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A Subsurface Stratigraphic Study of the Middle Atoka, Sebastian County, Arkansas

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A SUBSURFACE STRATIGRAPHIC STUDY OF THE MIDDLE ATOKA, SEBASTIAN COUNTY, ARKANSAS

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of the requirements for the degree of
Master of Science in Geology

By

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University of Arkansas
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ABSTRACT

Raster log images were analyzed to study the subsurface stratigraphy of the Middle Atoka in the Arkoma Basin of the western portion (Sebastian County) of Arkansas. The most significant sandstone units of the Middle Atoka in this area were determined to be two generally coarsening-upward sequences in the lower portion of the formation. Based on lithologic correlations, these two units were determined to be the informally named Casey and Freiburg members of the Middle Atoka. Thickness information based on picked tops was used to create isopach maps of the units of interest. The log signatures and geometry of the sand bodies indicate that they were deposited in a deltaic system that prograded across this portion of this basin. Distributary-mouth bar deposits dominate the Casey member, and are occasionally overlain by localized channel deposits. Avulsion of the delta lobe possibly occurred, and a new lobe then began to prograde, depositing the sediments that formed the Freiburg. This unit is also dominated by distributary-mouth bar deposits.

This thesis is approved for recommendation to the Graduate Council.

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I would like to begin by thanking Dr. Doy Zachry, who has been both my undergraduate advisor, and thesis advisor as a graduate student. His guidance throughout the years has played an important role in my accomplishments as a geology student. He deserves special thanks for his patience and willingness to help, in spite of his busy schedule.

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Thank you, also, to Dr. Xiangyang "Cheyenne" Xie, who has served as a thesis committee member, and to all the geology professors at the U of A who have shared their knowledge with me over the last few years.

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Finally, thank you to my lovely husband, Peter. He has always believed in me even when times seemed too difficult for me to believe in myself.

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1.0 INTRODUCTION

In the western and northern portions of the Arkoma Basin of Arkansas and Oklahoma several sandstone units of the Middle Atoka are substantial natural gas producing reservoirs. This makes understanding of the Middle Atoka of significance. The Middle Atoka is informally divided into sandstone units, which are separated by shales. These Middle Atoka sands in descending order are the: Glass, Morris, Tackett, Areci, Moyer, Bynum, Hurst, Freiburg, Casey, and Vernon (Table 1). All of these sands are major producers of natural gas, with the exception of the Glassy member, which is a minor producing interval. Determining the sedimentary origin and development of the sandstone units during subsidence of the Arkoma Basin during the Middle Atoka will increase the understanding of the depositional characteristics of these rock units.

The study area (Figure 1) is located in the western part of the Arkansas portion of the Arkoma Basin, south of Backbone Mountain and is generally within Townships 6 and 7 North, Ranges 31 and 32 West in Sebastian County, Arkansas. The general area is shown in Figure 1. Proximal to the area of investigation, the Atoka Formation ranges in thickness from about 5,500 feet in the northwestern part of the Greenwood Quadrangle to about 14,750 feet in the southeastern part (Haley and Hendricks, 1968). Tidally dominated shoreline facies are exposed along the Backbone Anticline north of the study area, and display a fining upward sequence that can be attributed to tidal flat sedimentation.

An understanding of the stratigraphy and depositional characteristics of these sandstones is important to developing them as reservoirs for natural gas. A general study of the Middle Atoka interval was conducted, and two significant sandstone units of interest were identified. A more detailed stratigraphic investigation of these two units was conducted to better understand the deposition history. Based on lithologic correlation of the sand units within the Middle Atoka the units of interest have been determined to be the Freiburg and Casey sandstones.

TABLE 1: INFORMAL NOMENCLATURE OF ATOKA UNITS

This Study	Other Commonly Used Names
Upper Carpenter	Carpenter, Carpenter A
Upper Alma *	
Middle Alma *	
Lower Alma *	
------------------------------Base of Upper Atoka (Haley and Hendricks, 1972)------------------------------	
Lower Carpenter *	Carpenter B
+++++++++++++++++++++++Base of Upper Atoka (Zachry, 1983)+++++++++++++++++++++++	
Glassy	
Morris *	Self, Tackett
Tackett *	Morris
Areci *	Self
Moyer	Hood, Upper Bynum
------------------------------Base of Middle Atoka (Haley and Hendricks, 1972)------------------------------	
Bynum[1]	
Hurst	Lower Bynum
Freiburg *	Henson, Pearson
Casey *	Hudson 1
Vernon	
+++++++++++++++++++++++Base of Middle Atoka (Zachry, 1983)+++++++++++++++++++++++	
Sells *	Dunn A, McGuire, Hudson 2
Upper Jenkins[2] *	Ralph Barton, Upper Alma, Jenkins
Lower Jenkins	Dunn B
Dunn C *	Dawson, Dawson A, Allen
Paul Barton	Dawson B, Russell, Lower Allen, Lower Dawson
Cecil Spiro *	Cecil, Hamm
Patterson	
Spiro *	Kelly, Orr, Barton, Basal Atoka, Greenland?
+++	

Zachry (1983) and Haley and Hendricks (1972) agree on the base of the Lower Atoka* - Names in bold-type are recognized basin-wide.

1 – In some cases the Bynum-Hurst interval may appear as a single sand, in which case the name "Bynum" is used.

2 – In some cases the Upper Jenkins-Lower Jenkins interval may appear as a single sand, in which case the name "Upper Jenkins" is used. (Table 1 is modified from Hacker, 2002)

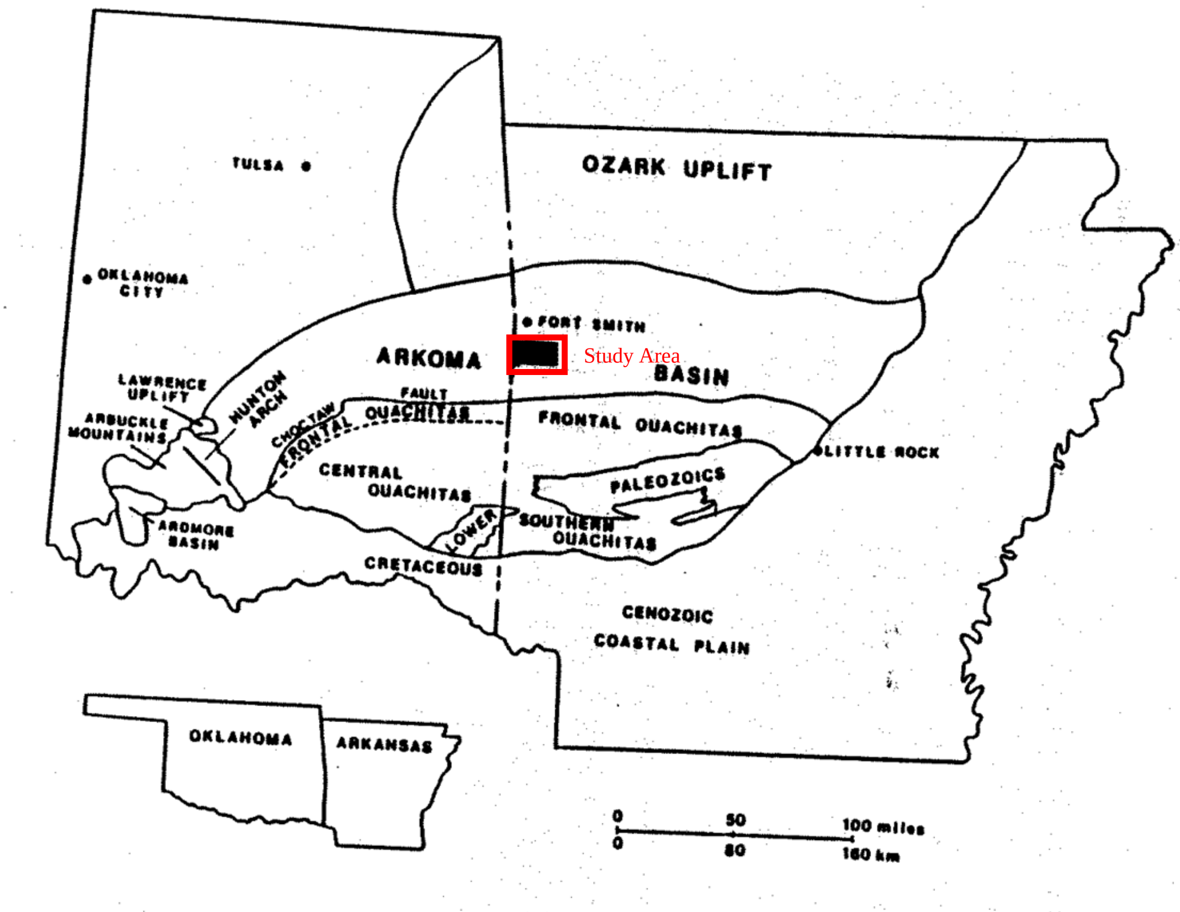


Figure 1. General location of study area in relation to geologic provinces of Arkansas and Oklahoma (from Zachry and Sutherland, 1984).

1.1 Methods

This study was concentrated in the area of T. 7 N. and T. 6 N., R. 31 W. and R. 32 W. (Figure 2). Because of active natural gas exploration, numerous well have been drilled in this area. Wireline well logs were used as the primary source of data for this study. All wells within the study area with raster images available were considered. For various reasons, including insufficient drilling depth, a total of 190 well logs were utilized (Figure 3).

Gamma ray, resistivity and conductivity curves were used to correlate the units of interest in the well logs. Tops and bases were determined for units of interest based on well log signatures. This information was loaded into Petra, a cross section and mapping software. Data collected included but was not limited to, the top and base of the Middle Atoka, top and base of the lower sand of the Middle Atoka, and individual units within this sand unit. From this data, thickness information was used to create isopach maps of desired intervals within the Middle Atoka.

Finally, boundary information was used in the construction of various stratigraphic north-south and east-west cross-sections. These cross sections give a general idea of the stratigraphic relationships in the subsurface.

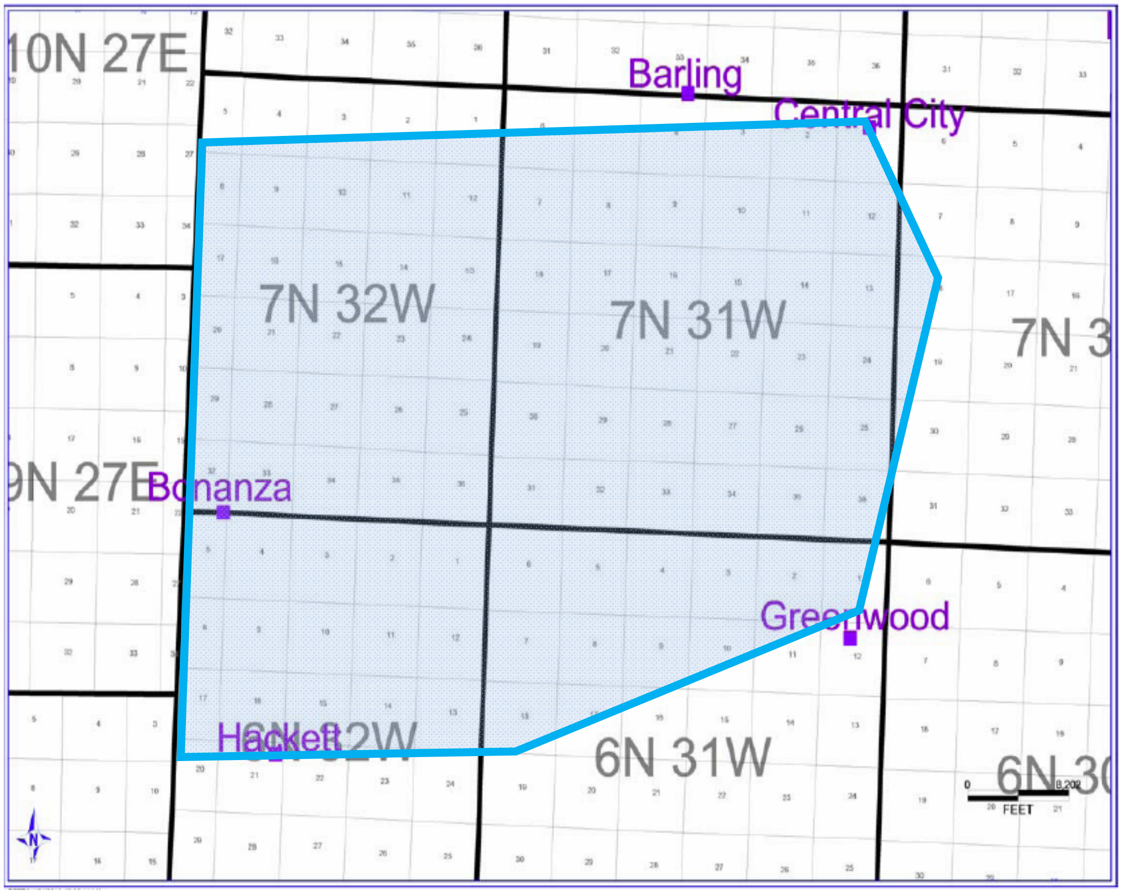


Figure 2. Location of study area (in blue) in Sebastian County Arkansas.

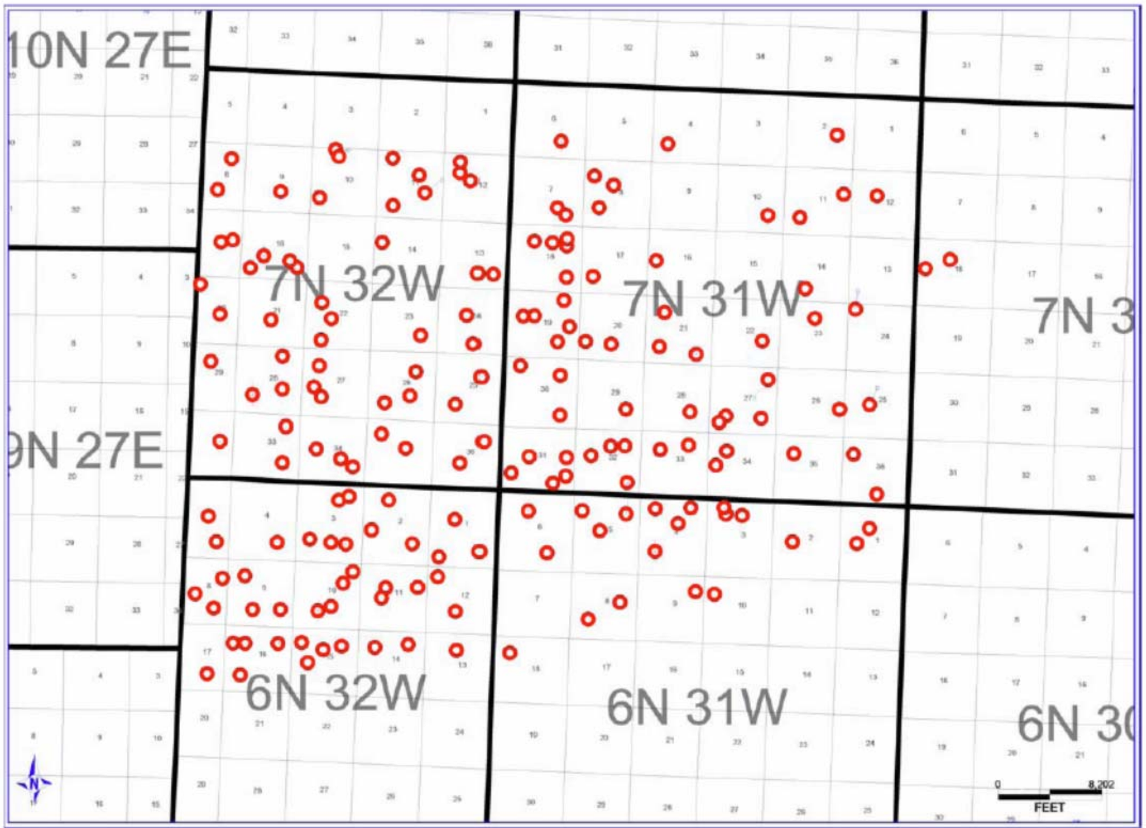


Figure 3. Base map of study area showing well locations highlighted in red.

1.2 Previous Investigations

Taff and Adams (1900) described a sequence of sandstone and shales located in southeastern Oklahoma while studying the Choctaw Coal Fields. This sequence of rocks reaches a thickness of almost 7000 feet and is found below the Hartshorne Formation. It was proposed that this interval of rocks be named the Atoka Formation. In 1930 Croneis recognized that the Atoka Formation in Oklahoma of Taff and Adams (1900) was equivalent to the Winslow Formation of Adams and Ulrich (1904). Croneis then proposed that the name Atoka Formation be used as the name for the rocks lying between rocks of Morrowan age and the Hartshorne Formation.

Deposition during the Atokan, in the northern Arkoma Basin and adjacent shelf, is characterized by repeating packages of sandstone and shale. These packages were deposited as fluvial-deltaic and tidal systems, and are thought to have prograded and aggraded along the northern part of the basin and adjoining shelf (Zachry, 1983; Sutherland, 1988).

Over the past few decades, the Atoka Formation has been the focus of numerous investigations. Several theses have been produced at the University of Arkansas concerning the Middle Atoka Formation. These include theses by Thomas (1983), Williams (1985), Gaston (1985), Stephens (1985), Hacker (2002), and Wenger (2002). Thomas (1983) focused on the Middle Atokan stratigraphy in the southern Arkoma Basin, and Williams' (1985) study was conducted in the western Arkoma Basin in the same general area of this investigation. Although Williams (1985) generally considered the entire Middle Atoka interval, the Birch-Borum interval was the focus of the study. Gaston (1985) focused on the Atokan stratigraphy of the eastern Arkoma Basin, and defined the thickness and areal extent of the three upper, middle and lower Atoka units. Stephens (1985) conducted a stratigraphic investigation of the Alma Formation of the Upper Atoka in the northeast portion of the Arkoma Basin. Hacker (2002) developed a framework of depositional history, and depositional systems models of the Lower Carpenter and Glassy intervals of the Middle Atoka in the central portion of the Arkoma Basin in Arkansas. Wenger (2002) studied the sequence stratigraphy and depositional systems of the Tackett member of the Middle Atoka. He determined that the log signature and geometry of the sand bodies indicate that they were deposited as a distributary –mouth bar facies of a prograding delta complex.

2.0 GEOLOGIC SETTING

The Arkoma Basin is a foreland basin that extends east-west across central Arkansas and east-central Oklahoma. It is approximately 250 miles long east to west, and 20-50 miles wide north to south (Figure 1). It is associated with the Ouachita fold belt, which serves as the southern boundary of the basin. It is bounded on the north by the Ozark Uplift and to the east by the Gulf Coastal Plain.

2.1 Ozark Uplift

The Ozark Uplift in Arkansas (Figure 2) usually refers to the Ozark Dome and the Arkansas Structural Platform (Chinn and Konig, 1973). It is a broad, elongate, structure that is centered in southern Missouri and extends into the northern part of Arkansas and to the northeastern part of Oklahoma (Jameson, 1998).

Paleozoic strata on the platform are almost horizontal (Chinn and Konig, 1973). The platform strikes east-west across the northwestern portion of the state. An increase in dip, number of faults and the presence of minor folding marks the southern boundary (Chinn and Konig, 1973).

2.2 Arkoma Basin

The Arkoma Basin in western Arkansas contains sedimentary rocks ranging from Cambrian to Pennsylvanian in age. Alternating shale and sandstone units of the Lower Pennsylvanian Atoka Formation dominate the basin's stratigraphic succession. The Atoka Formation ranges in thickness from a featheredge in northern Arkansas, to over 30,000 feet in the south adjacent to the Ouachita fold belt (Branan, 1968). This southward thickening reflects the developmental history of the basin as a structural feature (Figure 4). During Early and Middle Atokan time, the southern margin of the Arkoma shelf was subjected to flexural bending, caused by continued basin subsidence to the south that eventually resulted in the development of large east-trending syndepositional normal faults (Sutherland, 1988). Syndepositional faulting ceased at the end of Middle Atoka deposition but flexural subsidence continued through Desmoinesian time (Figure 4). Continued compression related to the Ouachita orogeny produced thrust faults and fault bend folds. Thrust faults cut Desmoinesian strata indicating that final orogenic effects postdate Desmoinesian time (Houseknecht, 1986).

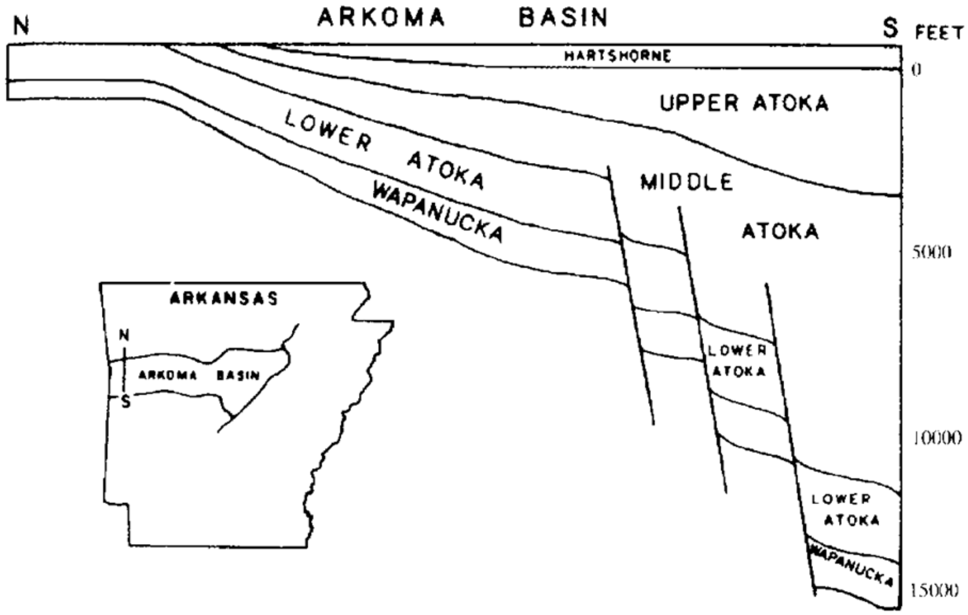


Figure 4. North-south cross section across the Arkoma Basin illustrating large syndepositional normal faults during the Middle Atokan time (modified after Zachry and Sutherland, 1984).

2.3 Ouachita Fold Belt

The Ouachita Fold Belt marks the southern boundary of the Arkoma Basin. It extends westward as a surface feature from Little Rock, Arkansas, to Atoka, Oklahoma. In Arkansas, the northern limit of the Frontal Ouachitas is the Choctaw and Ross Creek thrust faults (Sutherland, 1988). The Cretaceous deposits of the Gulf Coastal Plain define the southern and eastern margin of the surface exposures. In Arkansas, the Ouachita Mountain Fold Belt is approximately 50 to 60 miles wide and 100 miles from the Arkansas-Oklahoma border to the eastern boundary. The surface geology is dominated by east-west trending anticlines, synclines and thrust faults (Jameson, 1998). The rocks of the fold belt in this area are late Mississippian and early Pennsylvanian.

2.4 Tectonic and Structural History

Houseknecht and Kacena (1986) illustrate the tectonic evolution of the Arkoma Basin from the late Precambrian – earliest Paleozoic to the late Atokan – Desmoinesian (Figure 5). Figure 3A illustrates late Precambrian through early Paleozoic rifting that resulted in the opening of a proto-Atlantic ocean basin (Houseknecht and Kacena, 1983). The southern margin of the North American craton then evolved into a passive marine foreland basin that persisted through the earliest Mississippian (Figure 5B). Figure 5C illustrates the closing of the ocean basin, during the early Mississippian through earliest Atokan, due to the encroachment of Llanoria. By Middle Atokan time, (Figure 5D) the ocean basin had been consumed by subduction, and large down-to-the-south normal faults began to form as a result of the crustal loading. Figure 5E represents Late Atokan time, where fore-land style thrusting became predominant as the subduction complex pushed northwards (Houseknecht, 1986). By this time, although relatively minor folding and thrusting continued after the Desmoinesian, the gross structural configuration of the Arkoma-Ouachita system was essentially the same as present.

Subsidence rates increased markedly at the start of middle Atokan time (Figure 6). From 500 Ma to 300 Ma, subsidence occurred at a rate of 7 m/my, whereas during middle and late Atokan time, it increased to 1100 m/my.

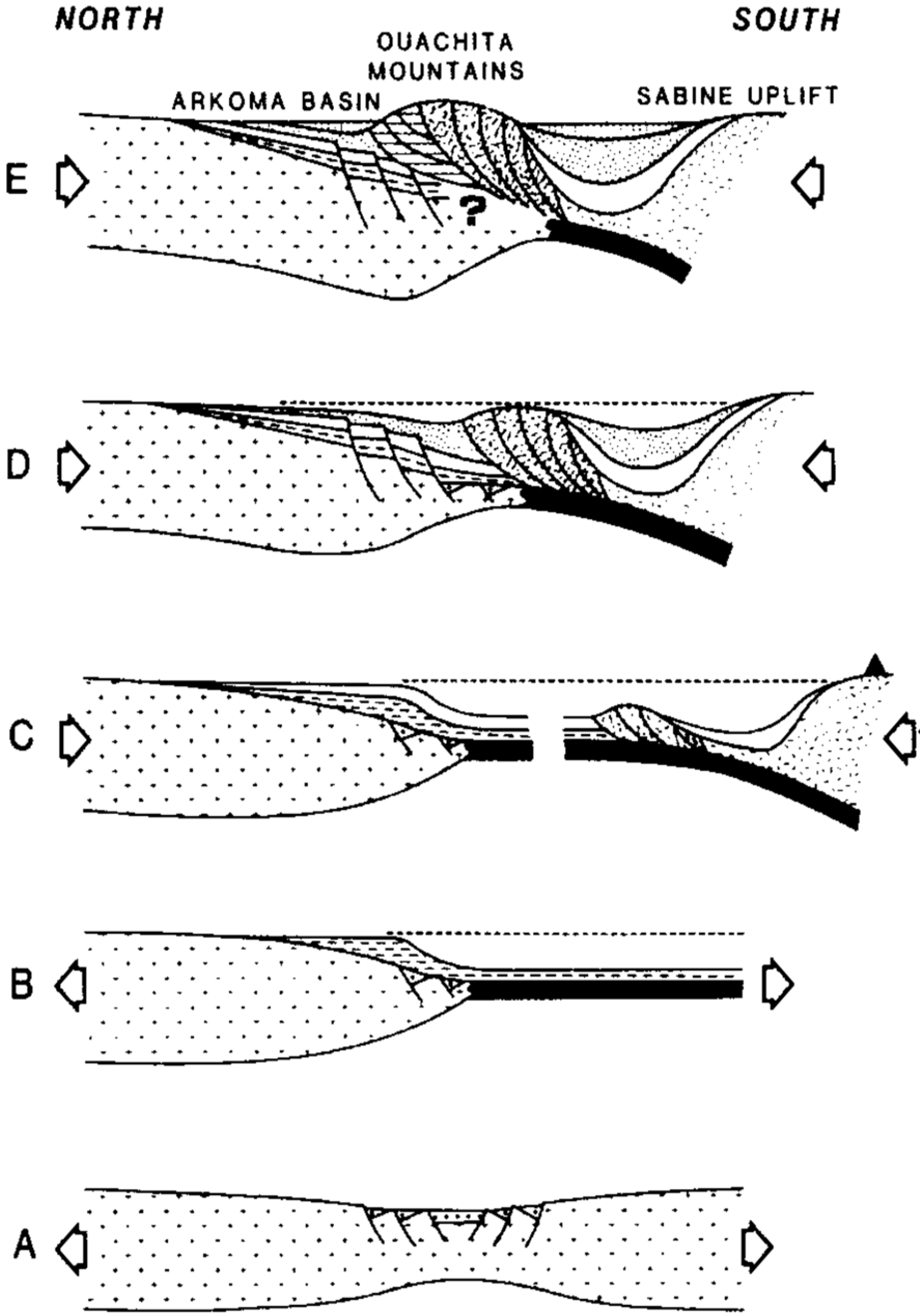


Figure 5. Tectonic evolution of the Arkoma Basin (from Houseknecht, 1986).

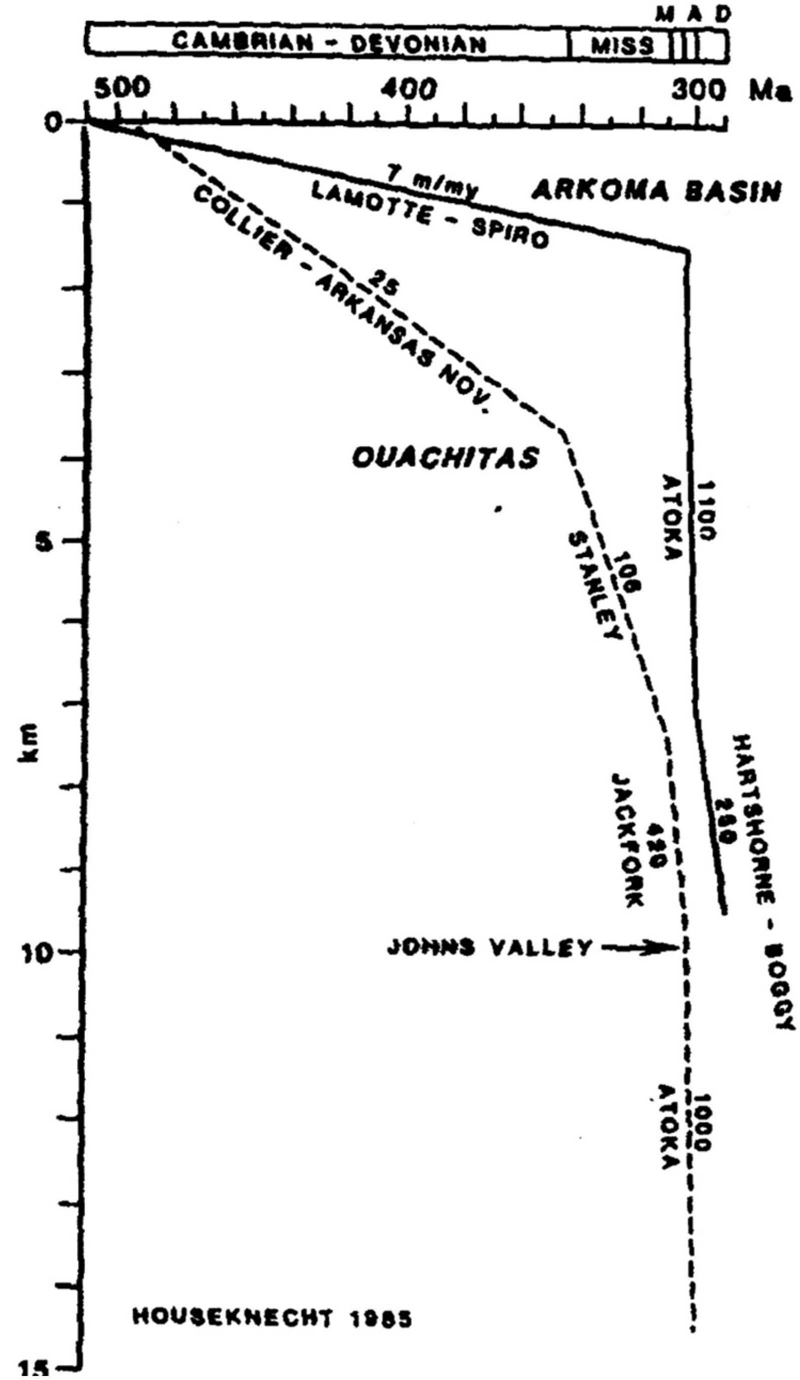


Figure 6. Graphic illustration of subsidence rates in the Arkoma Basin (Houseknecht, 1986).

2.5 Paleogeography and Depositional History

Several studies of the paleogeography of the southern mid-continent and the Arkoma Basin region during the Morrowan, Atokan and Desmoinesian have been published. Houseknecht and Kacena (1983), was the first and most complete. The paleogeography was broken into 5 time slices in which they related the building of the Ouachitas, the Ozark Dome, and the Appalachian Orogeny to the development of the Arkoma Basin. In 1988, Sutherland included a detailed discussion of the regional paleogeography. For this purposes of this study, the focus will remain on Atokan deposition.

During most of its history, the Arkoma Basin was depositionally part of a stable shelf along a passive continental margin. Deep –water deposits accumulated in the basin south of the shelf (Sutherland, 1988). The Arkoma shelf, which included the southern part of the present-day Ozark Uplift as well as the Arkoma Basin, continued as a significant depositional feature through Chesterian, Morrowan and Early Atokan time (Sutherland, 1988).

2.51 Atokan

During Early Atokan time, in Oklahoma, sediment was delivered to the Arkoma Basin from the northwest (Figure 7) by fluvial systems. Small deltas formed on the eroded surface of the underlying Kessler Limestone. This was followed by a rapid northward transgression of a coastal sand complex, known as the Orr, to form a blanket sand unit (Sutherland, 1988). In Arkansas, most of the sand was supplied from the northeast during this time.

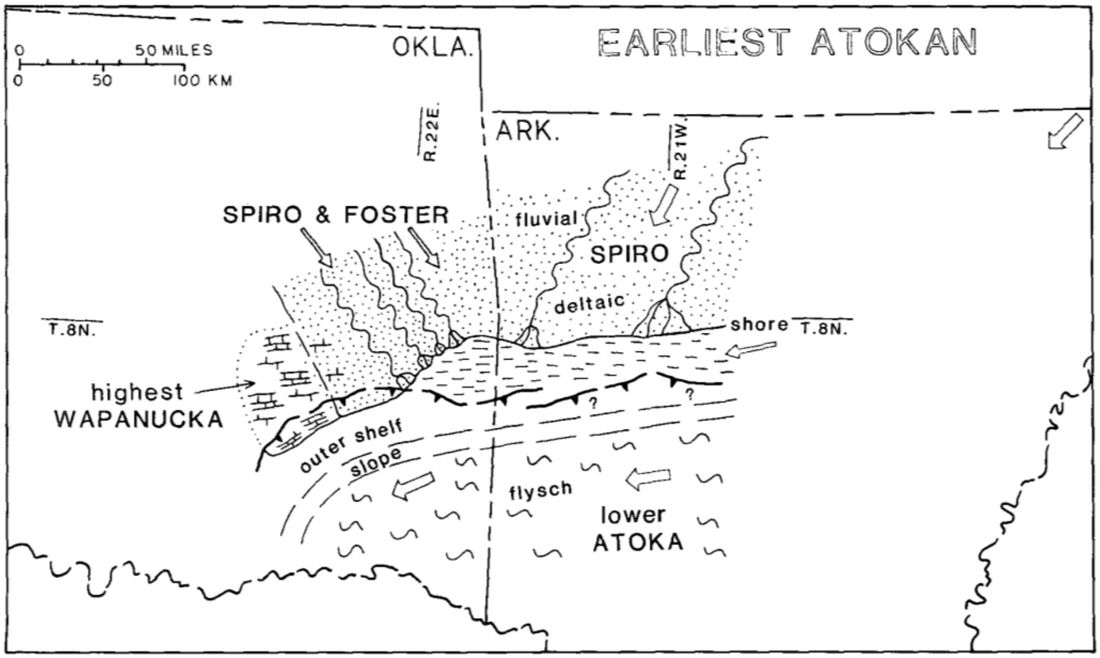


Figure 7. Early Atokan paleogeography (from Sutherland, 1988).

Redistribution of sand and the unit's sheet-like geometry were caused by meandering fluvial systems that graded into deltas that were terminated by a broad regional marine transgression to the north. To the south this sheet sand changes into shale deposits.

Beginning approximately with the deposition of the Middle Atoka, the southern margin of the Arkoma shelf was subjected to flexural bending, caused by continued basin collapse that resulted in large east-trending syndepositional normal faults (Sutherland, 1988). The development of these faults was not synchronous, and it appears that the southernmost faults became active earliest and that active faulting migrated northward with time (Houseknecht, 1986). These faults broke the shelf into a step-like structure upon which Middle Atokan sediments were deposited (Figure 4). The sediment originated from the southeast from the erosion of the already uplifted Black Warrior Basin (Thomas, 1984). These sediments were carried westward along the axis of the basin. The Middle Atokan sandstones of the shelf were deposited in delta and tidal flat environments that prograded towards the southwest (Figures 8 and 9). This section is dominated by shale interrupted by only a few thick sandstone units (Sutherland, 1988). There is some controversy over the deposition of the Middle Atoka sands. Vedros and Visher (1978) interpret these sands as being deep water sands. However, Houseknecht (1986) argues that these sands were deposited in shallow waters, yet below effective wave base. Turbidity current deposition occurred in the southern part of the basin.

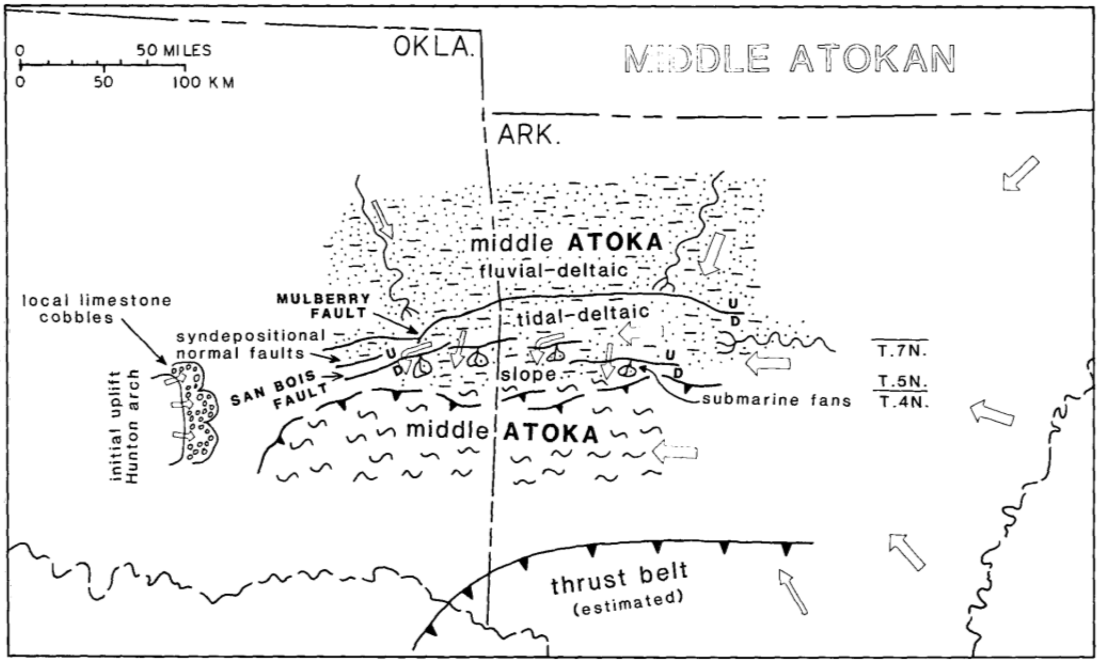


Figure 8. Middle Atokan paleogeography (from Sutherland, 1988).

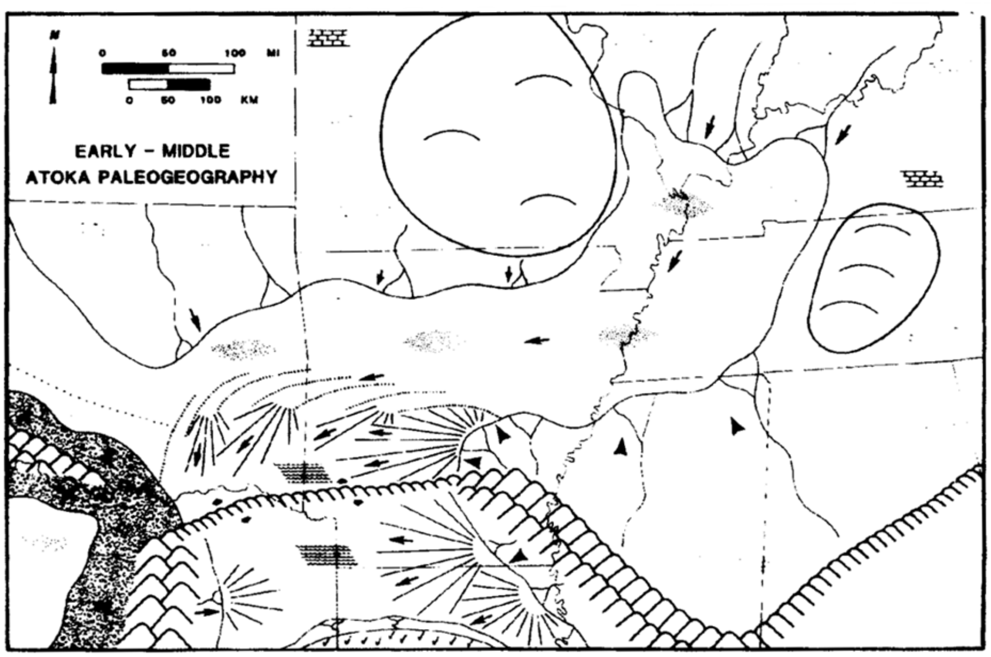


Figure 9. Regional paleogeography of the Early to Middle Atokan (from Houseknecht and Kacena, 1983).

The Ouachita Fold Belt had formed due to imbricate thrusting during the Ouachita Orogeny. The Arkoma Basin had formed on the northern edge of the fold belt. The northern Arkoma area remained unchanged from Middle Atokan time, and remains virtually the same today (Houseknecht, 1983). By this time, normal faulting that occurred during the Middle Atokan was no longer active.

2.52 Desmoinesian

The early Desmoinesian Hartshorne Sandstone was deposited in high-constructive, tidally-influenced deltaic systems that prograded from east to west coinciding approximately with the present-day axis of the Arkoma Basin (Sutherland, 1988).

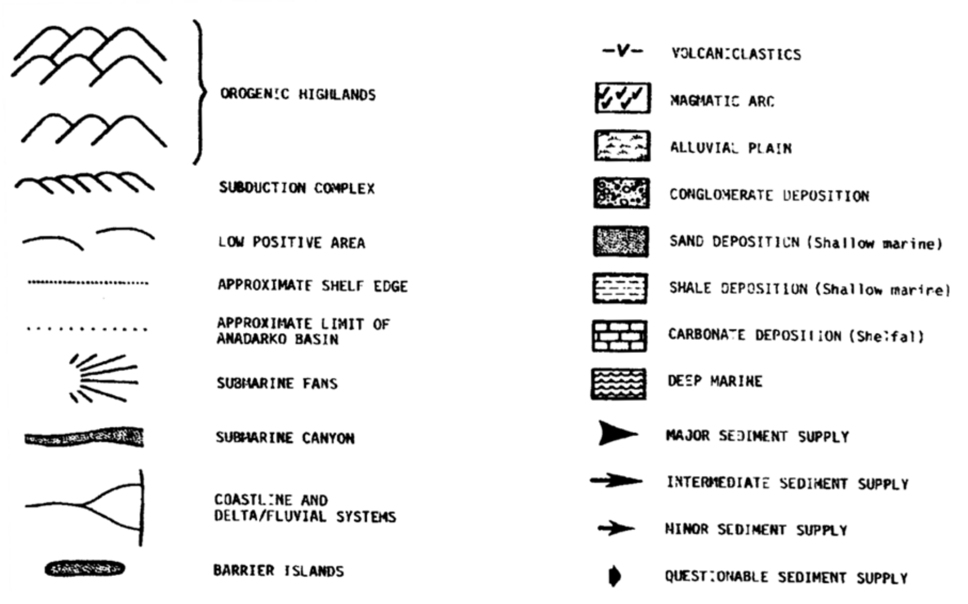


Figure 10. Explanation to the Houseknecht and Kacena (1983) paleogeographic diagrams.

Fluvial sediments in Arkansas came from the northeast, southeast, and possibly east (Houseknecht and Kacena, 1983). Figures 11 and 12 show the early Desmoinesian paleogeography, and the position of the Ouachitas in relation to the basin. The McAlester and Boggy Formations (Figure 13) included transgressions and regressions allowing deltaic systems to prograde across the shelf and into the Arkoma Basin. The Ozarks began their uplift in the Early Desmoinesian. The uplift of the Ouachita Fold Belt and the accompanying compression and folding of the Arkoma Basin ended the subsidence of the basin (Sutherland, 1988.)

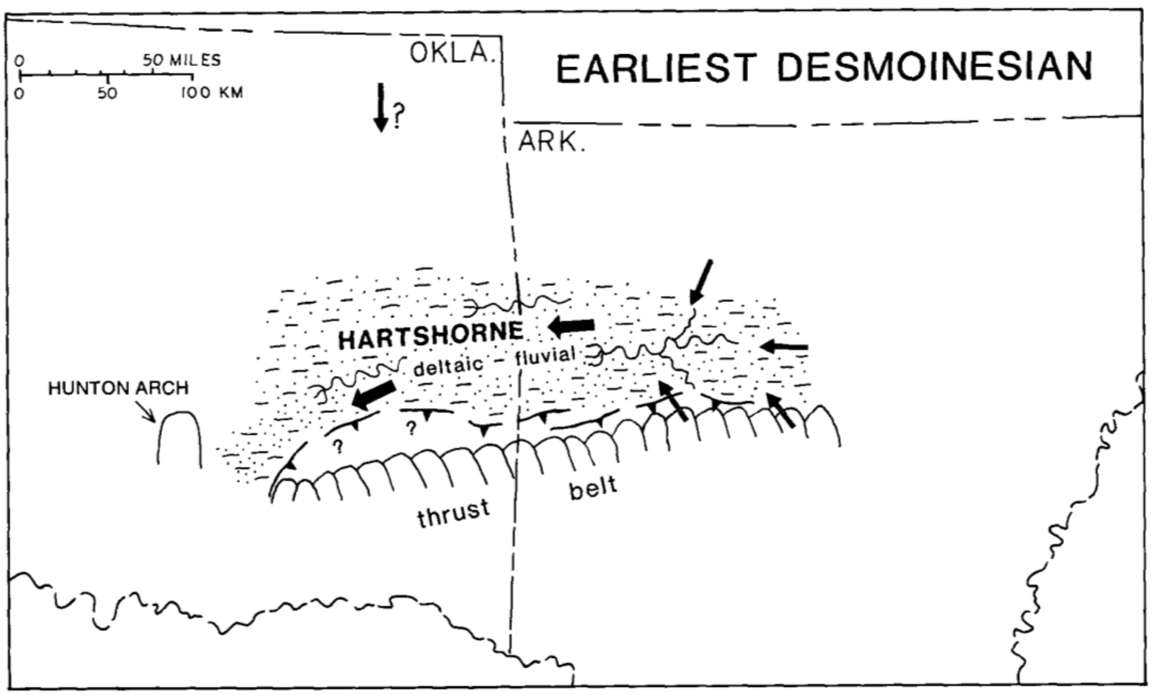


Figure 11. Earliest Desmoinesian paleogeography (from Sutherland, 1988).

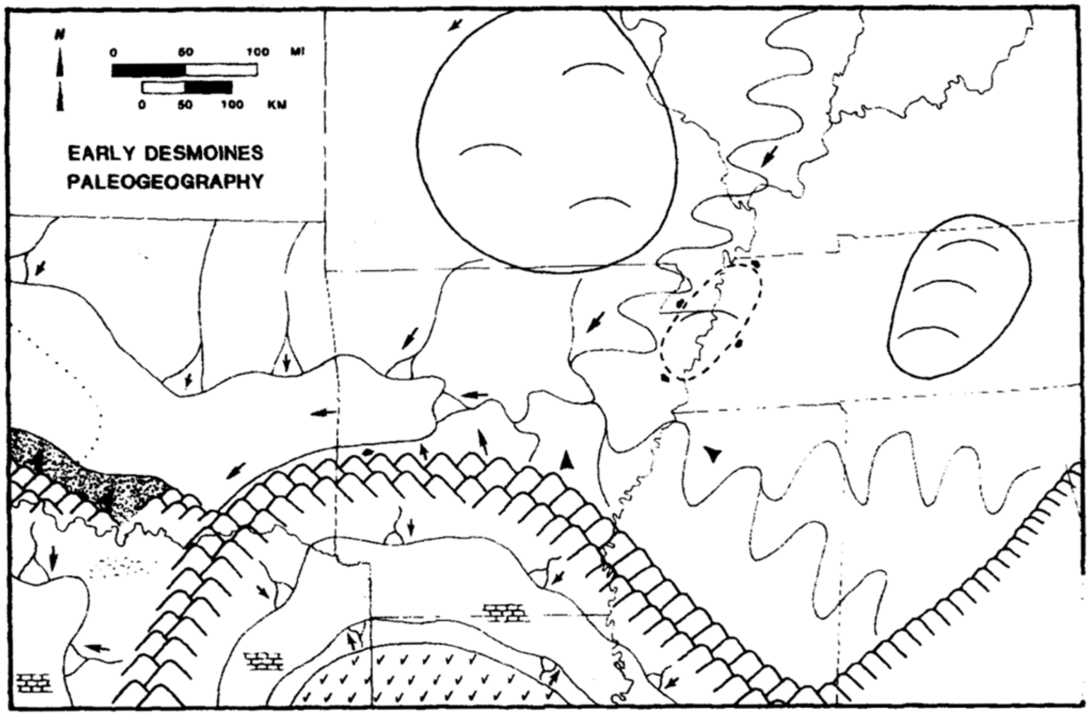


Figure 12. Regional paleogeography of the Desmoinesian (from Houseknecht and Kacena, 1983).

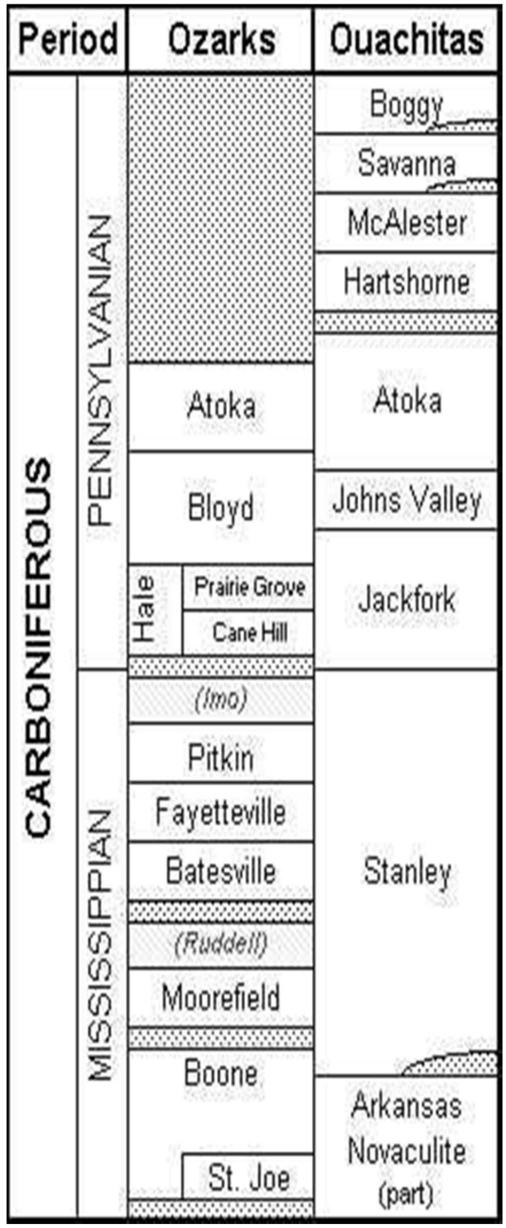


Figure 13. Stratigraphic column of the Carboniferous Period.
From McFarland, 1998.

2.6 General Regional Stratigraphy

The Arkoma Basin in western Arkansas contains sedimentary rocks ranging from Cambrian to Pennsylvanian in age. Alternating shale and sandstone units of the Lower Pennsylvanian Atoka Formation dominate the basin's stratigraphic succession. The Atoka Formation is informally divided into upper, middle and lower units on the basis of depositional character.

The lower unit ranges in thickness from 900 feet adjacent to the northern margin of the basin, to approximately 2000 feet near the southern margin (Zachry and Sutherland, 1984). Multiple sandstone units ranging from 20 to 200 feet in thickness, separated by shales, characterize the Lower Atoka in Arkansas and extreme eastern Oklahoma. These individual sand units are continuous throughout the northern and central parts of the basin.

The Middle Atoka in Arkansas is composed predominantly of shale, with laterally discontinuous sandstone units within the succession (Zachry and Sutherland, 1984). The unit thickens from approximately 1,200 feet in T.7 N. to more than 10,000 feet in T. 4 N. (Buchanan and Johnson, 1968). This southward thickening occurs along large east-trending normal faults (Figure 3).

The Upper Atoka in Arkansas is characterized by sandstone units alternating with thick intervals of shale (Zachry and Sutherland, 1984). The individual sandstone units of this interval are among the units of greatest continuity in the basin. The large normal faults that were active during the Middle Atoka interval are buried by Upper Atoka strata, indicating a cessation of fault activity (Buchanan and Johnson, 1968). Because these faults were not active during this time, the Upper Atoka strata do not thicken to the south as greatly as strata of the Middle Atoka.

2.7 Deltaic Sedimentation

Deltas can be broadly defined as coastal accumulations, both subaqueous and subaerial, derived from river born sediments (Coleman, 1981). This includes deposits that have been secondarily modified by marine agents such as waves, currents, or tides. Deltaic depositional facies result from dynamic processes that interact with one another. These different processes that control delta development can vary greatly, and can form a variety of different coastal features and include distributary channels, river-mouth bars, open and closed interdistributary bays, tidal flats, tidal ridges, beaches, beach ridges, dunes, and swamps and marshes (Wright, 1978). When a river supplies clastic sediments to the coast and inner shelf faster than the sediment can be removed by marine processes, progradation occurs.

3.0 LOCAL STRATIGRAPHY

The Middle Atoka in northern and central Arkansas is characterized by sandstone intervals separated by intervals of shale. Westward in Oklahoma, the overall sandstone content of the Middle Atoka decreases, as the interval becomes predominantly shale with some sandy shale and siltstone (Thomas, 1983). The study area is in the shallow water shelf setting, with the deep-water off-shelf setting south of a fault zone. In the study area, the Middle Atoka extends vertically from the top of a thin sandstone unit just below the Lower Carpenter of the Upper Atoka down to the top of the Sells sandstone unit of the Lower Atoka. The thickness of the Middle Atoka in the area of study is around 1900 feet, however, south of the growth fault zone at the southern border of the study area the character and thickness of the Middle Atoka changes drastically (Figure 14). This drastic thickening occurs on the downthrown side of a large, high-angle syndepositional normal fault (Thomas, 1983).

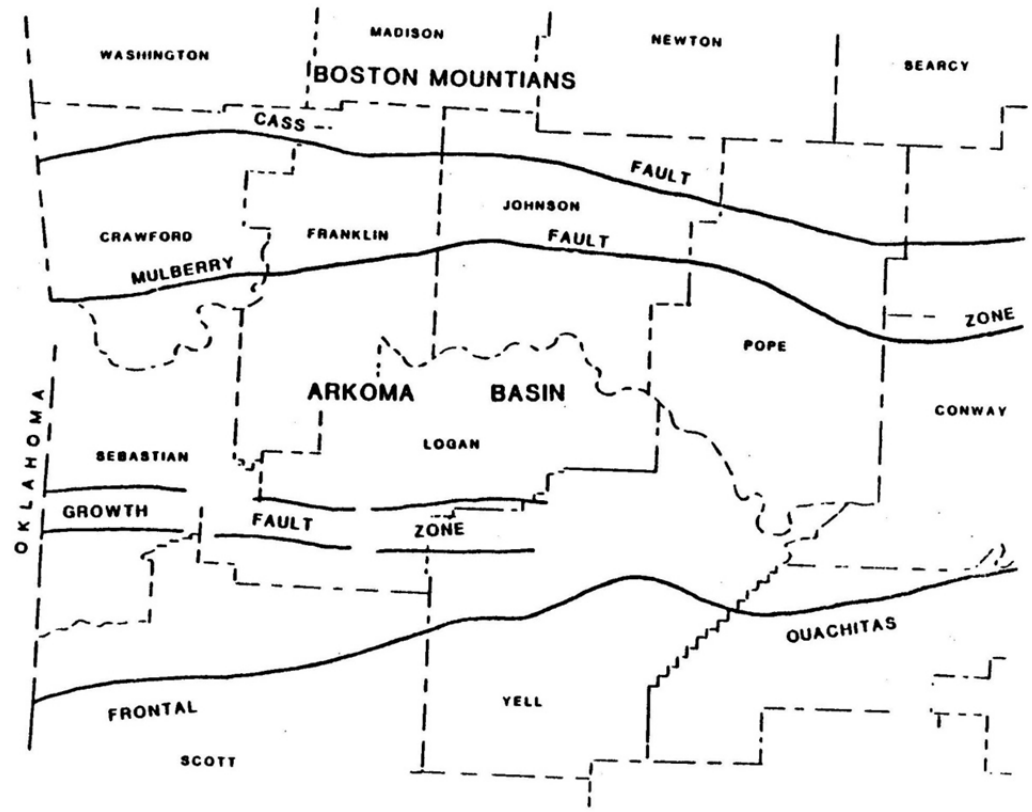


Figure 14. Location map of the growth fault zone that lies south of the study area (from Zachry, 1983).

The Middle Atoka section in the northern portion of the study area consists of several well-defined coarsening-upward sandstone sequences, separated by shales. Sandstone units range in thickness from tens of feet to 200 feet. Shale units between the sandstones are thicker and may be up to 600 feet thick. Positioned in the lower portion of the Middle Atoka succession are two coarsening-upward sandstone sequences that are of interest to this study. Well log correlations suggest that the lower sequence is the informally named Casey member of the Middle Atoka. Located above the Casey sandstone is another sandstone unit that is designated the Freiburg member of the Middle Atoka.

In the southern half of the study area, sandstone units in the upper and middle part of the Middle Atoka succession thin and pinch out farther to the south (Figure 15). The upper and middle parts of the section are largely dominated by thick shale intervals. The most significant sandstone units in this part of the study area are the pair of coarsening-upward sequences present at the lower portion of the Middle Atoka section.

The Casey sandstone (Table 1) ranges in thickness from around 240 feet in the northeast to 100 feet in the southwest, with some gradual thinning to the northwest (Figure 17). It is underlain by a thick shale interval, and overlain by another coarsening-upward sand. The sandstone can further be divided based on the characteristics of the well log signatures. Throughout most of the study area, there are three individual intervals defined by gamma ray curves (Figure 18), with a fourth interval present in some areas (Figure 19).

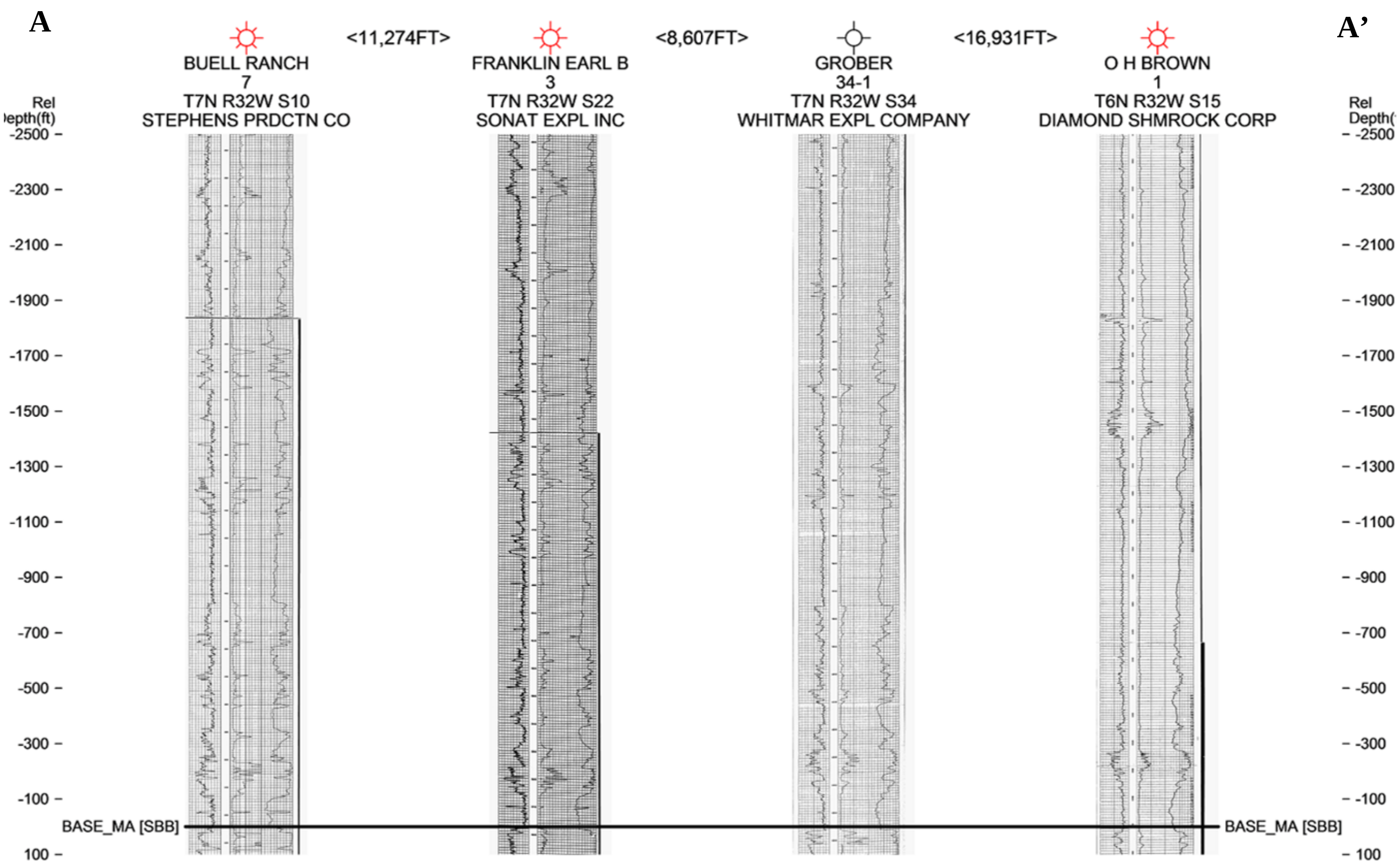


Figure 15. North-south stratigraphic cross section of the Middle Atoka showing sand content diminishing to the south (see Figure 16 for location).

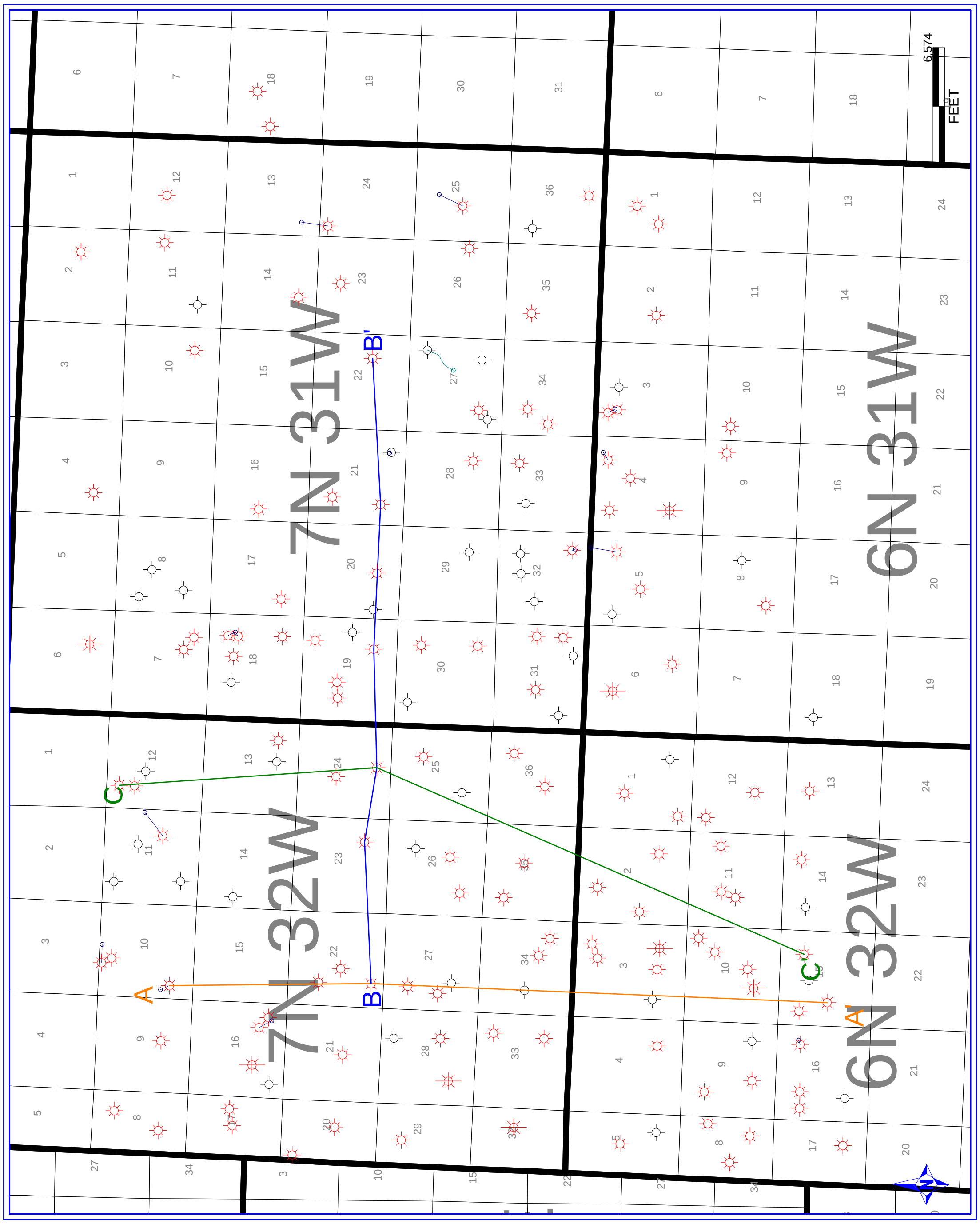


Figure 16. Index map of cross sections.

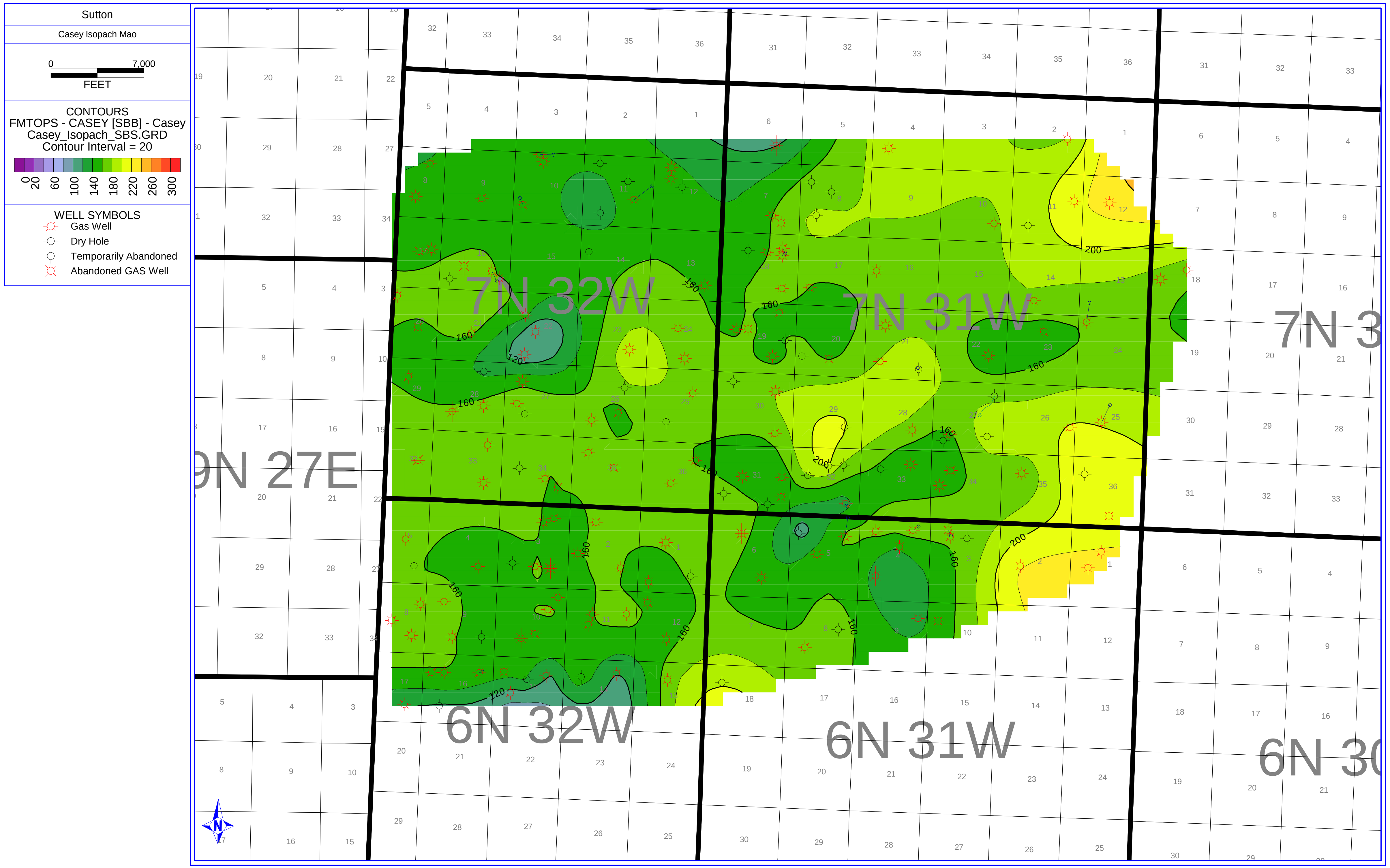


Figure 17. Isopach map of the Casey sandstone unit of the Middle Atoka.

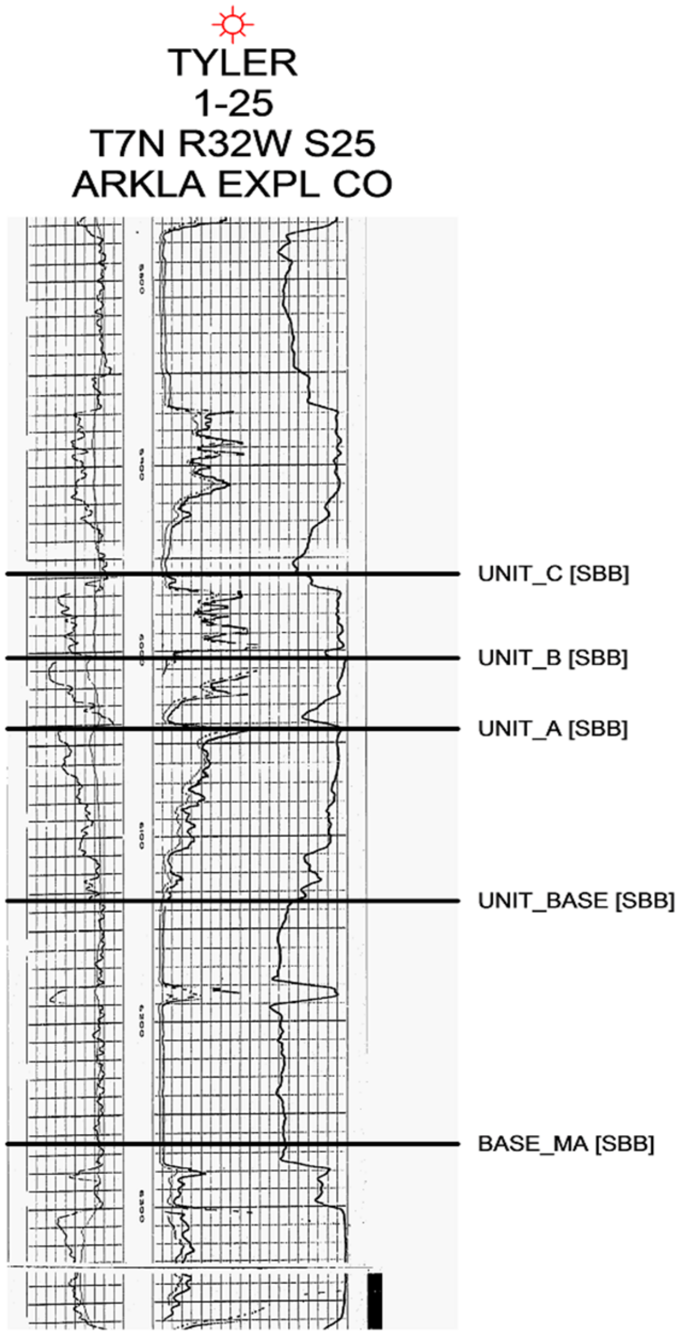


Figure 18. Stratigraphic divisions (Units A, B and C) of the lower Casey sand package in the central portion of the study area.

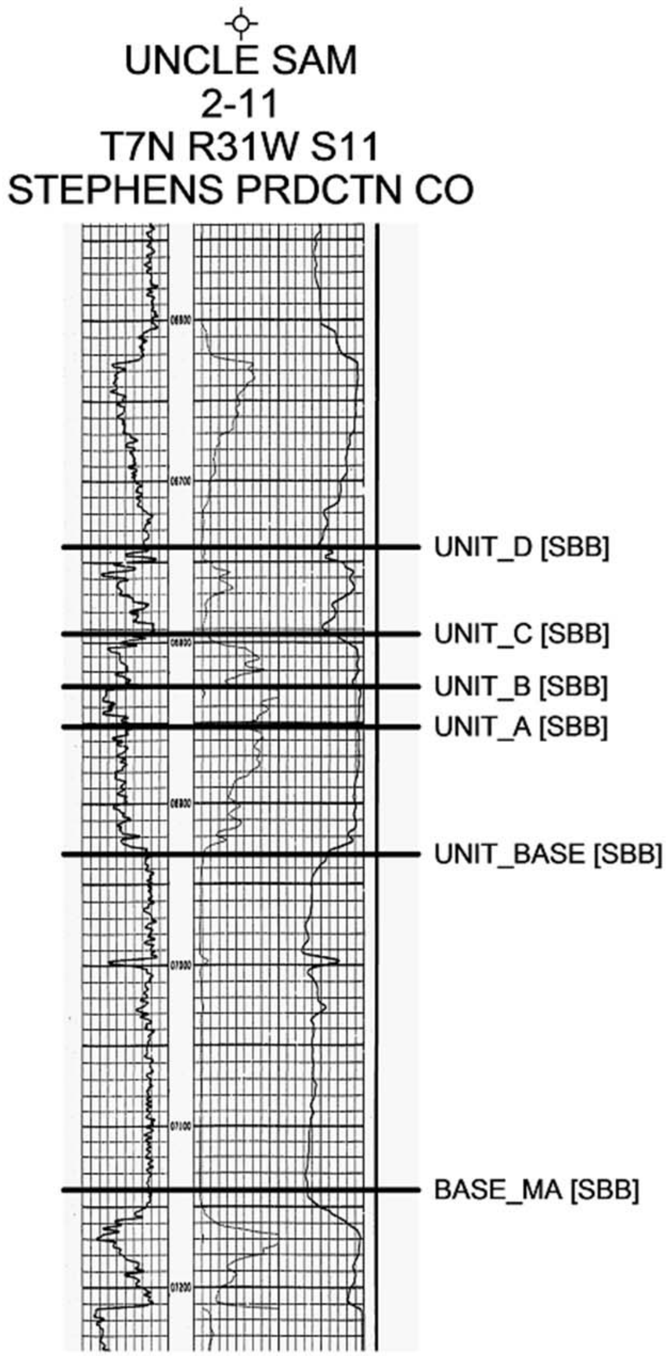


Figure 19. Stratigraphic divisions (Units A, B, C and D) of the Casey sand package in the central portion of the study area.

Unit A, the lower most unit, is a gradually coarsening-upward sandstone that ranges in thickness from around 25 feet to 100 feet and can be identified throughout the study area (Figure 20). The gamma ray curve is very high at the base of this unit, indicating the presence of shale, and decreases up section to its lowest point. This is interpreted as a series of beds that gets progressively thicker and coarser grained up section, with shale at the base. The thickest deposits of this unit are in the southwest and central portion of T. 7 N., R. 31 W., close to the middle of the study area. Gradual thinning to the south and south west is present, with the addition of slight thinning to the north. Above Unit A, is another coarsening-upward sand sequence (Unit B). This unit ranges in thickness from 10 feet to 125 feet (Figure 21). Thinnest deposits are in the north and southwest, with thickest deposits in the southeast. The gamma ray signature for this unit is much like that of Unit A. In some wells, Unit A and Unit B appear as one larger coarsening-upward sequence. Unit C is above Unit B, and has a blocky gamma ray signature. This unit has an abrupt base and top, where the gamma ray value drops, remains steady, and then abruptly rises again moving up section. This unit is found throughout most of the study area. It is thickest in the southwest and northeast, with gradual thinning to the center of the study area in T. 7 N., R. 31 W. Thickness of Unit C ranges from less than 18 feet to 65 feet (Figure 22). In some portions of the study area, another unit (Unit D) exists at the top of this sequence. This unit is not present in every well within the study area. When present, it ranges from a few feet up to 50 feet in thickness. It is thickest in the northeastern portion of the study area, and thins to the south and southwest (Figure 23). It is not present in the west central portion of the study area. The gamma ray curve at the base of this unit is high, indicating a shale unit that varies in thickness from a few feet to 30 feet thick. Moving up section, the gamma curve varies from fining upward to slightly coarsening upward. After this point, the gamma ray begins to become jagged, indicating interbedded sand and shale at the top of the unit (Figure 17).

The Freiburg sandstone (Figure 23), which lies above the Casey, is characterized by a coarsening upward gamma log pattern that is consistent throughout the study area. The coarsening-upward sand is underlain by a shale interval that lies above Unit C (or in some cases, Unit D) of the Casey. This interval ranges in thickness from 50 feet to 140 feet, with thickest sediments in the central portion of 7N-31W (Figure 24). Thinning occurs to the south and southwest. In some portions of the study area, there is also a blocky somewhat serrate pattern that exists at the top of the coarsening upward pattern (Figure 18).

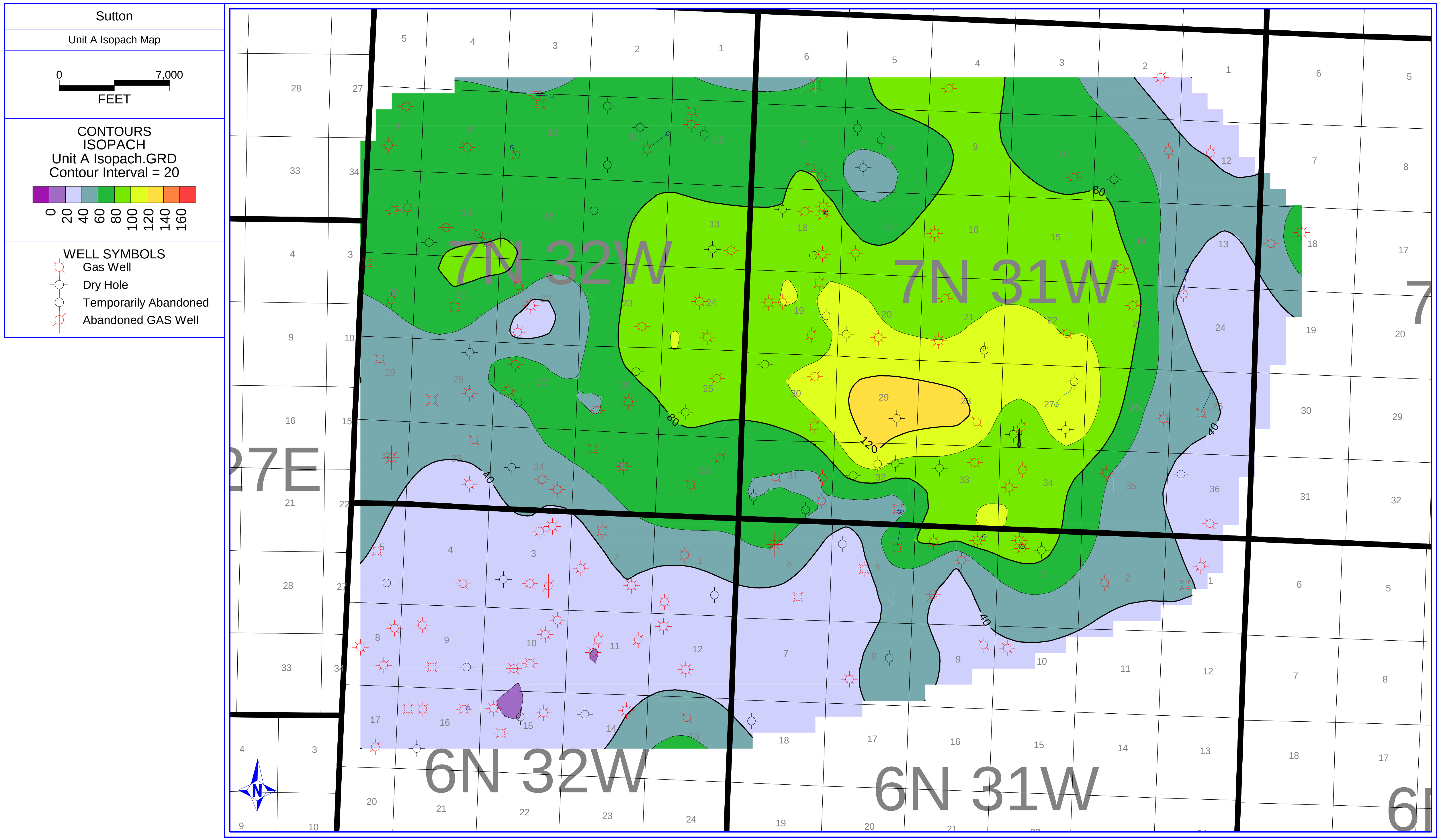


Figure 20. Isopach map of Unit A of the Casey.

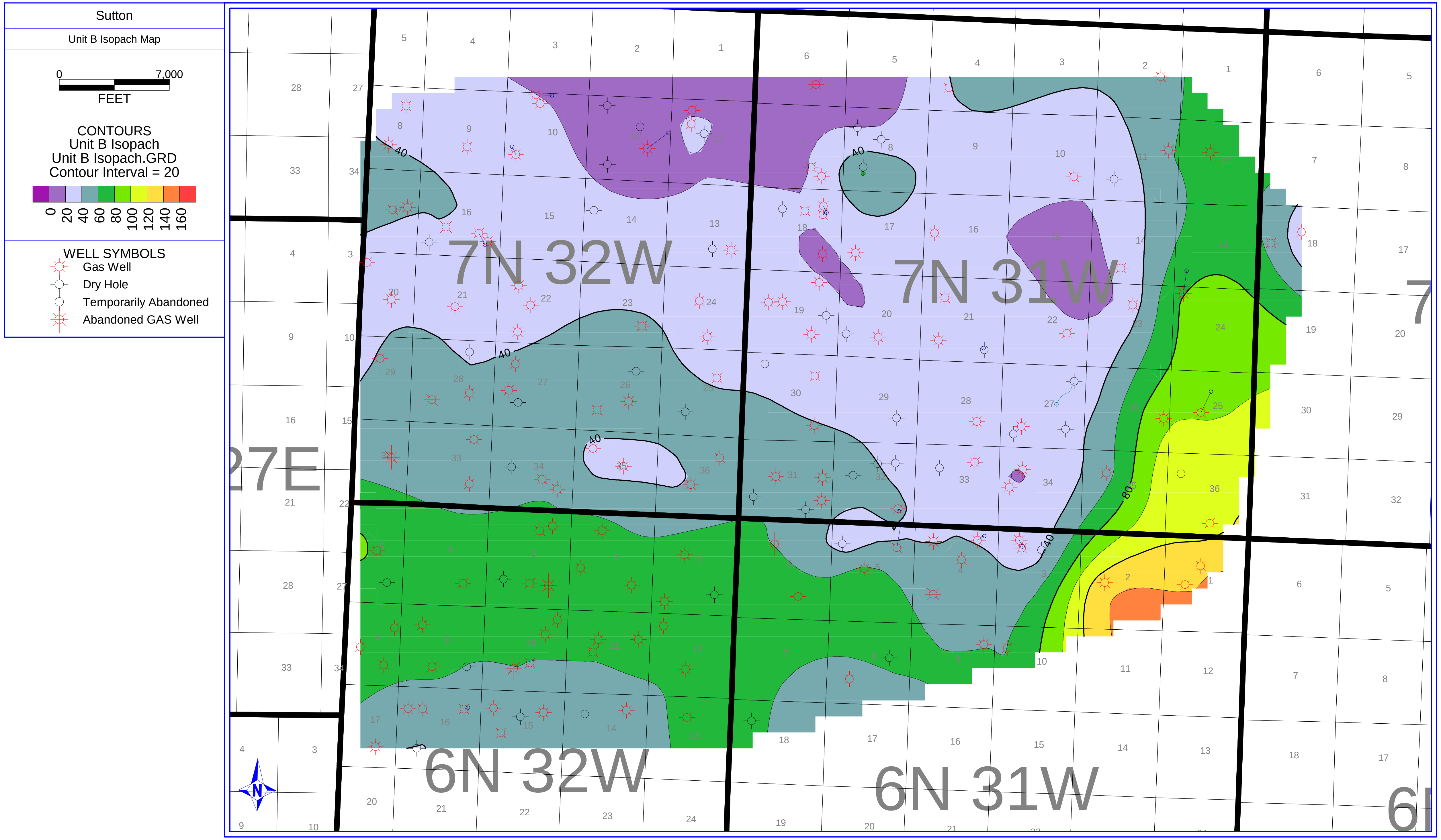


Figure 21. Isopach map of Unit B of the Casey.

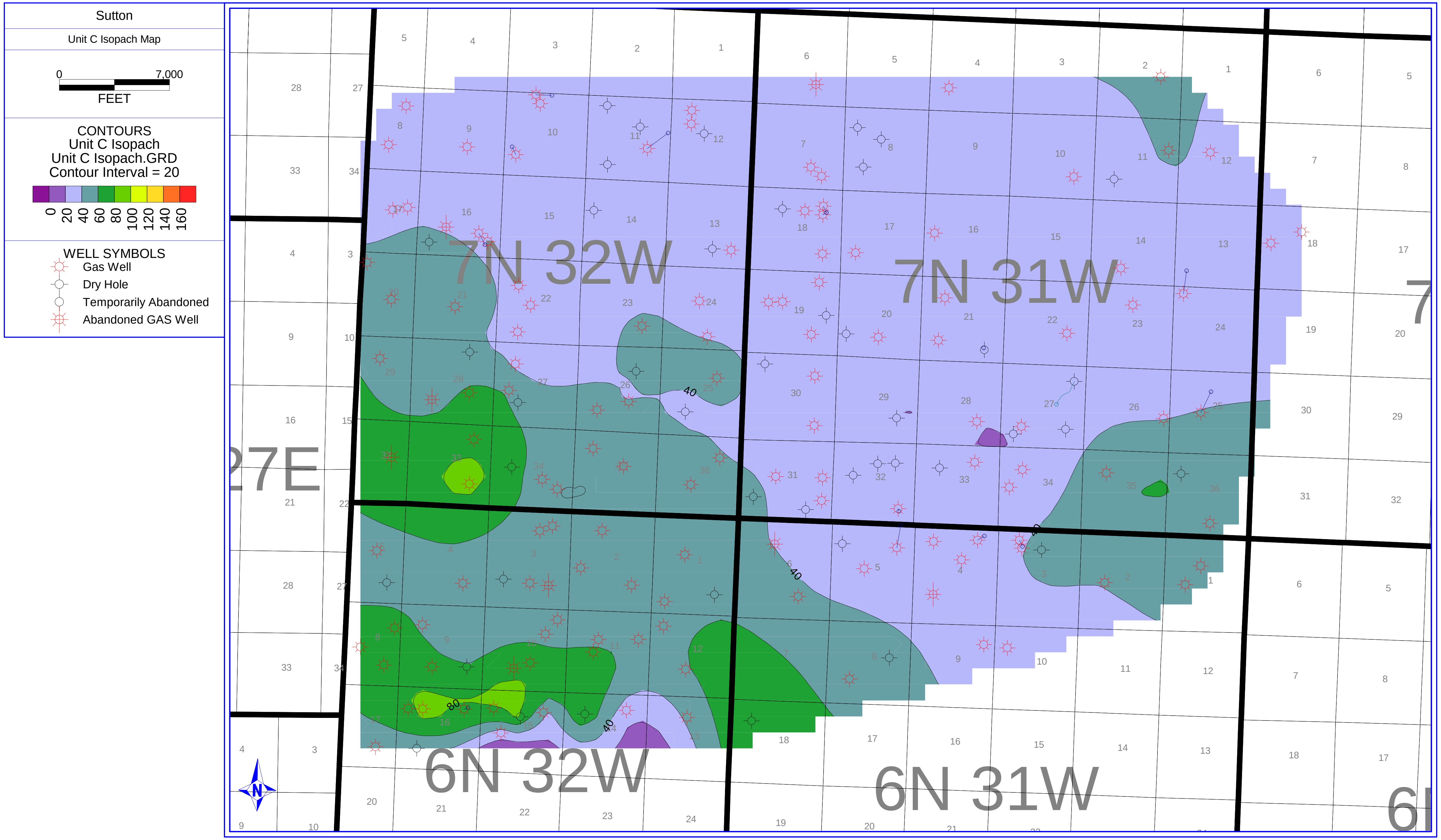


Figure 22. Isopach map of Unit C of the Casey.

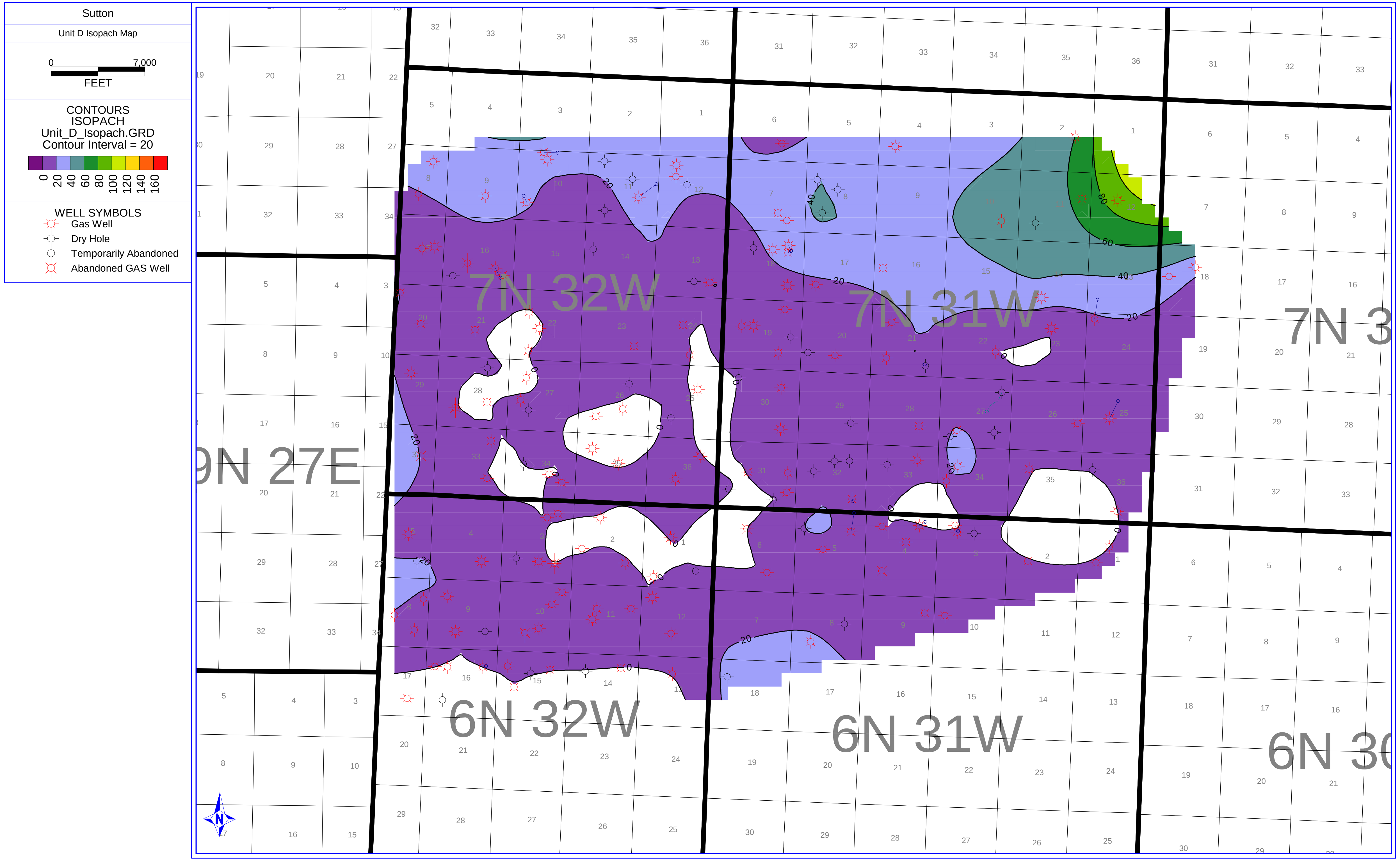


Figure 23. Isopach map of Unit D of the Casey.

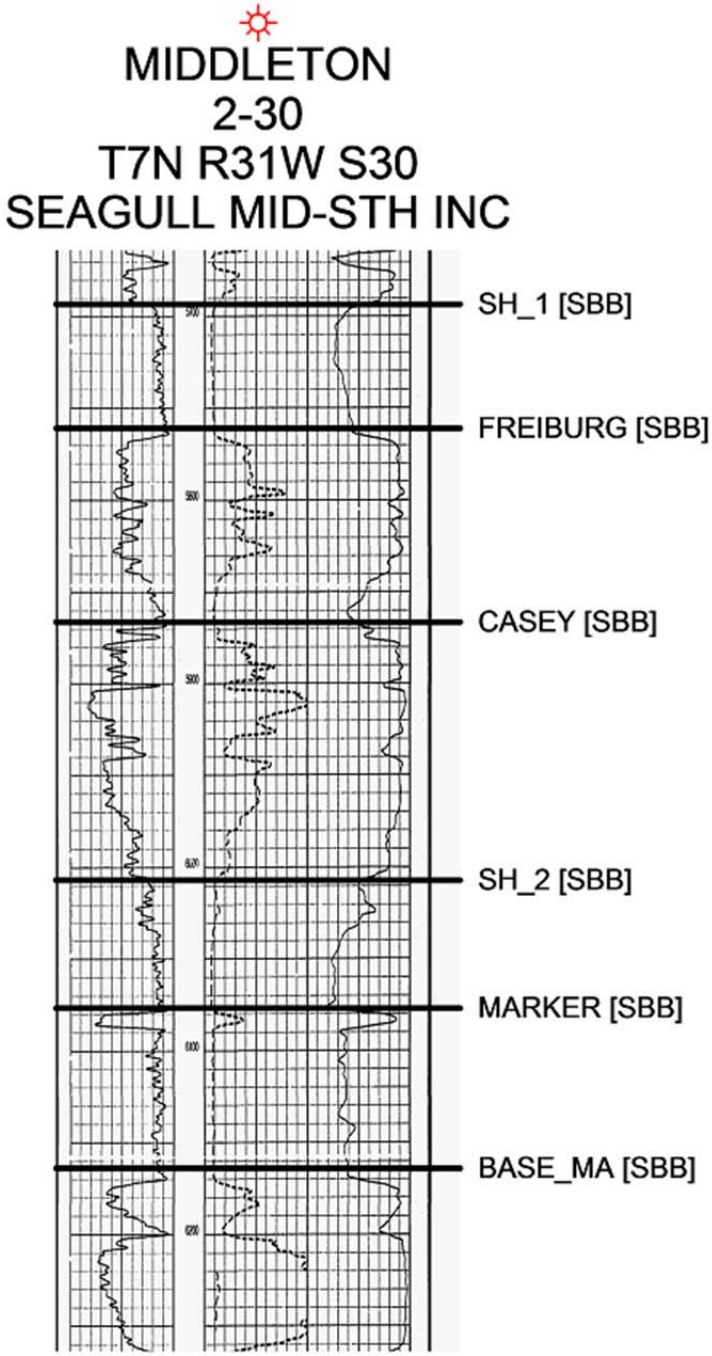


Figure 24. Log showing the stratigraphic divisions of the interval of interest.

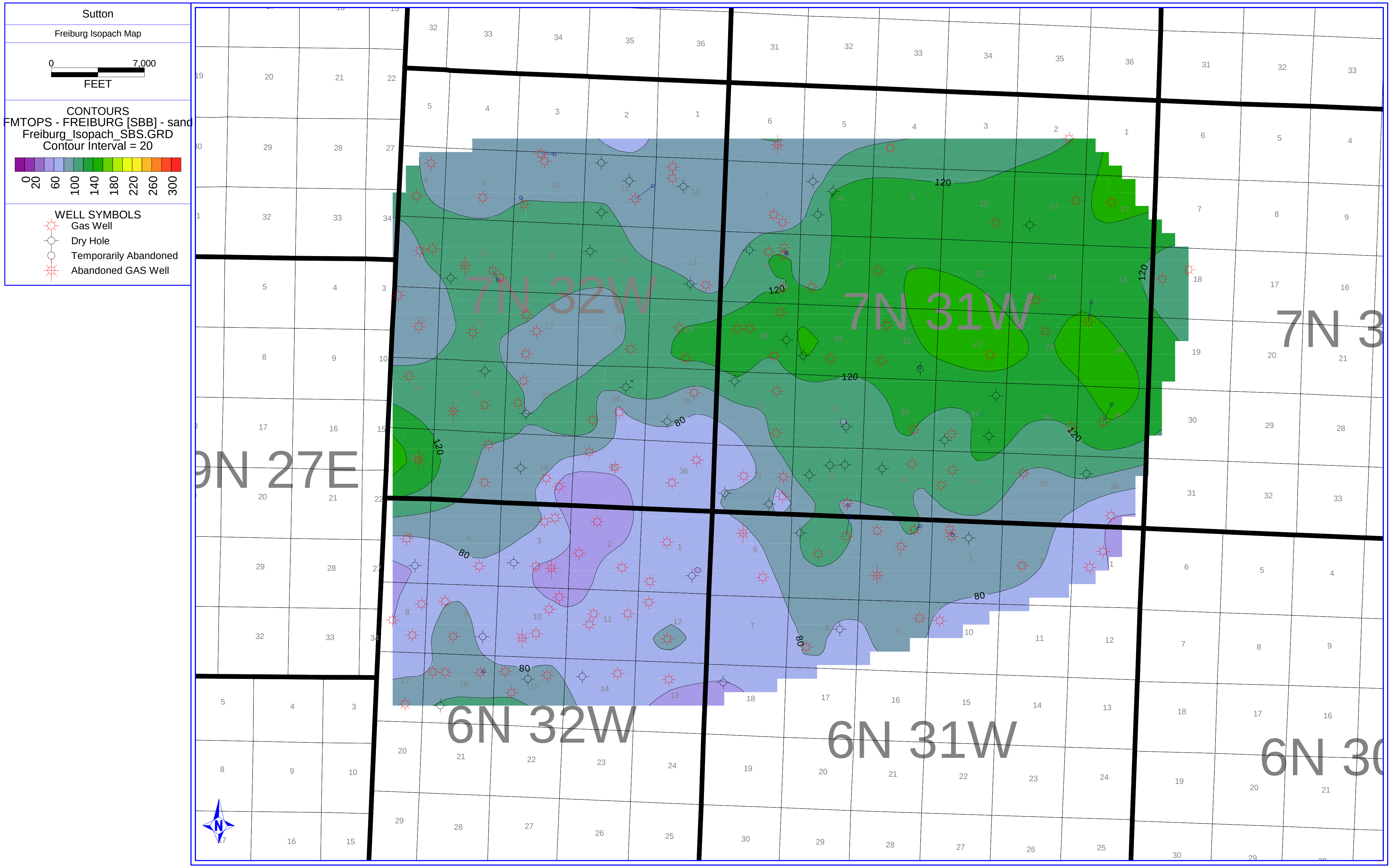


Figure 25. Isopach map of the Freiburg sandstone unit of the Middle Atoka.

4.0 STRATIGRAPHIC ANALYSIS

The lower part of the Middle Atoka succession in west-central Sebastian County directly overlies the Lower Atoka Sells sandstone. The interval contains two sandstone units, the Casey and the Freiburg, that display complex stratigraphic and sedimentological relationships. A thin sandstone bed within the shale interval below the Casey is continuous over most but not all of the study area and is a consistent marker in defining the Casey and Freiburg (Figure 24). The Freiburg sandstone is overlain by a shale interval here designated as Shale 1. Shale 1 has a clearly defined gamma log signature (Figure 24) and serves as the upper boundary of the lower Middle Atoka interval considered in this study. Without core or outcrop data, specific environment of deposition can be difficult to determine, since sedimentary structures are often key indicators. However, certain gamma and resistivity characteristics of well logs, incorporated with stratigraphic maps, can be analyzed to establish a probable environment of deposition.

Figures 24 and 26 show the lower Middle Atokan Freiburg and Casey intervals. These log signatures are very similar to the standard wire-line logs of the Coleman model for deltaic environments (Figure 27). Figure 28 shows an idealized coarsening-upward signature from a deltaic environment. The interpretation of an idealized log signature formed from a deltaic environment can be applied to log signatures seen in this study. The Casey and Freiburg intervals both exhibit a general coarsening-upward log character, with more shaly deposits at the base and increasingly coarser deposits up-section. Overall, both coarsening upward intervals diminish in size and amount of sand in the southern portion of the study area (Figure 30).

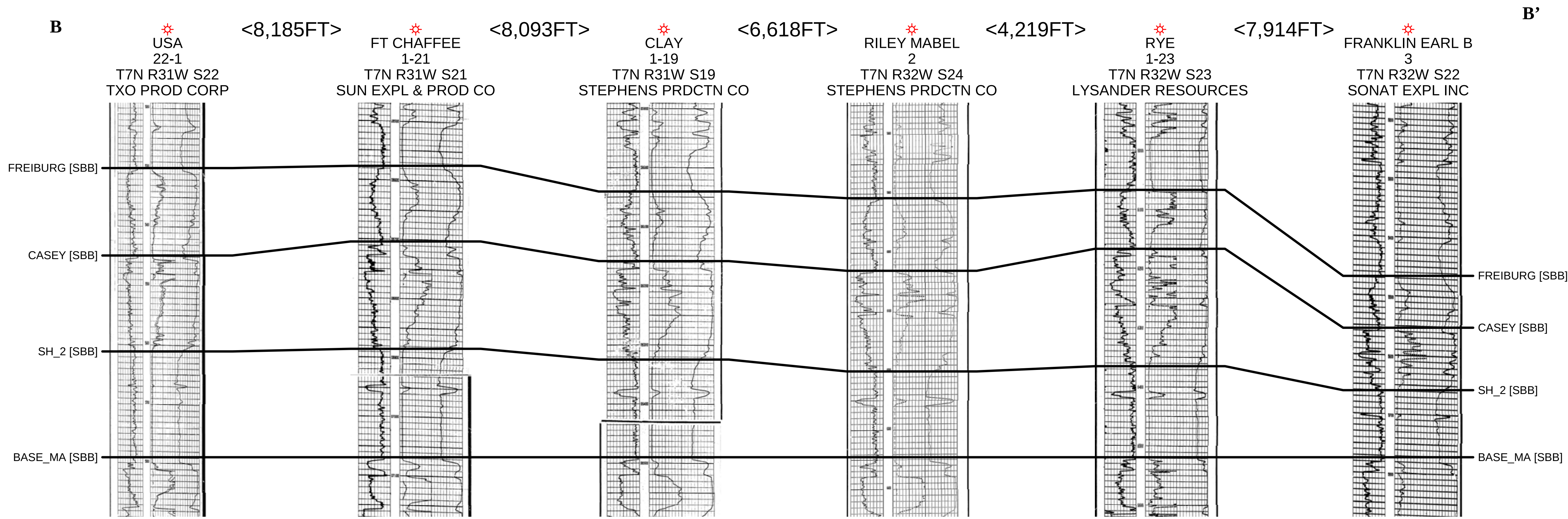


Figure 26. West – East cross section showing intervals of interest and lateral continuity of Shale 2 (see Figure 16 for location of cross section).

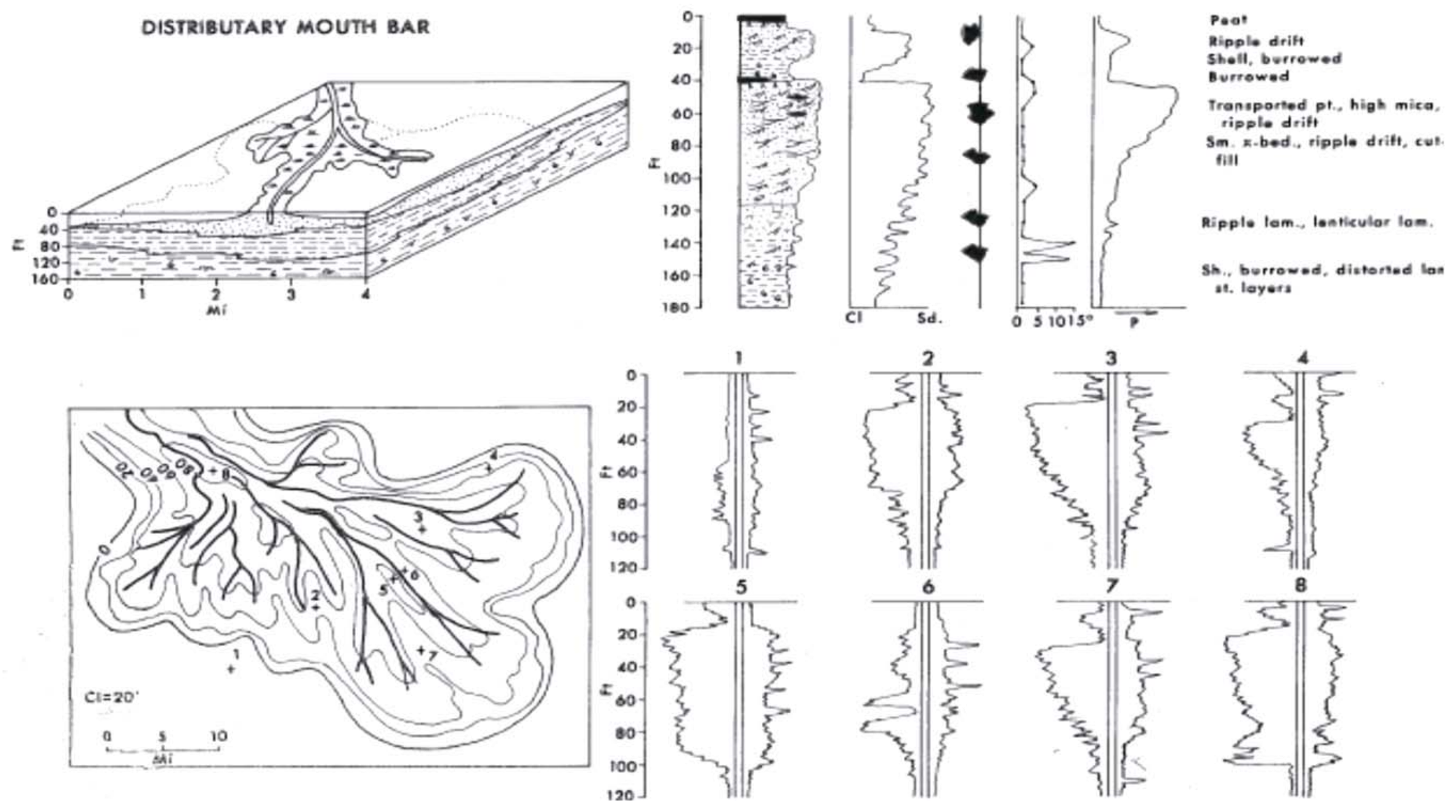


Figure 27. Geometry and log signatures of distributary-mouth bar deposits (Coleman and Prior, 1980).

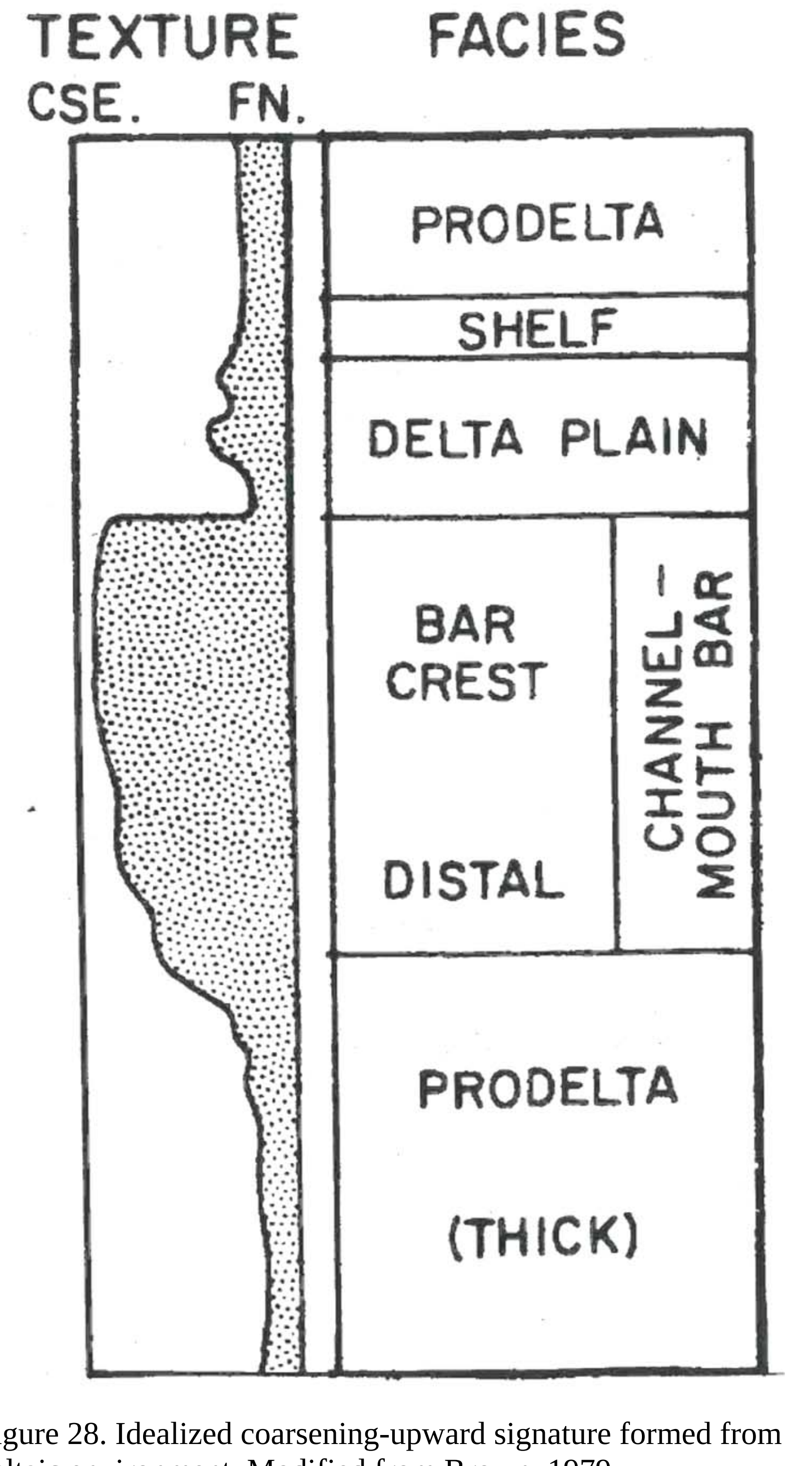


Figure 28. Idealized coarsening-upward signature formed from a deltaic environment. Modified from Brown, 1979.

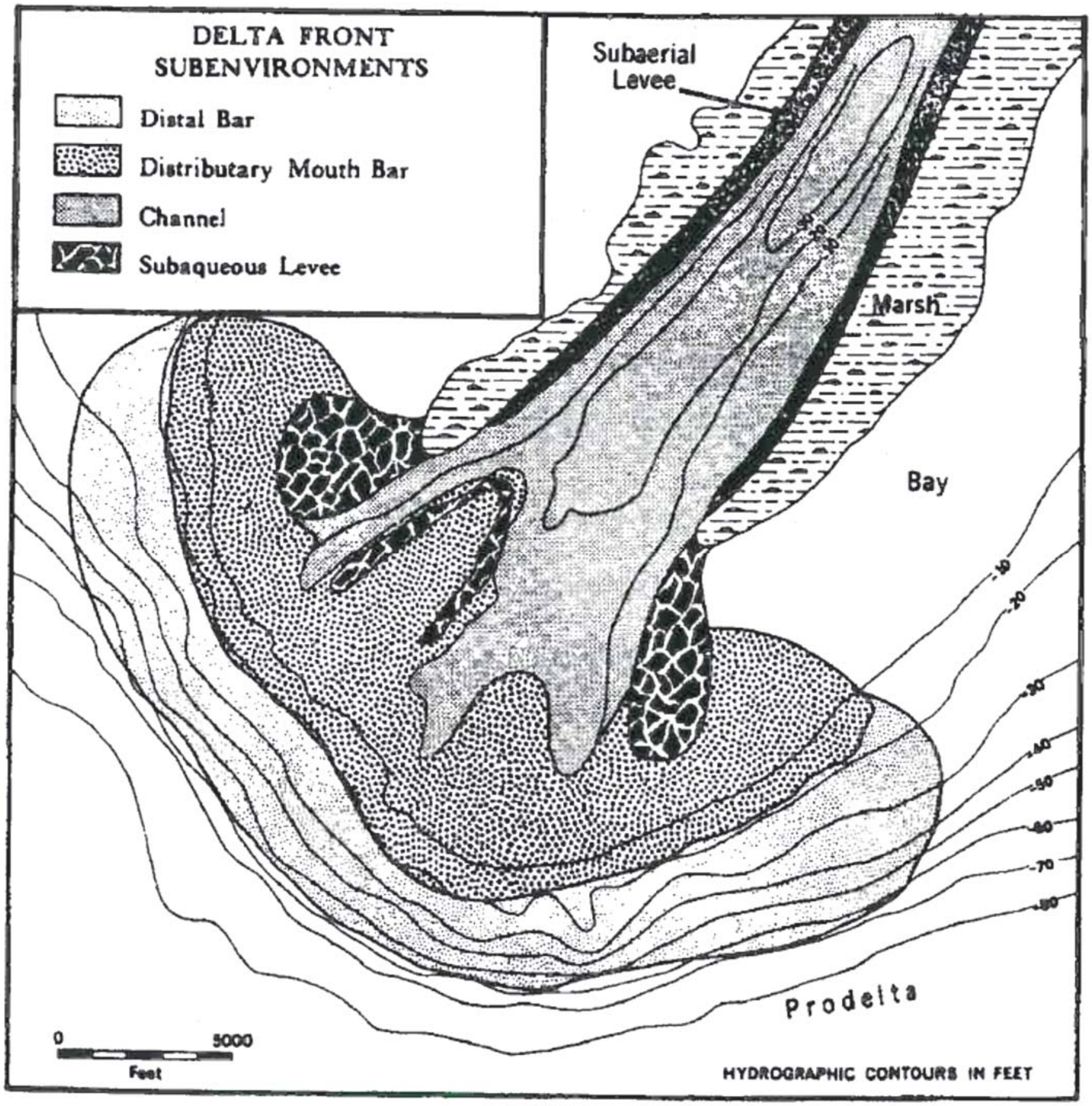
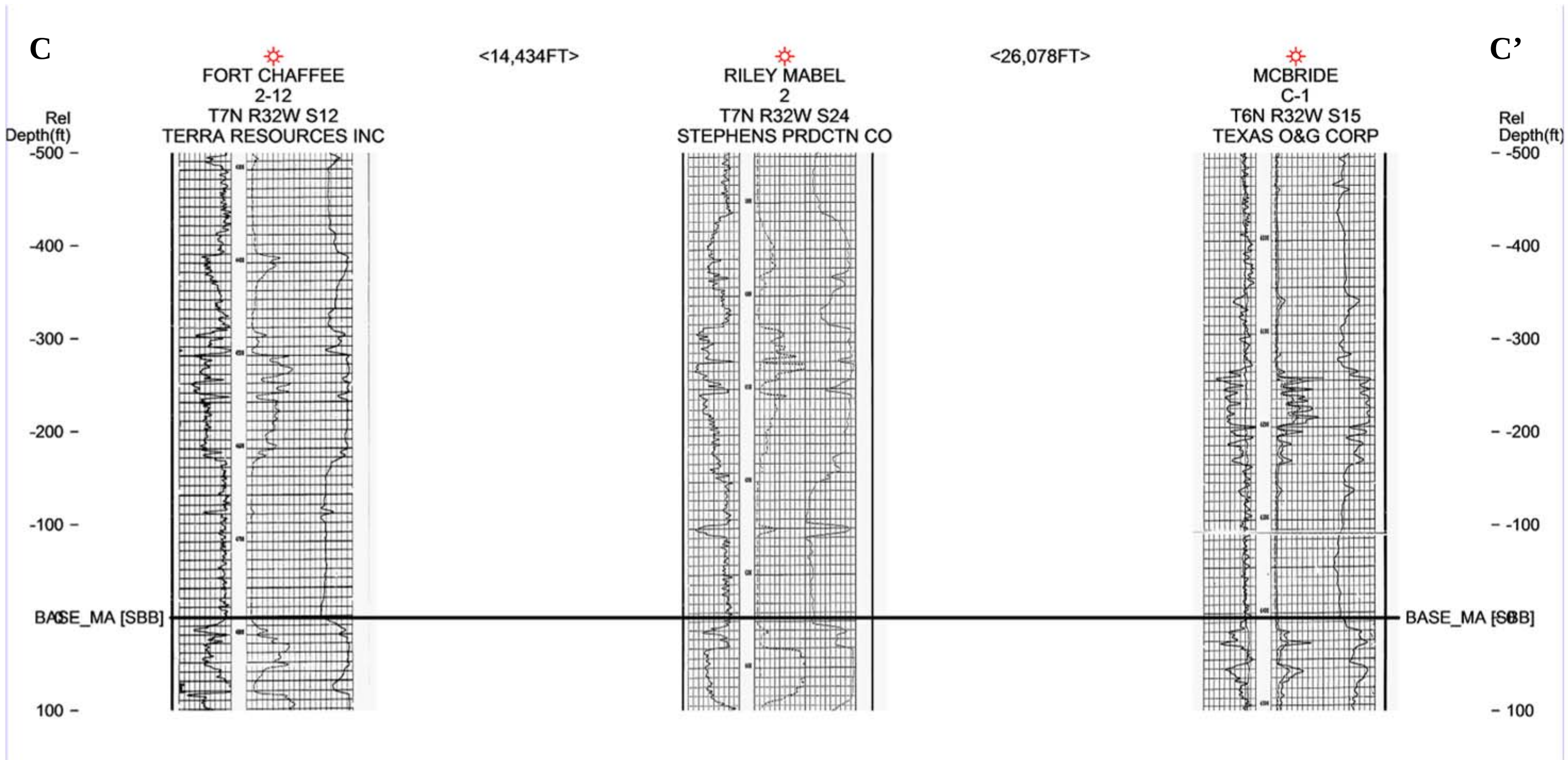


Figure 29. Sedimentation zones in a delta front environment. From Coleman and Prior, 1981.



North-South cross section showing diminishing sand content towards the south (see Figure 16 for cross section location).

Shale 2 at the base of the Casey (Figure 24) formed as prodelta muds that were deposited from suspension below effective wave base. The prodelta directly overlies the sediments of the inner shelf environment, and is the base for most deltaic sequences (Wright, 1979). These suspension deposits are characteristically a blanket of clays having high lateral continuity and low lithologic variation (Figures 30).

As the delta lobe prograded, the shoaling-upward process began, introducing coarser material into the sediment mix. Upward within the vertical sequence, the delta front overlies the prodelta facies (Figures 23 & 24). Unit A (Figures 18 & 19) represents delta front facies. Delta front deposits can consist of distal bar, distributary-mouth bar, tidal ridge, or shoreface deposits (in high wave energy environments) (Wright, 1978). Unit A is interpreted as distal bar deposits.

In this case, distal bar deposits grade upward into distributary-mouth bar sands, which are common to the delta front. These distributary-mouth bar sands are represented by Unit B and the upper portion of Unit A. As the delta continues to prograde seaward, coarser, shallow water material is deposited above the delta front sediments. Typically, these sediments are above wave base. Higher energy from the distributary results in removal or clay and silt.

The coarsening upward sequence then culminates in a somewhat blocky log signature (Unit C) at the top of the Casey throughout most of the study area (Figure 18 & 19). This log signature is blocky to blocky-serrate and is determined to be channel deposit sands.

Unit D lies above Unit C, and is somewhat laterally discontinuous (Figure 23). Above the delta-front channel fill, crevasse splay, and levee deposits can sometimes be present. Lateral continuity of these deposits tends to be low, which would explain why Unit D isn't present or very well developed in parts of the study area. This unit typically exhibits a fining upward or slightly coarsening upward log signature (Figure 19).

The Seagull Mid-South Inc. Middleton 2-30 (Figure 31) shows a typical coarsening-upward sequence that would be formed from a prograding delta. Prodelta clays are located at the base of the interval. Sediments then grade upward through distal bar deposits and distributary-mouth bar deposits as coarser material is added to the sediment mix. This interval then culminates in channel deposits at the top of the sequence.

An abrupt change from sandstone to shale at the top of the Casey, indicates some sort of erosional surface and a change in depositional patterns. It is possible that, as the result of avulsion, the site of active sedimentation accumulation switched to a new lobe. It is interpreted that the second lobe that prograded to form the coarsening upward sequence of the Freiburg was more distant from the depocenter. This is evident as the sediments tend to be overall finer than those of the Casey (Figure 23 and 26). Shale at the base of the Freiburg is recognized as prodelta deposits. As progradation of this delta lobe proceeded, coarser material was added to the mix, resulting in the coarsening-upward log pattern similar to that of the Casey. Up section, sediments above the prodelta clays and silts transitioned to sandy silts of the distal bar deposits. These sediments then grade into distributary mouth bar deposits, much like that of the Casey.

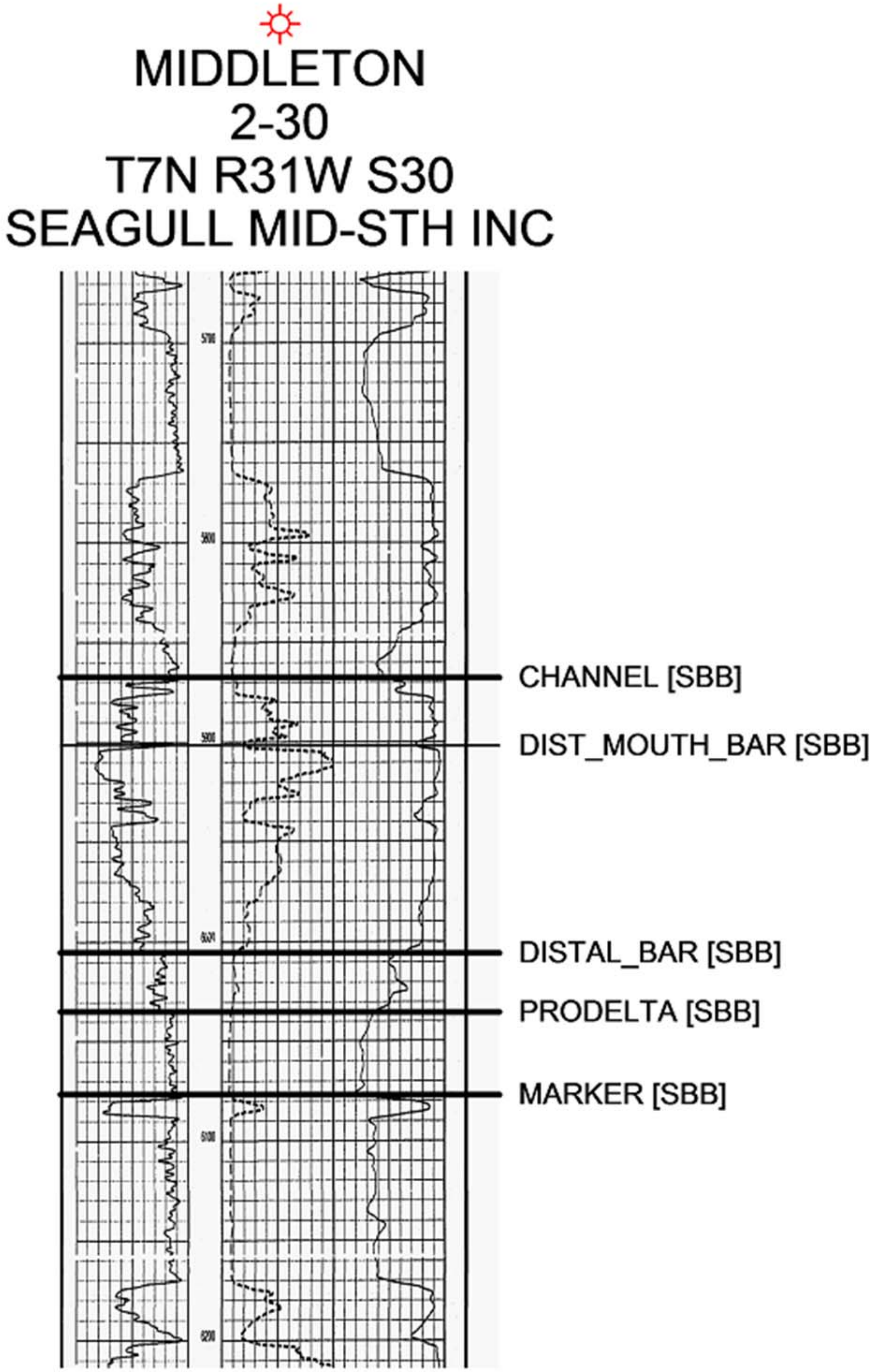


Figure 31. Log showing depositional environments of a prograding delta.

5.0 CONCLUSIONS

The Middle Atoka in the area of study is characterized by several coarsening-upward sandstone sequences that are separated by shale. Sandstone units of the Middle Atoka thin and pinch out to the south. The most significant sandstone units in this area are two generally coarsening-upward sequences that are present in the lower Middle Atoka. These sandstone units were identified using log correlation as the informally named Freiburg and Casey members of the Middle Atoka. The log signatures and geometry of the sand bodies indicate that they were deposited when a delta lobe prograded across this portion of the basin. The Casey sandstone is dominated by distributary-mouth bar deposits, occasionally overlain by localized channel deposits. Following the deposition of the Casey, avulsion of the delta lobe possibly occurred. As this lobe prograded across the area, sediments of the Freiburg were deposited. This unit is dominated by distributary-mouth bar deposits.

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APPENDIX A

Well Information and Major Tops (SSTVD)

API #	Well Name	Well #	Operator	Township	Range	Section	CASEY	FREIBURG	UNIT_A	UNIT_B	UNIT_C	UNIT_D
3131000020000	WESTERN COAL&MINING	2	SHELL OIL CO	7N	32W	35	-5306	-5221	-5403	-5371	-5309	-5309
3131000040000	WESTERN COAL & MNG	3	SHELL OIL CO	7N	31W	31	-5271	-5202	-5366	-5310	-5275	-5275
3131000050000	R A YOUNG	1	SHELL OIL CO	6N	32W	2	-5358	-5307	-5474	-5405	-5358	-5358
3131000060000	ACEE PURE MILK CO	1-3	SHELL OIL CO	6N	32W	3	-5372	-5292	-5498	-5427	-5377	-5377
3131000070000	WESTERN COAL & MNG	1	SHELL OIL CO	7N	32W	36	-5326	-5253	-5423	-5385	-5325	-5325
3131000670000	MISSOURI IMPROVMENT	1	SHELL OIL CO	7N	32W	25	-5379	-5295	-5460	-5415	-5378	-5378
3131000730000	JOHNSON	1-11	SHELL OIL CO	6N	32W	11	-5356	-5285	-5495	-5415	-5367	-5357
3131000740000	JOHNSON	2	SHELL OIL CO	6N	32W	10	-5391	-5321	-5523	-5452	-5400	-5394
3131000760000	CLARKLAND INC	1	ARK LA GAS CO ET AL	6N	32W	5	-6135	-6057	-6268	-6188	-6135	-6120
3131000780000	EDWARDS	1	SHELL OIL CO	6N	31W	6	-5478	-5405	-5582	-5524	-5485	-5484
3131000790000	DOUGLAS	1	SHELL OIL CO	6N	32W	4	-5534	-5455	-5654	-5586	-5533	-5533
3131000800000	GILMORE	1	SHELL OIL CO	6N	32W	1	-5320	-5256	-5438	-5367	-5324	-5324
3131000810000	SKINNER	1	SHELL OIL CO	6N	31W	4	-6809	-6726	-6898	-6850	-6823	-6808
3131000860000	BULL	1	SHELL OIL CO	7N	32W	26	-5424	-5353	-5517	-5466	-5427	-5427
3131000870000	GROEBER	1	SHELL OIL CO	7N	32W	34	-5494	-5413	-5602	-5541	-5497	-5497
3131000880000	E HAMILTON	1	SHELL OIL CO	6N	32W	12	-5460	-5375	-5583	-5521	-5463	-5448
3131000930000	A R CARTER	1	SHELL OIL CO	6N	32W	10	-5581	-5504	-5715	-5655	-5583	-5567
3131100040000	MABEL RILEY	1	STEPHENS PRDCTN CO	7N	32W	24	-5439	-5319	-5512	-5477	-5442	-5442
3131100150000	MISSOURI IMPROVMENT	1	LEBEN DRLG CO INC	7N	31W	32	-6346	-6230	-6442	-6392	-6363	-6345
3131100370000	FT CHAFFEE	3	STEPHENS PRDCTN CO	7N	31W	18	-5152	-5050	-5217	-5194	-5170	-5155
3131100400000	H H LEONARD	1	DIAMOND SHMROCK CORP	7N	31W	19	-5368	-5238	-5433	-5401	-5370	-5362
3131100970000	ACEE PUR MILK	2-3	SHELL OIL CO	6N	32W	3	-5335	-5278	-5471	-5396	-5340	-5340
3131101100000	MISSOURI IMPROVMT	1-28	ARKLA EXPL CO	7N	31W	28	-5725	-5601	-5778	-5756	-5736	-5728
3131101130000	WOODS	1	HANNA OIL & GAS CO	6N	32W	14	-5487	-5414	-5622	-5568	-5490	-5490
3131101210000	WOLFE	1-33	ARKLA EXPL CO	7N	31W	33	-6081	-5965	-6145	-6119	-6094	-6081
3131101230000	TYLER	1-25	ARKLA EXPL CO	7N	32W	25	-5408	-5318	-5491	-5453	-5407	-5407

3131101350000	HOLLEMAN	1	ARKLA EXPL CO	6N	31W	5	-6668	-6563	-6784	-6719	-6685	-6669
3131101360000	NELCH	1	STEPHENS PRDCTN CO	7N	31W	34	-6147	-6024	-6217	-6199	-6179	-6149
3131101380000	MCNABB	1-6	ARKLA EXPL CO	6N	31W	6	-6704	-6630	-6817	-6750	-6708	-6708
3131101410000	SCOTT BALL	1	STEPHENS PRDCTN CO	7N	31W	35	-6610	-6513	-6714	-6662	-6607	-6607
3131101420000	WESTERN	1	SAMSON RESOURCES CO	7N	32W	36	-5441	-5382	-5533	-5483	-5442	-5442
3131101530000	MISSOURI IMPROVEMNT	1	ARKLA EXPL CO	7N	31W	33	-6037	-5936	-6089	-6068	-6046	-6036
3131101540000	KUYKENDALL	1	SAMSON RESOURCES CO	6N	32W	1	-5439	-5380	-5571	-5495	-5438	-5438
3131101560000	RICHARD DAVIS	1-18	STEPHENS PRDCTN CO	6N	31W	18	-7869	-7810	-8032	-7968	-7891	-7868
3131101620000	MIDDLETON	1-30	ARKLA EXPL CO	7N	31W	30	-5591	-5487	-5660	-5631	-5602	-5591
3131101650000	MISSOURI IMPROVEMNT	1-32	ARKLA EXPL CO	7N	31W	32	-6528	-6409	-6616	-6576	-6546	-6529
3131101670000	WOODS	1	STEPHENS PRDCTN CO	6N	32W	13	-6212	-6148	-6328	-6261	-6218	-6218
3131101700000	GROBER	34-1	WHITMAR EXPL COMPANY	7N	32W	34	-5730	-5638	-5843	-5801	-5731	-5731
3131101730000	BASHAM	1-26	HADSON PET USA INC	7N	32W	26	-5656	-5532	-5745	-5699	-5656	-5656
3131101840000	MISSOURI IMPROVEMNT	2-32	ARKLA EXPL CO	7N	31W	32	-6352	-6243	-6432	-6398	-6373	-6354
3131101850000	WOODS	C-1	TEXAS O&G CORP	6N	32W	14	-5481	-5407	-5559	-5512	-5486	-5486
3131101910000	ROBISON	1	TEXAS O&G CORP	7N	32W	13	-5186	-5094	-5254	-5228	-5191	-5191
3131101930000	KERSEY	1	ARKLA EXPL CO	6N	31W	4	-6631	-6536	-6733	-6674	-6646	-6636
3131101940000	MITCHELL	1	REVERE CORP	6N	32W	2	-5348	-5283	-5470	-5403	-5349	-5349
3131101970000	TROTTER	1-9	WHITMAR EXPL COMPANY	6N	32W	9	-5706	-5623	-5846	-5779	-5713	-5713
3131102020000	CLAY	1-19	STEPHENS PRDCTN CO	7N	31W	19	-5598	-5480	-5687	-5644	-5610	-5597
3131102040000	EARL B FRANKLIN	2	DIAMOND SHMROCK CORP	7N	32W	22	-4587	-4479	-4660	-4624	-4589	-4589
3131102060000	TROTTER	1	REVERE CORP	6N	32W	12	-5327	-5262	-5451	-5380	-5327	-5327
3131102070000	MCBRIDE	C-1	TEXAS O&G CORP	6N	32W	15	-5547	-5463	-5628	-5581	-5549	-5549
3131102120000	RUTH WALKER	2	STEPHENS PRDCTN CO	6N	31W	3	-6706	-6613	-6784	-6750	-6712	-6712
3131102190000	F C FEDERAL	1-20	GULF OIL CORP	7N	31W	20	-5857	-5725	-5911	-5889	-5861	-5860
3131102240000	WHITE	1	ARKOMA PROD OF	7N	32W	16	-4942	-4842	-5038	-5011	-4961	-4947

3131102310000	BEULAH JOHNSON	1	REVERE CORP	6N	32W	1	-5335	-5272	-5456	-5392	-5338	-5338
3131102420000	HAZEL	2	ARKOMA PROD OF CA	6N	32W	8	-5793	-5716	-5947	-5882	-5809	-5794
3131102430000	REVERE JOHNSON	1-10	REVERE CORP	6N	32W	10	-5376	-5327	-5502	-5433	-5387	-5379
3131102540000	ACEE MILK	2-3	REVERE CORP	6N	32W	3	-5378	-5304	-5501	-5429	-5380	-5380
3131102640000	USA	22-1	TXO PROD CORP	7N	31W	22	-4996	-4848	-5045	-5023	-4997	-4997
3131102650000	FT CHAFFEE	1-21	SUN EXPL & PROD CO	7N	31W	21	-6201	-6073	-6284	-6250	-6223	-6206
3131102720000	ALVERSON	1	SAMSON RESOURCES CO	7N	31W	27	-5984	-5855	-6062	-6029	-6000	-5988
3131102840000	UDOUJ	1	TXO PROD CORP	7N	32W	16	-4764	-4662	-4842	-4808	-4774	-4765
3131102850000	MARTINDALE	1-28	MUELLER THOMAS C	7N	32W	28	-5648	-5536	-5758	-5717	-5652	-5652
3131102930000	UDOUJ /A/	1	TXO PROD CORP	7N	32W	16	-4604	-4487	-4687	-4648	-4613	-4604
3131103080000	NEWMAN B""	1	TXO PROD CORP	6N	31W	1	-6574	-6504	-6759	-6624	-6578	-6578
3131103170000	DANIELS	1	SAMSON RESOURCES CO	7N	32W	34	-5403	-5361	-5517	-5449	-5406	-5406
3131103280000	QUOSS	1	DIAMOND SHAMROCK EXP	7N	32W	27	-5825	-5727	-5943	-5886	-5835	-5835
3131103410000	DIDIER A""	1	TXO PROD CORP	7N	32W	14	-4308	-4204	-4382	-4358	-4323	-4310
3131103500000	GROBER MOUNTAIN	1	TXO PROD CORP	7N	31W	18	-5364	-5245	-5434	-5413	-5387	-5364
3131103620000	COOPER BILL	1	TXO PROD CORP	7N	31W	31	-5250	-5167	-5355	-5297	-5253	-5253
3131103920000	WALKER	1-28	MUELLER THOMAS C	7N	32W	28	-5237	-5130	-5318	-5281	-5239	-5239
3131104070000	BROWN GEORGE	2	STEPHENS PRDCTN CO	7N	32W	17	-4418	-4319	-4505	-4461	-4433	-4420
3131104080000	OLD GLORY	1	STEPHENS PRDCTN	7N	31W	10	-6012	-5883	-6114	-6091	-6058	-6011
3131104110000	NEUMAN	1-27	LYSANDER RESOURCES	7N	32W	27	-5749	-5645	-5863	-5805	-5745	-5745
3131104170000	RYE	1-23	LYSANDER RESOURCES	7N	32W	23	-5603	-5503	-5699	-5656	-5615	-5602
3131104210000	DANIELS	1-26	LYSANDER RESOURCES	7N	32W	26	-5593	-5485	-5700	-5643	-5596	-5596
3131104400000	UNCLE SAM	2-11	STEPHENS PRDCTN CO	7N	31W	11	-6277	-6140	-6387	-6362	-6329	-6276
3131104600000	MCBRIDE	2-20	MUELLER THOMAS C	7N	32W	20	-4686	-4599	-4788	-4754	-4707	-4687
3131104770000	FARMERS BANK	1	TERRY DEV INC	6N	31W	4	-6619	-6517	-6695	-6658	-6619	-6619
3131104780000	MITCHELL	1-19	MUELLER THOMAS C	7N	31W	19	-5755	-5619	-5807	-5785	-5754	-5754
3131104790000	FORT CHAFFEE	23-1	SOUTHWESTERN ENRG PR	7N	31W	23	-4841	-4704	-4901	-4872	-4850	-4850

3131104820000	KATHY	1	DANIEL-PRICE EXPL CO	6N	32W	16	-5784	-5706	-5919	-5871	-5793	-5793
3131104830000	HODGE RITA	3	ESCO EXPL INC	6N	32W	3	-5326	-5269	-5467	-5388	-5334	-5334
3131104860000	FORT CHAFFEE	14-1	SOUTHWESTERN ENRG PR	7N	31W	14	-5261	-5128	-5352	-5327	-5294	-5261
3131104940000	MCBRIDE C""	2	TXO PROD CORP	6N	32W	15	-5600	-5518	-5723	-5681	-5597	-5597
3131104970000	FRANKLIN EARL B	3	SONAT EXPL INC	7N	32W	22	-4917	-4829	-4990	-4955	-4920	-4920
3131105020000	SKINNER	2	SONAT EXPL INC	6N	31W	9	-6843	-6755	-6939	-6877	-6845	-6845
3131105150000	FORT CHAFFEE	24-1	SOUTHWESTERN ENRG PR	7N	31W	13	-5007	-4864	-5137	-5053	-5025	-5007
3131105170000	FIRST WESTERN PROPE	1	SONAT EXPL INC	6N	31W	10	-6958	-6883	-7068	-7010	-6976	-6960
3131105200000	MCBRIDE	3-39	MUELLER THOMAS C	7N	32W	29	-5600	-5497	-5713	-5673	-5618	-5604
3131105860000	FORT	1-17	STEPHENS PRDCTN CO	7N	31W	17	-5849	-5731	-5921	-5899	-5869	-5851
3131105960000	FT CHAFFEE	2	BARRETT RES CORP	7N	31W	21	-6030	-5894	-6113	-6076	-6048	-6028
3131105970000	HAZEL	3-8	SEAGULL MID-STH INC	6N	32W	8	-5876	-5817	-6026	-5959	-5897	-5878
3131105980000	BELROSE	1	REVERE CORP	6N	32W	10	-5469	-5392	-5600	-5542	-5468	-5455
3131106110000	STEPHENS G""	1	TXO PROD CORP	7N	31W	27	-5895	-5778	-5969	-5934	-5910	-5898
3131106150000	SCHOEN	1	REVERE CORP	6N	32W	3	-5437	-5364	-5566	-5491	-5445	-5440
3131106220000	CLARKLAND	2	HOOVER-WILSON EXP&PR	6N	32W	5	-5778	-5720	-5908	-5843	-5796	-5773
3131106260000	MCBRIDE C""	3	SONAT EXPL INC	6N	32W	15	-5545	-5463	-5670	-5628	-5546	-5546
3131106280000	FORT CHAFFEE	1-25	SOUTHWESTERN ENRG PR	7N	31W	25	-5903	-5764	-6057	-5961	-5920	-5906
3131106370000	LUCILLE	3	UMC PETR CO	6N	32W	16	-5654	-5571	-5788	-5740	-5658	-5658
3131106410000	RILEY MABEL	2	STEPHENS PRDCTN CO	7N	32W	24	-5431	-5308	-5505	-5471	-5431	-5431
3131106450000	TROTTER	2-9	MUELLER THOMAS C	6N	32W	9	-5623	-5545	-5746	-5687	-5627	-5614
3131106500000	GROBER MOUNTAIN	2	SONAT EXPL INC	7N	31W	18	-5542	-5414	-5620	-5597	-5569	-5543
3131106500100	GROBER MOUNTAIN	3	SONAT EXPL INC	7N	31W	18	-5542	-5429	-5621	-5600	-5571	-5545
3131106580000	AYERS	1-1	SOUTHWESTERN ENRG PR	6N	31W	1	-6544	-6483	-6731	-6594	-6547	-6547
3131106710000	BROOKS	1	FREEDOM ENERGY	7N	31W	32	-6548	-6450	-6631	-6588	-6565	-6550
3131106720000	DILLARD B""	1	SONAT EXPL INC	7N	31W	19	-5347	-5221	-5408	-5380	-5345	-5335
3131106760000	MIDDLETON	2-30	SEAGULL MID-STH	7N	31W	30	-5379	-5273	-5454	-5412	-5389	-5381

			INC									
3131106780000	NICHOLS	2-29	SEAGULL MID-STH INC	7N	31W	29	-6364	-6267	-6438	-6407	-6388	-6372
3131106820000	MIDDLETON	3	HOOVER-WILSON EXP&PR	7N	31W	30	-5524	-5405	-5599	-5563	-5527	-5527
3131106830000	FT CHAFFEE	3	BARRETT RES CORP	7N	31W	21	-6118	-5983	-6196	-6166	-6137	-6120
3131106850000	FORT CHAFFEE	1-26	SOUTHWESTERN ENRG PR	7N	31W	26	-5836	-5716	-5992	-5895	-5856	-5839
3131106900000	LIND JENNY	1	FREEDOM ENERGY	7N	31W	32	-6669	-6567	-6754	-6712	-6685	-6670
3131106950000	PRAIRIE CREEK	2	HANNA OIL & GAS CO	7N	31W	31	-5659	-5574	-5744	-5700	-5672	-5660
3131107000000	PRAIRIE CREEK	3	HANNA OIL & GAS CO	7N	31W	31	-5536	-5435	-5631	-5573	-5539	-5538
3131107010000	FORT CHAFFEE	4-7	STEPHENS PRDCTN CO	7N	31W	7	-5347	-5238	-5433	-5411	-5383	-5351
3131107030000	DILLARD	2	SAGELY FLOYD O&G CO	7N	31W	20	-5877	-5736	-5936	-5913	-5880	-5865
3131107050000	STEPHENS G""	2	PROVIDENCE E&P INC	7N	31W	27	-5887	-5788	-5964	-5938	-5920	-5888
3131107120000	FARMERS BANK	2	SONAT EXPL INC	6N	31W	4	-6591	-6496	-6671	-6635	-6598	-6598
3131107240000	FORT CHAFFEE FEDERA	2	SONAT EXPL INC	7N	31W	19	-5486	-5345	-5540	-5519	-5486	-5472
3131107270000	RESERVE	1-36	STEPHENS PRDCTN CO	7N	31W	36	-6334	-6273	-6501	-6389	-6339	-6339
3131107380000	CHAFFEE	1-27	GRUBBS ENERGY CORP	7N	31W	27	-5657	-5541	-5720	-5699	-5671	-5660
3131107440000	RYE HILL	1	OXLEY PETROLEUM CO	7N	32W	13	-5117	-5015	-5192	-5168	-5133	-5118
3131107470000	NELCH	2	STEPHENS PRDCTN CO	7N	31W	34	-6359	-6256	-6419	-6396	-6363	-6363
3131107840000	WALKER RUTH	4	STEPHENS PRDCTN CO	6N	31W	3	-6773	-6676	-6848	-6818	-6774	-6773
3131108470000	RESERVE	2-36	STEPHENS PRDCTN CO	7N	31W	36	-6331	-6226	-6512	-6391	-6332	-6332
3131108480000	FORT	1-16	STEPHENS PRDCTN CO	7N	31W	16	-5443	-5307	-5517	-5496	-5471	-5443
3131108880000	WESTERN COAL & MINI	3	UNIT PETROLEUM CO	7N	32W	35	-5391	-5309	-5488	-5454	-5395	-5395
3131109140000	PRAIRIE CREEK	4	HANNA OIL & GAS CO	7N	31W	31	-5651	-5600	-5747	-5694	-5652	-5652
3131109330000	LIND JENNY	2	HANNA OIL & GAS CO	6N	31W	5	-6655	-6553	-6735	-6710	-6681	-6659
3131109380000	JOHNSON H L	4	STEPHENS PRDCTN CO	6N	31W	8	-6631	-6553	-6752	-6688	-6642	-6632
3131109990000	MARTINDALE	1-33	XTO ENERGY INC	7N	32W	33	-5955	-5857	-6075	-6033	-5960	-5960

3131110060000	WALKER RUTH	6	OXLEY PETROLEUM CO	6N	31W	3	-6724	-6631	-6796	-6764	-6725	-6726
3131110620000	GROBER MOUNTAIN	4-18	XTO ENERGY INC	7N	31W	18	-5574	-5458	-5647	-5629	-5599	-5584
3131300040000	REO FULPHAM	1	TRAHAN J C	7N	32W	28	-5786	-5684	-5900	-5839	-5788	-5788
3131300080000	T J MCBRIDE UNIT	1	TENNECO OIL CO	7N	32W	20	-4992	-4897	-5085	-5048	-5001	-4991
3131300110000	T H GILCHRIST	1	ARKLA EXPL CO	7N	32W	33	-5985	-5889	-6128	-6076	-5990	-5990
3131300120000	SIDNEY O TERRY ETAL	1	SHAMROCK O&G CORP	7N	32W	21	-4983	-4882	-5074	-5038	-4986	-4986
3131300170000	TROTTER	1	MONSANTO CO ETAL	6N	32W	9	-5683	-5602	-5832	-5758	-5701	-5683
3131300180000	EARL B FRANKLIN	1	SHAMROCK O&G CORP	7N	32W	22	-4713	-4627	-4781	-4749	-4714	-4714
3131300190000	BEN R DOLAN	1	SHAMROCK O&G CORP	7N	32W	27	-5242	-5144	-5327	-5282	-5245	-5245
3131300220000	HAZEL	1	MONSANTO CO ETAL	6N	32W	8	-5805	-5730	-5957	-5895	-5823	-5805
3131300230000	GEORGE BROWN	1	STEPHENS PRDCTN CO	7N	32W	17	-4412	-4306	-4495	-4452	-4422	-4409
3131300240000	LUCILLE	1	MONSANTO CO ETAL	6N	32W	16	-5760	-5672	-5890	-5846	-5758	-5758
3131300310000	J A YATES	B-1	DIAMOND SHMROCK CORP	7N	32W	32	-6194	-6058	-6317	-6266	-6196	-6176
3131300320000	JAMES WESLEY KELLEY	1	DIAMOND SHMROCK CORP	7N	32W	16	-4791	-4678	-4883	-4842	-4807	-4793
3131300330000	LENNIER	1	AMAX PETROLEUM CORP`	6N	32W	17	-5853	-5758	-5938	-5892	-5849	-5864
3131300370000	LUCILLE	2	MONSANTO CO ETAL	6N	32W	16	-5802	-5699	-5885	-5845	-5804	-5817
3131300380000	O H BROWN	1	DIAMOND SHMROCK CORP	6N	32W	15	-5869	-5772	-5955	-5903	-5873	-5873
3131300410000	HOWARD HAMILTON	1	STEPHENS PRDCTN CO	6N	31W	2	-6661	-6577	-6838	-6701	-6661	-6661
3131100120000	W W AYERS	1	STEPHENS PRDCTN CO	7N	32W	11	-4064	-3979	-4140	-4126	-4089	-4065
3131100430000	CHAFFEE	1	MONSANTO CO ETAL	7N	32W	12	-4169	-4080	-4244	-4224	-4193	-4172
3131100460000	ARK WSTRN CHAFFEEL	1	ARKANSAS WESTERN GAS	7N	31W	8	-5768	-5644	-5871	-5845	-5810	-5773
3131101020000	FT CHAFFEE GOVT	2-1	WOODS PETROLEUM CORP	7N	31W	2	-5885	-5766	-6036	-5986	-5945	-5884
3131101080000	SPIRIT OF 76 UNIT	1	HANNA OIL & GAS CO	7N	32W	8	-4480	-4385	-4559	-4524	-4503	-4474
3131102370000	U S A	1-8	OLD DOMINION OIL	7N	31W	8	-5762	-5654	-5904	-5841	-5811	-5769
3131102390000	FORT CHAFFEE	12-1	TOWNER PETROLEUM CO	7N	32W	12	-4109	-4026	-4188	-4166	-4136	-4111
3131102580000	U S A	2-18	SANTA FE ENERGY	7N	30W	18	-4497	-4387	-4592	-4567	-4527	-4499

3131102710000	SEBASTIAN COUNTY	2-6	STEPHENS PRDCTN CO	7N	31W	6	-4626	-4526	-4683	-4669	-4639	-4625
3131102950000	QUANEX	1	TXO PROD CORP	7N	32W	11	-4280	-4190	-4363	-4347	-4309	-4283
3131103800000	FORT CHAFFEE	3-7	STEPHENS PRDCTN CO	7N	31W	7	-5139	-5071	-5222	-5201	-5172	-5139
3131103830000	FEDERAL	1-4	STEPHENS PRDCTN CO	7N	31W	4	-5983	-5880	-6085	-6045	-6008	-5984
3131104360000	FORT CHAFFEE	2-12	TERRA RESOURCES INC	7N	32W	12	-4007	-3922	-4083	-4064	-4035	-4006
3131105100000	USA	12-2	REVERE CORP	7N	31W	12	-6814	-6669	-7002	-6936	-6899	-6810
3131105420000	STEPHENS UNIT	1-11	WHEELER ENERGY CO	7N	32W	11	-4111	-4007	-4164	-4147	-4113	-4097
3131105490000	USA 18""	3	BROWN TOM INC	7N	30W	18	-4497	-4386	-4619	-4563	-4531	-4500
3131106070000	UNCLE SAM	3-11	STEPHENS PRDCTN CO	7N	31W	11	-6566	-6430	-6736	-6676	-6634	-6567
3131106540000	BUELL RANCH	4	STEPHENS PRDCTN CO	7N	32W	9	-4406	-4319	-4489	-4458	-4430	-4403
3131107420000	CONTROL TOWER	1-8	STEPHENS PRDCTN CO	7N	31W	8	-5513	-5427	-5609	-5589	-5556	-5516
3131107650000	BUELL RANCH	6	STEPHENS PRDCTN CO	7N	32W	10	-4504	-4414	-4595	-4575	-4539	-4507
3131107690000	BUELL RANCH	7	STEPHENS PRDCTN CO	7N	32W	10	-4475	-4372	-4557	-4529	-4494	-4473
3131112800000	MITCHELL	2-2	XTO ENERGY INC	6N	32W	2	-5378	-5320	-5510	-5433	-5379	-5379
3131106560000	BROWN	3	FREEDOM ENERGY	7N	32W	8	-4520	-4418	-4598	-4559	-4534	-4515
3131056570000	WALTER AYERS	1	ARKANSAS OKLA EXP CO	7N	32W	11	-4064	-3980	-4137	-4123	-4090	-4067
3131086490000	BUELL RANCH	1	ARK-OKLA GAS	7N	32W	10	-4321	-4240	-4398	-4376	-4344	-4320
3131113250000	JOHNSON H L	5	STEPHENS PRDCTN CO	6N	31W	8	-7174	-7092	-7296	-7245	-7197	-7173
3131114060000	JOHNSON	4-11	HIGHLAND OIL&GAS LLC	6N	32W	11	-5370	-5301	-5509	-5432	-5379	-5371
3131114350000	JOHNSON	6-11	HIGHLAND OIL&GAS LLC	6N	32W	11	-5385	-5316	-5525	-5462	-5395	-5385