THE PETROLEUM POTENTIAL OF THE UPPER "VIOLA LIMESTONE GROUP" IN SOUTH-CENTRAL LOGAN COUNTY, OKLAHOMA

By

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My parents, Charles and Dana Andrews, deserve special acknowledgment for instilling in me the values and discipline required to complete a study of this nature, and for encouraging me every step of the way.

Lastly, to all my friends and family, thank you for all the good-natured ribbing and patience. I'm sure they will be excited that I have finally ended my seemingly eternal status as a student.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF PLATES

ABSTRACT

The reservoir rock of the Viola Group has been show to produce commercial quantities of oil and gas in scores of fields across Oklahoma. It is shown here to have analogous qualities with the reservoir rocks of the Hunton Group in the West Carney Hunton Field, in Lincoln and Logan Counties Oklahoma, where profitable quantities of oil and gas are produced in association with large amounts of water. This "dewatering" play has proven profitable in the Hunton Group Reservoir; therefore, because of its analogous properties, may prove profitable within the Viola Group reservoir. Viola rocks of the Sooner Trend in Garfield County, Oklahoma have also proven to produce profitable quantities of oil and gas while "dewatering" the reservoir. The reservoir consists of a porous and permeable zone described here, and shown here to exist in the study area in Logan County, Oklahoma. The ability to identify this porosity/permeability zone from wireline logs and use this information for constructing meaningful maps may lead to the development of new Viola plays in the future.

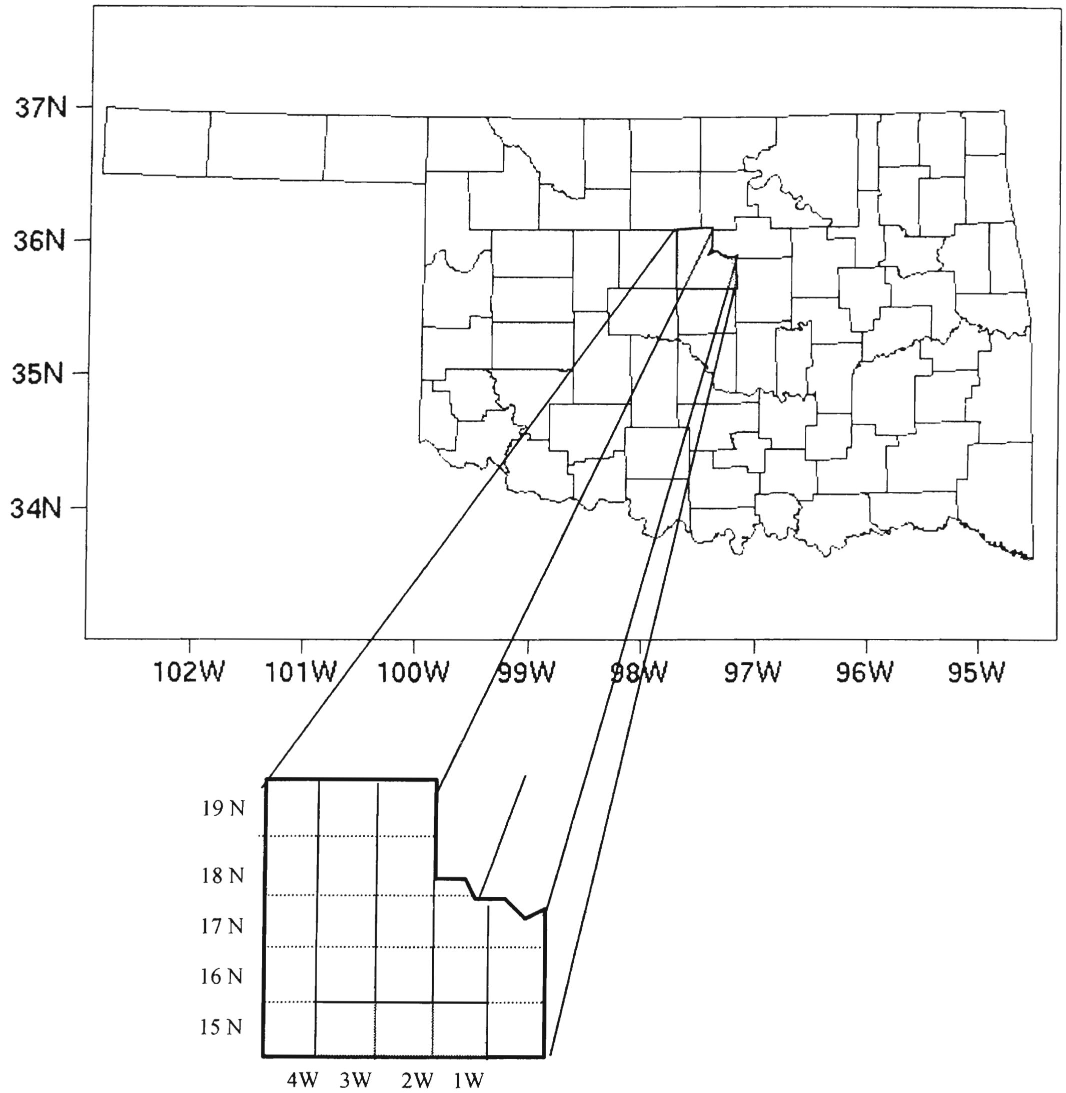

Figure 1. Location Map of the Study Area, Logan County, Oklahoma
The study area comprises Township 15 North, Ranges 1, 2, and 3 West

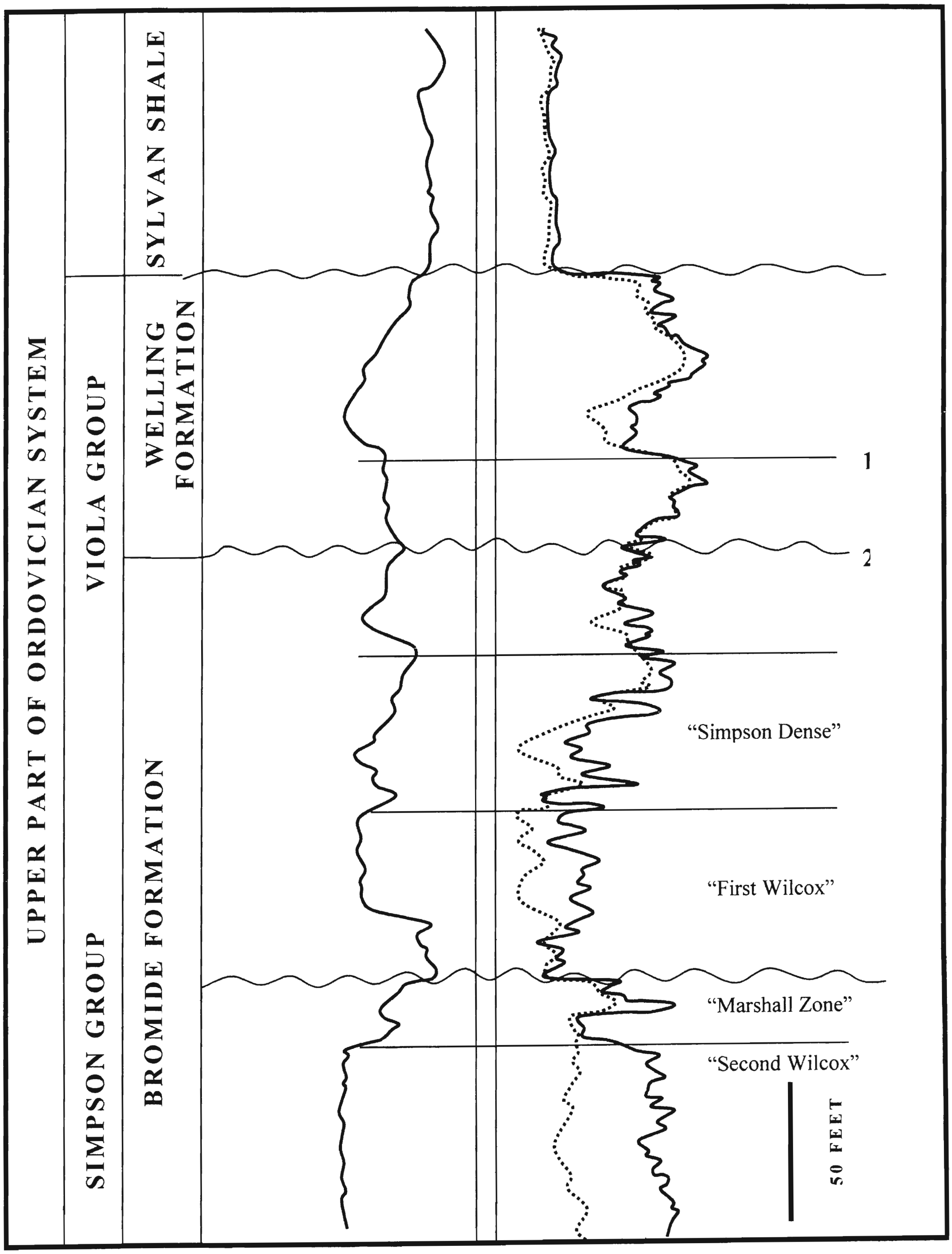

Figure 2. "Type" Electric Log and Stratigraphic Section of the study area. Except for the Sylvan Shale, all names are informal rock-stratigraphic units. Type log modeled after Funk Exploration No. 1 Kellog, SW/4, Sec. 30 T. 15 N., R. 1 W., Logan Co., Oklahoma

are identifiable by wireline-log signatures (Figure 2). Within this set of strata are rock units that crop out in southern Oklahoma, and there are named as the Bromide Formation of the Simpson Group. The uppermost part of the exposed Bromide Formation (Figure 3) is composed of the Pooleville Limestone Member below and the Corbin Ranch Limestone Member above (Cronenwett, 1958, p. 172, Figure 1), which of course, is the uppermost rock stratigraphic unit of the Simpson Group. Here physical continuity of the Pooleville and Corbin Ranch from southern Oklahoma into Logan County is considered to be a stable assumption, but the positions in sequence of these strata have not been established by descriptions in publications. In the study area, the members probably are within the stratigraphic section that overlies the First Wilcox Sandstone and underlies the set of strata shown as the Viola Formation (Figure 2). Almost certainly the strata equivalent to the Corbin Ranch are neither higher in sequence than the position marked "1" in Figure 2, nor lower than the position marked "2." Formal nomenclature of strata between the bed marked "1" and the First Wilcox remains to be established by careful correlation across long distances on physical and biostratigraphic criteria. In fact, the formal names of strata beneath the Sylvan Shale and above the Second Wilcox are yet to be described by publication, evaluated, and accepted. For purposes addressed in the present study, rocks that underlie the Sylvan Shale and overlie the position marked "2" are called the "Viola Formation."

The Viola is important in exploration of the subsurface. The Upper Ordovician rock is in distinct log-signature contrast with the superjacent Sylvan Shale (Figure 2), and therefore is a reliable marker bed. This datum has been used not only to approximate the configuration of the top of the Viola, but also to estimate structure of sandstones of

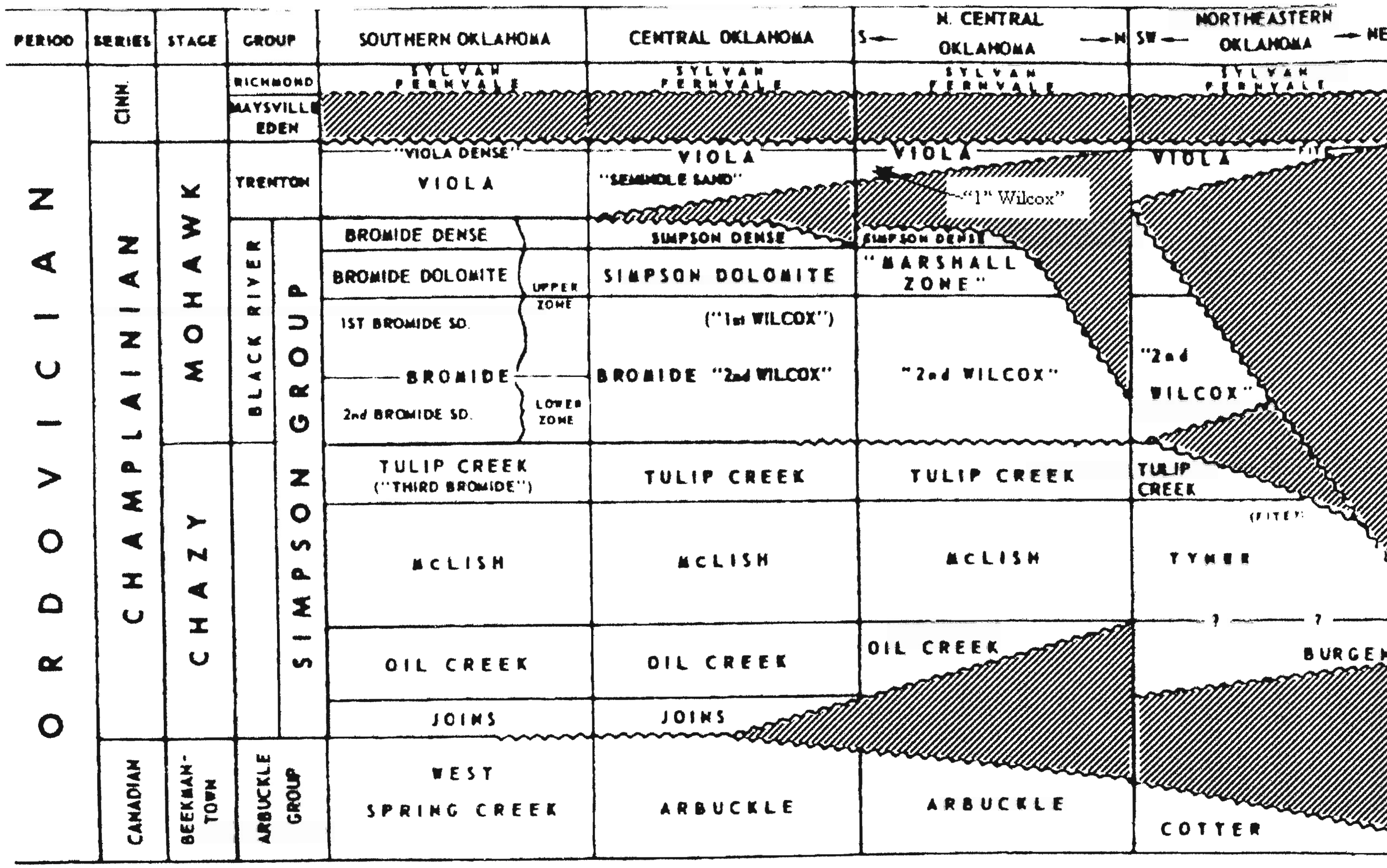

Figure 3. Stratigraphy of Simpson Group in southern, central, and northeastern Oklahoma (after Cronenwett, 1956, p. 172, Figure 1)

the underlying First Wilcox and Second Wilcox (Figure 2). At many places in Oklahoma (Figure 4), the Viola has produced significant quantities of oil and gas; in a large portion of these fields the underlying Wilcox sandstones (Figure 2) are productive. If completed efficiently, wells produced from the Viola yield much profit during periods when the prices of oil and gas are high.

Description of the Problem

This study was concerned primarily with testing a method for exploration of the Viola in north-central Oklahoma. The principle question to be answered was "Can production of oil and gas from the Viola be attributed primarily to stratigraphic entrapment of petroleum?" If "no," then can production be explained by difference of porosity and permeability of the Viola from place to place, in combination with anticlinal flexures or high-standing fault blocks?

Data were extracted from nearly 500 well logs, from scout tickets, and from information published about volumes of petroleum produced. Structural geologic maps, isopach maps, and cross sections were constructed in order to interpret local geology. In the course of this study, questions fundamental to the purpose began to develop: (1) Can porous and permeable rock within the Viola be approximated from wireline logs, for use in isopach mapping? (2) Can an isopach map be made to illustrate rock in the Viola that is porous and permeable, and that can be shown to deliver petroleum in profitable quantities? (3) Can fields that produce oil and gas from the Viola be used as models to

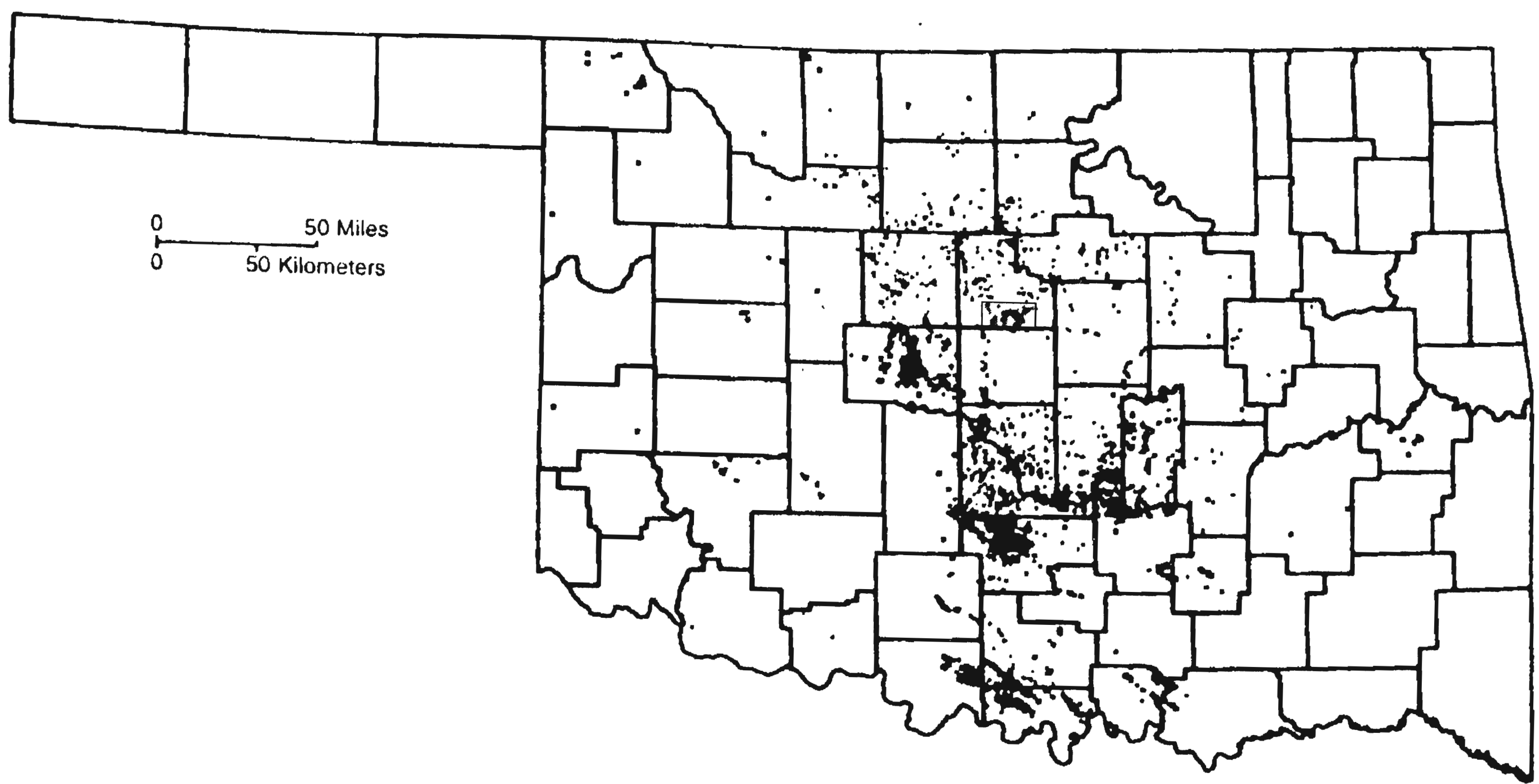

Figure 4. Map of Oklahoma showing distribution of leases known to produce from the Viola Group (after Northcutt and Johnson, 1997, p. 56, Figure 11).

link these fields to localities that show evidence of similar critical attributes? (4) Can oil and gas prospects of economically attractive size be described by use of these methods?

Previous Investigations

Studies of Stratigraphy

Taff (1902) named the Viola from exposures near the Native American village of Viola in what is now Johnston County, Oklahoma. He concluded that the nearly 700 feet thick, generally massive limestone was deposited during Ordovician time (Table 1). In 1903, Taff (1903, as described by Wengerd, 1948, p. 2187) realized he had included the upper part of the "Simpson Formation" (Table 1) in his original description of the Viola. He described the Simpson-Viola contact as being gradational, and dated the Viola as early Trentonian through early Richmondian. Ulrich (1911, as described by Teague, 1982, p. 4) proposed the term "Bromide Formation" for the pre-Trentonian part of the upper Simpson Group. He also correlated portions of the Viola to the Fernvale Formation of Tennessee; he therefore called the uppermost unit the Fernvale Limestone Member of the Viola Formation, and the lowermost unit the Viola Limestone Member. Edson (1930) recognized unconformities at the contacts between the Bromide Formation and the Viola Limestone Member, between the Viola Limestone Member and the Fernvale Limestone Member, and between the Fernvale Limestone Member and the overlying Sylvan Shale. Ireland (1936) studied insoluble residues from the Viola and identified unconformities at the Bromide-Viola Limestone Member contact and at the Fernvale Limestone Member-Sylvan Shale contact, but found no evidence of an unconformity at the Fernvale-Viola contact.

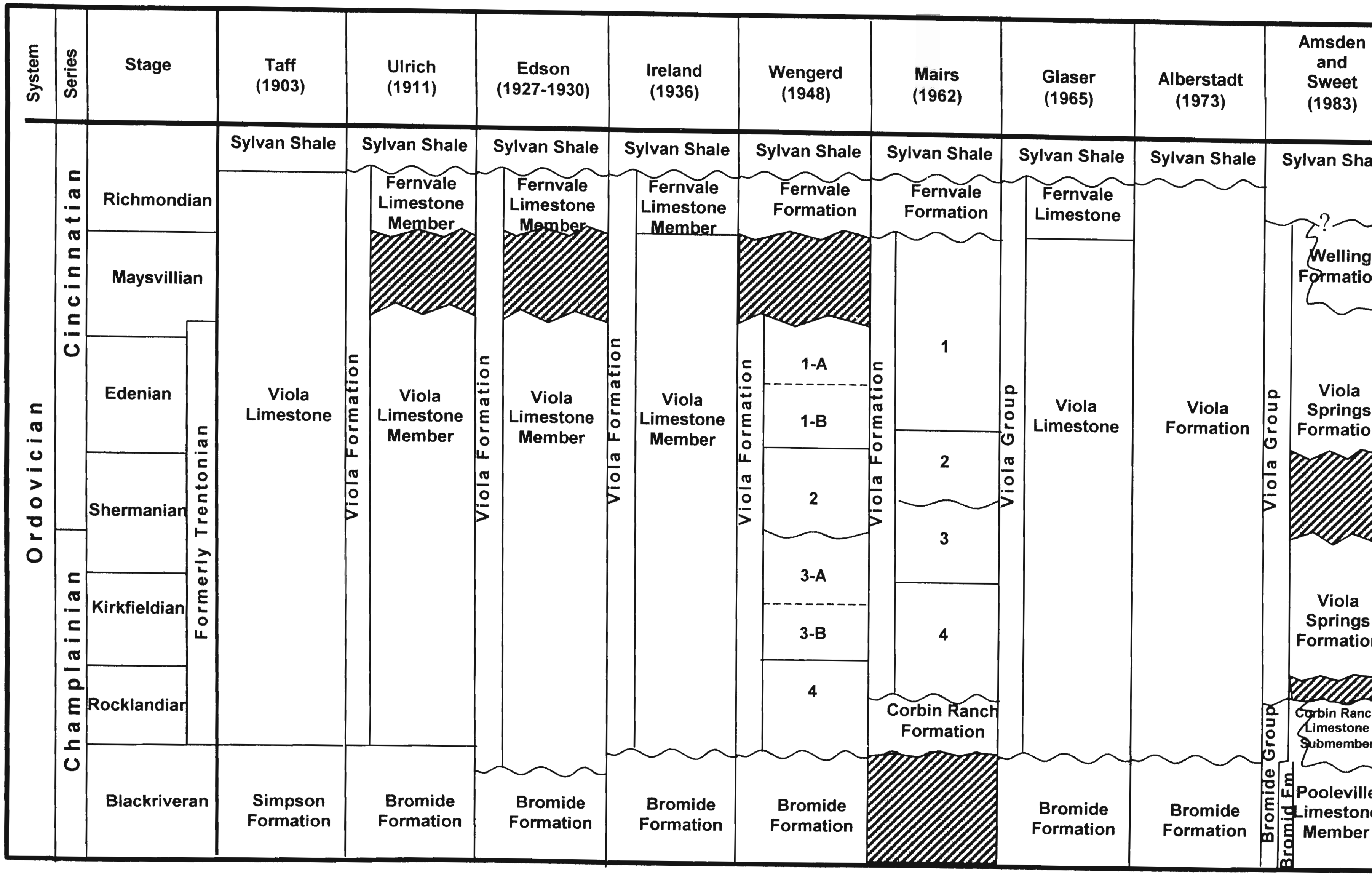

Table 1. Summary of Previous Investigations

Wengerd (1948) conducted a comprehensive, yet detailed work as a doctoral thesis at Harvard University. He placed the Viola in the Trentonian Stage and the Fernvale in the Richmondian Stage (Table 1). He concluded that a regional unconformity exists between the Viola and Fernvale, and that the two members of the Viola Formation should be classified as separate formations. Furthermore, he divided the Viola Formation into four distinct members; he numbered each, from 1 to 4, in the same order that a drill bit would penetrate the strata (Table 1). Mairs (1962, p. 4) confirmed that Wengerd's divisions held true for the Viola of the Arkoma Basin although he was unable to correlate Wengerd's submembers (see Table 1). From study of 18 outcrops in the Arbuckle Mountains, Glaser (1965) described the Viola-Fernvale contact as being conformable. Furthermore, Glaser used the term "Viola Group," and divided the group into the "Fernvale Limestone" above and the "Viola Limestone" below. Alberstadt (1973, p. 5), asserted that the term "Fernvale" is inappropriate for the upper part of the Viola in Oklahoma, because the conodont fauna of the upper Viola (from samples taken in the Arbuckle Mountain region) in Oklahoma are distinctly different from the fauna of the Fernvale type locality in Tennessee. From study of biostratigraphy of brachiopods in exposed Viola strata of the Arbuckle Mountains, he determined that no evidence of a hiatus could be documented within the Viola; therefore, he called the entire unit the Viola Formation.

Amsden and Sweet (1983) used biostratigraphy of conodonts to designate Ordovician strata subjacent to the Sylvan Shale and superjacent to the Bromide Formation as the Viola Group. They found evidence to divide the Viola Group into two formations: an "upper Viola" which they named the Welling Formation, and the "lower

Viola," which they named the Viola Springs Formation (Table 1). From study of conodonts, they dated the Viola Springs Formation as Rocklandian through Maysvillian, but recognized a hiatus within the formation (Table 1). They asserted that the name "Welling Formation" should replace the term "Fernvale," and dated the formation as Maysvillian.

Studies of Depositional Environments

Wengerd (1948, p. 2191 and p. 2250) suggested that the Viola and Fernvale were deposited in widespread eperic seas during a time of orogenic stability in south-central Oklahoma. He proposed a platform-basin depositional setting with Viola and Fernvale sediments having been deposited within the Arbuckle geosyncline, on a shallow submerged platform. Mairs (1962, p. 14) interpreted depositional environment and geologic history on the basis of types of limestone, distributions of thickness of the Viola, and history of structural deformation of the Arkoma Basin. He concluded that within the Arkoma Basin were two depositional environments manifested as a shallow-water platform facies and a deep-water platform slope facies. Glaser (1965) also proposed a basin-and-platform depositional environment, based on variations in thickness of the Viola. He recognized shallowing-upward sequences within the Viola strata of the Arbuckle Mountains. Reid (1980, as described by Teague, 1983, p. 7) studied the northeastern part of the Arbuckle Mountains and concluded that the Viola Formation shows evidence of having been deposited on a platform in slowly transgressing seas. Teague (1982, p. 43) described four lithofacies within the Viola, and stated that they indicated deposition on an unrestricted shelf. He recognized that these lithofacies record deposition in an anaerobic lower-ramp environment to an aerobic shallow-ramp environment. Teague concluded that these interpretations are consistent with those reached by Glaser (1965), Galvin (1982), Smith (1982), and Grammer (1983).

Other Studies of Importance

Sykes, Puckette, Abdalla, and Al-Shaieb (1997) studied 24 cores from the Viola and 12 outcrops of the Viola in south-central Oklahoma, for evidence of karstification. This study suggested several episodes of karstification, dated as intra-Viola Springs, pre-Sylvan, post-Pennsylvanian, Late Cretaceous, and Recent.

Northcutt and Johnson (1997, p. 48) discussed Viola oil and gas reservoirs. They noted that the Viola is potentially a good reservoir where it is fractured, where fractures are opened by dissolution, and where the Viola is on anticlinal folds or fault blocks from which rocks of the Simpson Group produce. Furthermore, they asserted that opportunity to discover bypassed Viola reservoirs still exists

CHAPTER III

STRATIGRAPHIC FRAMEWORK

The Problem of Nomenclature

As mentioned above, the Viola Limestone was described and named by Taff (1902) from study of the type locality, near the village of Viola in what is now Johnston County, Oklahoma. Taff did not recognize a separate Fernvale Formation. Several geologists have since recognized evidence and need for dividing the section and have attempted to define an upper and lower part of the Viola

The nomenclature of these two units and the nature of their contacts have been the source of much confusion (this paper, p.xx). The lower unit has commonly been referred to as either the Viola Formation or the Viola Springs Formation; the upper unit has commonly been referred to as either the Fernvale Formation, or the Welling Formation. Subsurface equivalents of the Fernvale and Viola Formations are poorly understood and are separated by a contact that is not easily and consistently detected in well-log signatures. Due to this fact, the formations have not been subject to description by precise stratigraphic nomenclature (Chenoweth, 1966, p. 110), and have been used in various fashions interchangeably. Hollingsworth (1940, as described in Wengerd, 1948, p. 2191) suggested the term "Viola Group" and argued that geologists could not distinguish the Fernvale from the Viola, so as to map each one independently.

The purpose of my work did not include thorough analysis of the stratigraphic nomenclature of Ordovician rocks younger than the Second Wilcox (Figure 2), nor was rectification of the nomenclature expected and attempted. To do so would have exceeded resources of time, funding, and resources provided by the author's level of experience. Therefore, the terms "Viola," and "Viola limestone" as *ad hoc* names are intended to describe rocks that overlie the Simpson Dense and underlie the Sylvan Shale (Figure 2).

Summary Description of Local Stratigraphy

In central and north-central Oklahoma, the Viola is Upper Ordovician. In this study the term "Viola" or "Viola Formation" are is to describe all strata that lie between the superjacent Sylvan Shale and the subjacent Bromide Formation (Figure 2). Contacts of the Viola Formation with the Sylvan Shale above and the Simpson Group below are unconformable, as described in works shown in Table 1. According to Amsden and Sweet (1983, p. 3-5), in accepted nomenclature the term "Viola" refers to the Viola Group. The Viola Group consists of two formations: the Welling Formation above, and the Viola Springs Formation below. As shown in Table 1, Amsden and Sweet described an unconformity between the Welling Formation and Viola Springs Formation, and described a hiatus within the Viola Springs Formation From information found in study of conodonts Amsden and Sweet (1983, p. 5) determined that the Viola Springs thins eastward and wedges out in the subsurface, a few miles downdip and east of the outcrop in the Arbuckle Mountains. The Welling Formation directly overlies the Corbin Ranch Limstone Member of the Bromide Formation in most of the Arkoma Basin.

Detailed correlations from outcrop into north-central Oklahoma, specifically Logan County, have not been established by description in publications. However, Amsden and Sweet's work indicates that the Viola Springs Formation is absent within the study area; here the Viola Group may be composed entirely of the Welling Formation.

CHAPTER IV

STRUCTURAL GEOLOGIC SETTING

Regional Structural Geology

The structural framework of Oklahoma is a complex of several depositional and structural elements (Figure 5). The area of study is on the Central Oklahoma Platform, a structural element bounded by the Nemaha Range on the west, the Ozark Uplift on the east and northeast, the Hunton-Pauls Valley Uplift on the south, and the Arbuckle Uplift and Arkoma Basin on the south and east.

During the deposition of Viola strata, Oklahoma was tectonically and sedimentologically simple (Figure 6). The Simpson and Viola strata were deposited in a broad, shallow epicontinental sea across the Oklahoma Basin (Johnson and Cardott, 1992, p. 21). According to Johnson (1991, p. 5), stratigraphic units deposited in most parts of the Oklahoma Basin are widespread, laterally persistent, and reflective of orogenic near-stability of the region during early Paleozoic time. The complex of depositional and structural elements of the present are results of several episodes of orogenic activity, which occurred mainly during the Pennsylvanian.

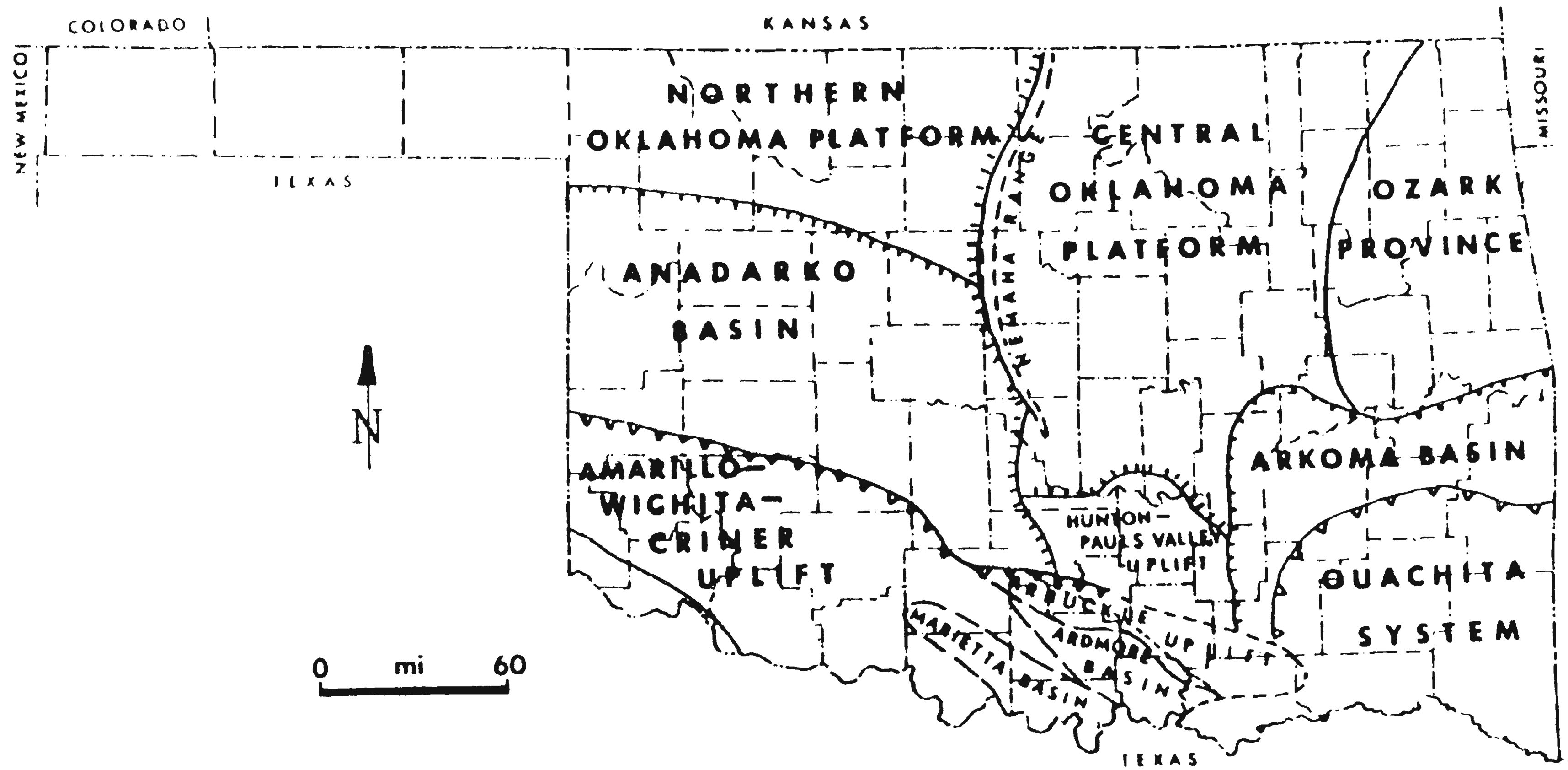

Figure 5. Structural Framework of Oklahoma (after Fritz, 1978, as illustrated in Roark, 1997, p. 18, Figure 4)

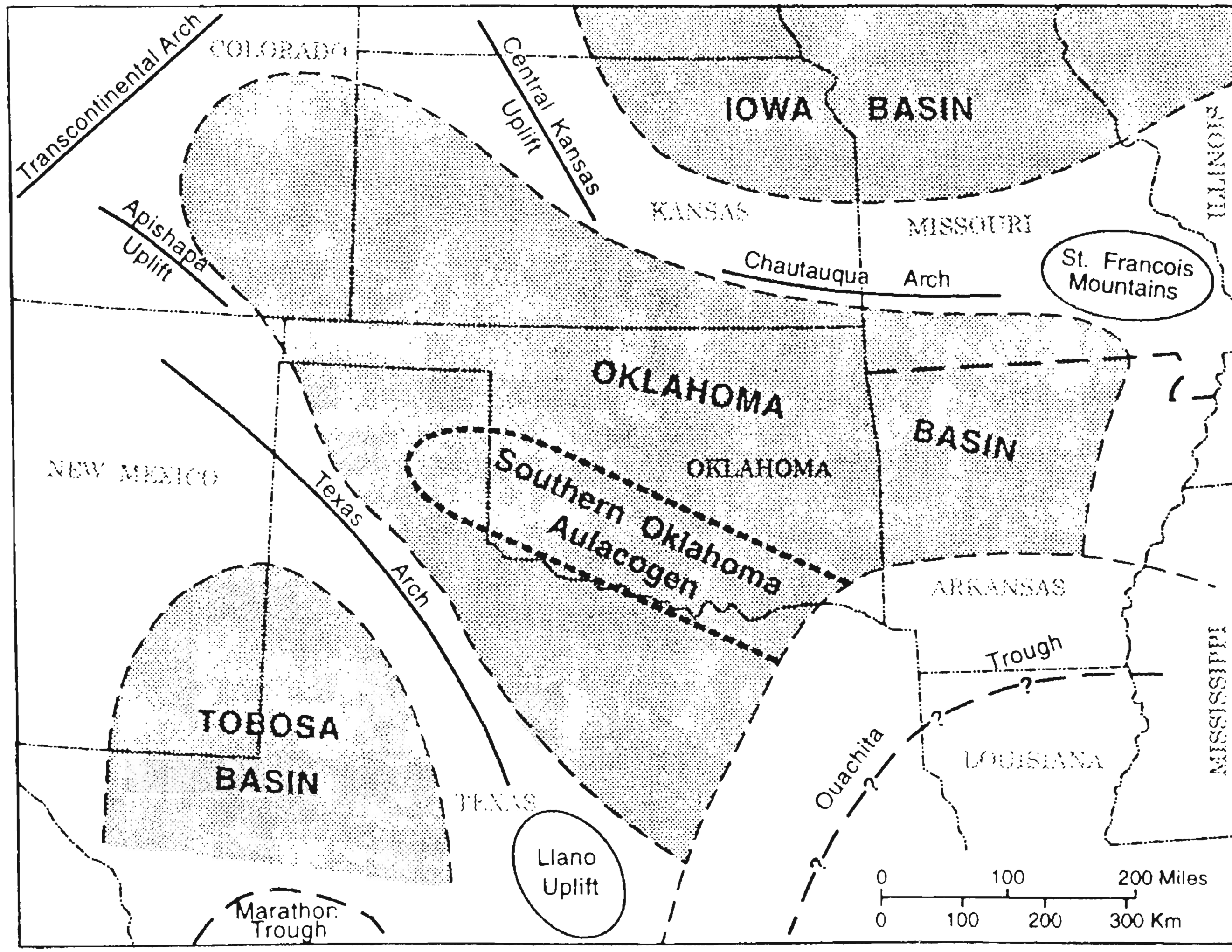

Figure 6. Map showing outline of Oklahoma Basin and other major features that existed in early and late paleozoic time (after Northcutt and Johnson , 1997, p. 49, Figure 2)

Structural Geology of the Study Area

Local structural geology was interpreted from analysis of structural contour maps of the base of the Sylvan Shale (Plate I) and of the top of the "Marshall Zone" (Plate II). General strike of the Viola is northward to northwestward; dip is westward to southwestward. Average dip at the base of the Sylvan is approximately 50 to 60 feet per mile (Plate I); however, superimposed on the regional homocline are many anticlinal and synclinal noses and a few anticlines and synclines (Figure 7).

At some localities of 40 acres or more the elevation of the top of the Viola is higher than that at localities of similar size nearby. These local, small, high localities can be depicted by use of a small contour interval; therefore, structural geologic maps were constructed with contour intervals of 20 feet. This was the outcome: several small "anticlinal" features and small faults disrupt the regional homocline (see Plate I). One major fault trends eastward, intersecting the western boundary of the study area approximately 2 miles north of the southwestern corner of the study area (see Plate I). Throw of this fault is generally 80 to 100 feet, but as mapped is as small as 45 feet (Sec. 20, T. 15 N., R. 1 W.) and as great as 156 feet (Sec. 20, 29, T. 15 N., R. 2 W.). The southern side is downthrown (Plate I, N/2, Sec. 26, T. 15 N., R. 2 W.; N/2, Sec. 29, T. 15 N., R. 2 W.) A smaller northeast-trending fault converges with this fault in Sec. 22, T. 15 N., R. 1 W., where they form a wedge-shaped block (Plate I). A smaller wedge-shaped block is in Sec. 22 and Sec. 23, T. 15 N., R. 3. W. (Plate I). The northeast-trending fault on the north flank of this feature may be part of the northeast-trending fault

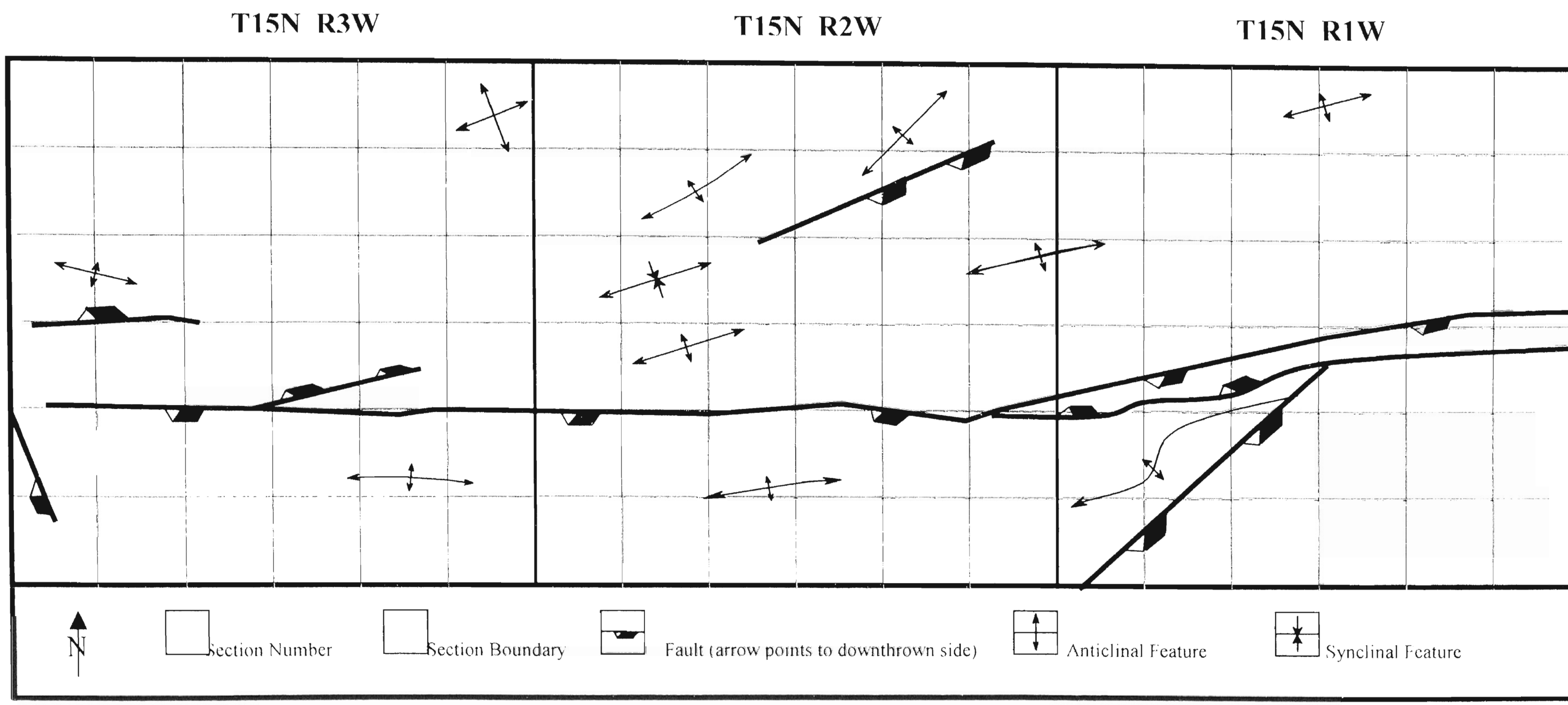

Figure 7. Map of Structural Elements in Study Area

that strikes across the northeastern part of T. 15 N., R. 2 W. (Plate I; see especially the configuration of contour lines in Sec. 16, 17, and 18, T. 15 N., R. 2 W.).

CHAPTER V

OIL AND GAS PRODUCTION FROM THE VIOLA

Oil and gas are produced from the Viola in scores of fields, in every major basin of Oklahoma and every major structural province except the Ouachita Uplift (compare Figures 4 and 5). Some fields are clustered, elsewhere they are scattered broadly, and a few are isolated (Figure 4). According to Northcutt and Johnson (1997, p. 48), Viola production data in Oklahoma are commonly unavailable because oil and gas produced from the Viola are regularly commingled with petroleum from other formations. Also, they stated that of the total amount of oil and gas recovered from the Viola, much was produced in years before the State of Oklahoma started keeping official records. Therefore, all production information in this section should be considered as the best approximation, based on published data.

In the study area, comparatively small amounts of oil and gas have been produced from the Viola. Figure 8 was compiled from data obtained through PI/Dwights (2000, 2001) and NRIS (National Resources Information System) (2001), concerning amounts produced from active and inactive oil and gas wells. It shows the concentration of oil and gas production from the Viola within the study area, according to field. Field names and boundaries were approximated from locations of fields in accordance with the published data. Relative areas of oil fields and gas fields are not necessarily representative of quantities produced; however, the figure shows areas where wells have

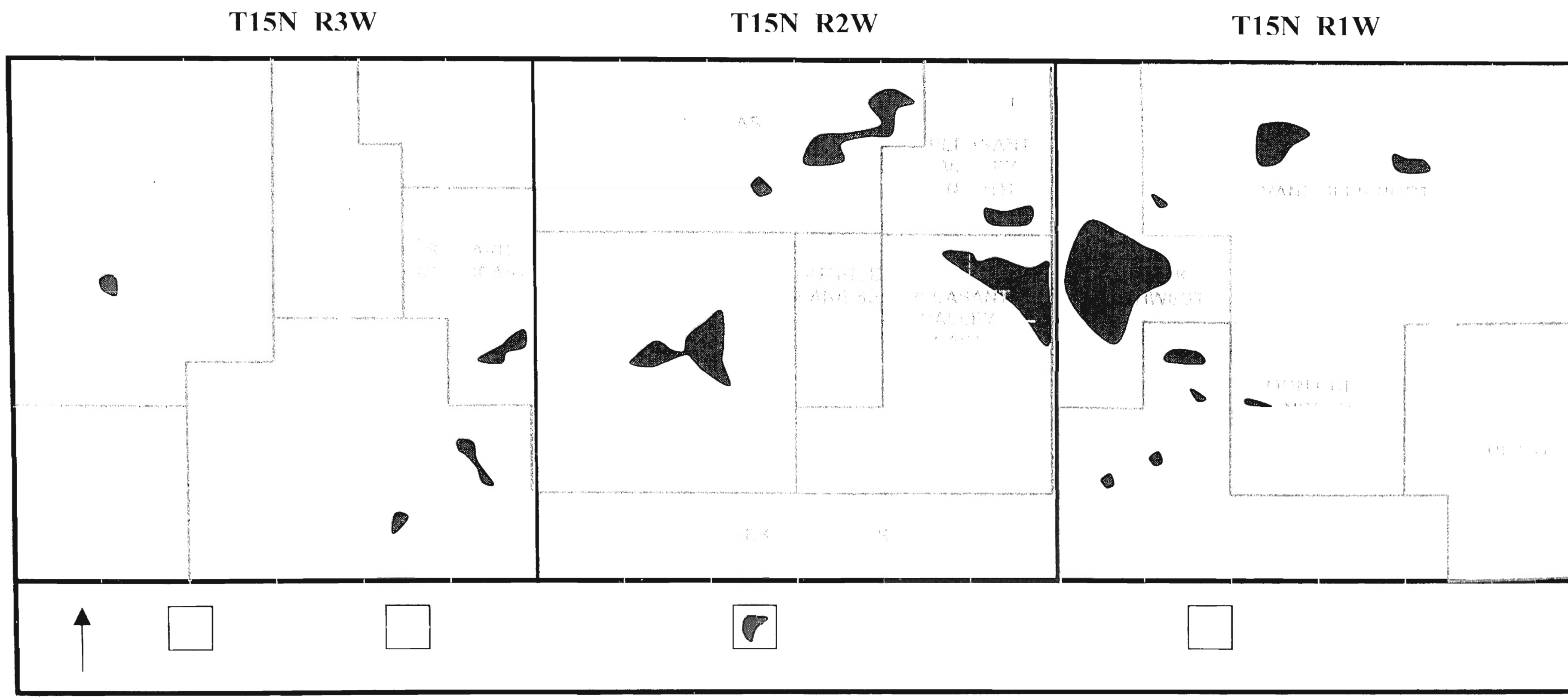

Figure 8. Map displaying field boundaries and concentrations of past and present Viola oil and gas production.

*Boundaries of oil and gas fields are approximations derived from PI/Dwights (2001) data.
**Locations of Viola production show only rough approximations of where the Viola has produced, based on data from PI/Dwights. They do not reflect the quantities of oil and gas actually produced.

produced from the Viola. As Figure 8 illustrates, 16 fields within the study area are described: 11 include wells known to have produced from the Viola.

Table 2 shows the volumes of oil and gas produced from the Viola, according to field. In the three-township study area, 69 wells have produced oil and gas from the Viola: 12 wells are producing and 57 wells have been abandoned or are otherwise inactive. Amounts of petroleum were assembled from data recorded in various oil and gas reports: PI/Dwight's Oklahoma Crude Production Report, Northeast (2001, p. 200-208), PI/Dwight's Natural Gas Well Production Histories, Northeast (2001, p.138-140), PI/Dwight's Abandoned or Inactive Crude Leases Report, Northeast (2000, p.82-87), and PI/Dwight's Abandoned or Inactive Gas Leases Report, Northeast (2000, p. 37-38). In the study area approximately 1.3 million barrels of oil and 9.3 billion cubic feet of gas have been produced from the Viola. The most substantial Viola production recorded is from the Fair Oak Southwest field, where 13 wells have produced almost 539,000 barrels of oil and nearly 1.9 billion cubic feet of gas.

Reservoir Rocks of the Viola: General Properties

No work published to this point has defined or described the reservoir characteristics of Viola in the area of this study. Little to no information is available concerning analysis of the Viola rocks of north-central Oklahoma. However, Northcutt and Johnson (1997, p. 52) made a blanket description of the reservoir characteristics of the Viola in Oklahoma: At many localities, the Viola was fractured and partly dissolve

		VIOLA WELLS			OIL IN BARRELS		GAS IN MCF	
	FIELD NAME	TOTAL WELLS	TOTAL ACTIVE WELLS	TOTAL INACTIVE WELLS	CUMULATIVE OIL PROCUTION	AVERAGE OIL PRODUCTION PER WELL	CUMULATIVE GAS PRODUCTION	AVERAGE GAS PRODUCTION PER WELL
T15N, R1W	Evansville Northwest	9	0	9	33899	3767	254,843	28316
	Fair Oak Southwest	13	1	12	538656	41435	1893987	145691
	Coon Creek	5	1	4	39961	7992	721024	144205
	Coon Creek North	1	1	0	2000	2000	435000	435000
	Coon Creek Northeast	0	0	0	0	0	0	0
T15N, R2W	Coon Creek Northwest	0	0	0	0	0	0	0
	Pleasant Valley East	7	0	7	271606	38801	264470	37781
	Pleasant Valley North	4	1	3	100987	25247	507352	126838
	Guthrie Lake East	15	6	9	83588	5573	2728115	181874
	Guthrie Lake Southeast	0	0	0	0	0	0	0
	Pleasant Valley South	8	1	7	227643	28455	1252617	156577
T15N, R3W	Seward Southeast	2	0	2	9656	4828	22489	11245
	Seward Northwest	1	0	1	149	149	0	0
	Seward East	0	0	0	0	0	0	0
	Navina	1	1	0	14000	14000	42000	42000
	Prairie Bell Northwest	0	0	0	0	0	0	0
	Waterloo North	3	0	3	0	0	1217455	405818
	TOTAL	69	12	57	1322145	19162	9,339,352	135353

Table 2 Production of active and inactive Viola wells, by field, within the study area

CHAPTER VI

METHODOLOGY

Information Analyzed

Nearly 500 well logs were used to retrieve data for construction of maps and cross-sections contained within this report. All wells that penetrated strata of the Viola were considered, with the rare exceptions of unavailable logs and logs of wells recently drilled but not released. According to the Oklahoma Corporation Commission (2001, chapter 10, p. 24) an operating company may hold well-log information in confidentiality for as long as one year. The types of logs studied included: Gamma Ray, Induction, Spontaneous Potential, Microlog, Compensated Density, and Compensated Neutron. The investigation included both "modern logs" (logs recorded since 1960) and "ancient logs;" the modern logs are the more reliable for the interpretations employed in this study. In addition, the study included nearly 100 logs of wells located within a mile or so of the study area, so that trends of contour lines could be mapped near the margins of the maps.

Scout tickets of wells provided information concerning initial production, treatments of perforated strata, and tests. Published production data from PI/Dwights and NRIS were extracted for volumes of current and recent production. PI/Dwights also in association with uplift and erosion; these processes resulted in vuggy porosity and karst. Sykes, Puckette, Abdalla, and Al-Shaieb (1997, p. 66-74) conducted a study of core and outcrop of the Viola in the Arbuckle Mountain Region. In this study they documented evidence that karst and vuggy porosity were developed in both outcrop and the subsurface Viola.

As described above, a few cores from within the area of this study were available. The cores show evidence of vuggy porosity, and karst (Appendix A). Fractures are common to abundant in the cores, enhanced by dissolution in places. From macroscopic study only, the matrix appeared to be impermeable.

Petrography and petrophysics of the Viola must be studied over a large region in north-central Oklahoma before definitive statements can be made about reservoir characteristics of the formation. In the opinion of the author, the limited information about cores described in Appendix A, is evidence that the reservoir characteristics described by Northcutt and Johnson (1997, p. 52) are also descriptive of the Viola in the study area.

publishes information about abandoned or inactive oil and gas leases, which was useful in this work. Certain limitations pertain to the use of these data. Data generally are tabulated by lease tracts, rather than as individual histories of wells. Also, the initial recording of data commonly is begun on a date significantly later than initial production from the well. In this study, all inferences made about relative production capacities of wells have been based on information obtained from a combination of published information about production and scout tickets; additional unpublished resources are noted and referred to where appropriate (example: production data from an operating company).

Data compiled from cores of the Viola were sparse. Scout tickets, and files of the Oklahoma Geological Survey Core Library, indicate that only eight cores were taken from Viola strata in the study area. Of these eight, only four were available from the Geological Survey's library; of these four, only one core cut what in this study is referred to as the "porosity/permeability zone" of the Viola. A vague description and the bottom 8 inches of one other core were obtained from Mr. Joe Podpechan, but the core has been lost. The analysis of two cores from the study area are included in Appendix A of this work.

Definition of "Marker Beds"

The top of the Viola, and the top of the "Marshall Zone" are designated in this study as "marker beds" in order to aid in the development of structural maps, isopach maps, and cross-sections. These markers were chosen because they are easily recognized from subsurface logs, and they can be correlated reliably over a large area. Furthermore, most geologists should be able to reproduce the general results of mapping, if they desire to do so.

Other strata between the base of the Sylvan Shale and the top of the "Marshall Zone" could be used effectively for marker beds. The top of the Simpson Dense and the top of the " First Wilcox" were tested for use as markers for mapping, but were rejected. In the author's opinion these formation tops are neither easily and consistently recognized in wireline logs, nor are they likely to be correlated reliably over the study area.

As shown in Figures 2 and 9, the Sylvan-Viola contact and the First Wilcox-Marshall Zone contact are clearly identifiable on wireline logs.

Sylvan-Viola Contact

Where the Sylvan Shale overlies the Viola, the spontaneous-potential curve is displaced negatively (leftward) from the shale base line (Figure 2).

Configuration of the gamma-ray curve is similar to that of the SP curve at and below the Sylvan-Viola contact. Throughout the Sylvan, the gamma-ray log maintains a signature typical of shale; it is within a few chart divisions of the log's central track, and averages between 75 and 100 API units (Figure 9). Where the Sylvan and Viola are in contact, the gamma-ray log is deflected abruptly leftward in the Viola; through the Viola the gamma-ray log ranges between 7 and 20 API units (Figure 9).

In most wells, resistivity of the Sylvan Shale exceeds 10 ohm-m at only a few places (for example, Figure 9, deep-induction curve). However, resistivity of the Viola is commonly more than 100 ohm-m (Figure 9).

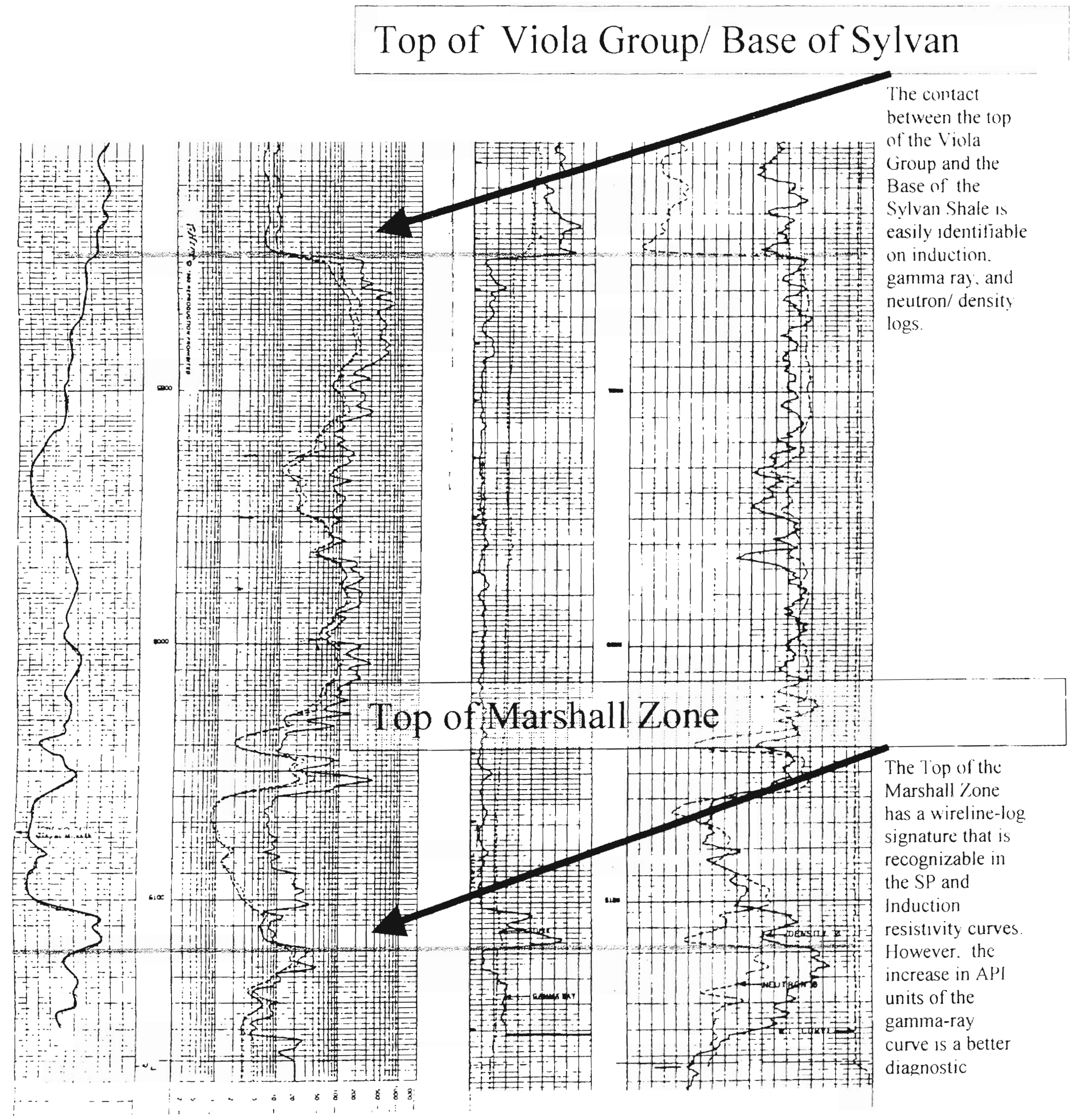

Figure 9. Wireline-log signatures of Sylvan Shale, Viola Group, and Marshall Zone. Oiltex International No. 1 Rogers, NE/4, Sec. 30, T. 15 N., R. 1 W.

First Wilcox-Marshall Zone Contact:

The most easily recognizable aspect of log signature where the First Wilcox overlies the Marshall Zone is recorded in the gamma-ray curve (Figure xx). Nearly all strata between the Sylvan Shale and the top of the Marshall Zone are recorded by a small number of API units,[1] indicating that the rock includes a relatively small volume of shale. However, the top of the Marshall Zone is marked by a "hot streak" – a relatively high API count, recognizable across the region.

The spontaneous-potential curve tends to be less diagnostic of the First Wilcox-Marshall Zone contact than of the Sylvan-Viola contact; however, the log pattern associated with this contact can be learned quickly. The SP should be examined in conjunction with the induction log in evaluating this signature (Figure 9). The top of the Marshall Zone is marked in log signature by moderate negative deflection of the SP, and a strong increase in resistivity.

Interpretation of the Porosity/Permeability Zone

The critical element of this study is the definition, correlation, and mapping of the *ad hoc* porosity/permeability zone of the Viola. For the purpose of this study, the porosity/permeability zone can be described as the zone in the Viola that, from evidence on wireline logs, appear to have the volume of porosity necessary to store hundreds of

[1] Calibration standards for gamma-ray logs have been established by the American Petroleum Institute; all total-intensity gamma-ray logs are recorded in API units, defined from an artificially radioactive formation constructed at the University of Houston (Ellis, 1987, p. 186).

thousands of barrels of fluid, and the permeability required to transmit large quantities of fluid from the formation to the borehole.

Defining this *ad hoc* porosity/permeability zone requires qualification and quantification of the description outlined above.

Micrologs

In this study, electric log-microlog combinations were considered to be the most reliable source of evidence for determining permeable rock, both in sets of modern- style logs and in antique-style logs. Thickness of permeable rock was determined from parts of the microlog where the micronormal curve showed higher resistivity than the microinverse curve, commonly described as "positive separation" (Figure 10). Millidarcies of permeability cannot be measured from mircologs, but the logs are excellent for locating sections of permeable rock and for measuring thickness of permeable strata.

Caliper Logs

The caliper tool is used to measure the borehole diameter. The caliper curve records the build up of "mudcake," shown by places where the borehole is anomalously small. Of course, the accumulation of mudcake is indicative of permeable rock. In this endeavor, evidence of mudcake was used to help qualify the existence of the *ad hoc* porosity/permeability zone. The fundamental assumption was that if – under pressure exerted by the column of drilling mud – the rock takes in enough fluid to build mudcake,

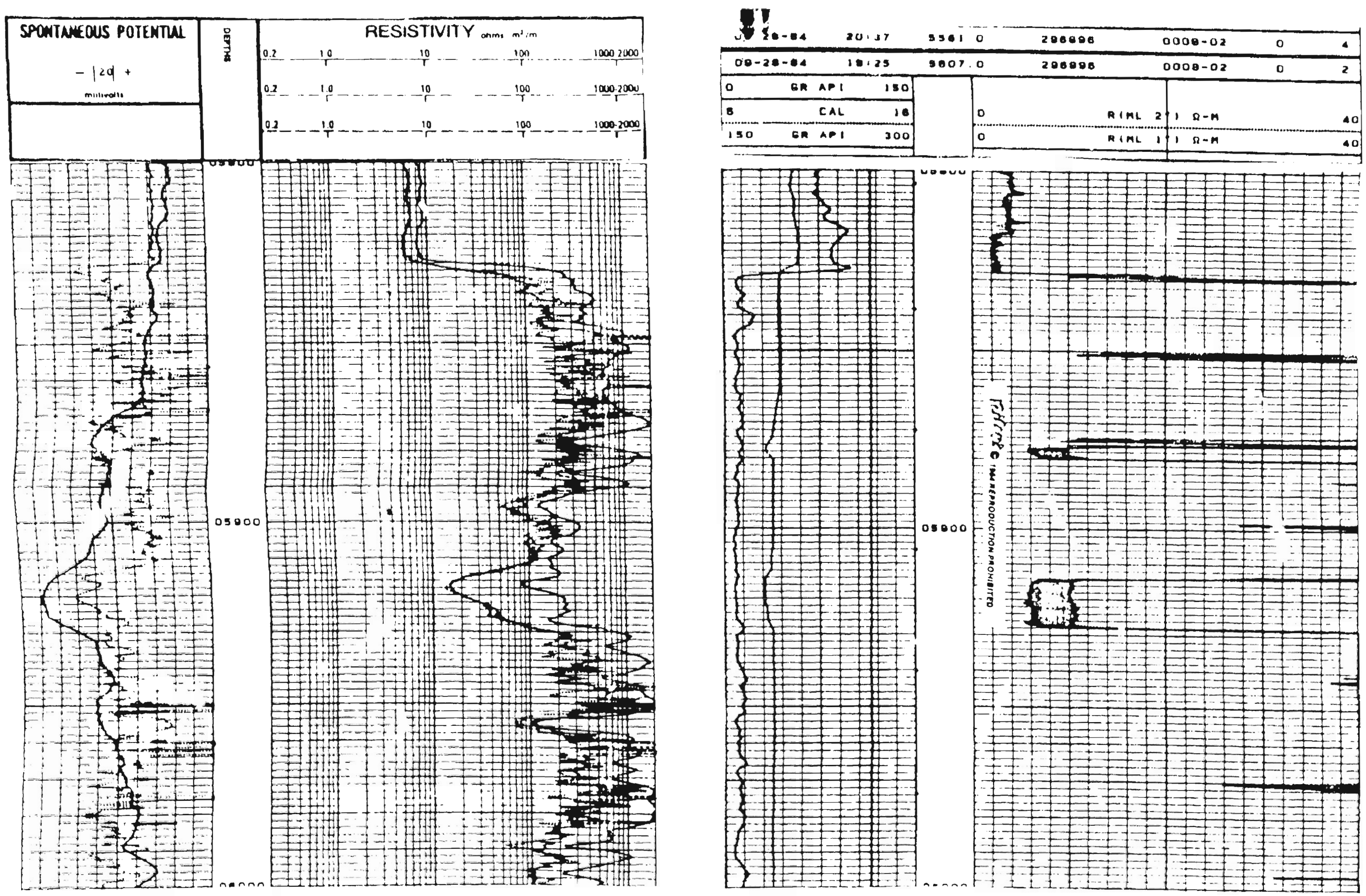

Figure 10. Explanation of microlog and caliper log. The porosity/permeability zone in this log is between 5914 ft. and 5928 ft. Logs shown are of the John P. Downey, Inc. No. 1 Camp, in the SE/4, Sec. 13, T.15 N., R. 2 W.

then the rock should yield fluid. The caliper curve also records places where the borehole's diameter is larger than the diameter of the drill bit; these enlargements commonly are referred to as "wash-outs."

Density-porosity Logs

The Density-porosity logs are very good indicators of a formation's porosity. Treatment of density-porosity logs included correction of matrix density to 2.71 g/cm^3 (limestone matrix assumed) where any other matrix value was used, which "equated" all porosity recorded as lithology-adjusted porosity. Porosity was recorded from the density-porosity curve at two-foot intervals (Figure 11). These values were then doubled, added, and the sum was divided by the total number of feet. The quotient was recorded as average porosity.

To determine thickness of the porosity/permeability zone required a quantity of porosity to be regarded as a threshold value of "effective porosity." "Effective porosity" is described here , provisionally, as porosity sufficient for transmission of oil, gas, and water at rates to be measured in barrels per day. Micrologs and (or) caliper logs were inspected carefully for discovery of porous strata; the strata were marked on the logs. Micrologs and (or) caliper logs were correlated with density-porosity logs of the same wells, by rock-stratigraphic units, so that the porous strata could be "mapped" from micrologs or caliper logs to density logs (for example, see Figures 12 and 13). Density porosity of 3% was determined to be a stable and conservative indicator of effective porosity (as defined above). Qualitative indicators of permeability, such as well-developed negative SP deflection, mudcake, and positive separation of micronormal and

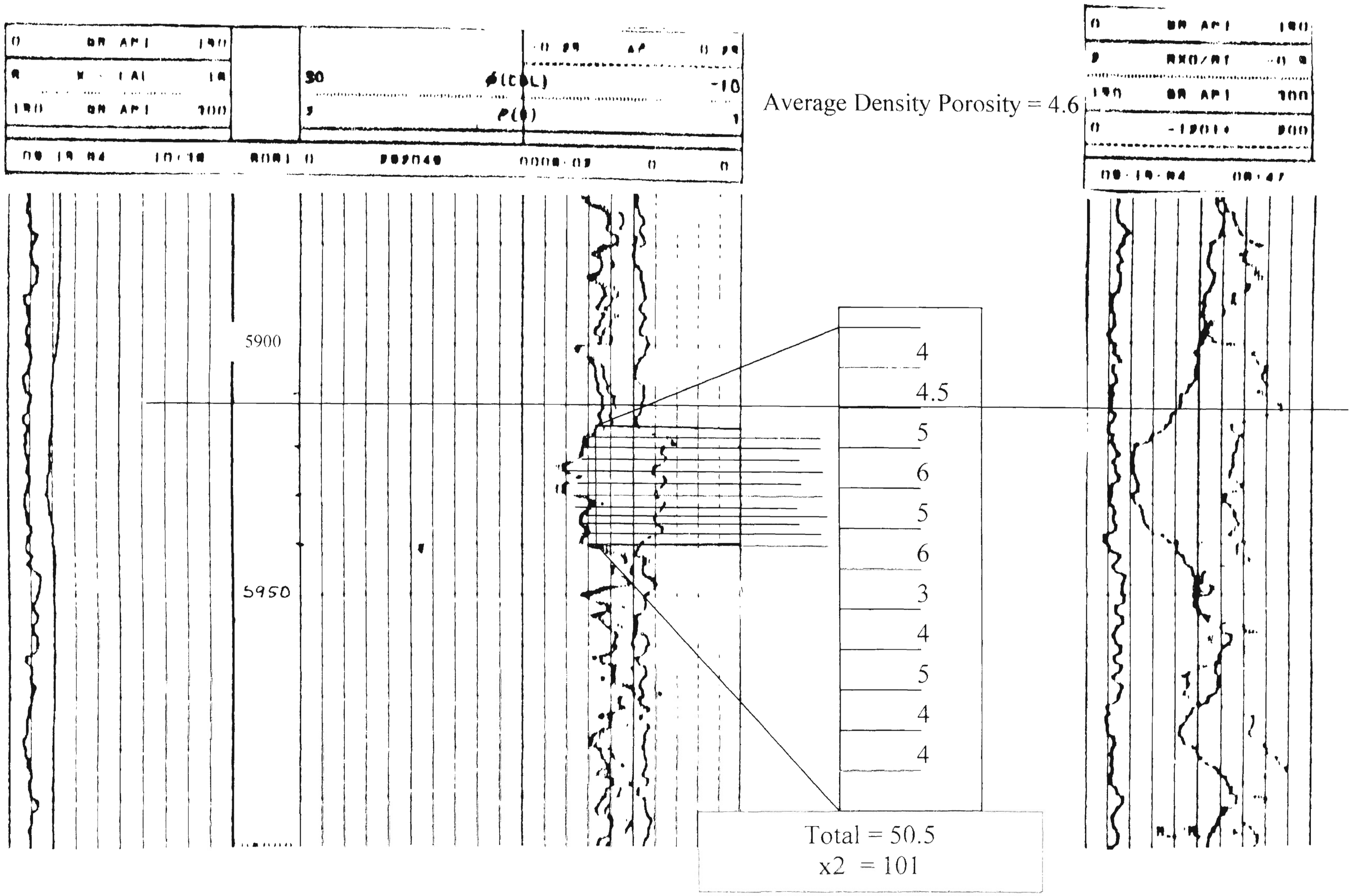

Figure 11. Measurement and calculation of average density porosity. Shea Oil and Gas No. 1 Leachman NE/4 Sec. 18, T. 15 N., R. 1 W. Sum of density porosity feet is 101. Footage measured : 22 feet. Average density porosity: 4.6%.

microinverse curves were not observed in parts of the study area Viola where density porosity is less than 3% (for example, see Figure 10).

Electric Logs and Induction Logs

In some wells, no micrologs, caliper logs, or density-porosity logs were recorded; ancient electric logs, induction-electric logs, or induction logs were the only logs on which the Viola was depicted. The author's alternative courses of action were to map with no data posted at the wells' locations, or to attempt to extract strictly qualitative, but useful information from electric logs and induction logs. If criteria could be established by which permeable rock could be described with a high level of probability, then thickness of the porosity/permeability zone could be measured. By comparison of spontaneous-potential logs and resistivity logs with density-porosity logs, or micrologs, or caliper logs of the same well – in the porosity/permeability zone – three indicative configurations of SP curves and resistivity curves were compiled. These configurations are shown as Criterion 4, below.

Criteria for Identification and Measurement of the Porosity/Permeability zone

In the manner described above, a set of strata in the Viola were named as the *ad hoc* "porosity/permeability zone." Criteria for identification and mapping of this zone are described below, in decreasing order of reliability.

1. Microlog shows positive separation.
2. Caliper logs show evidence of mudcake.

3. Density-porosity, adjusted to limestone matrix, shows porosity of 3% or more.

4. An "electric log" or induction log of the zone has these characteristics: (a) spontaneous-potential curve shows robust negative deflection, (b) separation between or among resistivity curves (an invasion profile) indicates that the rock is permeable, and (c) "true" resistivity of the Viola is measured in single digits or tens of ohm-meters, whereas parts of the Viola above and below show resistivities of hundreds of ohm-meters.

CHAPTER VII

DEVELOPMENT OF THE PROJECT: THE SEARCH FOR ANALOGUES

Some acknowledgement should be made of how this study was developed. Comparison of scout tickets and production data (PI/Dwights, 2000) made this fact evident: exploration for oil and gas in the Viola of the study area has been a "hit and miss" endeavor. Most prospects, especially in this region of Oklahoma, have been built on the basis of previously recognized structural features, in most instances, anticlinal traps from which oil and gas were produced from the underlying sandstones of the Simpson Group (Northcutt and Johnson, 1997, p. 48). Profitable quantities of oil and gas have been produced from fields found by use of this method of exploration, but of course any method that could be more efficient for exploration is worthy of being tested, either by the evaluation of its premises and deductions, or by the drilling of wells. A progression is described below to show how the methods under evaluation in this study were developed.

Analogue 1: The West Carney Hunton Field

The West Carney Hunton Field is in Townships 15 and 16 North, and Ranges 1, 2, and 3 East of Lincoln and Logan Counties, Oklahoma (Figure 12). Approximately 250 producing wells are in the field to date, 25 of which were cored by Marjo Operating

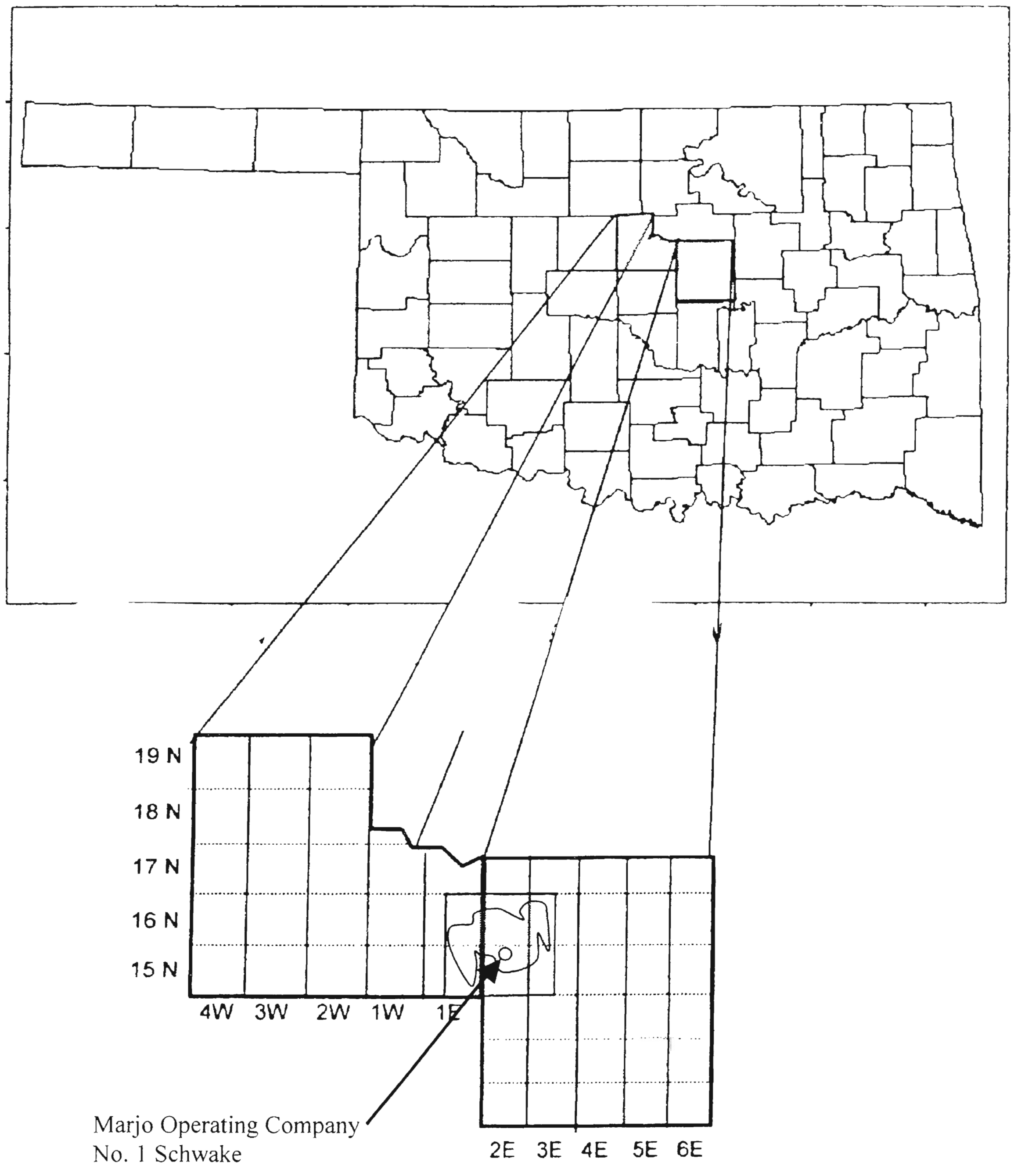

Figure 12. Location Map of the West Carney Hunton Field, Analogue 1

Company (Derby, Podpechan, and Ramakrishna, 2001, p. 6-7). The field produces approximately 6000 barrels of oil a day, 55 million cubic feet of gas per day, and 86 thousand barrels of water per day, from carbonate-rock strata of the Hunton Group (Podpechan, 2001, personal communication). Podpechan (2001) stated that exceptionally good wells in the field have produced several hundred barrels of oil per day, more than 1 million cubic feet of gas per day, and as much as 3000 barrels of water per day. According to Derby, Podpechan, and Ramakrishna (2001, p. 7) detailed analyses of logs and 22 cores have shown that porosity within the Hunton Group is consists mostly of vugs, solution-enhanced fractures, and interparticular porosity created by dissolution of matrix and/or cement. According to Podpechan (2001, personal communication) wells in the West Carney Hunton Field have these general attributes: (1) Soon after completion, wells produce large volumes of water with small volumes oil (small "oil cut"). (2) Volume of gas generally increases rather soon after completion. (3) Volumes of oil and percentage of oil cut generally increase within a brief time after completion of the wells. (4) Within several days to several weeks after completion, the wells produce profitable quantities of oil and gas.

Examination of cores of the Viola from the present study area (Appendix A) suggests that in some critical attributes the strata of the Hunton Group of the West Carney Field and the Viola of the study area may be similar. For example, the porosity/permeability zone of the Viola (Figure 15) is of diagenetic origin, consisting of vugs, fractures widened by solution, and open fractures (Appendix A).

Wireline logs of wells in the Hunton Group of the West Carney Field and of wells in the Viola of the study area have some characteristics in common. Marjo

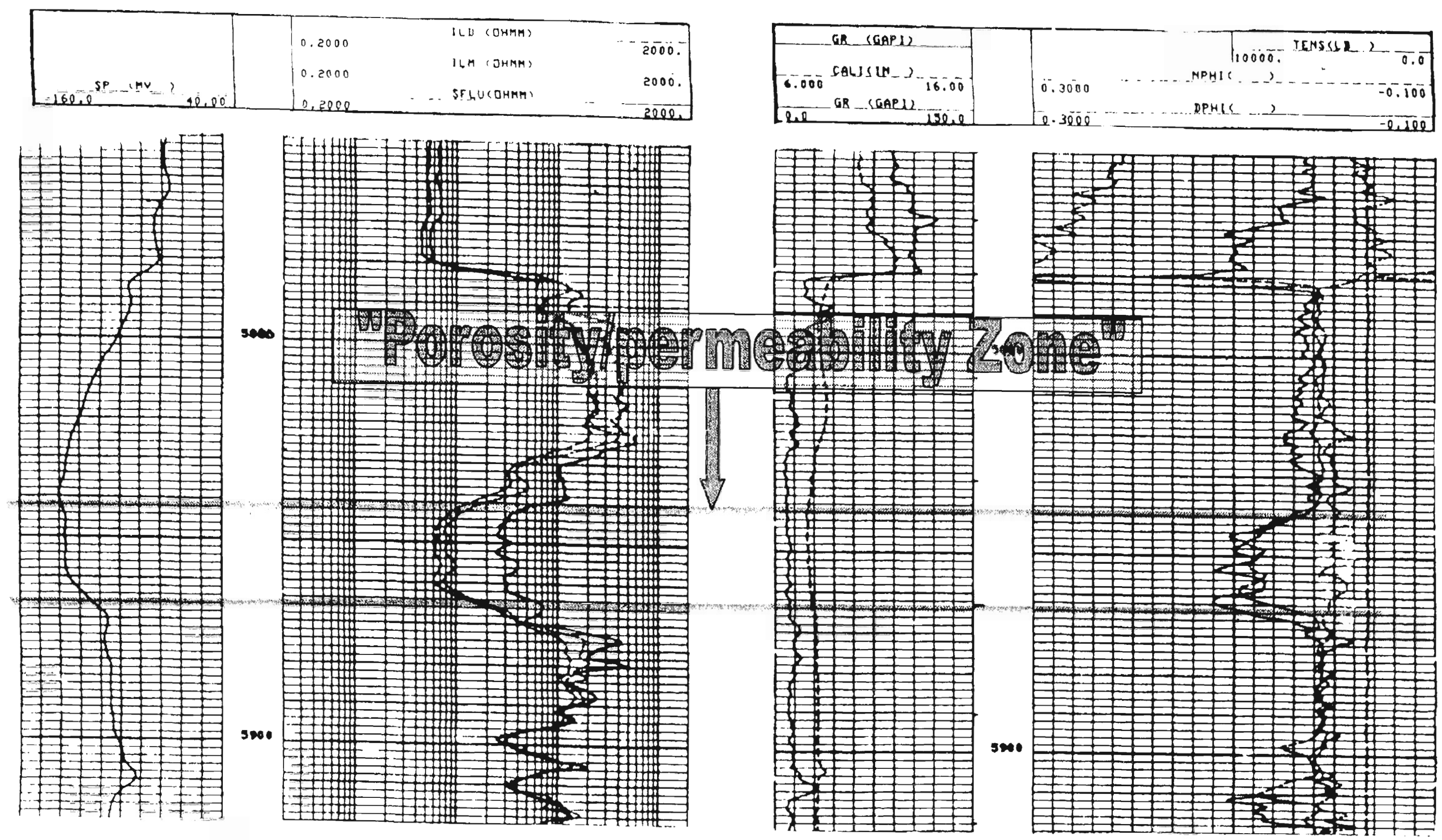

Figure 13. Hazelwood Oil and Gas No. 2 Kay, SE/4, Sec. 30, T. 15 N., R. 1 W., Logan County, Oklahoma. The porosity/permeability zone as defined in this work extends from depth 5940 ft. to depth 5962 ft.

Operating Company generously provided information about and logs of the Marjo No. 1-10 Schawke, shown in Figure 16. The Schwake well was completed in December 1999; it has produced nearly 24,000 barrels of oil, 94 million cubic feet of gas, and 111,000 barrels of water. Wireline logs shown in Figure 16 include the spontaneous-potential, gamma ray, induction, caliper, neutron-porosity, and density-porosity logs. The interval between of 4939 feet and 4978 feet probably is the reservoir rock (Frederick, 2001, personal communication). The following wireline-log characteristics apply to rocks of the Hunton in this well (Figure 16): (1) The gamma ray curve shows a reading of less than 15 API units, indicating that the formation includes very little shale. (2) The spontaneous-potential curve is well developed, with negative deflection substantially greater than that of the Woodford Shale above and the Sylvan Shale below. (3) The caliper curve records a slight decrease in the diameter of the bore hole, indicating the development of mudcake. (4) The "Deep Resistivity" induction curve shows moderate to high resistivity, approximately 30 to 130 ohm-meters. Also, separation is recorded between the spherically focused resistivity log, and the medium and deep focused logs. (5) The density-porosity curve and the neutron-porosity curve indicate that porosity ranges from about 1.5 percent to 6 percent.

The log characteristics listed above are similar to those of the Shea Oil and Gas No. 1 Leachman, shown in Figure 17. The Leachman 1 is in the northeast quarter of Section 18, Township 15 North, Range 1 West. This well, penetrated the top of the Viola at depth of 5837 feet (Figure 17). Observe that the porosity/permeability zone, the interval between depths of 5916 feet and 5940, resembles the Hunton Group shown in

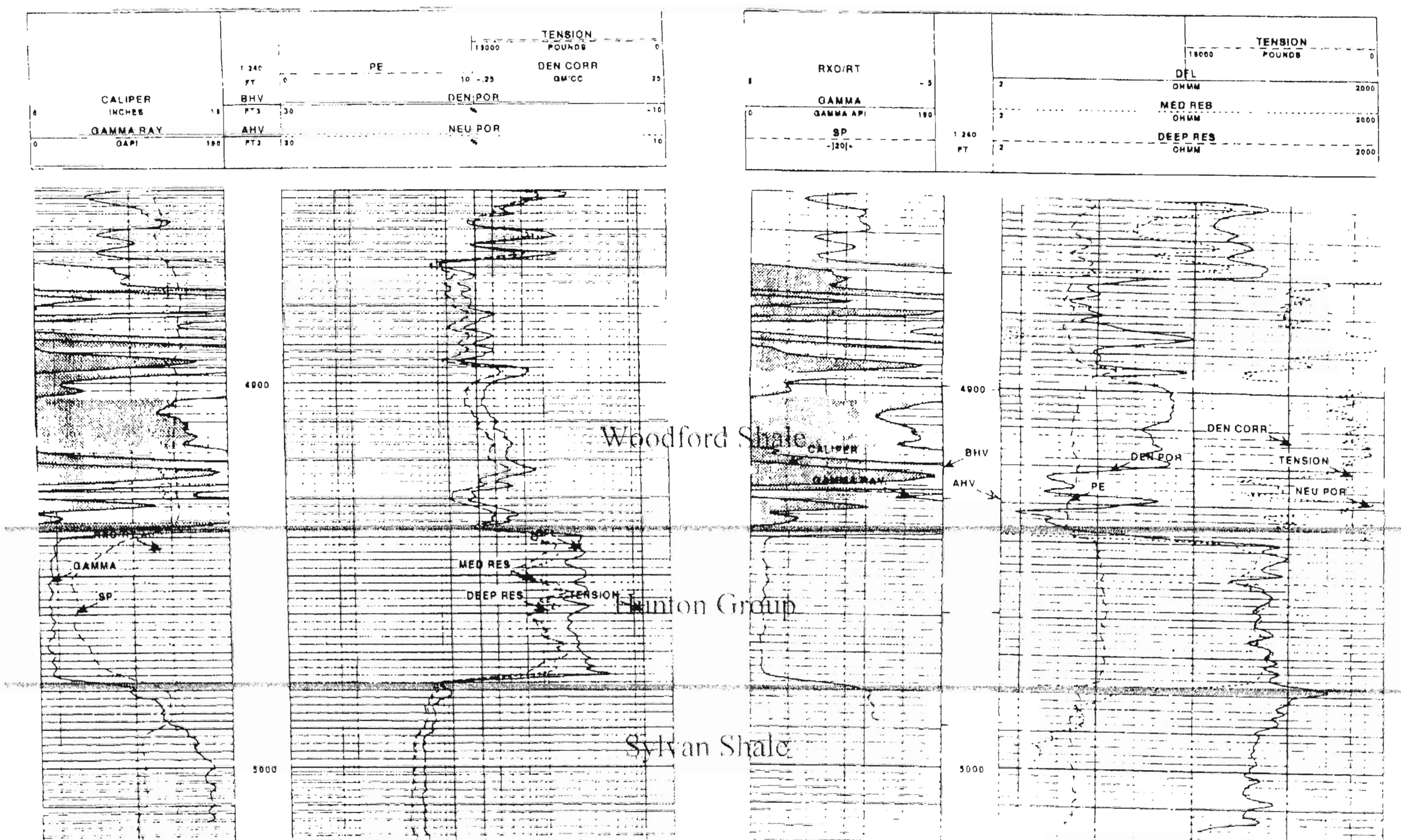

Figure 14. Marjo Operating Company No. 1 Schwake, SW/4 Sec. 10, T. 15 N., R. 2 E., Lincoln County, OK
The reservoir rock, as described earlier in this report, is from 4939 to 4978 feet.
The log characteristics shown here in the Hunton strata, share common attributes with the log characteristics of the porosity/permeability zone of Viola in Logan County, OK (Figure 15, Table 3)

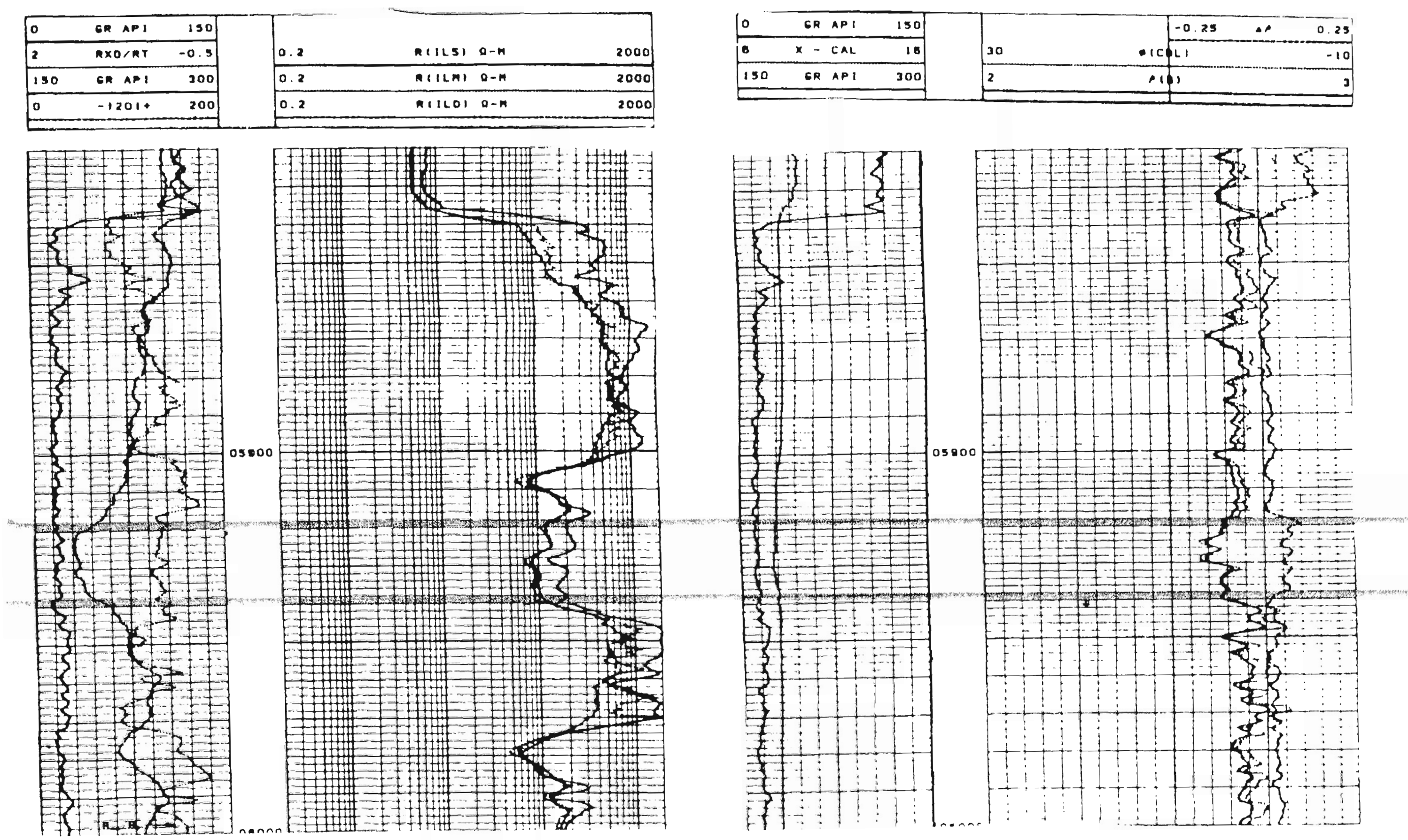

Figure 15. Shea Oil and Gas No. 1 Leachman, NE/4, Sec. 18, T. 15 N., R. 1 W., Logan County, OK. The porosity/permeability zone, as described earlier in this report, is from 5918 to 5938 feet.
The log characteristics shown here in the Viola share common attributes with the log characteristics of the Hunton strata of the Marjo Operating Company No. 1-10 Schwake (Figure 14, Table 3)

CHARACTERISTIC	Schwake No. 1 Marjo Operating SW/4, SEC. 10 T. 15 N., R. 2 E.	Leachman No. 1 Shae Oil and Gas NE/4 SEC. 18 T. 15 N. R 1 W.
Interval	4939'-4978'	5918' -5938'
Thickness	38 feet	20 feet
Spontaneous Potential: Deflection from shale baseline	(negative) 80-100 mV	(negative) 80-100 mV
Gamma Ray Range	7-15 API	8-16 API
Change in borehole diameter from Caliper log	decrease 0 - 0 25 in	decrease 0 25 -0 5 in
Deep Induction	30 - 130 ohm-meters	80-200 ohm-meters
Separation: SFL from Deep Induction	100 -200 ohm-meters	50-100 ohm-meters
Nuetron/Density Porosity Range	1.5 - 6 %	2 - 8 %
Nuetron-porosity average	3.4%	4.8%
Density-porosity average	2.7%	4.6%

Table 3. Comparison of log characteristics of Hunton reservoir in the Marjo Operating Company No. 1-10 Schwake and of the Viola porosity/permeability zone in the Shea Oil and Gas No. 1 Leachman. See Also Figures 14 and 15.

Figure 16. In fact, the porosity/permeability zone of the Viola in the Leachman 1 shares many critical attributes with the Hunton in the Schwake No. 1, as shown in Table 3.

The reservoir characteristics of the West Carney Hunton Field are currently being compiled in detail in a joint effort conducted by the United States Department of Energy, Marjo Operating Company, and the University of Tulsa (Derby, Podpechan, and Ramakrishna, 2001, p. 4). One aspect of this study is an attempt to discern the nature of the trapping mechanism. Currently, the trapping mechanism of the Hunton reservoir in West Carney Field is described as stratigraphic; furthermore, the interplay of impermeable and permeable rock making up the stratigraphic nature of the trap is probably very complex (Podpechan, 200l, personal communication).

The porosity/permeability zone of the Viola within the study area has some qualities analogous to those of the Hunton reservoir rock in the West Carney Field; therefore, the Viola and Hunton may produce oil and gas in similar quantities at similar rates, for similar reasons.. According to Podpechan (2001, personal communication), although operating Hunton wells in the West Carney Field is very expensive, return on investment is 2:1 or 3:1 over five years, depending on prices of oil and gas. If the porosity/permeability zone of the Viola in the study area is in fact operationally similar to reservoir rock of the Hunton in the Carney Field, then a method for improving exploration of the Viola may be surprisingly profitable.

Analogue 2: The Garfield County Viola Field

Any logical argument based on analogy of the Viola in the three-township study area in Logan County and strata in a distant place should involve the case history of a well or an oil field where the Viola has produced or is producing profitable quantities of oil and gas. A tactic of assessment would be to (1) compare strata of the Viola in Logan County to strata of the Viola at places where the Viola produces oil and gas, and if the strata can be shown to be similar, (2) to describe the traps from which the Viola produces petroleum, and (3) to search for similar trapping circumstances in the Viola of Logan County. Thereby the analogies should be established in attributes both of the reservoir and the traps. A suitable analogue is in Township 21 North, Range 6 West in Garfield County, Oklahoma, where approximately 15 wells produce oil and gas from strata of the Viola (Figure 18). The reader should note that Figure 18 has been simplified, so as to protect the interests of companies actively exploring for or producing oil and gas in the area. Nevertheless, the diagram should be adequate for illustration of evidence required to demonstrate the analogy.

The Fuller Production No. 1-22 Lewis is in the Sooner Trend, in the southeast quarter of Section 22, Township 21 North, Range 6 West. According to published information (NRIS, 2001), the well produced approximately 579,000 barrels of oil and1.8 billion cubic feet of gas from April 1979 to September 2001. However, the Fuller Production No. 1 Lewis and the Fuller Production No. 2 Krejci are in the same lease tract; volumes of oil and gas shown above must be attributed to both wells, but relative

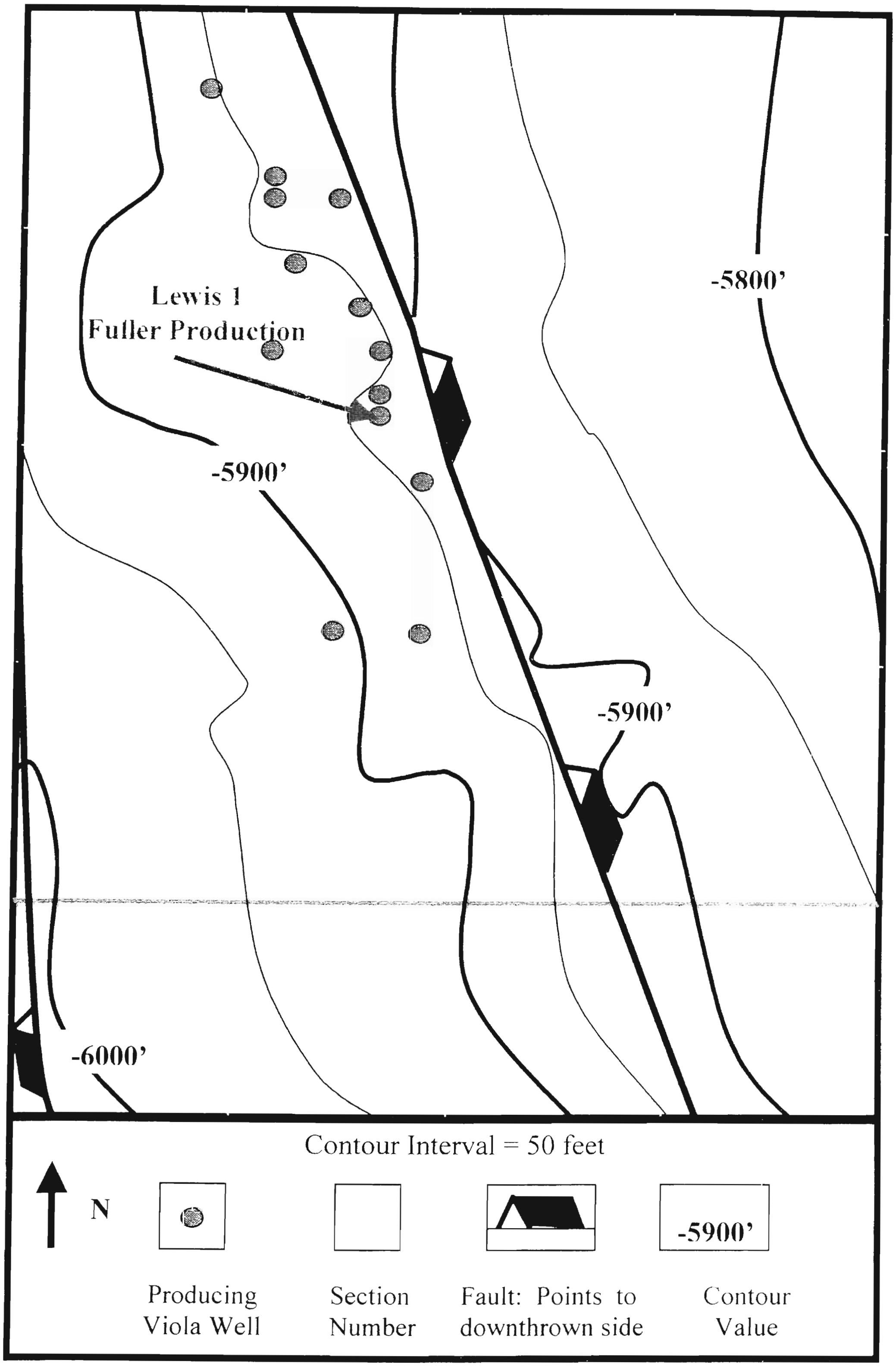

Figure 16. Viola production in the Sooner Trend Field, Garfield County, Oklahoma
Structure contour map on the base of the Sylvan Shale/top of Viola

proportions were not published. The cumulative amount of salt water produced from the Fuller No. 1-22 Lewis and No. 2 Krejci was not published. However, according to Charlotte Webb of Fuller Production (2001, personal communication), the Lewis well pumped roughly 900 barrels of water per day during early production, and currently produces 90 to 100 barrels per day.

Well logs of the Viola in Logan County were compared with logs of the Viola in Garfield County. Figure 19 shows logs of the Fuller Production No. 1 Lewis. The log signature of the perforated interval, 6980 feet to 7000 feet, bears a strong resemblance to the porosity/permeability zone in the Funk Exploration No. 1 Kellog, SW/4, Sec. 30, T. 15 N. , R. 1 W., Logan County, which extends from 5928 to 5944 feet (compare Figure 20. with Figure 19). Table 4 shows evidence of formidable similarity of the Viola in two wells a long distance apart. Reasoning by analogy almost certainly is justified. Mapping and testing of strata of the porosity/permeability zone in Logan County are merited.

Figure 16 (Podpechan, 2001 unpublished map), shows the basic structural conditions of the Viola field in the Sooner Trend of Garfield County. Figure 16 suggests a structural trap, where, the Viola extends up-dip across a high standing fault block. At the fault, the Viola is in contact with the Sylvan Shale, which is the lateral seal of the trap. Throw of the fault is about 60 feet. Podpechan (2001, personal communication) believes that stratigraphic entrapment also is operative in the Viola (probably the stratigraphic equivalent of the porosity/permeability zone of the Viola in Logan County) is in lateral, up-dip contact with impermeable strata of the Viola.

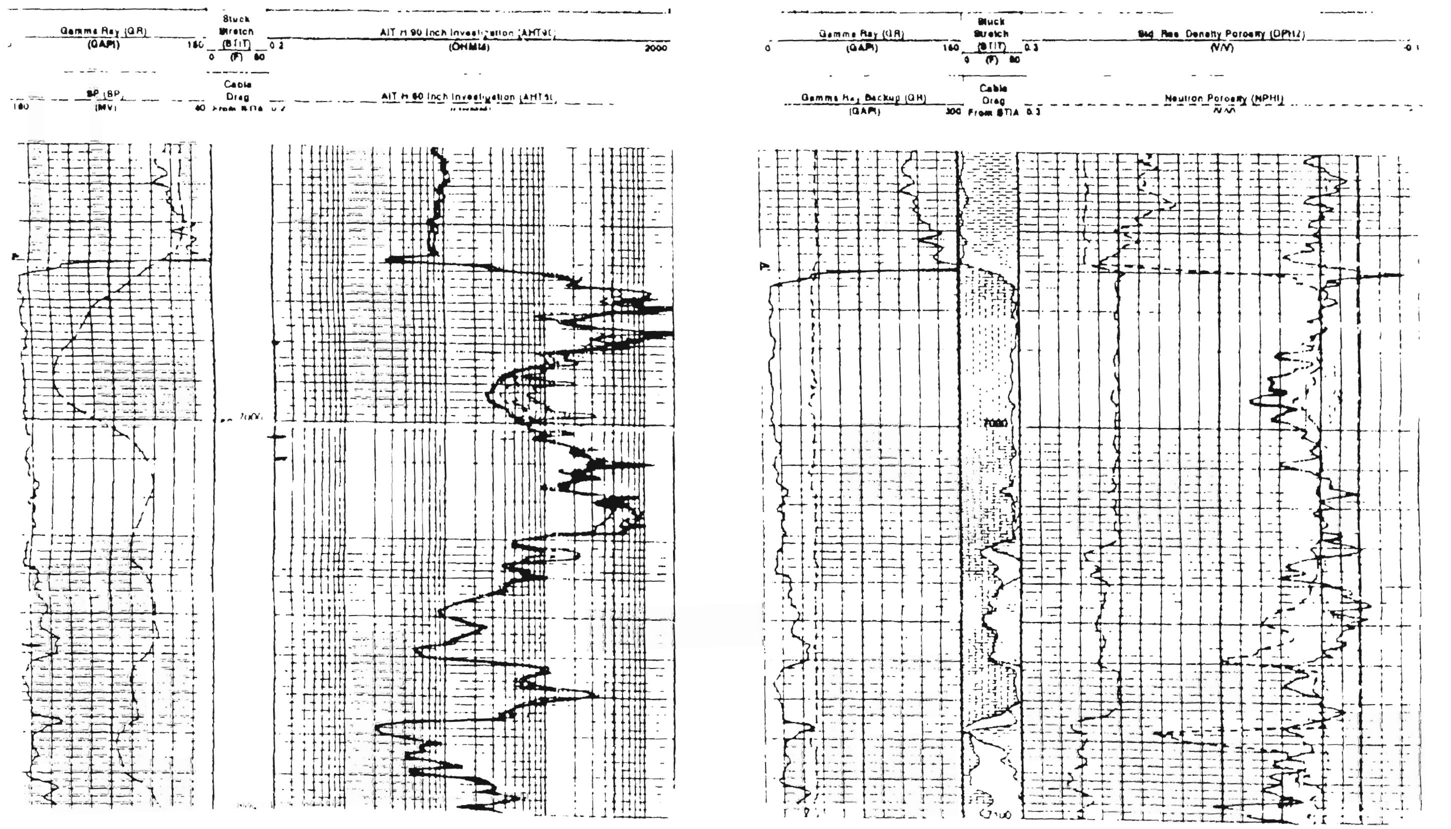

Figure 17. Fuller Production No. 1 Lewis. SE/4. Sec. 22, T. 21. N., R. 6 W. Garfield County, OK
The reservoir rock is from 6980 to 7000 ft. The log characteristics of the Viola strata of Garfield County strongly resemble the log characteristics of the porosity/permeability zone of the Viola in Logan County, Oklahoma (Figure 18, Table 4).

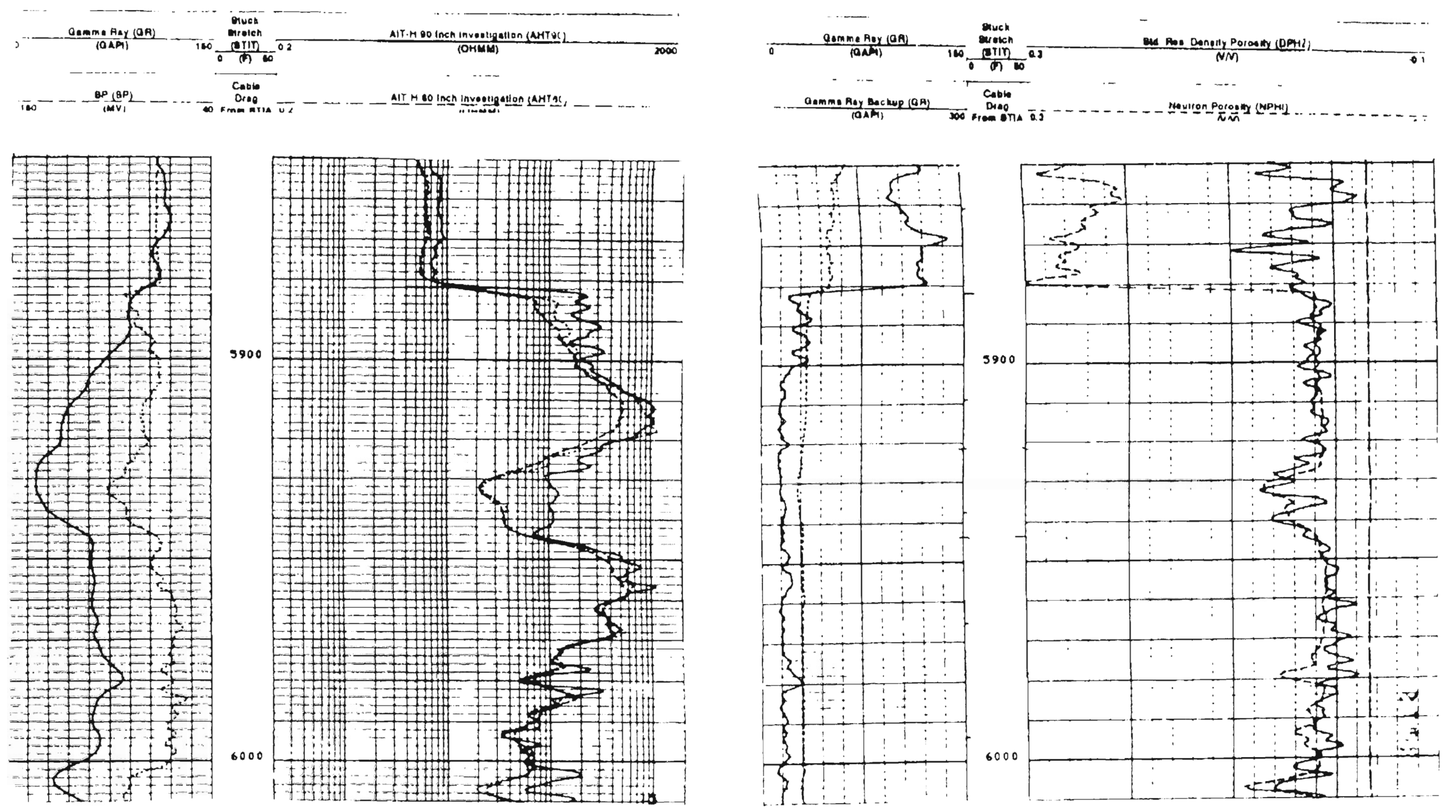

Figure 18. Funk Exploration No. 1 Kellog, SW/4 Sec. 30, T. 15 N., R. 1 W., Logan County, Oklahoma The reservoir rock is from 5928 to 5944 feet. Log characteristics shown here in the Viola strata of Logan County strongly resemble log characteristics of the reservoir strata of Viola in Garfield County, Oklahoma (Figure 17, Table 4).

CHARACTERISTIC	Lewis No. 1 Fuller Production. SE/4, Sec. 22, T 21 N., R. 6 W.	Kellog No. 1 Funk Exploration SW/4 Sec. 30,T. 15 N., R 1 W
Interval	6980'-7000'	5928' -5944'
Thickness	20 feet	16 feet
Spontaneous Potential: Deflection from shale baseline	(negative) 100-130 mV	(negative)100-120 mV
Gamma Ray Range	7-10 API	13-16 API
Change in borehole diameter from Caliper log	decrease 0 - 0.25 in	decrease 0 -0 25 in
Deep Induction	18 - 100 ohm-meters	13-110 ohm-meters
Separation: SFL from Deep Induction	40 -60 ohm-meters	60-100 ohm-meters
Nuetron/Density Porosity Range	2 - 7 %	2 -7 %
Nuetron-porosity average	1.8%	5.4%
Density-porosity average	4.4%	4.9%

Table 4. Comparison of log characteristics of the Viola reservoir in the Fuller Production No. 1 Lewis and of the Viola porosity/permeability zone in the Funk Exploration No. 1 Kellog. See also Figure 17 and Figure 18.

Analogue 3: An Analogue from the Study Area

Strata of the Viola in Garfield County -- known to produce commercial amounts of petroleum -- have been shown to share critical attributes with strata of the Viola in the study area. Because strata have been shown to be similar then it stands to reason that the Viola in the study area in Logan County may produce quantities of petroleum comparable to the Viola in the Sooner Trend of Garfield County. Such an analogue is presented in the Southwest Oil Corporation No. 1 Eggleston in the southeast SE/4, SW/4, NW/4, Sec. 13, T. 15 N., R. 2 W. (Figure 21).

According to published data from PI/Dwights (2001) the Eggleston No. 1 produced nearly 219,000 barrels of oil and 36 million cubic feet of gas. This accounts for approximately 80 percent of the oil production from the Viola in the Pleasant Valley East Field (Table 2), and roughly 16 percent of the Viola oil production for the entire study area.

The Eggleston well is one of the few wells in the area that was perforated and completed in the porosity/permeability zone, believed to be equivalent to the reservoir rock in Garfield County (see above). The porosity/permeability zone is shown on a wireline log (Figure 22) to be between depths 5890 feet and 5932 feet: the interval reportedly perforated and completed in was between 5882 feet and 5932 feet. All other nearby wells were perforated either at the very top of the formation, near the Sylvan-Viola contact, or just a few feet above the porosity/permeability zone defined in this work (Figure 22).

There is little evidence (Plate I) showing the porosity/permeability zone as being

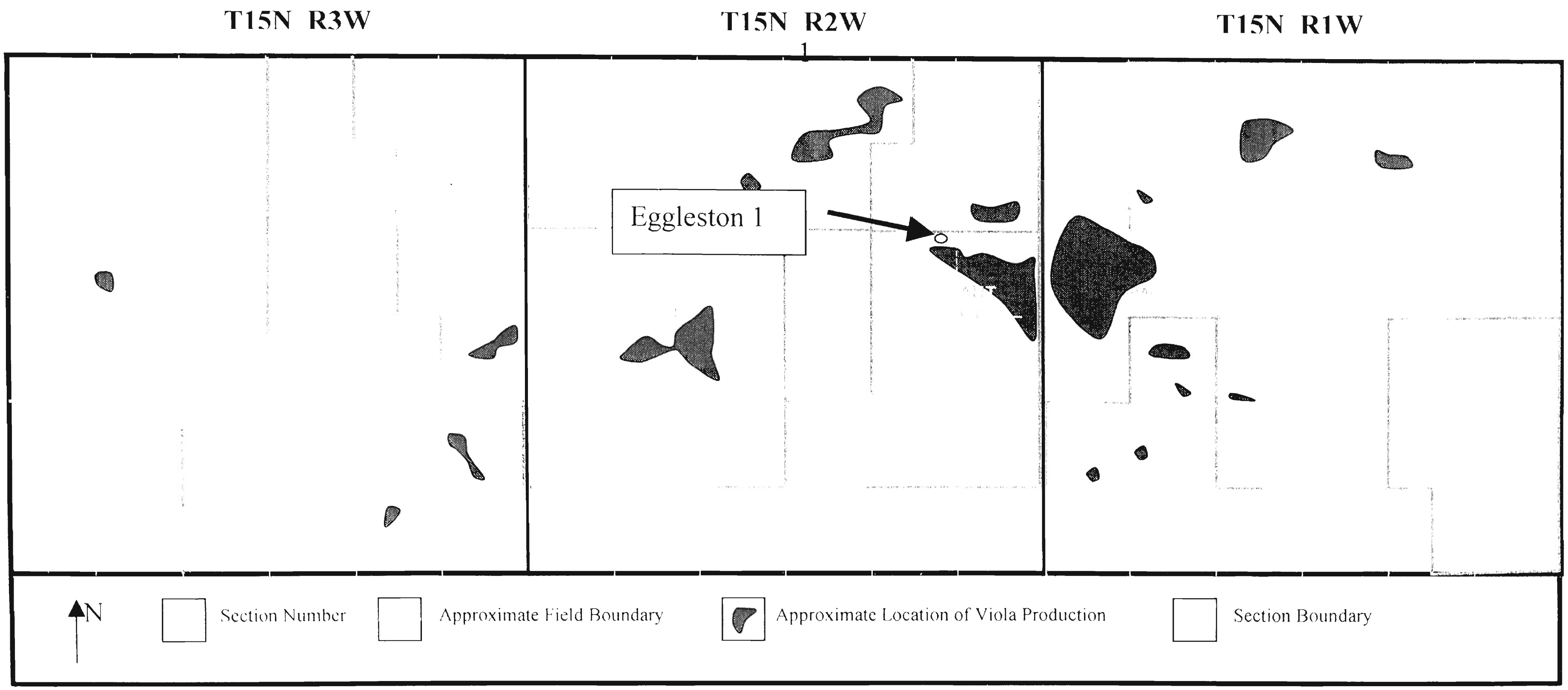

Figure 19. Map showing location of Southwest Oil Corporation No. 1 Eggleston, NW/4 Sec. 13, T. 15N., R. 2 W..

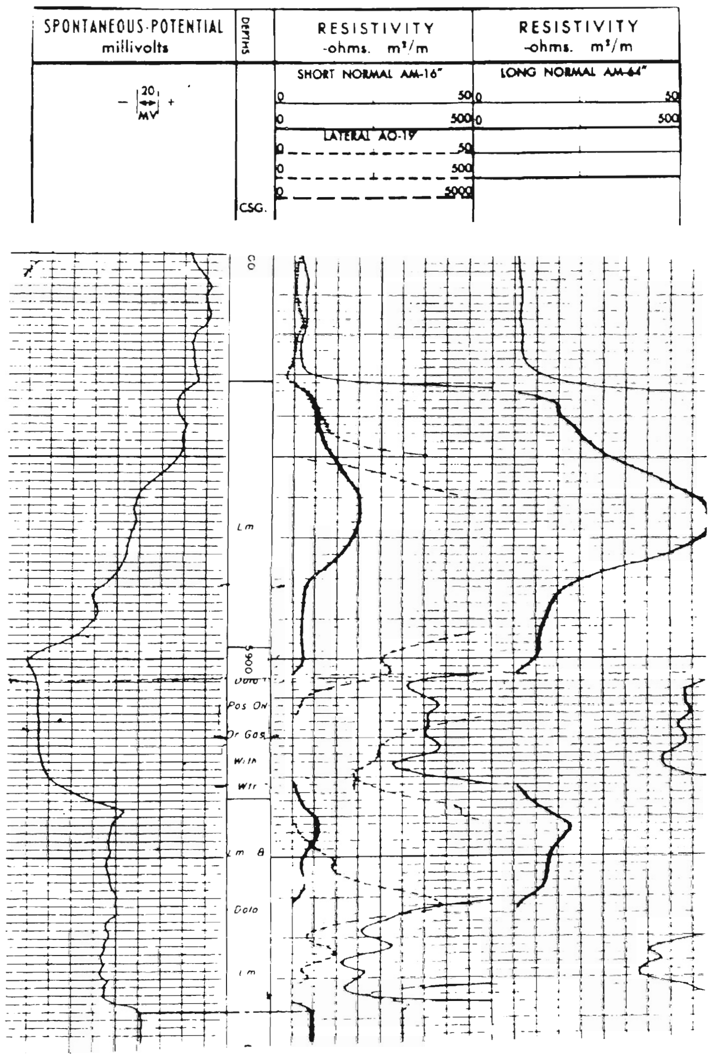

Figure 20. Southwest Oil Corporation No. 1 Eggleston, NW/4 Sec. 13, T. 15 N., R. 2 W., Logan County, OklahomaThe reservoir rock is from 5890 to 5932 feet.

associated with any significant structural trapping mechanism. Although the Eggleston well is on a slight "anticlinal nose" less than 2 miles north of a regional fault and less than 2 miles south of a local fault, the likelihood of a structural trap is subtle. However, study of the isopach map of the porosity/permeability zone (Plate III), does little to suggest a stratigraphic trap. Although the isopach map shows pinchout of the zone a mile west, it also shows thick intervals of the porosity/permeability zone to the north and south of the Eggleston well; therefore, the trapping mechanism should not be construed as solely a stratigraphic trap. The trapping mechanism could be a combination structural and stratigraphic trap, bordered on the north and south by faults, and on the east and west by impermeable rock (compare Plate I and Plate III); however, evidence is inconclusive as of now.

CHAPTER VIII

RESULTS OF THE INVESTIGATION

The primary purpose of this work was to develop a method for exploring for petroleum in the Viola Group of north-central Oklahoma, specifically in the three-township study area in Logan County. The goal of the writer was to develop a set of data and a set of methods that would be beneficial to the petroleum industry.

Tom Meason, a veteran with more than 20 years of experience exploring for Viola production in north-central and northeastern Oklahoma, stated that much of the oil and gas from Viola reservoirs has been discovered chiefly by searching for anticlinal folds or high-standing fault blocks. Evidence from scout tickets and well logs concerning perforated and completed intervals suggests that completions and perforations of the Viola have been either near the Viola-Sylvan contact at the very top of the formation, or only a few feet above the top of the porosity/permeability zone. Such evidence implies that such a procedure was followed in order to reduce the risk of perforating below an oil-water contact and have a potentially good well "water-out" (Podpechan, 2001 personal communication).

The recently developed procedures practiced by operating companies within the West Carney Hunton Field (this work, p. 39) suggest that some reservoirs in carbonate rocks produce profitable amounts of oil and gas, even though the disposal of large quantities of water is expensive.

Wireline-log characteristics of the porosity/permeability zone in the study area show some similarity when compared with wireline log characteristics of the Hunton reservoir rock of the West Carney Field (this work, p. 43). This hypothesis arose from the model of the West Carney Hunton Field: The carbonate-rock reservoir of the Hunton strata is known to have produced profitable quantities of oil and gas, delivered entrained in common proportions with enormous quantities of saltwater. Therefore, the carbonate-rock reservoir of the Viola in Logan County, shown to share critical attributes with the Hunton reservoir, may also produce profitable quantities of oil and gas entrained in moderate to very large volumes of saltwater.

As demonstrated earlier in this report (p. 43), the Viola of the Sooner Trend in Garfield County, Oklahoma, was shown to have reservoir rock that produces profitable quantities of oil and gas, in association with moderate to large volumes of water. The wells in this area are producing as of the date of this work. In the Sooner trend wireline-log characteristics of the perforated reservoir, strongly resemble the wireline characteristics of the porosity/permeability zone of the three-township area in Logan County, Oklahoma (compare figures 20 and 22). This hypothesis arose from the model of the Viola in Garfield County: The carbonate-rock reservoir in the Viola of Garfield County has been shown to permit movement of large quantities of fluid and thus is permeable and porous. Therefore, the porosity/permeability zone should be identifiable from wireline logs by critical attributes; these attributes should be applicable in Logan County as well as in Garfield County.

As described earlier in this report, the Southwest Oil Corporation No. 1 Eggleston in Section 13, Township 15 North, Range 2 West, has been shown to produce profitable quantities of oil and gas from reservoir rock of the Viola (probably in association with moderate to large quantities of water). The reservoir was perforated (Figure 22) in the porosity/permeability zone of the Viola, as approximated from wireline logs (Figure 22). This hypothesis arose from the Eggelston 1 model: The Viola within the study area has been shown to produce from a zone of rock that probably is quite porous and quite permeable, properties that are discernible from critical attributes of wireline logs. Therefore, an isopach map of the porous and permeable rock can be generated from information drawn from wireline logs.

The mechanism for entrapment of oil and gas of the Viola limestone within the study area is poorly understood. As shown in this report, oil and gas from the Viola of the Sooner Trend in Garfield County probably was trapped in the uppermost portion of an upthrown fault block (Figure 18). The trap from which the Southwest Oil Corporation No.1 Eggleston produces appears to have both stratigraphic and structural elements. On the east and west it is bounded by impermeable rock (Figure 23), and on the north and south by faulting. The Eggleston No. 1 is more than one mile from each of the elements that seem to act as barriers for the entrapment of oil and gas; the reader should note that the trapping mechanism in the immediate area is not made clear by the available information Consideration of the obscure trapping mechanisms in the Viola in Logan County resulted in the following hypothesis At some localities oil and gas are trapped structurally, at other localities the traps comprise structural and stratigraphic elements

As shown in this work (p. 32), a porosity/permeability zone in the Viola of the study area can be defined and mapped on the basis of log characteristics. As described

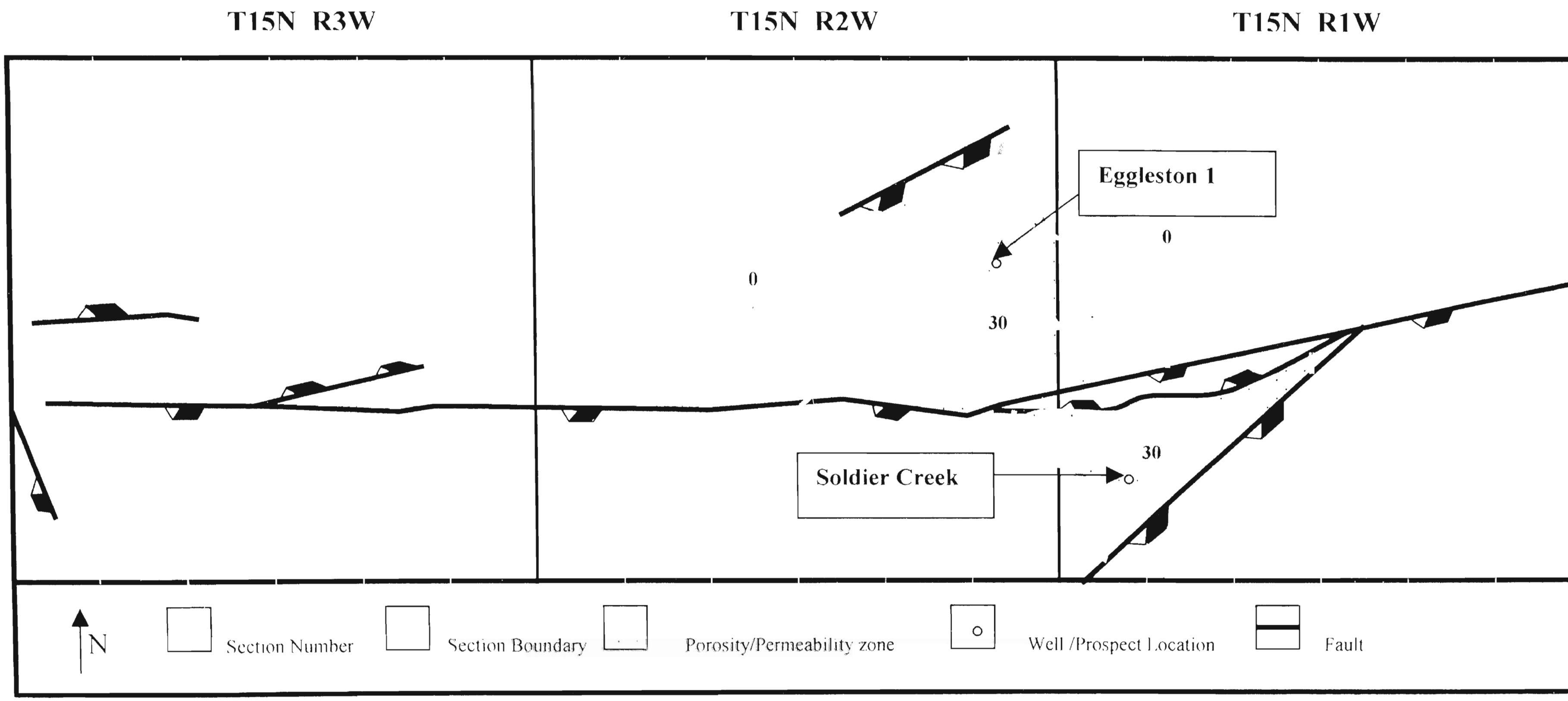

Figure 21. Principle faults in the study area, and locations of Southwest Oil Corporation No. 1 Eggleston and of Soldier Creek Prospect. Stippled pattern shows local extent of porosity/permeability zone of the Viola. Locally the zone is thicker than 30 feet.

above (p.23), this porosity/permeability zone stores and yields profitable quantities of petroleum. Plate III shows that the porosity/permeability zone can be mapped, based on the thickness of the zone The structural geologic map (Plate I) describes the faults, anticlinal features, and synclinal features of the area.

An example of how these methods could be effective in development of oil and gas prospects is below.

Example of Method: Soldier Creek Prospect

The writer's opinion is that the effective development of prospects must be classified as a "gamble based on scientific practices" and therefore is in and of itself inappropriate for academic endeavor. The reader should note that what follows is indeed the description of a prospect, but the subject under examination is the set of methods used to develop the prospect. The success or failure of these methods, while necessarily evaluated here by rational methods, will truly be determined only by the drilling and testing of wells drilled on the basis of these methods. The following is an example of where these methods are likely to work.

The Soldier Creek prospect is in the SE/4, Sec. 30, T. 15 N., R. 1 W. (Figure 23). This 160-acre area is appropriate for testing the methods involved here; the optimal location appears to be in the SW/4 , SE/4 , Section 30. In Figure 24 two logs are compared to show that the zone of porosity and permeability is well developed, with approximately 36 feet of potential reservoir rock. Plate III illustrates that the reservoir is well developed throughout the local area.

Circumstances for entrapment of petroleum in the Soldier Creek area are much like those in the area surrounding the Southwest Oil Corporation No. 1 Eggleston: thickness of the porosity and permeability zone approaches zero and the zone "pinches out" westward and northeastward (Figure 23), but a mile or more from the spot proposed for drilling. Throws of faults that define a narrow graben, approximately one mile north of the prospect, may be enough (perhaps as much as 100 feet) to seal the reservoir rock (Figure 23). Approximately one-half mile to the south is another fault, with approximately 40 feet of throw; the prospect area is on the upthrown side. Evidence for the interpretation made here is offered in comparison of the two wells in the southeast quarter of Section 29, Township 15 North, Range 1 West. In the Appelton Oil No. 1 Lesh, located just north of the fault in the SE/4, NW/4, SE/4, Sec. 30, Mississippian rocks are about 40 feet thinner than in the Rox Exploration No. 1 Elder, just south of the fault, in the SE/4, SW/4, SE/4, Section 30 (Figure 23).

The thickness of the porosity/permeability zone could result in a drainage area larger than 40 acres, and perhaps larger than 160 acres if the reservoir is well connected.

The two well bores closest to the proposed drilling site are the Calvert Drilling Company No. 1Bledsoe in the SW/4, SW/4, SE/4 of Section 30, and the Hazelwood Oil and Gas No. 2 Kay located in the NE/4, SW/4, SE/4 Section 30. Logs of the Viola in both wells have well-developed spontaneous-potential curves associated with low resistivity (in comparison to other parts of the Viola). Only "antique" logs are available of the Calvert No. 1 Bledsoe: however, the microlog indicates approximately 36 feet of permeable rock from 5814 to 5850 feet (Figure 22). In the Hazelwood No. 2 Kay, between 5840 and 5866 feet, average density porosity is 8.3 percent, and maximal porosity is 12 percent. Mudcake is identifiable from the caliper curve (Figure 15). Thus the porosity/permeability zone is almost certainly present in the area.

The presence of reservoir rock in combination with geologic circumstances favorable for entrapment of petroleum in the Soldier Creek area make the location a promising one. In the author's opinion, methods described in this work seem to have merit, to be effective, and perhaps to be efficient for defining prospects in carbonate rocks of the Viola. However, as noted above, the process will not be proven to be effective until wells staked on the basis of this method are drilled and tested. If the wells are commercially successful, then successive wells would demonstrate that the method is efficient, if the success ratio is improbably high.

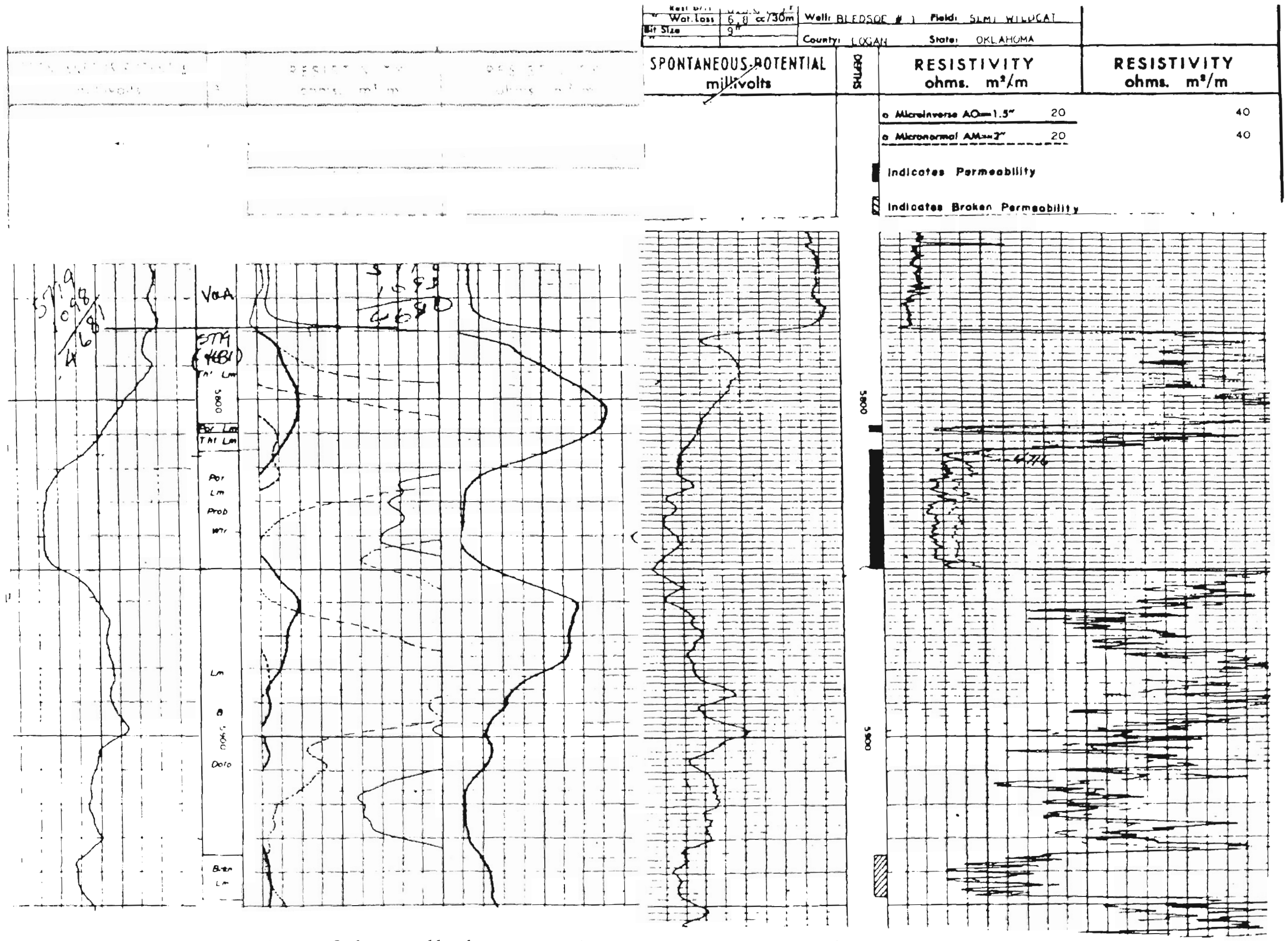

Figure 22. Wireline log of the well closest well to the Soldier Creek Prospect. Calvert Drilling Company No. 1 Bledsoe. SE/4 Sec. 30. T. 15 N.. R. 1 W.

CHAPTER IX

CONCLUSIONS

Principle conclusions of this study are as follows:

1. The "Viola Formation" of the study area must be regarded as an informal rock-stratigraphic unit, because neither the Viola nor the upper part of the Bromide Formation (Figure 2) has definitely been traced to outcrop and correlated with the formal rock-stratigraphic unit of the same age.

2. An interval of porous and permeable rock within the Viola can be identified from wireline logs. In this work, the interval was referred to by the *ad hoc* name "porosity/permeability zone."

3. The porosity/permeability zone can be described by combination of quantitative and qualitative criteria based on interpretation of wireline logs.

4. The middle to lower parts of the Viola are quite porous and permeable in a "belt" that trends northwestward across Township 15 North, Ranges 1 and 2 West. Oil and saltwater have been produced from the rock in large numbers of barrels per day, from at least one well. The reservoir rock "pinches out" down-dip southwestward, up-dip northeastward, and locally within the belt. The reservoir is thicker than 38 feet at several localities

5. The porosity/permeability zone within the study area was shown to have several petrographic qualities analogous to reservoir rock exploited in fields where profitable quantities of oil and gas are produced.

6. The porosity/permeability zone has been tested in the study area by the Southwest Oil Corporation No. 1 Eggleston, Sec. 13, T. 15 N., R. 2 W. The well has produced 219,000 barrels of oil and 36 million cubic feet of gas.

7. In parts of the study area, the Viola of the study area has potential for both stratigraphic and structural entrapment of petroleum.

In the author's opinion, methods described in this study will prove to be effective in development of oil and gas prospects of economically attractive size, within the study area, and elsewhere. The true value of this study will be known only after the drilling, testing, and completion of wells in the porosity/permeability zone of the Viola. Wells completed so as to produce extraordinarily large quantities of water (with oil) are predictable only after weeks or months of operation; therefore, the ultimate worth of the method will be based on histories of wells – not on initial production rates.

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APPENDIX A

CORE DATA

When available, information obtained from the examination of core gives the geologist insight to the rock formation that wireline logs cannot. Obtaining a core can be costly, yet invaluable. Two cores of interest were available in the study area through the Oklahoma Geological Survey Core and Sample Library in Norman Oklahoma.

Core was examined in this study in an attempt to correlate the physical rock properties of the formation rock to the wireline log characteristics used to define the reservoir rock (porosity/permeability zone). Study of the core in this work, focused on those visible characteristics of the reservoir rock which may indicate porosity and/or permeability: fractures, solution enhanced fractures, and vugs. Due to limited resources and the nature of this study, cores were examined on a macroscopic level (by use of naked eye or aide of a 10x powered hand lens); no thin sections were studied. Petrologs were constructed upon examination of each of the cores (Plates V and VI).

Meaningful data was obtained from the following two cores: Harper Oil Company No. 1 Cedar Oak, located in SW/4 Sec. 17, T. 15 N., R. 2 W., and Downey Oil Company No. 1 Calvert, located in SW/4 Sec. 7, T. 15 N., R. 1 W. From wireline logs (Figures 23 and 24), neither core can be considered an outstanding example of the porosity/permeability zone of the Viola Group as defined in this work. The Harper Oil Company No. 1 Cedar Oak appears to have zero feet of this reservoir: however, the wireline log of the Downey Oil Company No. 1 Calvert indicates approximately 10 feet of the porosity/permeability zone. By correlating these cores with their wireline logs and comparing them to each other, a meaningful conclusion was reached.

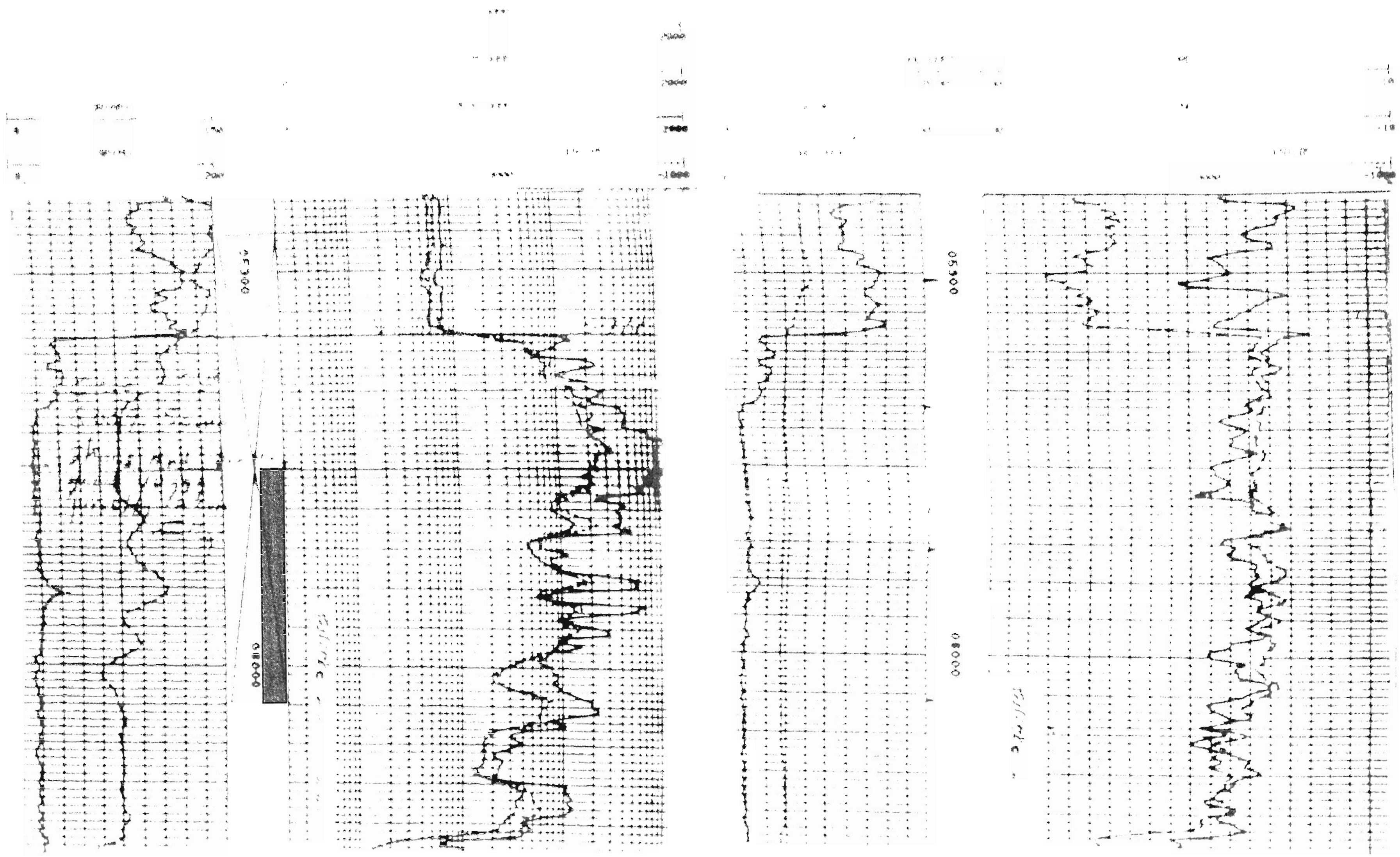

Figure 23. Wireline log of Harper Oil Company No. 1 Cedar Oak, SW/4 Sec. 17, T. 15 N., R. 2 W. Shaded area shows cored interval studied in this work.

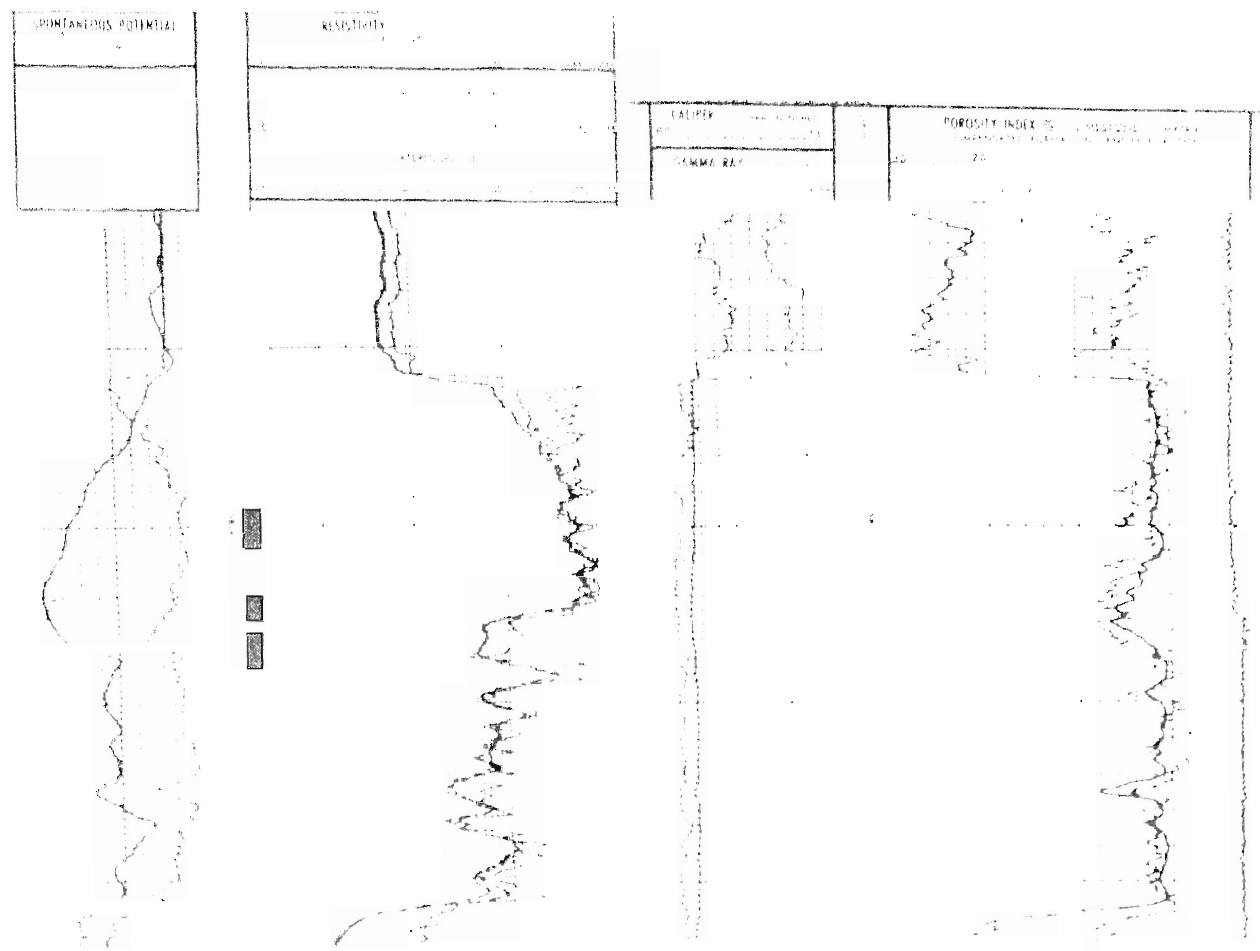

Figure 24. Wireline log of Downey Oil Company No. 1 Calvert, SW/4 Sec. 7. T. 15 N., R. 1 W. Shaded area represents cored interval after being adjusted to wireline log.

The Harper Oil Company No. 1 Cedar Oak core is composed of limestone. Both vertical and horizontal fractures were present throughout much of the core, however, these fractures were commonly "healed" with the development of secondary calcite especially near the base of the core (Plate V). Stylolites were common throughout. Vugs were mostly small and isolated found sparsely throughout the core, however, the upper 1.5 feet of the core studied contained rare, very large vugs. With the exception of the upper 1.5 feet, the core generally appeared tight. Comparison of the wireline log with the core data yields results consistent to the definition of the porosity/permeability zone defined in this work (compare Plate V and Figure 23).

The Downey Oil Company No. 1 Calvert core is composed of limestone. Stylolites were common throughout the core. Vertical and horizontal fractures were rare, found mostly in the upper 5 feet of the core (Plate VI). Both open and closed fractures were described. Vugs were small but abundant in places, described in the petrolog as "vuggy." Comparison of the wireline log with the core data yields results consistent to the definition of the porosity/permeability zone defined in this work (compare Plate VI and Figure 24). The vuggy rock, which appears under physical examination to be porous and permeable coincides with the wireline characteristics of the reservoir rock described in this report.

Though the study and description of these two cores yielded results consistent with the definition of reservoir rock described here, it should not be construed as conclusive evidence. Further investigations should include a more detailed petrologic study of the core, including thin sections and pore analysis, and more core should be studied as it becomes available.

APPENDIX B

LEGEND OF SYMBOLS USED IN MAPPING

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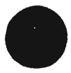
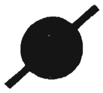
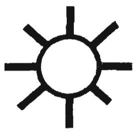
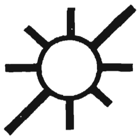
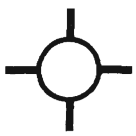
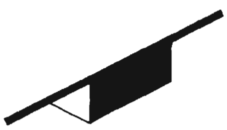

PRODUCING OIL WELL


PRODUCED AND ABANDONED OIL WELL


PRODUCING GAS WELL


PRODUCED AND ABANDONED GAS WELLL


DRY HOLE


FAULT: ARROW POINTS TO DOWNTHROWN SIDE

APPENDIX C

SELECTED POROSITY DATA DERIVED FROM

DENSITY-POROSITY WIRELINE LOGS

Location	Sec.	TS		R		Σ Thick	Φ Thick	Avg. Φ	Max Φ
NW SW NW	2	15	N	1	W	226	6	4.6	5
NW NW NW	3	15	N	1	W	236	18	ASL	ASL
NW NW NW	3	15	N	1	W	236	18	5.4	7
NE SE SW	3	15	N	1	W	234	12	5.3	7
NW SE SE	3	15	N	1	W	DNP-M	6	4.6	6
NW SW	3	15	N	1	W	234	8	NDL	NDL
C NW SE	3	15	N	1	W	234	10	7.2	9
C SW SE NW	3	15	N	1	W	DNP-M	14	5	6
SE SE NW	4	15	N	1	W	240	14	ASL	ASL
NE NW SE	4	15	N	1	W	DNP-M	34	5.5	9
SE NE	4	15	N	1	W	DNP-M	25	3.8	5
C NE NE	4	15	N	1	W	DNP-M	18	4.3	6.5
NE SE SE	4	15	N	1	W	DNP-M	12	4.6	5
C E/2 NE SE	4	15	N	1	W	DNP-M	12	7	6.5
E/2 SE SE SW	4	15	N	1	W	DNP-M	16	8.5	11
NE SE SW SW	7	15	N	1	W	236	10	5.6	8
SE SE SW	7	15	N	1	W	DNP-M	9	4	5
SE SW	7	15	N	1	W	DNP-M	4	5	5
NW SW	8	15	N	1	W	DNP-M	8	2.75	4
SW NE SW	9	15	N	1	W	DNP-M	2	9	9
NW NW NE	9	15	N	1	W	DNP-M	18	5.9	9
NE NW SE	9	15	N	1	W	DNP-M	24	6.17	9
NE NE NW	9	15	N	1	W	DNP-M	6	5.5	6
SE SE NW	9	15	N	1	W	253	24	ASL	ASL
SE SE	10	15	N	1	W	238	6	3.6	4
NE NE	10	15	N	1	W	242	12	5.8	6
SW SW SW	10	15	N	1	W	DNP-M	12	ASL	ASL
SE SE SE	11	15	N	1	W	238	8	ASL	ASL
NW NW	11	15	N	1	W	239	12	5.2	6
NW NW	14	15	N	1	W	241	6	6	7
C SE NW	18	15	N	1	W	258	18	5.3	8
C NE NW SE	18	15	N	1	W	DNP-M	14	5.5	9
C SW SE NE	18	15	N	1	W	DNP-M	20	4.7	6
SW NE SE	18	15	N	1	W	268	16	ASL	ASL
SW NW NE	18	15	N	1	W	264	24	7.4	11
C E/2 NE NW	18	15	N	1	W	254	30	5.2	8
C NW NW NW	18	15	N	1	W	256	16	7.5	9.5
SW SW NW	18	15	N	1	W	270	14	ASL	ASL
SE SE	18	15	N	1	W	DNP-M	24	7.5	12
N/2 NW SW	18	15	N	1	W	DNP-M	22	7.36	13
SW SW NW	19	15	N	1	W	266	24	ASL	ASL
NE NE SE	19	15	N	1	W	264	34	ASL	ASL
C NE NW	19	15	N	1	W	DNP-M	12	4.3	5
C NE SE	19	15	N	1	W	DNP-M	16	3	4
N/2 SW NW	19	15	N	1	W	DNP-M	24	3	4
SE SW	19	15	N	1	W	251	19	ASL	ASL
NW NW NW	20	15	N	1	W	270	22	ASL	ASL
C SW SW NE	20	15	N	1	W	266	19	ASL	ASL
C NW SE	20	15	N	1	W	272	26	2.8	4
NW SE SE SW	20	15	N	1	W	DNP-M	32	3.07	4
SW SW SE	20	15	N	1	W	272	15	3.3	4

S/2 NE SW	21	15 N	1 W	242	6	3	4
C NW SW SE	21	15 N	1 W	254	16	5	6
NE SW SW	21	15 N	1 W	242	14	3.71	5
SW SE SW	21	15 N	1 W	244	28	4.2	6
SW SW	24	15 N	1 W	228	4	3	3
N/2 NE SW	24	15 N	1 W	250	4	4	4
SW SW SW	27	15 N	1 W	216	12	4	4
C W/2 NE NW	28	15 N	1 W	252	28	NDL	NDL
SE SE NW	28	15 N	1 W	258	38	ASL	ASL
C NE NW	29	15 N	1 W	267	30	8.3	13
SW SW NE	29	15 N	1 W	DNP-M	20	6.2	11
NE SW SW	29	15 N	1 W	254	28	NDL	NDL
C SE NW SE	29	15 N	1 W	246	20	NDL	NDL
SW SW SE	29	15 N	1 W	256	36	9.5	23
NW NW SW	29	15 N	1 W	262	22	ASL	ASL
C NE NE NE	29	15 N	1 W	248	38	4.73	9
C NW SW	29	15 N	1 W	263	24	7.53	10
SW SW SE	30	15 N	1 W	277	36	ASL	ASL
S/2 SW	30	15 N	1 W	252	16	4.5	7
NE SE	30	15 N	1 W	DNP-M	20	4.4	9
C SE NE	30	15 N	1 W	272	26	7.2	10
NW NE SW	30	15 N	1 W	276	20	ASL	ASL
NE SW SE	30	15 N	1 W	272	26	8.5	12
NE SW NW	31	15 N	1 W	220	4	ASL	ASL
SW NW NE	31	15 N	1 W	258	18	ASL	ASL
S/2 NW NE	31	15 N	1 W	DNP-M	14	3.88	6
NE NE SW	31	15 N	1 W	218	4	ASL	ASL
SW NE NW	31	15 N	1 W	DNP-M	DNP-M	4.75	6
SE NW NW	31	15 N	1 W	226	10	ASL	ASL
NW SE NW	31	15 N	1 W	220	5	ASL	ASL
SW SE NW	31	15 N	1 W	218	0	ASL	ASL
C N/2 NW SW	31	15 N	1 W	210	8	3.6	5
N/2 NW NW	33	15 N	1 W	212	24	3.6	4.5
SE SE SE	33	15 N	1 W	172	0	ASL	ASL
SW SW NW	33	15 N	1 W	224	26	3.5	5
SE SE NW	34	15 N	1 W	194	0	ASL	ASL
NW SE SW	34	15 N	1 W	178	0	ASL	ASL
N/2 SE SW SE	1	15 N	2 W	DNP-M	0		
E/2 NE NE	1	15 N	2 W	DNP-M	4	4	5
SE SE SW	1	15 N	2 W	DNP-M	8	6.5	
SW SW NW	2	15 N	2 W	210	0	1.4	1.4
C NW SE SE	2	15 N	2 W	DNP-M	12	6.83	11
SW NE NE	2	15 N	2 W	DNP-M	0	2	
E/2 W/2 SW SW	2	15 N	2 W	228	12	3.6	4
NW NW SW	2	15 N	2 W	DNP-M	6	8.42	12
NW NW SE	2	15 N	2 W	DNP-M	4	4	4
SE SW	2	15 N	2 W	DNP-M	20	9	16
NE SE NW	2	15 N	2 W	DNP-M	0		
NE SW SW SE	3	15 N	2 W	DNP-M	18	5.61	10
NW NW SW	3	15 N	2 W	250	16	4.7	6
SE NE SW	3	15 N	2 W	228	0	ASL	ASL
SE SE SW	3	15 N	2 W	DNP-M	14	5.5	6

NE SE SE	4	15	N	2	W	286	40	ASL	ASL
NW SE SW	4	15	N	2	W	DNP-M	28	0	0
NW NW SE	4	15	N	2	W	DNP-M	32	7.7	11
C SW SW	4	15	N	2	W	DNP-M	10	3.11	4
SW SW NW	4	15	N	2	W	DNP-M	14	2.3	3
SE SE NW	4	15	N	2	W	DNP-M	22	5.8	9
SE NE SE	4	15	N	2	W	DNP-M	24	6	10
NE NE SW	4	15	N	2	W	DNP-M	27	2.2	3.5
SW SW SE	4	15	N	2	W	DNP-M	30	3	4.5
NW SE SE	6	15	N	2	W	226	0	1.8	
NE NE SE	8	15	N	2	W	DNP-M	0	1	
NE SW	8	15	N	2	W	302	0	2.4	
NW NE NW	8	15	N	2	W	247	0	3.5	
SW SW NW	9	15	N	2	W	274	0	ASL	ASL
SW NW SE	9	15	N	2	W	DNP-M	10	3.2	4
SW SW	9	15	N	2	W	DNP-M	6	8	10
NE NE NE	9	15	N	2	W	DNP-M	8	4.75	7
NE SW SE	9	15	N	2	W	250	0	ASL	ASL
SW NE SW	9	15	N	2	W	256	10	6	6
NW NE	9	15	N	2	W	DNP-M	14	5.14	7
NE SE	9	15	N	2	W	DNP-M	17	5.3	9
E/2 NE NW	9	15	N	2	W	DNP-M	18	4.5	6
SW NE NW	10	15	N	2	W	276	26	5.38	8
C SW NE	10	15	N	2	W	282	26	5.91	9
C W/2 E/2 NE	10	15	N	2	W	DNP-M	30	5.8	13
C NE SW	10	15	N	2	W	DNP-M	0		
SE NE NW NW	10	15	N	2	W	DNP-M	28	5.85	8
NE NW	11	15	N	2	W	DNP-M	34	7.9	11
C NE SE	11	15	N	2	W	244	20	ASL	ASL
S/2 W/2 NE	11	15	N	2	W	DNP-M	32	4.4	6
SW NE NE	11	15	N	2	W	DNP-M	26	NDL	NDL
SE SE	11	15	N	2	W	258	22	4.7	6
NE NE SE	12	15	N	2	W	214	0		
SE NW SW	12	15	N	2	W	DNP-M	8	4	5
NE SE SW	12	15	N	2	W	250	6		
C W/2 SW SE	12	15	N	2	W	250	8	5	6
W/2 SE SE	12	15	N	2	W	232	2	6	6
SW NW NE	13	15	N	2	W	DNP-M	14	4.7	7
E/2 SE NE	13	15	N	2	W	DNP-M	12	5.3	8
NW SE	13	15	N	2	W	266	18	5.3	8
SE NE SE	13	15	N	2	W	272	16	7.2	11
C N/2 N/2 SW	13	15	N	2	W	276	26	ASL	ASL
NW SW SE	13	15	N	2	W	264	17	ASL	ASL
NE NE NW	13	15	N	2	W	258	28	ASL	ASL
SE SW NW	13	15	N	2	W	DNP-M	34	ASL	ASL
SW SW SW	14	15	N	2	W	254	22	4.18	7
SE SE	14	15	N	2	W	282	22	ASL	ASL
SE SE SW	14	15	N	2	W	234	30	ASL	ASL
SE SE NE	14	15	N	2	W	286	42	ASL	ASL
NW NE SE	14	15	N	2	W	282	22	ASL	ASL
SW SE NW	15	15	N	2	W	214	O		
SW SW SE	17	15	N	2	W	224	6	3.6	4

SW SW SW	17	15	N	2	W	232	6	4	4
C SW SW SW	18	15	N	2	W	208	10	3.6	6
SE SW	18	15	N	2	W	220	12		
SW SE	18	15	N	2	W	232	9	4	4
NE SW SW	20	15	N	2	W	204	12	4.8	6
NW SW SE	20	15	N	2	W	198	6	ASL	ASL
W/2 NW NE	20	15	N	2	W	226	8	5	6
NW SW	20	15	N	2	W	198	6	5	5
NE SW NE NW	20	15	N	2	W	238	6	5	6
SE NW NW	20	15	N	2	W	233	6	4.6	6
NW SW SE	20	15	N	2	W	198	6	ASL	ASL
W/2 SW SE	21	15	N	2	W	188	6	3.3	4
NW SW SW	22	15	N	2	W	202	12	ASL	ASL
NE NE SE	22	15	N	2	W		2	ASL	ASL
NE	23	15	N	2	W	250	2	4	4
SW NE SW SE	23	15	N	2	W	204	5	3.5	3.5
NE NE NE	24	15	N	2	W	DNP-M	20	NDL	NDL
C NW SW	24	15	N	2	W	244	12	8	4.7
SE NE	24	15	N	2	W	DNP-M	20	NDL	NDL
SW NW	24	15	N	2	W	262	12	5.4	7
NE NE SW	25	15	N	2	W	238	6	ASL	ASL
W/2 SE SE	25	15	N	2	W		8	NDL	NDL
C NE NW	25	15	N	2	W	224	0	ASL	ASL
NW NE SE	25	15	N	2	W	260	10	3.2	4
SW NW SW	25	15	N	2	W	221	8	3	4
SE SE SW	25	15	N	2	W	218	0	ASL	ASL
NW NW NW	26	15	N	2	W	206	10	ASL	ASL
NW SW NE	27	15	N	2	W	190	8	ASL	ASL
NE NW SE SW	27	15	N	2	W	178	11	4.1	6
SE NW SW	27	15	N	2	W	DNP-M	4	3	3
NW NW NE	29	15	N	2	W	193	4	ASL	ASL
SW SW SW	30	15	N	2	W		6	ASL	ASL
SW NW NE	35	15	N	2	W	208	11	ASL	ASL
NW NW SW	35	15	N	2	W	211	8	ASL	ASL
NW NE NE	36	15	N	2	W		6	ASL	ASL
		15	N		W				
		15	N		W				
		15	N		W				
		15	N		W				
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		15	N		W				

VITA

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Candidate for the Degree of

Master of Science

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