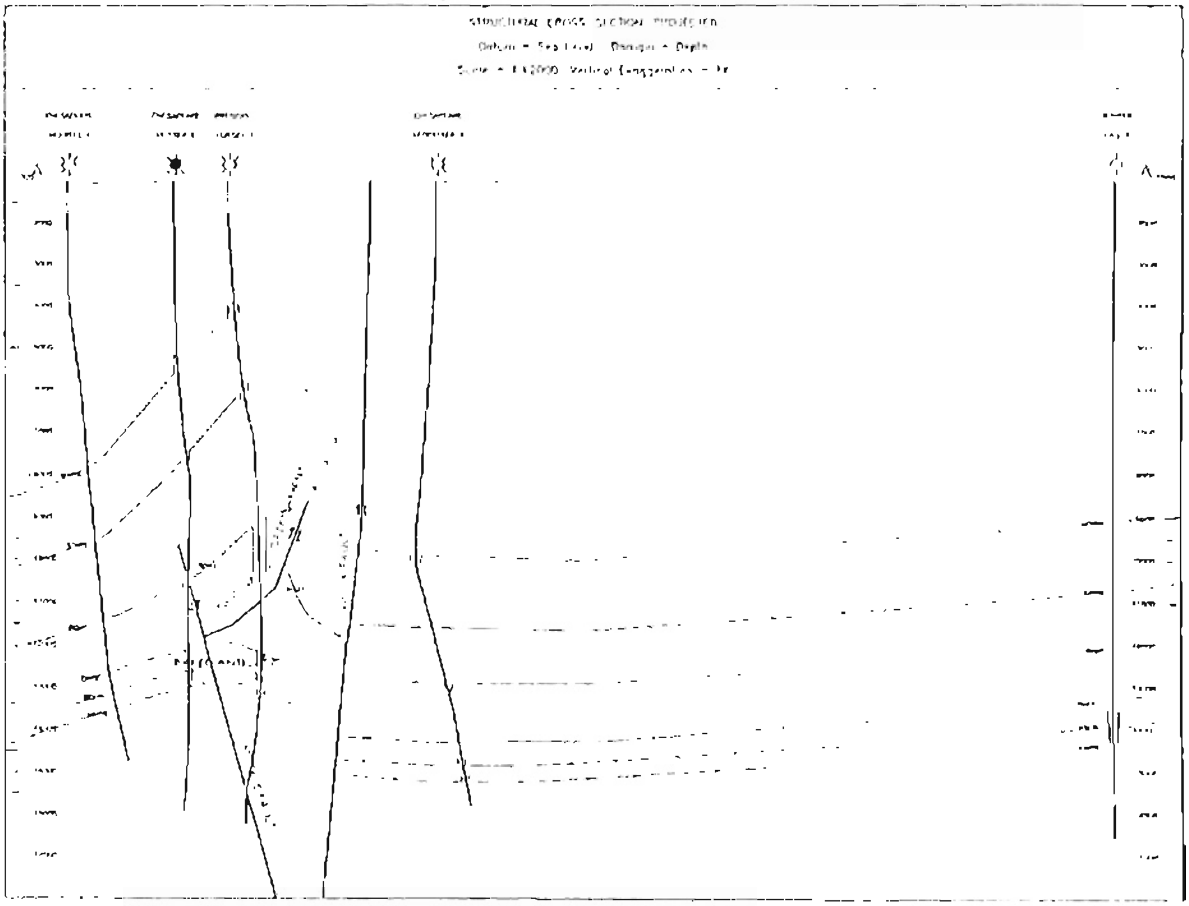


Figure 24. Structural cross-section A-A'. MRRW-top Morrowan Series, SPRG-top Springeran Series, BOAT-top Boat Marker, CNEY-top Caney Formation, WDFD-top Woodford formation, HNTN-top Hunton Formation. Faults- ⫽

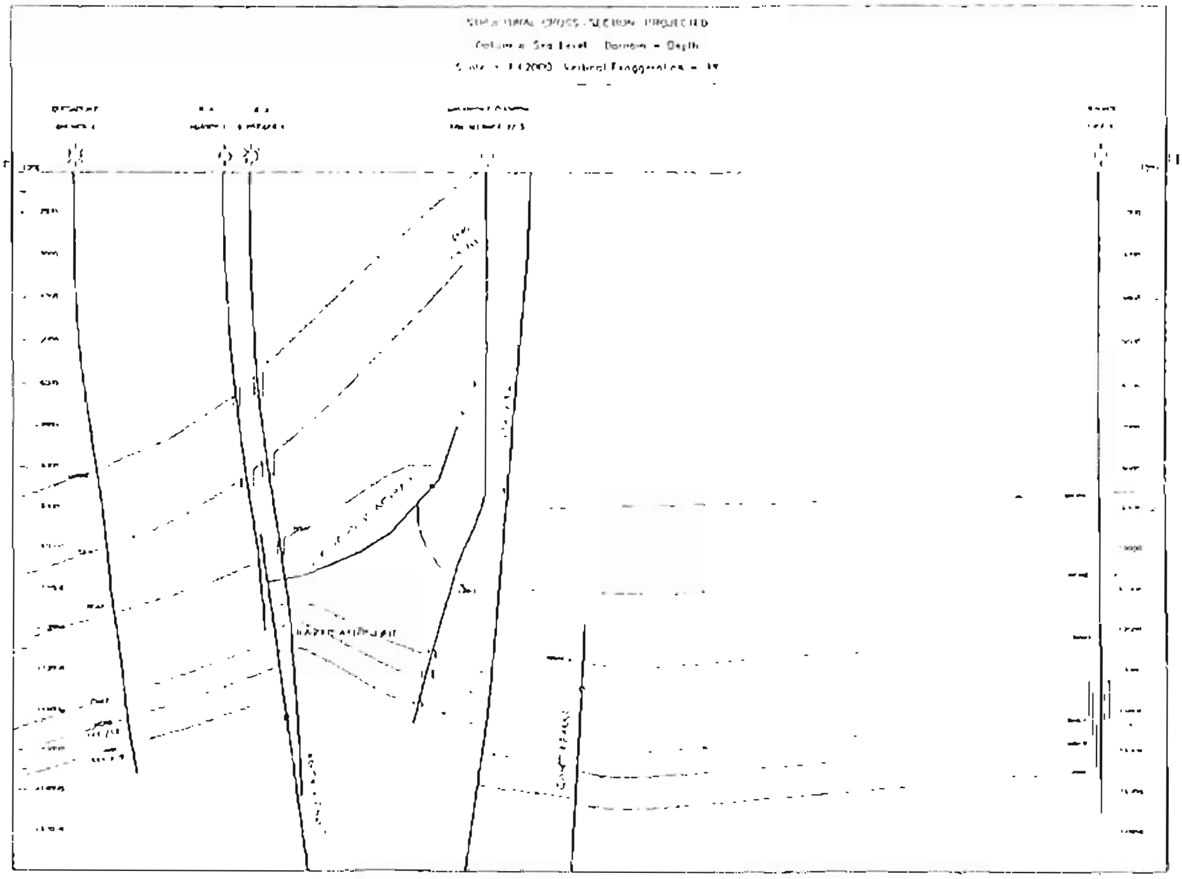


Figure 25 Stuctural cross-section B-B'. MRRW-top Morrowan Series, SPRG-top Springeran Series, BOAT-top Boat Marker, CNEY-top Caney Formation, WDFD-top Woodford Formation, VIOL-top Viola Formation Faults-

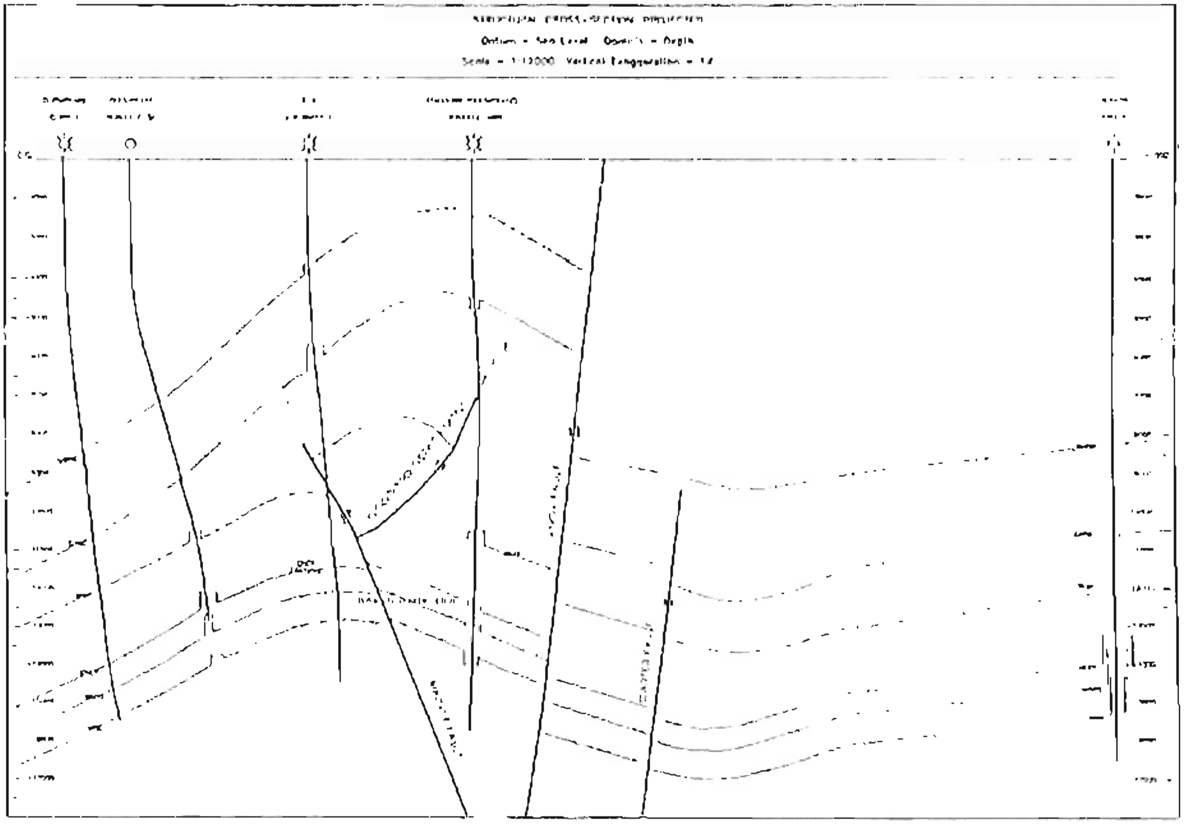


Figure 26. Structural cross-section C-C'. MRRW-top Morrowan Series, SPRG-top Springeran Series, BOAT-top Boat Marker, CNEY-top Caney Formation, WDFD-top Woodford Formation, VIOL-top Viola Formation. Faults- ⫽

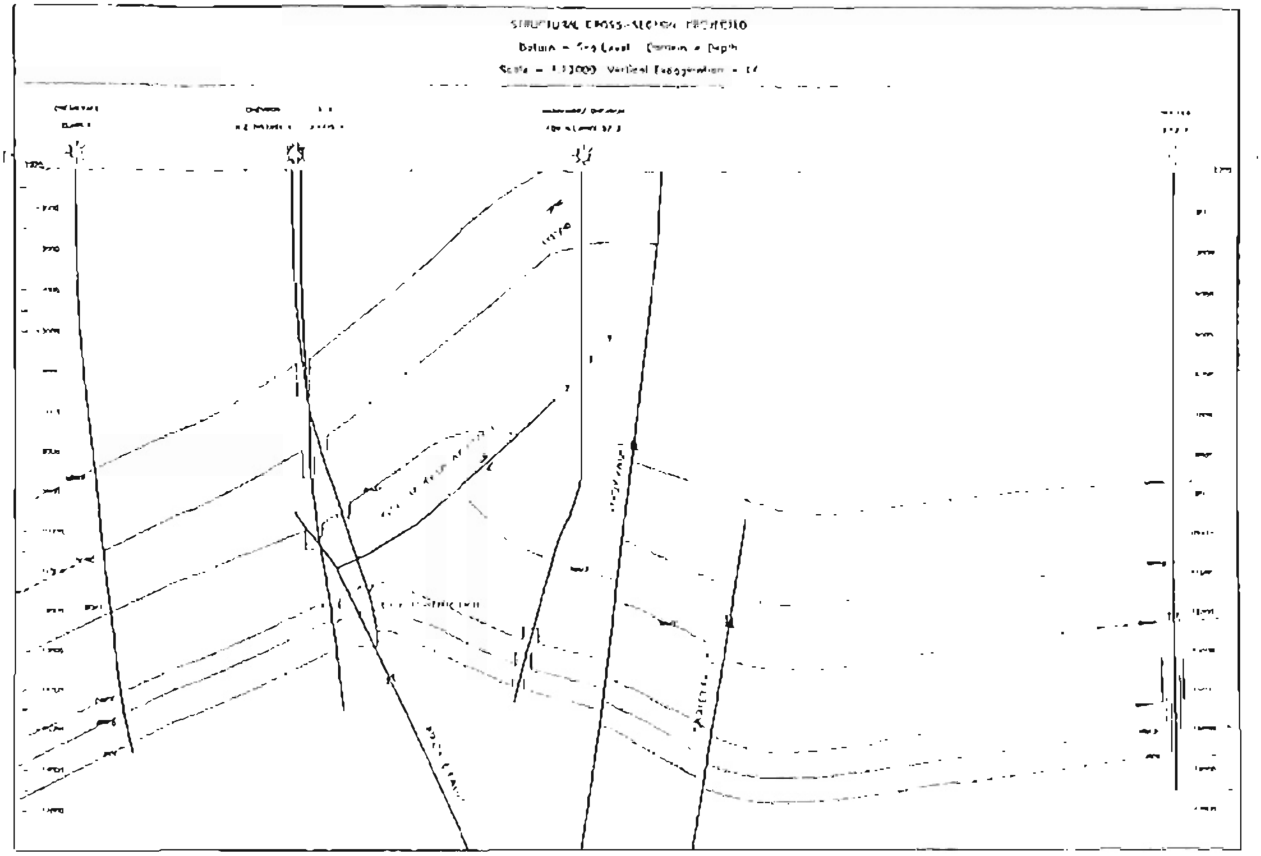


Figure 27. Structural cross-section D-D'. MRRW-top Morrowan Series, SPRG-top Springeran Series, BOAT-top Boat Marker, CNEY- top Caney Formation, WDFD-top Woodford Formation, VIOL-top Viola Formation Faults-

in Plates IX and X and Figures 30 and 32. The non interpreted seismic profiles are seen in Plates XI and XII and Figures 31 and 33.

The structural cross-sections, structural contour maps, and interpreted seismic profiles all depict the presence of a wrench fault system which produced a positive flower structure in the study area. The structural features in the area were previously interpreted as being formed by compressional tectonics similar to fold-thrust belts by Reedy and Sykes (1958). However, the structures interpreted on the seismic profiles and the interpreted cross-sections, based on wire-line well-log data and seismic profiles, can not be produced by a typical fold-thrust belt structure. They have most of the characteristics of a typical wrench fault system.

A major characteristic in the interpretation of a wrench fault in the study area is the presence of a single thoroughgoing master fault (Knox fault) which is unaltered in its trend. The second, a splay (Brickle fault) which has reverse separation, also giving evidence for the presence of a wrench fault forming a positive flower structure The presence of a vertical fault slice like, the Brickle fault, is thought to be the most concrete evidence for a wrench fault (Harding, 1990). The third is the presence of a narrow zone of deformation which also gives credible evidence for a wrench fault. If the tectonic environment were a typical compressional fold-thrust belt, it would consist of several fault sets or several faults seen in a zig zag pattern trace in map view, and have a large zone of deformation, sometimes many kilometers. These faults would also tend to join to a horizontal detachment surface at depth.

Baker Anticline

The Baker Anticline is seen in the structual cross-sections and interpreted seismic profiles (Figures 24-27, Plates III-VI). The Baker Anticline involves the Caney, Sycamore, Woodford, Hunton, Sylvan, and Viola Formations. The anticline is faulted on the northeast limb by the Knox and Brickle fault.

The Baker Anticline may have formed in Silurian time. Examination of wire-line well-log data reveals a thinning of the Hunton on the crest of the anticline, and a thickening of the Hunton on the limbs of the anticline. Reedy & Sykes (1958), also reported this thinning of the Hunton. The other formations within the anticline remain at a fairly constant stratigraphic thickness on the crest and limbs of the anticline. This suggests some type of orogenic activity during or after the deposition of the Hunton in Silurian time which may have produced the Baker Anticline.

Knox Fault

The Knox fault is interpreted as the master fault of a positive flower structure in a wrench fault system. Evidence used to delineate the study area as a strike-slip tectonic environment, rather than a compressional fold-thrust belt type structure as previously interpreted, came from the use of wire-line well-log data and 2-D seismic profiles. Dr. Cemen and I have also had a chance to study Marathon Oil Company's confidential 3-D seismic data at the Oklahoma City office, which backs our structural interpretations.

The interpreted 2-D seismic profiles show a steeply dipping to vertical fault which probably cuts the basement rock within the study area. However, continuation of the fault into the basement cannot be confirmed by seismic interpretations, due to

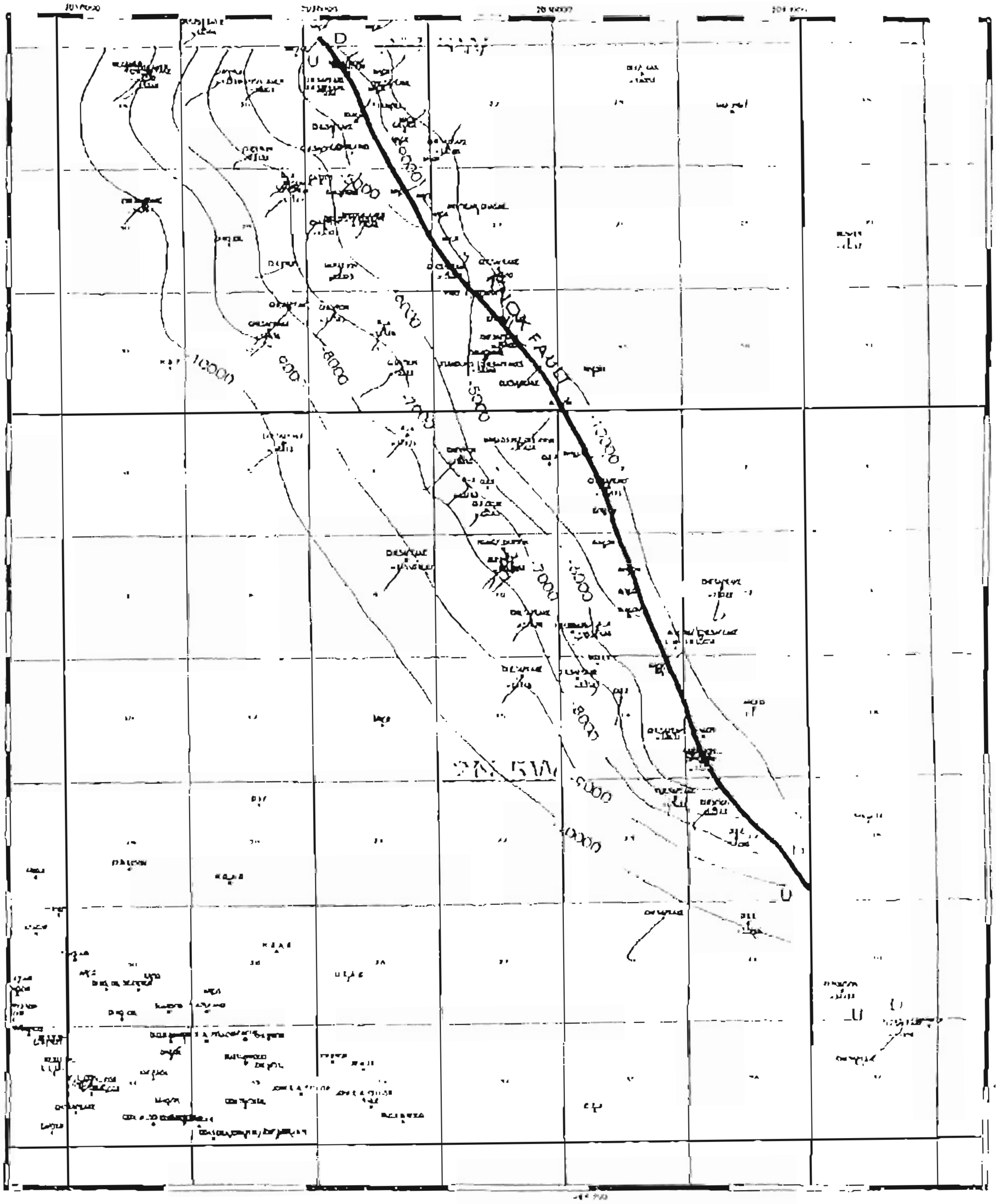


Figure 28 Stuctural contour map of the top of the Springer D-downthrown block U-upthrown block

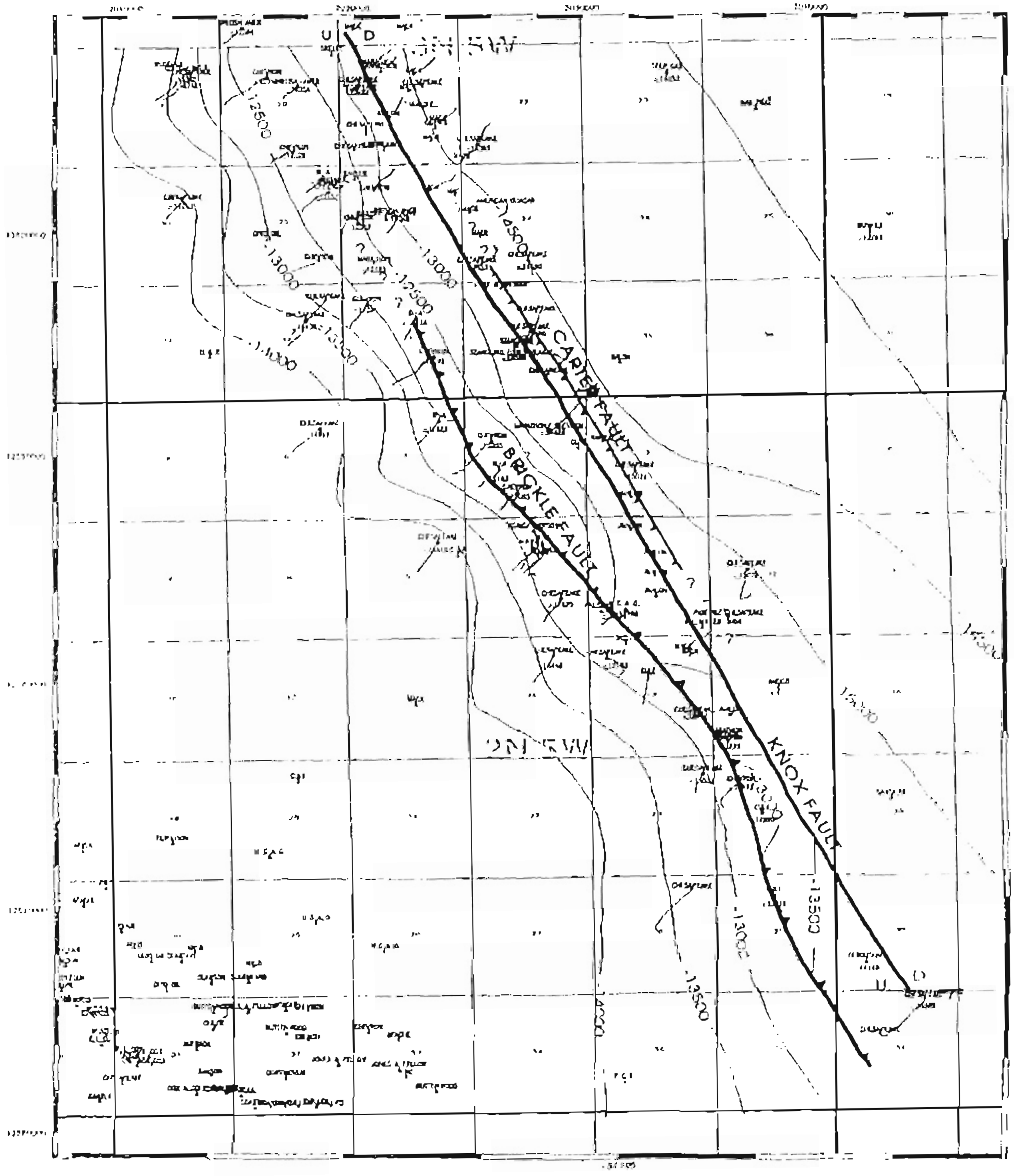


Figure 29. Structural contour map of the top of the Hunton D-downthrown block U-upthrown block

deterioration of the seismic with increase in time (Figures 30 and 32, Plates IX and X). When looking at the sequence of parallel seismic lines, this fault is seen cutting strata at all depths (Figures 30 and 32, Plates IX and X).

Map criteria, which gives good evidence for the Knox fault being the master fault is its undisrupted trace, seen in the Springer and Hunton structural contour maps (Figures 28 and 29, Plates VII and VIII). The trend of Knox fault is northwest and is straight to nearly straight. Wire-line well-log data, along with seismic data, was used to place the fault on the Springer and Hunton structural contour maps The placement of Knox fault, using wire-line well-log data, was done by looking at the differences in depths by neighboring wells to either the top of the Springer (Figure 28, Plate XII) or Hunton (Figure 29, Plate XIII). The combination of wire-line well-log data and seismic helped to accuratly place the fault on both structural contour maps.

The four structural cross-sections show the Knox fault cutting the Viola, Hunton, Woodford, Caney, Morrow, and Springer Formations as well as the Boat Marker. Seismic profiles were used for the placement of the fault on the structural cross-sections (Figures 24-27, Plates III-VI) because the vertical dip of the fault makes it difficult to determine on wire-line well-log data. The four structural cross-sections were constructed perpendicular to the trend of the southern end of the Carter-Knox structure

Brickle Fault

The Brickle fault is located southwest of the Knox fault, and is interpreted as a fault splay converging at depth with the Knox-fault. Convergence of the Brickle fault to the master fault can not be confirmed on seismic due to deterioration of the seismic with increased time (Figures 30 and 32, Plates IX and X). However, the dip of the fault is toward the Knox fault on the seismic profiles (Figures 30 and 32, Plates IX and X). If the Brickle fault continues with the same dip direction, then it should join the Knox fault at depth. The seismic profiles give preliminary evidence for the Brickle fault, with wire-line well-log data giving supporting evidence.

In wire-line well-log data, a repeated Boat Marker bed in the Brickle well (Sec. 4, T.2N., R.5W., operator British Amer. Oil Prod. Co.) is seen close to where the fault is believed to cut the Hunton. This repeat in the Boat Marker, along with the seismic profiles, gives good evidence for the Brickle fault being a splay with reverse separation. This repeat in the Boat Marker is also seen in wells HPC (Sec.14, T.2N., R.5W., operator Chesapeake), P. Diane No. 1 (Sec. 24, T.2N., R.5W., operator N.A.), J. Kaye No. 1 (Sec. 3, T.3N., R.5W., operator N.A.), and J. W. Baker No. 1 (Sec. 33, T.3N., R.5W., operator British Amer. Oil Prod. Co.).

The wells with a repeat Boat Marker, along with the seismic profiles, were used to place the Brickle fault on the Hunton structural countour map (Figure 29 and Plate VIII) The repeat of the Boat Marker seen in wire-line well-log data also helps in placing the Brickle fault on the structural cross-sections (Figures 24-27, Plates III-VI).

Carter fault

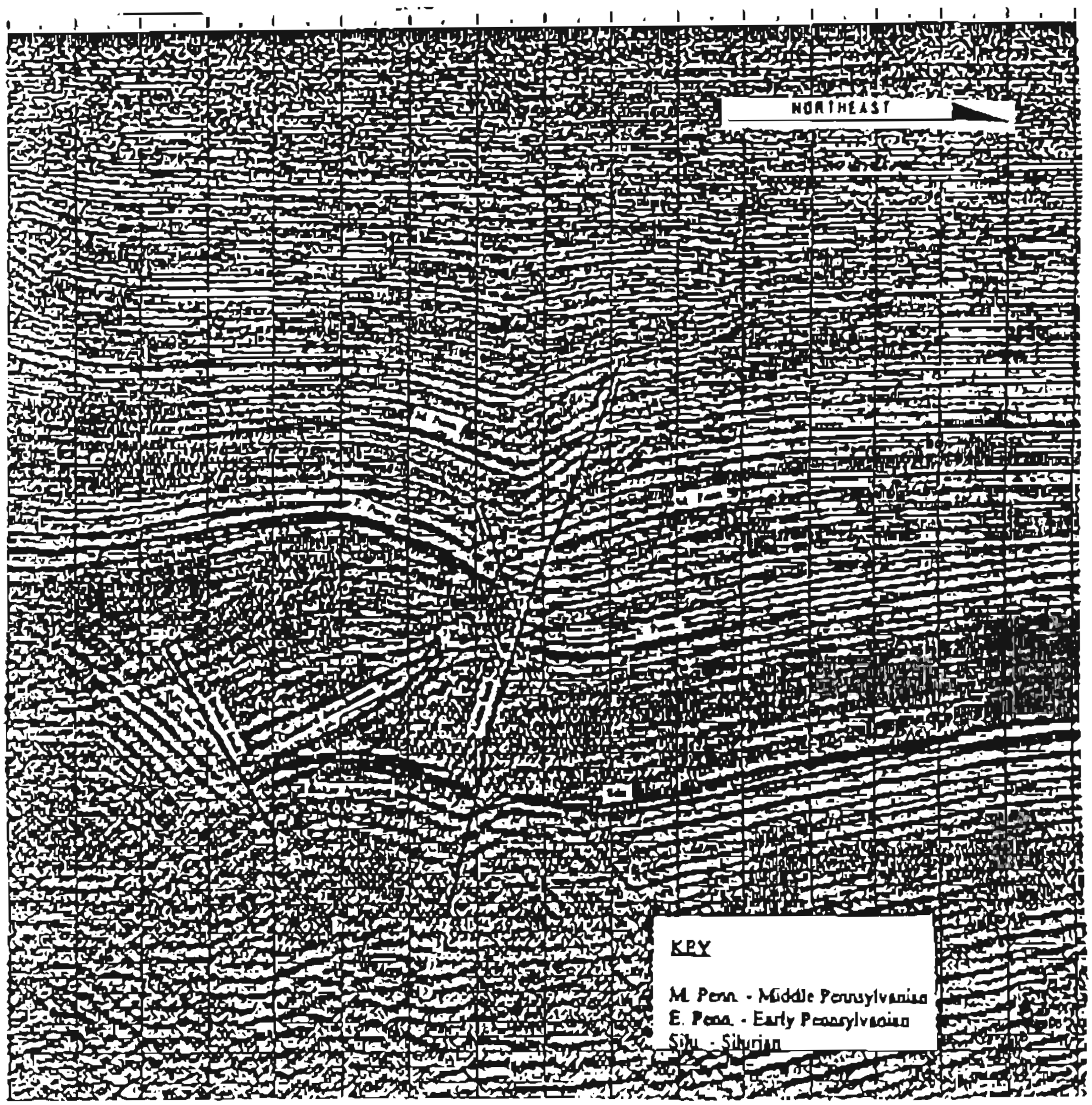


Figure 30. Interpreted Seismic A. Faults- 2/2

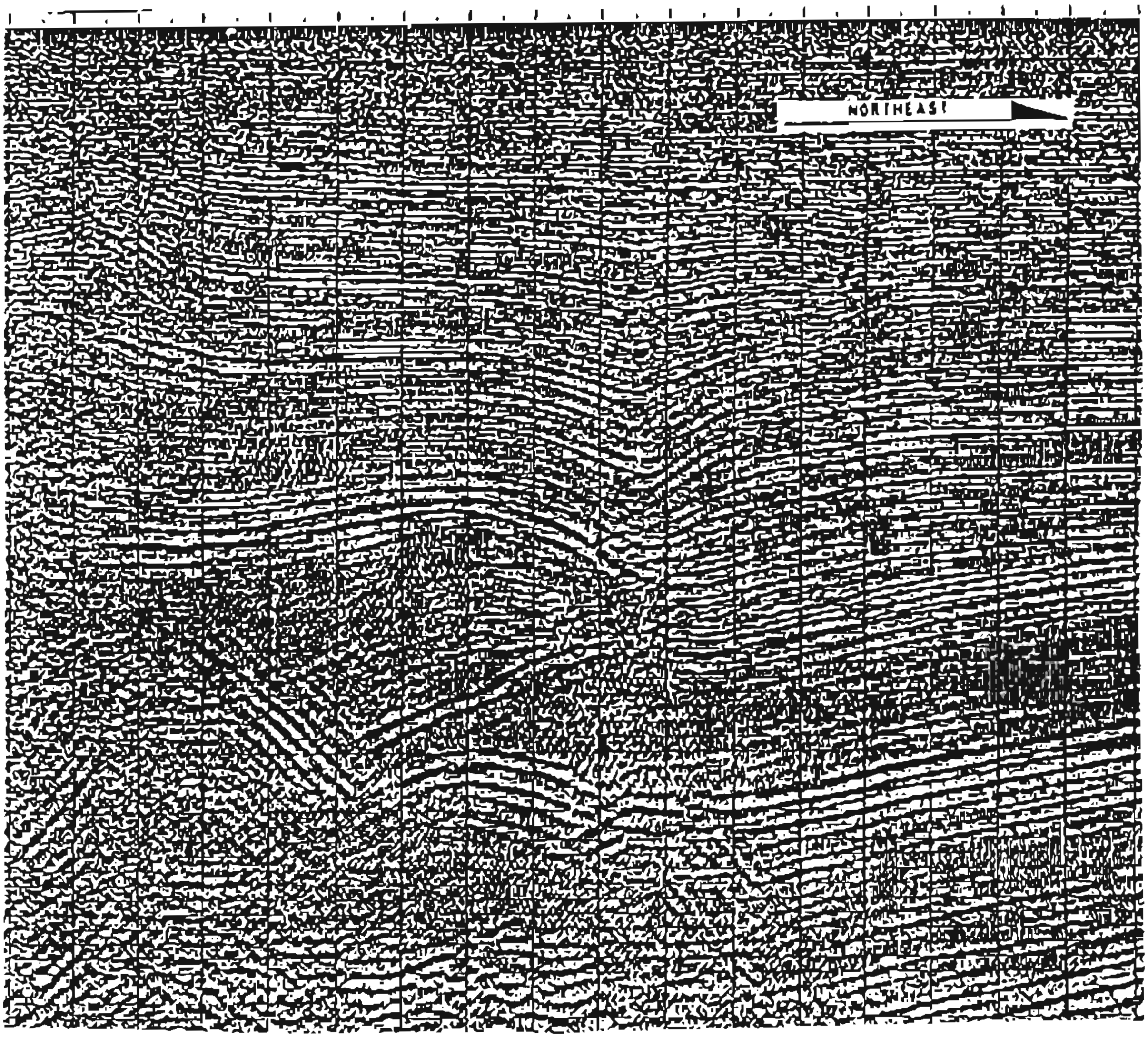


Figure 31. Uninterpreted Seismic A.

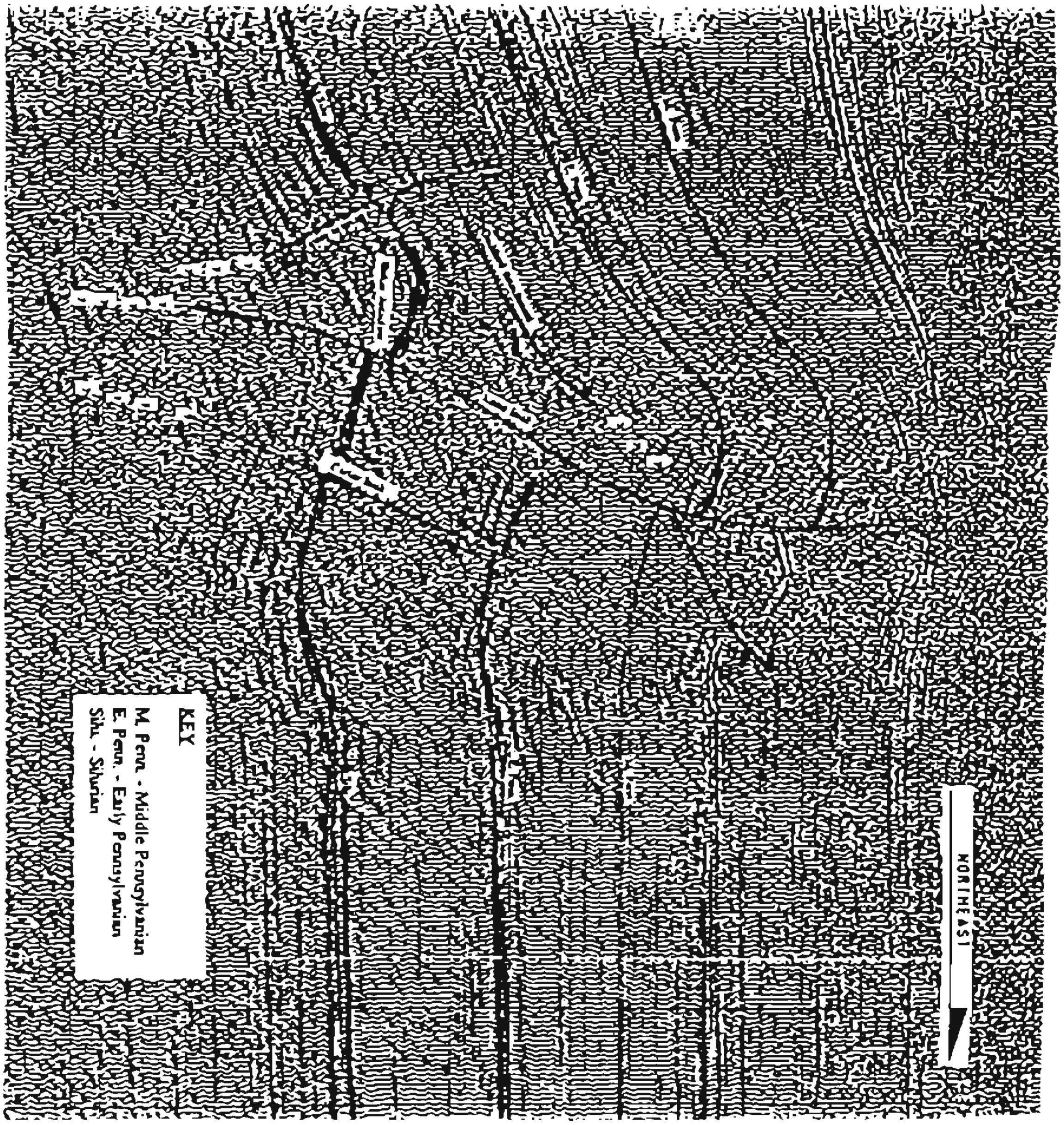


Figure 32. Interpreted Seismic B. Faults- 7/2

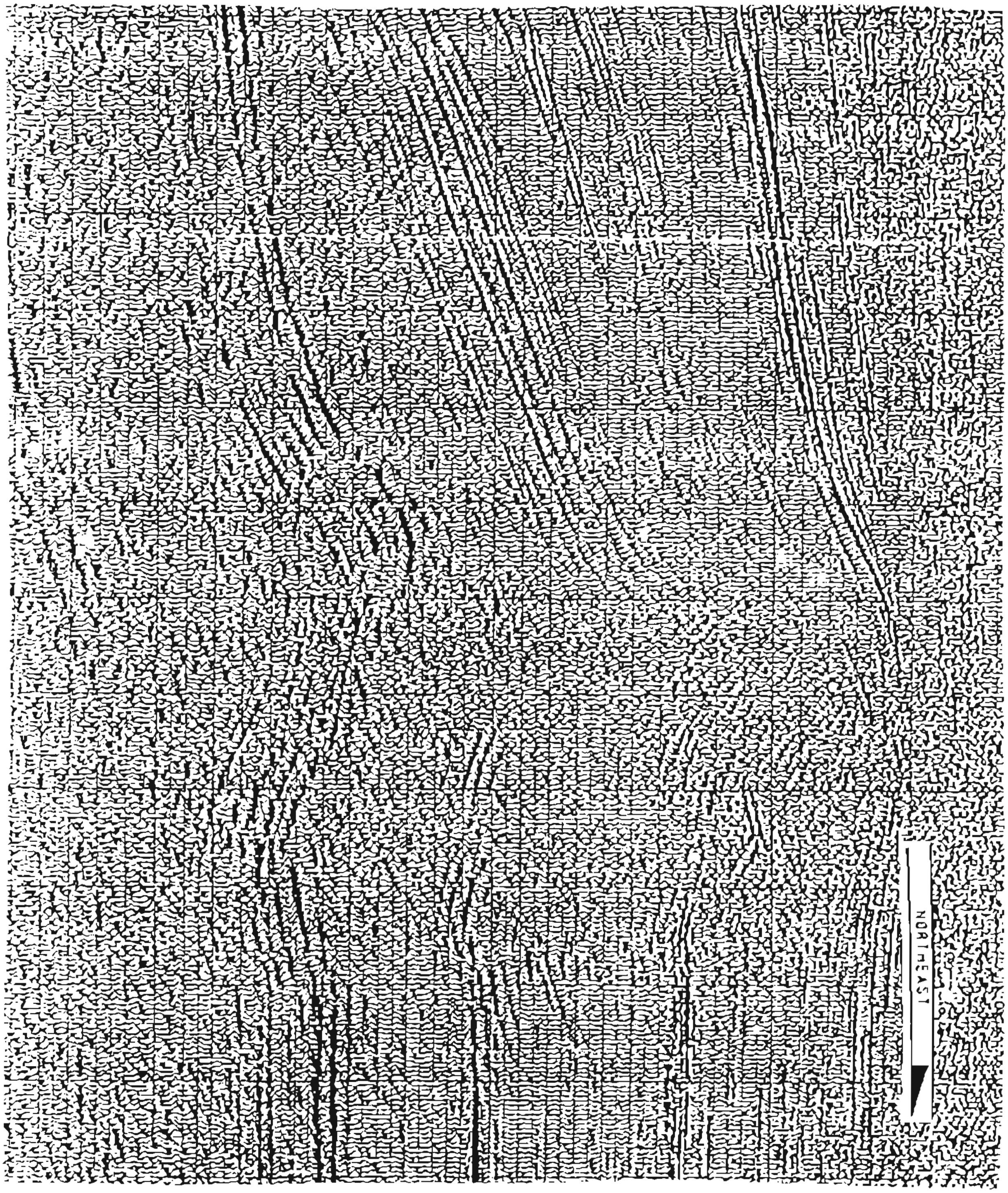


Figure 33 Uninterpreted Seismic B.

The Carter fault is interpreted as a fault with reverse seperation. Evidence used to delinate this is done by the use of 2-D seismic data rather than wire-line well-log data, due to the steepness of the fault. The northern 2-D seismic profile (Figure 32 and Plate X) shows a steeply dipping fault cutting up to the Springeran Series. However, the southern seismic profile shows no trace of the Carter fault (Figure 30 and Plate IX) This fault appears to have the same dip direction as the Knox fault, and therefore is believed not to join the Knox fault at depth.

The Carter fault is placed on the Hunton countour map (Figure 29 and Plate VIII) by the use of seismic profiles only. The fault is also positioned on the four structural cross-sections (Figures 24-27, Plates III-VI) using seismic profiles only.

Goddard Detachment

Between the Brickle fault and Knox fault is a thick sedimentary core (Figures 30 and 32, Plates IX and X). This increase in sedimentary thickness is interpreted as being caused by a fault named the "Goddard Detachment". The fault is interpreted as diverging off the Brickle fault and thrusting toward the Knox fault (Figures 24-27, Plates III-VI) It is unknown if the fault joins the Knox fault. The fault is interpreted as being present throughout the study area and confined between the Springeran Series and Caney Formation. When looking at the seismic profiles, it is difficult if not impossible to see this fault. This difficulty in delineating the thrust within the seismic is probable due to reflection continuity lost between the Knox and Brickle fault within the core of the structure. This phenomenon usually occurs in the presence of a ductile sedimentary section (Harding, 1985). This ductile sedimentary section is in the study area between the Springeran Series and the Caney Formation (Figure 9). Between the Springeran Series and Caney Formation are sedimentary beds consisting primarily of shale. Therefore, there is probably a reflection continuity lost. Another possibility for the difficulty in delineating the detachment in seismic is the fact that the seismic profiles may not be perpendicular to the detachment.

The positioning of the Goddard detachment, on the structural cross-sections, is done by using wire-line well-log data. First, the control well Ledbetter (Sec. 12, T.2N., R.5W., operator Chesapeake), is used to determine the stratigraphic thickness between the Caney Formation and Boat Marker. The positioning of the fault is then determined by looking at the differences in thickness between the Caney and Boat Marker in wells between the Brickle and Knox fault, compared to the control well thickness between the Caney and the Boat Marker. The stratigraphic thickness between the Caney and the Boat Marker increases from the Brickle fault toward the Knox fault (Figures 24-27, Plates III-VI) The exact placement of the Goddard detachment in wire-line well-log data is difficult. This is due to wire-line well logs being old and the thrust is probably confined to the Goddard shale.

Other possible scenarios for explaining the thickening of strata between the Brickle and Knox fault could be the presence of smaller detachments or faults off of the main Goddard detachment fault. The increase could also be caused from a hanging wall anticline produced by the Goddard detachment. The thick core could also be caused by squeezing of the ductile shale making the shale sequence thicker. However, the thickening in sedimentary strata within the core of the wrench fault is probably due to a combination of all of these.

Positive flower structures can also exhibit extra material within the core of the structure and are thought to be formed through small drag folds and/or thrust repetitions (Harding, 1985) This type of occurrence happens where positive flower structures are disharmonic with the basement. The relief of these structures usually decreases with depth and in some "instances replaced at depth by a simple, vertical separation of a sub horizontal basement surface" called a "squeeze-up" (figure 23a) structure (Harding, 1983)

The interpreted 2-D seismic profiles and structural cross-sections within the study area exhibit similar subsurface characteristics of a "squeeze-up" structure. This is seen with the Springeran and Morrowan Series having a great amount of vertical displacement, whereas the deeper formations have very little vertical displacement (Figures 24-27, Plates III-VI). However, the characteristic of the master fault being disharmonic with the basement cannot be made by seismic interpretation, due to deterioration of the seismic with increase in time (Figures 30 and 32, Plates IX and X). However, the seismic does show a greater amount of vertical displacement in the Pennsylvanian beds compared to the Silurian bed.

A wrench fault producing a positive flower structure always forms an anticlinal appearance on a seismic profile (Harding, 1990) This is also seen in the seismic profiles in the study area (Figures 30 and 32, Plates IX and X). These positive flower structures are usually formed due to convergence of two blocks normal to the wrench fault ("pop-up" structures), or are formed in a basin with a thick and ductile sedimentary section bounded by large faults with strike-slip movement ("squeeze-up" structures). This type of ductile sedimentary section is in the study area between the Springer Series and Caney Formation (Figure 9).

CHAPTER V

STRUCTURAL EVOLUTION OF THE STUDY AREA

The structural evolution of Carter-Knox, written by Reedy and Sykes, (1958), had a compressional event which produced thrusting in Late Pennsylvanian. Perry (1988), also explains that in Late Mississippian to Early Pennsylvanian the Anadarko Basin formed by compressional forces implemented on it by the convergence of the South American plate or a micro-continent with the North American plate during the close of the proto-Atlantic ocean. Perry (1988), also stated that with continued convergence in Late Pennsylvanian, transpressional forces became dominate forming many thrust cored en echelon anticlines within the southeastern Anadarko Basin The compressional forces, in Late Mississippian to Early Pennsylvanian, and transpressional forces, in Late Pennsylvanian are thought to be part of the deformational stage of the Southern Oklahoma Aulacogen.

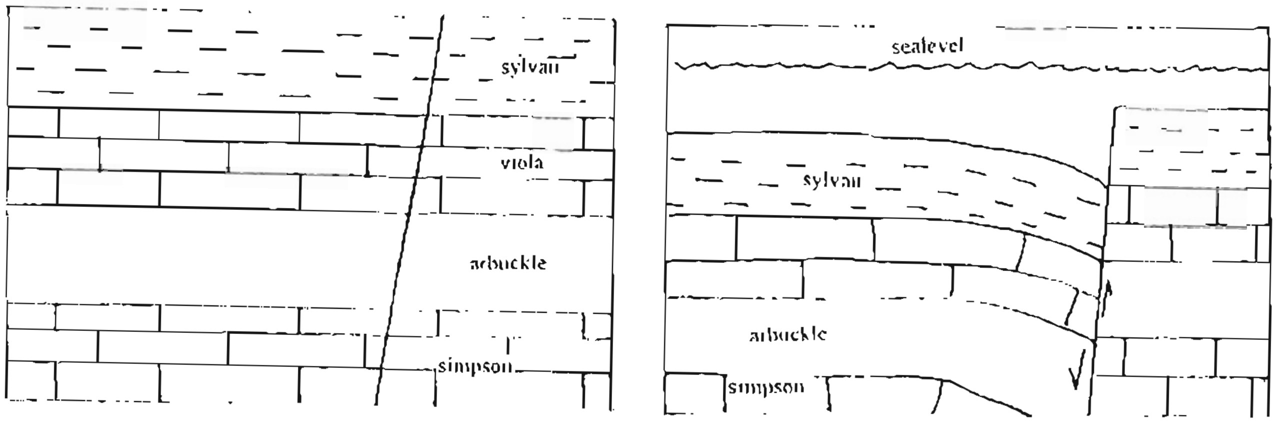
McBee (1995), proposed that the Anadarko Basin as well as other tectonic provinces (Figure 1), in Oklahoma were formed by a megashear known as the Oklahoma Megashear (OM). McBee stipulated that transpressional forces were active throughout the evolution, of the aulacogen. The transpressional forces, in Late

Pennsylvanian are thought to be brought about by an east west compressional stress regime termed "*Alleghenian*" (McBee, 1995). Regardless of the origin of the Pennsylvanian strike-slip movement, there is an agreement that the basins and uplifts in the area of the Southern Oklahoma Aulacogen (Figure 1) were produced by strong strike-slip deformation.

The study area became invaded by the sea in Late Cambrian. During this time, pre-Cambrian basaltic and gabbroic rocks were overlain by the deposition of marine sediments. Marine sedimentation continued with little orogenic activity until Silurian time. It is during Silurian time that the Baker Anticline probably formed.

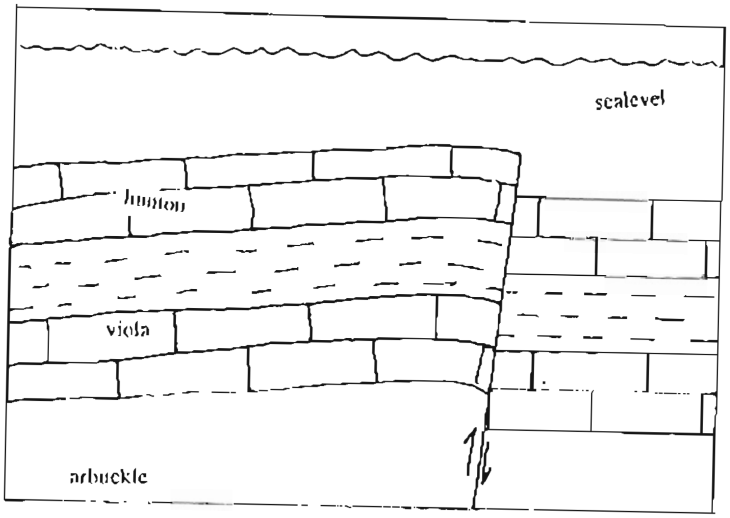
The Baker Anticline may have formed by either a rollover on normal faults that were active in the area, or by transpression of the area. An anticlinal structure would be produced by either proposal. However, the Baker Anticline may have formed by a rollover on a normal fault followed by transpression of the area (Figure 34).

The Baker Anticline may have first formed by a rollover on a normal fault that was active within the area before Silurian time (Figure 34b). This normal fault may have been the Knox fault. Some orogenic activity followed producing transpressional forces. This transpression may have produced structural inversion of the normal fault thought to be the Knox fault. This structural inversion of the fault would produce uplift, eroding the axis of the anticline but not the limbs (Figure 34d). The orogenic activity may have been confined to Silurian, since only the Hunton is thinned on the axis of the Baker Anticline (Figure 34e).



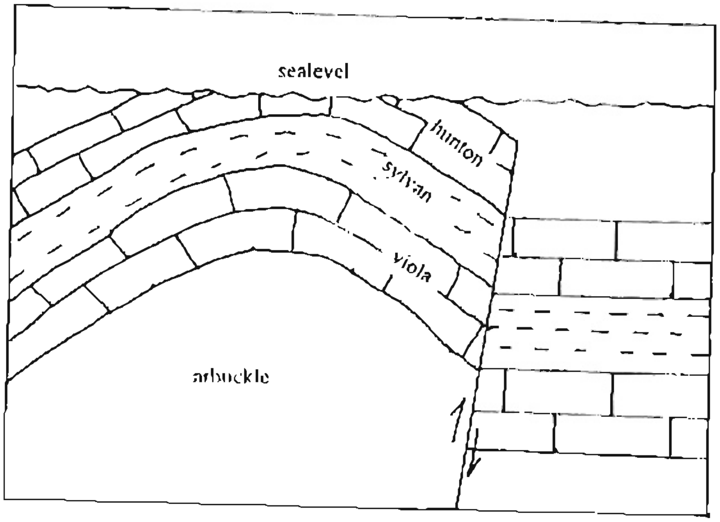
A Deposition of strata were an inactive Cambrian normal fault existed

B. The Cambrian fault becomes active before Silurian producing a rollover anticline.

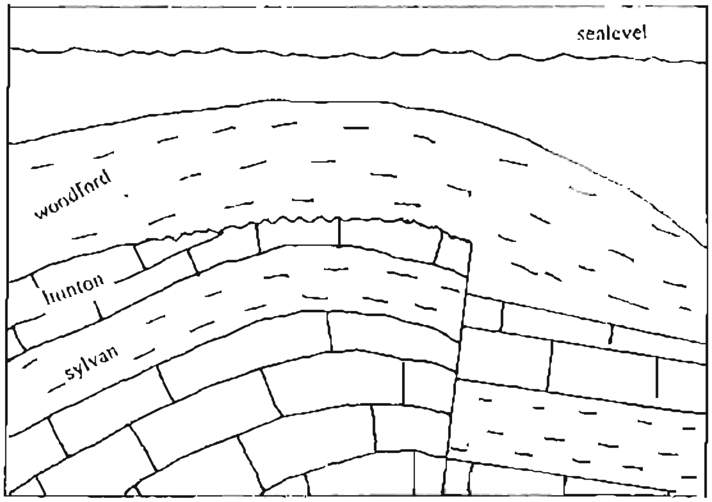


C. Silurian transpression produces structural inversion of the fault resulting in the uplift of the rollover anticline.

Figure 34. Sketch of the evolution of the Baker Anticline by Tony Perkins, 1997.



D. Continued uplift and/or a lower sea level in Silurian creates an erosional surface on the rollover anticline



E. After Silurian or before Woodford deposition, sea level rises depositing sediment during a period of no orogenic activity until Pennsylvanian

Figure 34. Continuation of the sketch of the evolution of the Baker Antcline by Tony Perkins, 1997

After the Silurian orogenic activity, deposition continued from Devonian into Mississippian with no major orogenic stresses implemented on the study area. Then in Pennsylvanian, major orogenic activity occured. This orogenic activity is probably responsible for reactivating the Knox fault, and forming the Brickle and Carter fault along with the Goddard detachment.

Perry (1988), and McBee (1995) give two differing origins for this orogenic activity. However, both origins produce transpressional forces in the study area producing strong strike-slip deformation.

The transpressional forces in Pennsylvanian probably produced strong strike-slip motion on the Sulphur, Washita, Criner, and Muenster faults (Figure 7) Tanner (1967), proposed that the Washita fault had left-lateral offset as much as 64 km Carter (1979), also suggested that the Washita had left-lateral offset measuring 32 km The Sulphur fault just to the north (Figure 7) is also thought to have left-lateral movement resulting in the uplift of the Tishamingo-Belton block (McBee, 1995).

Since the study area is located between the Sulphur and Washita faults (Figure 7) it was probably subjected to strong transpression between the faults beginning in Early Pennsylvanian. This transpression may have led to the formation of many flower structures including Carter-Knox.

The Carter-Knox structure, which includes the study area, is probably a "squeeze-up" flower structure. "Squeeze-up" structures are commonly formed in thick ductile shale filled basins which are flanked by larger faults much like the study area

. The "squeeze-up" structure in the study consists of the Knox fault, Brickle fault, and Goddard detachment. The "squeeze-up" structure subjected little deformation to the Baker Anticline; however, subjected a large amount of deformation, in the form of folding and faulting, on the younger strata above the Baker Anticline (Figure 30 and 32)

The Knox fault was probably the first fault formed within the study area. The Knox fault is possibily an older normal fault formed in Cambrian. The Pennsylvanian transpressional forces produced structural inversion of the Knox fault since it was between the Washita Valley fault and Sulphure fault. Continued transpressional forces into Late Pennsylvanian solidified the Knox fault as the master fault in a strike-slip region, cutting strata at all depths in the study area (Figures 24-27, 30, and 32)

The Brickle fault probably formed after the Knox fault due to continued transpressional force in Pennsylvanian. The Brickle fault formed as a splay from the Knox fault cutting the northeast limb of the Baker Anticline with reverse separation (Figures 24-27, 30, and 32)

The fault block produced by the Knox and Brickle fault deformed due to continued transpressional forces implemented on the study area into Late Pennsylvanian. The deformation of the block is probably due to a fault within the block This fault which was probably formed after the Brickle fault is termed the "Goddard Detachment" (Figures 24-27, 30, and 32) The defornaion of the block by the Goddard detachment may have been accompanied by other faults splintering off of the Goddarad, and/or squeezing of the shale strata within the fault block

The Carter fault may have been the last fault formed in Pennsylvanian. This interpretation is brought about by the short trend of the Carter fault seen within the study area (Figure 29 and Plate VIII). The fault is interpreted as having reverse seperation and may not joining with the Knox at depth due to both having similar dips (Figure 32 and Plate X).

CHAPTER VI

CONCLUSIONS

The major conclusion of this study is the reinterpretation of the southern part of the Carter-Knox structure as "squeeze-up" structure forming a positive flower structure. This interpretation is based on the interpretation of seismic profiles, construction of structural cross-sections, and structural contour maps which reveal the presence of:

1) A single subsurfac structure believed to be a "squeeze-up" structure, having a narrow zone of deformation consisting of the Knox fault, Brickle fault, and Goddard detachement

2) The Knox fault being the master fault of the structure cutting strata at all depths and being straight to almost straight in map view.

3) The Brickle fault showing reverse separation in wire-line well-log data probably forming as a splay from the Knox fault.

4) Thickening in the core of the structure due to the Goddard detachment along with other detachments and/or squeezing of the shale strata within the core.

Also, the Baker Anticline is interpreted as an older structure below the "squeeze-up" structure. It had little deformation implemented on it by the younger "squeeze-up" structure formed in Pennsylvanian. Wire-line well-log data reveals that the Baker Anticline has thinning of the Hunton on the axis and not on the limbs. This is interpreted as being due to uplift and erosion in Silurian time, or before deposition of the Woodford Shale.

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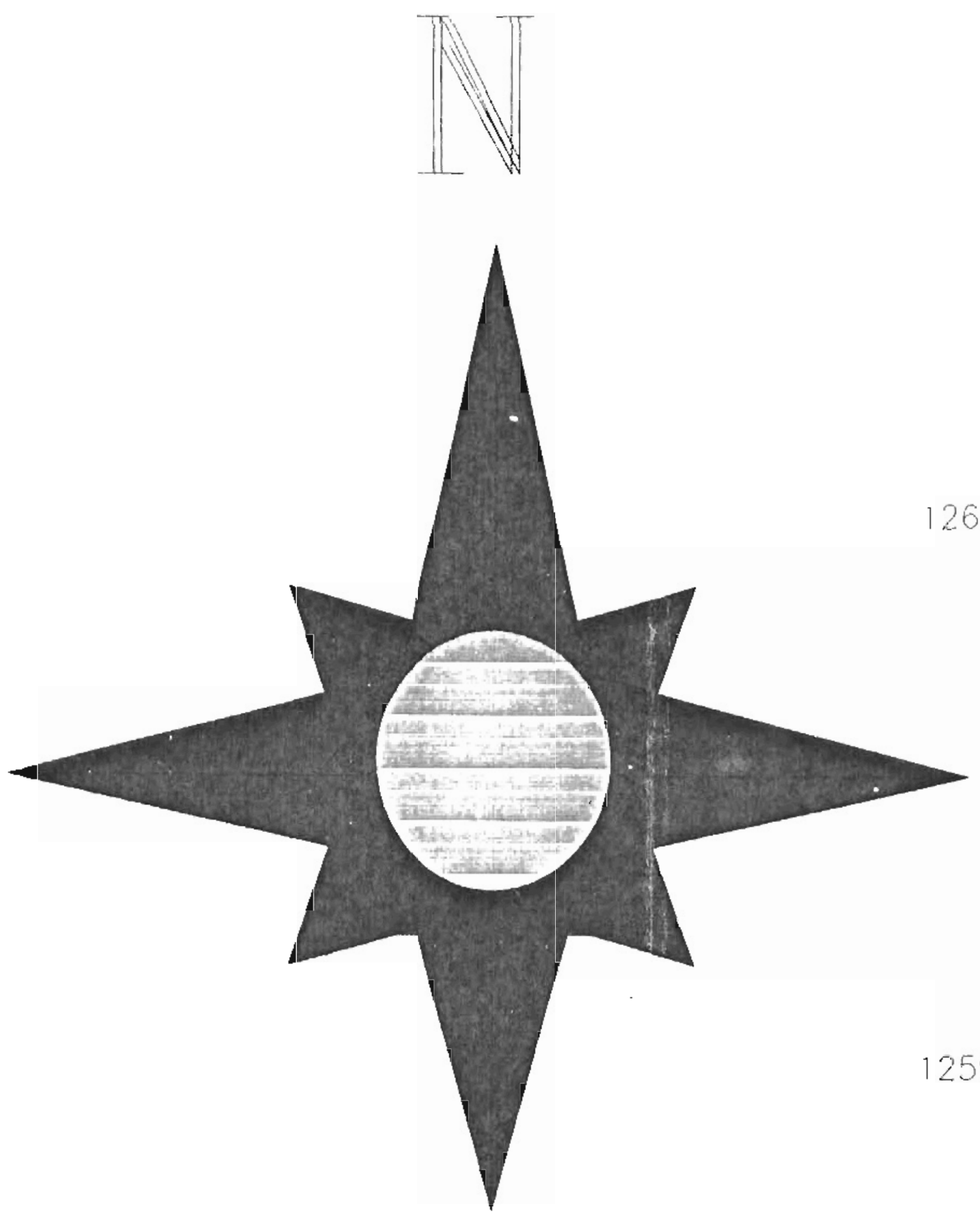
APPENDIX
Well log data sheets

Operator	Well	Location	Sec.	Field	K.B.	G.L.	County	Top Sprg.	Top Hntn
Mack Oil Co.	Bessie Mae	3N-5W-NE-NE-SE	21	Carter-Knox			Grady	9828	
Mack Oil Co.	Sledge deep 1	3N-5W-NE-NE-NW	21	Carter-Knox			Grady	9883	
Marathon Oil Co.	Sledge deep 2	3N-5W-NE-NE-NW	21	Carter-Knox			Grady	10536	
Mack Oil Co.	Barter	3N-5W-NW-NE-NE	21	Carter-Knox			Grady	8629	
Avalon Expl. Inc.	Marcer By-G	3N-5W-SW-SW-NE	21	Carter-Knox			Grady	5115	
Chesapeake oper. Inc.	Russel	3N-5W-E/2-W/2-SW	21	Carter-Knox			Grady	4497	13287
Chesapeake Oper. Inc.	Philmore	3N-5W-C-SW-NW	21	Carter-Knox			Grady	9745	N/A
Humble Oil & Refg. Co.	Eason-Knox	3N-5W-NE-NW-SE	21	Carter-Knox			Grady	4739	N/A
Stanolind Oil & Gas Co.	Olen Sledge A	3N-5W-C-SE-SW	21	Carter-Knox			Grady	10578	14385
Chesapeake Oper. Inc.	Monarch	3N-5W-S/2-N/2-SW	22	Carter-Knox			Grady	10793	14053
Mack Energy Corp	Magnolia	3N-5W-SW-SW-NW	27	Carter-Knox			Grady	9834	14526
Chesapeake Oper. Inc.	Sumner	3N-5W-SW-NE-SW	27	Carter-Knox			Grady	N/A	14880
Chesapeake Oper. Inc.	Cleb	3N-5W-SW-SW-SE	27	Carter-Knox			Grady	10904	N/A
Amer. Quasar Petr. Co.	Cunningham	3N-5W-C-SE-NW	27	Carter-Knox			Grady	9301	N/A
Mack Energy Corp.	Harrison Daniel	3N-5W-NE-SE-NE	28	Carter-Knox			Grady	8645	12307
Chevron USA Inc.	Gray Eva	3N-5W-NW-NW-SW	28	Carter-Knox			Grady	N/A	12871
Chevron USA Inc.	Gray Eva	3N-5W-NE-NE-NW	28	Carter-Knox			Grady	5998	N/A
British American Oil	Harrison B	3N-5W-SW	28	Carter-Knox			Grady	N/A	12323
Chevron USA Inc.	Randall Shl	3N-5W-SE-SW-NE	29	Carter-Knox			Grady	7273	12157
British American Oil	Harrison	3N-5W-NE	29	Carter-Knox			Grady	8979	12141
Ohio Oil Co.	E E Harrison	3N-5W-C-NE-SW	29	Carter-Knox			Grady	8655	N/A
Chesapeake Oper. Inc.	Dan Mary	3N-5W-SW-SW-NE	30	Carter-Knox			Grady	10292	N/A
Pan American Petr.	Harrison Unit	3N-5W-NE-SW-NE	30	Carter-Knox			Grady	10978	14293
Helmerich & Payne Inc.	Harrison	3N-5W-C-NE-SE	31	Carter-Knox			Grady	11705	N/A
Chesapeake Oper. Inc.	Hosely-A	3N-5W-NW-NW-SE	32	Carter-Knox			Grady	9642	13938
British Amer. Oil Prod.	Baker John W.	3N-5W-SW-SW-SW-NE	33	Carter-Knox			Grady	7397	12428
N.A.	J. Kaye #1	3N, 5W	33	Carter-Knox	1273	1245	Grady	7976	12222
Chesapeake Co.	Chandler #1-34	3N, 5W, SW, SE, NW, N	34	Cox City	1210	1183	Grady	10038	14880
Pan Amer. Petr. Corp.	Mitchell Unit Deep #1	3N-5W-SW-NE-NE-SW	34	Knox	N.A.	1204	Grady	4683	14388
Walsh F H Jr. Oper. Co.	Wright	3N-5W-SW-NE-SW	35	Carter-Knox			Grady	10963	N/A

Operator	Well	Location	Sec.	Field	K.B.	G.L.	County	Top Sprg.	Top Hntn.
	Maxwell #1	2N-4W-SW	30	S.W. Bray	1172	1150	Stephens	12212	15398
Chesapeake Oper., INC.	Hodge #1-2	2N-5W	2	Carter-Knox	1259	1231	Stephens	N/A	15071
Avalon Expl. Inc.	Jean Sharon 1	2N-5W-NE-SE-SW	2	Carter-Knox			Stephens	9816	N/A
British Amer. Oil Prod. Co.	Sally Krieger #1	2N-5W-NE-NW-SW-SW	3	Carter-Knox	1245	1230	Stephens	8143	12163
Chevron USA Prod. Co.	Fox Alliance #1	2N-5W	3	Carter-Knox	1235	1210	Stephens	2839	13426
Chevron USA Inc.	Fox Alliance #2	2N-5W-SE-NE-SE	4	Carter-Knox			Stephens	8026	12055
British Amer. Oil Prod. Co.	H.C. Brickell #1	2N-5W-SW-NE	4	Carter-Knox	1248	1235	Stephens	8597	12671
Chesapeake Oper., INC.	Clary #1-5	2N-W	5	Carter-Knox	1265	1242	Stephens	10597	14917
Chesapeake Oper., INC.	Greiner #1-9	2N-5W	9	Carter-Knox	1182	1160	Stephens	9957	14510
HG&G, INC.	Hussey #1-10	2N-5W-NW	10	Carter-Knox	1225	1199	Stephens	8441	12663
Alpine Oil & Gas	Hussey #1-10	2N-5W-NW	10	Carter-Knox	1223	1201	Stephens	8498	12546
British Amer. Oil Prod. Co.	Hussey #1-X	2N-5W-NW-SW-SW-NE	10	Carter-Knox	1235	1218	Stephens	8114	12589
Chesapeake Oper. Inc.	Spragins	2N-5W-C-SW-SE	10	Carter-Knox			Stephens	N/A	12920
HG&G, INC.	Hussey #1AX-11	2N-5W-SW	11	Carter-Knox	1202	1175	Stephens	5533	13488
HG&G Incorporated	Hussey Trust #1	2N-5W-NE-SW-SW-SW	11	Carter-Knox	1176	1149	Stephens	6301	13211
Chesapeake Oper. Inc.	Ledbetter #1-12	2N-5W-NE-SW-NE-SW	12	Carter-Knox	1234	1202	Stephens	11597	15079
Chesapeake Oper. Inc.	Gassius	2N-5W-NW-SW-SW	12	Carter-Knox			Stephens	10931	15056
Sinclair Oil & Gas Co.	Moody #1	2N-5W-SW-SW	13	Knox		1164	Stephens	8799	13226
Marathon	Anderson #1-13	2N-5W	13	Knox	1212	1188	Stephens	9136	13304
Standard Oil	Hussey #1	2N-5W-SW-SE-NW	14	Carter-Knox	1195	1170	Stephens	7604	13193
Chesapeake Oper. Co.	HPC #1-14	2N-5W	14	E. Bray	1212	1184	Stephens	4235	13431
Gulf Oil Corp.	Jones Stella	2N-5W-NE-NE-NW	14	Carter-Knox			Stephens	7705	N/A
Chesapeake Oper., INC	Maxwell #1-15	2N-5W	15	Knox	1170	1139	Stephens	9602	13448
Texas Pacific Coal & Oil Co.	Sledge Unit #1	2N-5W-NW-SE-NE	23	Knox Deep	1145	1126	Stephens	9101	13031
Gulf Oil Corp.	Daisy McKinney #1	2N-5W-SE-SE-NW	24	Carter-Knox	1180	1158	Stephens	7810	12990
N.A.	P. Diane #1	2N, 5W	24		1170	1138		8513	12923
Gulf Oil Corp.	Earl Graham #1	2N-5W-NW-SW-NE	25	Carter-Knox	1101	1083	Stephens	10438	13219
Chesapeake Oper. Inc.	Mahaffey	3N-5W-S/2-S/2-N/2	19	Carter-Knox			Grady	9540	13248
British Amer. Oil	WA Reed 1	3N-5W-SW-SW-NW	20	Carter-Knox			Grady	8380	12354
Chevron USA Inc.	Sierra K 1	3N-5W-SW-SW-NW	20	Carter-Knox			Grady	7546	12354
Chevron USA Inc.	Sierra K 2	3N-5W-SE-SE-SW	20	Carter-Knox			Grady	10485	N/A

Plates 1, 2, 3 ,
4, 5, 6, 7, 8, 9,
10, 11 and 12.



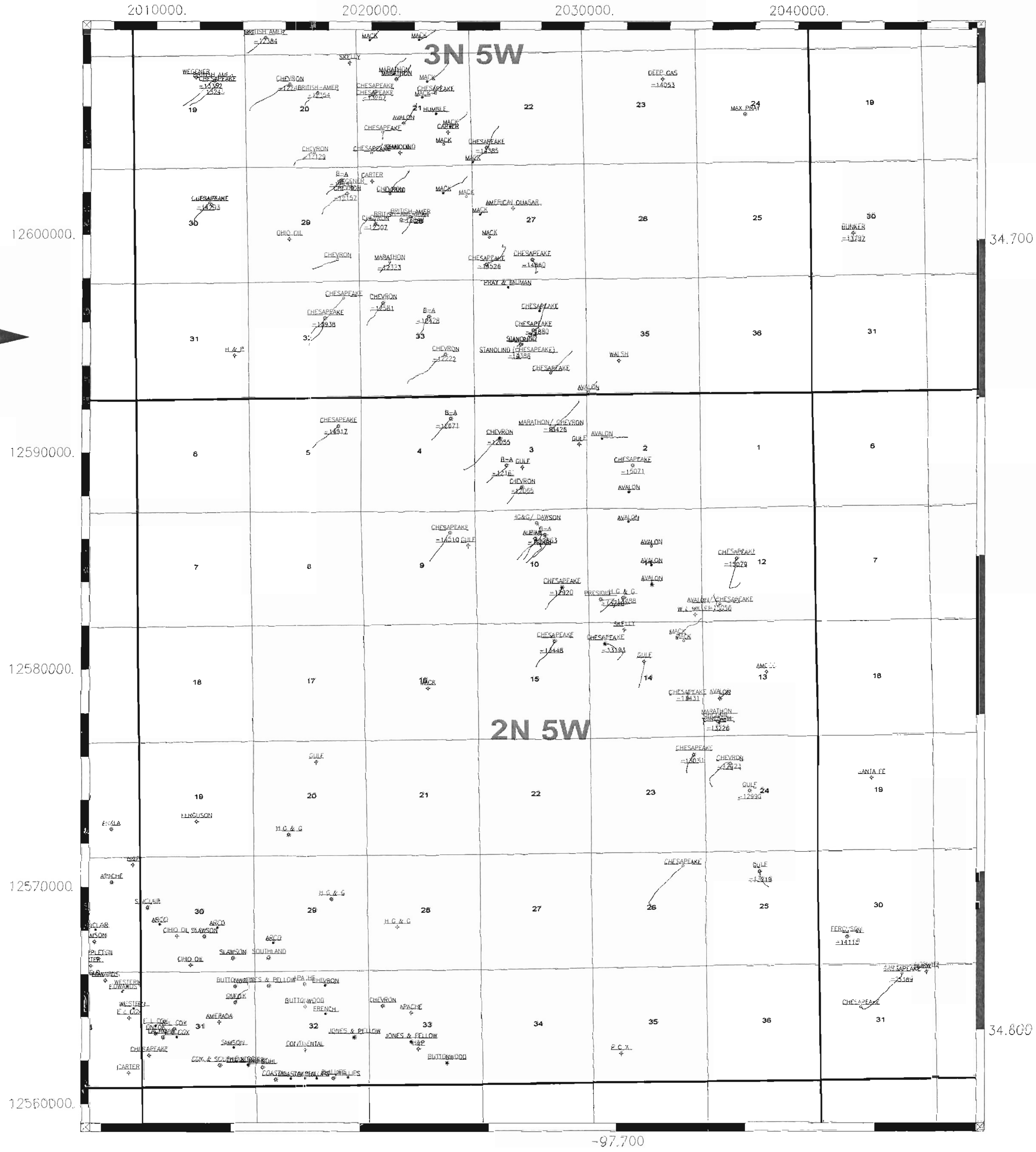
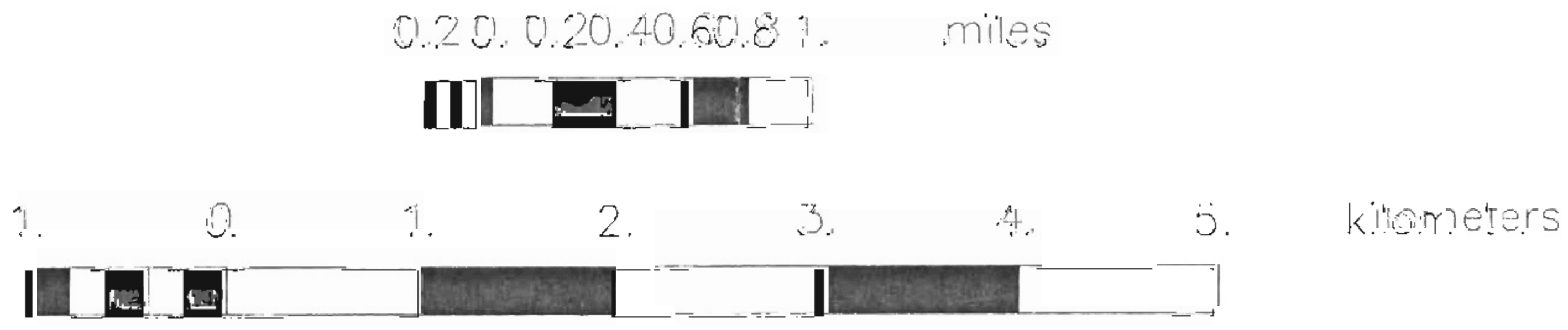
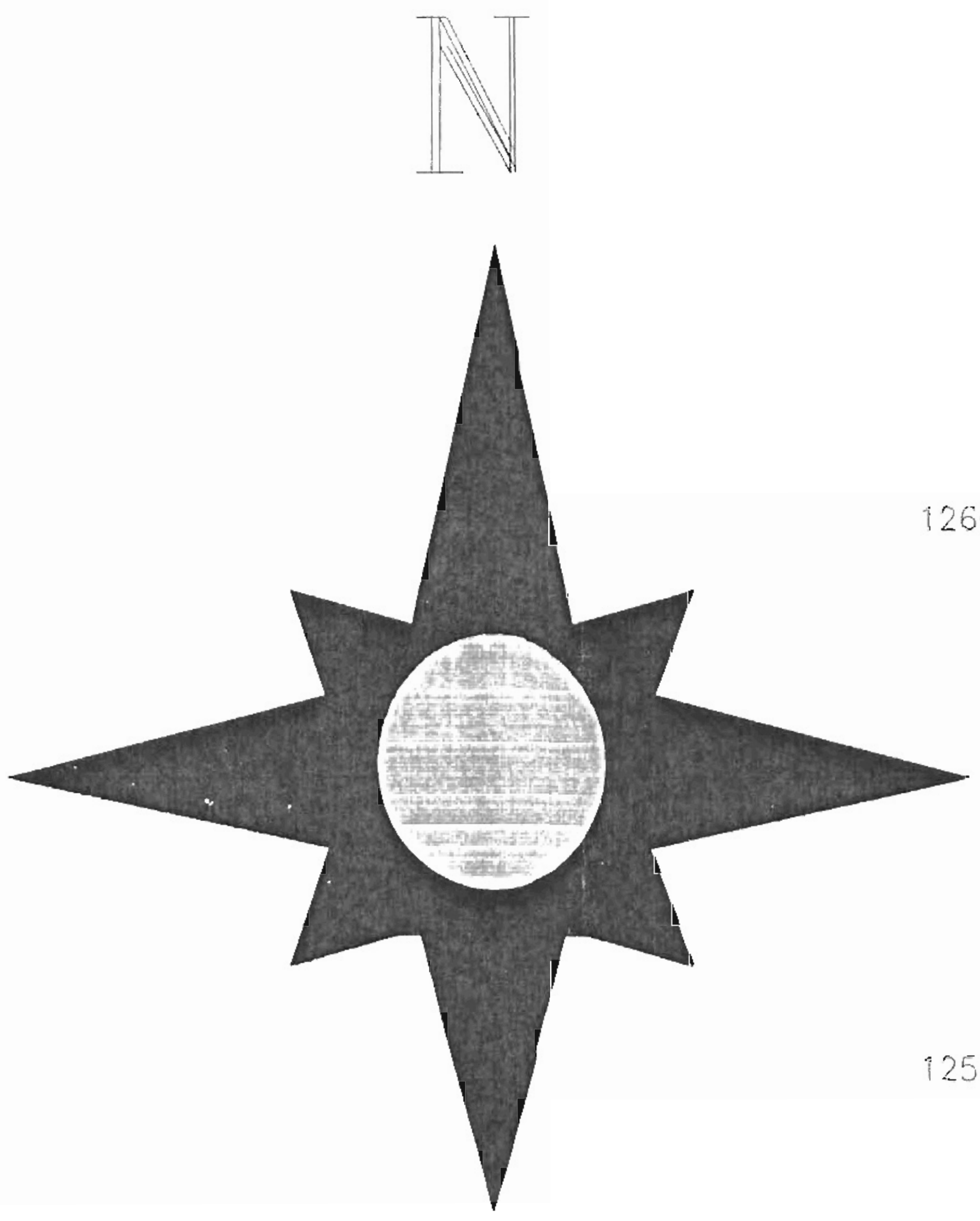


Plate I
Base map showing well locations

Jony Perkins		2-1997

Scale 1:36000.





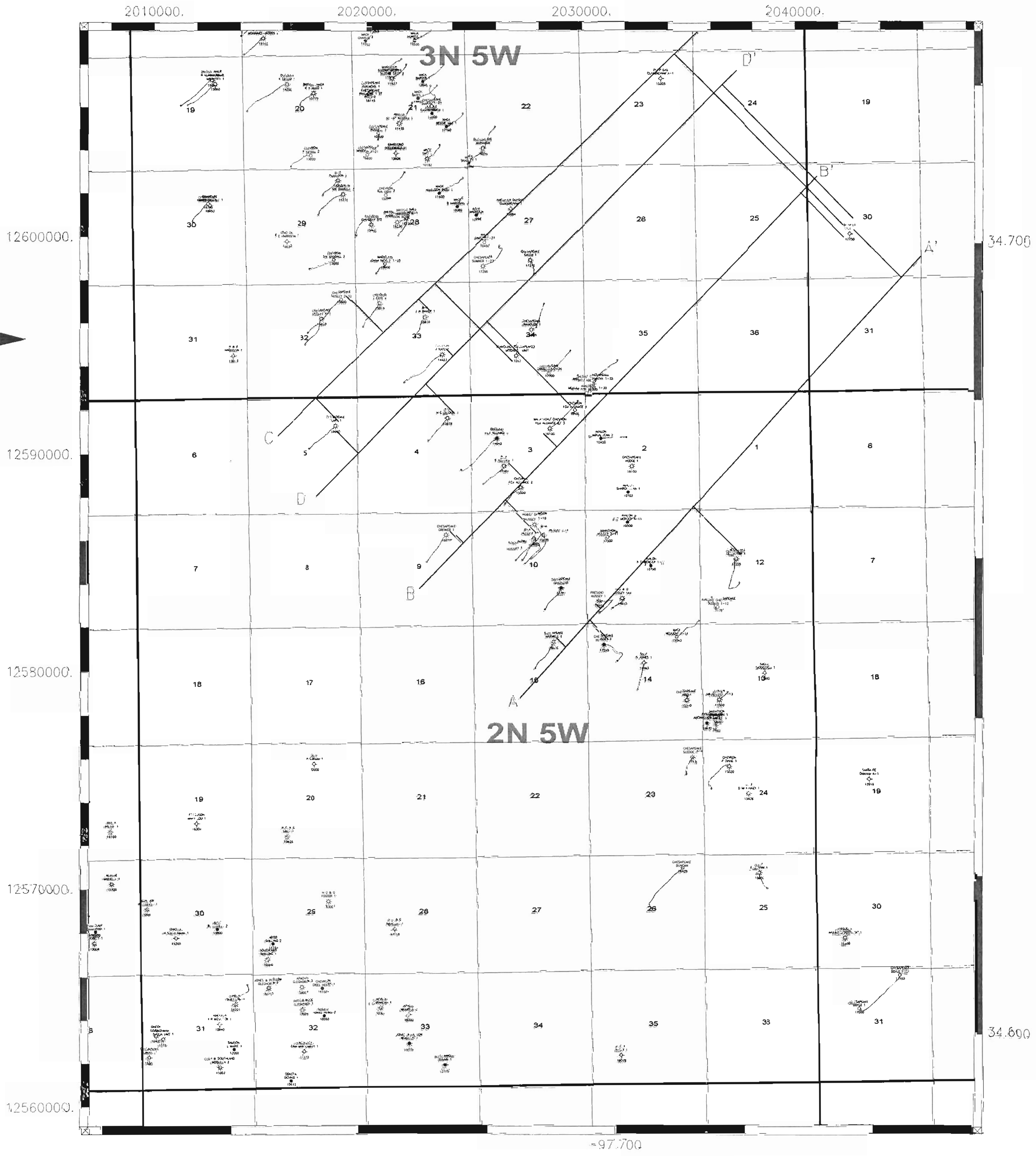
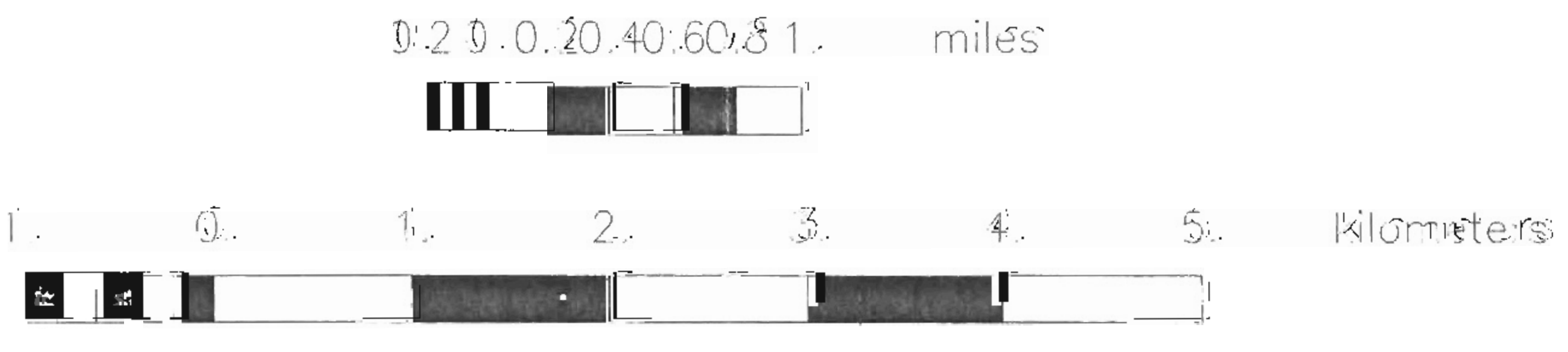


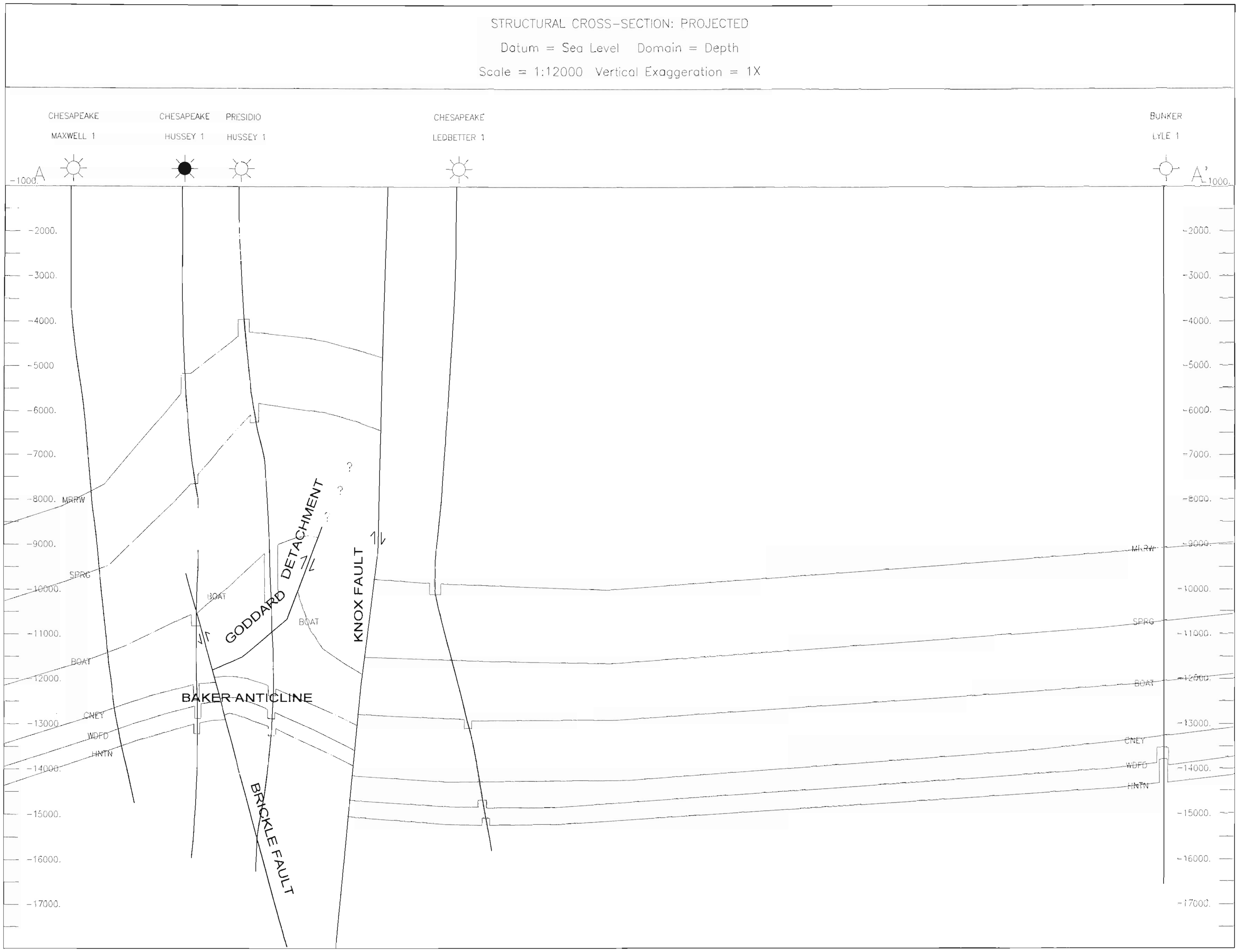
Plate II
Base map showing the lines of the structural cross-sections

Tony Perkins

2-1997

Scale 1:36000.



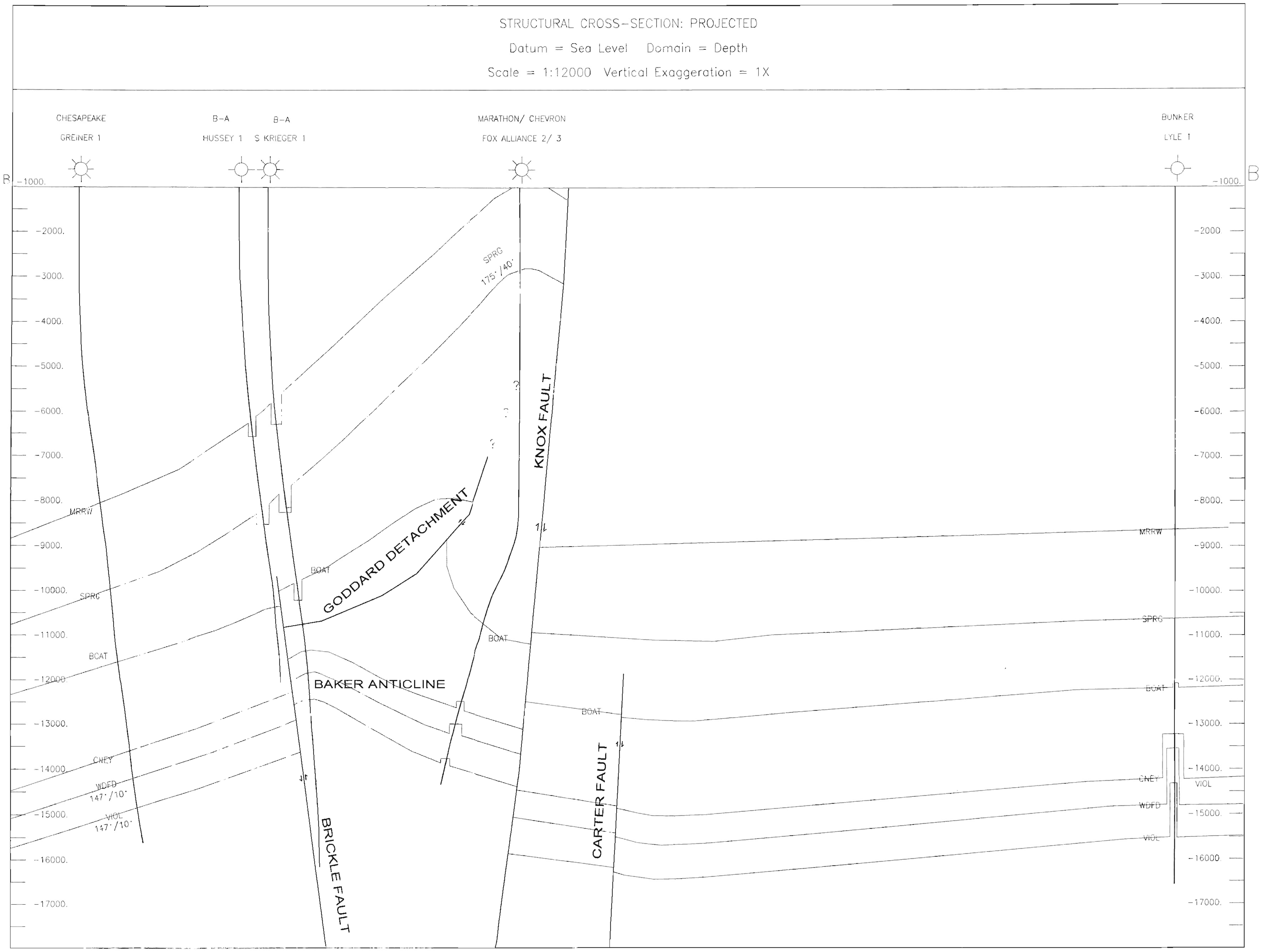


KEY

MRRW-MORROWAN SERIES
SPRG-SPRINGER SERIES
BOAT-BOAT MARKER
CNEY-CANEY SHALE
WDFD-WOODFORD SHALE
HNTN-HUNTON LIMESTONE

Plate III
Structural Cross-Section A-A'

Tony Perkins		2-1997
	Scale 1:1.18	


STRUCTURAL CROSS-SECTION: PROJECTED

Datum = Sea Level Domain = Depth

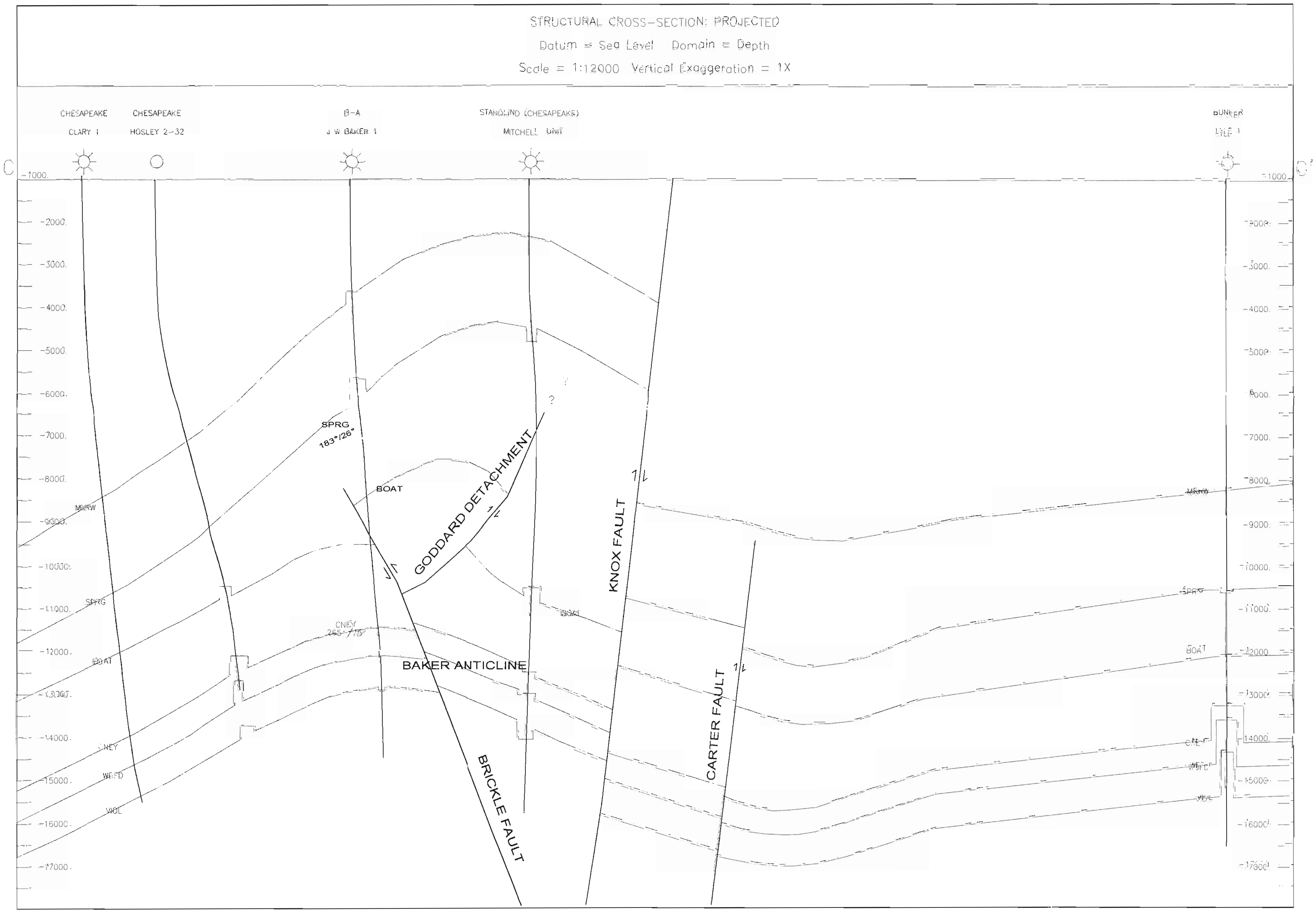
Scale = 1:12000 Vertical Exaggeration = 1X

KEY

MRRW-MORROWAN SERIES
SPRG-SPRINGER SERIES
BOAT-BOAT MARKER
CNEY-CANEY SHALE
WDFD-WOODFORD SHALE
VIOL-VIOLA LIMESTONE

Plate IV
Structural Cross-Section B-B'

Tony Perkins		2-1997
	Scale 1:1.22	



KEY

MRRW-MORROWAN SERIES
SPRG-SPRINGER SERIES
BOAT-BOAT MARKER
CNEY-CANEY SHALE
WDFD-WOODFORD SHALE
VIOL-VIOLA LIMESTONE

Plate V
Structural Cross-Section C-C'

Tony Perkins		2-1997
	Scale 1:1.29	

STRUCTURAL CROSS-SECTION: PROJECTED

Datum = Sea Level Domain = Depth

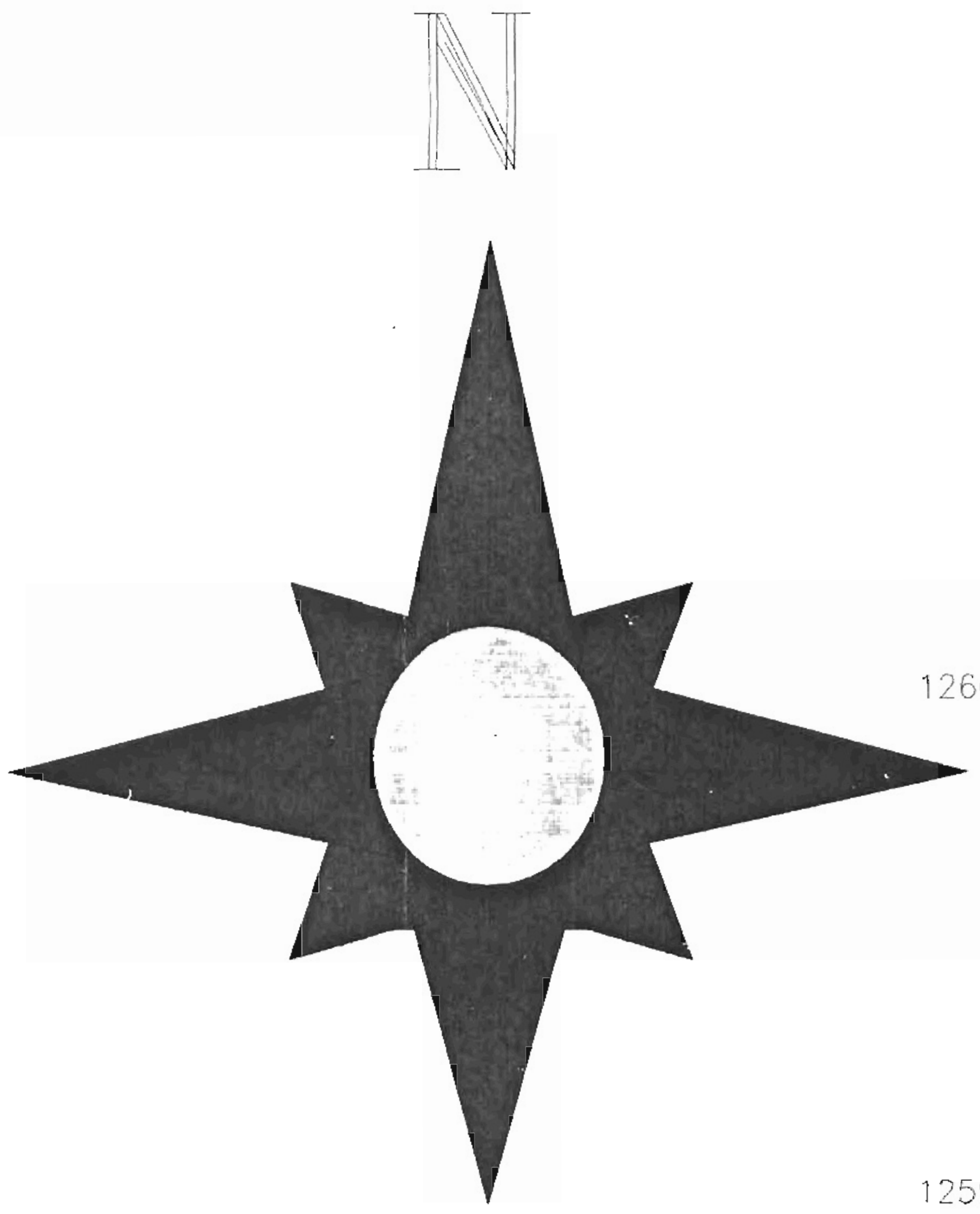
Scale = 1:12000 Vertical Exaggeration = 1X

KEY

MRRW-MORROWAN SERIES
SPRG-SPRINGER SERIES
BOAT-BOAT MARKER
CNEY-CANEY SHALE
WDFD-WOODFORD SHALE
VIOL-VIOLA LIMESTONE

Plate VI
Structural Cross-Section D-D'

Tony Perkins		2-1997
	scale 1:1	



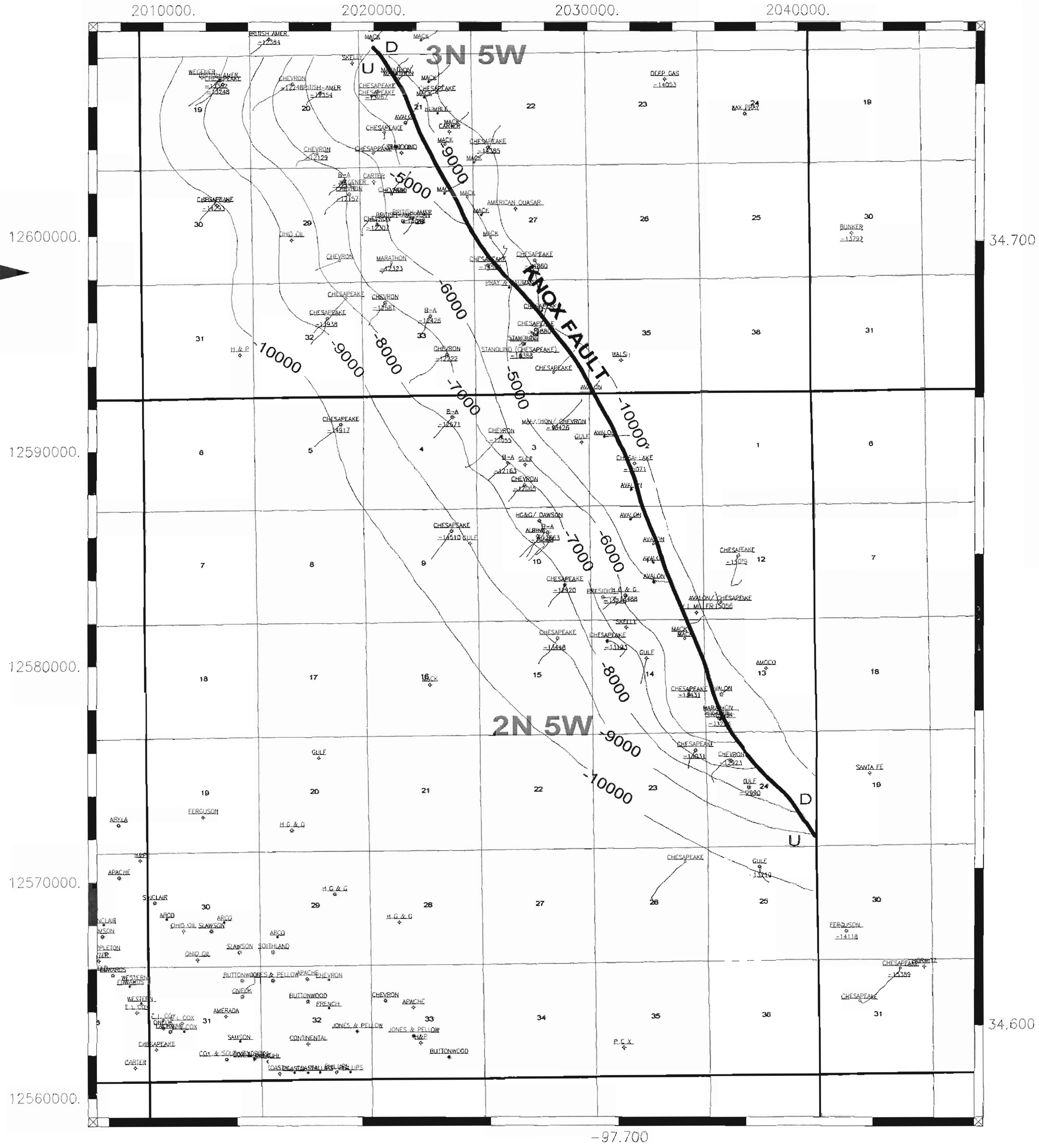
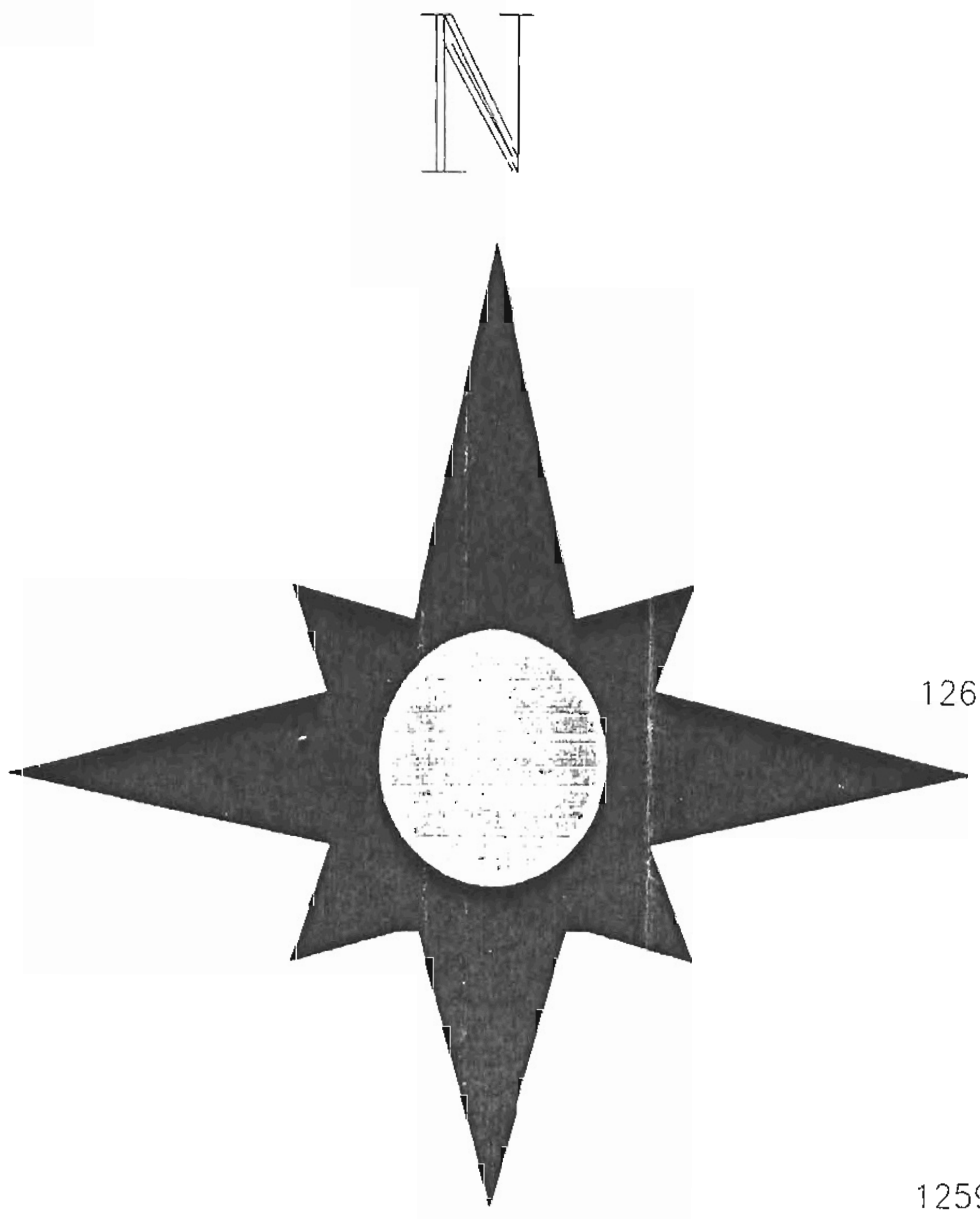


Plate VII
Structural contour map on the top of the Springer

Tony Perkins	2-1997

Scale 1:39052.02



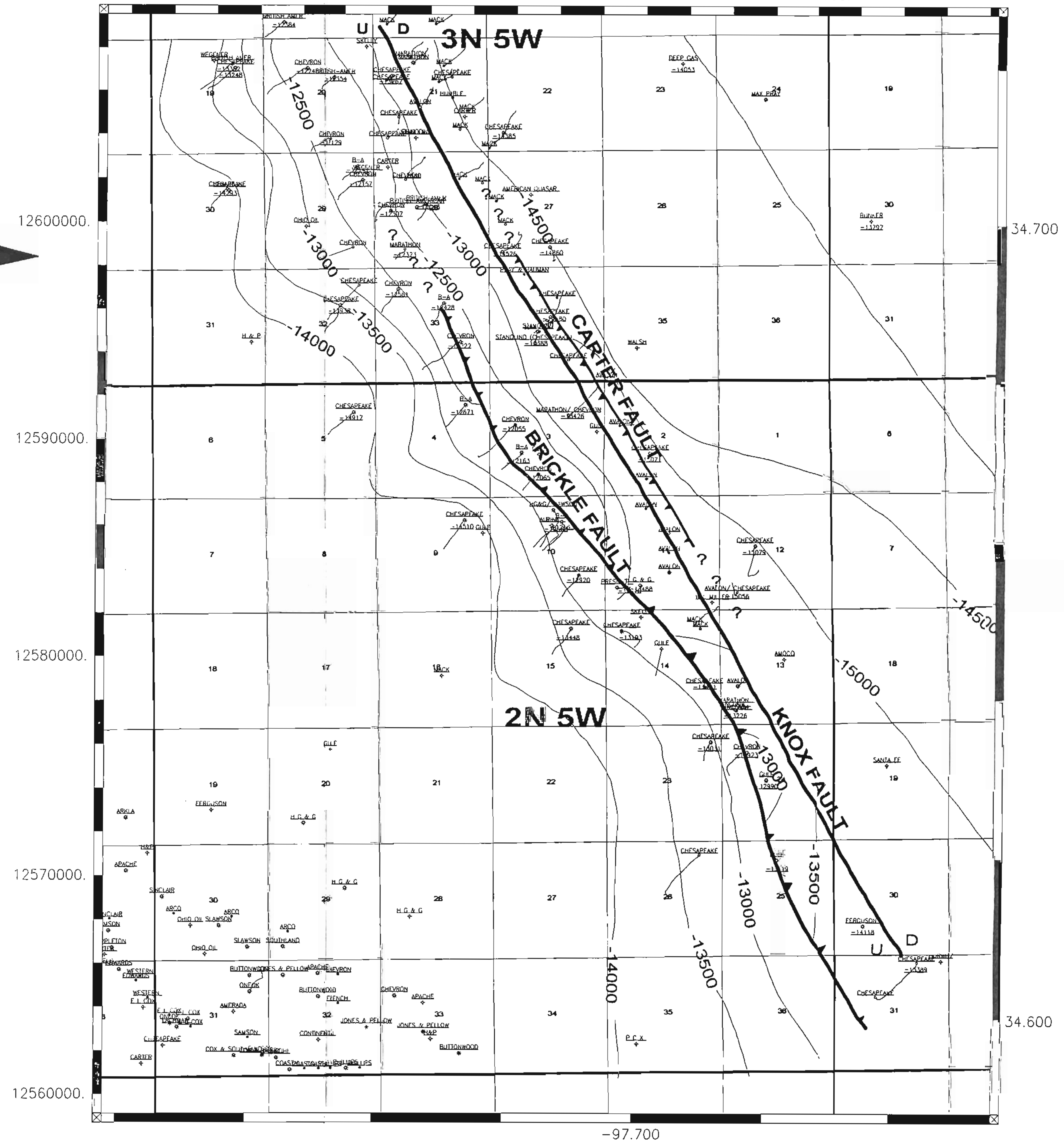
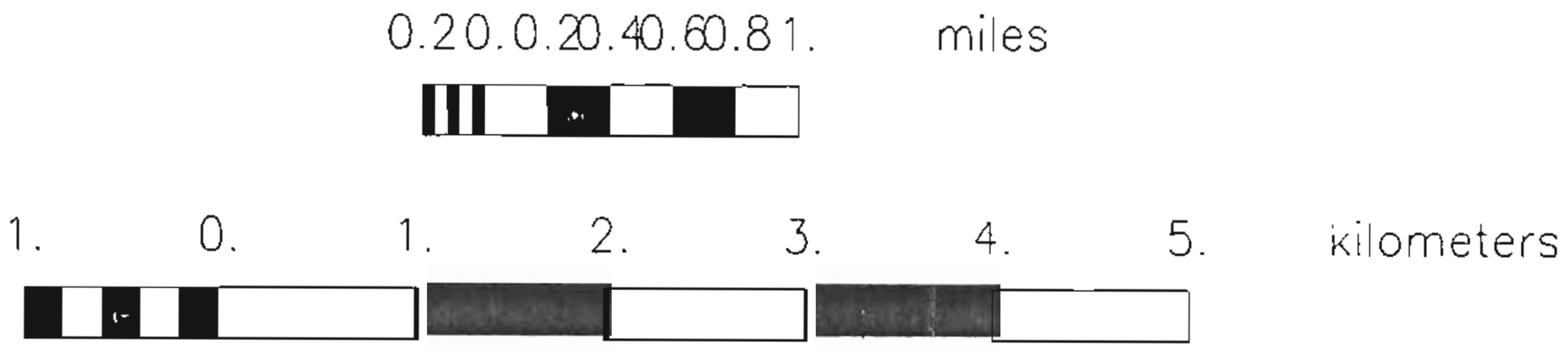


Plate VIII
Structural contour map on the top of the Hunton

Tony Perkins		2-1997
	Scale 1:39070.	

Scale 1:39070.



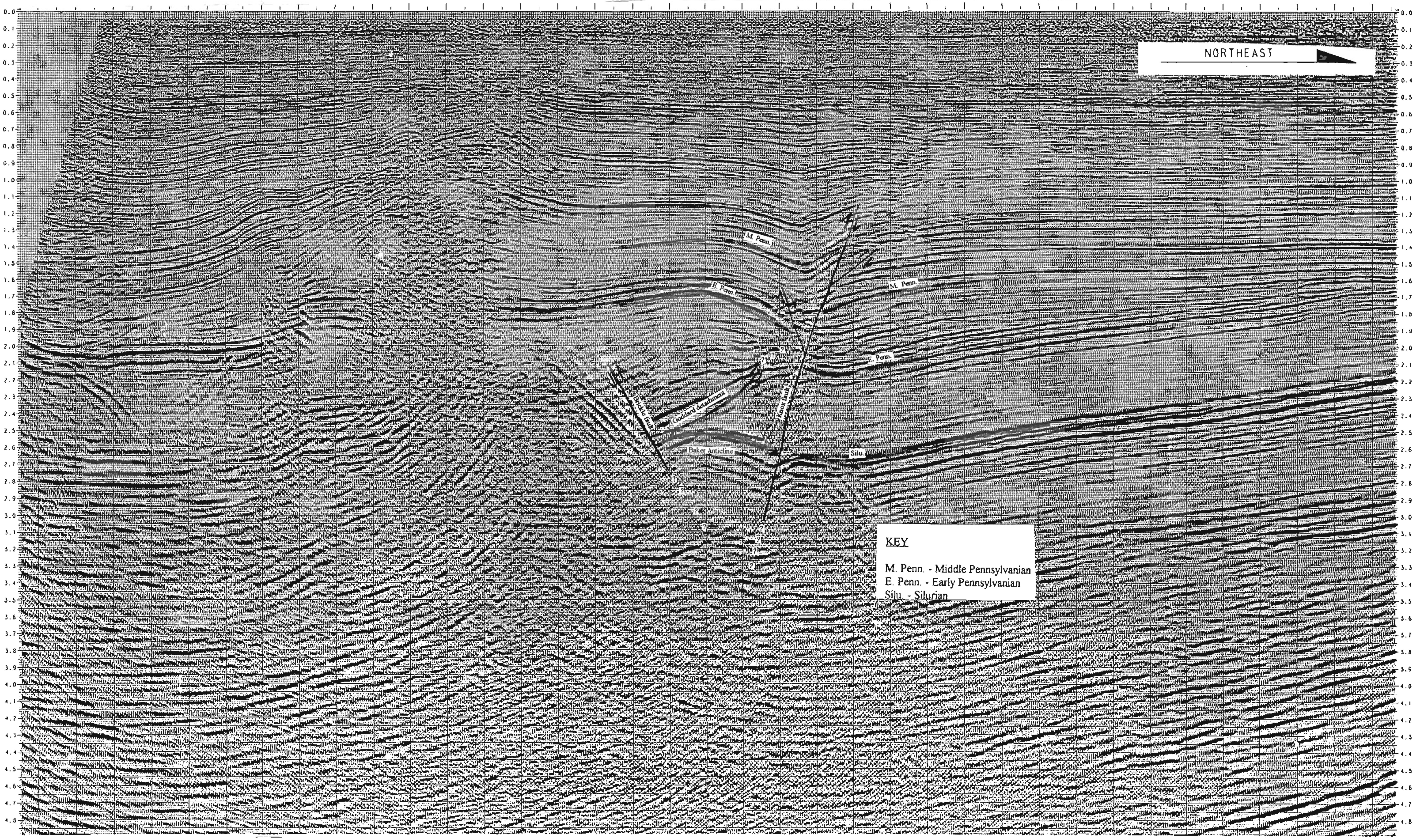


Plate IX Interpreted Seismic A	
Tony Perkins	2-1997

KEY

M. Penn. - Middle Pennsylvanian
E. Penn. - Early Pennsylvanian
Silu. - Silurian

Plate X Interpreted Seismic B	
Tony Perkins	2-1997

Plate XI
Uninterpreted Seismic B

Tony Perkins	2-1997

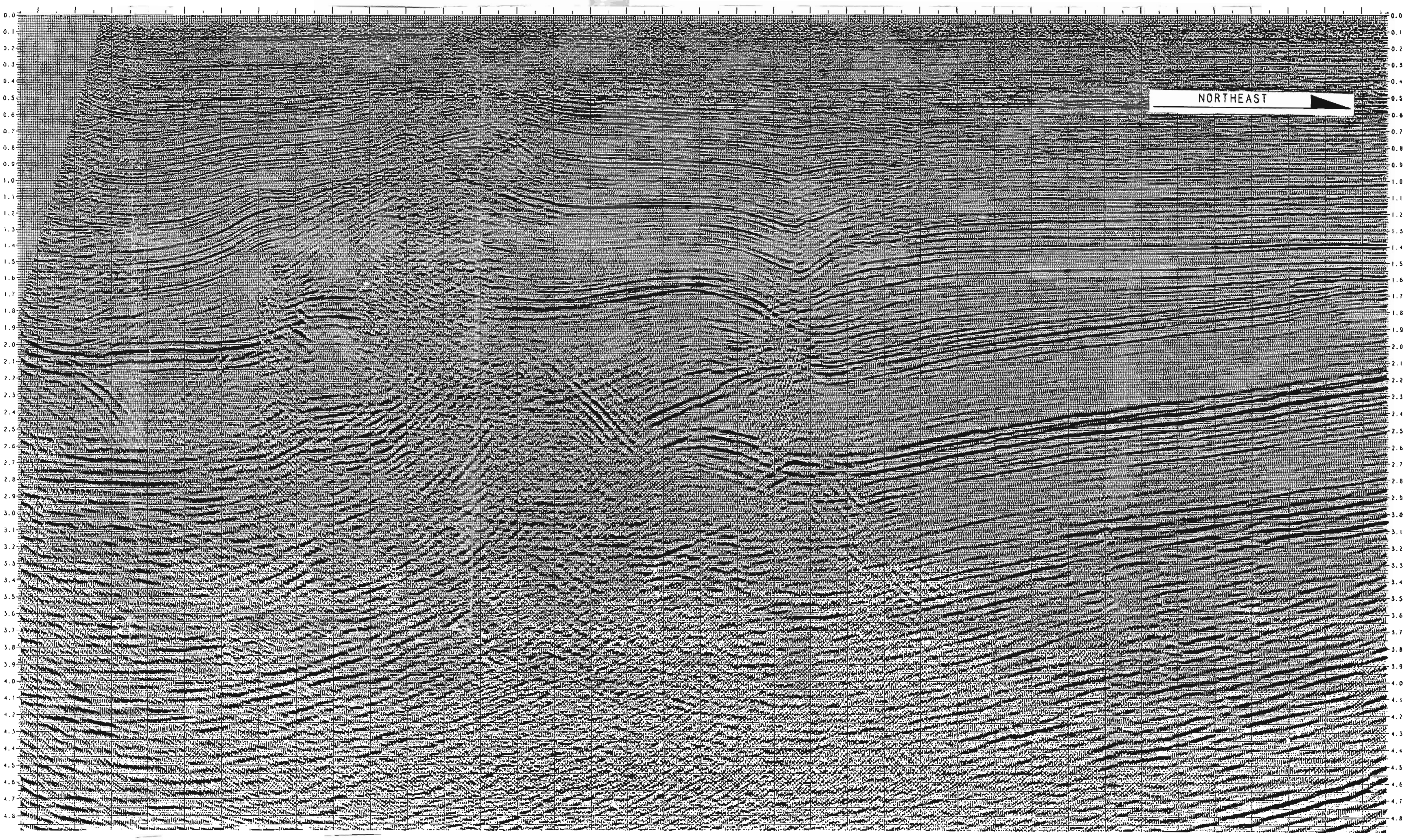


Plate XII
Uninterpreted Seismic A

Tony Perkins

2-1997

VITA

Tony Perkins

Candidate for the Degree of

Master of Science

Thesis: STRUCTURAL GEOMETRY OF THE SOUTHERN PART OF THE CARTER-KNOX STRUCTURE, ANADARKO BASIN, SOUTHERN OKLAHOMA

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Biographical:

Personal Data. Born in Corpus Christi, Texas, on December 3, 1971, the son of David and Cheryl Perkins

Education: Graduated from Edmon High School, Edmond, Oklahoma in May 1990, received Bachelor of Science degree in Geology from Oklahoma State University in December, 1994; completed the requirements for the Master of Science degree in Geology at Oklahoma State University in May, 1997

Professional Experience. Teaching Assistant: Department of Geology, Oklahoma State University.