TECHNIQUES FOR MAPPING PETROLEUM RESERVOIRS IN THE HUNTON GROUP AND THE "SECOND WILCOX SAND", IN PARTS OF LINCOLN, LOGAN, AND PAYNE COUNTIES, OKLAHOMA

By

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Bachelor of Science

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1972

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the degree of
MASTER OF SCIENCE
May, 1987

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PREFACE

A technique was developed to map the subsurface position of the upper surface of the porous, dolomitic part of the Hunton Group within T. 17 and 18 N., R. 1 and 2 E. Comparisons between the map and production of oil and gas from the dolomitic part of the Hunton demonstrated that three types of traps of oil and gas occur in the Hunton. Most oil and gas production from the Hunton in the area is related to traps caused primarily by faulting. Anticlinal traps and combination structural and stratigraphic traps occur also.

In addition, a method by which the top of the Second Wilcox Sand could be mapped structurally was developed. Production of oil and gas from the Second Wilcox was shown to be associated with three types of traps: those related to faulting, anticlinal traps of undetermined origin, and traps that are related to thinning of the Marshall Zone.

I wish to express my sincere appreciation to the many people who were of valuable assistance in this work and during my stay at Oklahoma State University. In particular, I am especially grateful for the financial support, assistance, and many constructive suggestions provided by my father Daniel H. Swartz, Sr., who also suggested the problem. This study could not have been done without him.

My deepest gratitude is also due to Dr. Gary Stewart, my major adviser, to whom I am indebted not only for his greatly valued assistance, care, and advisement on this study, but also for his help and guidance throughout much of my educational career at Oklahoma State University, and for generously sharing his insight and ideas.

I am also thankful to the other committee members, Dr. Zuhair Al-Shaieb and Dr. Arthur Cleaves, for their advisement and for giving their time during the course of this study.

Special thanks are also due to Bill Ermey for freely giving his time and assistance on electric-log analyses, which were a vital part of this study.

I would also like to express my sincerest appreciation to my family and friends for giving support and encouragement throughout the time it took to complete this study.

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CHAPTER I

INTRODUCTION

Location of the Study Area

The area of investigation includes T. 17 and 18 N., R. 1 and 2 E. It is located in north central Oklahoma near the juncture of Payne, Lincoln, and Logan Counties (Figure 1). Geologically, the area is located on the Northeast Oklahoma Platform, approximately thirty miles east of the Nemaha Ridge (Figure 2).

Statement of the Problem

The investigation encompassed several objectives. These objectives were to:

1. Develop a technique to map the subsurface position of the top of the porous, dolomitic portion of the Chimneyhill Subgroup of the Hunton Group (Figures 3 and 4).
2. Determine the extent of the porous, dolomitic part of the Chimneyhill Subgroup within the area.
3. Develop a technique to map structurally the top of the "Second Wilcox" sandstone (Figure 4).
4. Establish the relationship, if any, between production from the Hunton Group and the position of the top of the porous, dolomitic zone (Figure 3), in order to enhance

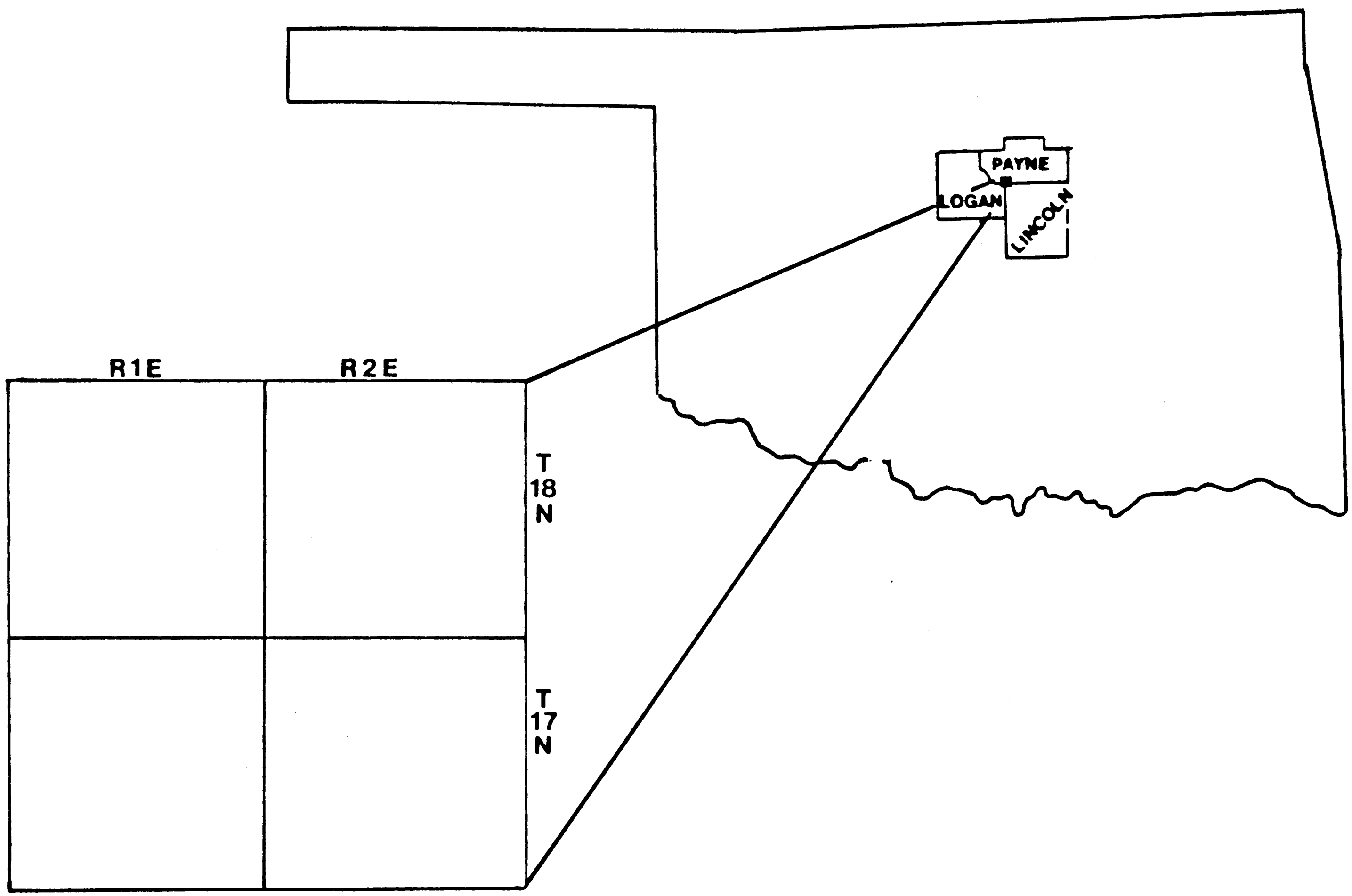


Figure 1. Location of the study area.

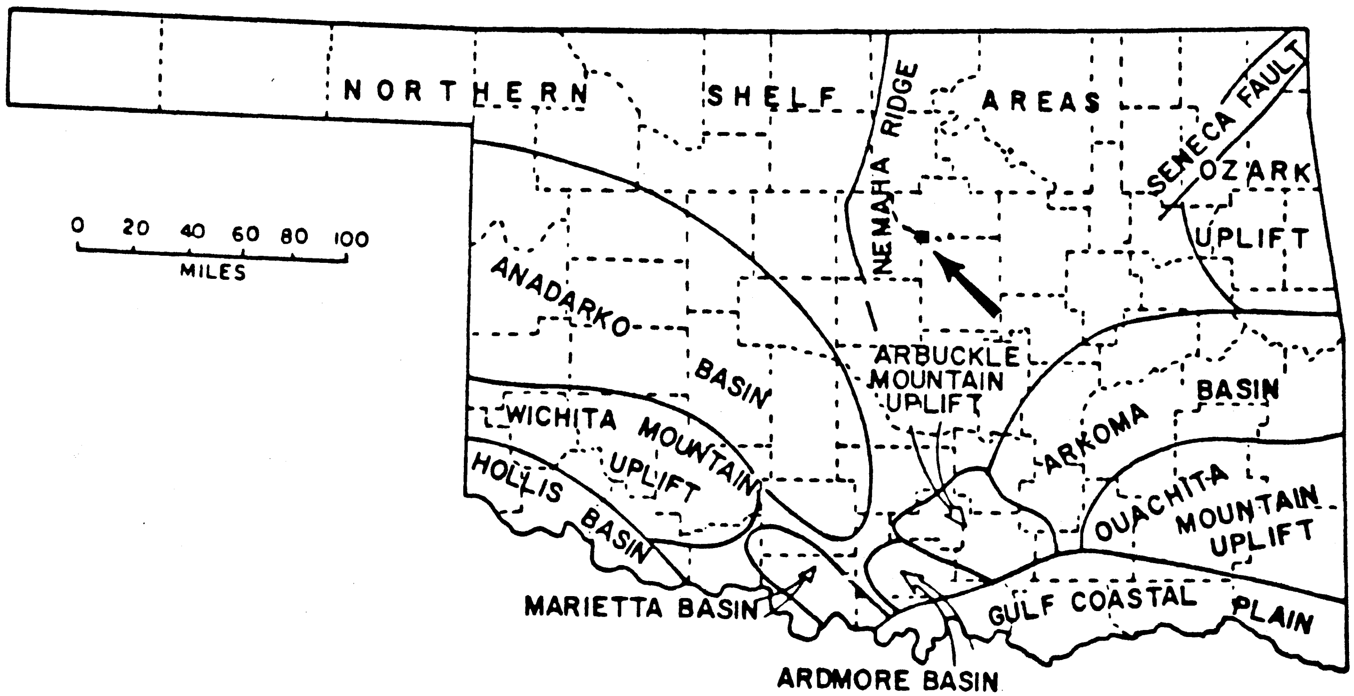


Figure 2. Major geologic provinces of Oklahoma (modified from Johnson and Denison, 1973). General location of study area shown by darkened square east of Nemaha Ridge.

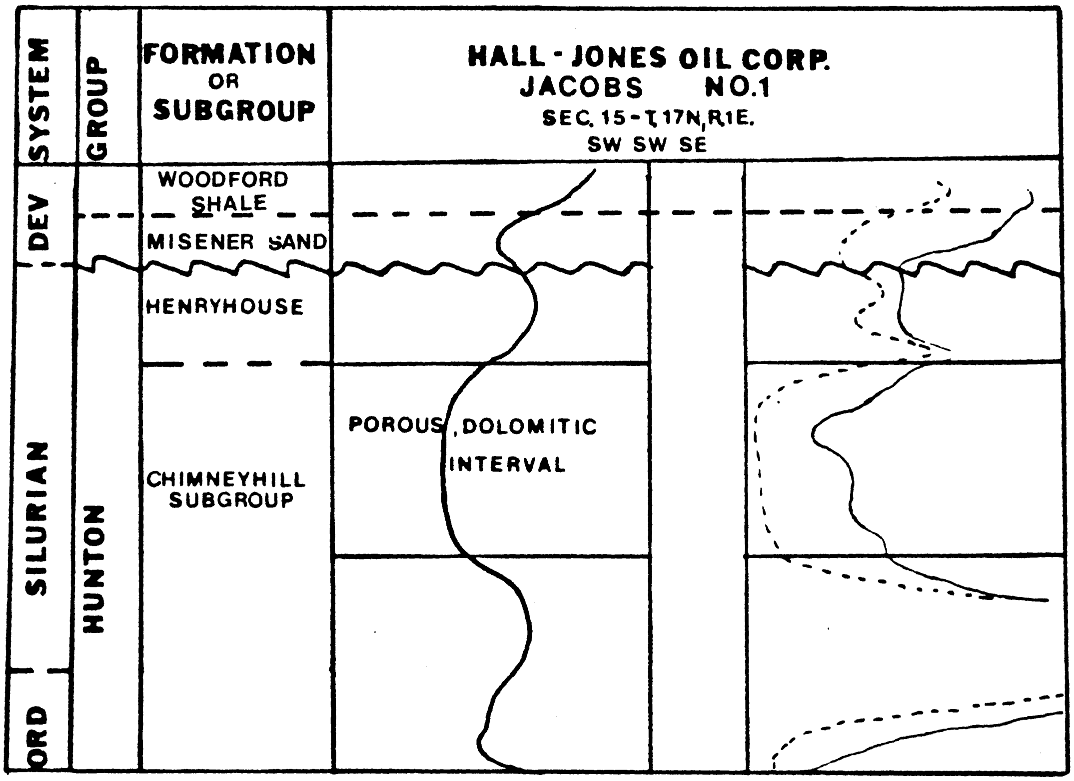


Figure 3. Type log of Hunton Group, showing nomenclature used in the thesis area (after Amsden, 1975). Curves shown are Spontaneous Potential (leftmost), Lateral (dashed), and Short Normal (rightmost).

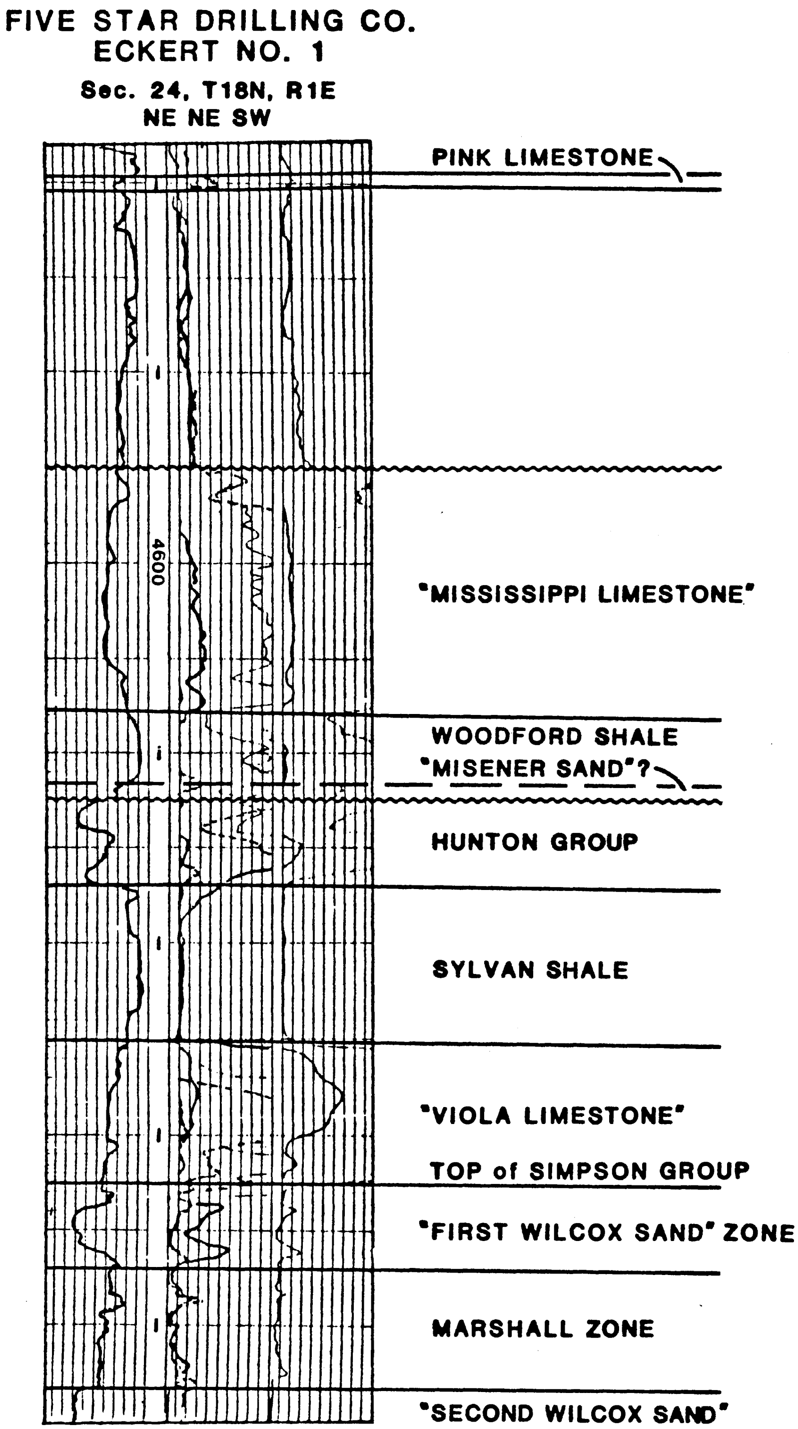


Figure 4. Type log of study area.

prediction of the most desirable locations for exploration.

5. Establish the relationship, if any, between production of oil and gas from the "Second Wilcox" and the Wilcox's structural position, in order to predict more accurately the most suitable locations for exploration.

6. Distinguish among different kinds and ages of Hunton and Second Wilcox oil and gas traps within the project area.

Previous Investigations

Much has been written regarding the regional geologic history of the thesis area. Several studies of the subsurface have contributed to understanding of the regional geologic history. These include theses by Verish (1979), Hollrah (1977), Akmal (1953), McKenny (1953), Graves (1955), Stringer (1957), and Cole (1955). Huffman's (1958) study of rocks exposed at the surface covered a portion of northeastern Oklahoma; this paper was very useful in establishing a geologic history of the region. Studies of a restricted nature, such as those which describe Ramsey Field (Frost, 1940; Umpleby, 1956) and Arcadia-Coon Creek Field (Carver, 1948) also have been instructive, particularly in providing information useful in determining the ages of various hydrocarbon traps (Figure 5).

The Hunton Group comprises strata of Late Ordovician

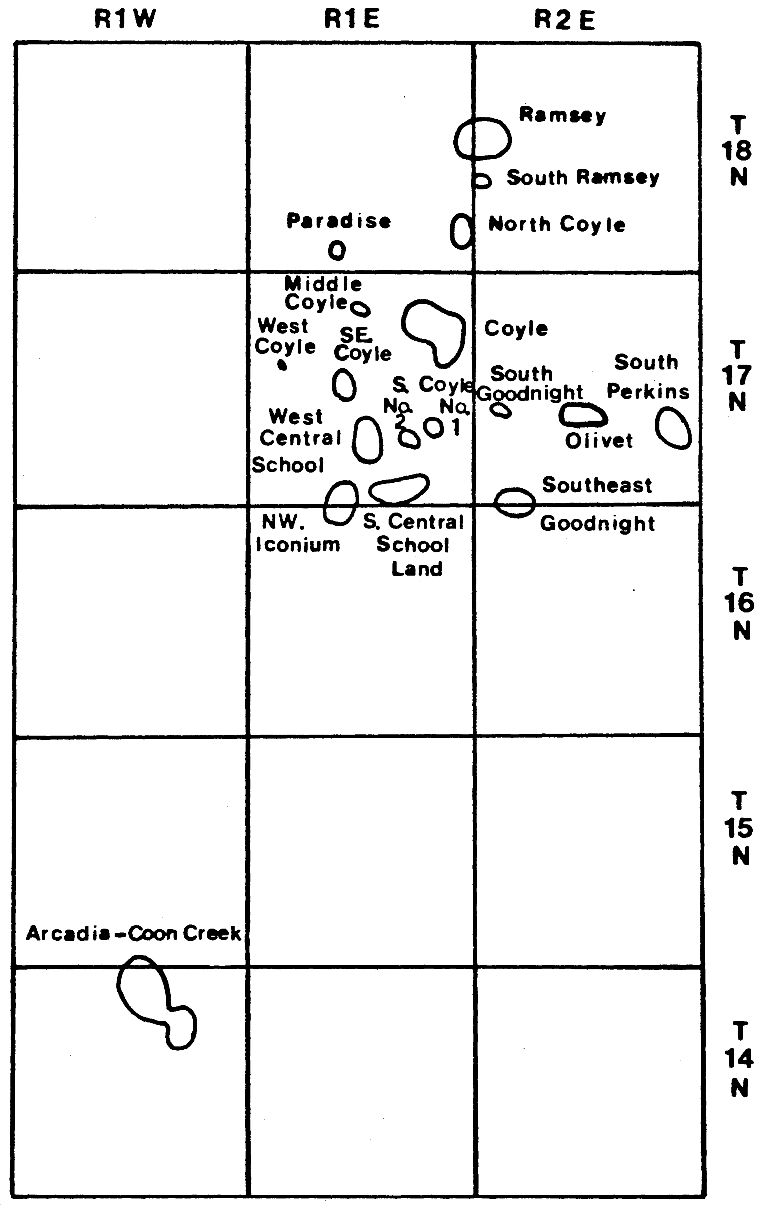


Figure 5. Locations of oil and gas fields cited as producing from the Hunton Group or Second Wilcox Sand.

to Early Devonian Age (Amsden, 1975). These rocks conformably overlie the Sylvan Shale of Late Ordovician age and are overlain unconformably by the Woodford Shale, of Late Devonian to Early Mississippian age, or by the Misener Sandstone, also of the latter age (Figure 3). The Chimneyhill Subgroup comprises the Keel, Cochrane, and Clarita Formations, in ascending order (Amsden, 1960) (Figure 3). The Henryhouse Formation overlies the Clarita; it is the youngest Hunton rock unit in the thesis area (Hollrah, 1977). According to Hollrah (1977), most oil and gas produced from rocks of the Hunton in the area is derived from dolomitized strata within the Clarita Formation.

The informal stratigraphic unit "Second Wilcox Sandstone" is a unit within the Simpson Group (Figure 4) and has a Middle Ordovician age (Cronenwett, 1956). Cronenwett (1956) divided the Bromide Formation of southern Oklahoma into the "First" and "Second" Bromide Sands. This division was based on a persistent shale bed that separates the two sands. This shale does not extend into the thesis area; therefore, within the thesis area, the First Bromide and Second Bromide are indivisible. The compound sand body is referred to as the Second Wilcox sand, which in the study area is the lowermost rock unit of concern, and the uppermost part of the Bromide Formation.

Methods and Procedures

Achievement of objectives of this investigation required construction of several isochore and structure contour maps. In turn, construction of these maps required adherence to certain procedures that should minimize errors and present a reasonable and coherent mapping of the subsurface. The mapping procedures are as follows:

1. Maps are constructed in the order in which the horizons that they represent occur in the subsurface, from youngest to oldest. This is the most logical sequence, because the most abundant data pertain to the shallowest (youngest) horizons and data become increasingly sparse with depth.

2. Each successive structure map is constructed sequaciously, such that the structural features of maps are concordant with one another. This assumption is logical: a deformational event that produced a structural closure or nosing in a young bed probably caused a similar and perhaps more pronounced result in older beds. For example, a syncline in rocks of the "Viola Limestone" (Figure 4) is not likely to underlie an anticline shown in strata of the Hunton Group. Considerable readjustment from one map to another may be required before agreement between all maps is satisfactory.

3. Unless data force a conclusion otherwise, a constant rate of dip is maintained for each horizon mapped. The

rate of dip is established best by mapping first in areas of densest well control (provided that the area is not one in which anomalous dip might be anticipated, such as areas near faults). Because rates of dip can change with depth, a different rate must be approximated with each successive horizon to be mapped.

Definition of Tops of Formations and of Porous Intervals

Electric logs were the preferred choice in determining boundaries of formations that were mapped. If no electric log of a given well was available, scout-ticket data or Oklahoma Corporation Commission reports were utilized.

Boundaries of the porous, dolomitic section of the Hunton (Figure 3) were determined with porosity logs where they were available. The most commonly used porosity logs in the area were compensated formation density, gamma ray-neutron, and density-neutron logs. Approximately 150 porosity logs were available of wells that penetrated the dolomitic part of the Hunton. In addition, micrologs were available for numerous wells in the thesis area. No porosity logs were available for most wells that penetrated this zone. In such instances the porous interval was identified through use of the Spontaneous Potential curve and the resistivity-survey invasion profile of each electric log. Generally, the Spontaneous Potential curve is developed best in thick, permeable beds of small shale content, provided that the resistivity of mud filtrate differs sufficiently from resistivity of formation water (Asquith, 1982). Nearly all tests in the area were drilled using freshwater-based drilling mud; thus most Spontaneous Potential curves are developed adequately.

Restricted use of the SP curve in assessing whether a particular interval is porous can be misleading; therefore, invasion profiles shown by accompanying resistivity surveys were used to provide supportive or nonsupportive information. This procedure enhances the probability of correct interpretation.

Empirical observations from comparisons among micrologs (of which more than 100 were available for wells drilled in the area), density-neutron logs, and electric-log surveys were made. Micrologs can be used to indicate permeable zones, determined primarily by the presence or absence of mudcake (Asquith, from Hilchie, 1978). In general, permeable (and probably porous) zones that were indicated by microlog surveys closely matched those indicated from the use of Spontaneous Potential curves and invasion profiles. Comparisons between microlog surveys and density-neutron porosity logs indicated that in dolomitic beds of the Hunton, permeability can reliably be taken as an indicator of porosity.

The most important criteria in selection of a lower cut-off limit for rock in the Hunton that should be considered as "porous" are governed by objectives of this investigation. The ultimate objective is to enhance success in locating oil and gas reserves through application of mapping techniques described here. Therefore, a section of rock is considered to be porous if its reservoir-potential implies the yielding of commercial quantities of hydrocarbons. In the instances of wells where density-neutron porosity logs were available, only those parts of the Hunton where porosities exceeded 5 percent (as determined by cross-plotting the density and neutron porosities) should be considered as having potential reservoir quality (Bill Ermey, personal recommendation). This value is intended to apply to strata where porosity is other than fracture porosity, such as primary or vuggy porosity. A much lower cut-off value would be appropriate for areas where porosity is due mainly to fractures (Bill Ermey, personal communication).

Available data, which include observations of drill cuttings, scout-ticket core descriptions, Oklahoma Corporation Commission reports, and the descriptions provided by Hollrah (1977), suggest that porosity in the dolomitized section of the Hunton is more commonly vuggy or solution-type rather than fracture porosity. Measurements of porosity derived from density-neutron logs generally are larger than would be expected if the porosity were mainly in the form of fractures. Perhaps the strongest evidence against fracture-porosity is that most wells completed in the Hunton have large cumulative production and production longevities that would not be expected of wells producing from primarily fracture-induced porous zones.

If the only logging survey available for a particular well was an electric log, the dolomitic interval was considered porous and permeable if both of the following criteria were met: (a) the spontaneous potential curve was well developed and generally, well-rounded, and (b) invasion was indicated by resistivity curves.

Subsurface Maps

After mapping procedures and criteria for defining porous zones were established, construction of the following maps was necessary to accomplish the objectives of this study:

1. A structural contour map of the top of the Pink limestone (Figure 4; Plate 1). The Pink limestone structural map provides excellent control in areas where relatively few wells penetrated pre-Pennsylvanian strata, such as at Olivet Field in T. 17 N., R. 2 E. (Figure 5). The Pink limestone is recognized easily by its electric-log signature, is widely distributed, and was deposited essentially horizontally, making this a logical stratum on which to map. Moreover, the distinctive log-signature of this marker bed facilitates regional correlations. Also, this map is useful in indicating relatively late faulting.

2. A structural contour map of the top of the

"Mississippi Limestone" (Figure 4; Plate 2). Although this surface is an unconformity, this map, when used in conjunction with an isochore map of Mississippian rocks, is particularly useful in delineation of faults and in estimating the times of their occurrences, the combination of which may be important factors in entrapment of oil and gas.

3. An isochore map of the "Mississippi Limestone" with post-Mississippian pre-Des Moinesian fault traces (Figure 4, Plate 3). The main purpose this map serves is to indicate post-Mississippian pre-Des Moinesian faulting and structural thinning. Abrupt changes in thickness of Mississippian strata, particularly where they occur in approximately linear geometry, commonly indicate faulting that occurred during post-Mississippian time. Given the main objective for which this map was constructed, to show faults that have been interpreted as a result of the map's construction, is appropriate (although depiction of post-depositional faults is not customary).

4. A map showing configuration of the upper surface of the dolomitic part of the Hunton (Figure 3; Plate 4). Within a given hydrocarbon reservoir, normally hydrocarbons migrate to the highest structural position attainable. In parts of T. 18 N., R. 1 and 2 E. and most parts of T. 17 N., R. 2 E. where this porous, dolomitic zone is present, it is generally near the top of the Hunton. In these townships, it is acceptable to construct the map by

direct contouring of sub-sea-level values of the top of the porous interval. In T. 17 N., R. 1 E. and the western extremity of T. 17 N., R. 2 E. the dolomitic zone was developed in progressively younger beds in a generally easterly direction (Plates 12, 13, 14, 15, and 16). Final interpretation of the position of the top of the porous zone requires construction of three maps: (1) A structural contour map constructed of the base of the Hunton (top of the Sylvan Shale) (Figure 4; Plate 8), accepted as a conformable contact. (2) An isochore map of the stratigraphic interval from the base of the Hunton to the top of the porous, dolomitic interval (Plate 7). This map shows directions in which the top of the porous interval locally increases or decreases with respect to the base of the Hunton. (3) A map derived by overlaying the two maps described above, marking intersects of subsea structural and isochore contours and their values, and adding the isochore contour value to the subsea structural contour value (which is negative) at each intersect. Figures 6 and 7 show examples of these three maps and of construction of the last one.

The resulting map provides additional and more accurate control between drill sites than could be achieved by mapping only the "subsea" value of the top of the porous, dolomitic zone at each drill site.

5. An isochore map of the Hunton Group with "post-Hunton pre Woodford" fault traces (Plate 5). The function

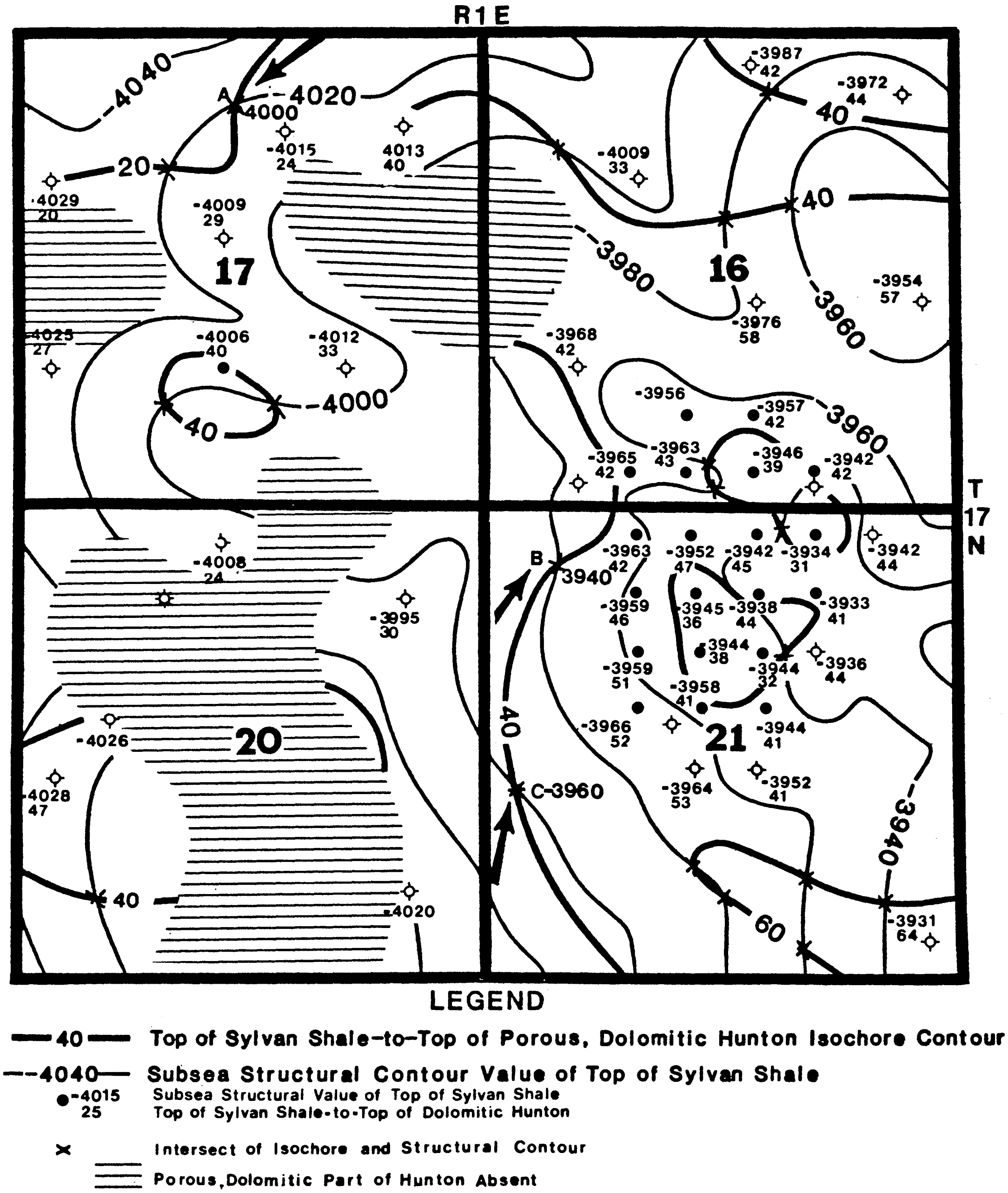
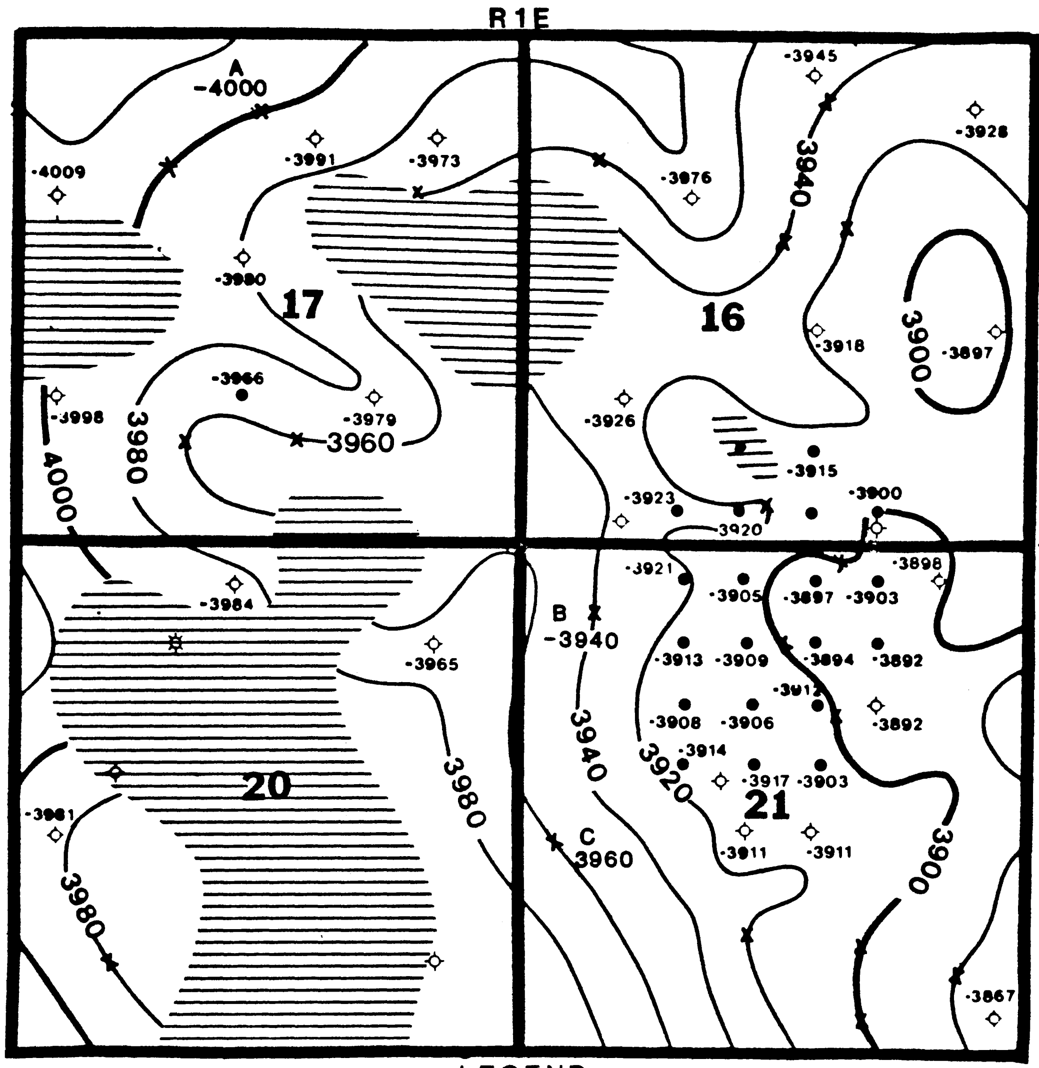


Figure 6. Illustration of the method by which the map of the upper surface of the porous, dolomitic Hunton is derived. The subsea structural contour values (negative) are added to isochore contour values at intersects. The resulting values at points A (-40000), B (-3940), and C (-3960) are shown. The map derived by this procedure is shown in Figure 7.



LEGEND

Porous, Dolomitic Part of Hunton Group Not Present

--3960— Subsea Contour Value of Upper Surface of Porous, Dolomitic Hunton

● -3917 Subsea Value of Upper Surface of Porous, Dolomitic Hunton

× Intersect of Isochore and Structural Contour

Figure 7. Map of the upper surface of porous, dolomitic Hunton derived by honoring all intersect values and well data. Areas where porosity is absent are shaded.

of this map is to illustrate the direction of uplift the region underwent in "post-Hunton pre-Woodford" time[1]. Thinning of the Hunton or its absence over anticlinal structures provides information as to the probably ages of such structures and as to the relative degrees of deformation the area may have undergone during post-Hunton pre-Woodford time.

6. An isochore of the Hunton porous, dolomitic interval (Plate 6). Knowledge of the extent and distribution of this zone is necessary in exploration for oil and gas in the Hunton.

7. An isochore map of the top of the Sylvan Shale to top of the Hunton porous, dolomitic interval (Plate 7). Construction of this map was necessary in T. 17 N., R. 1 E. and the western extremity of T. 17 N., R. 2 E., where the dolomitic zone was developed in progressively younger strata from approximately west to east. The method by which this map was used in construction of the map of the upper surface of the dolomitic part of the Hunton was described earlier (see No. 4).

8. A structural contour map of the top of the Sylvan Shale (Figure 4; Plate 8). This map was also necessary in construction of the map of the upper surface of the dolo-

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[1] Terms such as "Hunton" and "Woodford" are recognized to be rock-stratigraphic units rather than geologic-time units. Their use as quasi-geologic time units sometimes facilitates comparisons between certain maps and interpretations that resulted from construction of those maps.

mitic part of the Hunton in the area previously described. Its use is described in the section discussing construction of the latter map (see No. 4).

9. A structural contour map of the top of the "Viola Limestone" (Plate 9). Construction of a reasonably reliable structural contour map of the top of the Second Wilcox sand requires that this map be constructed first.

10. An isochore of the top of the Viola-to-top of the Second Wilcox interval (Plate 10). This map is necessary to develop a structural contour map of the top of the Second Wilcox.

11. A structural contour map of the upper surface of the Second Wilcox (Plate 11).

A major objective of this thesis was to predict the most satisfactory locations in the area in which to explore for reserves in the Second Wilcox. Satisfying this objective requires the most reliable subsurface structural contour map of the top of the Second Wilcox that can be made. Configuration of the Viola does not necessarily reveal accurately the configuration of the Second Wilcox, because of variations in thickness of the Marshall Zone, which separates the two (Figure 8). Inaccuracies probably would result if the map were constructed by honoring only the existing subsea values of the top of the Second Wilcox.

An additional consideration is the lack of control for the Second Wilcox; many wells have penetrated the

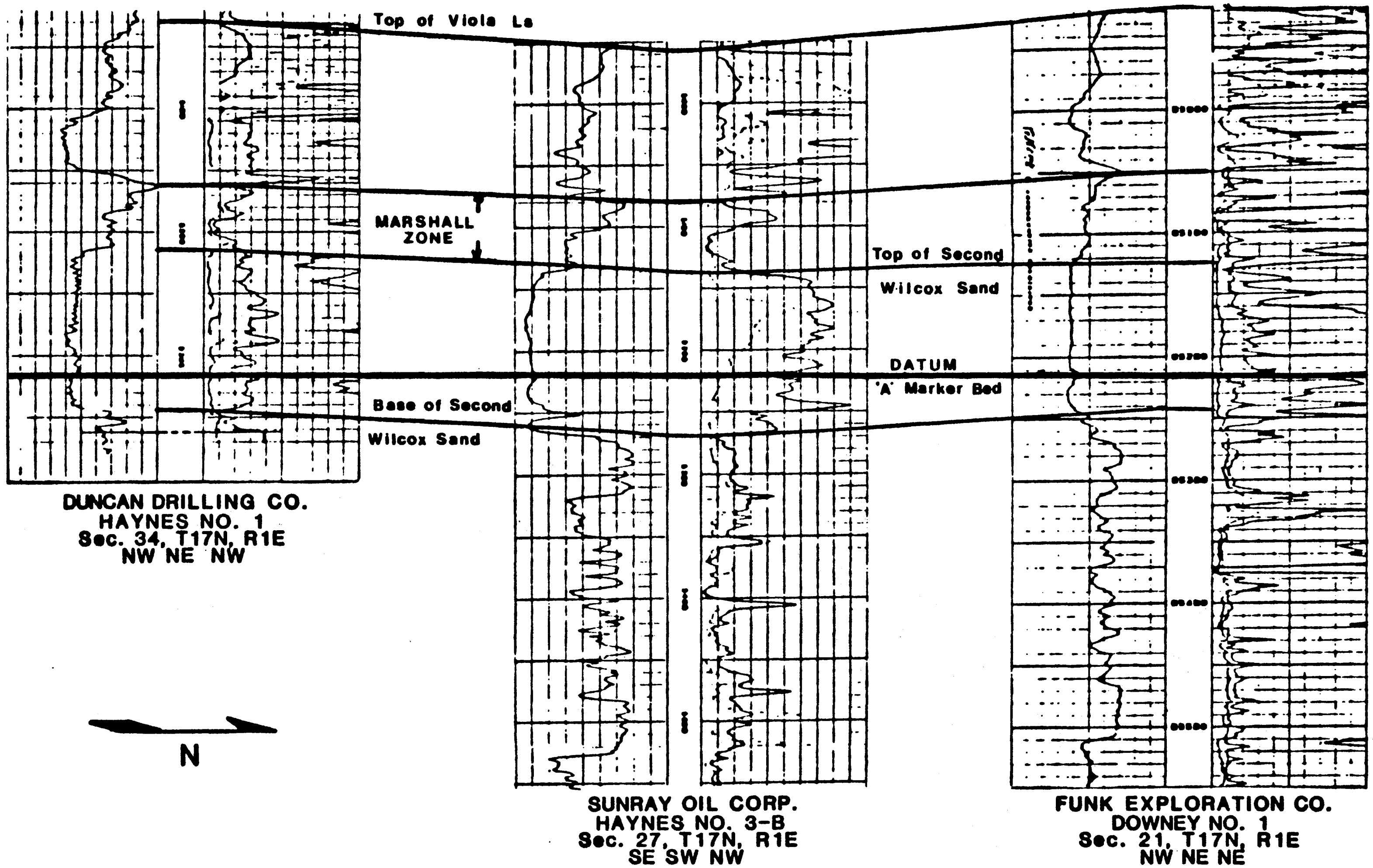
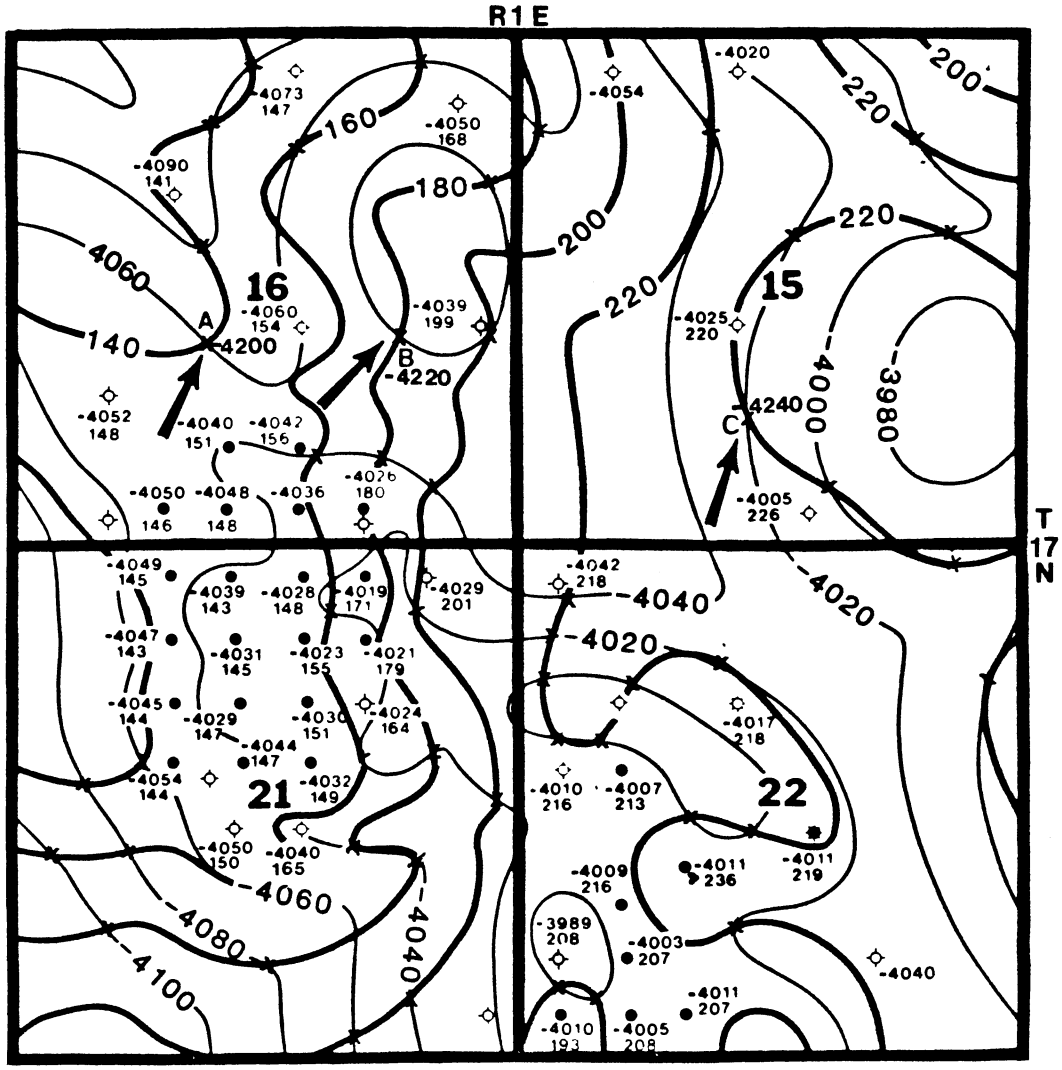


Figure 8. Stratigraphic cross-section showing that thickness changes of the top of Viola-to-top of Second Wilcox interval are due primarily to thickness changes of the Marshall Zone. Cause of Marshall Zone thickening may have been topographic, structural, or both.

Viola but not the Second Wilcox. The solution which probably results in the most logical and accurate map is to: (a) make a structural contour map of the top of the Viola, (b) make an isochore of the top of the Viola-to-top of the Second Wilcox interval, (c) overlay the two maps, marking intersects and values of the subsea structural and isochore contour values, (d) subtract the isochore contour values (which are negative), and (e) construct the final map by honoring all of the resulting intersect values and existing well data. The reliability of the derived Second Wilcox structural contour map is dependent upon the accuracy of the interpretations of the Viola structural contour and Viola-to-Second Wilcox isochore maps. Therefore, the technique is only useful where well data are sufficiently abundant to make a "reliable" map interpretation, or where significant changes in thickness of the Viola-to-Second Wilcox interval are observed, such as in T. 17 N., R. 1 and 2 E. An example of this procedure is shown in Figures 9 and 10. Variations in thickness of the Viola-to-Second Wilcox interval actually represent thickening or thinning primarily of the Marshall Zone; the Viola is of relatively uniform thickness throughout the area. Mapping thickness of the Viola-to-Second Wilcox interval is more advantageous than mapping thickness of the Marshall Zone, because the former interval can be more readily identified on wireline logs.



LEGEND

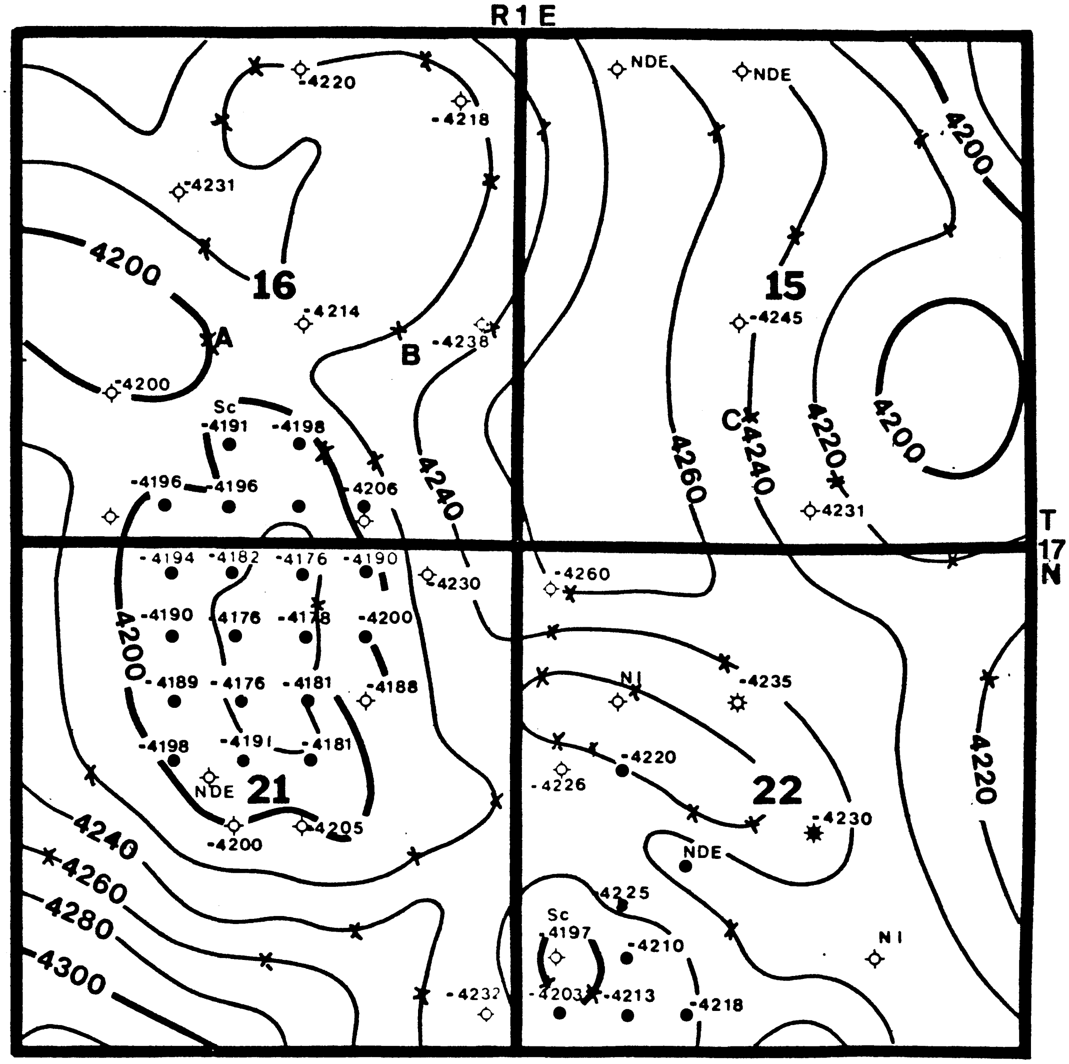
—140— Isochore Contour of Viola LS-to-Top of Second Wilcox Sand

—-4100— Subsea Structural Contour of Top of Viola LS

● -4056 Subsea Structural Value of Top of Viola LS
152 Top of Viola-to-Top of Second Wilcox Sd

× Intersect of Isochore and Structural Contour

Figure 9. Illustration of the method by which the structural contour map of the top of the Second Wilcox Sand was derived. The subsea structural contour values of the Viola (negative) are subtracted from the isochore contour values of the Viola-to-top of Second Wilcox at intersects. The resulting values at intersect points A (-4200), B (-4220), and C (-4240) are shown. The map derived by this procedure is shown in Figure 10.



LEGEND

——-4280——	**Subsea Structural Contour Value of Top of Second Wilcox Sand**
● -4223	Subsea Structural Value of Top of Second Wilcox Sand
NDE	Not Deep Enough
NI	No Information
×	Intersect of Isochore and Structure Contour

Figure 10. Structural contour map of the top of the Second Wilcox Sand derived by honoring all intersect values and well data.

CHAPTER II

REGIONAL HISTORY

Current regional structural features documented in the subsurface are results of several episodes of movement. The main post-Precambrian structural events were post-Arbuckle pre-Simpson, post-Hunton pre-Woodford, post-Mississippian pre-Cherokee, post-Permian, and post-Cretaceous (Stringer, 1957).[1]

Following deposition of the Second Wilcox, sands were exposed to eolian reworking, manifested by the frosted appearance of many grains of the Second Wilcox (Stringer, 1957).

Abrupt variation in lithology of shales, limestones, and dolomites that compose the Marshall Zone (Figure 4) probably are indicative of multiple transgressions and regressions of the sea during "Marshall Zone" time. Local and regional variations in thickness of the Marshall Zone may indicate that the Marshall Zone - "First Wilcox" contact is unconformable. McGee and Jenkins (1946) stated

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[1]The writer is aware that the terms "Arbuckle", "Simpson", "Hunton", and "Woodford", are rock-stratigraphic terms. The phrase "post-Arbuckle pre-Simpson", should be interpreted as meaning "after deposition of the Arbuckle Group and before deposition of the Simpson Group".

that the Oklahoma City uplift began to rise in the Ordovician and that an area 25 miles east and west and 40 miles north and south was affected. Carver (1948) cites the uplift as a possible cause for thinning of the Marshall Zone over the Arcadia-Coon Creek Field in T. 14 and 15 N., R. 1 W. (Figure 5). Local thinning of this zone across anticlines in Ordovician rock is common throughout the region (for example, see McKenney, 1953).

Contact of the Bromide and Viola may be disconformable (Cronenwett, 1956) and the upper surface of the Viola may be an unconformity (Wengard, 1948). However, if these unconformities exist, there is no evidence that either had a pronounced effect on structural geology in the thesis area; the Viola is almost uniformly 40 to 60 feet thick throughout the area.

Consistency of thickness and lithology of the Sylvan Shale indicates that stable-shelf conditions probably existed during deposition of this rock unit.

Fairly stable-shelf conditions likely were prevalent during deposition of the Hunton Group, when carbonates were deposited in warm, shallow seas. Several postulated disconformities within the Hunton Group suggest brief interruptions in deposition (Amsden, 1975). In Middle to Late Devonian time epeirogenic forces tilted the area south-southwestward, resulting in truncation of Hunton strata to the north and development of low-relief topography upon the Hunton. Previous regional investigations have revealed that many folds in portions of the Northeast Oklahoma Platform originated in post-Hunton pre-Woodford time (Johnson, 1958, from Albano, 1975).

The eroded Hunton was inundated as Woodford seas transgressed in Late Devonian and Early Mississippian. The sparsely distributed Misener sands were deposited in localities where the Hunton is thin, which suggests deposition in paleotopographically low areas (Bauernfeind, 1980). The Woodford Shale was deposited conformably upon the Misener and unconformably upon the Hunton in shallow, marine waters (Graves, 1956).

Mississippian strata were then deposited on the Woodford with no apparent hiatus. The most pronounced event to affect the area followed in post-Mississippian pre-Des Moinesian time, probably in late Morrowan time (Huffman, 1958), when the region underwent gentle uplift, folding, and faulting. This event probably coincided with a major epeirogeny that generated many of the major tectonic features of the midcontinent area, including the Nemaha Ridge and the Ozark Uplift. Many of the anticlines and most of the faults that are documented in the study area probably originated during this episode. Erosion followed, during which the region essentially was peneplaned and anticlinal folds, such as the Ramsey anticline, were bevelled. Folding and faulting recurred late in the Des Moinesian (Umpleby, 1956).

The region was tilted to the south and southwest in post-Permian time (Cole, 1955). During the Early Mesozoic the region was eroded. Cretaceous sedimentary rocks may have been deposited in the study area, but not such strata have been mapped or recorded. Southwestward tilting in post-Cretaceous time established the present regional dip (Stringer, 1957).

CHAPTER III

SUBSURFACE STRUCTURAL GEOLOGY

Subsurface Maps

The area mapped has undergone several episodes of uplift, folding, and erosion. As a result, structural features present on a given subsurface map might not be present on other maps. It is therefore necessary to describe each subsurface map individually.

Several subsurface structural characteristics are recognizable on all of the subsurface maps (see Plates 1 through 11):

1. Regional dip of subsurface beds is southwesterly. Average dip is approximately 50 feet per mile (although exceptions occur locally).
2. The most prevalent structural feature common to each map is a north-south-trending "ridge" that extends northward from section 35, T. 17 N., R. 1 E., through Coyle and Ramsey Fields (Figure 5), and through section 6, T. 18 N., R. 2 E.
3. A structural feature that exists in older beds is generally recognizable in younger beds, ordinarily causing the configurations of the structural maps to resemble one another (although structural closure of an anticline may

increase in older beds, such as at Ramsey and Coyle fields (Figure 5).

4. Overall appearance of the structural contour maps indicates that the area has been cross-folded. East-west and northwest-southeast trends occur.

Descriptions of the most significant geologic features shown on each map follow.

Structural Contour Map,
Top Pink Limestone

Structural closures of greater than 20 feet are uncommon at this datum (Figure 4; Plate 1). The largest closure is located at Ramsey Field, section 13, T. 18 N., R. 1 E. and section 18, T. 18 N., R. 2 E., where more than 80 feet of closure is demonstrated. Greater than 30 feet of closure is present at Coyle Field in section 12, T. 17 N., R. 1 E. North Paradise Field, in sections 20 and 21, T. 18 N., R. 1 E., may have greater than 20 feet. Perkins Field, in section 24, T. 17 N., R. 2 E., may have the amount of closure interpreted, but control data are sparse east of this area.

A north-south fault passes through Ramsey Field, extending from section 25, T. 18 N., R. 1 E. to the southern extremity of section 7, T. 18 N., R. 2 E. Umpleby's (1956) study of Ramsey Field showed that fault-movement occurred after deposition of the Oswego Limestone and probably before deposition of the Checkerboard Limestone (Umpleby referred to the Pink Limestone as the Inola Limestone to conform with Frost's earlier study of Ramsey Field, although he believed Pink limestone to be the correct datum). Evidence that this fault had an earlier origin will be presented when describing the Mississippi Limestone structural and isochore maps. The east-west fault that bounds the northern edge of Ramsey and the north-south fault west of Ramsey in section 13, T. 18 N., R. 1 E., also show structural displacement of the Pink limestone and may be related to the north-south fault described by Umpleby. Evidence that these faults originated before deposition of the Pink limestone will be cited, also.

The anomonously low sub-sea-level structural value of the top of the Mississippi Limestone of the E. H. Moore, Inc. No. 1 Means, C NW NW section 19, T. 18 N., R. 2 E. (for which only scout-ticket data are available and for which no Pink limestone call was made) is the reason for placement of the northwest-southeast fault between the former well and the nearest well to the east, the George Greer No. 1 Longan, SW NW NE of the same section. Evidence as to the youngest possible age of the latter fault is lacking, but if the fault is related to other faults in the Ramsey area, it may be "post-Pink limestone".

The fault shown in section 33, T. 18 N., R. 1 E., is a possible explanation for production data in the area.

The Canadian Exploration Corp. No. 33-1 Graham, SW SE NW of that section, produced from the top of Hunton porosity from perforations -4033 through -4035 feet. The Canadian Exploration Corp. No. 33-1 Downey, NW NE SW of section 33, also produced from the correlative zone from perforations -4049 through -4052 feet. The Canadian Exploration Corp. No. 33-2 Graham, SW NE NW section 33, was completed as a dry hole during the same year, but the correlative Hunton porosity drill-stem-tested saltwater at -4024 feet. A reservoir separation must occur between the two producing wells and the structurally higher dry hole. A stratigraphic separation would require a permeability barrier within the Hunton reservoir rock between the dry hole and the No. 33-1 Graham, which are only 1320 feet apart. No evidence supports existence of such a barrier in the area. Structural separation caused by a syncline would require at least 28 feet of dip reversal to separate the producing wells and dry hole; this would be anomalously steep dip. A fault, interpreted as shown, would separate the two producing wells from the structurally higher dry hole. Age of the fault cannot be postulated reliably. Fault displacement apparently is small; therefore, thickness variations of strata on either side of the fault that one might expect to observe due to post-faulting erosion are not evident (see Plates 3 and 5).

Fault displacement of structural contours of the top of the Pink limestone are shown in the northwest portion of T. 17 N., R. 1 E., inferring that fault displacement occurred after deposition of the Pink limestone.

The syncline east of Ramsey at the mutual boundaries of sections 8 and 17, T. 18 N., R. 2 E., is anomalous. Its proximity to Ramsey Field suggests that faulting is possible in this area, also.

Structural Contour Map, Top Mississippi Limestone and Isochore Map, Mississippi Limestone with Post-Mississippian pre-Des Moinesian Fault Traces

These maps are related, and it is frequently necessary to refer to both maps when discussing the structure of the Mississippi Limestone (Plates 2 and 3). The most salient difference between structural contour maps of the Pink limestone and the Mississippi Limestone is the increased number of faults observed on the latter map. The Mississippi isochore map provides the best evidence for the interpretations of faults that are shown. Many post-Mississippian, pre-Des Moinesian faults are not apparent from structural contour values of the top of the Mississippi Limestone, because post-faulting "peneplanation" removed most evidence of fault scarps throughout the region.

Most faults in the Ramsey area shown on the structural map of the Pink limestone probably are rejuvenated faults that originated during post-Mississippian pre-Des

Moinesian time, the most active episode of faulting in the area (compare Plates 1, 2, and 3).

At some localities, reverse faults are associated with the main north-south fault that passes through Ramsey and Coyle fields. One such fault is located approximately one mile south of Ramsey Field, in the northwest corner of section 30. T. 18 N., R. 2 E. One the electric-log of the Martgan No. 1 Warren, SW NW NW of that section (see Figure 11), the Hunton section is repeated; this is evidence for the interpretation shown. This fault possibly cuts the older normal fault and terminates near the post-Mississippian pre-Pennsylvanian contact (Stringer, 1957).

A reverse fault is interpreted at Coyle Field in section 12, T. 17 N., R. 1 E. A repeated Sylvan section on the electric-log of the Magnolia No. 4 Cain, E/2 NE SW of that section, is evidence of the fault (Figure 12).

A third reverse fault probably associated with the north-south fault is located in the southwest corner of section 24 and northwest corner of section 25, T. 17 N., R. 1 E. A repeated Viola section occurs in the British-American Oil Producing Co. No. 1 Anderson, NW NW NW section 25 (Figure 13). The electric-log of the British-American Oil Producing Co. No. 1 Hughes NW SW SW section 24, shows a repeated Simpson section that was caused probably by a reverse fault. Extensive erosion removed the Mississippian section from the No. 1 Anderson and No. 1 Hughes wells; therefore, the fault is post-Mississip-

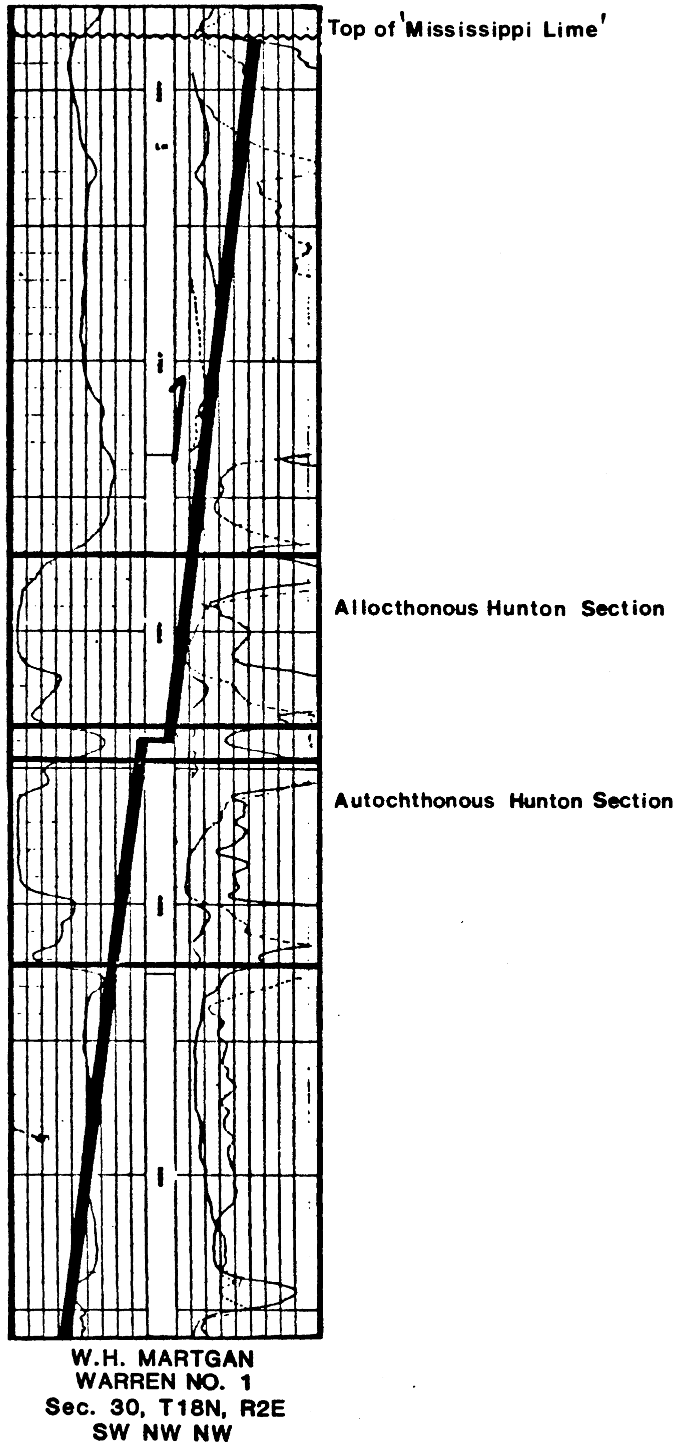

Figure 11. Electric-log showing repeated Hunton section in well that cut a high-angle reverse fault.

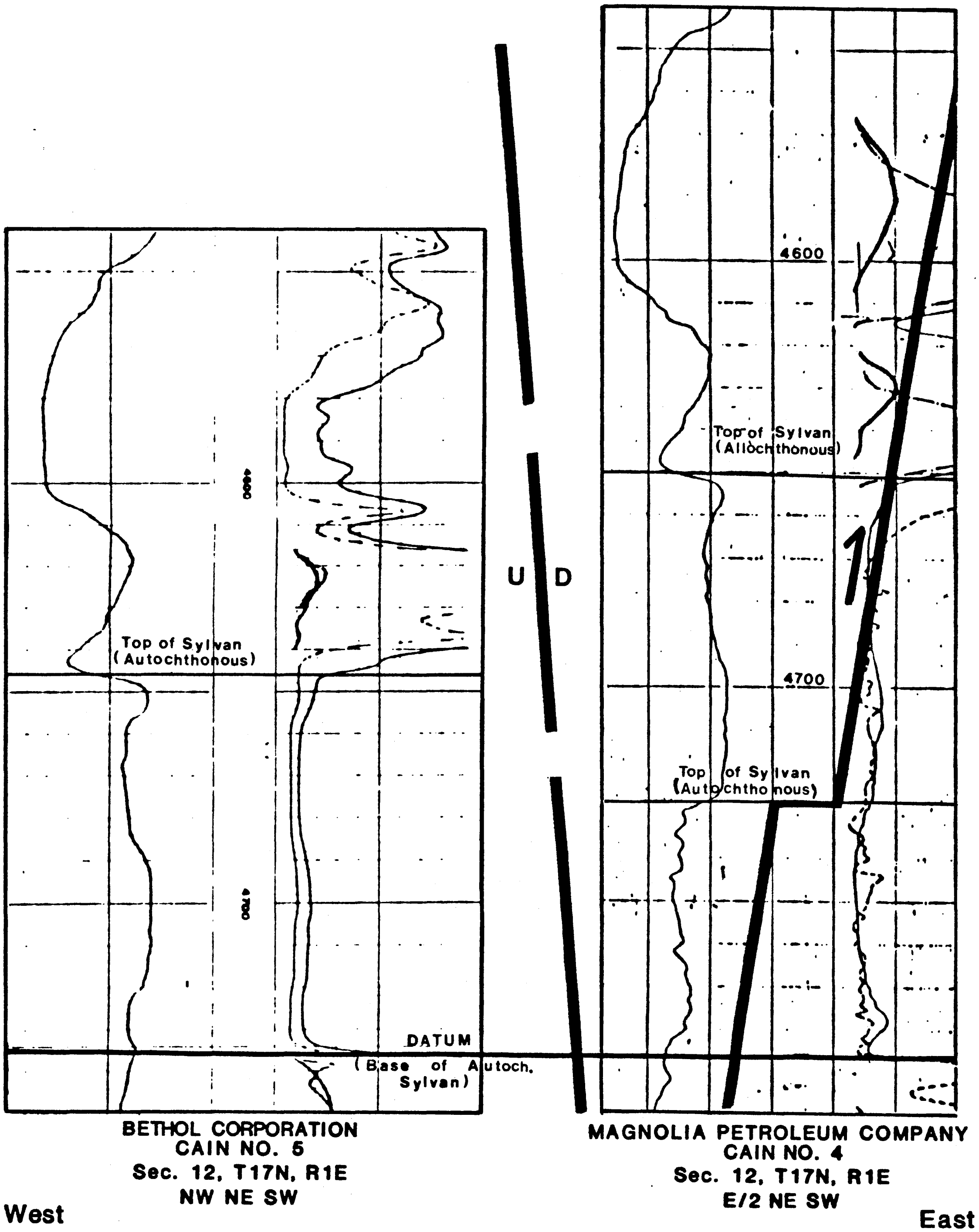

Figure 12. Stratigraphic cross-section (with faults) showing a typical Sylvan section, left, and a repeated Sylvan Section caused by a high-angle reverse fault, right.

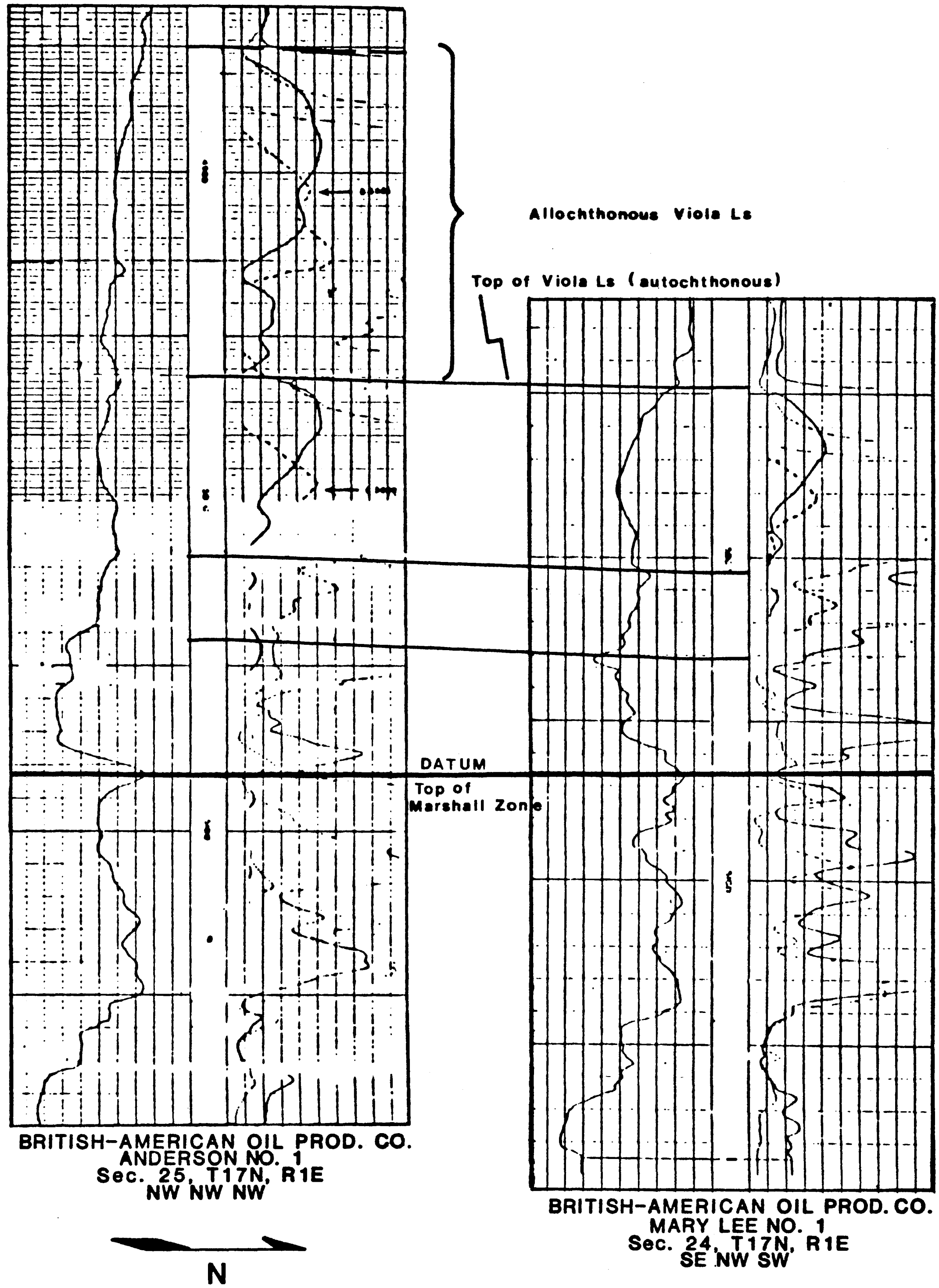

Figure 13. Stratigraphic cross-section showing a typical Viola section, right, and a repeated Viola section caused by a high-angle reverse fault, left.

pian pre-Des Moinesian, and possibly is related to the north-south fault.

Mississippian rocks are absent in three parts of the study area. Erosion removed the Mississippian section in parts of sections 31 through 34 T. 17 N., R. 1 E. on the uplifted side of the east-west fault that passes through those sections. The second area is that which was affected by the reverse fault in sections 24 and 25, T. 17 N., R. 1 E. (discussed above). Mississippian strata are absent in five wells at Ramsey Field in section 18, T. 18 N., R. 2 E. All are on the upthrown side of the north-south fault. As in the other two cases, post-Mississippian pre-Des Moinesian erosion removed the uplifted Mississippian rock. The structural contour map of the top of the Mississippi Limestone does not show evidence of horizontal motion along the north-south fault that passes through Ramsey Field; however, the isochore map of the Mississippi Limestone demonstrates that approximately 700 feet of horizontal movement occurred. The strike-slip movement occurred after deposition of the Mississippi Limestone and before that of the Pink limestone (compare Plates 1, 2, and 3).

Abrupt differences of thickness in Mississippian rock are not all fault-related. Thickness of the Mississippian section is 172 feet in the Bogert No. 1-7 Williams, NE NE NE, section 7, T. 18 N., R. 1 E. The section is 120 feet in the Bogert No. 1-8 Patsy, SW SW NW section 8 of the same township, although the two wells are only approximately 2000 feet apart. Correlation of the two logs shows that the difference in thickness is not caused by a fault; erosion is a more probable explanation (see Figure 14 and Plate 3).

Comparisons of the Mississippi structural and isochore maps demonstrates that the study area was folded and eroded in post-Mississippian time. Erosion caused thinning of Mississippian strata over positive structures. The relationship is documented best along the "ridge" that extends from Coyle to Ramsey fields. Mississippian rocks were preserved best in synclines, such as in sections 2 through 6, T. 17 N., R. 1 E.

Map Showing Configuration of Upper Surface of Dolomitic Part of Hunton Group

Although similarities between this map (Figure 3; Plate 4) and the structural contour map of the top of the Mississippi Limestone (Plate 2) are apparent, distinctive differences also exist. The most conspicuous one is the distribution of the Mississippi Limestone compared to that of dolomitic Hunton rock. Post-Hunton pre-Woodford erosion limited the present distribution of the Hunton Group (Plate 5), including the dolomitic zone within the Hunton section (generally at or near the top of the section. A detailed description will be given of the

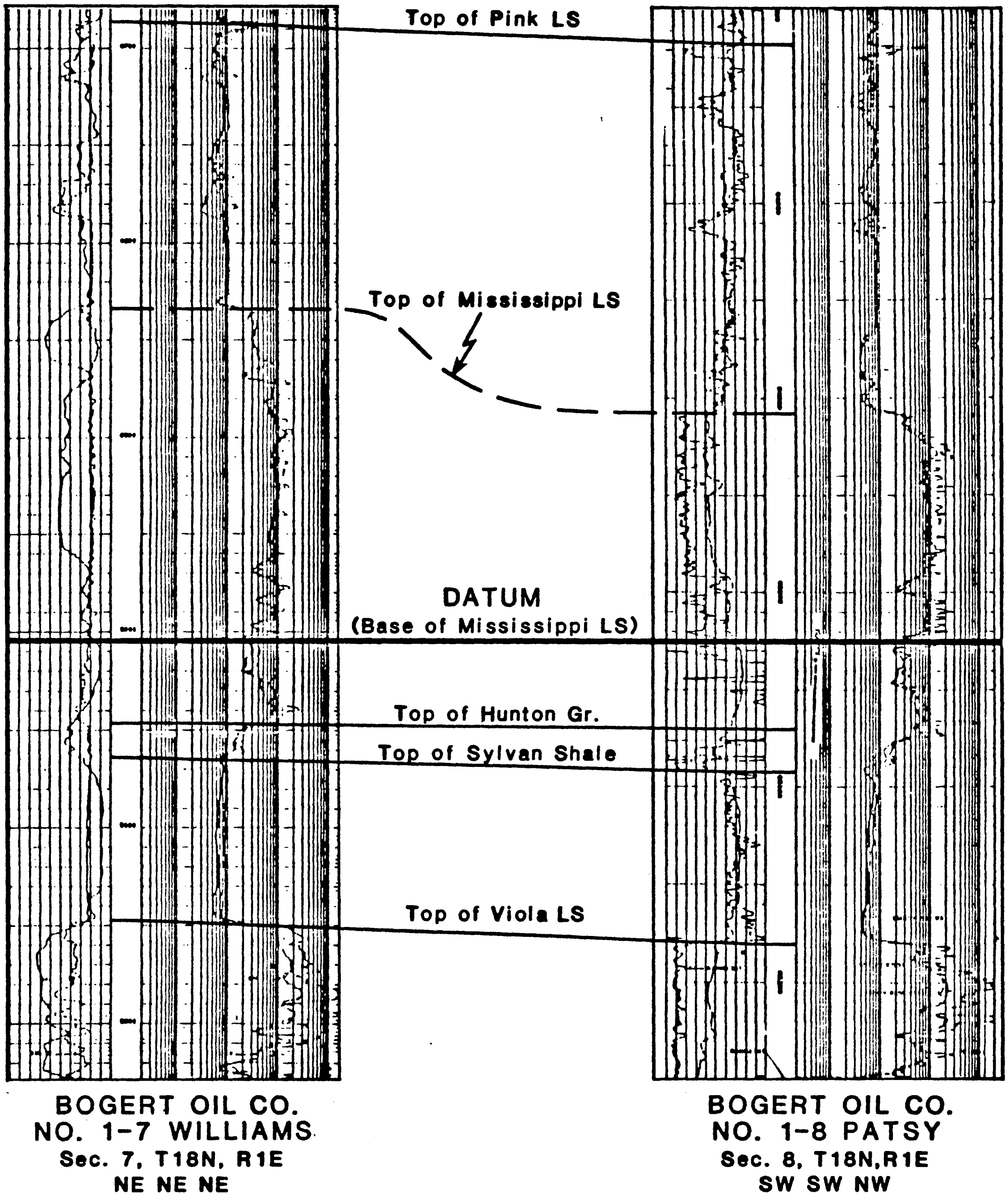

Figure 14. Stratigraphic cross-section illustrating that thickness changes of the Mississippi Limestone are not necessarily fault-related. In this figure, the difference in thickness is interpreted as being erosional (observe relative positions of top of Pink limestone and Mississippi Limestone).

distribution of dolomitic Hunton in the section of this paper that discusses the isochore map of the dolomitic Hunton, below). Another important distinction between the two maps is that evidence of structural displacement is observed across all faults on this datum. This contrasts with the top-of-Mississippi Limestone structural map, where fault displacement generally is not observed, owing to post-faulting erosion.

The isochore map of the Hunton Group (Plate 5) indicates that the fault shown in section 14, T. 17 N., R. 1 E., is probably post-Hunton pre-Woodford. The Hunton section in the Emerald No. 1 Goodnight, C NE SW section 14, is 99 feet thick; the Hunton interval in the Zinke and Trumbo No. 1-14 Berry, S/2 SW NW of the same section, is 76 feet thick. Post-faulting erosion is an explanation for the difference in thickness between the two wells (see Plate 5). Separation between the wells also must have occurred in order to explain production data: the Zinke and Trumbo well had a good "show" of oil. (Drill cuttings had saturated stain, strong odor, and streaming oil cut. The porous interval drill-stem-tested flow of gas with strong crude odor.) The Emerald well drill-stem tested saltwater with no show of oil or gas, despite being 15 feet higher structurally on the top of the dolomitic zone (-3813 feet and -3798 feet, respectively). The fault also separates the Zinke and Trumbo well from the Earth Energy Resources No. 1 Headquarters, C NW NW section 14, which produces from the correlative dolomitic rock, despite being 5 feet structurally lower on the same datum.

Isochore Map, Hunton Group with Post-Hunton Pre-Woodford Fault Traces

This map illustrates that Hunton strata thin to the east, north, and northwest (Plate 5). Correlations of electric-logs show that each correlative increment of Hunton strata thins to the east, possibly the result of continual uplift during deposition of the Hunton (see Plates 12, 13, 14, 15, and 16). Thinning to the north and northwest occured mainly from the top of the section (see Plates 17, 18, 19, and 20), and was the result of post-Hunton pre-Woodford uplift to the north and northwest.

The approximate boundary separating R. 1 E. and R. 2 E. forms an "axis" along which the thickest Hunton sections are found. It is interesting to note that this axis is nearly coincident with the main north-south fault that passes through Ramsey and Coyle fields.

A relationship can be observed in T. 17 N., R. 2 E. between thickness of Hunton strata and structure of Hunton rocks (Plates 4 and 5). (Throughout T. 17 N., R. 2 E. the top of the porous, dolomitic Hunton is generally less than 5 feet beneath the top of the Hunton section; therefore, the latter map would closely approximate a structural map of the top of the Hunton Group.) The Hunton thins over many anticlines in that area (such as at Olivet Field in sections 21 and 22). This is evidence that post-Hunton pre-Woodford folding and subsequent erosion occurred. Many anticlines in T. 18 N., R. 1 and 2 E. also may have originated during this time (approximately Middle-Late Devonian); however, data are not sufficient to confirm this relationship in these townships. No such relationship is apparent in T. 17 N., R. 1 E.

Isochore Map, Porous, Dolomitic Hunton

Similarities between this map (Plate 6; Figure 3) and the isochore of the Hunton Group (Plate 5) are: (a) The thickest porous, dolomitic sections coincide approximately with the "axis" along which Hunton sections are thickest. (b) Thinning of the Hunton over anticlines in T. 17 N., R. 2 E. coincides with thinning of porous, dolomitic Hunton rock. (c) Porous, dolomitic rock also thins to the east, north, and northwest. The principal reason for these similarities is that the dolomitic Hunton rock was developed generally near the top of the Hunton section (except in T. 17 N., R. 1 E. and the western extremity of T. 17 N., R. 2 E.) and was truncated.

Distribution of porous, dolomitic Hunton is more resticted than that of the Hunton Group. More significant differences between the two maps are evident in parts of T. 17 N., R. 1 E. Areas where dolomitic Hunton is absent are in sections 26, 27, 35, and 36. Here, absence of dolomitic rock apparently is not due to truncation; the strata in which porous rock generally is developed are present, but insignificant porosity exists. Two explanations are possible: (1) porosity was never developed, or (2) porosity, once present, was destroyed. More information than is accessible is necessary to establish which of the explanations is the more probable.

The fault in section 14, T. 17 N., R. 1 E., shown on the isochore of the Hunton Group (Plate 5), did not affect the thickness of dolomitic Hunton rock because the latter rock type is developed in Hunton strata older than those removed as the result of post-faulting truncation.

Isochore Map, Top of Sylvan Shale-to-Top Porous, Dolomitic Hunton

This map illustrates that porous, dolomitic rock of the Hunton in T. 17 N., R. 1 E. is developed generally in progressively younger beds from west to east.

An anomalously thin interval extends approximately from the western third of section 11, through the central portion of section 14, and terminates in the northeast quarter of section 23. Loss of porosity in this area occurred from the top of the dolomitic zone; this results in correspondingly thinner intervals from the top of the Sylvan to the top of the porous, dolomitic Hunton. The channel-like geometry shown indicates that the dolomitic zone may have been incised and filled with sediments that never developed porosity. A similar feature extends approximately from the north half of section 22 to the northwest corner of section 23.

Structural Contour Map, Top
Sylvan Shale

Detailed descriptions of this map (Plate 8) will not be given for two reasons: (1) A structural contour map of the top of the Viola Limestone was made. Thickness of the Sylvan is consistently about 85-90 feet throughout the study area; therefore, structural configurations of the Viola and Sylvan are strongly similar. (2) Construction of the Sylvan structural map was a step intermediate in preparation of the map showing configuration of the upper surface of the porous, dolomitic part of the Hunton (Plate 4) in T. 17 N., R. 1 E. and the western extremity of T. 17 N., R. 2 E.

Structural Contour Map, Top
Viola Limestone

This map (Plate 9) and the structural contour map of the surface of the porous, dolomitic Hunton (Plate 4) are similar: Anticlines and synclines shown in the Viola generally underlie their Hunton counterparts. Fault displacements shown on both maps do not differ significantly.

The most conspicuous difference between the two maps is that the Viola is present in the subsurface throughout the study area, whereas the dolomitic Hunton is not.

Isochore Map, Top Viola Limestone-to-Top Second Wilcox Sand Interval

Throughout most of the northern half of the study area, control with which to interpret reliably the changes in thickness of the Viola-to-Second Wilcox interval is insufficient.

Isochore-closures of greater than 30 feet are interpreted at three locations (See Plate 10): (1) West Central School Land Field (Figure 5), mainly in section 27, T. 17 N., R. 1 E., (2) Northwest Iconium Field (Figure 5) in section 33, T. 17 N., R. 1 E. and section 4, T. 16 N., R. 1 E. (the area of greatest closure is found in the latter section, which is outside the study area, and therefore is not shown on the map), and (3) Olivet Field (Figure 5), mainly in section 21, T. 17 N., R. 2 E.

Variations in thickness of the Viola-to-Second Wilcox interval are mainly in the Marshall Zone (Figure 4). Few wells penetrated the entire Second Wilcox section in the thesis area; therefore, evidence as to the origin of structurally positive anomalies in the Second Wilcox is inconclusive. McKenny (1953) suggested three hypootheses: (1) Anticlines may have been present on the "pre-Second Wilcox" surface. The Second Wilcox sand, according to this hypothesis, would thicken over these older structures. (2) Although the Second Wilcox generally is considered to be a sheet sand, local Wilcox highs may represent sand bars. The Marshall Zone would have thinned over topographically high areas and thickened on the flanks of such features. (3) Anomalous "highs" in the Second Wilcox may have been caused structurally. Carver (1948) stated that uplift occurred in "post-Arbuckle pre-Simpson" or during "Simpson" time.

The first hypothesis is probably the least likely. If the "pre-Second Wilcox" surface at West Central School Land Field, section 27, T. 17 N., R. 1 E., were an anticline, production might be expected from wells that penetrated older Simpson formations or the Arbuckle Group. Two such wells were drilled with no shows of hydrocarbons reported. Another weakness of this hypothesis is that it would require appreciable thicknesses of sand (30-40 feet) to be deposited over pre-existing anticlinal structures.

Cross-sections of wells that penetrated the Second Wilcox interval would be necessary to determine which of the remaining hypotheses is the more reasonable. Ideally, such cross-sections could be constructed across an area of Viola-to-Second Wilcox thinning, such as is observed at West Central School Land Field or Southeast Coyle Field; paucity of deep tests precluded construction of such cross-sections. Figure 8 is a stratigraphic cross-section that extends approximately north to south from the eastern flank of Southeast Coyle Field to the southern flank of West Central School Land Field. The Viola-to-Second Wilcox interval is 201 feet in the Funk Exploration No. 1 Downey, NW NE NE section 21, T. 17 N., R. 1 E.; 178 feet in the Sunray No. 3-B Haynes, SE SW NW section 27 of the same township; 185 feet in the Duncan No. 1 Haynes, NW NE NW section 34, also in T. 17 N., R. 1 E. Variation in thickness between the latter two wells is judged to be not significant. The interval between the former two wells varies by 23 feet (201 feet compared to 178 feet, respectively). About 10 feet of the Second Wilcox Sand in the Funk well appears to have been associated with some paleotopographic "build-up"; the Second Wilcox interval (from point "A" to top of sand) in the Funk Well is 96 feet compared to 86 feet in the Sunray well. Although the Second Wilcox Sand interval is thicker in the Funk Well than in the Sunray Well, the Viola-to-Second Wilcox interval (specifically, the Marshall Zone) is thicker in the Funk Well: the top of the Marshall Zone may be an unconformity. The cause(s) of Viola-to-Second Wilcox thinning (more specifically, Marshall-Zone thinning), whether topographic, structural, or a combination of the two, are not understood conclusively, and data necessary for generation of a conclusive explanation do not exist or are not accessible.

Structural Contour Map, Top Second Wilcox Sand

Although similarities between this map (Plate 4) and the structural contour map of the Viola (Plate 9) are evident, significant differences exist locally: (1) There is no structural closure shown at the top of the Viola at Southeast Coyle Field, sections 16 and 21, T. 17 N., R. 1 E., whereas closure on the Second Wilcox is greater than 20 feet. (2) Structural closure on the Viola is approximately 30 feet at West Central School Land Field in sections 22 and 27, T. 17 N., R. 1 E., but closure on the Second Wilcox exceeds 60 feet. (3) On the Viola, structural closure is approximately 10 feet at Northwest Iconium Field in section 33, T. 17 N., R. 1 E. and section 4, T. 16 N., R. 1 E.; on the Second Wilcox, closure is approximately 25 feet. (The greatest closure is found at the latter location, which is outside the study area.) (4) Approximately 30 feet of structural closure on the Viola are shown at Olivet Field, mainly in section 21, T. 17 N., R. 2 E.; more than 65 feet of Second Wilcox closure are interpreted. Structural closure at Olivet Field is against a fault.

The areas described are coincident with areas of significant thinning of the Viola-to-Second Wilcox interval (Plate 10), with the exception of the Southeast Coyle Field. Greatest thinning of the interval is immediately west of the field; this may represent the area of greatest relief on the Second Wilcox (structural, topographic, or a combination) in Ordovician time. Later tilting could have produced the current structural configurations and allowed movement of oil and gas into present positions at Southeast Coyle Field.

Subsurface Faults

Observations of the subsurface maps (Plates 1-11) reveal collectively that the major north-south trending fault system that passes through Ramsey and Coyle Fields cannot be categorized simply as a "normal", "strike-slip", or as a "high-angle reverse" fault. Characteristics of each of these types of faults are manifested along this fault system. The following observations provide evidence as to the most correct categorization for this fault (and possibly of the other major faults in the area):

1. The hade is steep. No evidence indicates that any wells at Ramsey Field cut the fault, despite close well spacing. The fault is believed to cut only one well in Coyle Field, the Magnolia No. 4 Cain, E/2 NE SW section 12, T. 17 N., R. 1 E.

2. "Normal" faulting is indicated by loss of section at two locations. Part of the Hunton section was cut by the fault in the Martgan No. 2 Warren, NW NW NW section 30, T. 18 N., R. 2 E. The Viola Section was faulted-out in the Davis No. 1 Crane, SW NW NE SW section 13, T. 17 N., R. 1 E.

3. "Reverse" type faulting is also indicated at locations along the fault: (a) The Hunton section is repeated in the Martgan No. 1 Warren, SW NW NW section 30, T. 18 N., R. 2 E. (b) The Magnolia No. 4 Cain, E/2 NE SW section 12, T. 17 N., R. 1 E., shows a repeated Sylvan section. (c) Repetition of the Simpson section is documented in

the British-American No. 1 Hughes, NW SW SW section 24, T. 17 N., R. 1 E. (d) The Viola section is repeated in the British-American No. 1 Anderson in the NW NW NW of section 25 of the same township. (These four wells were discussed in the section describing the structural contour map of the Mississippian System.)

4. Evidence of vertical displacement of less than 120 feet (particularly of pre-Mississippian strata) generally is observed along this fault. The "fault" may be discontinuous, as an en echelon fault system, or possibly faulting is not evident because no vertical displacement occurred in some areas (as in parts of section 1 and 24, T. 17 N., R. 1 E.). The latter instance would make detection of the fault by isochore or structural mapping impractical, if not impossible.

Walper (1970) described wrench faulting in the mid-continent. Many characteristics Walper described apply to the fault system under discussion; therefore, "wrench" fault is perhaps the most satisfactorally descriptive term to use. Walper's wrench faults and the Ramsey-Coyle fault system share the following characteristics: (a) They are essentially vertical, so that the fault resembles a high-angle normal or reverse fault. (b) Movement may have been both horizontal and vertical. (c) Movement may have continued over considerable periods of geologic time. Several episodes of faulting may have been required to release stress. (d) Anticlines are recognized to be associated with wrench faults at some localities. The Ramsey and Coyle anticlines are possible examples of such structures.

Wrench-movement of rock could have caused high-angle reverse faults such as those in the area. As tectonic forces moved rocks past one another, their movement might have been impeded locally by frictional resistance; the rocks could have become lodged temporarily. Stress would have continued to build as tectonic forces persisted, eventually resulting in fracturing and allowing dislodged older rocks to slide over younger ones, the classification of which would be that of a local high-angle reverse fault.

Information is insufficient to support or condemn the hypothesis that other faults in the area are wrench faults, although it is probable that they, too, are high-angle faults. (No wells cut the east-west fault that bounds Coyle Field to the north, for example.) In addition, possible evidence of fault rejuvenation in the northwestern portion of T. 17 N., R. 1 E. has previously been cited.

CHAPTER IV

PETROLEUM GEOLOGY, DOLOMITIC ROCKS OF THE HUNTON GROUP

Areas that Produce from the "Dolomitic Hunton"

Oil and gas are produced from porous, dolomitic Hunton (Figure 3) rocks in the following locations within the study area (Figure 5):

1. Ramsey Field
2. North Coyle Field
3. Paradise Field
4. Coyle Field
5. South Coyle Field (sections 24 and 25, T. 17 N., R. 1 E. and referred to as "South Coyle Field No. 1" on Figure 5)
6. South Central School Field (sometimes called South Coyle Field)
7. Southeast Goodnight Field
8. South Goodnight Field
9. South Perkins Field
10. The Earth Energy Resources No. 1 Headquarters, C NW NW section 14, T. 17 N., R. 1 E.

11. Possibly the Rhoades No. 1 Harris, SW NE SW section 30, T. 17 N., R. 2 E. (No electric-log was available for this well; therefore, it was not possible to determine whether production was from the correlative zone.)
12. The Allied Minerals No. 1 Coe, N/2 SE SE section 11, T. 17 N., R. 2 E.
13. The N.F.C. Petroleum Corp. No. 1-28 Cruse, E/2 NW NE section 28, T. 17 N., R. 2 E.

Types of Traps in the Dolomitic Hunton

The map showing configuration of the upper surface of the dolomitic part of the Hunton (Plate 4) shows that oil and gas from dolomitic Hunton rock is produced from the following types of traps: (a) traps that are controlled primarily by faulting, (b) anticlinal traps, and (c) combination structural and stratigraphic traps. Much production from the Hunton actually is from combination traps, although a particular trapping mechanism may have been the more important. For this reason, production from the dolomitic Hunton rock will be classified according to the primary cause of hydrocarbon entrapment.

Traps Caused Primarily by Faulting

As stated previously, anticlinal folds are associated with (and possibly caused by) wrench faults at numerous localities; therefore, it may be a simplification to classify resultant structures as "fault" traps. The largest Hunton fields in the area, Ramsey and Coyle fields, (Figure 5) probably were caused by faulting. Although the Ramsey anticline probably was caused by faulting, migration of hydrocarbons in the Hunton did occur across the north-south fault (Umpleby, 1956). Other Hunton fields caused primarily by faulting include North Coyle, Paradise, South Coyle, and South Central School Land fields (Figure 5). Changes in lithology also may be an important trapping agent at South Central School Land Field (Figure 5; Plates 4 and 6). Absence of porosity on the northeastern side of this field may have prevented further migration of hydrocarbons and restricted them to their present position.

Traps Related to Anticlines

Production from anticlinal traps in Hunton rock mainly is in T. 17 N., R. 2 E. South Goodnight, Southeast Goodnight, and South Perkins fields (Figure 5) are related principally to folding, although stratigraphic conditions also influence production in these three fields. Hunton production is restricted to the southern flank of the structure at South Goodnight, because the Hunton reservoir rock was truncated from the highest part of the structure. Other optimal drilling locations (those in which reservoir rock is both present and above the oil-water contact of approximately -3748 feet) have not been drilled to date.

At South Perkins Field, truncation of the dolomitic Hunton section over the main area of closure was incomplete; however, further northeastward migration of hydrocarbons in the Hunton was restricted by pinch-out of reservoir strata.

Most single-well production from dolomitic Hunton is caused by folding. The Earth Energy Resources No. 1 Headquarters, C NW NW section 14, T. 17 N., R. 1 E., is an example. In these instances, generally production is governed also by local distribution of the porous, dolomitic strata, which may be restricted to the flanks of an anticline in the Hunton. Examples in T. 17 N., R. 2 E. are the N.F.C. Petroleum Corp. No. 1-28 Cruse, E/2 NW NE section 28, and the Rhoads No. 1 Harris, SW NE SW section 30.

Traps Caused by Combination of Structural Geology and Stratigraphy

The Allied Minerals No. 1 Coe, N/2 SE SE section 11, T. 17 N., R. 2 E., produced from the dolomitic part of the Hunton as a result of both its structural and stratigraphic position. Dolomitic Hunton strata were truncated north and east of this well. The distinction between Hunton production from this well and other single-well production from the Hunton in the township is this: In the No. 1 Coe, production is caused both by stratigraphic and structural position, whereas other single-well production is caused by folding, but limited by stratigraphic relationships (extent of the Hunton reservoir strata may be limited due to truncation, for example).

Ages of Traps in the Dolomitic Hunton

The main north-south fault system that caused entrapment of oil and gas in Hunton rocks at Coyle, North Coyle, and South Coyle fields (Figure 5, Plate 4) probably is post-Mississippian pre-Des Moinesian. Ramsey Field is excluded because oil and gas migrated across the fault. The east-west fault that bounds South Central School Land Field to the north (Plate 4) probably also originated during that episode, although earlier stratigraphic containment of hydrocarbons also may have been important.

Oil and gas in the Hunton at South Perkins Field probably was entrapped as a result of two events: (1) post-Hunton pre-Woodford truncation of the porous, dolomitic Hunton prevented further migration to the northeast, and (2) post-Mississippian pre-Des Moinesian faulting may have formed the South Perkins anticline.

Post-Hunton pre-Woodford entrapment of Hunton oil and gas related to anticlines is indicated by local thinning of Hunton strata over anticlinal structures, such as that at Southeast Goodnight Field. Most single-well oil and gas production from Hunton rocks in T. 17 N., R. 2 E., is probably also from post-Hunton pre-Woodford entrapment.

Oil and gas in Hunton rock in the Allied Minerals No.

1 Coe, N/2 SE SE section 11, T. 17 N., R. 2 E., probably was trapped as the result of eastward pinch-out of strata during deposition of Hunton strata, thereby limiting development of porosity.

Age of the hydrocarbon trap at Paradise Field (Figure 5) could not be determined, but was interpreted as having developed after deposition of the Pink limestone (see Plate 1).

CHAPTER V

PETROLEUM GEOLOGY OF THE "SECOND WILCOX" SAND

Areas Where the Second Wilcox Sand Produces Oil and Gas

Oil and gas is produced from the second Wilcox in the following areas (Figure 5):

1. Middle Coyle Field
2. Southeast Coyle Field
3. West Central School Land Field
4. South Coyle Field (section 26, T. 17 N., R. 1 E. and referred to as "South Coyle Field No 2" on Figure 5)
5. South Central School Land Field
6. Ramsey Field
7. Coyle Field
8. West Coyle Field (the Deck No. 2 City of Coyle, NW SE NE section 18, T. 17 N., R. 1 E.)
9. Northwest Iconium Field
10. The Ryan No. 1 Madison, NE NW SW section 34, T. 17 N., R. 1 E. (a separate closure of South Central School Land Field)

Types of Oil and Gas Traps in the Second Wilcox Sand

In the area of study, oil and gas are produced from three types of traps in the Second Wilcox (Plates 10 and 11): (a) traps that are related primarily to faulting, (b) traps related to local thinning of the Viola-to-Second Wilcox interval (which is due principally to thinning of the Marshall Zone), or (c) anticlinal traps of undetermined origin.

Traps Related Primarily to Faulting

Second Wilcox oil and gas production from fault traps occurs at Ramsey, Coyle, and South Central School Land (the portion in section 35, T. 17 N., R. 1 E.) (Figure 5; Plates 10 and 11).

Only two wells at Coyle Field produce from the Second Wilcox. Both are located near the north-south fault, approximately in the area of greatest Second Wilcox structural closure (which is located against the fault). The Second Wilcox does not produce in the southern part of section 2, T. 17 N., R. 1 E., where the structurally highest position of the top of the Second Wilcox is located. One explanation is that the area that produces from the Second Wilcox was structurally highest during the time of migration of oil into the Second Wilcox. The area that is presently highest structurally might have developed its current structural closure after migration.

The two areas are separated by a syncline, which possibly prevented migration of oil and gas to the structurally higher area in section 2. A second explanation is that the north-south fault possibly acted as a seal of oil and gas in the Second Wilcox, whereas the east-west fault could have "leaked" hydrocarbons and allowed them to migrate up-dip. A fault seal can be caused by fault gouge, or by juxtaposition of a permeable bed against a nonpermeable bed.

Production from the Second Wilcox at Ramsey Field is from the structurally highest area, which is on the upthrown side of the main north-south fault. Although the Viola-to-Second Wilcox interval increases in thickness south of Ramsey Field, evidence is insufficient to support the hypothesis that Second Wilcox production at Ramsey is other than fault-related.

Entrapment of oil and gas in the Second Wilcox at South Central School Land Field, in section 35, T. 17 N., R. 1 E. (Plate 11), may be fault-related, although the eastward extent of the fault that bounds the field to the north is not known. Many wells in the section also produce from the Hunton and First Wilcox. Production from those three reservoirs also is documented at Ramsey and Coyle Fields, both of which are fault-related traps.

Traps Related to Thinning of the Marshall Zone

The isochore map of the Viola-to-Second Wilcox interval (Plate 10) indicates that production from the Second Wilcox at West Central School Land, Northwest Iconium, South Coyle (section 26, T. 17 N., R. 1 E.), and Southeast Coyle fields (Figure 5) may be related to thinning of the Viola-to-Second Wilcox interval. In turn, thinning of the latter interval is caused primarily by thinning of the Marshall Zone. Production from the Ryan No. 1 Madison, NE NW SW section 34, T. 17 N., R. 1 E. (Plate 10), also may be related to such thinning. It has been stated previously that maximum thinning of the Marshall Zone in the Southeast Coyle area is west of the oil field; the stratigraphic interval thickens east of the field. The area west of the field probably represents the highest position of the Second Wilcox during the Ordovician; subsequent folding allowed hydrocarbons to migrate to their present position. Therefore, production at Southeast Coyle probably is related to thinning of the Marshall Zone. Southeast Coyle Field differs from West Central School Land and Northwest Iconium fields (Figure 5) mainly in that production from the Second Wilcox does not coincide with the locality of thinnest Viola-to-Second Wilcox interval.

It should be observed that structural closures on the Viola of greater than 30 feet are seldom associated with this type of trap; therefore detection of such traps by seismic methods may prove impractical.

Anticlinal Traps of Undetermined Origin

Oil and gas production from the Second Wilcox that apparently is not related to faulting or to Marshall-Zone thinning is recorded at two locations: Middle Coyle Field (Figure 5) and the Deck Oil No. 2 City of Coyle, NW SE NE section of 18, T. 17 N., R. 1 E., in West Coyle Field (Plate 5). Structural closure on the Second Wilcox is indicated at both locations, but the origin of the structures is not known.

Age of Traps Where Oil and Gas Are Produced from the Second Wilcox

Fault-related traps in the Second Wilcox probably originated after the Mississippian and before the Des Moinesian. However, reservoir fill-up may have continued for a considerable length of time after formation of traps (Umpleby, 1956).

Traps related to thinning of the Marshall Zone probably were formed in the Ordovician, possibly during the "post-Second Wilcox, pre-Marshall Zone" interval of time.

The origin of anticlinal traps, such as those represented at West and Middle Coyle Fields, has not been determined. Evidence of relatively late migration of oil at Ramsey (Umpleby, 1956) suggests that these traps could have formed during the Des Moinesian or later. No evidence of earlier entrapment exists. The isochore map of the Mississippi Limestone (Plate 3) does not show information leading to the conclusion of a post-Mississippian pre-Des Moinesian origin, and the isochore map of the Viola-to-Second Wilcox interval (Plate 10) does not indicate deformation during the Ordovician.

CHAPTER VI

CONCLUSIONS

The principal conclusions of this study are as follows:

1. Only dolomitic Hunton rock in which porosity exceeds 5 percent should be considered as being effectively "porous" (as determined by cross-plotting the density and neutron porosities). If the only logging survey available for a given well is an electric-log, the dolomitic interval should be considered porous if the SP curve is well developed and generally well-rounded, and if invasion is indicated by separation of resistivity curves.
2. Abrupt changes in thickness of Mississippian strata commonly indicate post-Mississippian faulting. Thinning of Mississippian strata generally occurs over anticlinal features.
3. The map showing the configuration of the upper surface of the dolomitic part of the Hunton shows a relationship between the latter surface and production of oil and gas from dolomitic Hunton strata; therefore, this map could be useful in predicting the most advantageous locations for exploration.
4. In T. 17 N., R. 1 E. and the western extremity of T.

17 N., R. 2 E., the dolomitic Hunton zone was developed in progressively younger beds in a generally easterly direction. In this area, final interpretation of the position of the upper surface of the dolomitic zone requires construction of three maps: (a) a structural contour map of the top of the Sylvan Shale, (b) an isochore map of the top of Sylvan-to-top of porous, dolomitic Hunton interval, and (c) a "structural contour" map of the top of the porous zone, derived by the process described in pages 14 through 17.

5. Thinning of the Hunton or its absence over anticlines, shown on the isochore map of the Hunton Group, provides information as to the degree of post-Hunton pre-Woodford deformation the area may have undergone. Post-Hunton pre-Woodford deformation is believed to have occurred in T. 17 N., R. 2 E.; evidence as to whether deformation occurred elsewhere in the study are is more uncertain.

6. The isochore map of the porous, dolomitic part of the Hunton shows that the rock is absent in the eastern, northeastern, western, and northwestern portions of the map.

7. The Viola-to-Second Wilcox interval varies significantly in thickness locally; this causes structural configurations of the Viola and Second Wilcox to differ significantly.

8. As a result of thickness variations of the Viola-to-Second Wilcox interval, the most reliable structural

contour map of the top of the Second Wilcox requires construction of three preliminary maps: (a) a structural contour map of the top of the Viola, (b) an isochore map of the Viola-to-Second Wilcox interval, and (c) a structural contour map of the top of the Second Wilcox (derived by the method described on pages 19 through 23). The technique by which the Second Wilcox structural contour map is derived is useful only in areas where data are sufficiently abundant to make "reliable" interpretations. In the study area, the mapping technique was applied in T. 17 N., R. 1 and 2 E.

9. The derived structural contour map of the top of the Second Wilcox shows a positive correlation between production of oil and gas from the Second Wilcox and the Wilcox's anticlinal structural position; therefore, the derived structural contour map should be useful in predicting the most suitable locations for exploration.

10. Oil and gas is produced from the porous, dolomitic part of the Hunton in traps related primarily to faulting, anticlinal traps, and combination structural and stratigraphic traps.

11. Most traps in the dolomitic part of the Hunton that are related to faulting are post-Mississippian pre-Des Moinesian. Most anticlinal and combination structural-stratigraphic traps are post-Hunton pre-Woodford.

12. Oil and gas production from the Second Wilcox results from the following types of traps: (a) traps related

primarily to faulting, (b) traps related to thinning of the Marshall Zone (determined by thinning of the Viola-to-Second Wilcox interval to facilitate correlations), and (c) anticlinal traps of undetermined origin.

13. Most fault-related traps in the Second Wilcox are post-Mississippian pre-Des Moinesian. Traps related to thinning of the Marshall Zone were formed in the Ordovician, possibly in "post-Second Wilcox, pre-Marshall Zone" time. Other anticlinal traps may be Des Moinesian or younger.

14. The cause(s) of thinning of the Marshall Zone cannot be determined with existing data. Additional subsurface studies and data are necessary to provide more conclusive evidence as to the timing, duration, and existence of erosional periods that may have existed during or shortly after "Marshall Zone" time.

15. In fields that produce from the Second Wilcox where traps are related to thinning of the Marshall Zone, structural closure on the top of the Viola generally is less than 30 feet. Detection of such traps by seismic methods may not be practical.

REFERENCES CITED

Akmal, M. G., 1953, Subsurface geology of northeast, Lincoln and southeast Payne Counties, Oklahoma: Shale Shaker, v. 3, pp. 5-16.

Albano, M. A., 1975, Subsurface stratigraphic analysis "Cherokee" Group (Pennsylvanian), northeast Cleveland County, Oklahoma: Shale Shaker, v. 25, pp. 94-137.

Amsden, T. W., 1960, Stratigraphy and paleontology of the Hunton Group in the Arbuckle Mountain region, part 6, Hunton stratigraphy: Okla. Geol. Survey Bull. 84, 311 p.

Amsden, T. W., 1975, Hunton Group (Late Ordovician, Silurian, and Early Devonian) in the Arkoma Basin of Oklahoma: Okla. Geol. Survey Bull. 121, 214 p.

Asquith, George, 1982, Basic well log analysis for geologists: Am. Assoc. Petroelum Geologists, Methods in Exploration Series, 216 p.

Bauernfeind, P. E., 1980, The Misener Sandstone in portions of Lincoln and Creek Counties, Oklahoma: Shale Shaker, v. 30, pp. 173-185.

Carver, G. E., Jr., 1948, Arcadia-Coon Creek pool, Oklahoma and Logan Counties, Oklahoma, Structure of typical American oil fields, a symposium on the relation of oil accumulation to structure: Am. Assoc. Petroleum Geologists, v. 3, pp. 319-340.

Cole, J. A., 1955, Subsurface geology of east-central Lincoln County, Oklahoma: Shale Shaker Digest, v. 2, pp. 79-96.

Cronenwett, C. E., 1956, A subsurface study of the Simpson Group in east-central Oklahoma: Shale Shaker, v. 7, pp. 8-34.

Ermey, W. R., Log analyst, personal interview. Tulsa, Oklahoma, October 21, 1983.

Frost, V. L., 1940, Ramsey oil pool, Payne County, Oklahoma: Bull. of the Am. Assoc. Petroleum Geologists, v. 24, pp. 1995-2005.

Graves, J. M., 1955, Subsurface geology of a portion of Lincoln and Payne Counties, Oklahoma: Shale Shaker, v. 6, pp. 6-37.

Hilchie, D. W., 1978, Applied openhole log interpretation: Golden, Colorado, 161 p.

Hollrah, T. L., 1977, Subsurface lithostratigraphy of the Hunton Group, in parts of Payne, Lincoln, and Logan Counties, Oklahoma: M.S. thesis, Oklahoma State University, 63 p.

Huffman, G. C., 1958, Geology of the flanks of the Ozark Uplift, northeastern Oklahoma: Oklahoma Geological Survey Bull. 77, 281 p.

Johnson, K. S., and Denison, R. E., 1973, Igneous geology of the Wichita Mountains and economic geology of Permian rocks in southwest Oklahoma: Geol. Soc. Amer. Geol. Survey, 33 p.

Johnson, R. K., 1958, Subsurface geology of northeast Cleveland County, Oklahoma: Shale Shaker, v. 9, pp. 4-19.

McGee, D. A., and Jenkins, H. D., 1946, West Edmond oil field, central Oklahoma: Am. Assoc. Petroleum Geologists Bull., v. 30, p. 1803.

McKenny, J. W., 1953, Subsurface geology of northeastern Logan County, Oklahoma: Shale Shaker, v. 3, pp. 6-15.

Stringer, C. P., Jr., 1957, Subsurface geology of western Payne County, Oklahoma: Shale Shaker, v. 7, pp. 3-20.

Umpleby, S. S., 1956, Faulting, accumulation, and fluid distribution in Ramsey pool, Payne County, Oklahoma: Am. Assoc. Petroleum Geologists Bull., v. 40., pp. 122-139.

Verish, N. P., 1979, Reservior trends, depositional environments, and petroleum geology of "Cherokee" sandstones in T. 11-13 R., R. 4-5 E., central Oklahoma: Shale Shaker, v. 29, pp. 209-236.

Walper, J. W., 1970, Wrench faulting in the Mid-Continent: Shale Shaker, v. 21, pp. 32-40.

Wengard, S. A., 1948, Fervale Viola limestones of south-central Oklahoma: Bull. Am. Assoc. Petroleum Geologists, v. 12, pp. 2183-2253.

VITA

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Candidate for the Degree of

Master of Science

Thesis: TECHNIQUES FOR MAPPING PETROLEUM RESERVOIRS IN THE HUNTON GROUP AND THE "SECOND WILCOX SAND", IN PARTS OF LINCOLN, LOGAN, AND PAYNE COUNTIES, OKLAHOMA

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Biographical:

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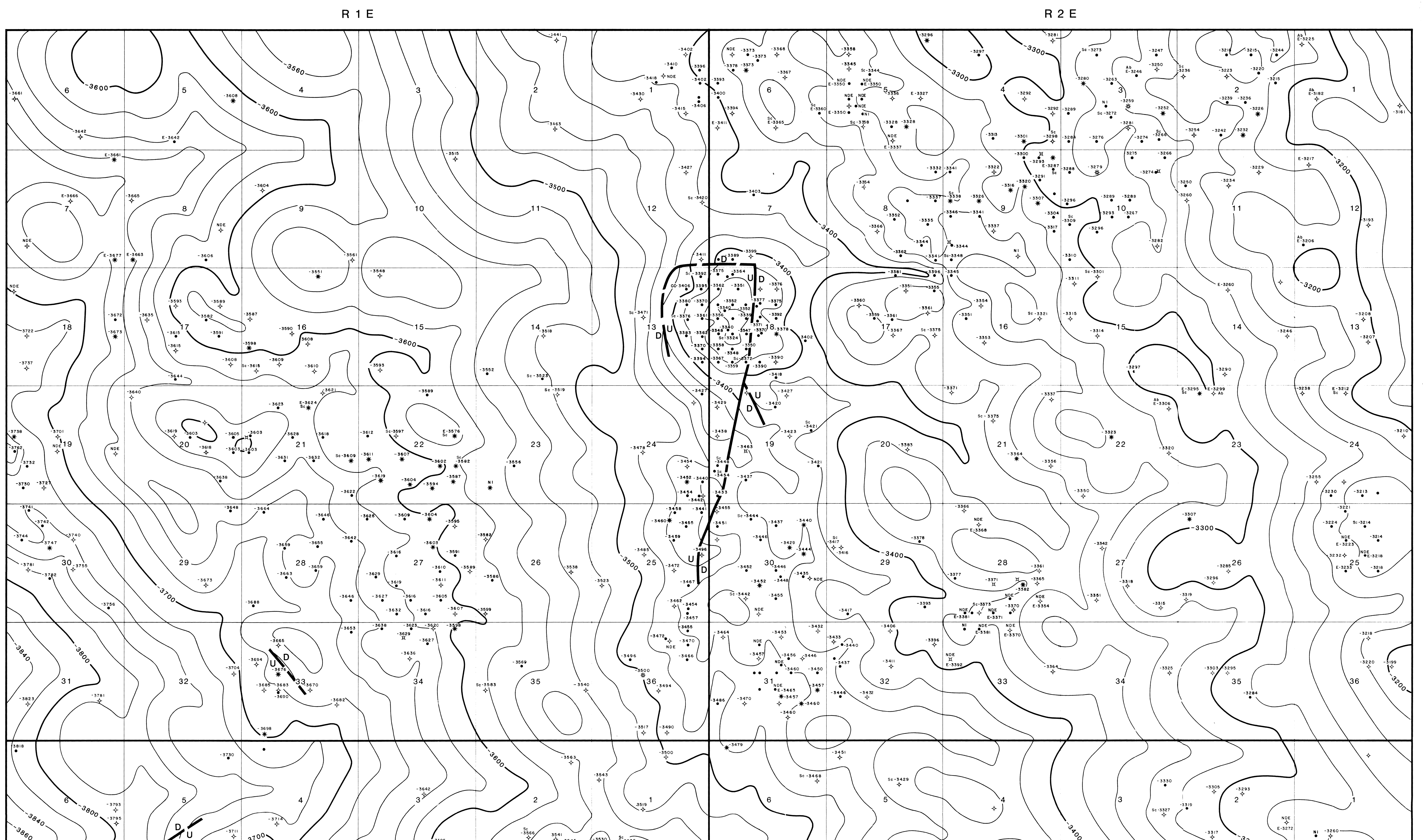
Education: Graduated from Bixby High School, Bixby, Oklahoma, in May, 1968, received Bachelor of Science Degree in Biology from Oklahoma State University in December, 1972.

Professional Experience: Research Assistant, Department of Geology, Oklahoma State University, August, 1983, to December, 1983



LEGEND

Ab	Absent
CC	Oklahoma Corporation Commission Data
E	Estimated
Sc	Scout Ticket Data
NDE	Not Deep Enough
NI	No Information
	Fault
-3512	Subsea Value, Top Pink Limestone

PLATE 1

Structural Contour Map
TOP PINK LIMESTONE

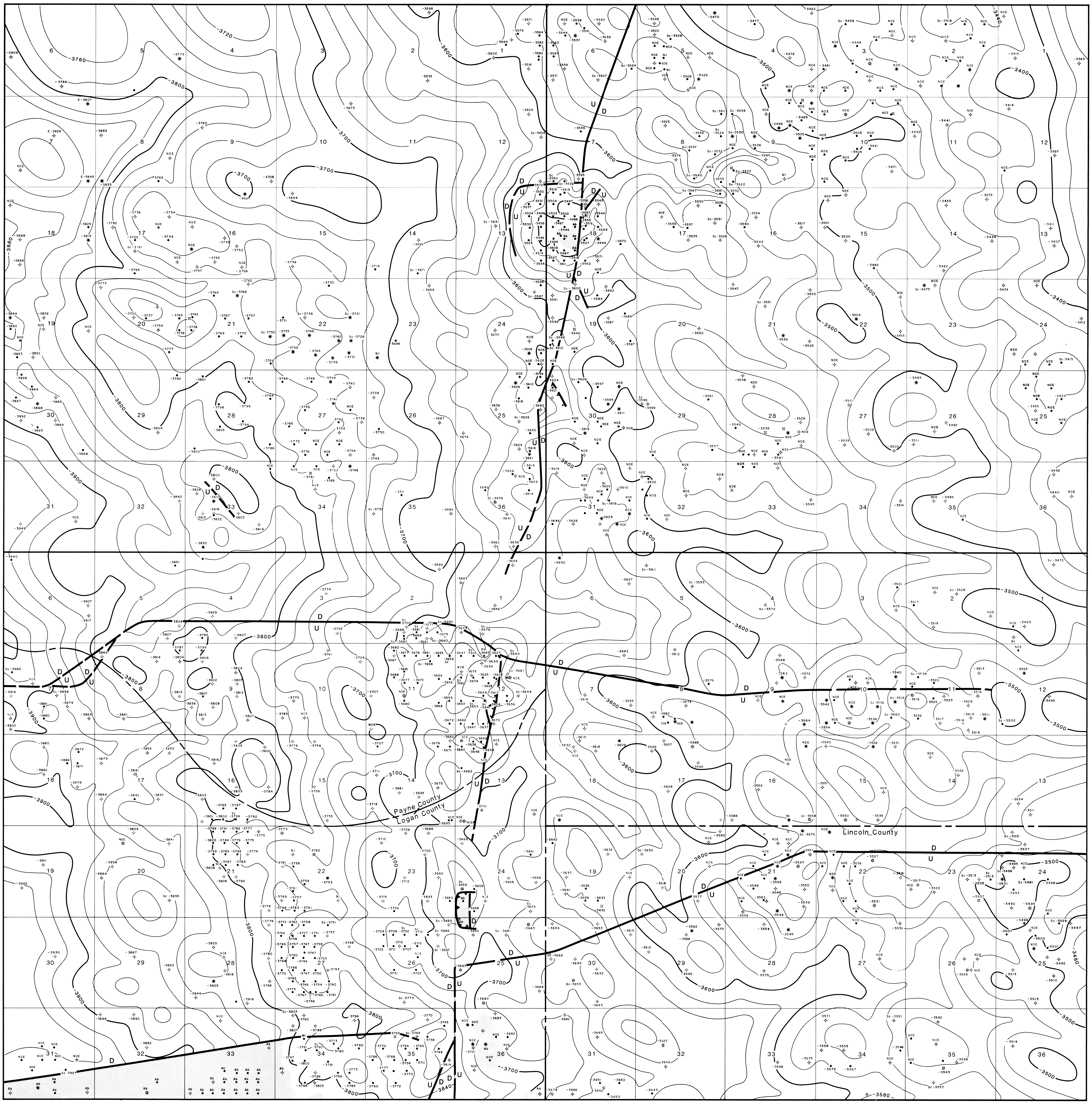
T 17 and 18N, R 1 and 2E
Payne, Lincoln and Logan Counties, Oklahoma

Contour Interval = 20 Feet

0 2000' 4000'

Scale: 1 inch = 2000 feet

Dan Swartz 1987



LEGEND

Ab	Absent
CC	Oklahoma Corporation Commission Data
E	Estimated
Sc	Scout Ticket Data
NDE	Not Deep Enough
NI	No Information
	Fault
-3653	Subsea Value, Top Mississippi Lime
	Mississippi Limestone Absent

PLATE 2

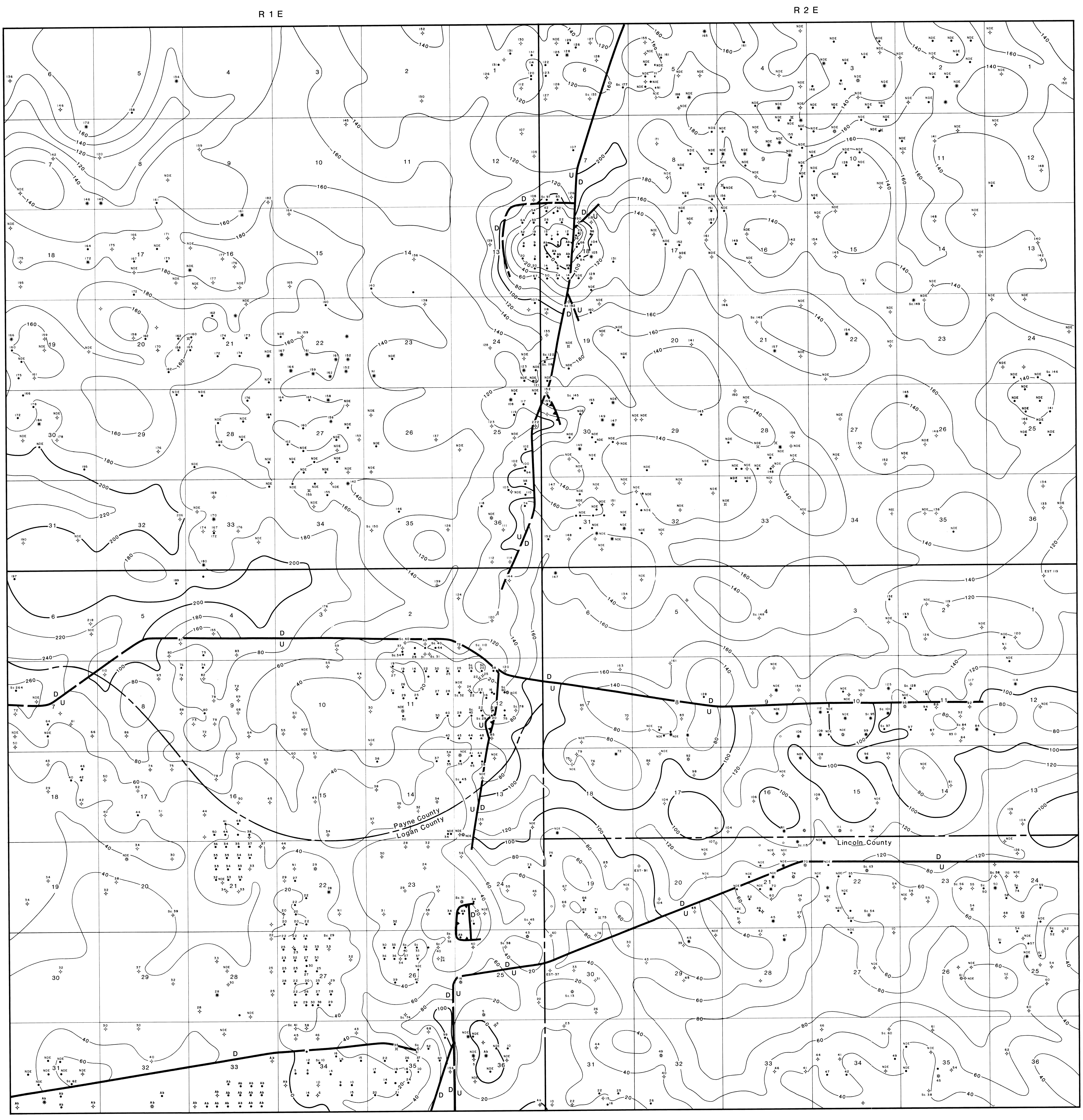
Structural Contour Map
TOP MISSISSIPPI LIMESTONE

T 17 and 18N, R 1 and 2E
Payne, Lincoln and Logan Counties, Oklahoma

Contour Interval = 20 Feet

0 2000' 4000'
Scale: 1 inch = 2000 feet

Dan Swartz 1987



LEGEND

Ab Absent
CC Oklahoma Corporation Commission Data
E Estimated
Sc Scout Ticket Data
NDE Not Deep Enough
NI No Information
Fault
37 Thickness of Mississippi Limestone
Mississippi Limestone Absent

PLATE 3

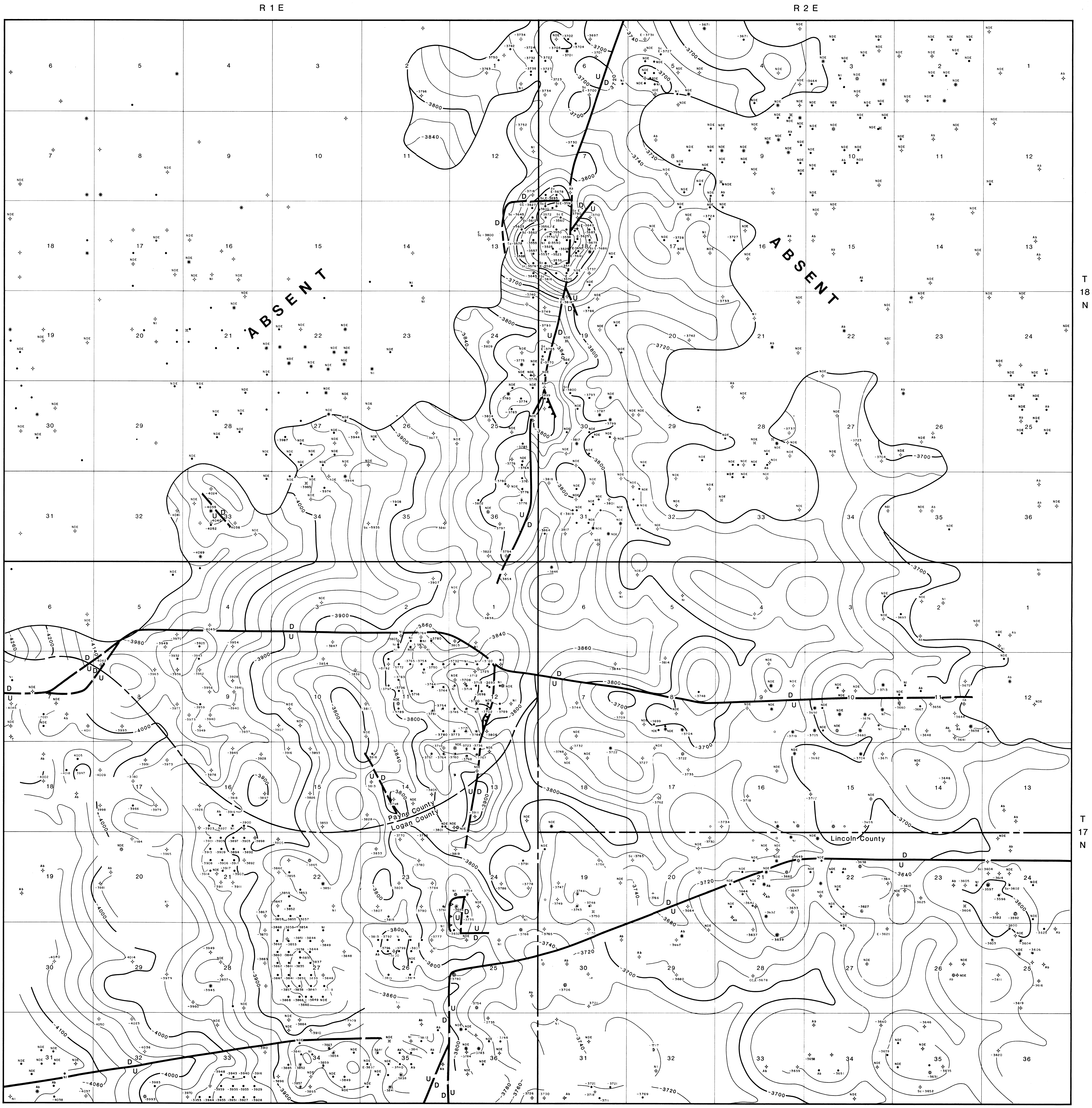
Isochore Map
MISSISSIPPI LIMESTONE
with POST-MISSISSIPPIAN
PRE-DES MOINESIAN FAULT TRACES

T 17 and 18N, R 1 and 2E
Payne, Lincoln and Logan Counties, Oklahoma

Contour Interval = 20 Feet

0 2000' 4000'
Scale: 1 inch=2000 feet

Dan Swartz 1987



LEGEND

Ab Absent
CC Oklahoma Corporation Commission Data
E Estimated
Sc Scout Ticket Data
NDE Not Deep Enough
NI No information

Fault

-3711 Subsea Value, Top Porous, Dolomitic Hunton

Production from Porous, Dolomitic Interval

Porous, Dolomitic Hunton Absent Locally

PLATE 4

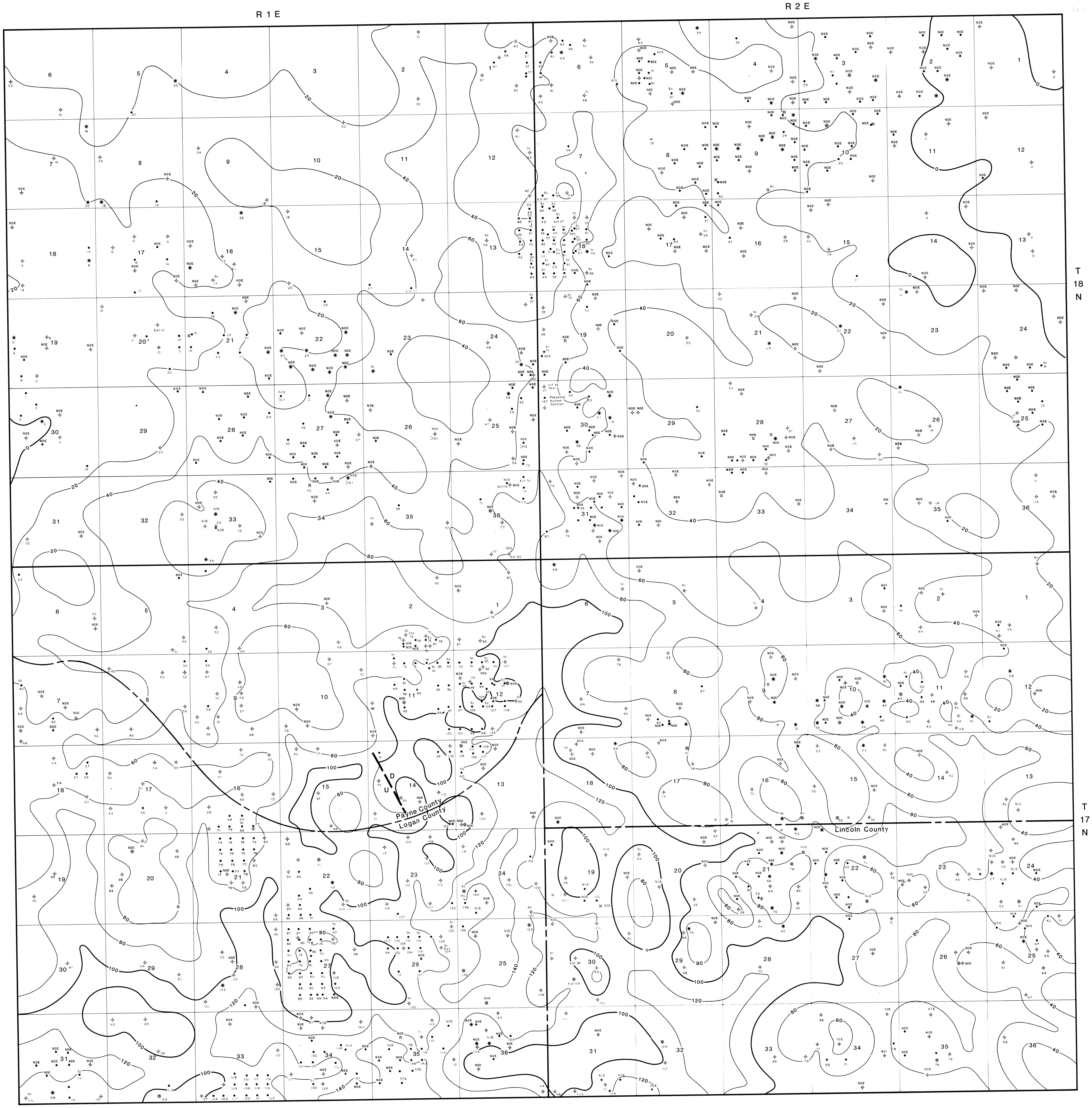
MAP SHOWING CONFIGURATION
of UPPER SURFACE of POROUS,
DOLOMITIC PART of HUNTON GROUP

T 17 and 18N, R 1 and 2E
Payne, Lincoln and Logan Counties, Oklahoma

Contour Interval = 20 Feet

0 2000' 4000'
Scale: 1 inch = 2000 feet

Dan Swartz 1987



LEGEND

Ab Absent
CC Oklahoma Corporation Commission Data
Est Estimated
Sc Scout Ticket Data
NDE Not Deep Enough
NI No Information
Fault

71 Thickness of Hunton Group

PLATE 5

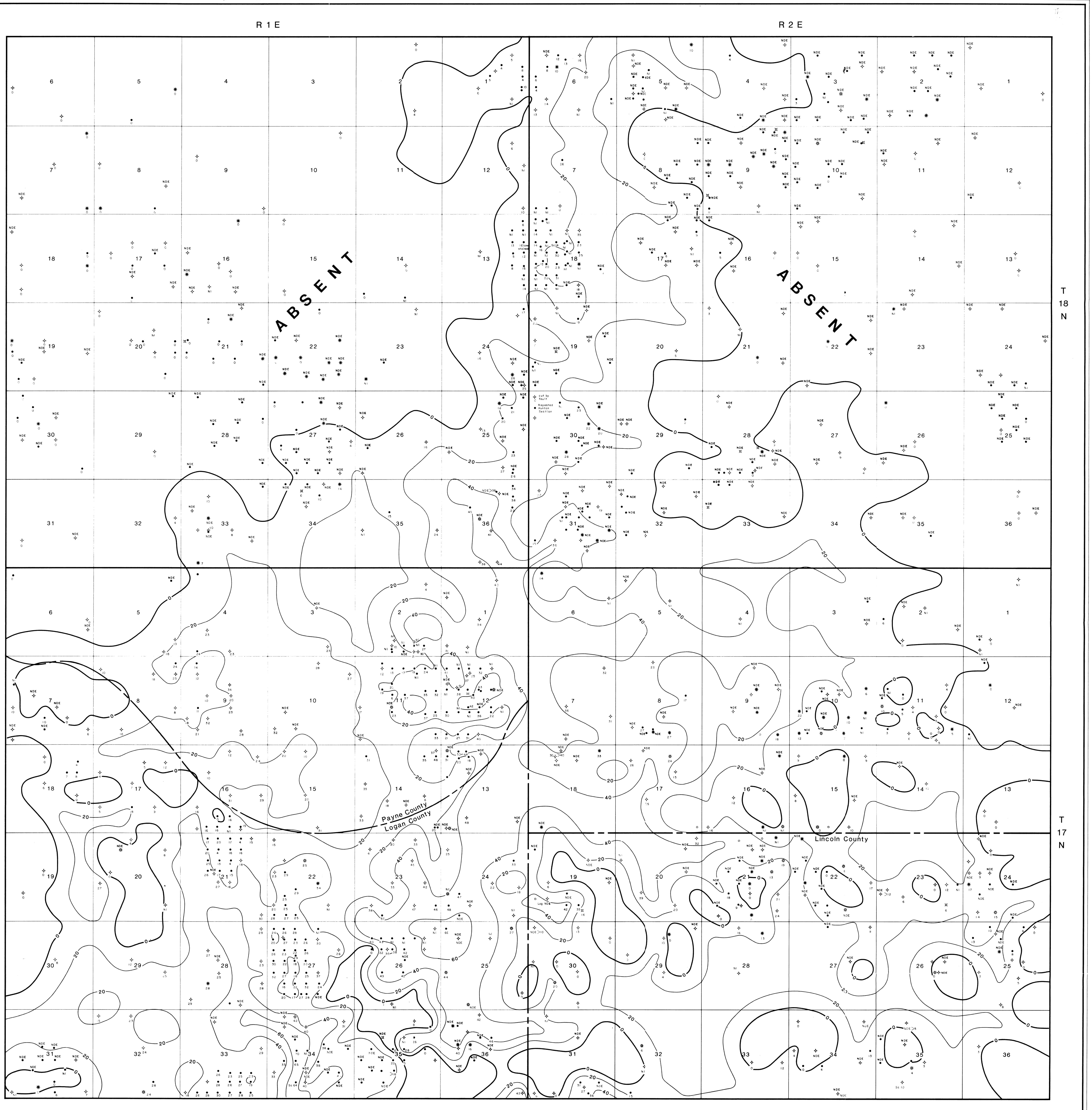
Isochore Map
HUNTON GROUP

T 17 and 18N, R 1 and 2E
Payne, Lincoln and Logan Counties, Oklahoma

Contour Interval = 20 Feet

0 2000' 4000'
Scale: 1 inch = 2000 feet

Dan Swartz 1987



LEGEND

Ab Absent
CC Oklahoma Corporation Commission Data
E Estimated
Sc Scout Ticket Data
NDE Not Deep Enough
NI No Information

33 Thickness of Porous, Dolomitic Hunton

Porous, Dolomitic Hunton Absent Locally

PLATE 6

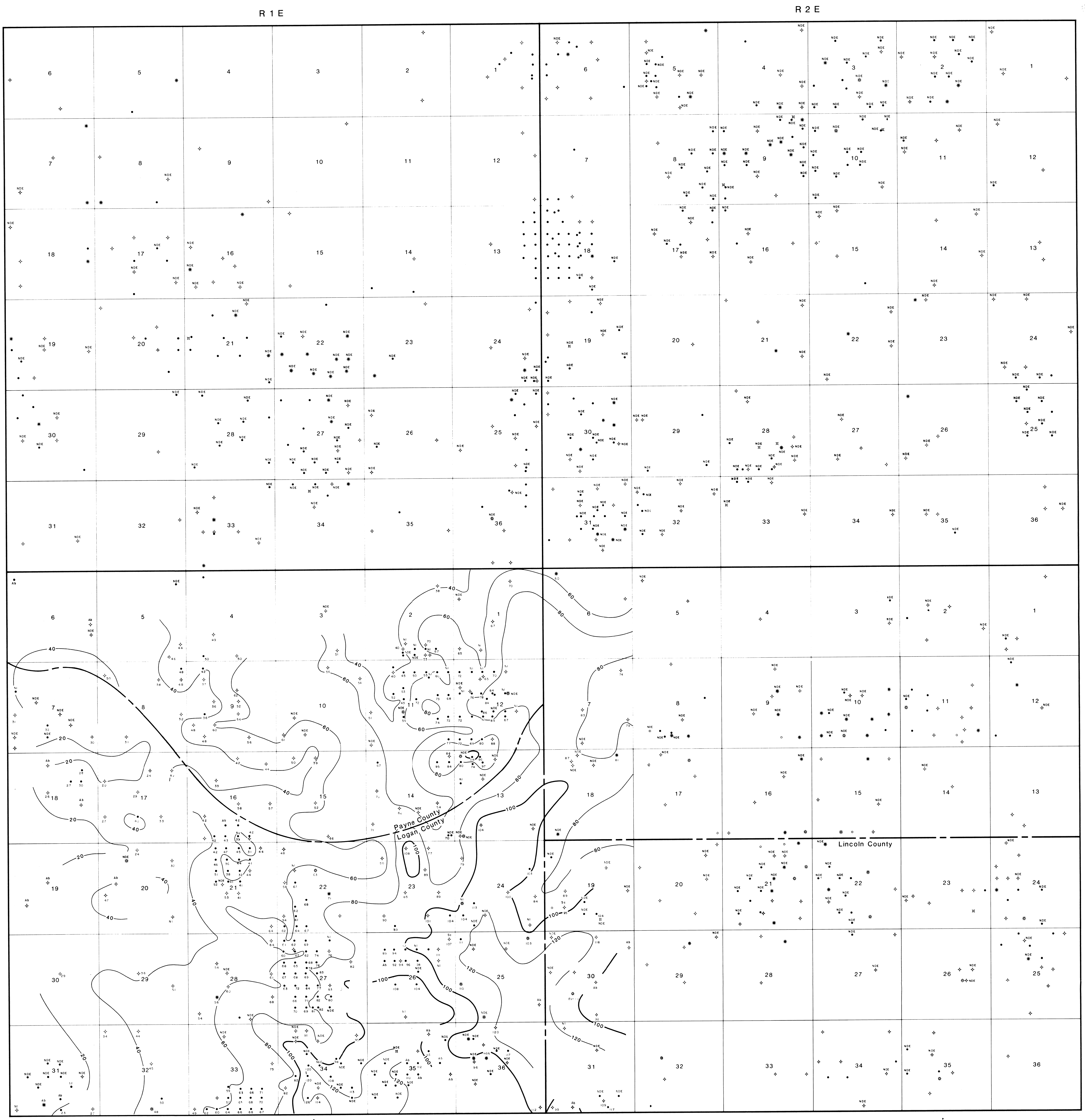
Isochore Map
POROUS, DOLOMITIC HUNTON

T 17 and 18N, R 1 and 2E
Payne, Lincoln and Logan Counties, Oklahoma

Contour Interval = 20 Feet

0 2000' 4000'
Scale: 1 inch = 2000 feet

Dan Swartz 1987



LEGEND

Ab Absent
CC Oklahoma Corporation Commission Data
E Estimated
Sc Scout Ticket Data
NDE Not Deep Enough
NI No Information

89 Top Sylvan Shale to Top Porous, Dolomitic Hunton Interval

Porous, Dolomitic Hunton Absent

PLATE 7

Isochore Map
TOP SYLVAN SHALE-to-
TOP POROUS, DOLOMITIC HUNTON

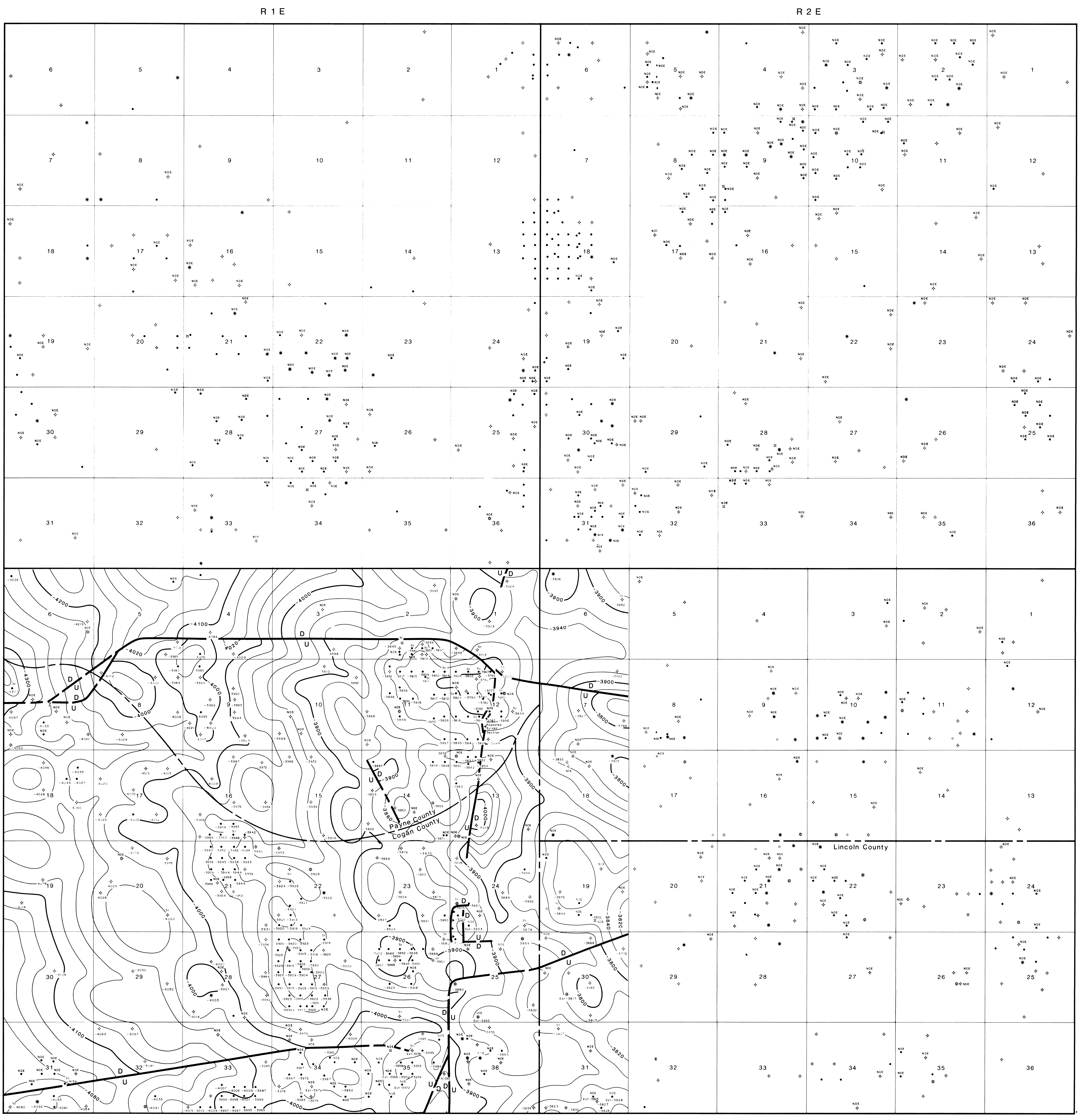
T 17 and 18N, R 1 and 2E
Payne, Lincoln and Logan Counties, Oklahoma

Contour Interval = 20 Feet

0 2000' 4000'

Scale: 1 inch = 2000 feet

Dan Swartz 1987



LEGEND

Ab Absent
CC Oklahoma Corporation Commission Data
Est Estimated
Sc Scout Ticket Data
NDE Not Deep Enough
NI No Information
Fault

-3918 Subsea Value, Top Sylvan Shale

PLATE 8

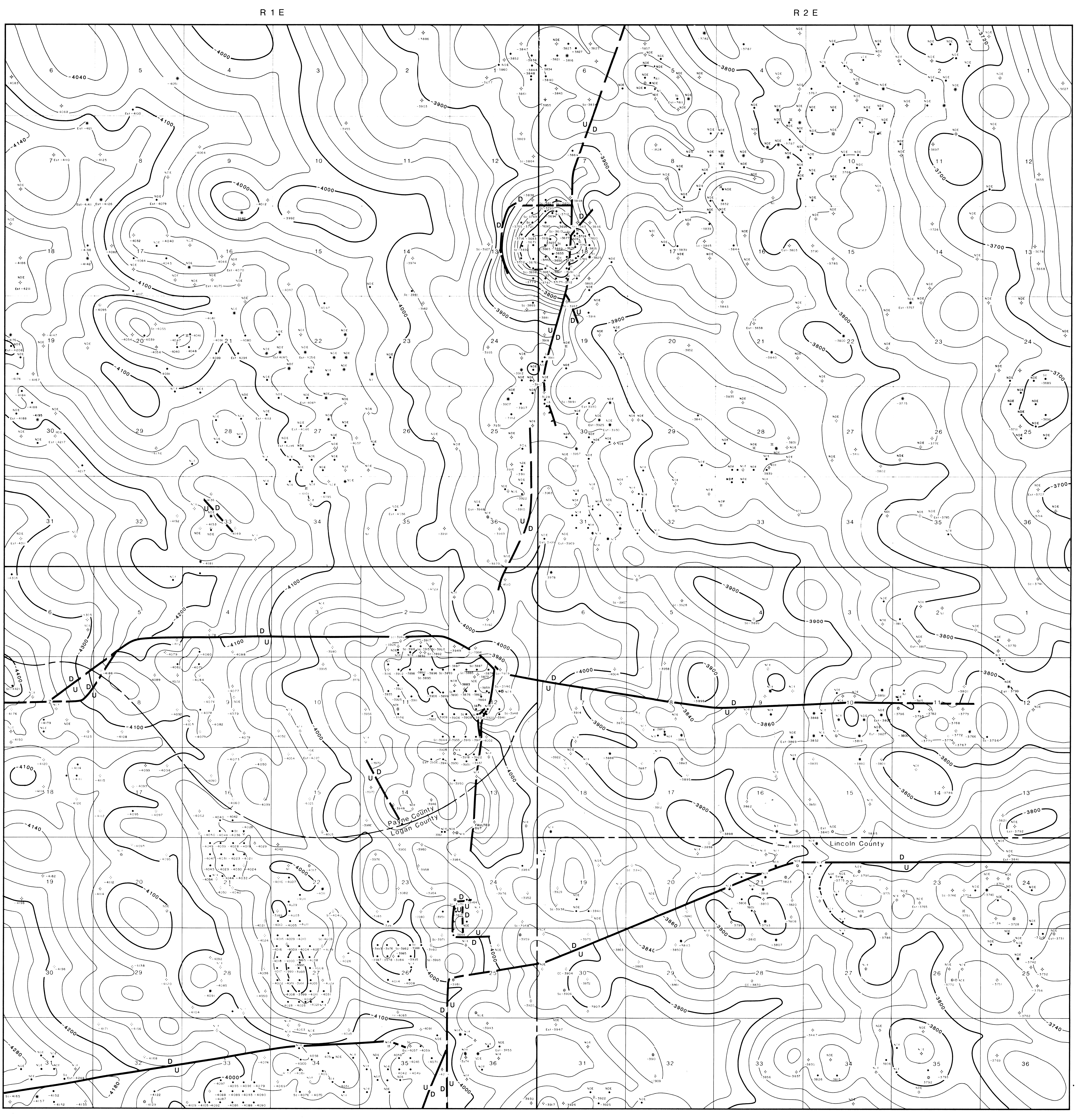
Structural Contour Map
TOP SYLVAN SHALE

T 17 and 18N, R 1 and 2E
Payne, Lincoln and Logan Counties, Oklahoma

Contour Interval = 20 Feet

0 2000' 4000'
Scale: 1 inch = 2000 feet

Dan Swartz 1987



LEGEND

Ab Absent
CC Oklahoma Corporation Commission Data
Est Estimated
Sc Scout Ticket Data
NDE Not Deep Enough
NI No Information

Fault

-3909 Subsea Value, Top Viola Limestone

PLATE 9

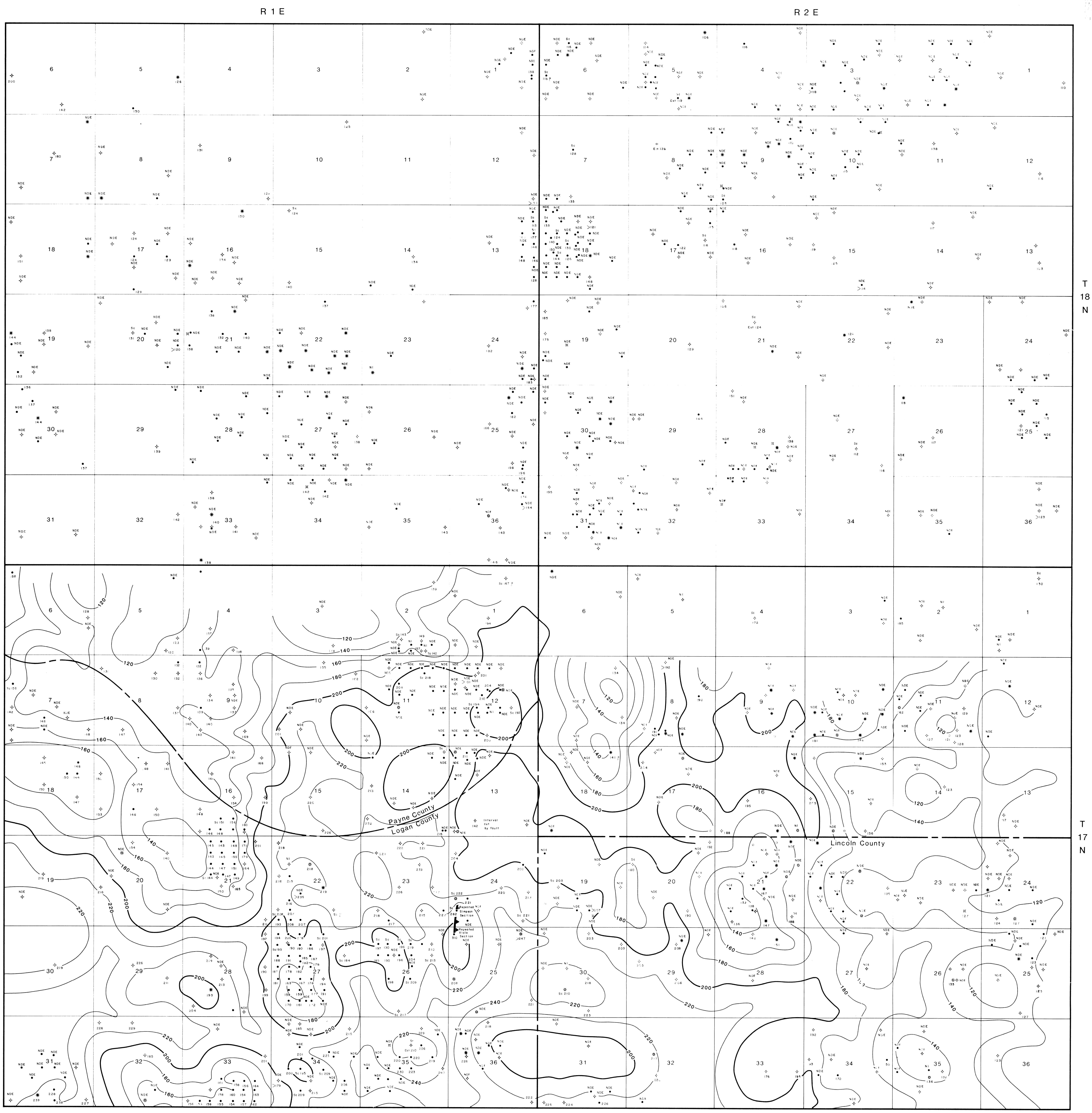
Structural Contour Map
TOP VIOLA LIMESTONE

T 17 and 18N, R 1 and 2E
Payne, Lincoln and Logan Counties, Oklahoma

Contour Interval = 20 Feet

0 2000' 4000'
Scale: 1 inch = 2000 feet

Dan Swartz 1987



LEGEND

- Ab Absent
- CC Oklahoma Corporation Commission Data
- Est Estimated
- Sc Scout Ticket Data
- NDE Not Deep Enough
- NI No Information
- Fault
- 224 Top Viola Lime to Top Second Wilcox Sand

PLATE 10

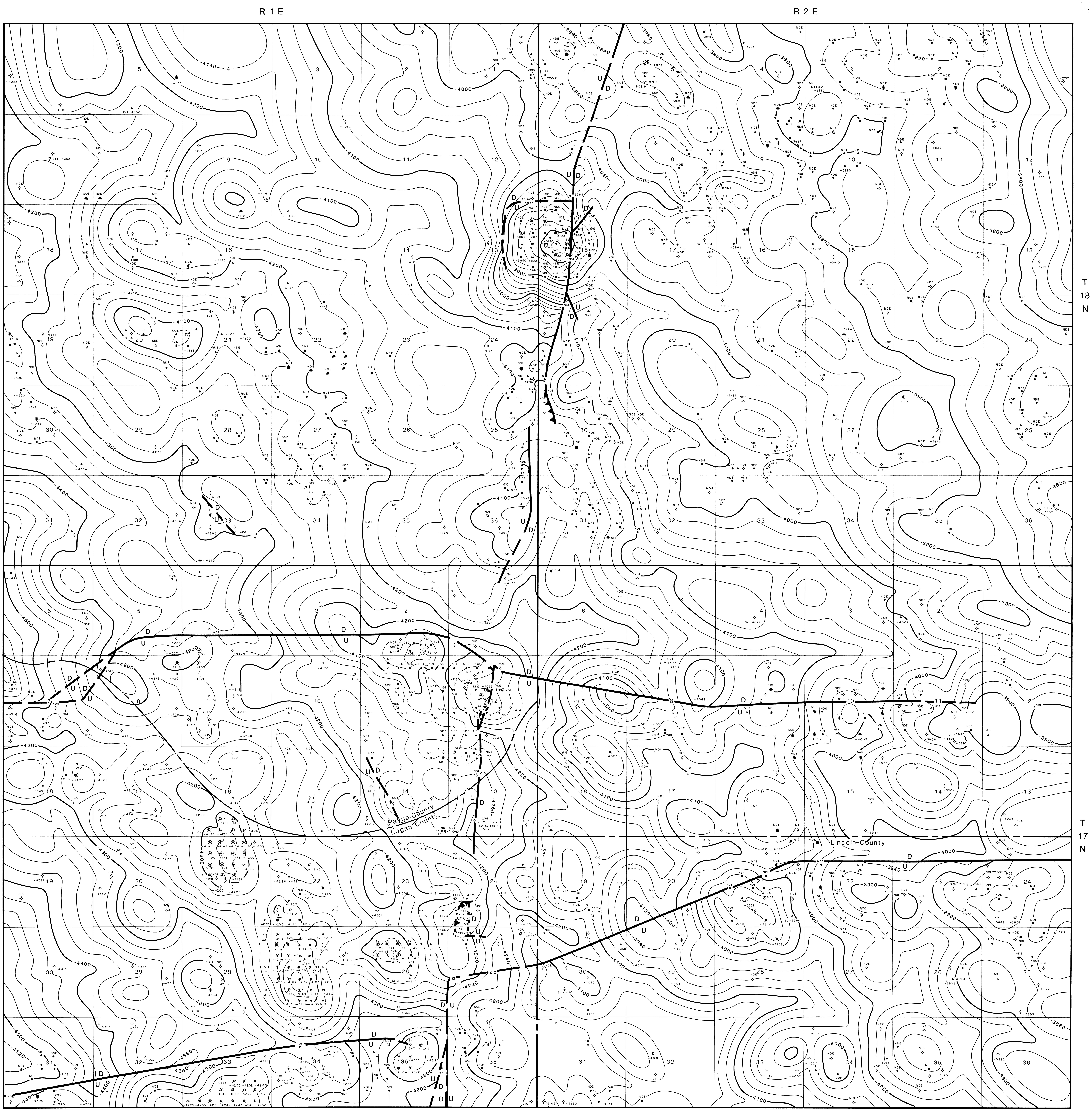
Isochore Map
TOP VIOLA LIMESTONE-to-
TOP SECOND WILCOX SAND

T 17 and 18N, R 1 and 2E
Payne, Lincoln and Logan Counties, Oklahoma

Contour Interval = 20 Feet

0 2000' 4000'
Scale: 1 Inch = 2000 feet

Dan Swartz 1987



LEGEND

Ab Absent
CC Oklahoma Corporation Commission Data
Est Estimated
Sc Scout Ticket Data
NDE Not Deep Enough
NI No Information

Fault

-3985 Subsea Value, Top Second Wilcox Sand

Second Wilcox Production

PLATE 11

Structural Contour Map
TOP SECOND WILCOX SAND

T 17 and 18N, R 1 and 2E
Payne, Lincoln and Logan Counties, Oklahoma

Contour Interval = 20 Feet

0 2000' 4000'

Scale: 1 inch = 2000 feet

Dan Swartz 1967

1. Pawnee Petroleum Co. No. 1 Steil
   C SW SE Sec. 6,T 18 N,R 1 E.
2. Bogert Oil Co. No. 1-5 Jack
   SE SE SW Sec. 5,T 18 N,R 1 E
3. Bill Ligon Drilling Co. and Belco Pet. Cor No. 1 Murphy
   NE NE SE Sec. 5,T 18 N,R 1 E
4. Powel Briscoe, Inc. No. 1 Neundorf
   NE NW NE Sec. 2,T 18 N,R 1 E.
5. North American Petroleum Co. No. 1 Monr
   SW SW NE Sec. 1,T 18 N,R 1 E.
6. North American Petroleum Co. No. 1 Snow
   NE NE SE Sec. 1,T 18 N,R 1 E.
7. R.L. Parker No. 2 Knight
   NE SW NW Sec. 6,T 18 N,R 2 E.
8. Robert Palmer and Mohawk Drilling Co. No Newport
   SW NW NE Sec. 6,T 18 N,R 2 E.
9. Stanton Energy, Inc. No. 1 Jody
   SW NE NW Sec. 4,T 18 N,R 2 E.
10. Wilcox Oil Co. No. 1 Sam
    SW NW SW Sec. 3,T 18 N,R 2 E.
11. Parker-Duerr Drilling Co. No. 1 Marone
    C NE SE Sec. 1,T 18 N,R 2 E.

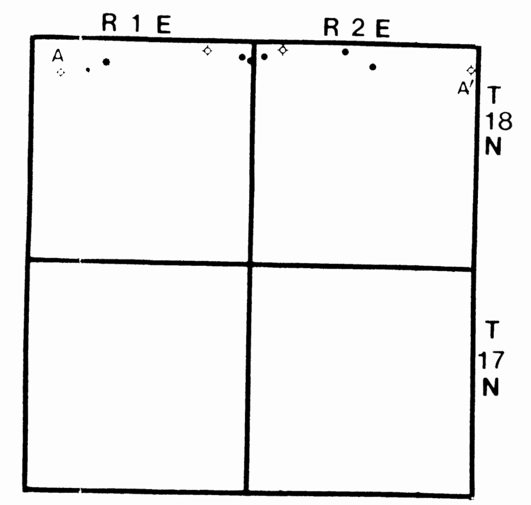


PLATE 12

STRATIGRAPHIC CROSS SECTION A–A′

DATUM: TOP SYLVAN SHALE
Showing Porous, Dolomitic Part of Hunton Group

Daniel H. Swartz 1986

1. Tri Energy Oper.,Inc. No. 1 Faulkner
SW SW NW Sec. 19,T 18 N,R 1 E.
2. Bogert Oil Co. No. 1-20 Gunkel
NW NW NW Sec. 20,T 18 N,R 1 E.
3. Blackwell Oil and Gas Co. No. 1 Gunkel
SE SE NE Sec. 20,T 18 N,R 1 E.
4. Mid-Continent Petroleum Corp. No. 1 Wetzel
SE SW NE Sec. 21,T 18 N,R 1 E.
5. Beard Oil Co. No. 2 Bentley
C NE SW Sec. 22,T 18 N,R 1 E.
6. Five Star Drilling Co. No. 1 Eckert
NE NE SW Sec. 24,T 18 N,R 1 E.
7. Stanton Energy, Inc. No. 1 Ramsey
SW NW NW Sec. 19,T 18 N,R 2 E.
8. Massey and Moore No. 1 Poling
NE NW SE Sec. 20,T 18 N,R 2 E.
9. Service Drilling Co. No. 1-21 Wolfe
C NW SE Sec. 21,T 18 N,R 2 E.
10. Harrison Oil Co. No. 1 Herod
SE SE NW Sec. 22,T 18 N,R 2 E.

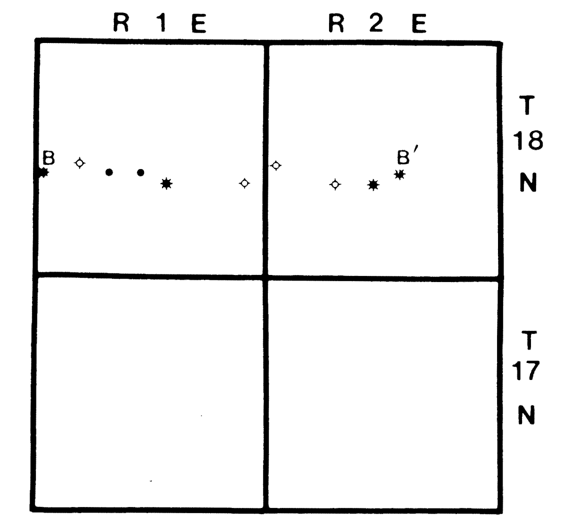


PLATE 13

STRATIGRAPHIC CROSS SECTION B-B′

DATUM: TOP SYLVAN SHALE
Showing Porous, Dolomitic Part of Hunton Group

Daniel H. Swartz 1986

1. Dirickson and Lewis Oil Co. No. 1 Lantz
   NW NW NW Sec. 6,T 17 N,R 1 E.
2. C.L. McMahon, Inc. No. 1 Maryott
   NE NE SE Sec. 6,T 17 N,R 1 E.
3. Fordee-Rhoades Oil Co. No. 3 Goble
   NE SE SE Sec. 5,T 17 N,R 1 E.
4. Kingwood Oil Co. No. 1 Goble
   SW NE SW Sec. 4,T 17 N,R 1 E.
5. Massey and Massey No. 1 Longan
   E/2 SW SE Sec. 3,T 17 N,R 1 E.
6. Massey and Massey No. 3 Cundiff
   NE SW SE Sec. 2,T 17 N,R 1 E.
7. Ryan Oil Co. No. 1 Smalley
   NE NE SW Sec, 1,T 17 N,R 1 E.
8. Graham Petroleum No. 1-6 Ringwald
   NE NW NW Sec. 6,T 17 N,R 2 E.
9. Petroleum Reserves Corp. No. 2-1 Sasser
   NW SE SW Sec. 2,T 17 N,R 2 E.

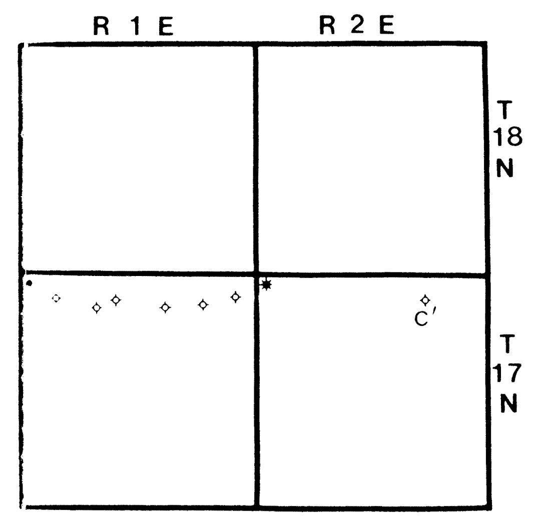


PLATE 14

STRATIGRAPHIC CROSS SECTION C–C′

DATUM: TOP SYLVAN SHALE
Showing Porous, Dolomitic Part of Hunton Group

Daniel H. Swartz 1986

1. Deck Oil Co. No. 2 City of Coyle
   NW SE NE Sec. 18,T 17 N,R 1 E.
2. Johnson and Gill and Arthur Ramsey No. 1 Ramsey
   SE NW SE Sec. 17,T 17 N,R 1 E.
3. The Feagin Co. No. D-2 State
   SW SE SW Sec. 16,T 17 N,R 1 E.
4. Hall-Jones Oil Corp. No. 1 Jacobs
   SW SW SE Sec. 15,T 17 N,R 1 E.
5. Percy Butler No. 1 Myers
   NW SW SW Sec. 14,T 17 N,R 1 E.
6. Emerald Operating Co. No. 1 Goodnight
   NE SW Sec. 14,T 17 N,R 1 E.
7. Mohawk Drilling Co. No. 1 Parks
   NW NE SE Sec. 14,T 17 N,R 1 E.
8. Davis Oil Co. No. 1 Crane
   SW NW SE SW Sec. 13,T 17 N,R 1 E.
9. Atlantic Refining Co. and Mid-Continent No. 1 O'Hara
   W/2 NE NW Sec. 18,T 17 N,R 2 E.
10. Rhoades Oil Co. No. 1-3 Crystal
    NW NE NE Sec. 18,T 17 N,R 2 E.
11. Santa Fe Energy No. 1 Scott
    NW NE Sec. 17,T 17 N,R 2 E.
12. F.P. Menager and Portable Drilling Co. No. 1 Westfall
    NW NW SW Sec. 15,T 17 N,R 2 E.
13. Earth Energy Resources No. 3 Tohee
    NW NE Sec. 15,T 17 N,R 2 E.
14. Anderson Oil and Gas No. 1 Kent
    NE NE Sec. 15,T 17 N,R 2 E.
15. The Wil-Mc Corp. No. 1 Sadler
    SW SW NE Sec. 14,T 17 N,R 2 E.
16. Jefferson-Williams Energy Corp. No. 1 Ferguson
    C SW Sec. 13,T 17 N,R 2 E.

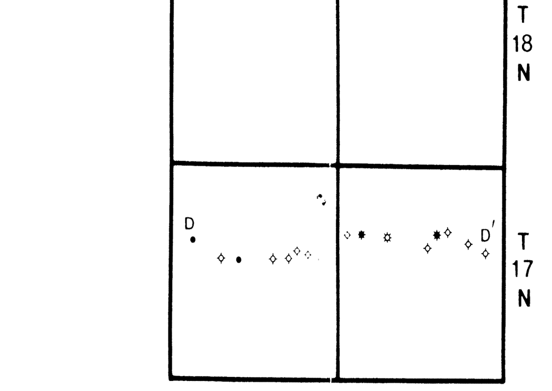
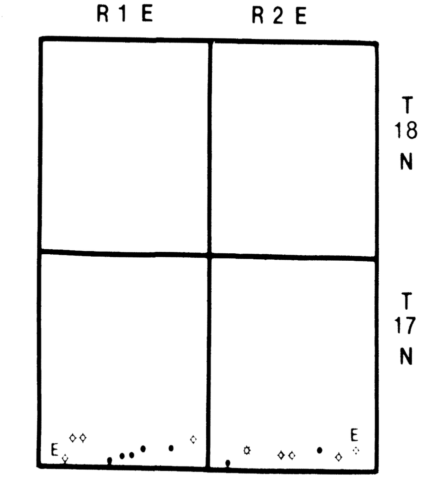


PLATE 15

STRATIGRAPHIC CROSS SECTION D-D′

DATUM: TOP SYLVAN SHALE
Showing Porous, Dolomitic Part of Hunton Group

Daniel H. Swartz 1986



1. Jordan Petroleum Co. No. 1 Biggs
SE SE SE Sec. 31,T 17 N,R 1 E.
2. Garr-Wooley No. 1 Black
NW NW NW Sec. 32,T 17 N,R 1 E.
3. Canadian Exploration Corp. No. 32-1 Ledington
NE NE NW Sec. 32,T 17 N,R 1 E.
4. Deck Oil Co. No. A-2 Ball
SE SE SW Sec. 33,T 17 N,R 1 E.
5. Deck Oil Co. No. 1 Clark
SW NE SE Sec. 33,T 17 N,R 1 E.
6. Ryan Oil Co. No. 1 Madison
NE NW SW Sec. 34,T 17 N,R 1 E.
7. George Rodman, Inc. No. 1 Gains
C SW NE Sec. 34,T 17 N,R 1 E.
8. Canary and Assoc. and Dirickson and Lewis No. 1 Anderson
SW SW NE Sec. 35,T 17 N,R 1 E.
9. British-American Oil Prod. Co. No. 1 State
NE NE NW Sec. 36,T 17 N,R 1 E.
10. W.H. Martgan No. 1 Orner
SE SW SE Sec. 31,T 17 N,R 2 E.
11. Blake Oil and Gas Properties No. 1 Morgan
C SE NW Sec. 32,T 17 N,R 2 E.
12. Blackwell Oil and Gas and White Eagle No. 1 Chloe
NW NW SE Sec. 33,T 17 N,R 2 E.
13. Petroleum Resources No. 1 Allen
NE NE SE Sec. 33,T 17 N,R 2 E.
14. Glenn Smith No. 1 Elson
SE SE NE Sec. 34,T 17 N,R 2 E.
15. C.E. McCaughey No. 1 Brandon
NW NW SE Sec. 35,T 17 N,R 2 E.
16. Cimarron Petroleum Corp. CPC 121 Jones
NE SE SW NW Sec. 36,T 17 N,R 2 E.

PLATE 16

STRATIGRAPHIC CROSS SECTION E-E′

DATUM: TOP SYLVAN SHALE
Showing Porous, Dolomitic Part of Hunton Group

Daniel H. Swartz 1986

1. George Rodman, Inc. No. 1 Gaines
SW NE Sec. 34,T 17 N,R 1 E.
2. Fordee Rhoades Oil No. 3 Jacobs
NE SE SW Sec. 27,T 17 N,R 1 E.
3. Davis Bros. Oil Producers, Inc. No. 1 Haynes
W/2 SE NW Sec. 27,T 17 N,R 1 E.
4. J.G. Catlett No. 1 Haynes
NW NW NW Sec. 27,T 17 N,R 1 E.
5. Hall-Jones Oil Corp. No. 1 Wilks
NE SE NW Sec. 22,T 17 N,R 1 E.
6. Hall-Jones Oil Corp. No. 1 Jacobs
SW SW SE Sec. 15,T 17 N,R 1 E.
7. Josaline Prod. Co. No. 1 Bostian
NW SW SW Sec. 10,T 17N,R 1 E.
8. Baker-Mundy Drilling Co. and Basin Oil Co. No Longan
NW NW NE Sec. 10,T 17 N,R 1 E.
9. Massey and Massey No. 1 Longan
E/2 SW SE Sec. 3,T 17 N,R 1 E.
10. Canadian Exploration Corp. No. 33-3 Graham
NW NW SE Sec. 33,T 18 N,R 1 E.
11. Virgil Cloer No. 4 Phillips
NW SW Sec. 27,T 18 N,R 1 E.
12. K.W.B. Oil Property Management No. 2 Buntin
NE NW Sec. 27,T 18 N,R 1 E.
13. Beard Oil Co. No. 2 Bentley
NE SW Sec. 22,T 18 N,R 1 E.
14. Canadian Exploration Corp. No. 15-1 Cundiff
SW SW Sec. 15,T 18 N,R 1 E.
15. Hall-Jones Oil Corp. and Shelburne, Inc. No. 1 Wetzel
NE NW NW Sec. 15,T 18 N,R 1 E.
16. Davidor and Davidor No. 1 U.S.A.
NW NE NE Sec. 10,T 18 N,R 1 E.

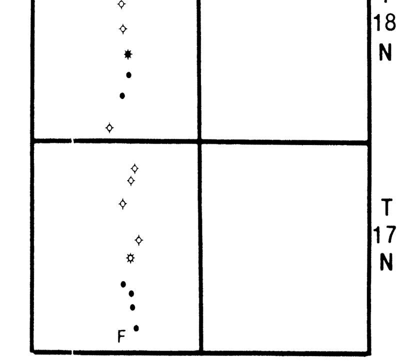


PLATE 17

STRATIGRAPHIC CROSS SECTION F-F′

DATUM: TOP SYLVAN SHALE
Showing Porous, Dolomitic Part of Hunton Group

Daniel H. Swartz 1986

1. W.H. Martgan No. 1 Orner
   SE SW SE Sec. 31,T 17 N,R 2 E.
2. T.T. Eason and E.A. Obering No. 1 Clark
   SW SW SE Sec. 30,T 17 N,R 2 E.
3. Service Drilling Co. No. 1 Clark
   NW NW SE Sec. 30,T 17 N,R 2 E.
4. Palace Exploration Co. No. 30-1 Neitman
   NW NW NE Sec. 30,T 17 N,R 2 E.
5. Service Drilling Co. No. 1 Fiala
   NW SW SE Sec. 19, T 17 N,R 2 E.
6. Rhoades Oil Co. No. 1 Skaer
   NW NE NE Sec. 18,T 17 N,R 2 E.
7. Mabee Royalties, Inc. No. 1 Mileham
   SE NE SE Sec. 7,T 17 N,R 2 E.
8. Rhoades Oil Co. No. 1 Skaer
   C NE NE Sec.7,T 17 N,R 2 E.
9. Graham Petroleum No. 1-6 Ringwald
   NE NW NW Sec. 6,T 17 N,R 2 E.
10. Home Stake Production Co. No. 1 State
    NW NW SE Sec. 36,T 18 N,R 1 E.
11. John Lindas Oil, Inc. No. 1 Cook
    SW SE SE Sec. 25,T 18 N,R 1 E.
12. Ketal Oil Producing Co. No. "A" Leach
    E/2 NW NE Sec. 25,T 18 N,R 1 E.
13. Mid-Continent Petroleum Corp. No. 1 Graham
    NE SE SE Sec. T 18 N,R 1 E.
14. Royal Petroleum Corp. No. 1 Barrett
    SE SE SE Sec. 12,T 18 N,R 1 E.
15. North American Petroleum Corp. No. 1 Snow
    NE NE SE Sec. 1,T 18 N,R 1 E.

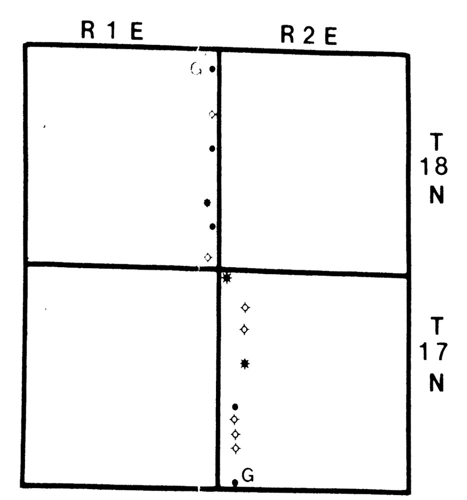


PLATE 18

STRATIGRAPHIC CROSS SECTION G-G′

DATUM: TOP SYLVAN SHALE

Showing Porous, Dolomitic Part of Hunton Group

Daniel H. Swartz 1986

1. Glenn J. Smith No. 1 Elson
SE SE NE Sec. 34,T 17 N,R 2 E.

2. Summit No. 1 Gordon
NE NE NE Sec. 27,T 17 N,R 2 E.

3. Finston and Co. No. 1 Carpenter
NE NE SE Sec. 22,T 17 N,R 2 E.

4. Earth Energy Resources No. 3 Tohee
C NW NE Sec. 15,T 17 N,R 2 E.

5. Earth Energy Resources No. 1 Wall
C SW SE Sec. 10,T 17 N,R 2 E.

6. Petroleum Reserve Corp. No. 2-1 Sasser
NW SE SW Sec. 2,T 17 N,R 2 E.

7. Wayne Abbot,et al No. 1 Bryan
SW NW SE Sec. 27,T 18 N,R 2 E.

8. Harrison Oil Co. No. 1 Herod
SE SE NW Sec. 22,T 18 N,R 2 E.

9. Lincoln Rock Corp. No. 1 ERA-TXO
C SW SE Sec. 15,T 18 N,R 2 E.

10. Wilcox Oil Co. No. 1 Lee
NE NE SW Sec. 10,T 18 N,R 2 E.

11. Wilcox Oil Co No. 1 Sam
SW NW SW Sec. 3,T 18 N,R 2 E.

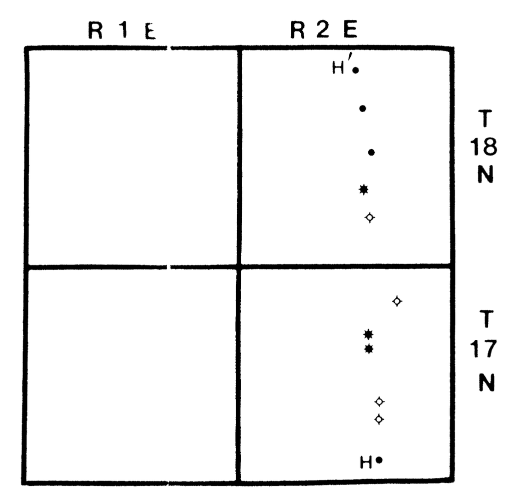


PLATE 19

STRATIGRAPHIC CROSS SECTION H-H′

DATUM: TOP SYLVAN SHALE
Showing Porous, Dolomitic Part of Hunton Group

Daniel H. Swartz 1986

1. Cimarron Petroleum Corp. No. CPC 121 Jones
   NE SE SW NW Sec. 36,T 17 N,R 2 E.
2. Falcon Seaboard Drilling Co. No. 1 Bolles
   SE SE SW Sec. 25,T 17 N,R 2 E.
3. Bunker Exploration Co. No. 1-24 Teter
   SW SW SW Sec. 24,T 17 N,R 2 E
4. Jefferson-Williams Energy Corp. No. 1 Ferguson
   C SW Sec. 13,T 17 N,R 2 E.
5. Cox Exploration, Inc. No. 1 Holbrook
   NW SE NW Sec. 12,T 17 N,R 2 E
6. Payne, Inc, O.S.U. No. 1 Cowboy
   C SW NE Sec. 36,T 18 N,R 2 E.
7. Fullerton Oil Co. No. 1 Nelson
   NE SW NE Sec. 25,T 18 N,R 2 E.
8. Highlands,Goodall, and Greer No 1-B Gates
   C NW SE Sec. 13,T 18 N,R 2 E.
9. Eason Oil Co. No. 1-12 Gates
   C NW SE Sec. 12,T 18 N,R 2 E.
10. Parker-Duerr Drilling Co. No. 1 Malone
    C NE SE Sec. 1,T 18 N,R 2 E.

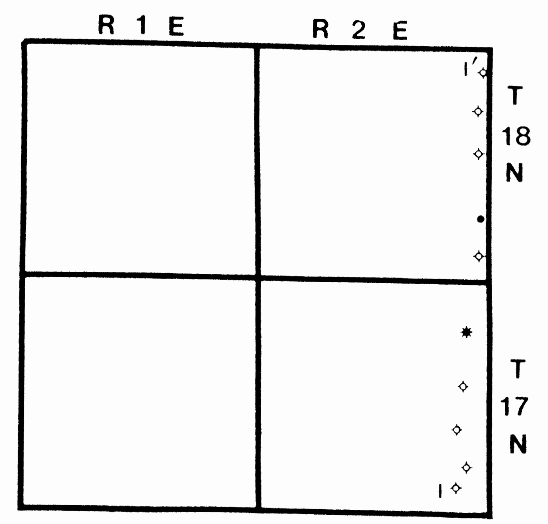


PLATE 20

STRATIGRAPHIC CROSS SECTION I-I′

DATUM: TOP SYLVAN SHALE
Showing Porous, Dolomitic Part of Hunton Group

Daniel H. Swartz 1986