THE DEPOSITIONAL ENVIRONMENT, PETROLOGY, DIAGENESIS, AND PETROLEUM GEOLOGY OF THE RED FORK SANDSTONE IN CENTRAL OKLAHOMA

By

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CHAPTER I

ABSTRACT

The Red Fork Sandstone is part of the Krebs Group (Cherokee Group) of the Desmoinesian Series of the Pennsylvanian System. The Red Fork Sandstone, as are other Cherokee sandstones, is contained within an interbedded sandstone and shale "package" that is bounded by transgressive-limestone marker beds (Jordan, 1957). The Red Fork Sandstone format is defined as the interval between the base of the Pink Limestone and the top of the Inola Limestone.

In the study area (T.6N.-T.11N., R.3E.-R.6E.), it is highly probable that the Red Fork Sandstone was deposited in a deltaic distributary channel environment. Evidence from previous investigations, distribution of the sandstone based on subsurface maps and stratigraphic cross sections, internal features observed in cores, and depositional and facies models support this interpretation.

The Red Fork Sandstone is a very fine to fine grained, moderately to well sorted, subrounded, submature to mature, sublitharenite to litharenite. Detrital constituents of the Red Fork Sandstone are quartz, feldspars, metamorphic-rock fragments, shale fragments, chert, muscovite, detrital

matrix, zircon, rutile, chlorite, glauconite, and organic matter. Authigenic constituents are dolomite, calcite, siderite, quartz overgrowths, kaolinite, illite, chlorite, hematite, pyrite, and leucoxene.

Two major diagenetic processes have changed the morphology and mineral composition of the Red Fork Sandstone: mechanical processes resulting in compaction of rock fragments to produce a pseudomatrix, and chemical processes such as dissolution, precipitation, alteration, and replacement.

In the Red Fork Sandstone, primary porosity (0 to 3%) is of minor significance in the development of effective porosity. Secondary porosity ranges from 3 to 27 percent, and averages 16 percent of the rock. Secondary porosity consists of partial dissolution of detrital grains and matrix, grain molds, oversized pores, corroded grains, honeycombed grains, fractured grains, and microporosity associated with authigenic clays.

Reservoir quality of the Red Fork Sandstone has been affected severely by diagenetic processes. Diagenetic minerals such as cements and clays have major influence on porosity, permeability, and water saturation.

The Red Fork Sandstone is productive in more than 400 wells in 35 fields in the study area. Exploration for traps in the Red Fork Sandstone should be delineated through isolation of structural and stratigraphic criteria similar to those instrumental in trapping observed in fields that produce from the Red Fork Sandstone.

CHAPTER II

INTRODUCTION

Location

The subject of this investigation is the Red Fork (Earlsboro) Sandstone (Krebs Group, Desmoinesian Series, Pennsylvanian System) in Central Oklahoma. The study area consists of 24 townships (T.6N. through T.11N., R.3E. through R.6E.) in portions of Pottawatomie, Seminole, Okfuskee, and Pontotoc counties, Oklahoma (Figure 1).

Objectives

The main objectives of this study were:

1. To determine the correct stratigraphic position of the Red Fork Sandstone within the study area.

2. To interpret the depositional environments associated with Red Fork Sandstone deposition.

3. To investigate the petrographic and diagenetic characteristics of the Red Fork Sandstone.

4. To interpret the relationship of stratigraphy, structural geology, depositional environments, and diagenesis to entrapment of oil and gas in the Red Fork Sandstone.

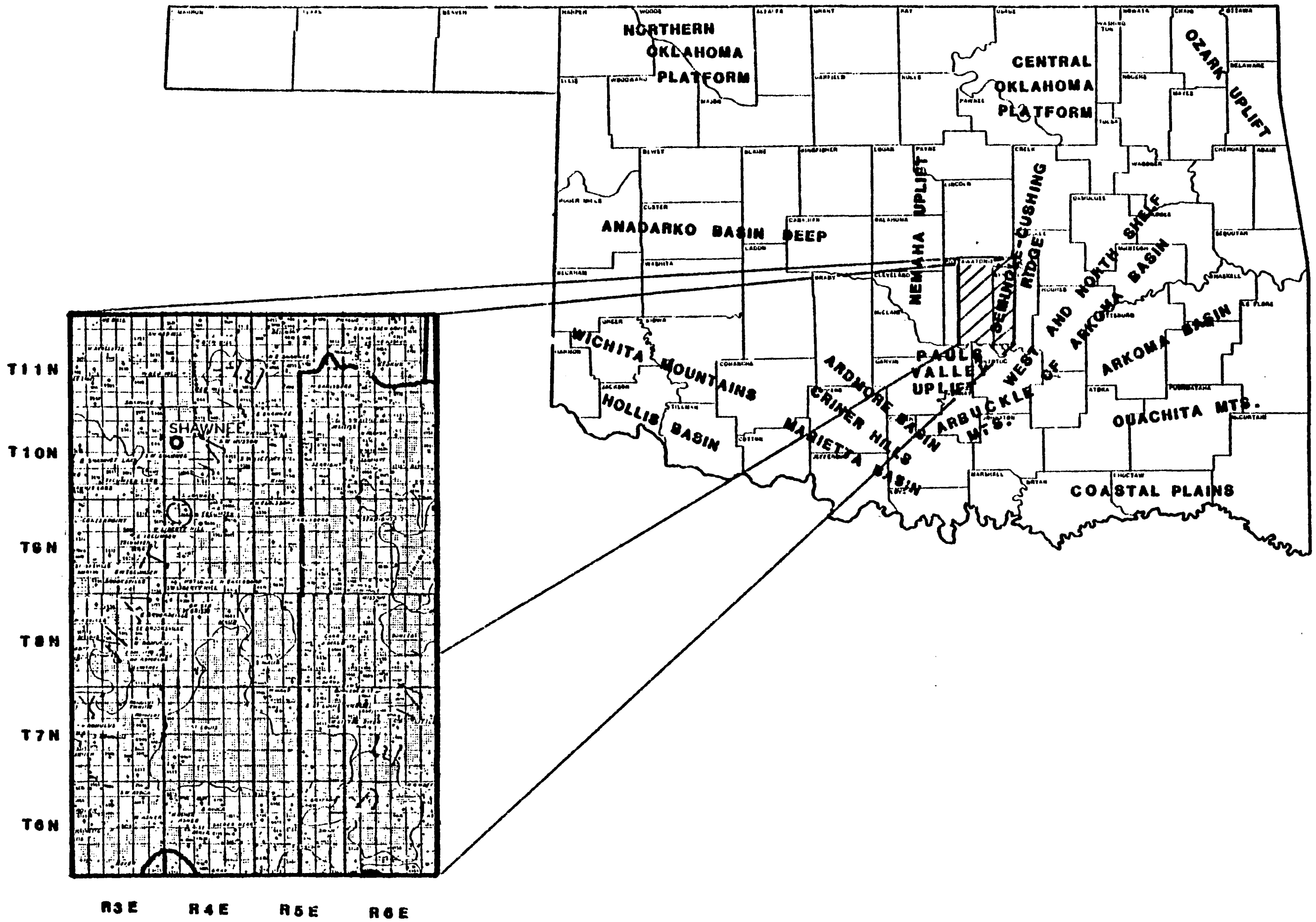

Figure 1. Location Map of Study Area With Respect to Major Tectonic Features of Oklahoma

Method of Study

To accomplish the objectives of this study, the following methods were used:

1. Review of selected literature on the Red Fork Sandstone, depositional environments, and diagenetic processes.

2. Logging and sampling of thirteen cores of the Red Fork (Earlsboro) Sandstone from the study area.

3. Thin-section analysis, X-ray diffraction, and scanning electron microscopy of core samples in order to support quantitatively inferences about the petrology and diagenetic processes of the Red Fork Sandstone.

4. Construction of a suite of stratigraphic cross sections utilizing 103 well logs, and of subsurface maps utilizing more than 1500 well logs, to define the stratigraphic, structural, and sedimentological relationships of the Red Fork Sandstone.

5. Local mapping studies of selected oil fields within the study area to deduce and illustrate the entrapment of oil and gas in the Red Fork Sandstone.

6. Preparation of various diagrams to illustrate the petrology, depositional environments, diagenesis, and reservoir characteristics of the Red Fork Sandstone.

CHAPTER III

STRUCTURAL FRAMEWORK

Regional Setting

The study area is located on the southernmost portion of the stable Central Oklahoma or "Cherokee" Platform. Major tectonic features include the Seminole Uplift (Late Morrowan) (Pulling, 1979) in the eastern part of the study area, the Nemaha Uplift (post-Mississippian, pre-Middle Pennsylvanian) to the west, the Pauls Valley Uplift (Post-Morrowan) to the south, and the Arkoma Basin (Late Morrowan through Desmoinesian) to the southeast (Figure 1).

Local Setting

Using the top of the Verdigris Limestone (Figure 2) as a mapping datum, structural features in the study area are illustrated by a structural contour map (Plate I). The Verdigris Limestone was used as a reference because it is the most consistent Cherokee marker bed within the study area.

The Verdigris Limestone shows a homoclinal westward dip that ranges from 80 to 100 feet per mile. Anticlinal noses and synclines are the main structural features

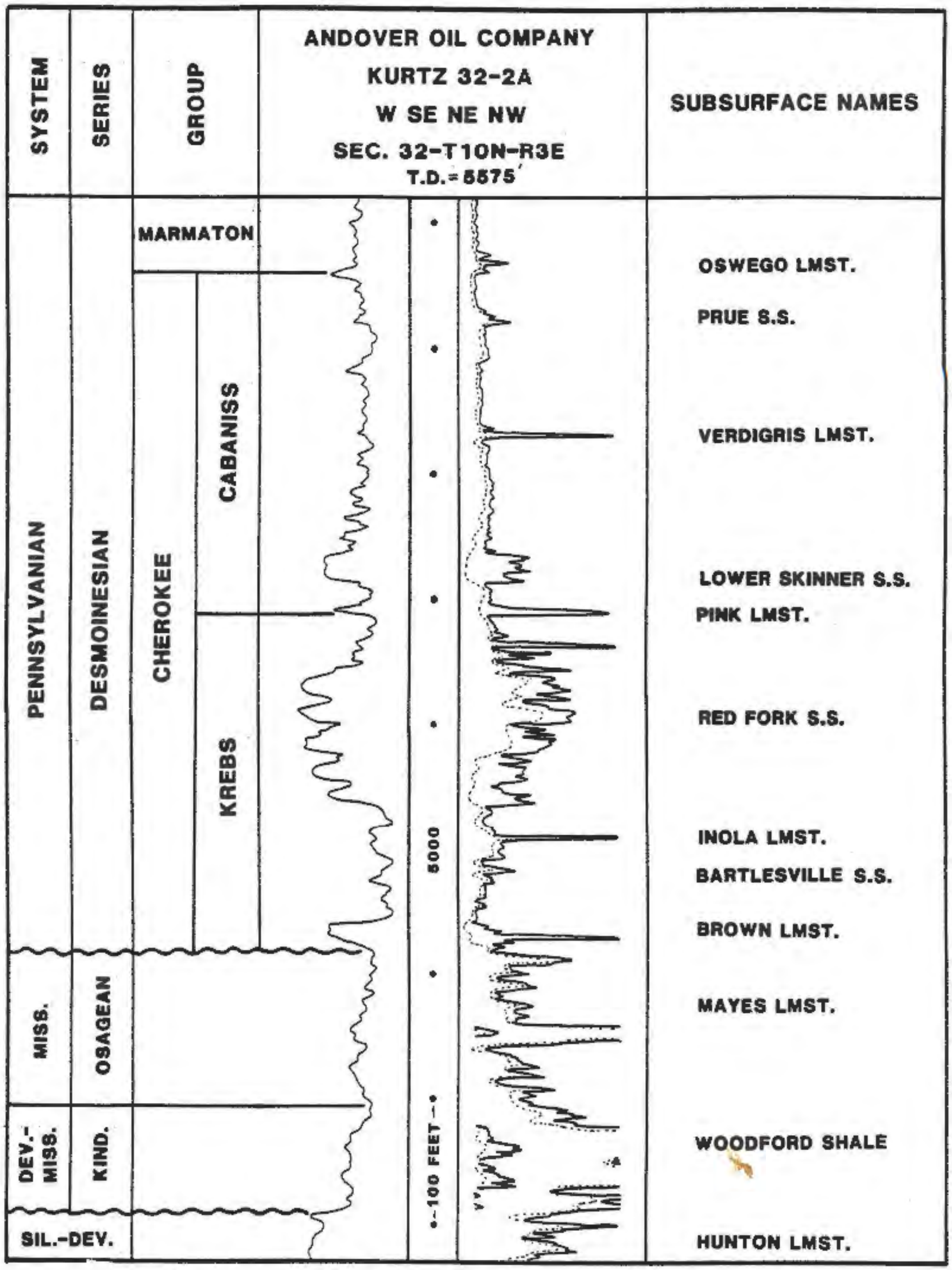

Figure 2. Type Log of Study Area

affecting "Cherokee" strata. Most anticlinal features are associated with oil and gas fields. The structural nosing is probably due to draping of Pennsylvanian strata over older structural features (Pulling, 1979).

Another significant structural feature is the north-northeast trending Wilzetta Fault (Plate I) which bounds the west flank of the Seminole Uplift. The Wilzetta Fault is a normal fault that has a maximal displacement of 175 to 200 feet in T.11N., R.4E..

CHAPTER IV

STRATIGRAPHIC FRAMEWORK

The Red Fork Sandstone is part of the Krebs Group (Cherokee Group) of the Desmoinesian Series of the Pennsylvanian System. The Cherokee Group includes all rocks from the base of the Oswego Limestone to the base of the Desmoinesian Series (Figure 2). In the study area, the Cherokee Group is unconformable upon rocks of Ordovician (Sylvan Shale) to Mississippian (Caney Shale, Mayes Limestone) age (Figure 2) except in extreme eastern parts of the study area where the Cherokee Group is conformable upon Atokan sediments (Figure 3).

The Red Fork Sandstone, as are other Cherokee sandstones, is contained within an interbedded sandstone and shale "package" that is bounded by transgressive-limestone marker beds (Jordan, 1957). The Verdigris, Pink, Inola, and Brown Limestones are the limestone marker beds that divide the Cherokee Group. The Red Fork Sandstone format is defined as the interval between the base of the Pink Limestone and the top of the Inola Limestone. In parts of the thesis area, the local subsurface equivalent of the Red Fork Sandstone is the Earlsboro Sandstone (Jordan, 1957).

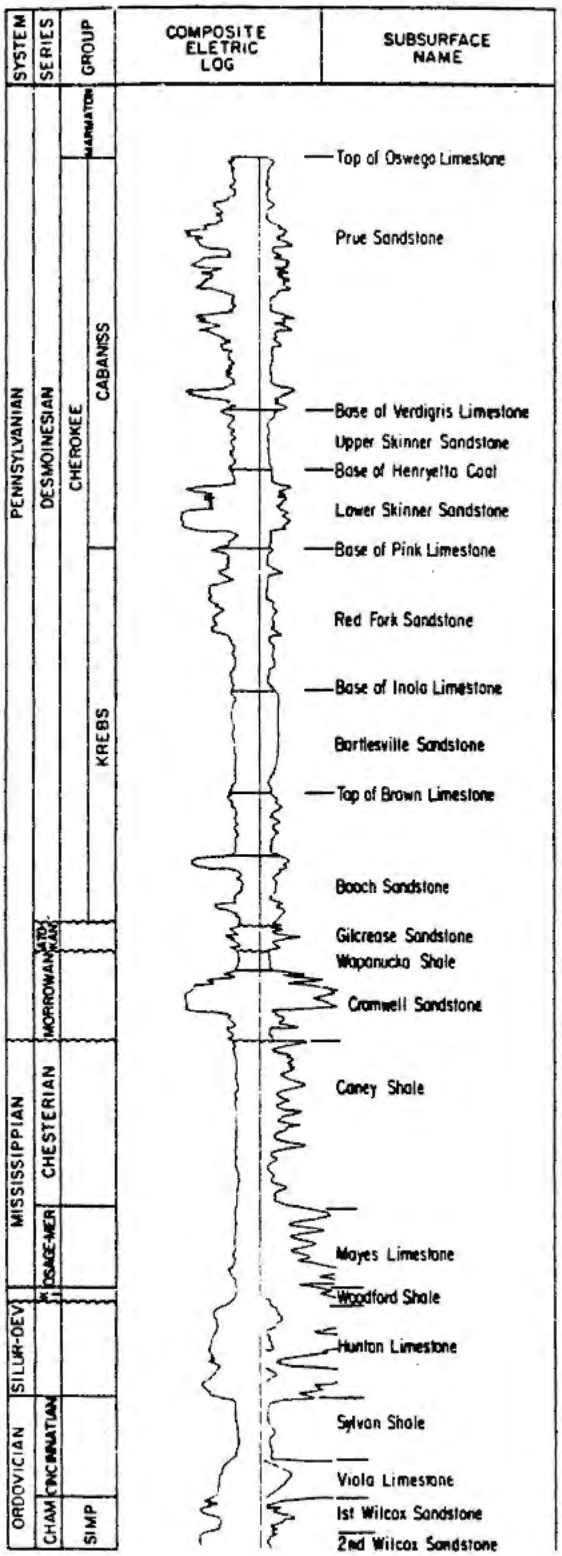

Figure 3. Type Log, Northern Seminole County, Okla. (From Walker, 1982)

In the study area, the Earlsboro has been applied incorrectly to both the Bartlesville and Skinner Sandstones; therefore, a main objective of this thesis is the determination of the correct stratigraphic position of the Red Fork (Earlsboro) Sandstone.

Correlations

Five east-west (Plates II-VI) and eight north-south (Plates VII-XIV) regional stratigraphic cross sections were constructed in a grid network in the area of study (Figure 4). The Verdigris Limestone was selected as the datum because it is present throughout the region, except in southern parts of the study area where the Henryetta Coal is a reasonable approximation for the Verdigris Limestone (Krumme, 1975). Correlations on the cross sections were made from the top of the Verdigris Limestone to the top of the Brown Limestone. Correlation of the Pink and Inola Limestones distinguish the boundaries of the Red Fork Sandstone Interval.

Thirteen cross sections were constructed to illustrate the following:

1. The correct stratigraphic position of the Red Fork Sandstone within the Cherokee Group.

2. The thickness, boundaries, and lateral continuity of the Red Fork Sandstone.

3. Typical well-log signatures of the Red Fork Sand stone.

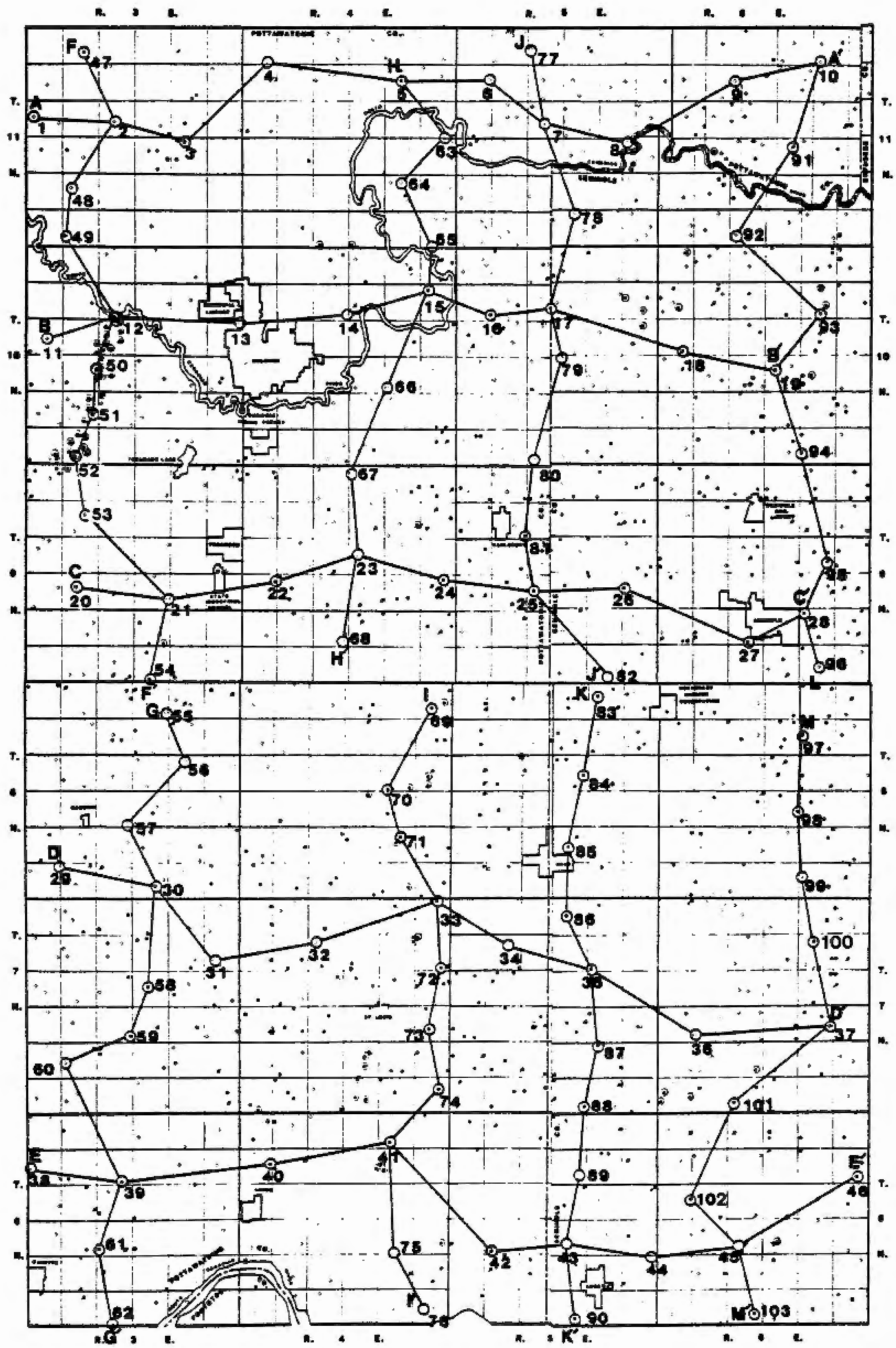

Figure 4. Index Map of Stratigraphic Cross Sections

4. Thickening and thinning of the correlated Cherokee section.

East-West Stratigraphic Cross Sections

Cross section A-A' (Plate II) is an east-west section crossing the extreme northern part of the study area from T.11N., R.3E. to T.11N., R.6E.. Red Fork Sandstone is well developed in wells 1, 3, 5, 6, 7 and 9. In these wells, log patterns of the Red Fork are blocky with characteristic abrupt basal contacts and vertical stacking of sand bodies, which are suggestive of channel-fill deposits.[1] Thicknesses of these channel-fill deposits range from 50 to 115 feet. Erosion of the Inola Limestone, prior to deposition of the Red Fork Sandstone, is illustrated in well 1. Erosion of the Pink Limestone, prior to deposition of the Skinner Sandstone, is illustrated in well 10. Nonchannel and/or overbank deposits of the Red Fork Sandstone with characteristic sharp basal contacts and gradational lateral and upper contacts are illustrated in wells 2, 4, 8, and 10. These overbank deposits range from 11 to 40 feet thick.

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[1]For the sake of simplicity in discussing development of sandstone in the cross sections, deposits of Red Fork Sandstone have been interpreted initially as channel-fill or nonchannel (overbank) deposits. Interpretation of Red Fork Sandstone deposits as channel deposits is based on the following: 1) well logs that show blocky or bell-shaped SP curves, 2) location of wells on the Net-sand Isolith Map (Plate XV), 3) lenticular shapes of the sandstone bodies in cross sections, and 4) erosion of the underlying Inola Limestone.

A significant feature observed in cross section A-A' is thickening of the Cherokee section, from the top of the Verdigris Limestone to the top of the Brown Limestone, between wells 5 and 6. The section thickens from 475 feet in well 6 to 515 feet in well 5. The Red Fork interval thickens from 115 feet in well 6 to 175 feet in well 5. The thicker Cherokee section is located on the downthrown western block of the Wilzetta Fault, which probably was active during deposition of the Cherokee. The Cherokee section also thickens from west to east. The section from the top of the Verdigris Limestone to the top of the Brown Limestone ranges from 370 feet in well 2 to 564 feet in well 9.

Cross section B-B' (Plate III) is an east-west section across the northern part of the study area from T.10N., R. 3E. to T.10N., R.6E.. Well-developed Red Fork channel-fill sandstones are in wells 11, 12, 13, 15, 16, 17, and 19. These channel sandstones range from 50 to 155 feet in net-sandstone thickness. Erosion of the Inola Limestone is recorded in well 17. Absence of the Pink Limestone and possible erosion of the Red Fork Sandstone is illustrated in well 11. Well 11 and 12 illustrate stacking of the Lower Skinner and Red Fork Sandstones, which is typical of the northern part of the Northwest Tecumseh Field in T.10N., R.3E.. The stacked Lower Skinner and Red Fork channels make up the reservoir in the northern part of this field. The stacked nature of these sandstones and absence of the Pink

Limestone marker bed have created problems in correlation. Wells 14 and 18 illustrate overbank deposits of the Red Fork Sandstone.

Thickening of the Cherokee section from west (well 11, 315 feet) to east (well 19, 568 feet) is obvious. The Cherokee section shows relatively uniform thickness across the Wilzetta Fault (wells 14 and 15); thus, this part of the Fault might have been inactive during deposition of the Cherokee.

Cross section C-C' (Plate IV) is an east-west cross section across the central part of the thesis area from T.9N., R.3E. to T.9N., R.6E.. Red Fork channel-fill sandstones are in wells 21, 23, 25, 27, and 28. These channel sandstones range from 30 to 100 feet thick. Erosion of the Inola Limestone is recorded in well 23. Wells 20, 22, 24, and 26 penetrated overbank deposits of the Red Fork Sandstone.

The section from the top of the Verdigris Limestone to the top of the Brown Limestone thickens eastward. The section is 280 feet in well 20 and 620 feet in well 28. Relatively uniform thickness of the Cherokee section across the Wilzetta Fault (wells 22 and 23) indicates that the fault was probably inactive during deposition of the Cherokee.

Cross section D-D' (Plate V) is an east-west section that crosses the southern part of the area of investigation from T.8N., R.3E., to T.7N., R.6E.. Well-developed

Red Fork channel-fill sandstones are in wells 33, 34, 35, and 36. Total-isolith thicknesses of these stacked channel sands range from 75 to 114 feet. A minor channel sandstone with a thickness of 16 feet is in well 29. Nonchannel and/or overbank deposits are in wells 30, 31, 32, and 37.

A significant feature observed in cross section D-D' is thinning of the Cherokee section from the top of the Verdigris Limestone to the top of the Brown Limestone from east (well 37) to west (well 33). The section is 740 feet in well 37 and thins to 390 feet in well 33. The Brown Limestone oversteps the pre-Pennsylvanian unconformity between wells 33 and 32 as the Cherokee section thins westward to 215 feet in well 29. The thicker Cherokee section, which is in the extreme eastern part of the study area (wells 36 and 37) is thicker eastward toward the Arkoma Basin (Figure 5). During deposition of the Cherokee, the Wilzetta Fault probably was inactive, because the section does not thicken significantly across the fault (wells 31 and 32).

Cross section E-E' (Plate VI) is an east-west section that crosses the extreme southern part of the study area from T.6N., R.3E. to T.6N., R.6E.. Minor Red Fork channel-fill sandstones are in wells 41, 42, 43, 45 and 46 and range from 15 to 36 feet thick. Wells 40 and 44 illustrate overbank deposits of the Red Fork. The section from the top of the Verdigris Limestone to the top of the Inola

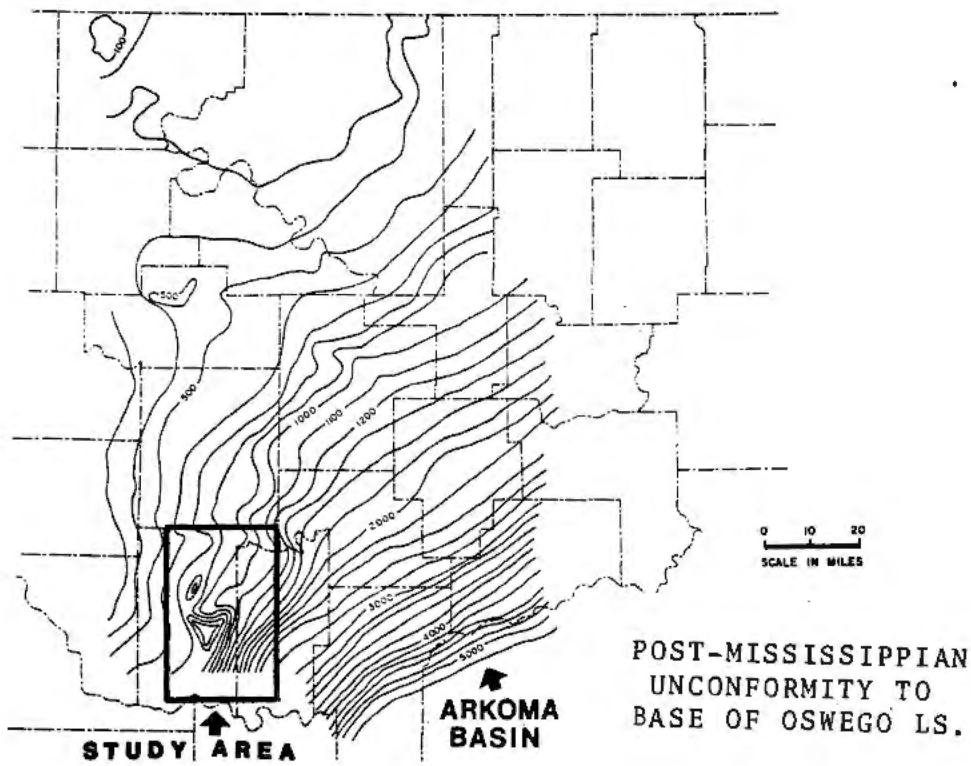


Figure 5. Isopach Map of Cherokee Group in North-central Oklahoma Illustrating Thickening of Cherokee Section East of Study Area Toward the Arkoma Basin (After Visher, Saitta, and Phares, 1971, Fig. 2)

Limestone thins from east (well 46) to west (well 40). The section is 510 feet in well 46 and 280 feet in well 40. Whether the Brown Limestone was deposited in this area is not known. Thus no correlation was made. The Cherokee section from the top of the Verdigris to the top of the pre-Pennsylvanian unconformity thins from east to west. The section is 315 feet thick in well 43 and 36 feet in well 38. The Red Fork interval pinches out between wells 39 and 40 as the Pink Limestone and Inola Limestone both overstep the pre-Pennsylvanian unconformity.

North-South Stratigraphic Cross Sections

Cross section F-F' (Plate VII) is a north-south cross section across the western part of the thesis area from T.11N., R.3E. to T.9N., R.3E.. Well-developed Red Fork channel-fill sandstones are in wells 1, 49, 12, 50, 52, and 21. These sandstones range from 56 to 112 feet thick. Erosion of the Inola Limestone prior to deposition of the Red Fork Sandstone, is illustrated in well 49. Wells 12, 50, and 51 illustrate stacking of Lower Skinner and Red Fork sandstones, which combine to form a single reservoir; this was also noted in cross section B-B' (Plate III). The Pink Limestone is absent in these wells owing to down-cutting of channels in which the Lower Skinner Sandstone was deposited. Nonchannel and/or overbank deposits of the Red Fork Sandstone are in wells 47, 48, 51, 53 and 54.

The Cherokee section (Verdigris to Brown Limestone) thins from 370 feet in well 47 to 293 feet in well 54.

Cross section G-G' (Plate VIII) is a north-south section that crosses the western part of the study area from T.8N., R.3E. to T.6N., R.3E.. A minor, 25-feet-thick, Red Fork channel is in well 57. Overbank deposits of the Red Fork Sandstone as thick as 22 feet are in wells 55, 56, 30, 58, 59 and 60.

Thinning of the Cherokee section from the top of the Verdigris Limestone to the top of the pre-Pennsylvanian unconformity in cross section G-G' is significant. The Cherokee section is 305 feet in well 55 and 25 feet in well 63. The Brown Limestone oversteps the pre-Pennsylvanian unconformity between wells 56 and 57. The Red Fork interval pinches out between wells 60 and 39, where the Pink Limestone and Inola Limestone both overstep the unconformity.

Cross section H-H' (Plate IX) is a north-south cross section across the central part of the thesis area from T.11N., R.4E. to T.9N., R.4E.. Well-developed channel-fill sandstones are in wells 5, 63, 64, 65, 15, 66 and 23. These channel sandstones range from 38 feet to 147 feet in net-sand thickness. Evidence of channel downcutting and erosion of the Inola Limestone is in wells 65 and 23. In well 64, absence of the Pink Limestone is due to channeling of streams associated with the overlying Lower Skinner

Sandstone. Overbank sandstones, siltstones, and shales are in wells 67 and 68.

The Cherokee section from the top of the Verdigris Limestone to the top of the Brown Limestone thins from north (well 5, 520 feet) to south (well 68, 330 feet).

Cross section I-I' (Plate X), a north-south section that crosses the central part of the area of investigation from T.8N., R.4E. to T.6N., R.4E., shows major Red Fork channels in well 70 (84 feet), well 33 (114 feet), and well 73 (75 feet). A minor, 25-feet-thick, Red Fork deposit is illustrated in well 41. Nonchannel and/or overbank deposits of the Red Fork Sandstone are in wells 69, 71, 72, 74, 75, and 76.

The section from the top of the Verdigris Limestone to the top of the Brown Limestone thins southward. The section is 338 feet in well 69 and thins to 256 feet in well 41. The Brown Limestone oversteps the pre-Pennsylvanian unconformity between wells 41 and 75 and the Cherokee section thins southward to 230 feet in well 76.

Cross section J-J' (Plate XI) crosses the central part of the study area from T.11N., R.5E. to T.9N., R.5E.. Red Fork channel-fill sandstones are in wells 77, 7, 78, 17, 79, and 81; they range from 45 feet to 155 feet thick. Erosion of the Inola Limestone is recorded in well 17. Red Fork nonchannel deposits are in wells 80, 25, and 82.

The Cherokee section (Verdigris Limestone to Brown Limestone) thins southward from 530 feet in well 77 to 440 feet in well 82.

Cross section K-K' (Plate XII) extends southward across the central part of the thesis area from T.8N., R.5E. to T.6N., R.5E.. Red Fork channel-fill sandstones are in wells 86, 35, 87 and 88. They range from 35 to 100 feet thick. Overbank deposits of the Red Fork are in wells 83, 84, 85, 89, 43, and 90.

The Cherokee section from the top of the Verdigris Limestone to the top of the Brown Limestone thins slightly from north (well 83, 412 feet) to south (well 89, 400 feet). The Brown Limestone oversteps the pre-Pennsylvanian unconformity between wells 89 and 43. The Cherokee section thins southward to 250 feet in well 90.

Cross section A'-L (Plate XIII) crosses the eastern part of the study area from T.11N., R.6E. to T.9N., R.6E.. Red Fork channel sandstones are in wells 91, 92, 93, 19, 95, 28 and 96. These channel sandstones range from 23 to 85 feet in net-sandstone thickness. In wells 10 and 94 are overbank deposits of the Red Fork Sandstone.

The Cherokee section (Verdigris Limestone to Brown Limestone) thickens southward from 530 feet in well 10 to 585 feet in well 96.

Cross section M-M' (Plate XIV) extends southward across the eastern part of the study area from T.8N., R.6E. to T.6N., R.6E.. Major Red Fork channel-fill sandstones are in wells 97 and 101. Overbank and/or nonchannel deposits are in wells 98, 99, 100, 37, 102, 45 and 103. The Cherokee section from the Verdigris Limestone to the Brown Limestone thickens southward (580 ft. (well 97) cf. 703 ft. (well 101)). The section from the Verdigris Limestone to the Inola Limestone thins from well 101 (555 feet) to well 102 (370 feet). The Brown Limestone may not have been deposited at locations of wells 102, 45, and 103.

Conclusions About The Stratigraphic Framework

Based chiefly on evidence from thirteen stratigraphic cross sections, the following conclusions seem to be justified:

1. The Red Fork Sandstone is discontinuous throughout the study area.

2. The Red Fork Sandstone is composed of channel-fill and nonchannel-fill deposits. Channel-fill deposits are suggested by blocky log patterns with characteristic abrupt basal contacts and stacking of individual channels. Therefore, lateral contacts must be abrupt as well. Nonchannel and/or overbank deposits generally have abrupt basal contacts and gradational lateral and upper contacts, which are indicated by a serrated log pattern.

3. General thickening and thinning of the Cherokee section is the overall result of the regional tectonic setting. Thickening of the Cherokee section from west to

east illustrates partial filling of the Arkoma Basin. Thinning of the Cherokee section from north to south suggests the influence of the Pauls Valley Uplift (Plates VIII and X). The thicker Cherokee section on the downthrown western block of the Wilzetta Fault (Plate II, wells 5 and 6) in T.11N., R.4E. is evidence that this part of the fault was active during deposition of the Red Fork format.

CHAPTER V

DEPOSITIONAL ENVIRONMENT

Introduction

In the study area, interpretation of the depositional environments associated with Red Fork Interval deposition was based on the following sources of evidence:

1. Previous investigations in Central Oklahoma in which the depositional environments associated with Red Fork Sandstone deposits were interpreted.

2. Distribution (trends, widths, thicknesses, and boundaries) of the Red Fork Sandstone in the study area as indicated by stratigraphic cross sections, a net-sandstone isolith map, and a log-signature map.

3. Internal features (sedimentary structures, grain size, texture, and petrology) of the Red Fork Sandstone, based on detailed examination of 13 cores within the study area.

4. Depositional and facies models, drawn from work of several geologists.

Previous Investigations

Numerous surface and subsurface investigations have been completed on the Cherokee Group in Oklahoma. Nearly all these studies include written description of the depositional environment or framework of the Red Fork Sandstone. The following investigations have been reviewed by the author: Oakes (1953); Branson (1954); Benoit (1957); McElroy (1961); Branson (1962); Clayton (1965); Hawissa (1965); Shulman (1966); Cole (1969); Berg (1969); Dogan (1969); Cutolo-Lozano (1969); Hudson (1969); Visher, Saitta and Phares (1971); Albano (1975); Shipley (1975); Candler (1977); Pulling (1979); Verish (1979); Bennison (1979); Glass (1981); Walker (1982); and Robertson (1983).

In a subsurface study by Hawissa (1965) in western Payne County, Oklahoma (T.17N.-T.19N., R.1E.-R.3E.), the Red Fork was interpreted mainly as channels with deltaic patterns. This interpretation was based on maps, cross sections, and analyses of well cuttings.

Shulman (1966) interpreted the Red Fork as channel sandstones according to various cross sections in western Lincoln and southeastern Logan Counties (T.14N.-T.16N., R.1E.-R.3E.).

In a regional investigation of the Cherokee Group on the east flank of the Nemaha Uplift in north-central Oklahoma (T.10N.-T.29N., R.1E.-R.10E.), Cole (1969, p. 152) stated "The Red Fork Sandstone presents a complex pattern of bifurcating, anastomosing dendroids forming a north-south trending belt." He also stated "The sandstone bodies in the southern half of the area give the appearance of having a southern source." Cole's interpretations were based on a net-sandstone isolith map and an isopach map of the Red Fork interval (Figure 6).

Hudson (1969) studied the Red Fork Sandstone in south-central Kansas and north-central Oklahoma, utilizing cores and cross sections. He (1969, p. 74) concluded that "The Red Fork equivalent sands represent a large river and delta complex or system whose limits are yet to be found."

Dogan (1969) interpreted Red Fork Sandstone in central Oklahoma (T.7N.-T.15N., R.2W.-R.2E.) as a complex of deltaic environments, as based on a study of cross sections. He suggested that source areas of the Red Fork were to the south, west, and north.

Albano (1975) presented a detailed subsurface stratigraphic analysis of the Cherokee Group in Cleveland and McClain Counties (T.8N.-T.10N., R.2W.-R.1E.). He (1975, p.116) concluded that "The Red Fork Sandstone was deposited in pro-gradating (sic) deltaic channels along a coastal plain of low relief." Evidence to support this interpretation was based on isopach maps and cross sections.

Shipley (1975, p. 48) studied Cherokee sandstones in Payne County (T.18N.-T.19N., R.1W.-R.2E.). In his opinion "Both the isopach map of net-sandstone and the log map of

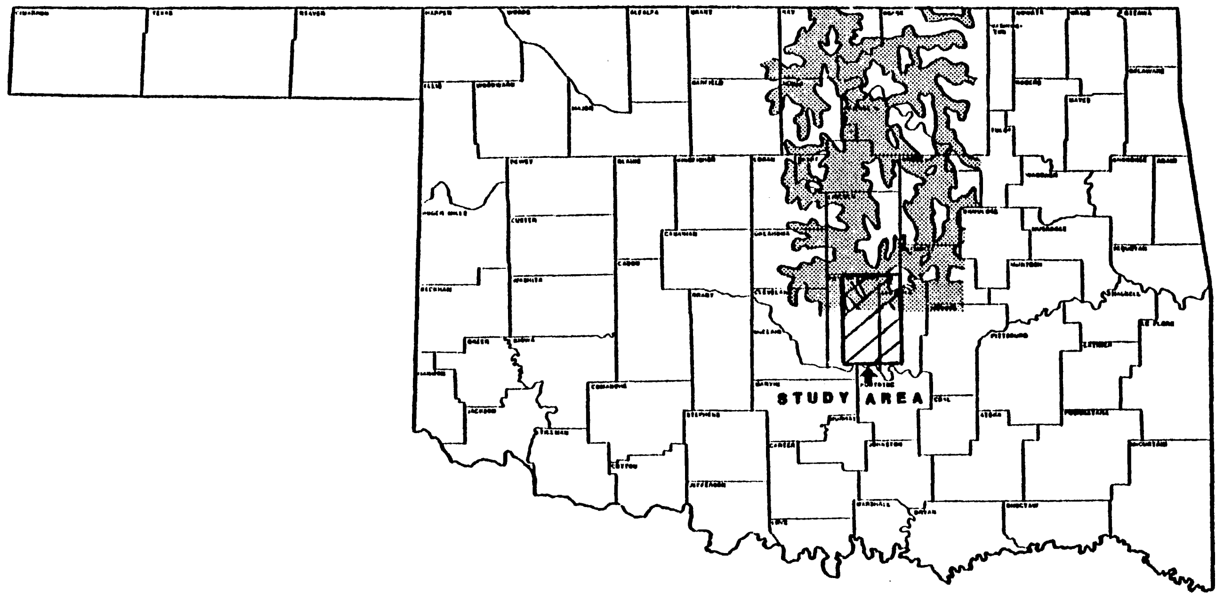


Figure 6. Red Fork Sandstone Trends in North-central Oklahoma (After Cole, 1969)

Red Fork Sandstone show a complex sandstone geometry. The trends of thick Red Fork Sandstone within the study area represent deposition in channels, which were probably major and minor distributaries of a deltaic system."

Candler (1977) interpreted the Red Fork Sandstone as a lower deltaic plain facies in southern Noble County (T.20N.-T.21N., R.1W.-R.2E.) based on a net-sandstone map and a log map.

Verish (1979) analyzed Cherokee sandstones in central Oklahoma (T.11N.-T.13N., R.4E.-R.5E.) based on cross sections and a log-signature map. He surmised that the Red Fork Sandstone illustrated various elements of deltaic complexes.

In an investigation of the subsurface geology in Pottawatomie County (T.8N.-T.10N., R.2E.-R.4E.) Pulling (1979, pp. 150-151) stated "A deltaic distributary channel origin for the Red Fork channel is supported by the following: 1) bell-shaped SP curve, 2) thickening of the sand at the expense of the underlying shale, 3) lenticularity of the sands, 4) the areal distribution of the sands, and 5) the association of these sands with marine shales. These marine shales have a probable pro-delta origin."

Walker (1982) studied Lower and Middle Pennsylvanian Sandstones in central Oklahoma (T.11N.-T.13N., R.6E.-R.7E.). He analyzed log signatures of the Red Fork Sandstone, which he interpreted as being suggestive of channel-fill sandstones and delta-fringe environments.

Robertson (1983) studied the Red Fork Sandstone in north-central Oklahoma (T.17N.-T.23N., R.1E.-R.2E.). Based on examination of cores, a log map, cross sections, an isopach map of the Red Fork interval, and a net-sandstone isolith map, Robertson interpreted the depositional environment of the Red Fork Sandstone as a fluvial-deltaic complex.

Distribution of the Red Fork Sandstone

Introduction

Thirteen stratigraphic cross sections (Plates II-XIV, discussed in Chapter IV), a net sandstone isolith map (Plate XV), and a log map (Plate XVI) of the Red Fork Sandstone were constructed and examined in order to determine and predict the distribution (trends, widths, thicknesses, and boundaries) of the sandstone.

The net-sandstone map illustrates the total sandstone thickness of the Red Fork Interval (base of Pink Limestone to top of Inola Limestone). Determination of net sandstone was made with the use of the SP (spontaneous potential) curve, with sandstone being defined as any point 20 millivolts or more to the left (negative deflection) of the shale base line.

The log-signature map, which is based upon the characteristics of the short normal curve and the SP curve, was used to interpret trends and boundaries of the Red Fork Sandstone (Plate XVI). The log shapes illustrate typical log signatures of the Red Fork Sandstone and define sandstone trends and boundaries more accurately than do the numbers used on the net-sandstone isolith map.

Trends and Widths

In the study area, the Red Fork Sandstone has a bifurcating and anastomosing pattern. In the northern part of the thesis area (T.9N.-T.11N., R.3E.-R.6E.), major sandstone trends are oriented primarily north-to-south. Several distinct north-south trends were mapped (see Net-sand Isolith Map, Plate XV). Widths of these trends range from less than one-half mile to 3 miles. In the southern part of the thesis area (T.6N.-T.8N., R.3E.-R.6E.), major sandstone trends switch from north-south orientation (T.8N., R.3E.-R.6E.) to northwest-southeast orientation (T.7N.-T.6N., R.4E.-R.6E.). A northwest-to-southeast trend is in T.7N., R.4E. to R.6E. Widths of these trends range from one-half mile to 5 miles.

Thickness

In the study area, the Red Fork sandstone has a maximum sandstone thickness of 155 feet as seen in well 17 located in Section 9, T.10N., R.5E. (Plates III, XI, and XV). Thickness increases toward the central parts of major sandstone trends where stacking of units as thick as 60 feet make up multistoried deposits (Plate XVI).

Boundaries

Major Red Fork Sandstone trends are lenticular sandstone bodies in cross section with abrupt basal and lateral contacts (Plate XVI). Abrupt basal contacts are associated with shale rip-up channel-lag deposits. Thicker accumulations, associated with the central parts of the major sandstone trends, are results of channeling or downcutting, whereby the Red Fork Sandstone was emplaced into or below the Inola Limestone (Plates II - XIV). Upper contacts are either sharp or gradational. Gradational upper contacts are associated with fining upward of grain size to interlaminated very fine grained sandstone, siltstone, and shale. Major bodies of Red Fork sandstone are shown commonly by a blocky or bell-shaped log pattern.

Minor Red Fork sandstone bodies, which are located between and on the edges of major sandstone trends, show evidence of abrupt basal contacts and gradational lateral and upper contacts. Log patterns of these sandstone bodies generally are serrated or otherwise poorly developed.

Internal Features of the Red Fork Sandstone

Documentation of internal features is based upon examination of 13 cores within the study area. Five cores are from the Northwest Tecumseh Field in T.10N., R.3E., five are from the St. Louis Field in T.7N., R.4E., one is from the North Searight Field in T.10N., R.6E., one is from the South Prague Field in T.11N., R.6E., and one is from a wildcat location in T.11N., R.3E. (Figure 7).

Sedimentary Structures

In approximate order of abundance, common sedimentary structures are horizontal laminations, ripple laminations, interstratified sandstone and shale, convolute bedding (flowage), massive bedding, small-scale trough cross-bedding, medium-scale planar cross-bedding, inclined laminations, channel lag, bioturbation, burrows, microfaults, and water-escape features. A consistent and complete vertical sequence of sedimentary structures is not evident in cores of the Red Fork sandstone. However, a general vertical sequence of sedimentary structures, characteristic of cores from the Red Fork located within major sandstone trends (Figure 8) appeared to be as follows:

1. A lower zone of massively bedded sandstone that contains shale rip-up clasts from the underlying shale unit (Figure 9). This massively bedded rock commonly grades upward into horizontally laminated (Figure 10)

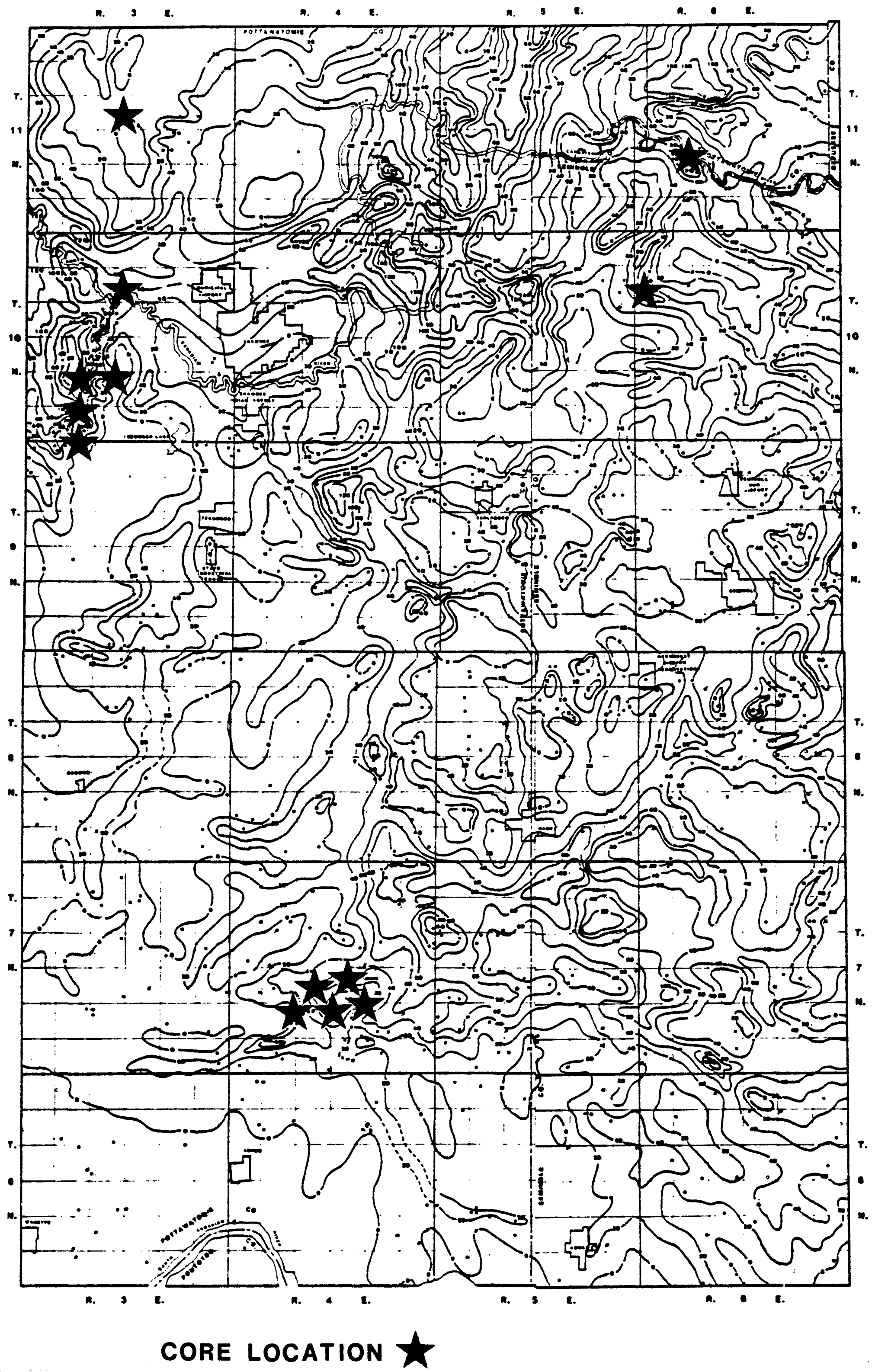


Figure 7. Index Map, Locations of Wells From Which Cores Were Studied

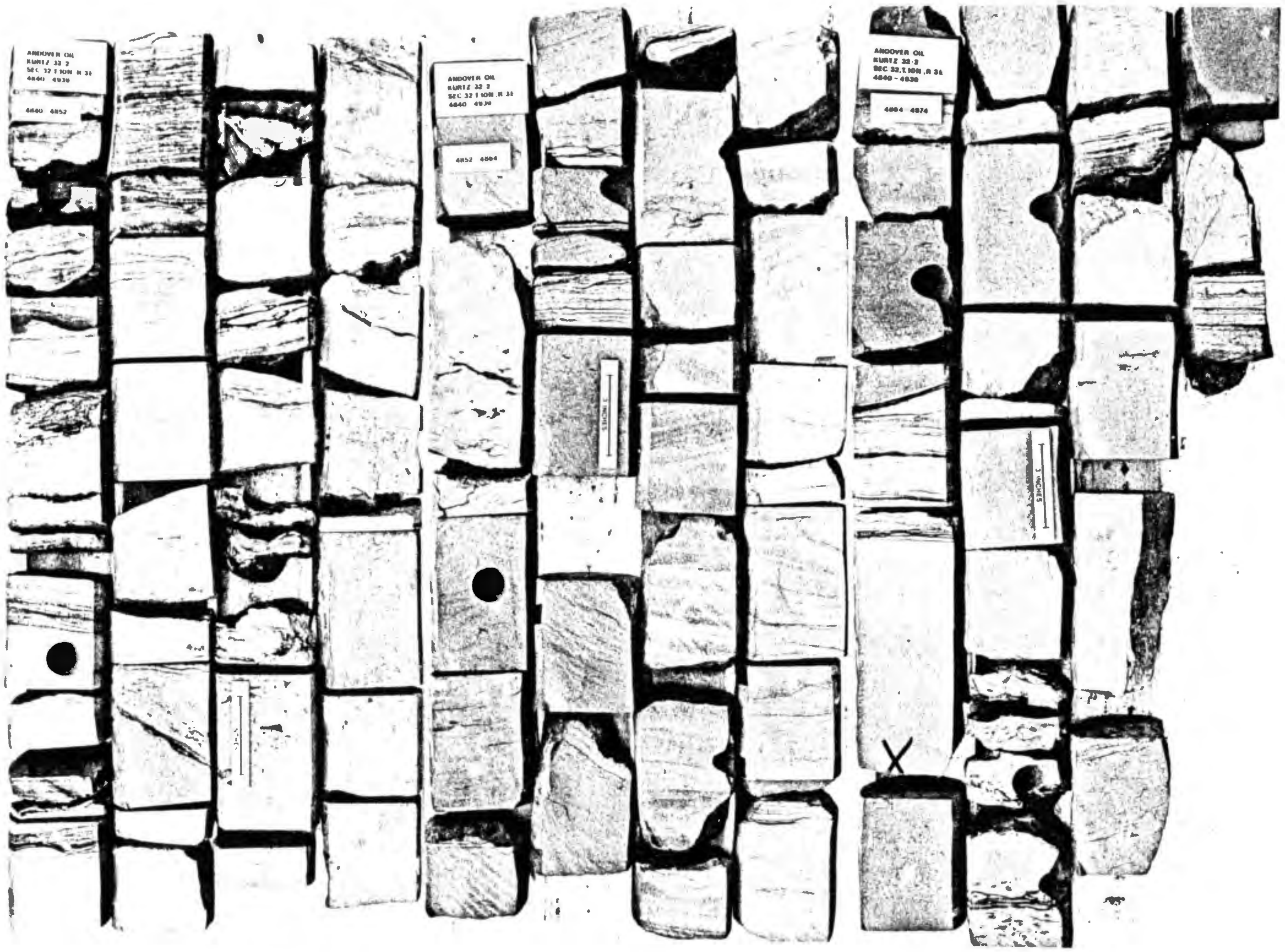


Figure 8. Photograph of Core from Andover Oil, Kurtz 32-2A. Depth: 4840-4874 ft.

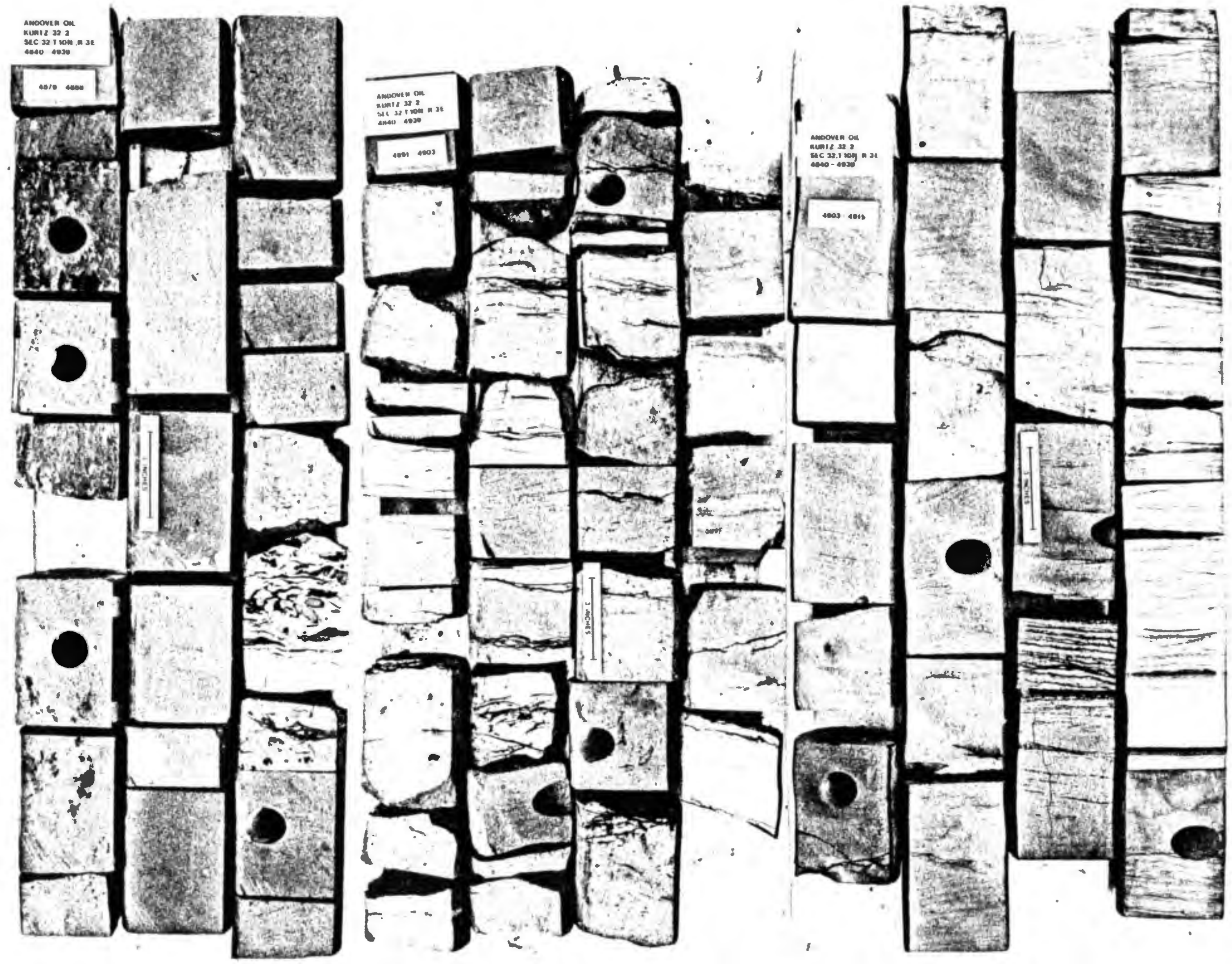


Figure 8. (Continued). Depth: 4879-4915 ft.

Figure 8. (Continued). Depth: 4915-4939 ft.

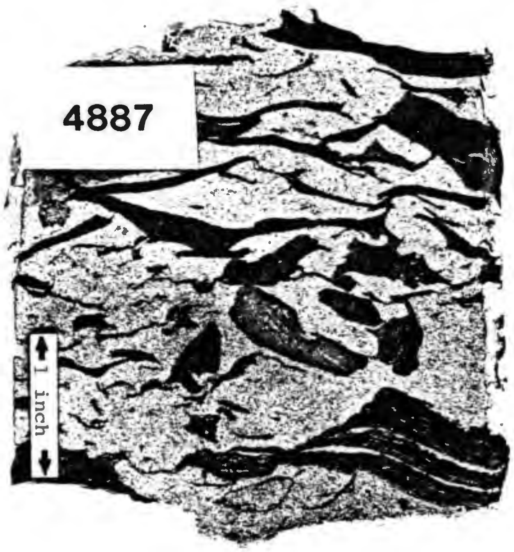


Figure 9. Rip-up Clasts from Underlying Shale. Core from Andover Oil, Kurtz 32-2A

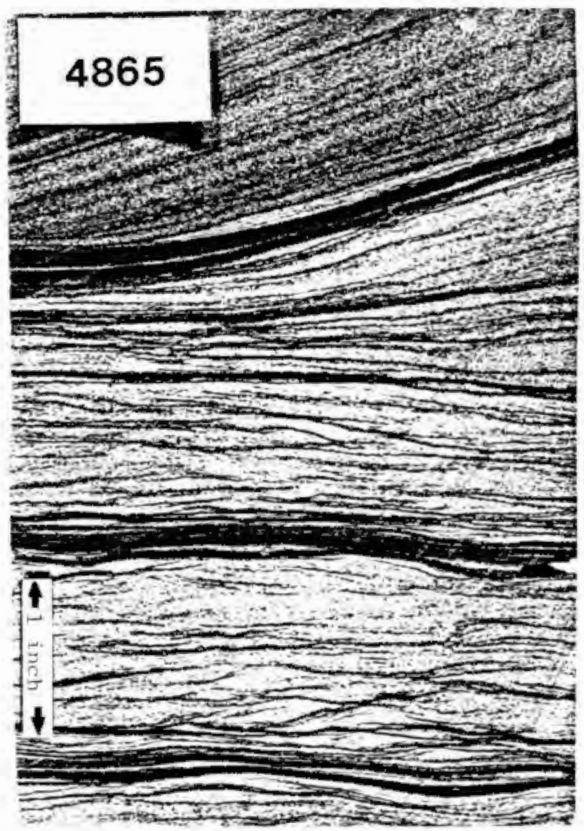


Figure 10. Horizontal Laminations Grading Upward into Inclined Laminations. Core from Andover Oil, Kurtz 32-2A

and medium-scale planar cross-bedded sandstones. Inclined laminae (Figure 10) and convolute bedding also were documented (Figure 11).

2. An upper zone of small-scale trough cross-bedded (Figure 12), horizontally laminated (Figure 13), and ripple laminated (Figure 14), interstratified sandstone, siltstone, and shale. Flowage features (Figure 15), water-escape features, sideritic laminae, pyrite nodules, bioturbated rock, burrows, and coal (Figure 16) are common in this interstratified zone.

Sedimentary structures characteristic of Red Fork sandstone located between and on the edges of major sandstone trends (Figure 17) include horizontal laminations, ripple laminations, convolute bedding (flowage), small-scale trough cross-beds, microfaults, bioturbated rock, and burrows within an interstratified, very fine grained sandstone, siltstone, and shale sequence.

Sideritic laminae (Figure 18), pyrite, rootlets, burrows (Figure 19), fossils (Figure 20), and laminae of coal are within beds of black shale.

Discussion of Cores

Andover Oil, Kurtz 32-2A. The core from the Kurtz 32-2A (Figure 22) is located in the central part of a major Red Fork sandstone trend. The well is located at W SE NE NW, Sec. 32, T.10N., R.3E., in the Northwest Tecumseh Field.

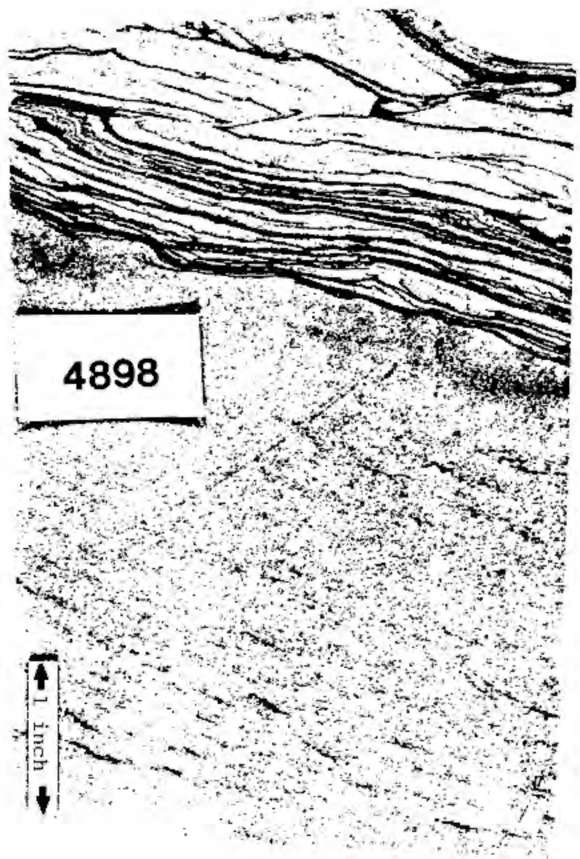


Figure 11. Convolute Bedding.
Core from Andover
Oil, Saunders 29-1

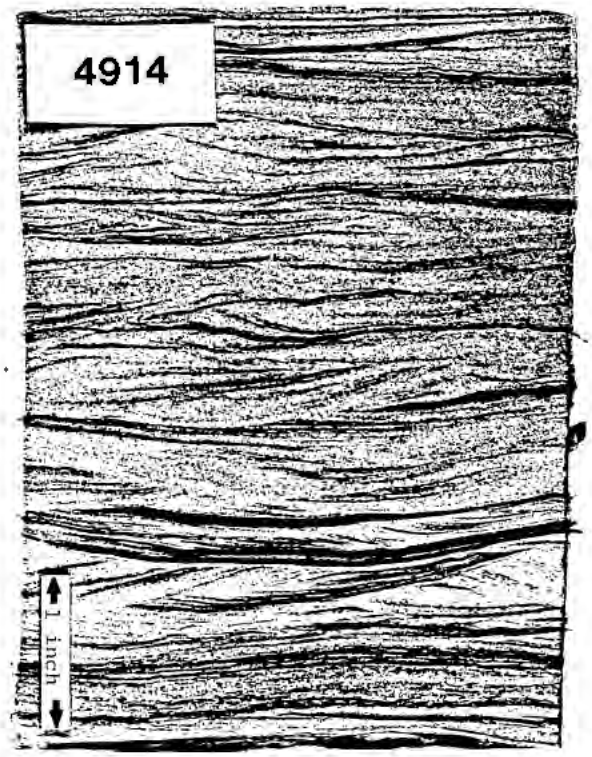


Figure 12. Small-Scale Trough Cross-Beds. Core from Andover Oil, Kurtz 32-2A

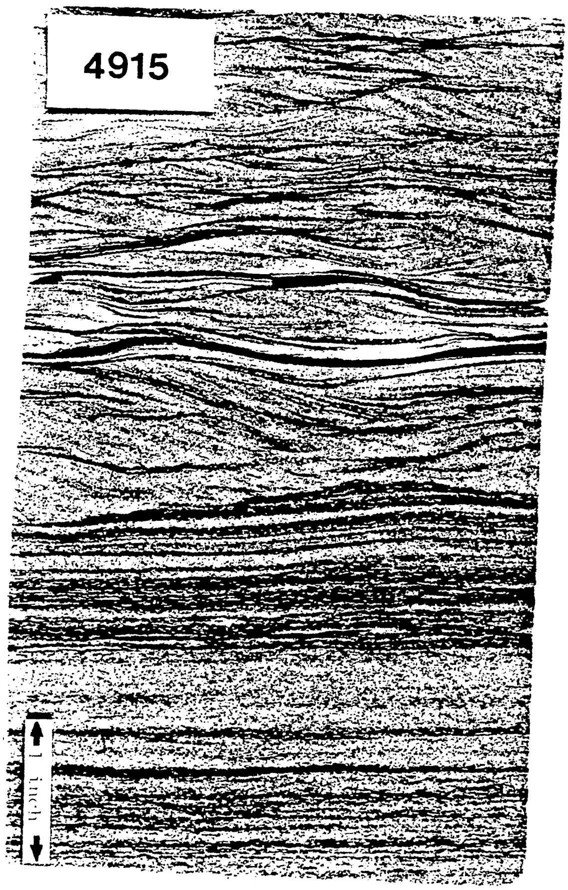


Figure 13. Horizontal Laminations and Ripple Laminations. Core from Andover Oil, Kurtz 32-2A

Figure 14. Ripple Laminations and Climbing Ripples. Core from Andover Oil, Irons 32-2

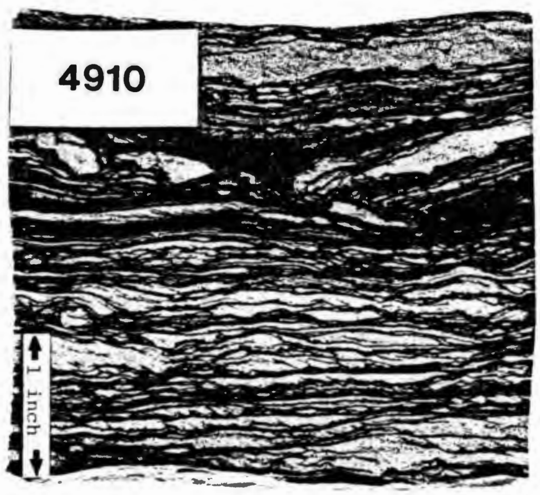


Figure 15. Flowage Features.
Core from
Andover Oil,
Irons 32-2

Figure 16. Coal. Core from Andover Oil, Kurtz 32-2A

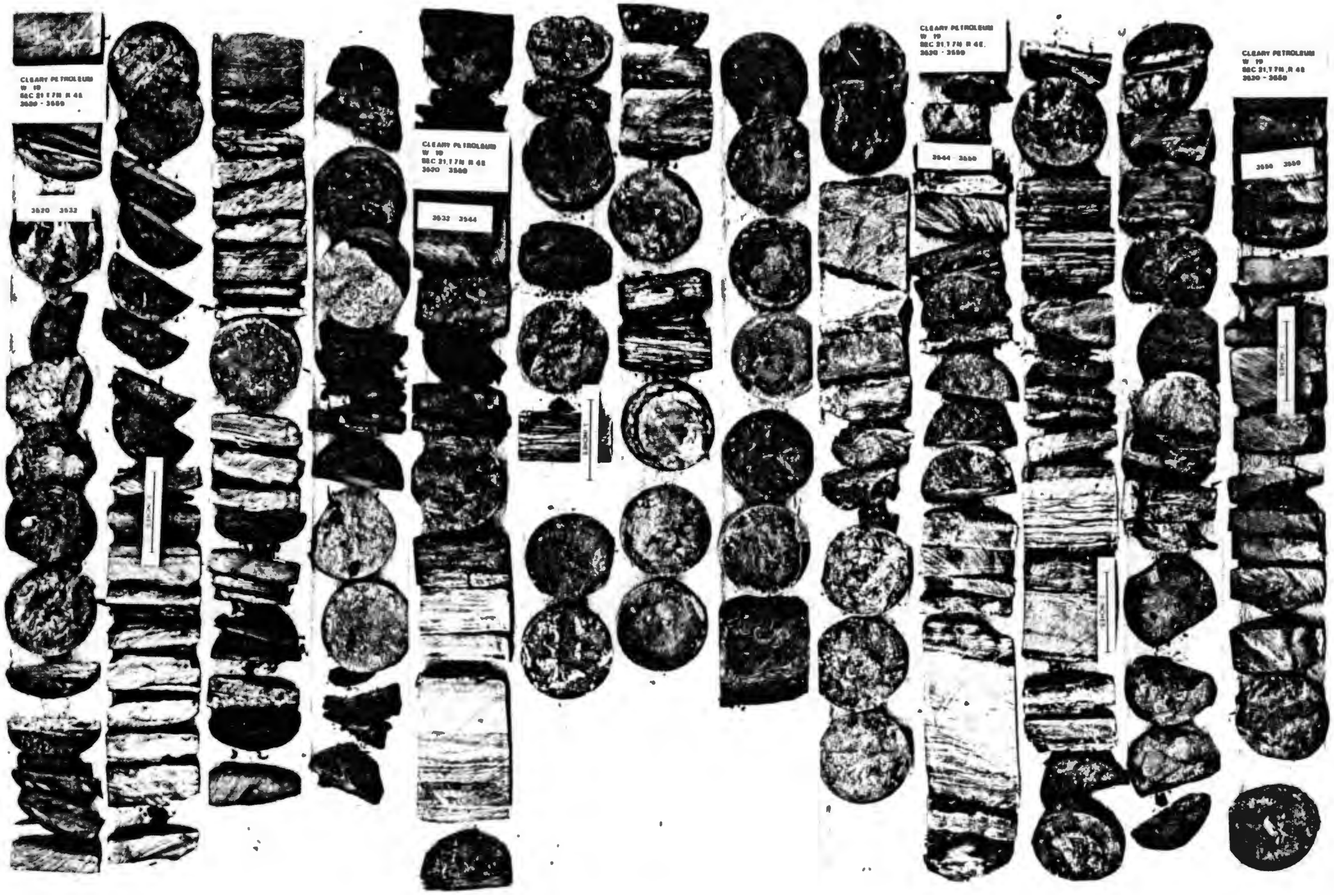


Figure 17. Photograph of Core from Cleary Petroleum, W-19. Depth: 3520-3559 ft.

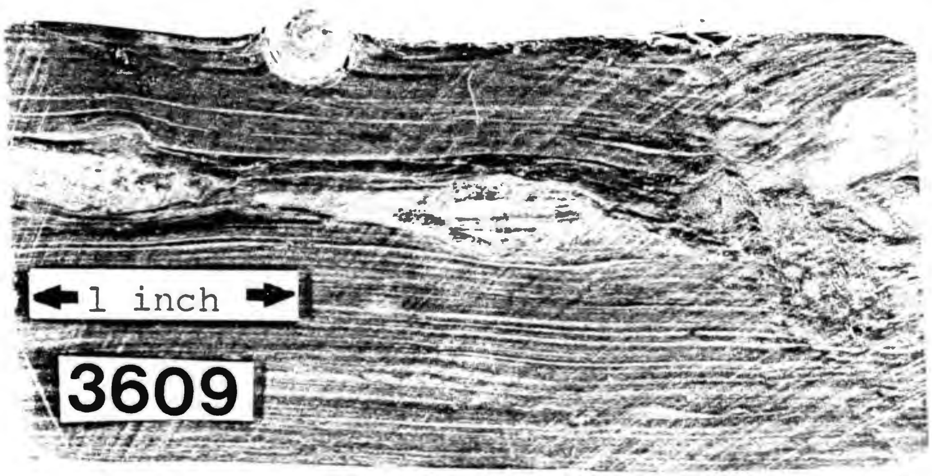


Figure 18. Siderite Nodule and Laminae. Core from Cleary Petroleum, W-14

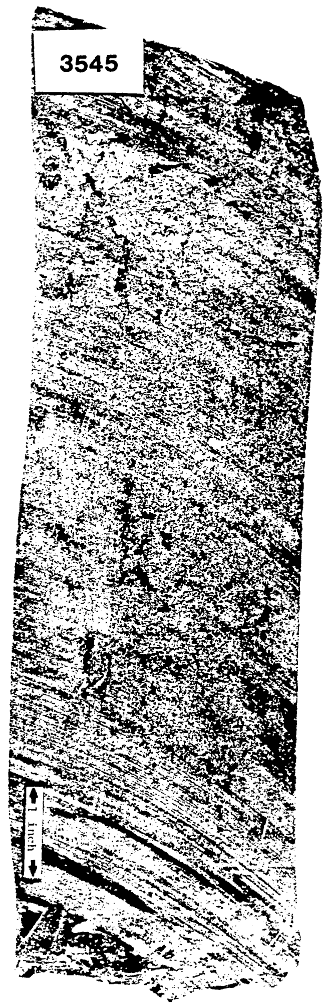


Figure 19. Vertical Burrows.
Core from Cleary
Petroleum, W-19

Figure 20. Fossils Within Black Shale. Core from Cleary Petroleum, W-14

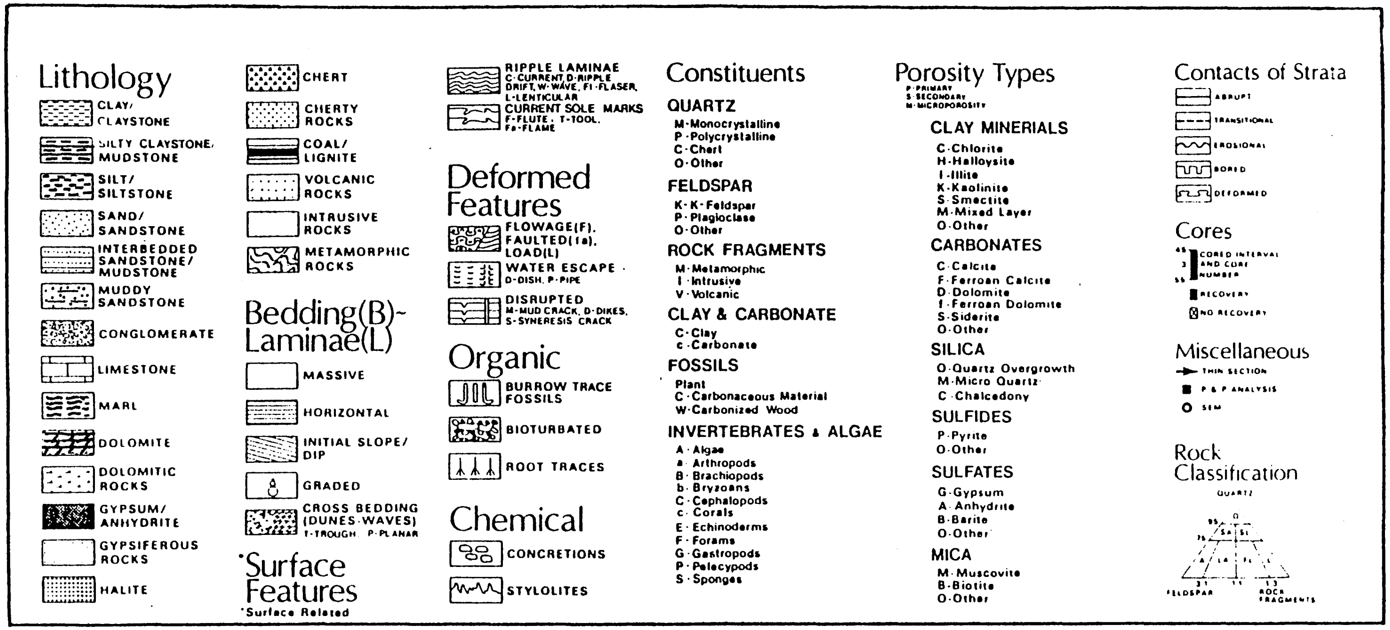


Figure 21. Key for Description of Cores

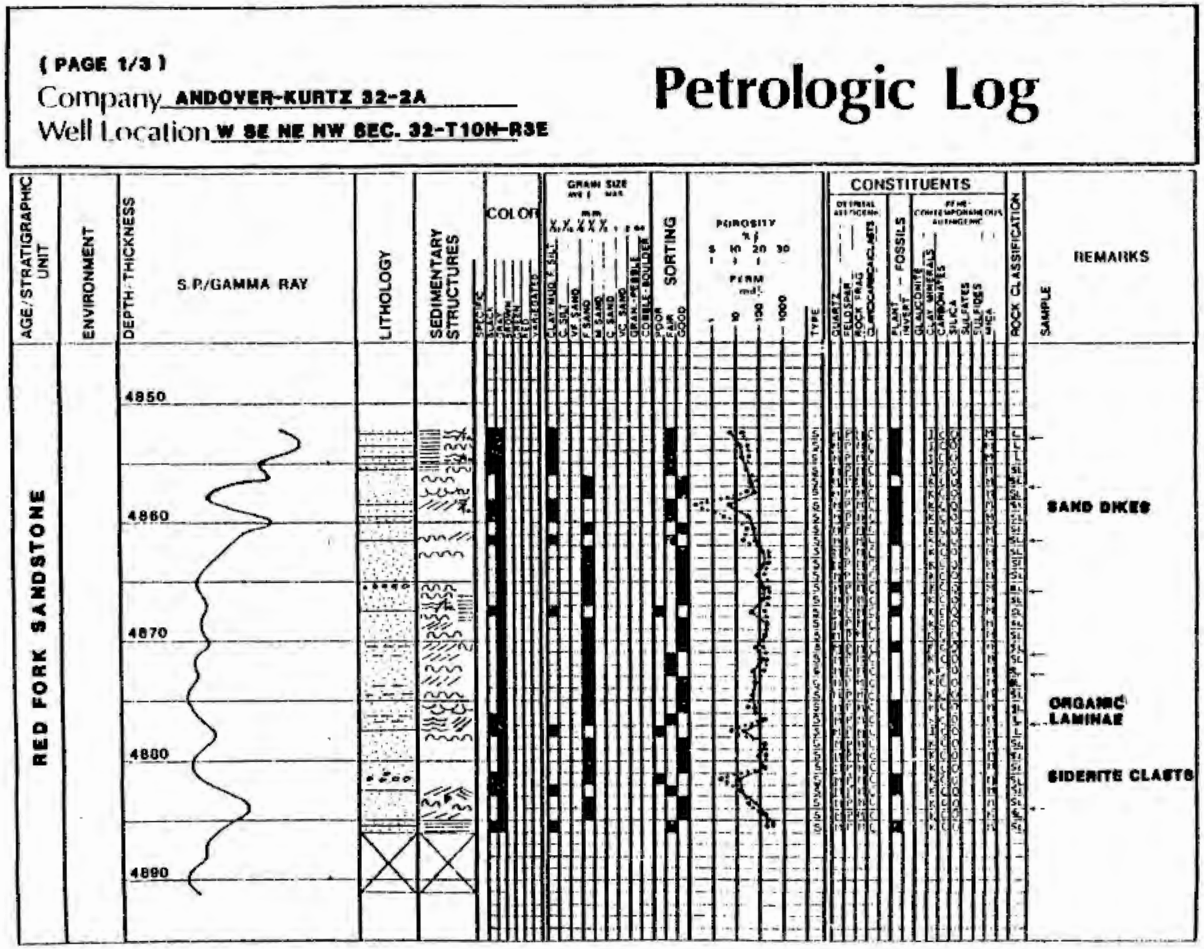


Figure 22. Description of Core from Andover Oil, Kurtz 32-2A

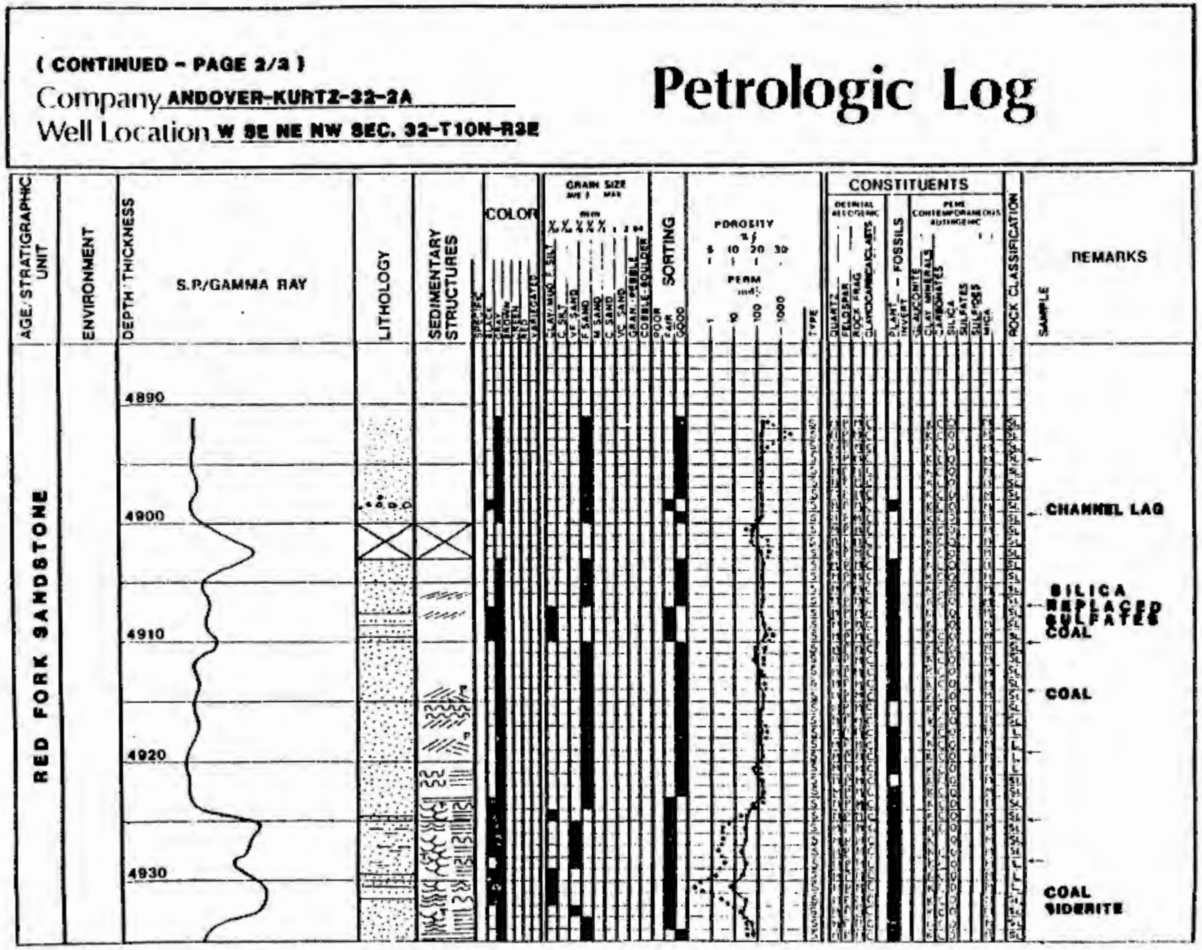


Figure 22. (Continued)

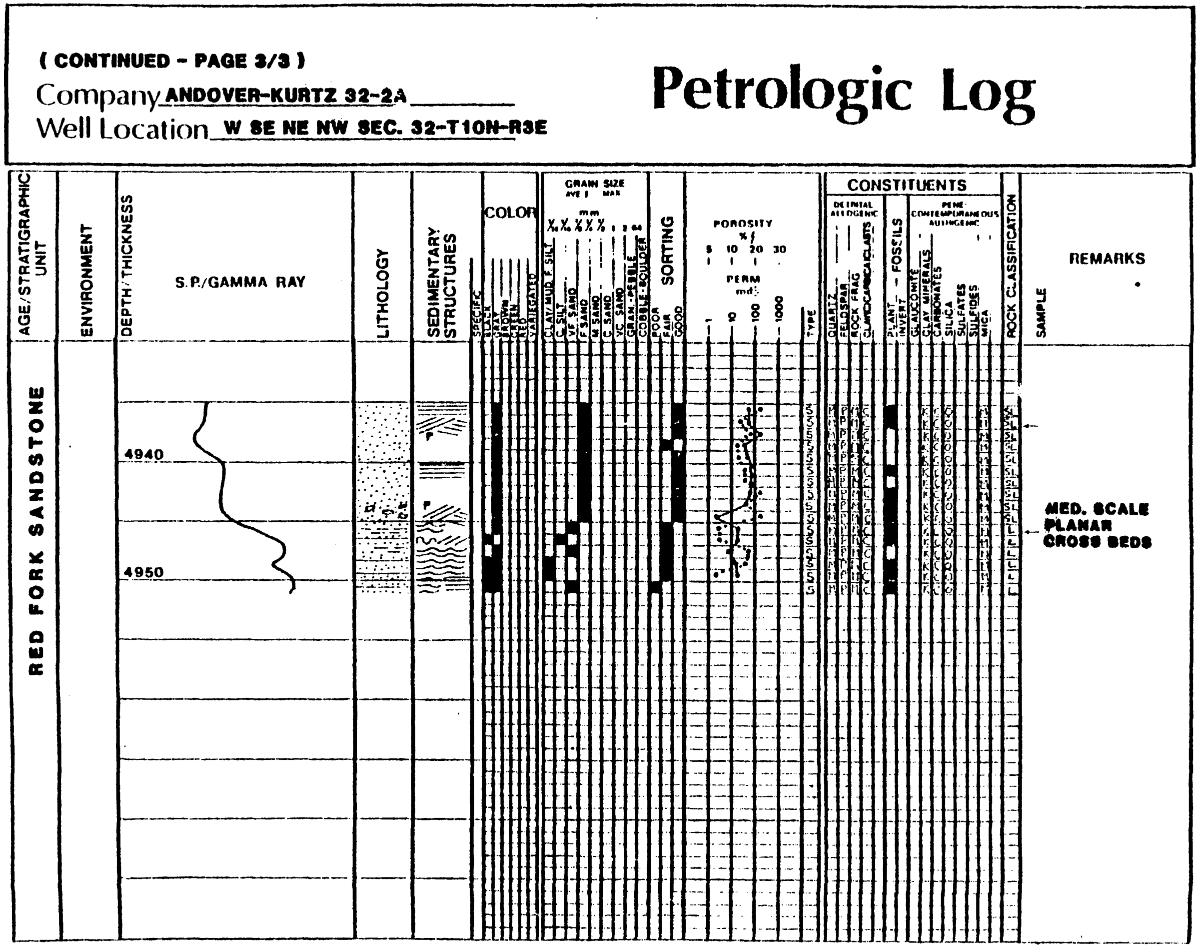


Figure 22. (Continued)

The core contains fine grained, sublithic sandstone and dark gray to black shale.

The cored interval is approximately 100 feet of sandstone. Four sandstone bodies were identified in the Kurtz 32-2A core (4857 to 4883 feet, 4885 to 4900 feet, 4904 to 4925 feet, and 4925 to 4946 feet). Sharp basal contacts and channel lag are characteristic of each sandstone body. Abundant organic laminae are throughout the core. The sand is fine grained and almost uniform throughout the section. A general vertical sequence of sedimentary structures from the base to the top of each sandstone body consists of massively bedded sandstone, medium-scale planar cross-beds, horizontal laminae, inclined laminae, small-scale trough cross-beds, ripple laminae, and flowage or convolute bedding. Gradational contacts with overlying interstratified sandstone and shale are characteristic of each sandstone body. Laminae of coal and lenses of siderite are near the top of each sequence.

Andover Oil, Irons 32-2. The core from the Irons 32-2 (Figure 23) is located in the same major sandstone trend as the core of Kurtz 32-2A. This well is located at NW SE SW, Sec. 32, T.10N., R.3E., in the Northwest Tecumseh Field.

The cored interval is approximately 75 feet of interbedded very fine grained, sublithic sandstone and black shale. The lower 40 feet of core (4900 to 4940 feet)

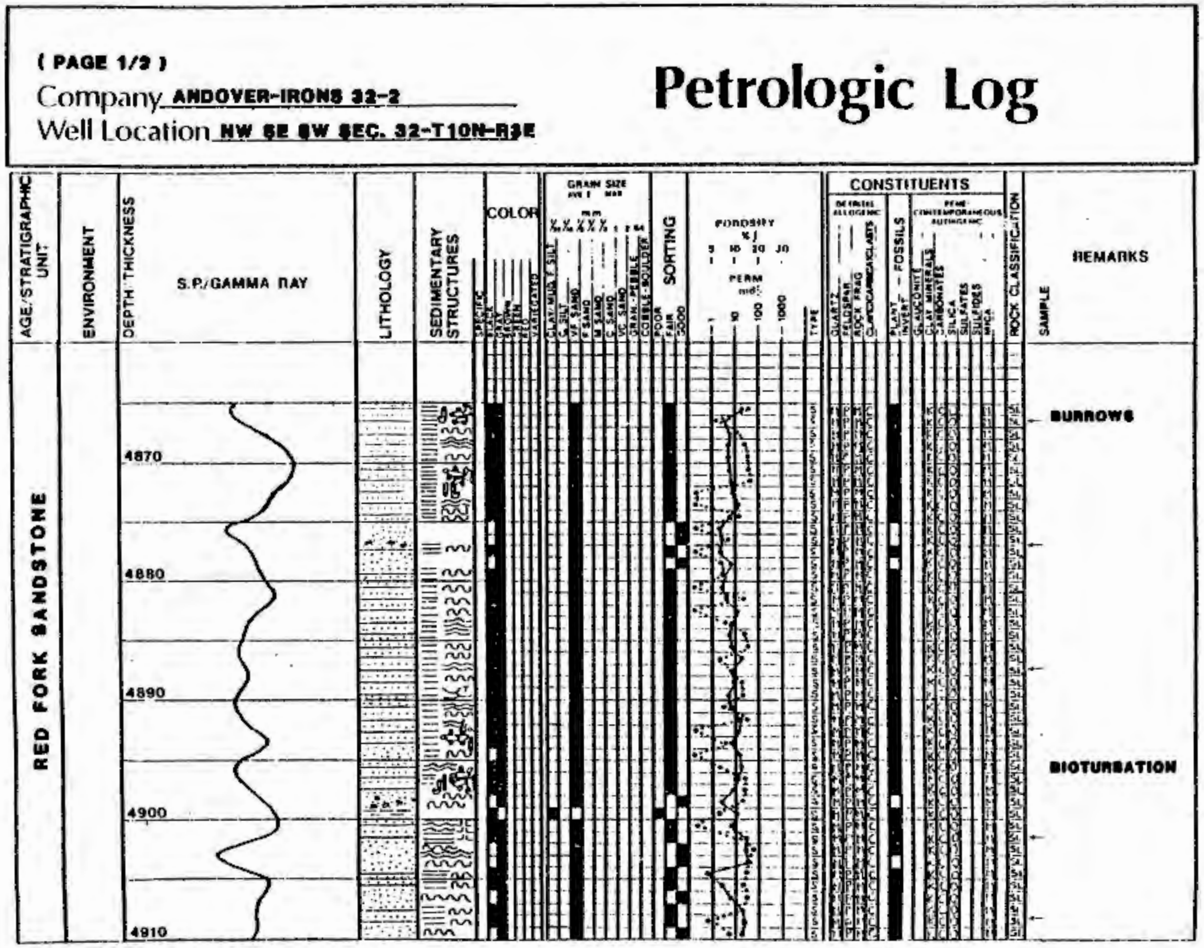


Figure 23. Description of Core from Andover Oil, Irons 32-2

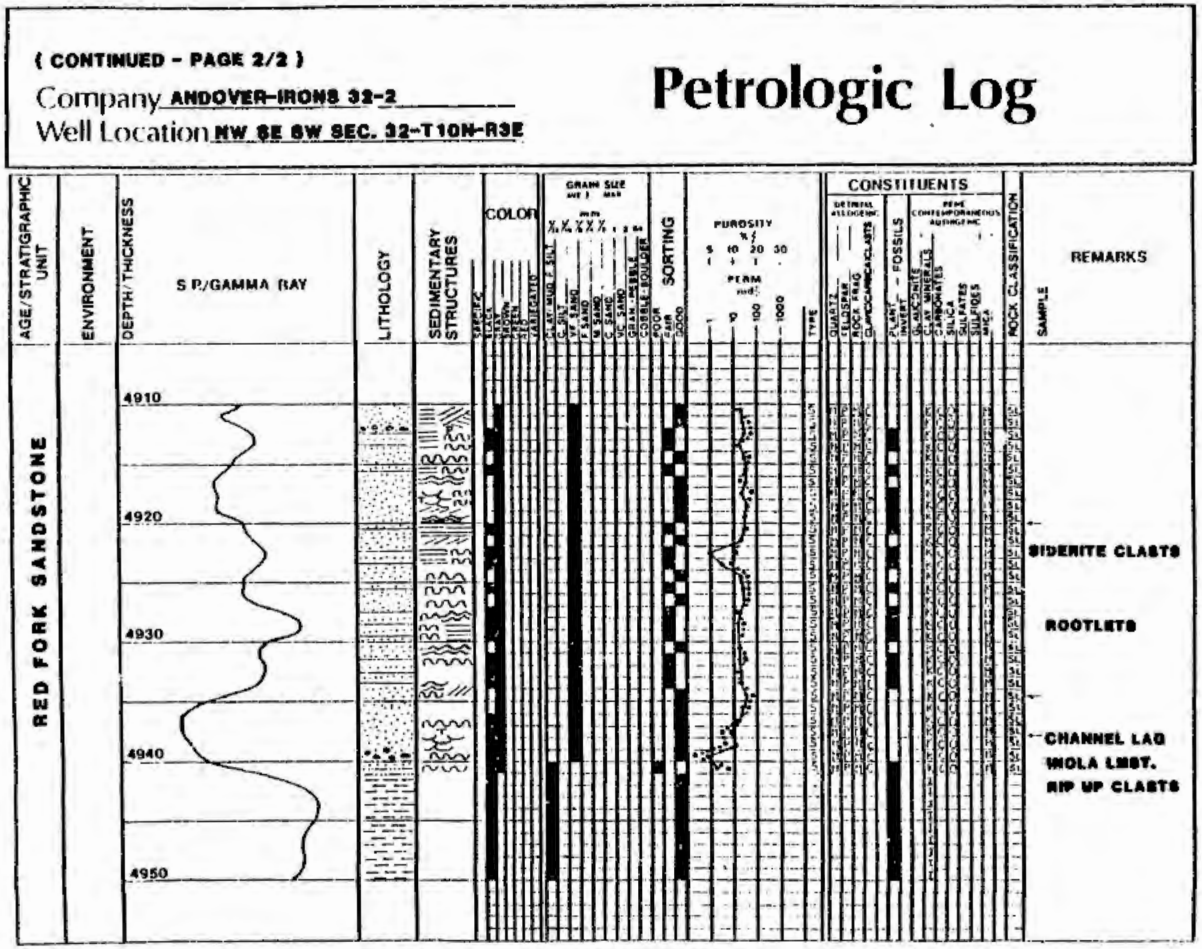


Figure 23. (Continued)

predominantly is sandstone with interstratified shale beds, the upper 35 feet (4865 to 4900 feet) is approximately 50 percent sandstone and 50 percent shale, interbedded.

The lower 40 feet of the core can be divided into two sandstone bodies (4900 to 4920 feet, and 4920 to 4940 feet). These units probably correlate with the lower two sandstone bodies identified in the Kurtz 32-2A core. An abrupt basal contact, above which channel lag is recorded in the sandstone body at the base of the Irons 32-2 core (4920 to 4940 feet).

Common sedimentary structures in the lower 40 feet of the Irons 32-2 core include small-scale trough cross-beds, ripple laminae, horizontal laminate, inclined laminae, and flowage features. Common sedimentary structures in the upper 35 feet of interbedded sandstone and shale include horizontal laminae, ripple laminae, convolute bedding, bioturbated rock, burrows, microfaults, and water-escape features. Abundant organic laminae, lenses of siderite, and rootlets are in shaly sections throughout the core.

Andover Oil, Saunders 29-1. The Saunders 29-1 (Figure 24) is located at NW SW SE, Sec. 29, T.10N., R.3E., in the Northwest Tecumseh Field.

The core contains very fine grained, sublithic sandstone, and dark gray to black shale.

The cored interval is approximately 30 feet of sandstone with local interstratification of sandstone and shale.

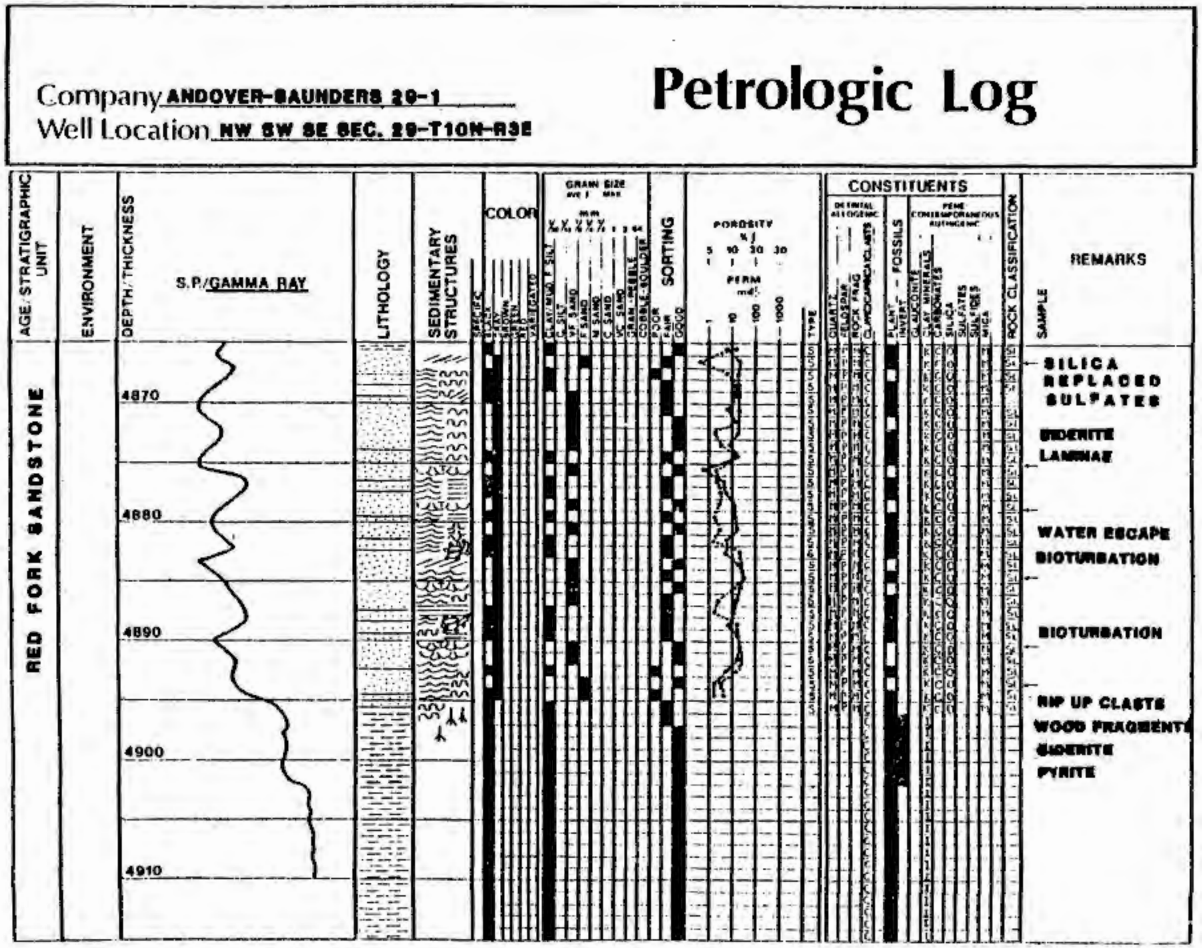


Figure 24. Description of Core from Andover Oil, Saunders 29-1

An abrupt contact and channel lag is at the base of the sandstone. The sand is fine grained and almost uniform throughout the section. Sedimentary structures common in the sandstone include small-scale trough cross-beds, horizontal laminae, inclined laminae, ripple laminae, and evidence of flowage.

Sedimentary structures in the interstratified sandstone and shale sections include horizontal laminae, ripple laminae, evidence of flowage, and bioturbated rock. Rootlets, siderite, and pyrite are in the carbonaceous shale that underlies the sandstone body (4896 feet).

American Exploration, Garrett No. 1. The Garrett No. 1 (Figure 25) is located in the central part of a major Red Fork sandstone trend. The well is located at SW SE SE, Sec. 9, T.10N., R.3E., in the northern part of the Northwest Tecumseh Field.

The cored interval is approximately 125 feet of fine grained sandstone and dark gray to black shale. The lower 75 feet of core (4835 to 4910 feet) is dominated by fine grained sandstone with interbedded shale. Shale rip-up clasts are at 4855, 4888, and 4909 feet. Common sedimentary structures include medium-scale planar cross-beds, massive beds, horizontal laminae, inclined laminae, ripple laminae and evidence of flowage.

Sedimentary structures in the sections of interbedded sandstone and shale include horizontal laminae, ripple

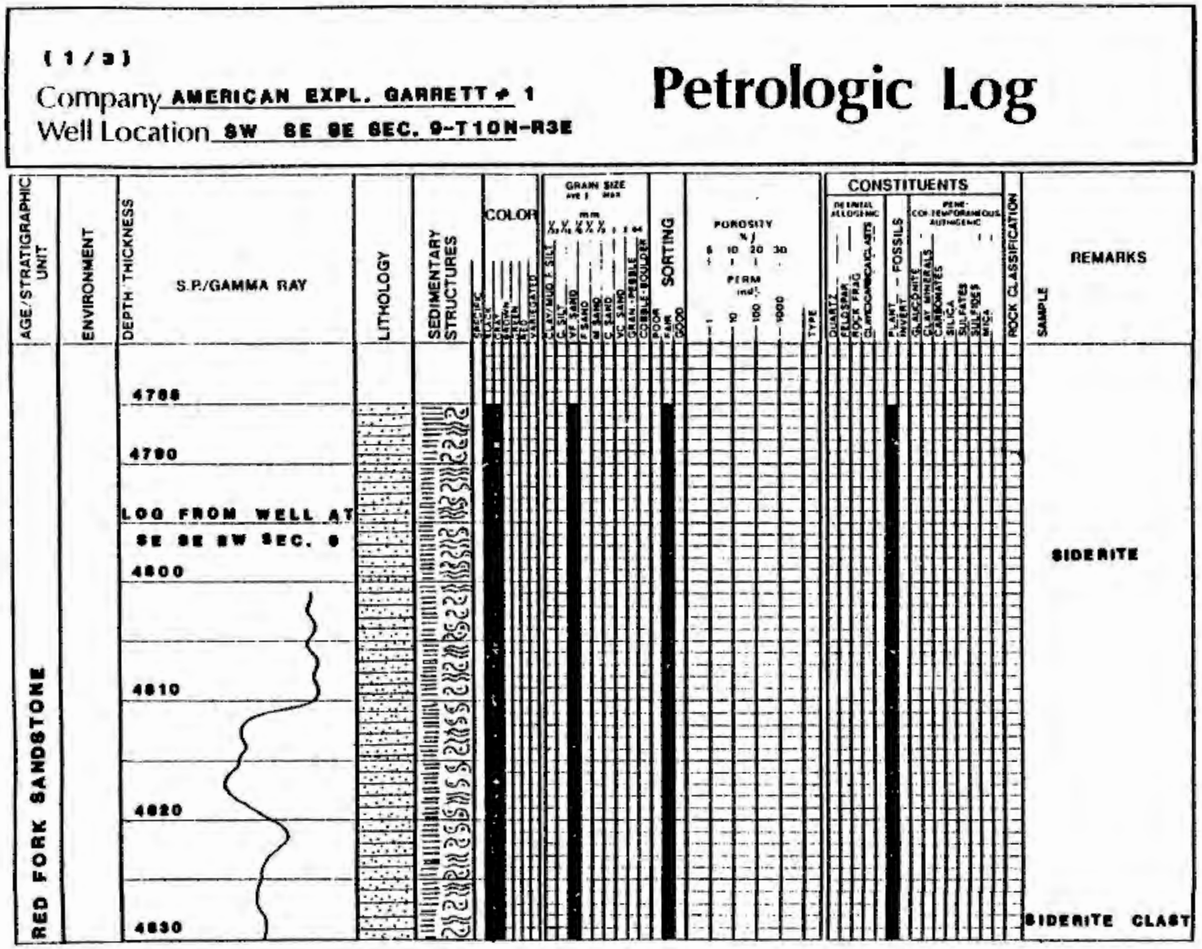


Figure 25. Description of Core from American Exploration, Garrett No. 1

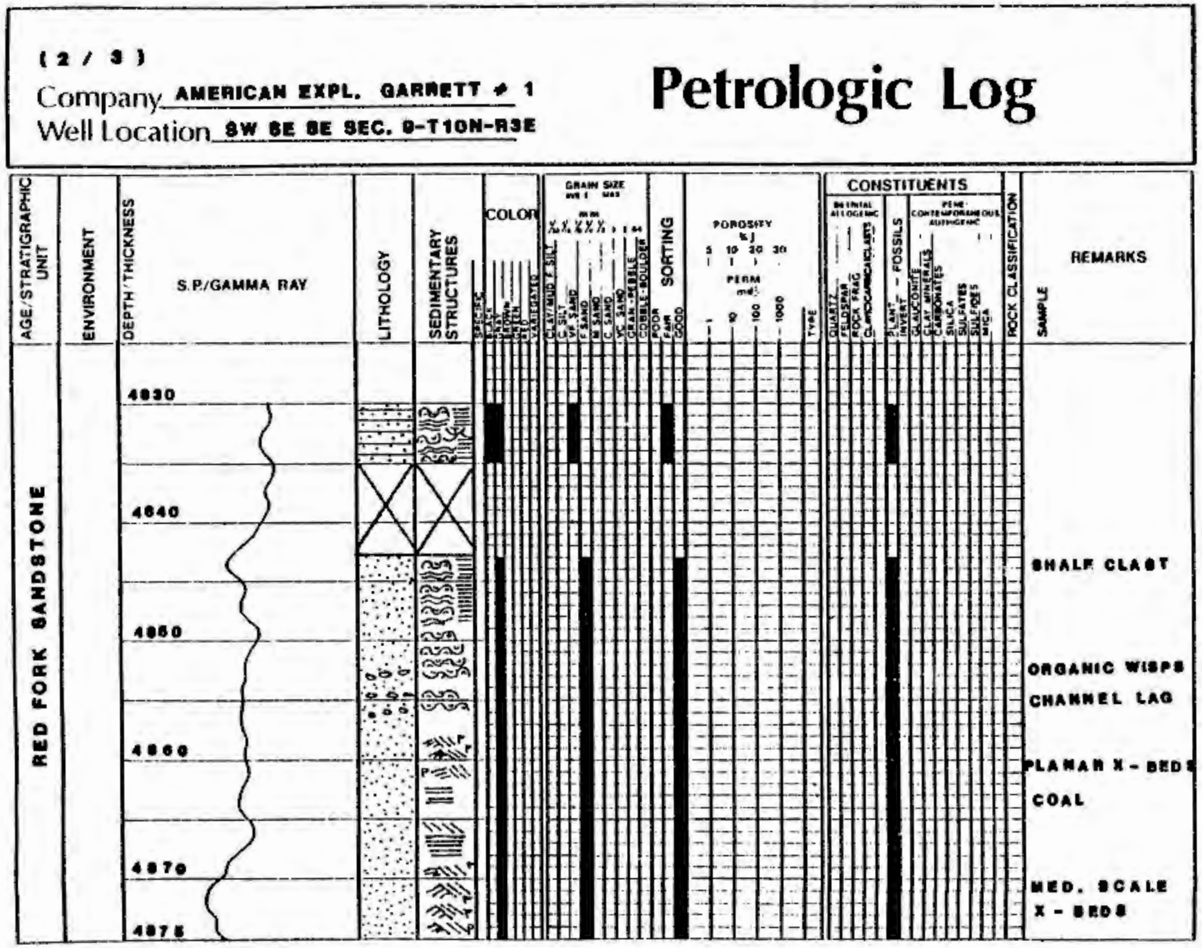


Figure 25. (Continued)

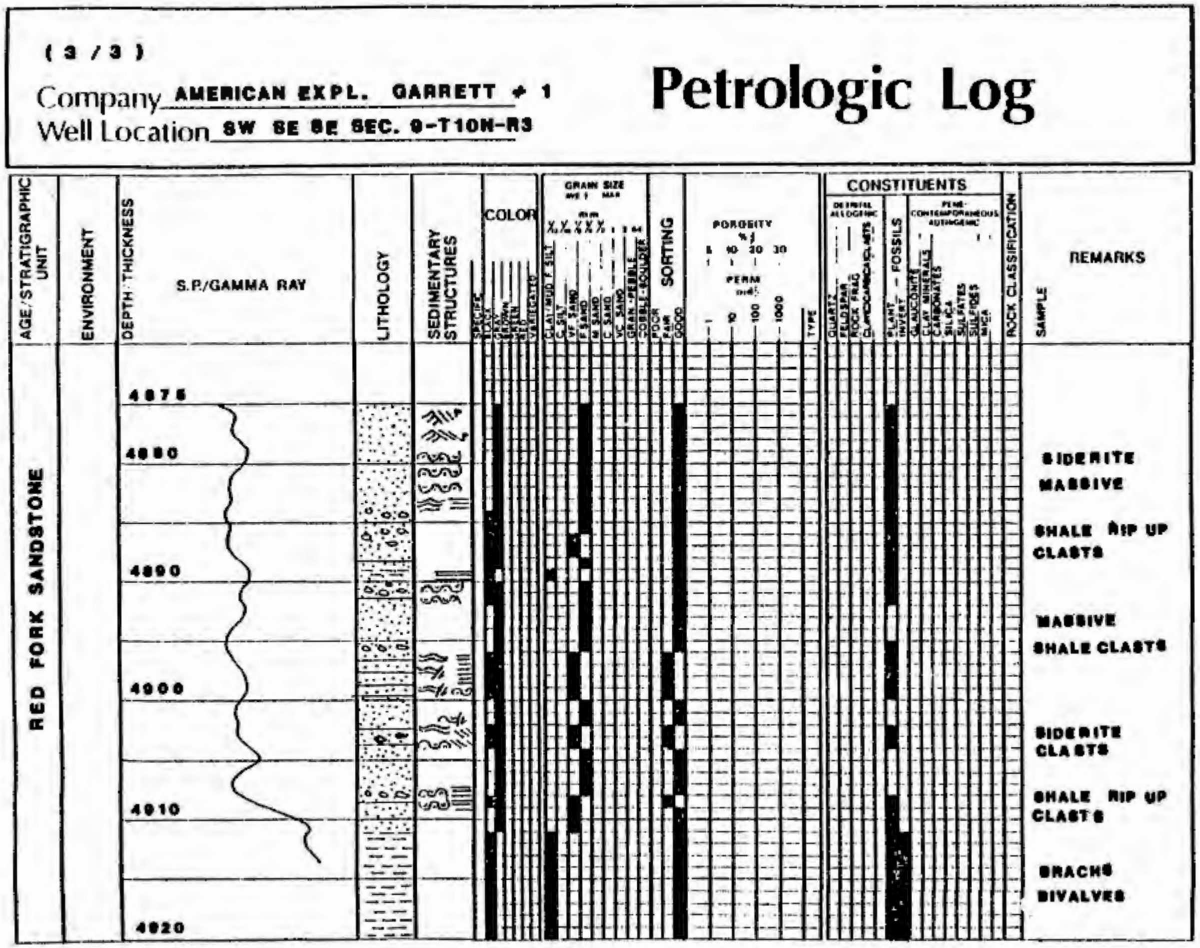


Figure 25. (Continued)

laminae, convolute bedding and microfaults. Wisps of organic material and nodules of siderite are present. Fine sand extends throughout the section.

The upper 50 feet of the core (4785 to 4835 feet) is interbedded, very fine grained sandstone and black shale.

Sedimentary structures in the upper unit are horizontal and ripple laminae, and flowage. Siderite is common within the black shale. Brachiopods, and possibly bivalves, are in the black shale in the lowermost 9 feet of core (4911-4920 feet).

American Exploration, Harrell A 28-1A. The core from the Harrell A 28-1A (Figure 26), a well located at NW NE NW, Sec. 28, T.10N., R.3E., is from the marginal part of the major Red Fork sandstone trend that makes up the reservoir in the Northwest Tecumseh Field.

The core is composed of 50 feet of interbedded black shale, siltstone, and very fine grained sandstone. The lower 26 feet is interbedded very fine grained sandstone and shale. Sedimentary structures in this section are horizontal laminae, ripple laminae, and flowage features.

The upper 24 feet of core is interbedded siltstone and black shale. Horizontal laminations and convolute bedding are in this section. Siderite lenses are within the shale throughout the core.

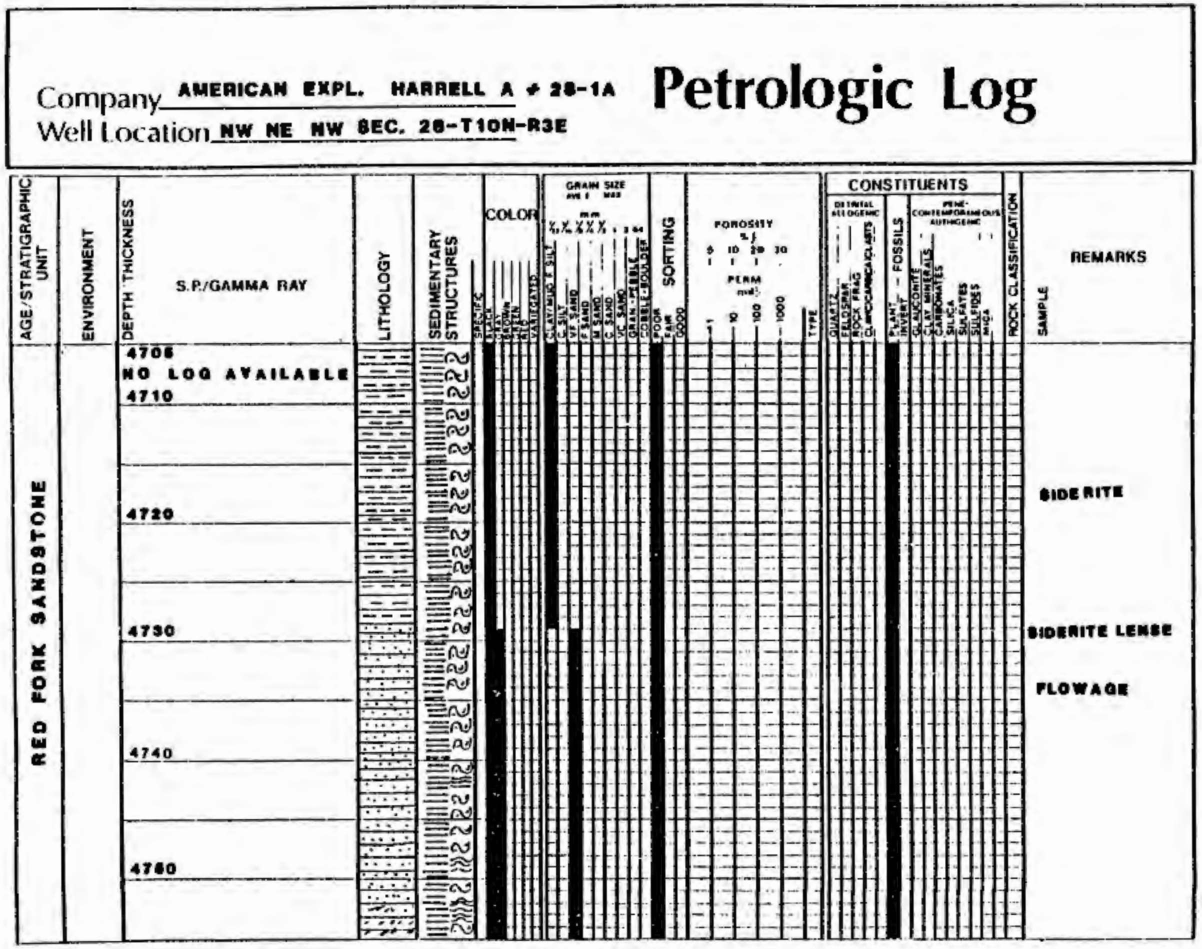


Figure 26. Description of Core from American Exploration, Harrell A 28-1A

Cimarron Petroleum, Cunze. The core from the Cunze well (Figure 27) is located between major Red Fork trends in Sec. 16, T.11N., R.3E..

The cored interval (4834 to 4861 feet) is 27 feet of black shale interbedded with very fine grained sandstone. Sedimentary structures include horizontal laminae, ripple laminae, flowage features, microfaults, burrows, and evidence of bioturbation. Siderite is within shale beds throughout the core.

Barton Valve, Brown No. 1. The Brown No. 1 well (Figure 28) is located at NW NW NE SW, Sec. 20, T.11N., R.6E.. The core is in a trend of Red Fork Sandstone that is approximately 80 feet thick as based on the net-sandstone isolith map (Plate XV).

The cored interval is 19 feet of fine to very fine grained sandstone and black shale. The cored interval is assumed to represent the top 19 feet of the 80-foot-thick trend of Red Fork Sandstone.

The lower 8 feet of core (3516 to 3524 feet) is horizontally laminated, ripple laminated, small-scale trough cross-bedded, and convolute-bedded, fine grained sandstone. The next higher 8 feet of core (3508 to 3516 feet) grades into very fine sandstone. Sedimentary structures are small-scale trough cross-beds, inclined laminae, ripple laminae, horizontal laminae, and flowage features.

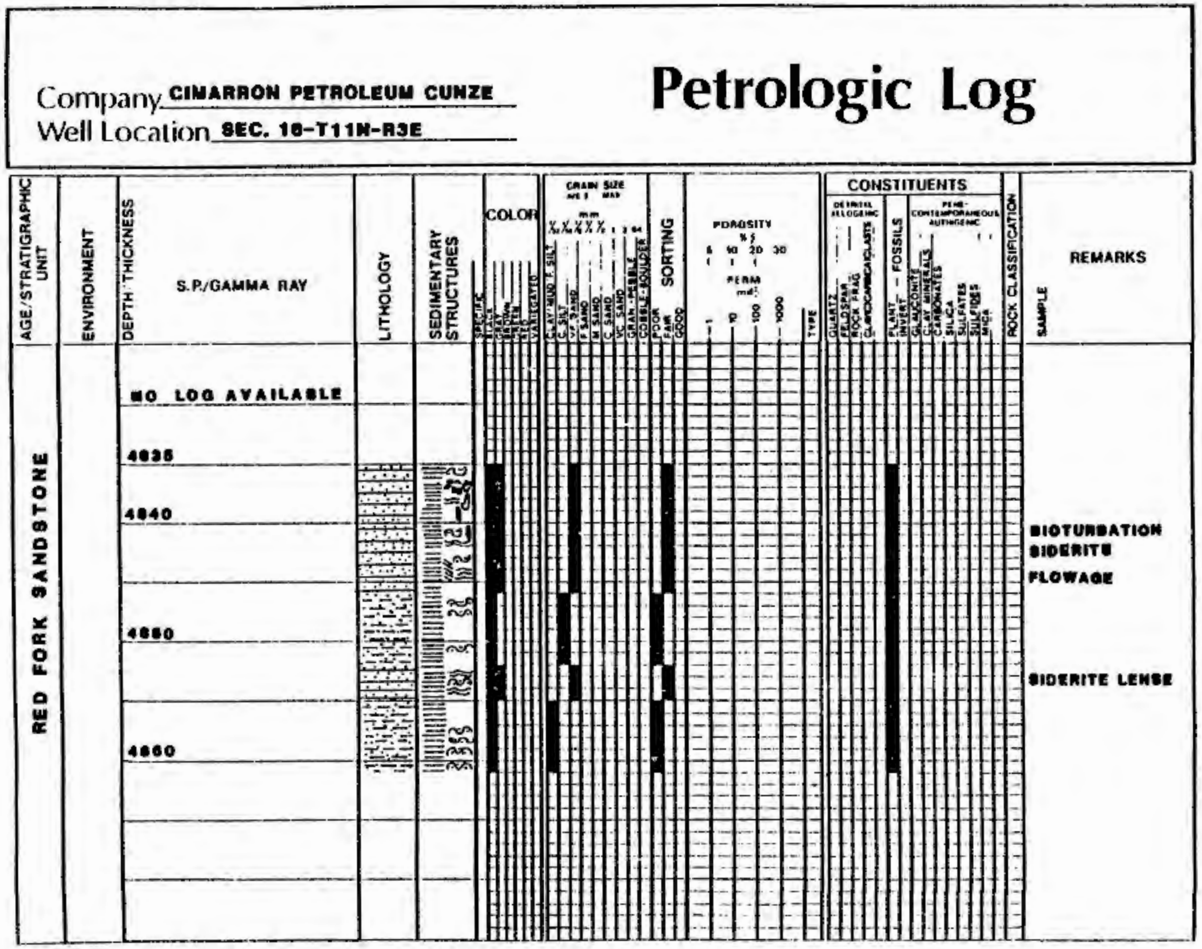


Figure 27. Description of Core from Cimarron Petroleum, Cunze

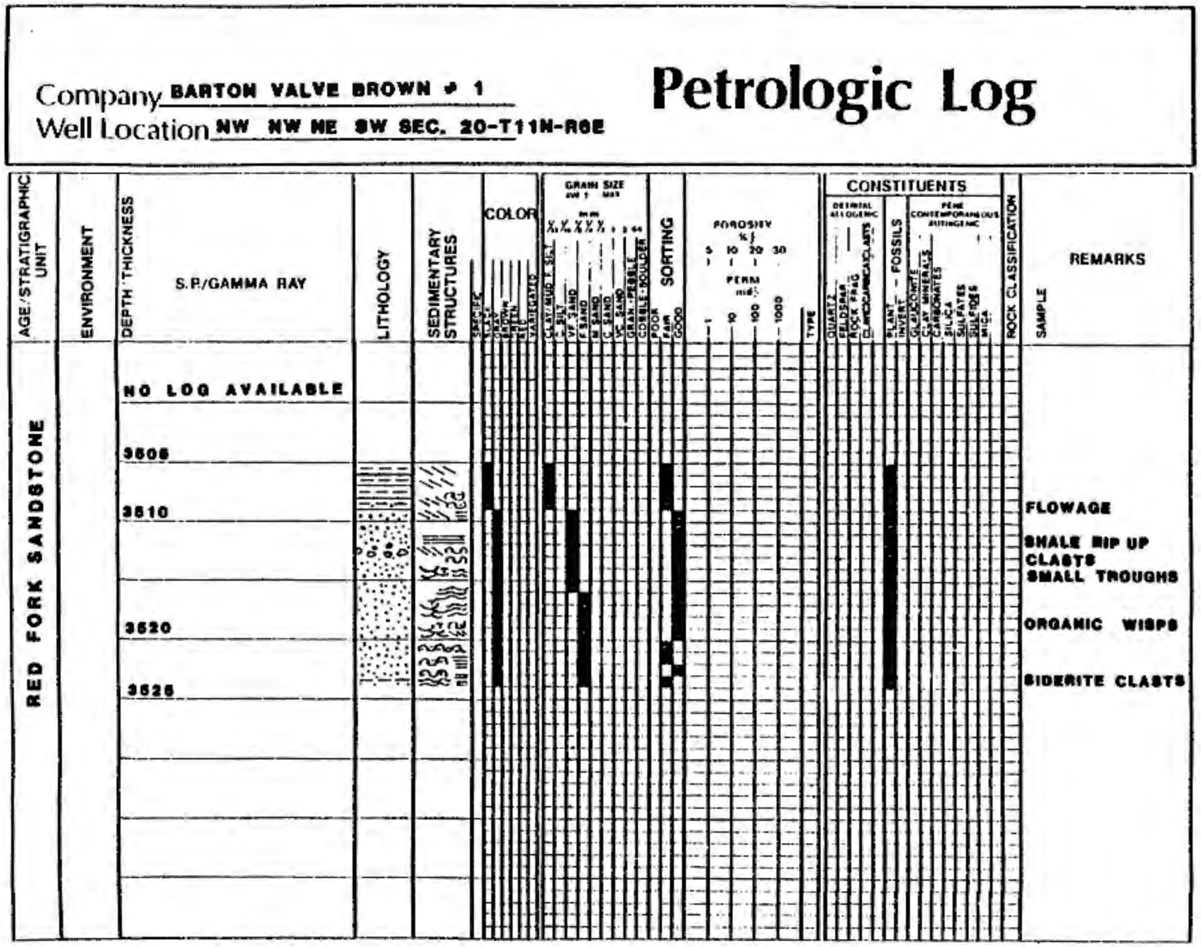


Figure 28. Description of Core from Barton Valve, Brown No. 1

The top 3 feet of core are composed of siltstone and black shale.

Etal Oil, Foreman No. 1. The Foreman No. 1 well (Figure 29) is located at N NW SW SW, Sec. 7, T.10N., R.6E., in the North Searight Field. This core is located in a major trend of Red Fork Sandstone that is approximately 80 feet thick on the net-sandstone isolith map (Plate XV).

The cored interval is 21 feet of very fine grained lithic sandstone and black shale. The cored interval is assumed to represent the upper part of the Red Fork trend. The lower 13 feet of core (3618 to 3631 feet) is composed of very fine grained sandstone with interbedded shale. Sedimentary structures include massive beds, medium-scale planar cross-beds, horizontal laminae, ripple laminae, small-scale trough cross-beds, flowage, and microfaults. The upper 8 feet of core (3610 to 3618 feet) are black shale with lenses of siderite.

Cleary Petroleum, Waterflood P-44. The Waterflood P-44 well (Figure 30) is located at NW SE SE NW, Sec. 21, T.7N., R.4E., in the St. Louis Field. This core is located near the edge of a Red Fork Sandstone trend.

The cored interval (3480 to 3553 feet) contains very fine grained lithic to sublithic sandstone and dark gray, black, and green shale. The lower 17 feet of core (3536 to 3553 feet) is horizontally laminated, convolute bedded, and burrowed black shale. Siderite laminae are also present.

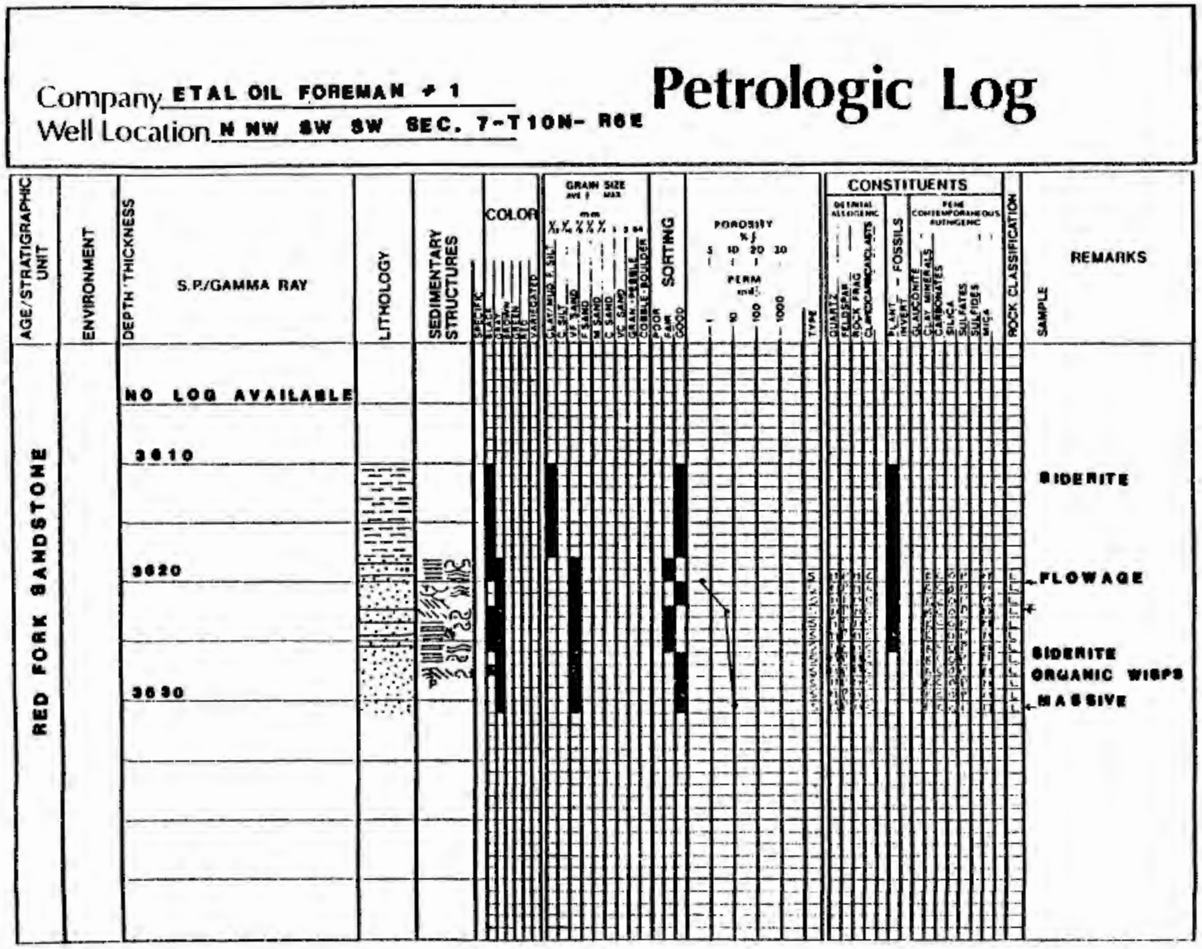


Figure 29. Description of Core from Etal Oil, Foreman No. 1

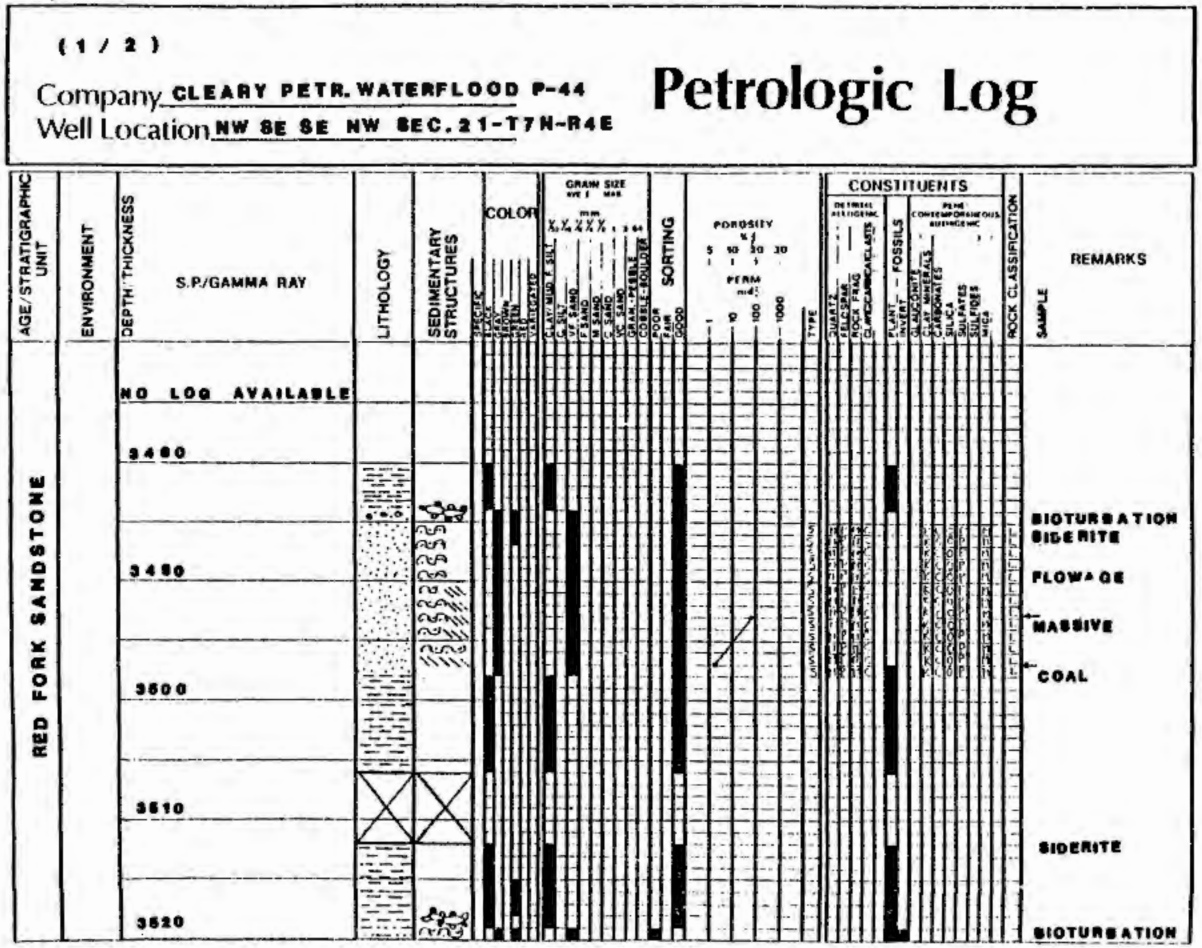


Figure 30. Description of Core from Cleary Petroleum, Waterflood P-44

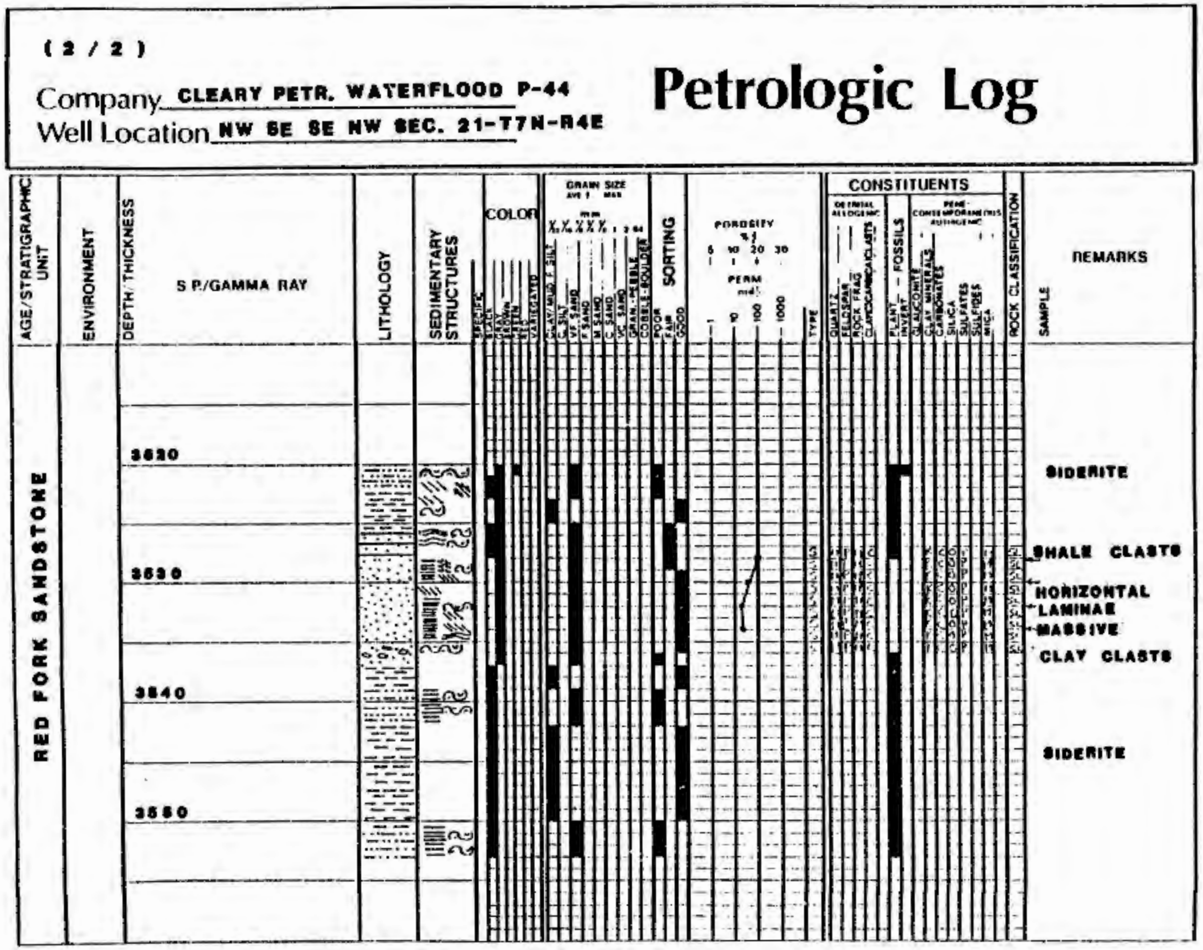


Figure 30. (Continued)

The overlying 11 feet of core (3525 to 3536 feet) are very fine grained sandstone. Sedimentary structures in this interval are horizontal laminae, inclined laminae, ripple laminae, convolute bedding, and water-escape features. This sandstone body is overlain by 27 feet (3498 to 3525 feet) of black shale. The overlying 14 feet of core (3484 to 3498 feet) is very fine grained sandstone. Inclined laminae and flowage features are throughout this interval. At the top of this sandstone body (3484 feet), a bioturbated green clay with calcareous nodules is observed (Figure 31).

Cleary Petroleum, W-14. The W-14 well (Figure 32) is located near the edge of a Red Fork Sandstone trend in Sec. 21, T.7N., R.4E., in the St. Louis Field.

The cored interval (3600 to 3642 feet) is very fine grained, lithic sandstone and black shale. The lower 14 feet of core (3628 to 3642 feet) is black shale. Siderite lenses, pyrite nodules, and brachiopods are within this shale interval. The overlying 9 feet of core (3619 to 3628 feet) is very fine grained sandstone interlaminated with shale. Inclined laminae, ripple laminae, and convolute bedding are features in this interval.

Coal, pyrite, and siderite are present at and near the top of the sandstone body (3619 feet). Bioturbated black shale containing brachiopods overlies the sandstone

Figure 31. Bioturbated Green Clay with Calcareous Nodules

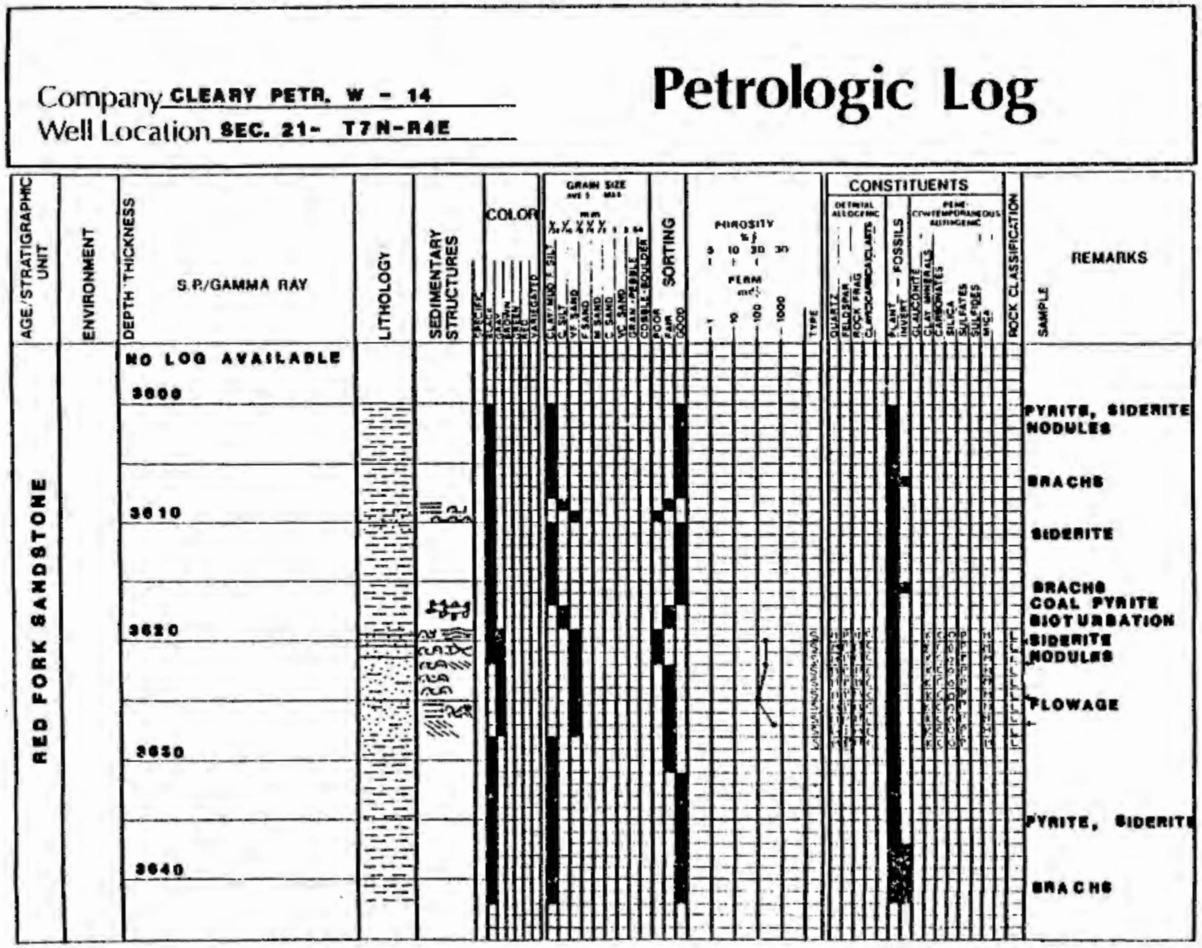


Figure 32. Description of Core from Cleary Petroleum, W-14

body (3600 to 3619 feet). Pyrite and siderite are within this shale section.

Cleary Petroleum, W-19. The W-19 core (Figure 33) is from a well located in Sec. 21, T.7N., R.4E., in the St. Louis Field.

The cored interval (3520 to 3559 feet) is 39 feet predominantly of black shale with interbedded siltstone and very fine grained sandstone.

Sedimentary structures in this core include small-scale trough cross-beds, ripple laminae, horizontal laminae, and flowage features. Brachiopods, siderite lenses, pyrite, and evidence of bioturbation are observed within the shale beds.

Cleary Petroleum, W-15. This well is near the edge of a Red Fork trend in Sec. 21, T.7N., R.4E., in the St. Louis Field.

The core (Figure 34) contains very fine grained sandstone and black shale. The lower 12 feet of core (3515 to 3527 feet) is massively bedded, very fine grained sandstone. The overlying 25 feet (3490 to 3515 feet) is black shale. Brachiopods, crinoids, siderite, pyrite, and bioturbated rock are in this interval.

Cleary Petroleum, W-20. Located in Sec. 21, T.7N., R.4E. in the St. Louis Field, the Cleary W-20 well is near the edge of a Red Fork sandstone trend.

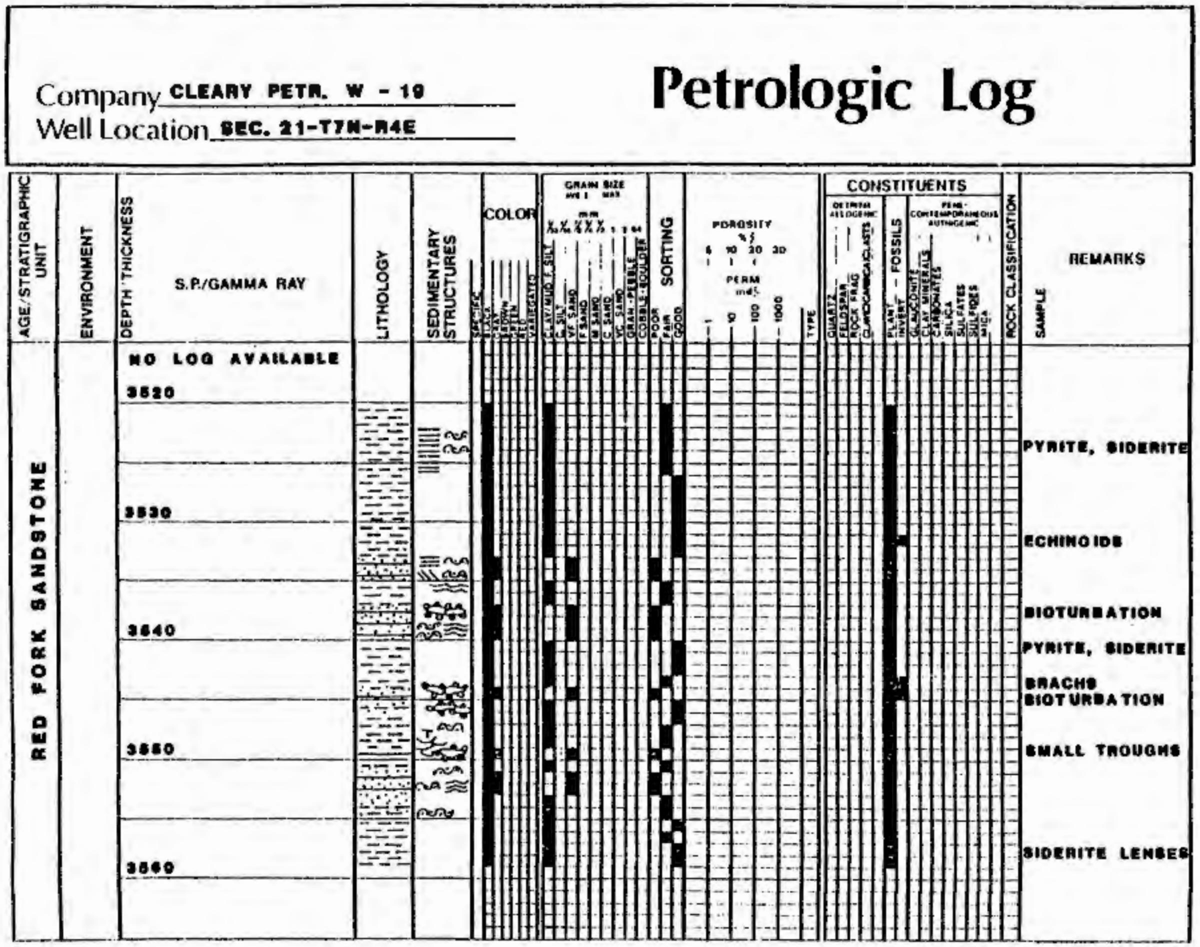


Figure 33. Description of Core from Cleary Petroleum, W-19

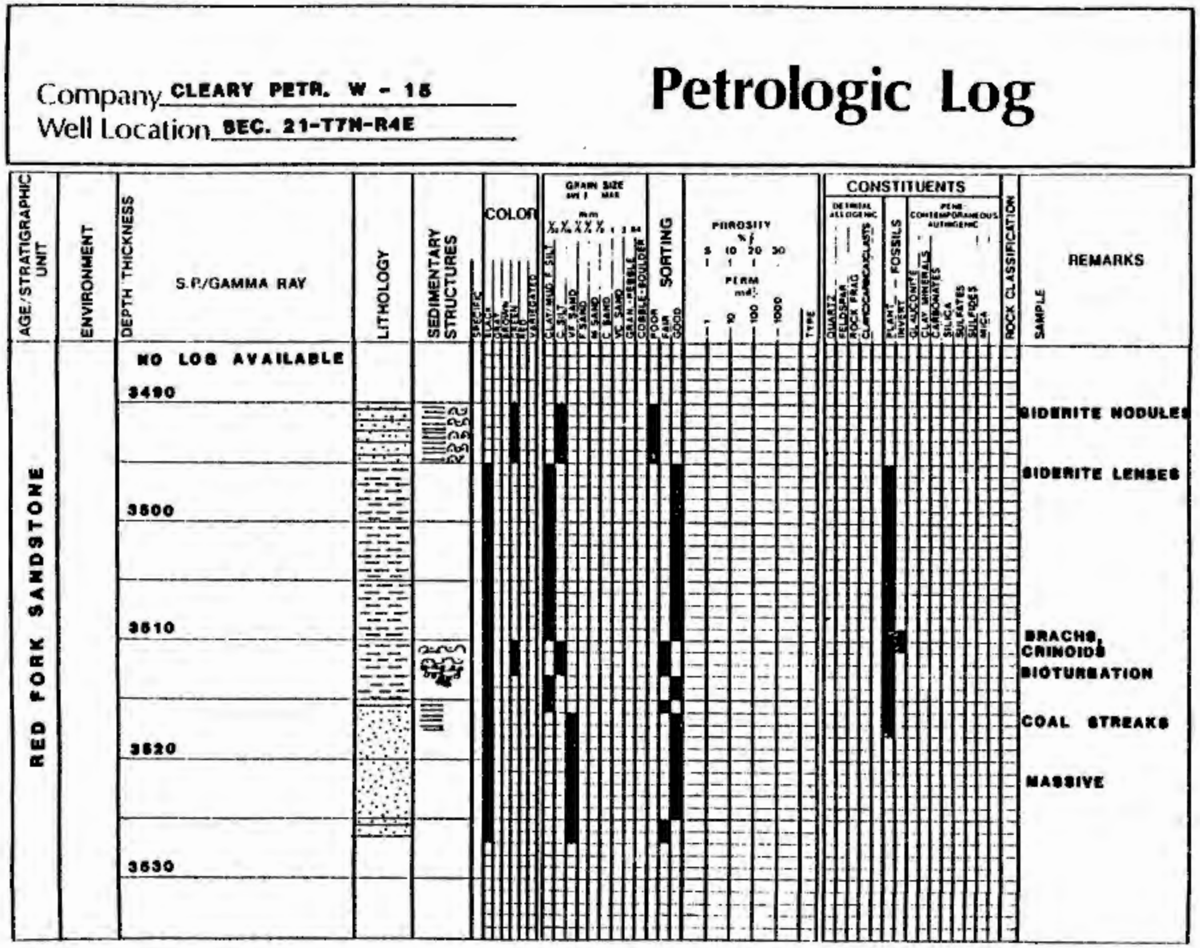


Figure 34. Description of Core from Cleary Petroleum, W-15

The core (Figure 35) contains very fine grained sandstone, siltstone, and black shale. The lower 14 feet (3445 to 3459 feet) is black shale that grades upward into interlaminated shale and siltstone (3445 to 3450 feet). Ripple laminae, inclined laminae, and flowage features are within the interlaminated shale and siltstone. The overlying 10 feet (3435 to 3445 feet) is very fine grained sandstone that grades upward into interlaminated siltstone and shale (3438 feet). Convoluted bedding is within the sandstone. Laminae of coal and siderite, brachiopods, bioturbated rock, and filled burrows are in the interlaminated siltstone and shale interval (3425 to 3438 feet).

Depositional Model

The consensus of opinions of several geologists who have interpreted depositional environments of Red Fork sandstone on the Central Oklahoma Platform is that the Red Fork Sandstone was deposited primarily in deltaic distributary channels and secondarily in associated paleogeomorphic terrain (see section on Previous Investigations). In the absence of strong evidence to the contrary, the conclusion seems highly probable that Red Fork sandstone in the study area was deposited in distributary channels and as associated facies on a delta plain.

Numerous publications outline the distinguishing characteristics of deltaic distributary channels and their related facies on delta plains. The publications reviewed

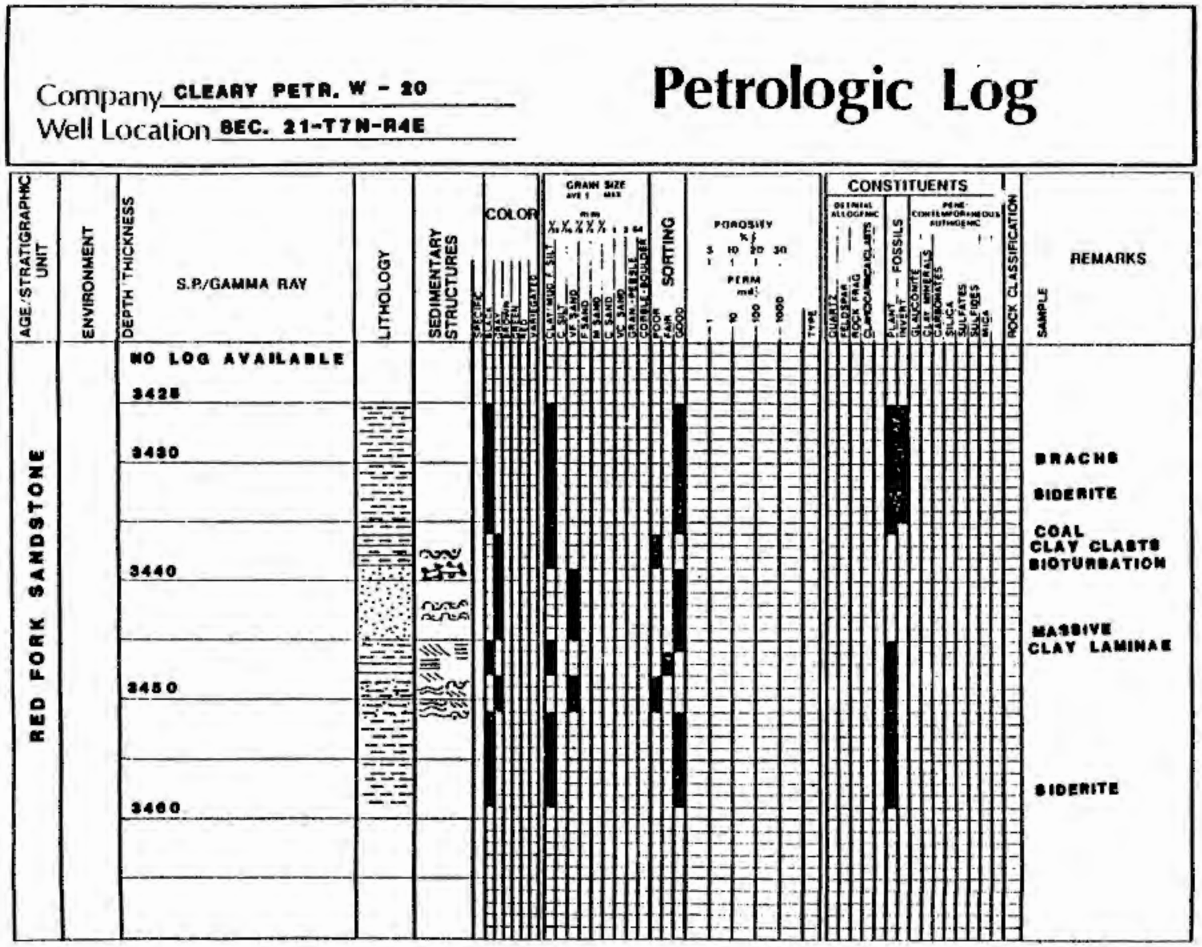


Figure 35. Description of Core from Cleary Petroleum, W-20

by the author, which provide frameworks for the interpretation of facies are Fisher and Brown (1972); Horne, Ferm, Caruccio, and Baganz (1978); Brown (1979); and Coleman and Prior (1982).

Basic Evidence from Analysis of Cores

As previously mentioned, inferences about internal features of the Red Fork Sandstone are based upon the detailed examination of 13 cores from within the study area. A general, vertical sequence of sedimentary structures (from bases to tops of individual sandstone bodies) observed in cores located in major sandstone trends are channel lag, massive bedding, horizontal laminations, medium-scale planar cross-bedding, inclined laminations, small-scale trough cross-bedding, ripple laminations, interstratified sandstone, siltstone, and shale, convoluted bedding, water-escape features, laminae of coal, bioturbated rock, and filled burrows. Sedimentary structures characteristic of cores located between and on the edges of major sandstone trends are horizontal laminations, ripple laminations, convolute bedding, small-scale trough cross-bedding, microfaults, bioturbated rocks, and burrows within interbedded sandstones, siltstones, and shales. Laminae of siderite, nodules of pyrite, rootlets, bioturbated rock, burrows, fossil fragments, and coal are within black shale.

The Red Fork sandstone is very fine to fine grained, moderately to well sorted, subrounded, submature to mature, sublitharenite to litharenite. Detrital grains of Red Fork sandstone mostly are quartz, feldspars, and metamorphic-rock fragments (Chaper VI).

Basic Evidence from Cross Sections and Log-signature Map

The following features are observable in the 13 cross sections (Plates II-XIV) and from the log-signature map (Plate XVI):

1. The Red Fork Sandstone is discontinuous laterally across the study area.

2. The major sandstone trends are composed of lenticular sandstone bodies in cross sections with sharp basal and lateral contacts. Upper contacts are sharp or gradational. Major Red Fork sandstone bodies are characterized by blocky or bell-shaped log patterns (SP curve and short-normal or lateralog curves).

3. In areas between major trends or near the boundaries of major trends, bodies of sandstone have sharp basal contacts and gradational lateral and upper contacts. These sandstone bodies are characterized by serrated or otherwise poorly developed log patterns.

4. Thickness of sandstone increases toward the central parts of the major sandstone trends, where the sandstone is multistoried.

5. Removal of the Inola Limestone by channeling is recorded in several wells.

6. In detail, the Red Fork is consistent neither in thickness nor in stratigraphic position.

Basic Evidence from Net-sandstone Isolith Map

In the study area, the Net-sandstone Isolith Map of the Red Fork Sandstone (Plate XV) illustrates the following features:

1. The Red Fork Sandstone has a bifurcating and anastomosing pattern.

2. Major sandstone trends switch from general north-south orientation (T.9N.-T.11N., R.3E.-R.6E.) to general northwest-southeast orientation (T.6N.-T.8N., R.3E.-R.6E.).

3. Widths of these sandstone trends range from one-half mile to 5 miles.

4. The Red Fork Sandstone is as thick as 155 feet in terms of net sandstone.

Interpretation of Depositional Environments[2]

On the basis of evidence previously discussed, a set of inferences about the depositional environments of the Red Fork Sandstone should involve one or more of the

[2]The following discussion is based on a primary assumption that data recorded from the study area are representative of the true nature of the Red Fork Sandstone in the study area. Also, the fact is acknowledged that 13 cores must be regarded as a very small sample of the Red Fork sandstone and that lithic features critical to correct interpretation of the Red Fork may be absent from the rock inspected in the study area.

following: (1) alluvial channels and alluvial plain, (2) deltaic distributary channels and delta plain, and (3) distributary mouth bars.

Basically two kinds of river channels have been recognized on alluvial plains (Selley, 1978): Low-sinuosity braided channel complexes and high-sinuosity meandering channels.

If the Red Fork had been deposited in a braided-channel environment, then the following lithic features should have been observed:

1. Sheet-like, thick, laterally extensive, geometry (Selley, 1978).

2. Sandstone consisting of conglomerates, coarse sand, with minor amounts of fine sands and silt (Selley, 1978).

3. No glauconite or carbonaceous organic matter, due to the oxidizing environment (Selley, 1978).

4. Red coloration of sandstone due to ferric oxide (Selley, 1978).

5. Characteristic double erosion surfaces above and below shale units (Selley, 1978).

6. No fossils due to the oxidizing nature of the depositional environment (Selley, 1978).

These lithic features were not observed in the study area and none have been recorded nearby. Therefore, the inference that deposition of the Red Fork Sandstone occurred in a braided channel environment is regarded as being an improbable explanation, and therefore is rejected.

If deposition of the Red Fork Sandstone had occurred in a meandering-channel environment, then the following features should have been observed:

1. A general upward-fining grain-size sequence. Extraformational pebbles, intraformational mud pellets, fragmented bones, and waterlogged drift wood near a sharp base. From base to top: massive bedding, planar bedding, trough cross-bedding, micro-cross laminations, and planar bedding that grade into siltstones (Selley, 1978).

2. Red coloration and nodular carbonate caliches (if deposits were alluvial and from semiarid regions) (Selley, 1978).

3. No marine fossils (Selley, 1978).

On the basis of an argument similar to the one above, the inference that deposition of the Red Fork Sandstone occurred in a meandering channel environment is rejected as being highly improbable, because these characteristic features were not recorded.

If deposition of the Red Fork Sandstone had occurred in distributary mouth bars, then such characteristic features as a coarsening upward of grain size, transitional boundaries, slump features, intrusion of mudlumps into the sandstone, and upstream narrowing and thinning of sandstone bodies should have been recorded (Fisk, 1961). No such evidence was observed in the study area. Therefore, the inference that deposition of the Red Fork Sandstone in the study area occurred in distributary mouth bars is rejected.

If deposition of the Red Fork Sandstone had occurred in a deltaic distributary channel environment, then the following characteristic features (Figure 36) should have been observed:

1. Fine to medium grained sandstones, moderately well sorted, with mud clasts and fragments of wood (Fisher and Brown, 1972).

2. Sandstone bodies with almost uniform grain size throughout the vertical section (Brown, 1979).

3. Common trough cross-bedding, tabular cross-bedding, and ripple laminae (Fisher and Brown, 1972).

4. Distinctive box-like log patterns (Brown, 1979) (Figure 37).

5. Sandstone bodies that are narrow and that show bifurcating and anastomosing patterns (Brown, 1979).

6. Channel-fill sands that are elongate and symmetrical with convex-downward bases and "flat" top (Fisher and Brown, 1972).

7. Sandstone units that are as thick as 300 feet and as wide as 4 to 5 miles (Fisher and Brown, 1972).

8. Common multistoried sandstone bodies, due to differential compaction and subsidence (Fisher and Brown, 1972).

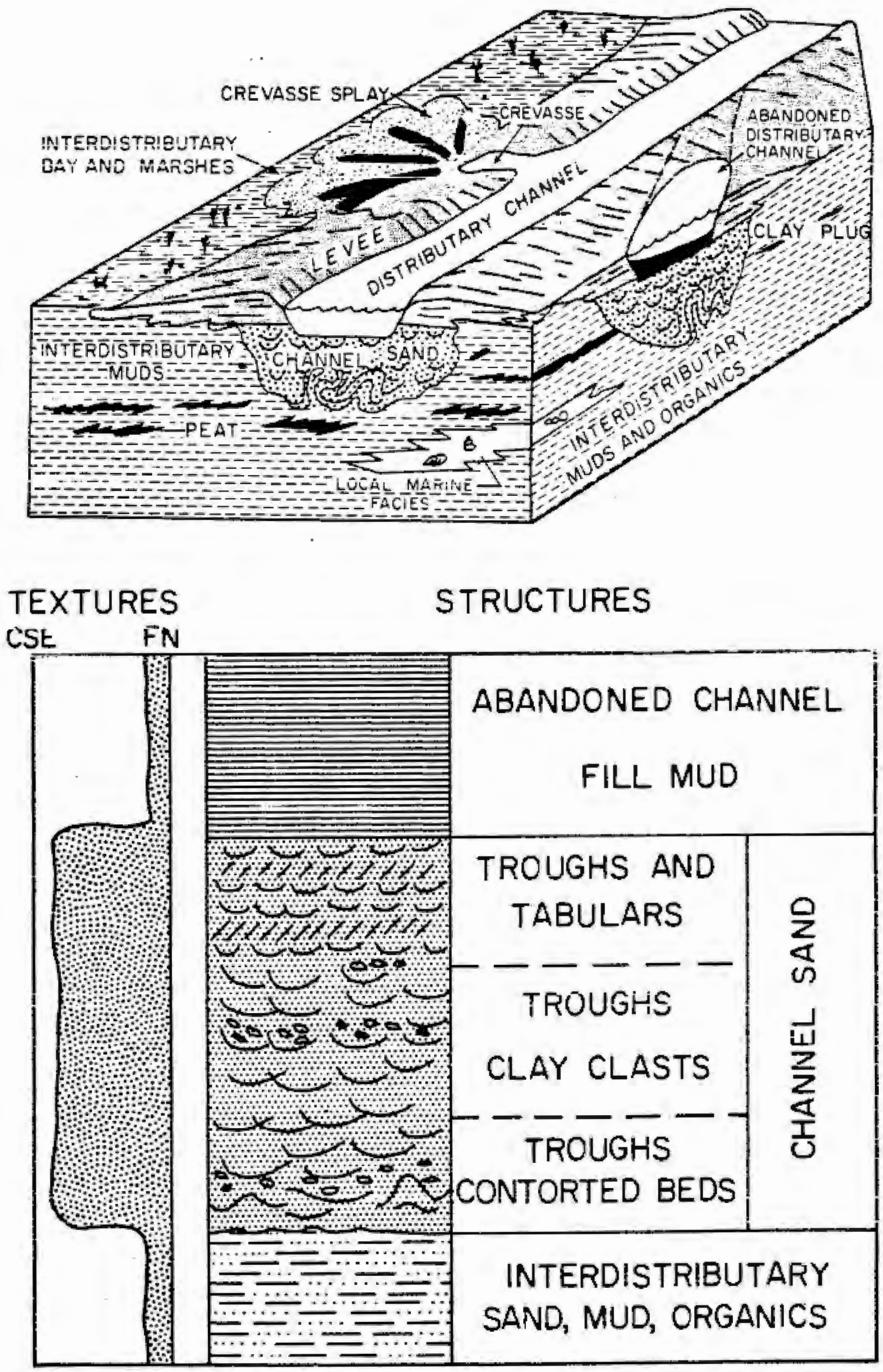


Figure 36. Deltaic Distributary Channel Model (After Brown, 1979, Fig. 16)

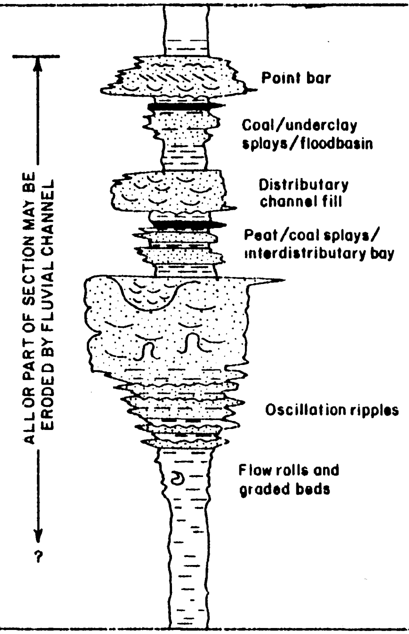
ENVIRONMENTS/FACIES				IDEALIZED LOG PATTERN AND LITHOLOGY	DEPOSITIONAL PHASES		DESCRIPTION
DELTA SYSTEM	SUBAERIAL	UPPER DELTA PLAIN; MID- AND LOWER DELTA PLAIN	POINT BAR; DISTRIBUTARY CHANNEL-FILL; CREVASSE SPLAYS; FLOODBASIN/ INTERDISTRIBUTARY BAY; MARSH/ SWAMP PEAT		DELTA CONSTRUCTION	SUBAERIAL AGGRADATION	Point-bar sandstone: fining upward from conglomerate lag to silty levees, upward change from large trough-filled crossbeds to tabular crossbeds and uppermost ripple crossbeds. Distributary channel-fill sandstone: fine- to medium-grained, trough-filled crossbeds, local clay, clast conglomerate, abundant fossil wood. Crevasse splay sandstone: coarsening upward, trough and ripple crossbeds, commonly burrowed at top. Floodbasin/interdistributary mudstone: burrowed, marine fossils, grade updip to non-marine, silty near splays. Coal/peat: rooted, overlie underclay (soil).
	SUBMARINE	DELTA FRONT	BAR CREST			PROGRADATION	Well-sorted, fine- to medium-grained sandstone, plane beds (high flow regime) common, channel erosion increases updip, distal channel fill plane-bedded, some contemporaneous tensional faults.
			CHANNEL-MOUTH BAR				Fine- to medium-grained sandstone, trough-filled crossbeds common, commonly contorted bedding, local shale or sand diapirs in elongate deltas.
			DELTA FRINGE				Fine-grained sandstone and interbedded siltstone and shale, well-bedded, transport ripples, oscillation ripples at top of beds, growth faults in lobate deltas, some sole marks and contorted beds at base.
		PRODELTA	PROXIMAL				Silty shale and sandstone, graded beds, flow rolls, slump structures common, concentrated plant debris.
			DISTAL				Laminated shale and siltstone, plant debris, ferruginous nodules, generally unfossiliferous near channel mouth, grades downdip into marine shale/limestone, grades along strike into embayment mudstones

Figure 37. Idealized Log Patterns of Pennsylvanian Deltaic Sandstone Facies of the Midcontinent (After Brown, 1979, Fig. 12)

9. Well-developed levees, crevasse splays, and inter-distributary bays as associated facies (Fisher and Brown, 1972).

As discussed above, such evidence is well shown in the study area and is described from bordering regions (see section on Previous Investigations). No basis is judged to exist that requires rejection of this explanation. Therefore, the depositional environment that comes closest to accounting for the facts of lithology and the stratigraphic sequence of the Red Fork Sandstone in the study area is the deltaic distributary environment. I regard this setting to be highly probable as the basic depositional environment.

Assuming that the depositional framework described above is correct for all practical purposes, facies of the Red Fork Sandstone can be interpreted in the following manner:

Based on evidence described above, it is highly probable that cores located within major Red Fork Sandstone trends (i.e., Kurtz 32-2A, Irons 32-2, Saunders 29-1, Garret No. 1, Brown No. 1, and Foreman No. 1) were deposited in deltaic distributary channels.

Characteristic features observed within interdistributary bay fill sequences (Figure 38) are:

1. Thick coarsening-upward sequences of shale and siltstone (Horne et al., 1978).

2. Dark-gray to black shales, dominant in the lower part of the sequence (Horne et al., 1978).

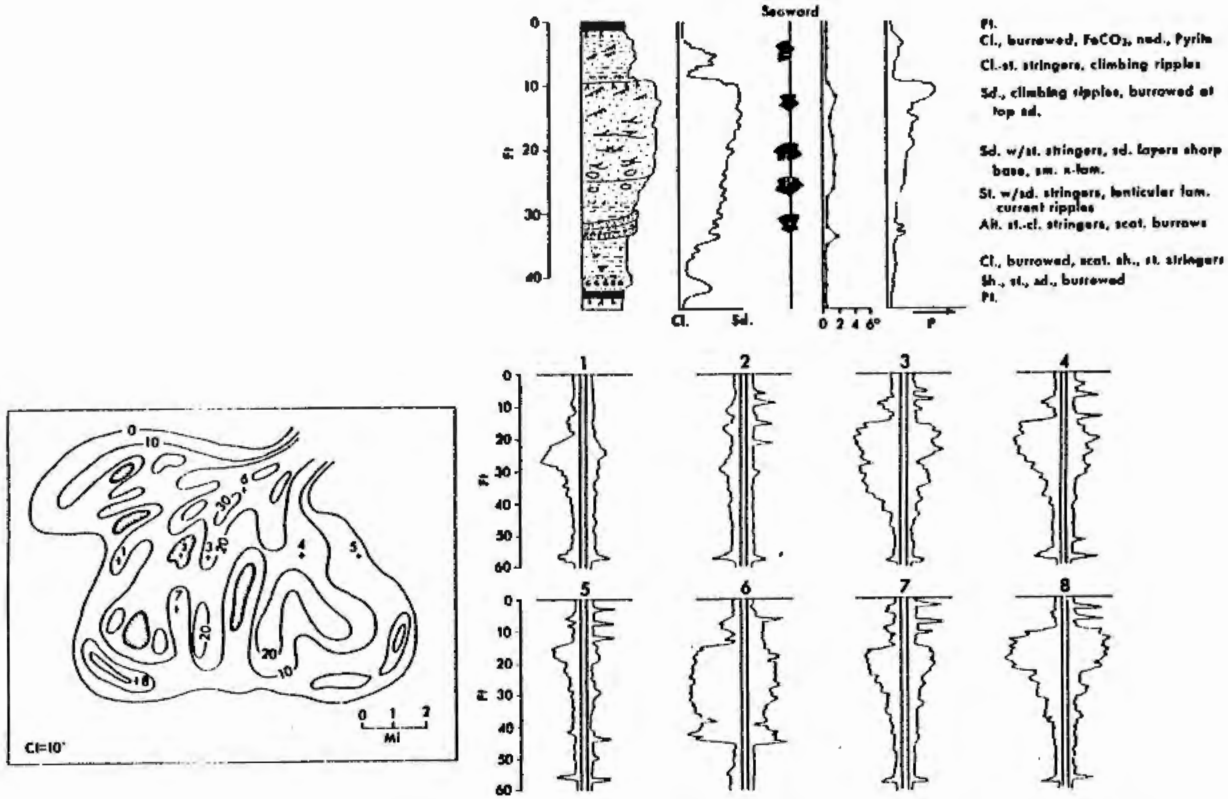


Figure 38. Major Characteristics of Interdistributary Bay-fill Deposits (After Coleman, J. M., and D. B. Prior, 1982, Fig. 9)

3. Sandstones with ripple laminae and other current-related structures in the upper part of the sequence (Horne et al., 1978).

4. Coals, where bays filled to form a surface upon which plants could take root (Horne et al., 1978).

5. Persistent bands or concretions of chemically precipitated siderite, commonly along bedding surfaces (Horne et al., 1978).

6. Common marine and/or brackish-water fossils and burrow structures (Horne et al., 1978).

7. Crevasse splays, which introduced sandstone into the interdistributary bay, as an associated sub-facies (Horne et al., 1978).

Characteristic features of interdistributary bay sequences are observed within cores located between and near the edges of major Red Fork Sandstone trends. Therefore, it seems highly probable that these cores (i.e., Harrell A28-1A, Cunze, Waterflood P-44, W-14, W-19, W-15, W-20) were deposited in an interdistributary bay environment on the delta plain.

Delta Model

Donaldson, Martin, and Kanes (1970) studied the Holocene Guadalupe delta, a small bayhead delta prograding into the shallow water of San Antonio Bay of the Texas Gulf Coast. Certain similarities between the Red Fork delta system in the study area and the Holocene Guadalupe delta have been noted. Important similarities include: (1) deltaic progradation onto a stable, slowly subsiding platform; (2) digitate sand distribution; (3) subordination or complete absence of prodelta muds; and (4) erosion of underlying beds unrelated to the active delta by distributary channels (i.e., Red Fork delta--erosion of Inola Limestone). These features result in progradational facies that are thin with aggradational facies of the distributary channel system predominate, as noted in the study area. Therefore, a large-scale bayhead delta model is suggested as a delta model for the Red Fork in the study area.

Source of the Red Fork Sandstone

As mentioned in previous investigations, Cole (1969) and Dogan (1969) suggested source areas of the Red Fork Sandstone from the north, west, and south. In this study, cross-sections E-E' (Plate VI) and G-G' (Plate VIII) illustrate the Red Fork Sandstone interval pinching out in the extreme southeastern part of the study area (T.6N., R.3E.). The Red Fork Sandstone trends observed in the net-sandstone isolith map (Plate XV) illustrate a north to south orientation, which suggests a predominantly northern source for the Red Fork Sandstone. Based on sandstone trends illustrated by the net-sandstone isolith map, and thinning of the Red Fork Sandstone interval to the south illustrated by stratigraphic cross sections, it seems highly probable that the deltaic distributary channels in which the Red Fork Sandstone was deposited had a source to the north of the study area.

CHAPTER VI

PETROLOGY

Methodology

Determination of the qualitative and quantitative mineralogy of the Red Fork Sandstone was accomplished by:

1. Thin section analysis of 65 selected samples.

2. X-ray diffraction of the less than 2 micron fraction (clays) of 32 selected samples.

3. Scanning electron microscopy of 3 selected samples.

Thin section analysis provided the means for a quantitative mineralogic determination. More than 300 points were counted for each thin section. The amount of each mineral observed was then averaged.

X-ray diffraction of the less than 2 micron fraction gives a semi-quantitative determination of the clay minerals present (Figure 39).

Areas under X-ray diffraction peaks corresponding with 100 percent intensity peaks for each clay mineral were calculated using an Apple computer. These areas were used in

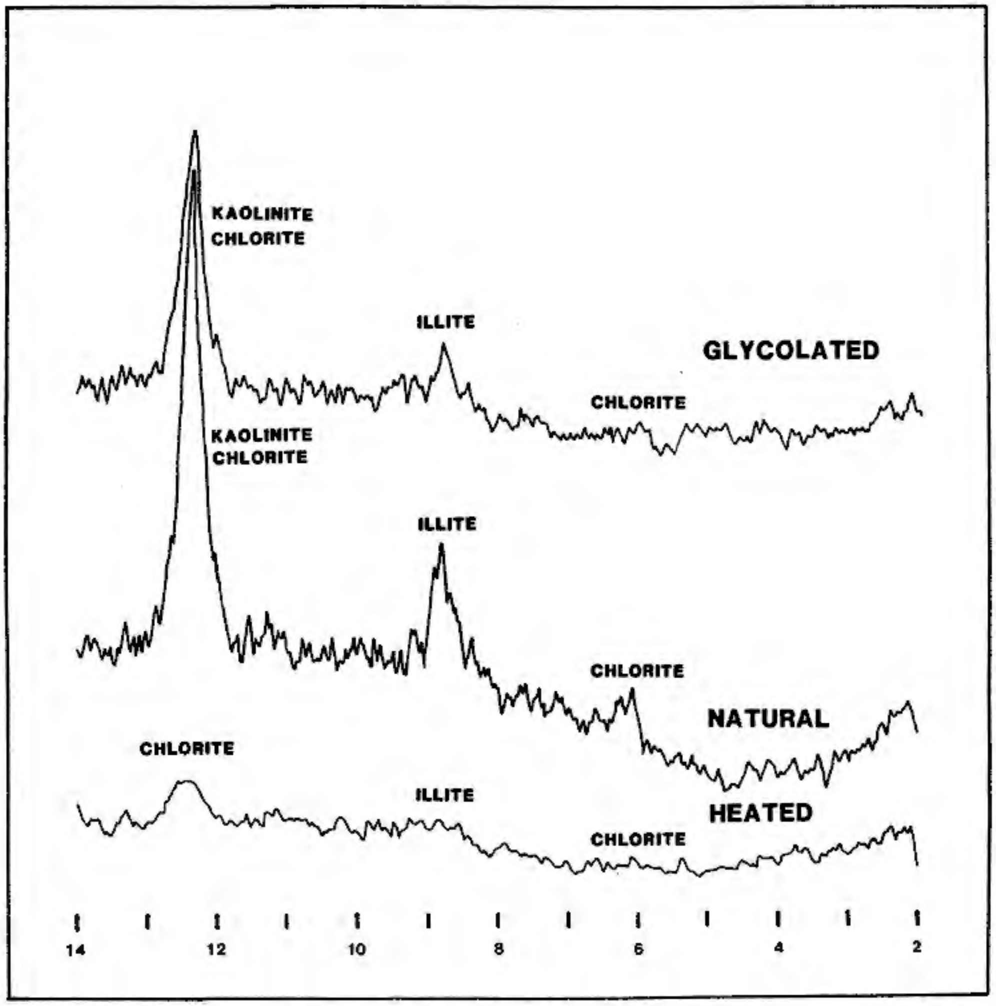


Figure 39. Characteristic X-ray Diffraction Peaks Illustrating Clay Minerals in the Red Fork Sandstone

calculations to determine the relative percentages[3] of clay minerals in each sample. The following equations were used in order to calculate the percentages:

1. Three clay minerals present:

$$I_i(.29) + I_{ch}(.55) + I_k(.15) = cI_{Total}$$

2. Two clay minerals present (i.e., kaolinite and illite):

$$I_i(.29) + I_k(.15) = cI_{Total}$$

I_i = area under illite curve

I_{ch} = area under chlorite curve

I_k = area under kaolinite curve

cI_{Total} = total area

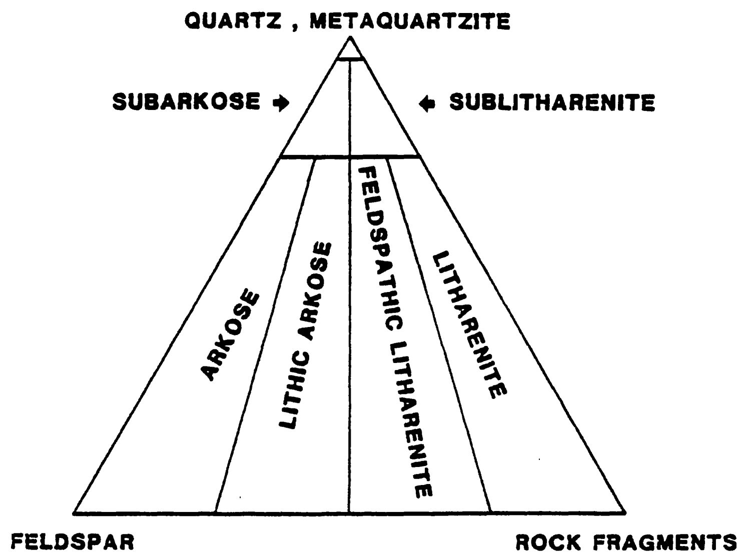
(.29), (.55), and (.15) = absorption coefficients of the respective clays

(Personal communication, Al-Shaieb, 1983)

Classification

In the study area, the Red Fork Sandstone is classified as a very fine to fine grained, moderately to well sorted, subrounded, submature to mature, sublitharenite to litharenite (Figures 40, 41 and 42) (Table I).

[3]The term "relative percentage" of a certain type of clay--for example, illite--means simply the fractional part that illite composes of 100% clay.



ANDOVER OIL COMPANY
SAUNDERS 29-1
NW SW SE SEC. 29-T10N-R3E

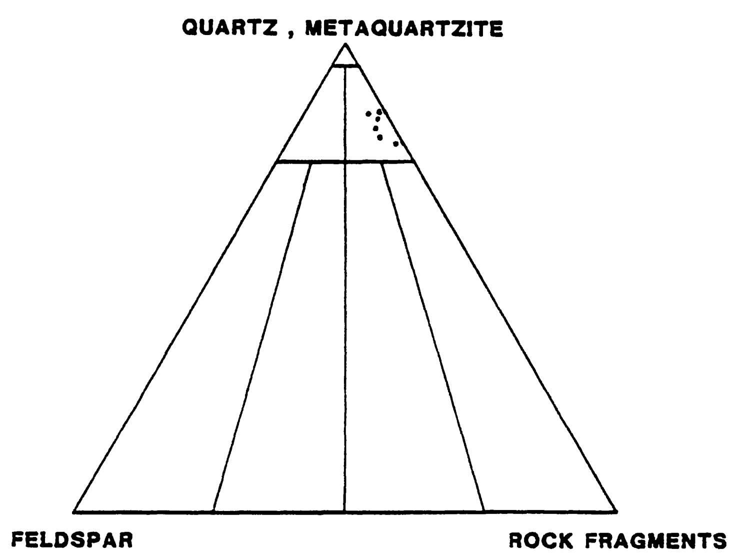
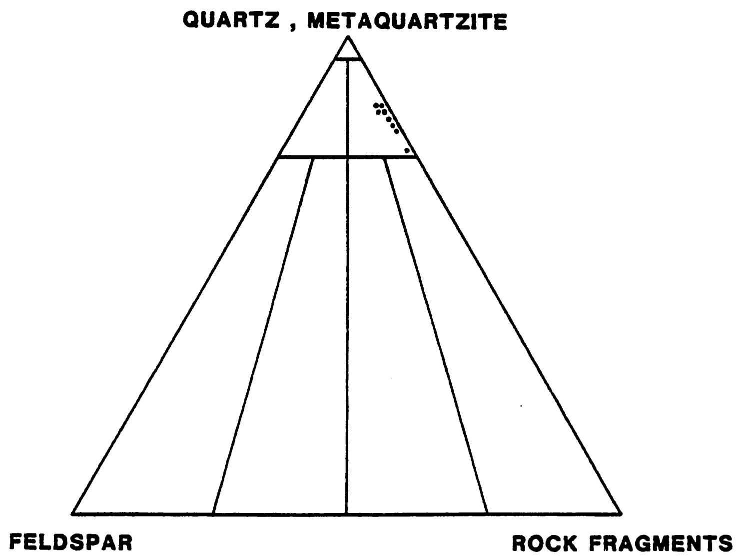


Figure 40. Classification of Red Fork Sandstone

ANDOVER OIL COMPANY
IRONS 32-2
NW SE SW SEC. 32-T10N-R3E



ANDOVER OIL COMPANY
KURTZ 32-2A
W SE NE NW SEC. 32-T10N-R3E

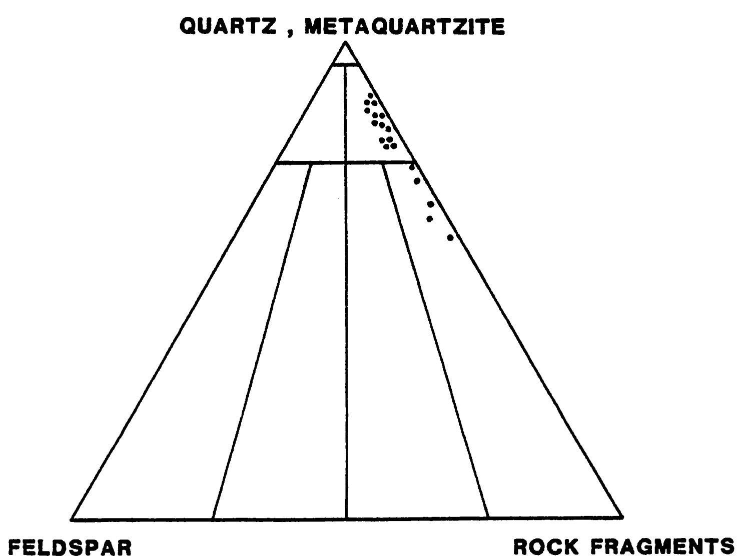
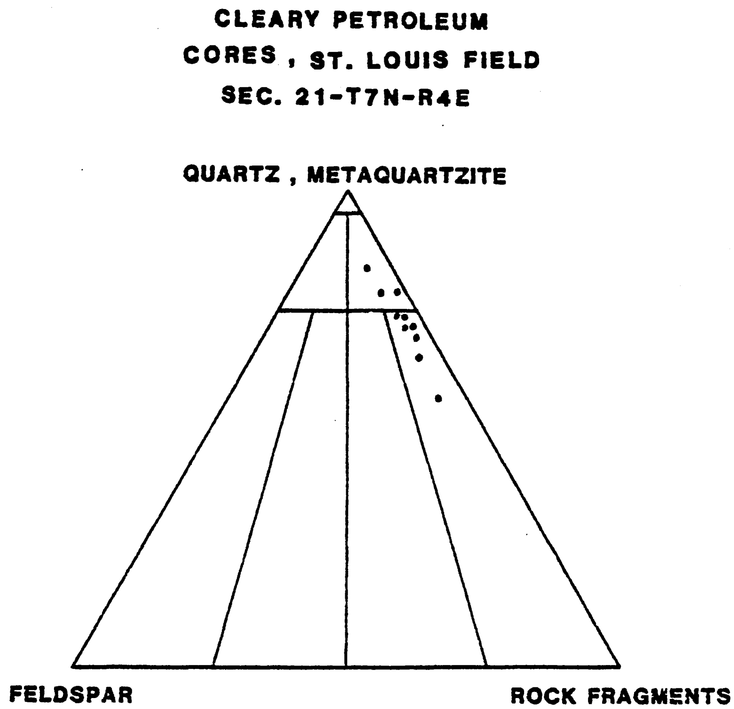


Figure 41. Classification of Red Fork Sandstone



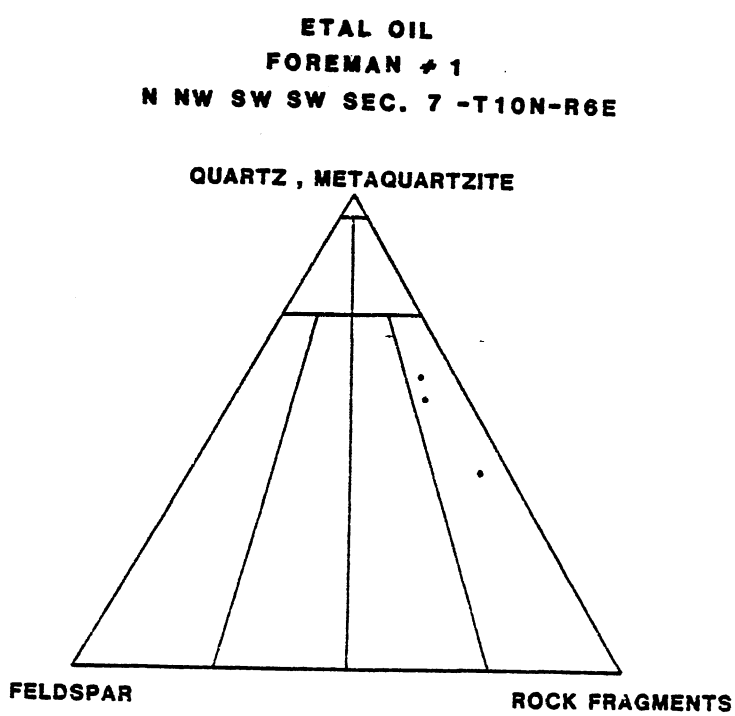


Figure 42. Classification of Red Fork Sandstone

TABLE I

MINERALOGIC COMPOSITION OF THE RED FORK SANDSTONE

Detrital Constituents	Percentage Average	Percentage Range
Quartz	52 (62)	36 to 64
Feldspar	2 (2)	1 to 5
Metamorphic Rock Fragments	11 (13)	4 to 20
Shale Fragments	1 (1)	2 to 3
Chert	1 (1)	1 to 2
Muscovite	1 (1)	1 to 3
Zircon	Trace	
Rutile	Trace	
Chlorite	Trace	
Glauconite	Trace	
Organic Matter	Trace	
Detrital Matrix	2 (2)	2 to 3
Diagenetic Constituents		
Quartz Overgrowths	2 (2)	1 to 4
Dolomite	4 (5)	0 to 10
Calcite	1 (1)	1 to 2
Siderite	Trace	
Kaolinite	3 (4)	3 to 4
Illite	2 (2)	1 to 3
Chlorite	1 (1)	Trace to 1

Note: Bulk rock includes average porosity of 16%. Therefore, sum of constituents equals 84%. Numbers in parenthesis are percentage equivalents of rock without porosity.

Detrital Constituents

Monocrystalline quartz is the dominant framework grain in the Red Fork Sandstone (Figure 43). Quartz ranges from 36 to 64 percent and averages 52 percent in thin sections. A minor amount (1-2%) of polycrystalline quartz, appearing to have been metamorphic in origin, was observed.

Feldspars (plagioclase, microcline, and orthoclase) are not very abundant, averaging 2 percent and ranging from 1 to 5 percent in thin sections (Figures 44 and 45).

Rock fragments make up 7 to 25 percent and average 13 percent of the sample. Rock fragments include shale (2-3%) (Figure 46), chert (1-2%), and low-grade metamorphic-rock fragments (4-20%) (Figure 47).

Minor amounts of muscovite (1-3%)(Figure 48), detrital matrix (mainly illite, 2-3%), zircon (trace), rutile (trace), chlorite (trace), glauconite (trace), and organic matter (trace) were also observed in thin sections.

Texture of Detrital Constituents

The texture is typical of litharenites and sublitharenites. The rock is supported structurally by a framework of quartz, feldspar, and rock fragments (Figure 49). Four to six percent of the rock is composed of shale fragments and detrital matrix that have undergone ductile deformation, resulting in a pseudomatrix that intrudes into pore space and surrounds competent framework grains. In

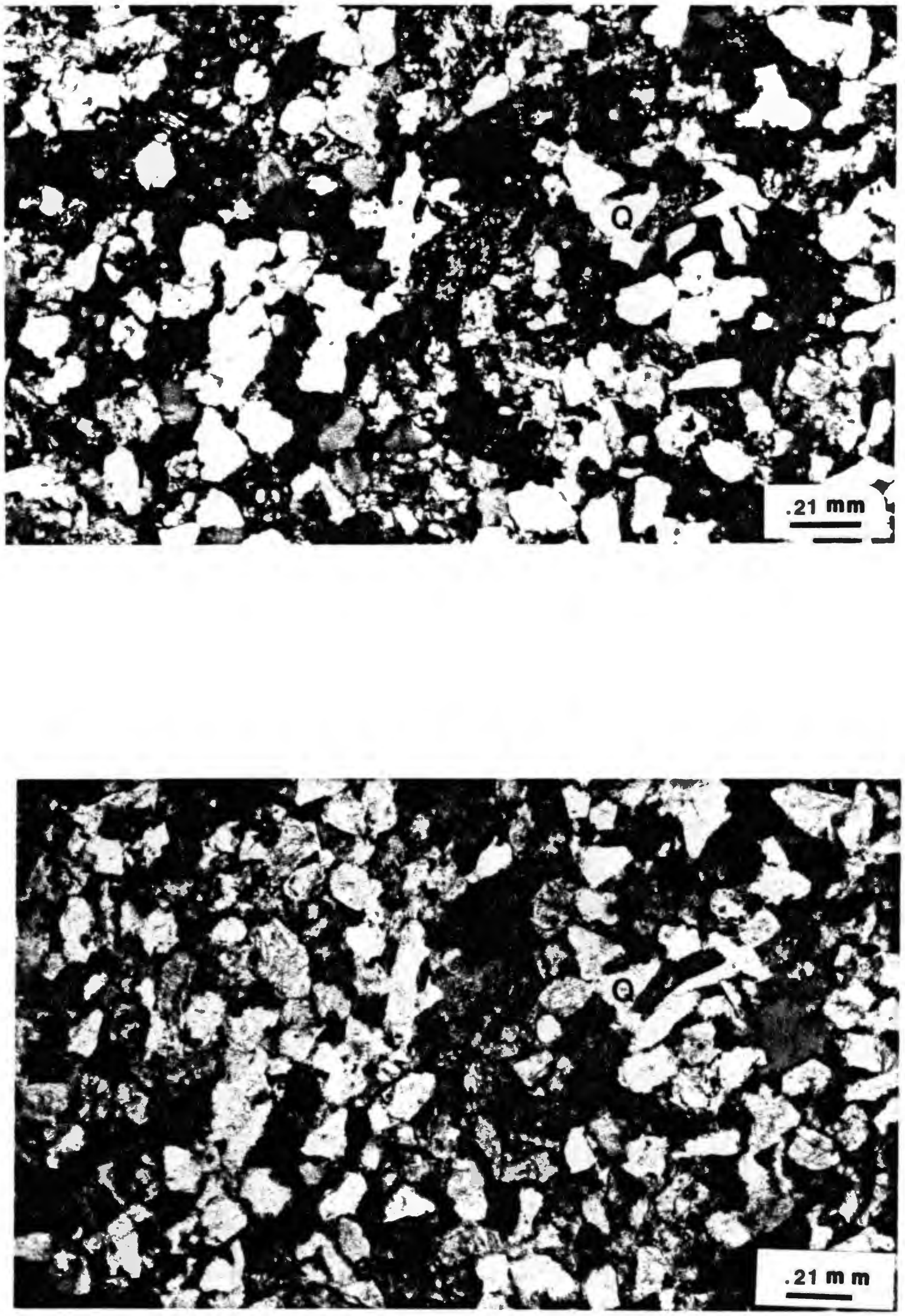


Figure 43. Photomicrograph of Monocrystalline Quartz Framework Grains (40X, XN-top, PPL-bottom)

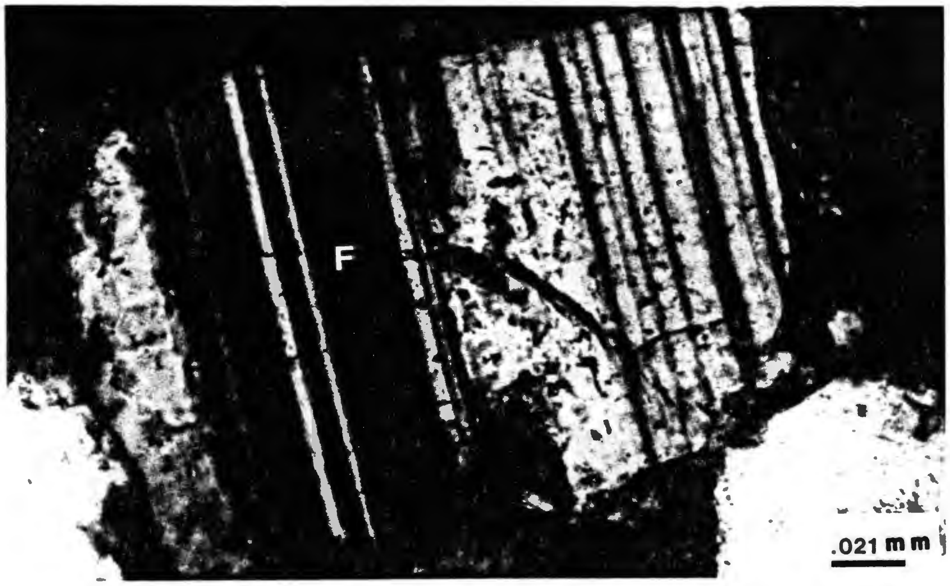


Figure 44. Photomicrograph of Plagioclase Feldspar Grain (400X, XN)

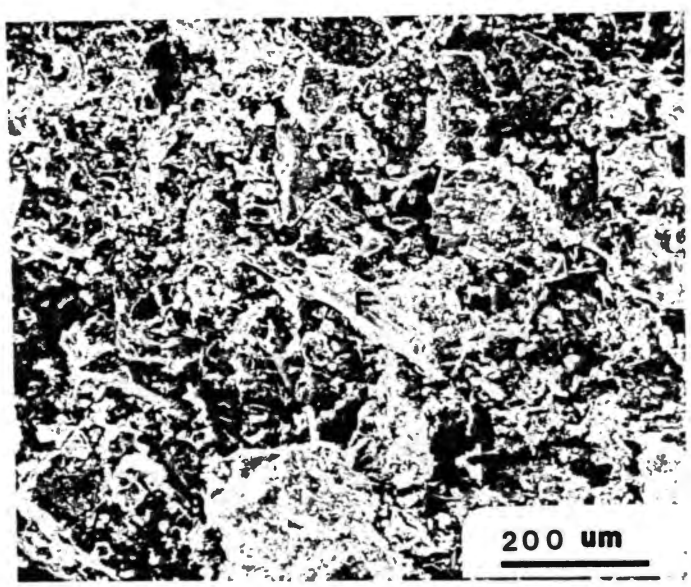


Figure 45. SEM Photomicrograph of Feldspar Grain (100X)

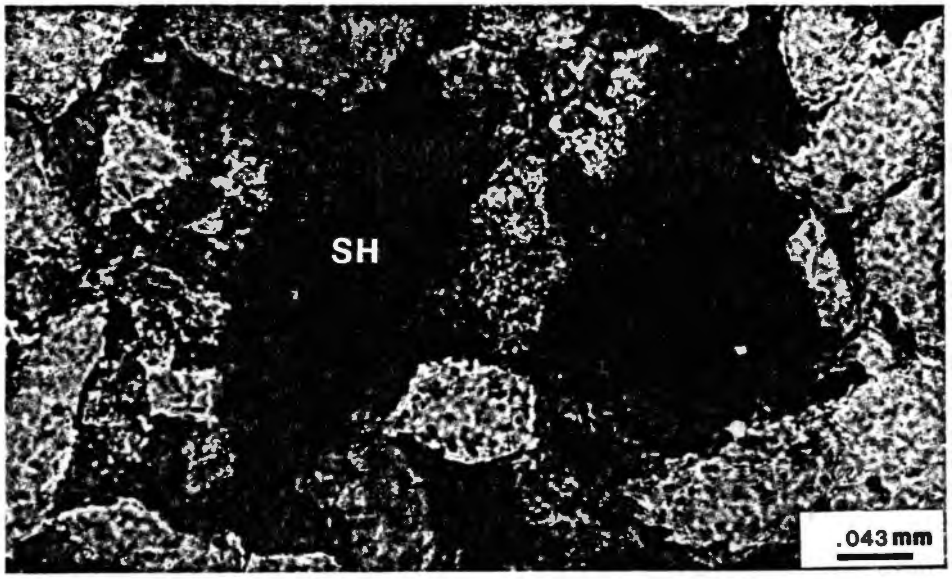


Figure 46. Photomicrograph of Shale Rock Fragments (200X, PPL)

Figure 47. Photomicrograph of Quartz, Feldspar, and Metamorphic-Rock Fragments (200X, XN)

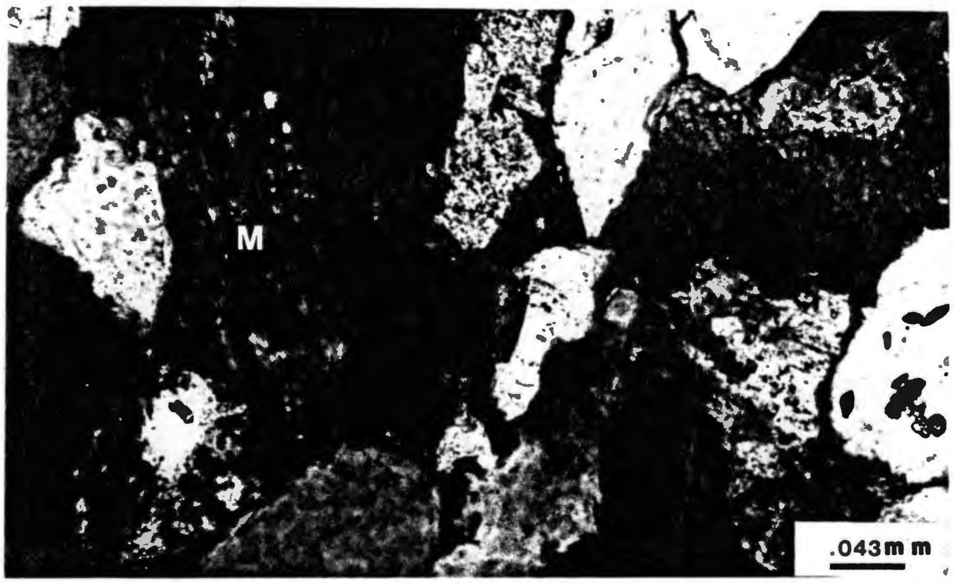


Figure 48. Photomicrograph of Muscovite
(200X, XN)

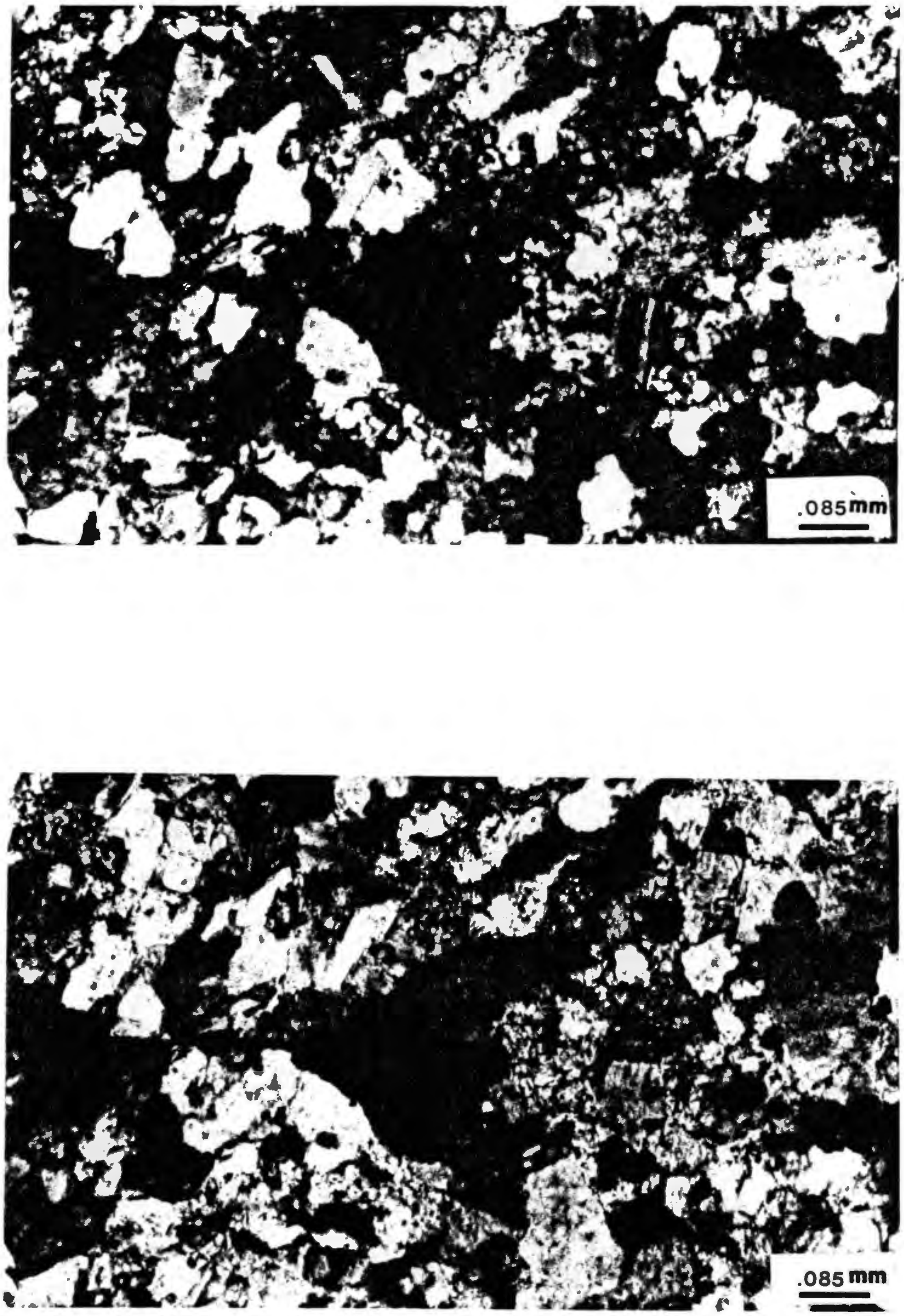


Figure 49. Photomicrograph Illustrating Quartz, Feldspar, and Rock Fragments of a Sublitharenite Facies (100X, XN-top, PPL-bottom)

addition, metamorphic-rock fragments (4-20%) also have undergone deformation.

Authigenic Constituents

In the Red Fork Sandstone, authigenic minerals average 8 to 15 percent in thin sections. Four to twelve percent consist of authigenic cements such as quartz, dolomite, calcite, and siderite, whereas authigenic clays (kaolinite, illite, chlorite) make up 4 to 7 percent. Hematite, pyrite, and leucoxene are contained in minor amounts (trace).

Authigenic Cements

Carbonate cement (dolomite and calcite) is present in the Red Fork Sandstone as a mosaic of interlocking (poikilotopic) cement that fills pore space and replaces quartz, feldspars, and rock fragments (Figure 50). Carbonate cement ranges from 0 to 10 percent and averages 4 percent in thin sections. Dolomite, with undulose extinction, is the most abundant carbonate cement. Minor amounts of calcite cement (1-2%) with straight extinctions are seen in certain thin sections. Traces of siderite are also evident. Authigenic quartz, ranging from 1 to 4 percent and averaging 2 percent of the rock, is present as secondary overgrowths precipitated in optical continuity with detrital quartz grains (Figures 51 and 52).

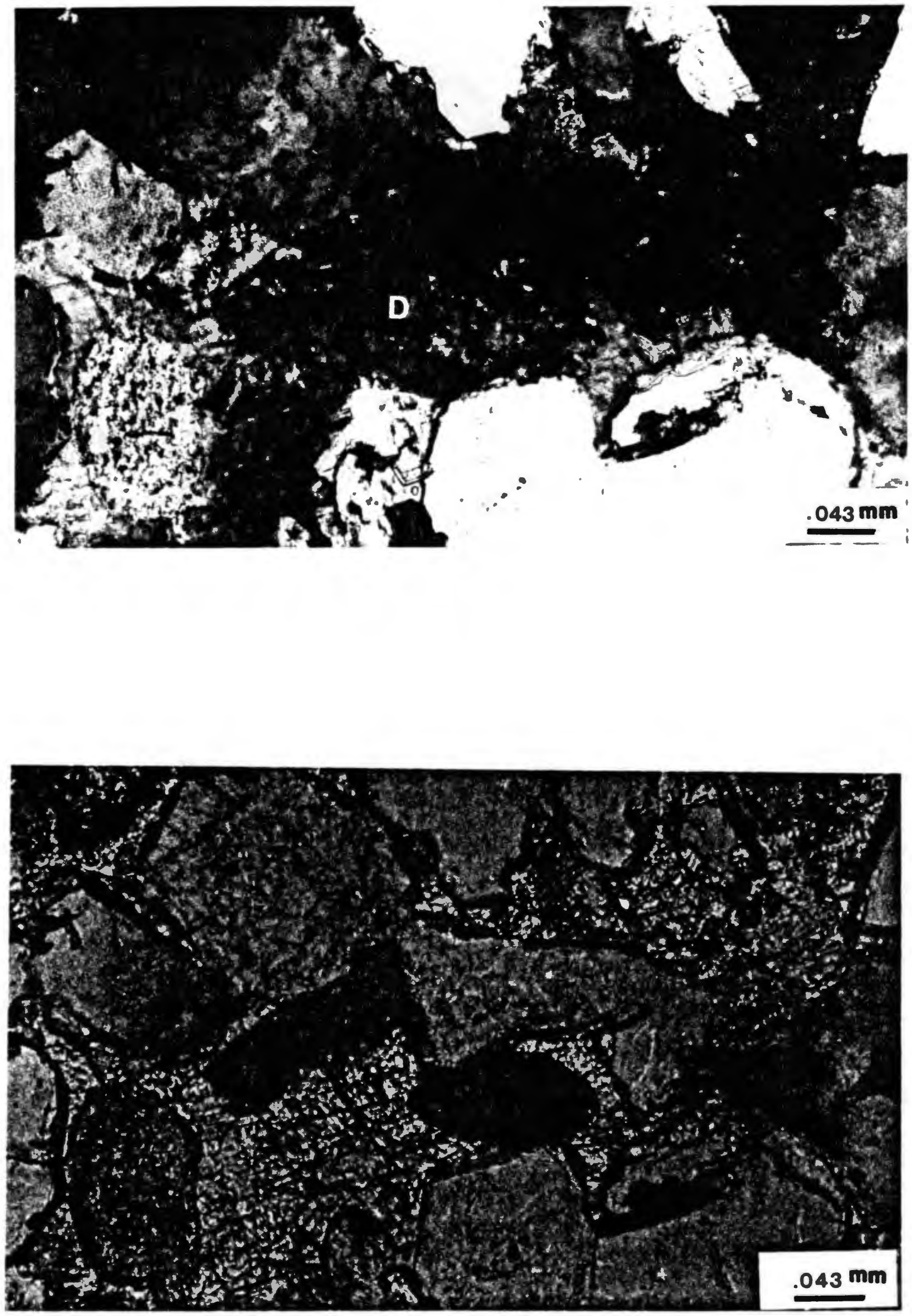


Figure 50. Photomicrograph of Dolomite Cement (200X, XN-top, PPL-bottom)

Figure 51. Photomicrograph of Detrital Quartz Grains with Syntaxial Quartz Overgrowths (400X, XN)

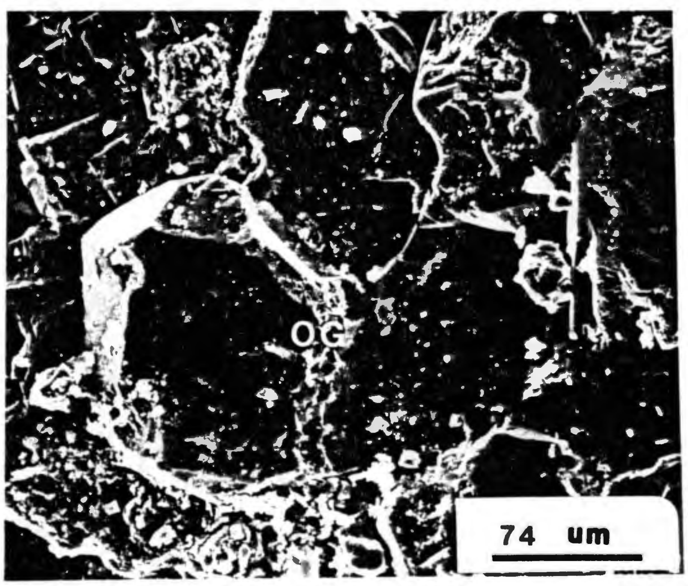


Figure 52. SEM Photomicrograph of Quartz Overgrowths (270X)

Authigenic Clays

Authigenic clays range from 4 to 7 percent in the samples. Kaolinite is the most abundant authigenic clay (3%) in samples of the Red Fork (Figure 53). It commonly forms booklets of pseudohexagonal crystals that generally are loose pore filling (Figures 54 and 55). Illite averages 1 to 2 percent of the rock; it was precipitated as grain coats (Figures 56 and 57). Chlorite is relatively rare, being less than 1 percent of the 6 percent average of authigenic clay present (Figure 58). Based on the X-ray diffraction peaks, the percentage of each clay type is: kaolinite 74 percent; illite, 20 percent; chlorite, 6 percent. These values include both authigenic and detrital clays.

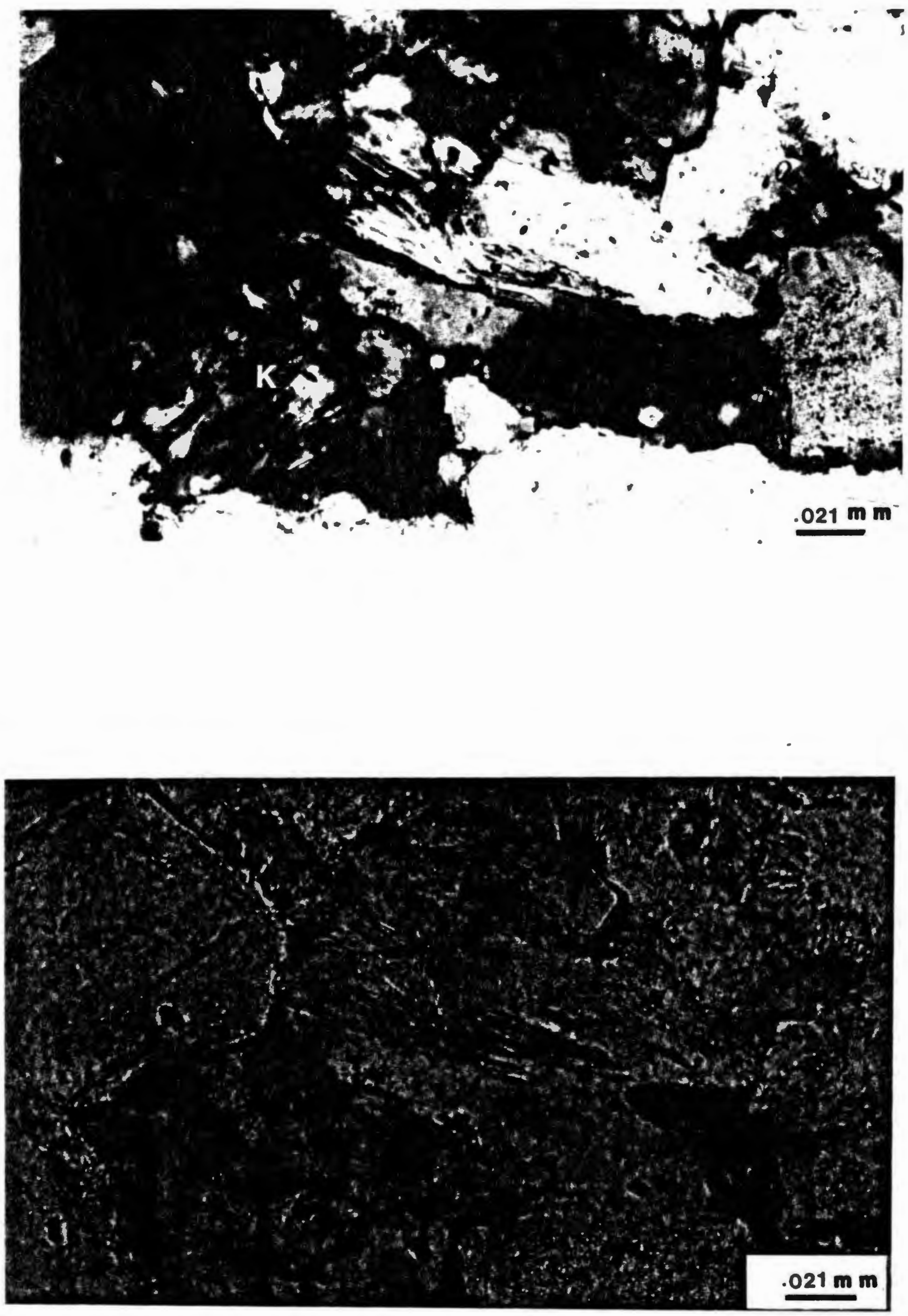


Figure 53. Photomicrograph of Kaolinite Within Pore Space (400X, XN-top, PPL-bottom)

Figure 54. SEM Photomicrograph Illustrating Kaolinite Forming Booklets of Pseudohexagonal Crystals (1000X)

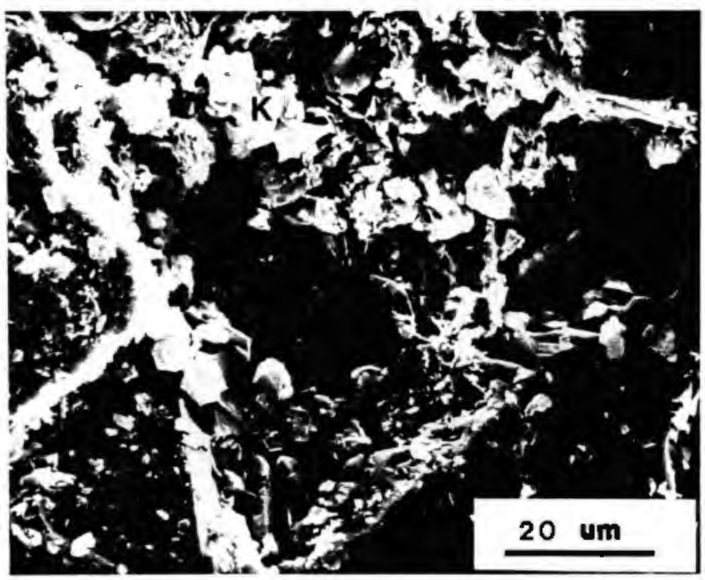


Figure 55. SEM Photomicrograph Illustrating Kaolinite Forming A Loose Pore Fill (1000X)

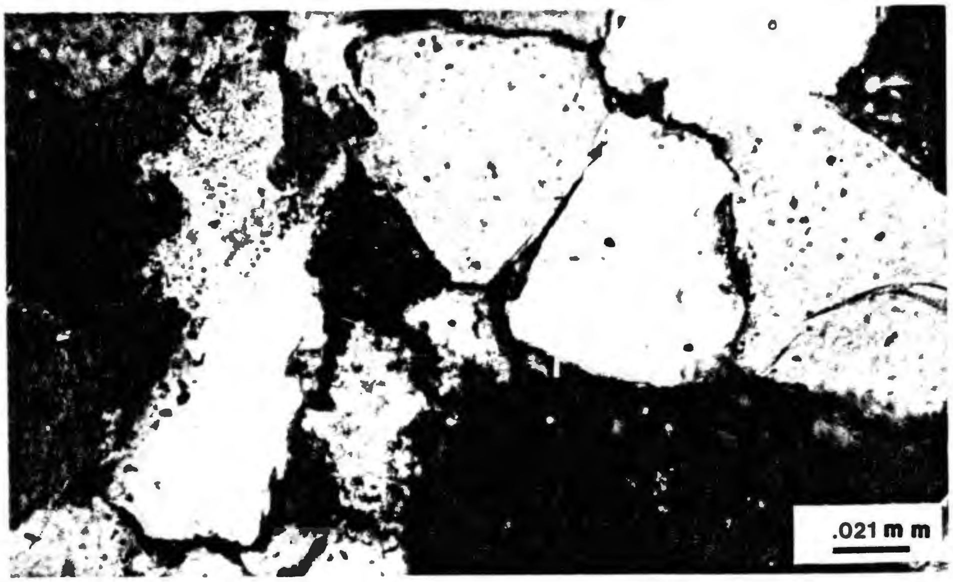


Figure 56. Photomicrograph of Illite Along Grain Boundaries (400X, XN-top, PPL-bottom)

Figure 57. SEM Photomicrograph of Illite (3000X)

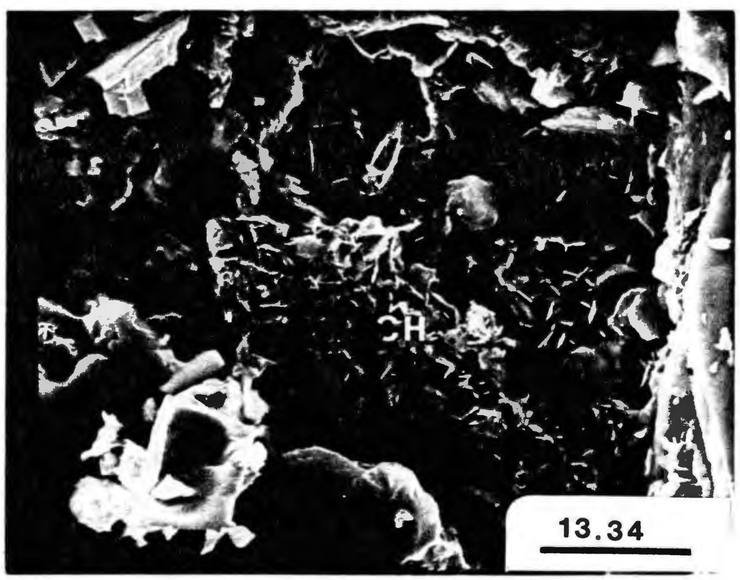


Figure 58. SEM Photomicrograph of Chlorite (1500X)

CHAPTER VI

DIAGENESIS

Diagenetic Processes

Two major diagenetic processes have changed the morphology and mineral composition of sandstone in the Red Fork: mechanical processes resulting in compaction of rock fragments to produce a pseudomatrix, and chemical processes such as dissolution, precipitation, alteration, and replacement. Deformed rock fragments owing to compaction are common in the Red Fork Sandstone. Compaction results from overburden of sediments. The result of compaction is the emplacement of soft argillaceous rock fragments around and between rigid, competent framework grains into a pseudomatrix (Figure 59). This pseudomatrix can destroy effective porosity, which in turn governs fluid-flow rates and mineral reactions that determine chemical diagenetic reactions.

Chemical processes in the Red Fork Sandstone included dissolution, precipitation, alteration, and replacement. Feldspar, quartz, quartz overgrowths, rock fragments, detrital matrix and calcite cement, all have been recorded in thin sections as products of dissolution (Figures 60, 61, 62 and 63). Of these, rock fragments, feldspars, and

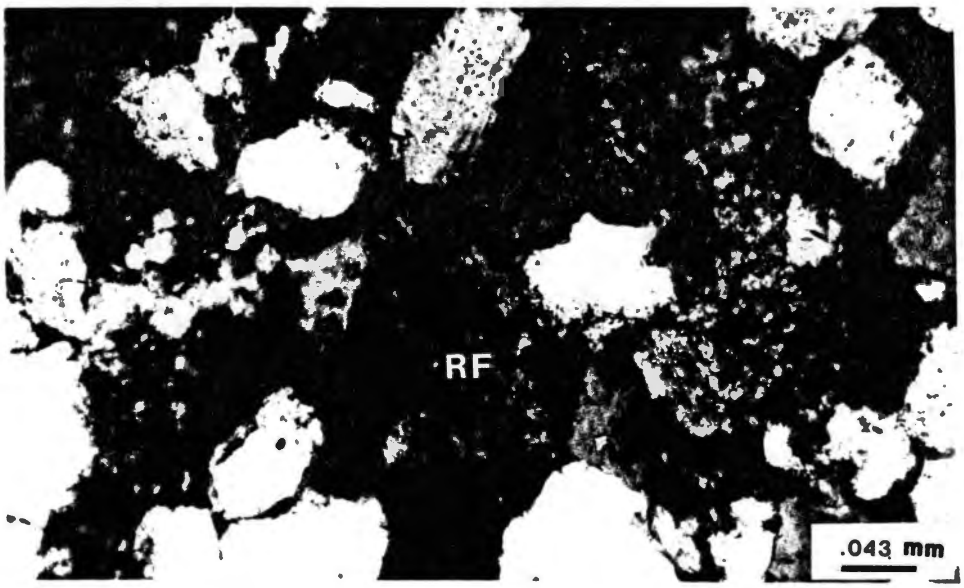
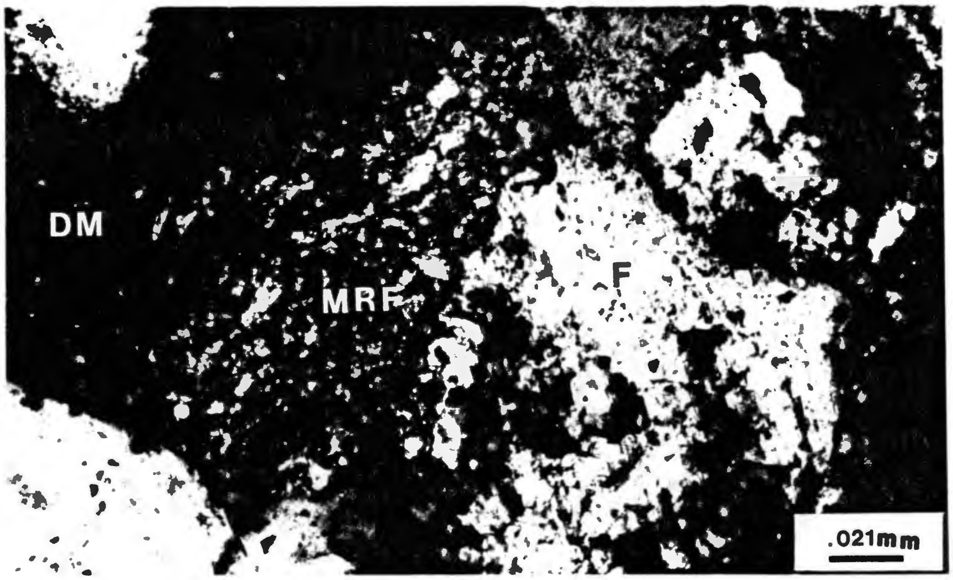


Figure 59. Photomicrograph Illustrating Rock Fragments That Have Undergone Compaction (200X, XN)



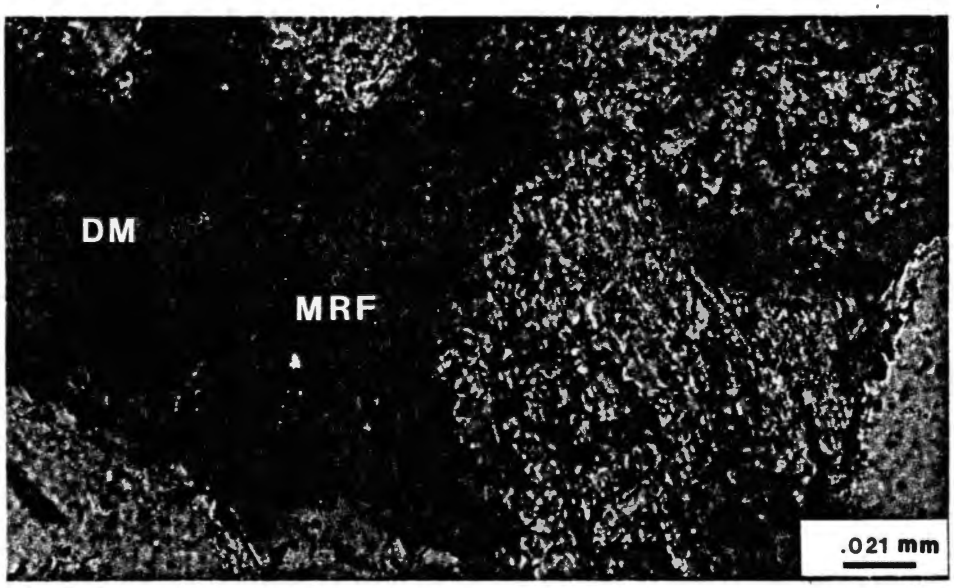


Figure 60. Photomicrograph Illustrating A Feldspar Grain, A Metamorphic-Rock Fragment, and Detrital Matrix That Have Been Partially Dissolved (400X, XN-top, PPL-bottom)

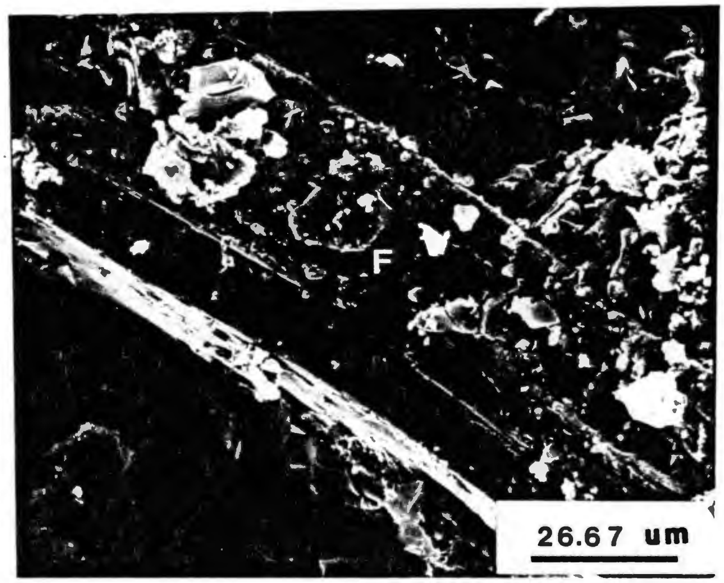


Figure 61. SEM Photomicrograph of A Partially Dissolved Feldspar Grain (750X)

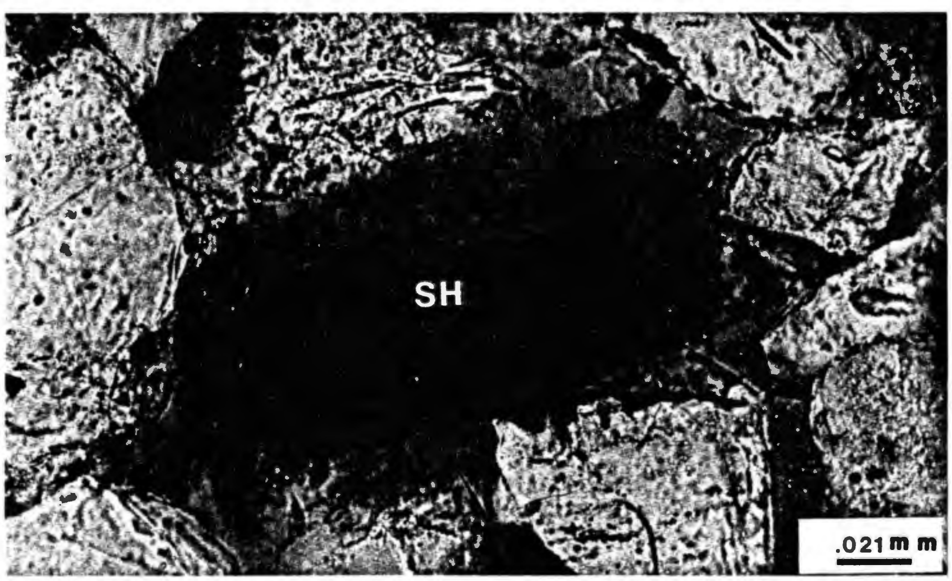


Figure 62. Photomicrograph of A Partially Dissolved Shale Fragment (400X, PPL)

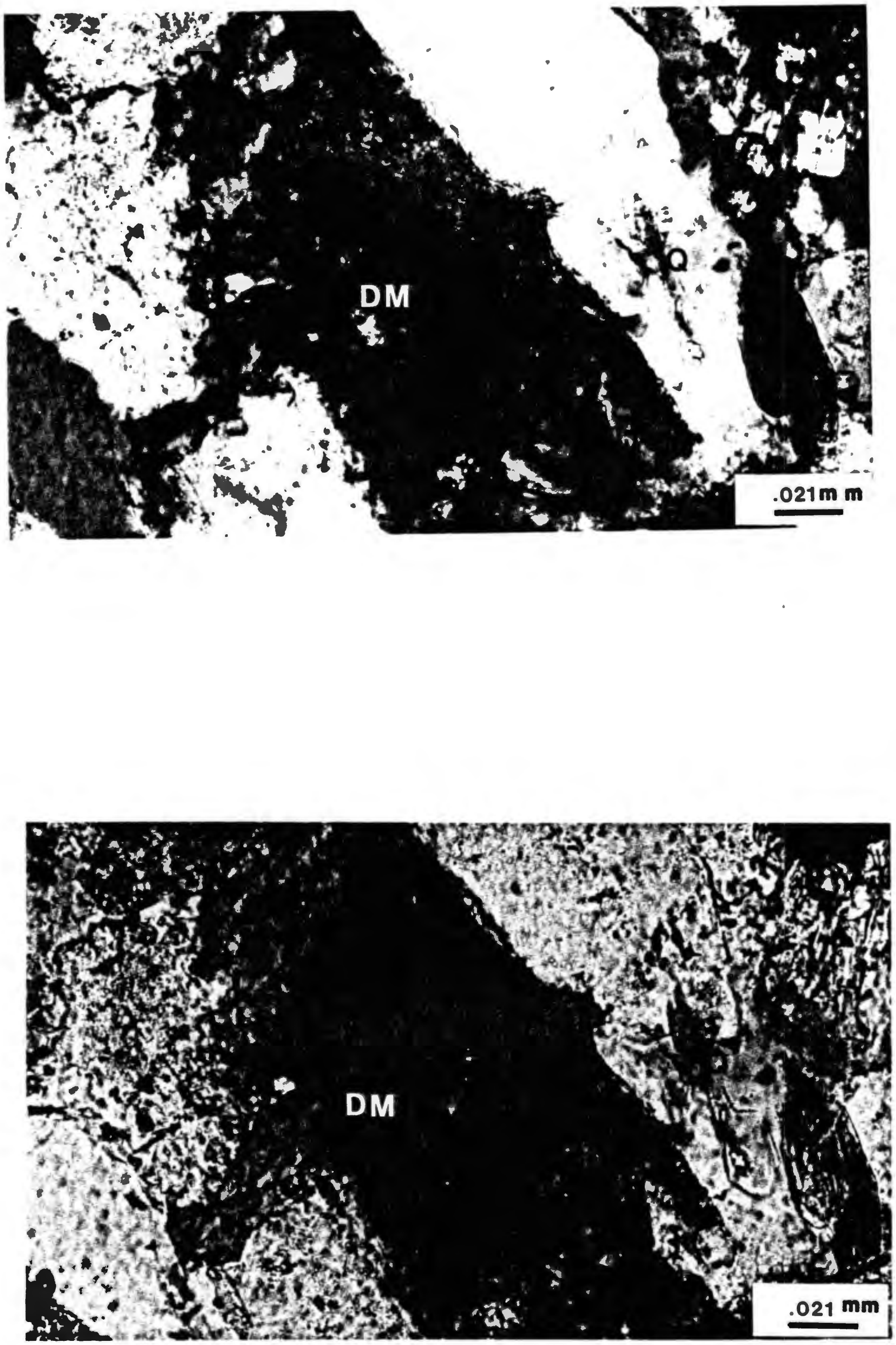


Figure 63. Photomicrograph of Partially Dissolved Quartz and Detrital Matrix (400X, XN-top, PPL-bottom)

calcite cement were frequently dissolved. Products of precipitation are syntaxial quartz overgrowths, calcite, dolomite, siderite, kaolinite, illite, chlorite, and pyrite.

Alteration in the Red Fork Sandstone consisted of kaolinization and illitization of feldspar and rock fragments, and dolomitization of calcite cement. Finally, replacement was due to detrital feldspar, quartz, and rock fragments having been partially replaced by calcite and dolomite cement (Figure 64). An uncommon feature seen in the Kurtz 32-2A core and Saunders 29-1 core is the replacement of sulphate cement by silica (Figure 65). This sulphate cement, as discussed by Bissell (1984, p. 79), could have developed in an environment that was periodically subaerial, for example, beaches, levees, or crevasse splays.

Diagenetic History

The diagenetic history of the Red Fork Sandstone is very complex. As stated by Mason (1982, p. 109), "The rock-water system is dynamic, quite complex, and when examined over geologic time, cannot be considered to be in equilibrium. The presence and duration of each of the diagenetic processes was a direct response to the changing composition of the pore fluid, the detrital constituents, the temperature and the pressure." The parameters effecting the rock-water system must be considered when interpreting the diagenetic history of the Red Fork Sandstone. The following

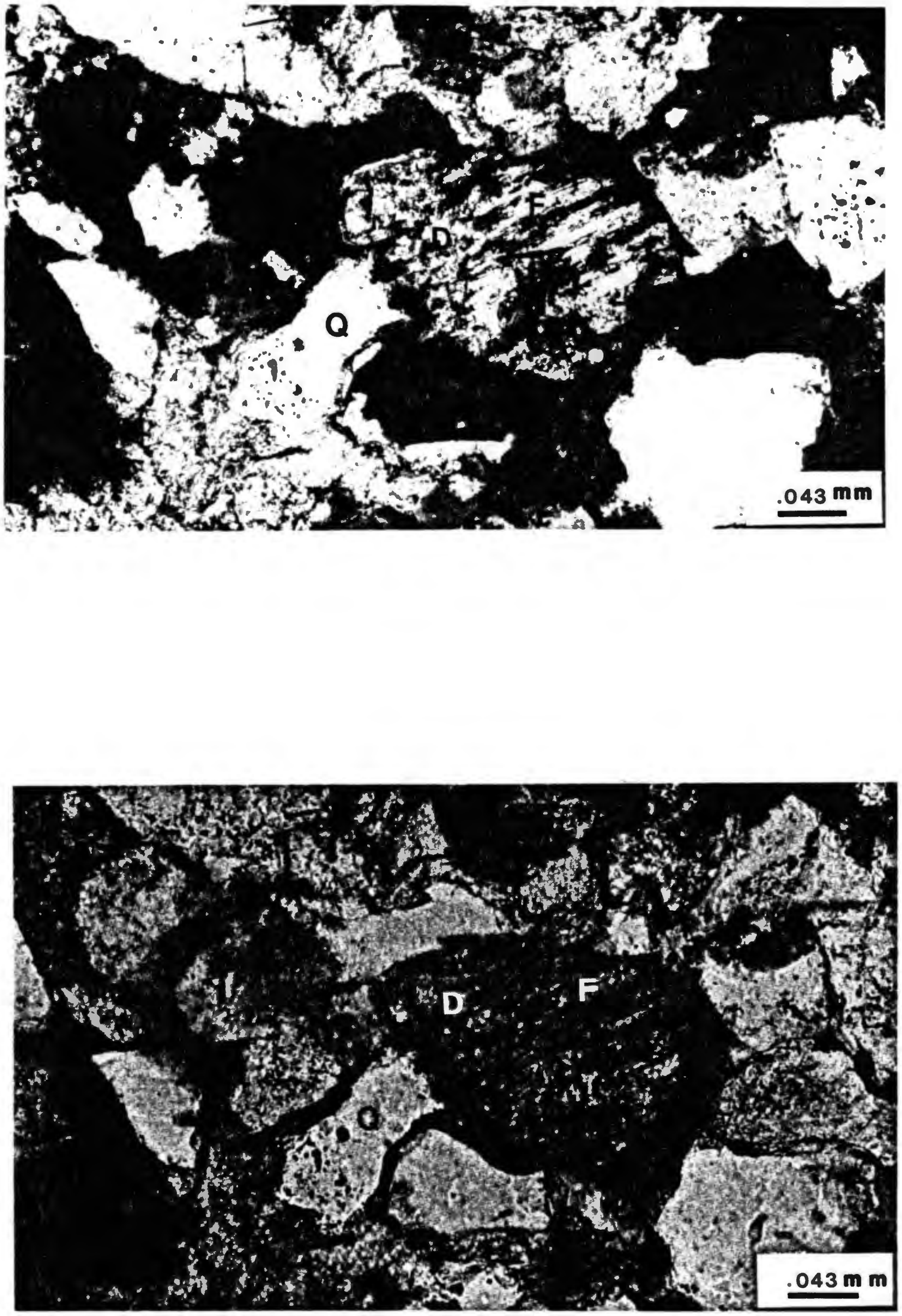


Figure 64. Photomicrograph Illustrating Quartz and Feldspar That Have Been Replaced Partially by Dolomite (200X, XN-top, PPL-bottom)

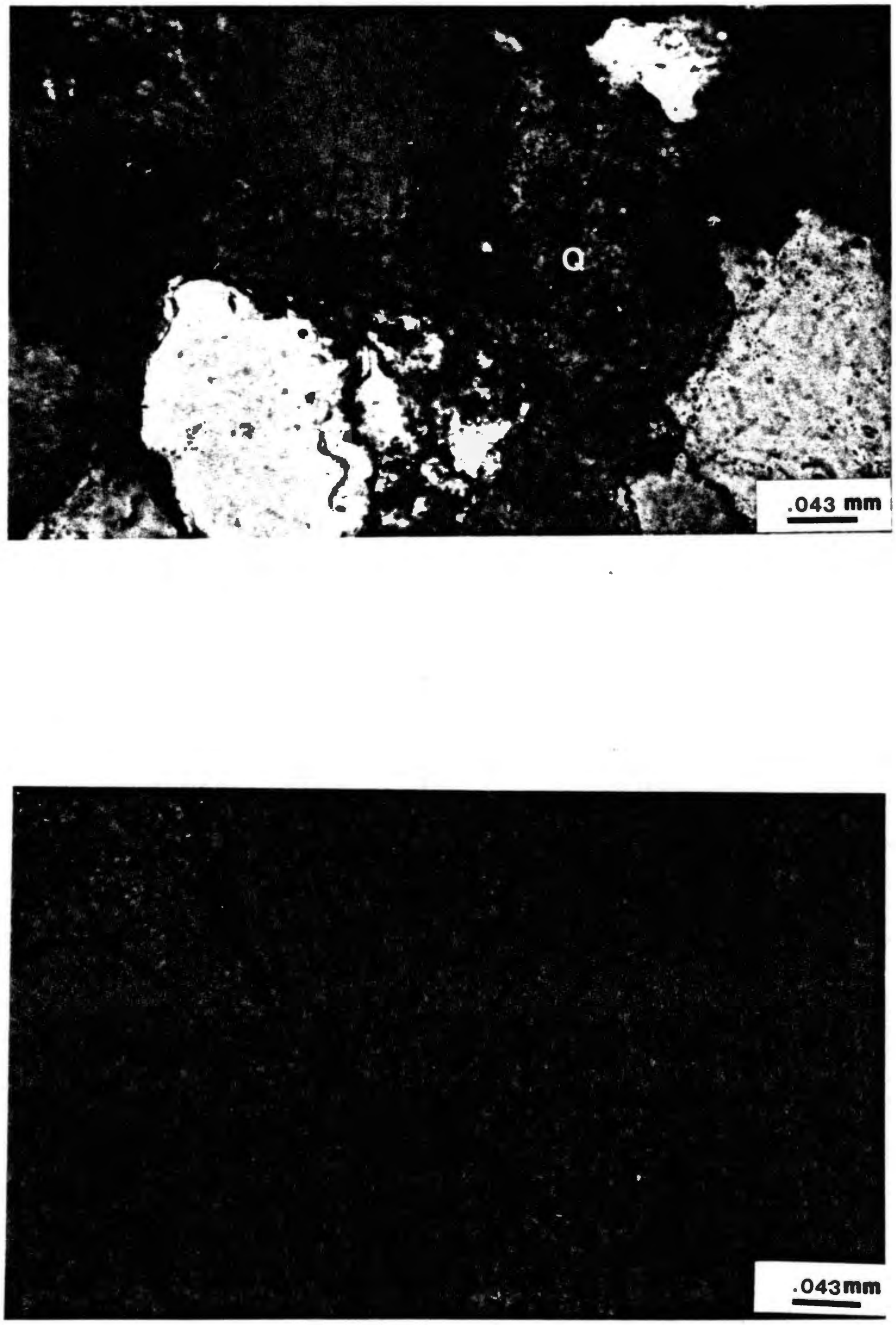


Figure 65. Photomicrograph of Quartz-after-sulphate Cement (200X, XN-top, PPL-bottom)

interpretation is a general sequence of diagenetic events based on cross-cutting relationships observed in analysis of thin sections and on literature dealing with diagenetic aspects of sandstones (Pittman and Wilson, 1977; Pittman and Wilson, 1979; Hayes, 1979; Schmidt and McDonald, 1979):

1. Formation of dust rims (illite or chlorite) along quartz grains.

2. Precipitation of syntaxial quartz overgrowths.

3. Precipitation of siderite and calcite cement.

4. Dissolution of calcite cement.

5. Dissolution of feldspars, rock fragments, and detrital matrix and their subsequent alteration to kaolinite.

6. Precipitation of kaolinite.

7. Precipitation of chlorite.

8. Precipitation of illite.

9. Dissolution of metastable quartz grains and overgrowths.

10. Precipitation of dolomite cement and dolomitization of calcite cement.

11. Migration of oil.

12. Precipitation of pyrite.

13. Alteration of pyrite to hematite.

(see Figure 66 for illustration of paragenetic sequence.)

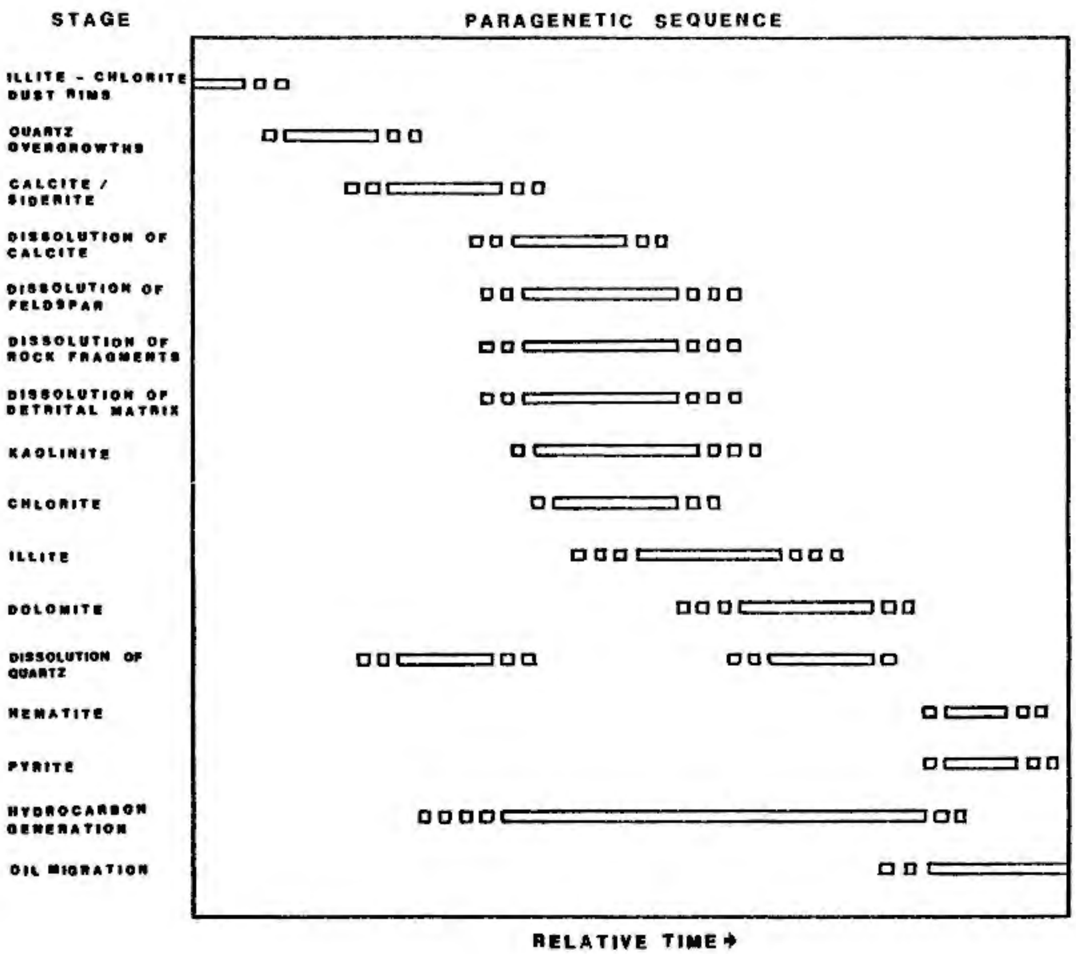


Figure 66. Paragenetic Sequence of Red Fork Sandstone in the Study Area

CHAPTER VIII

POROSITY

In the area of investigation, diagenesis has altered greatly the original porosity of the Red Fork Sandstone. Based on thin-section analysis, the Red Fork Sandstone contains: primary or intergranular porosity, and secondary porosity. Primary or intergranular porosity is of minor significance in the development of effective porosity. Primary porosity ranges from 0 to 3 percent of the rock. Fracturing, shrinkage, and dissolution are the diagenetic processes that resulted in the evolution of secondary porosity. Secondary porosity ranges from 3 to 27 percent and averages 16 percent of the rock. Secondary porosity consists of partly dissolved grains, grain molds, oversized pores, corroded grains, honeycombed grains, fractured grains, and microporosity associated with authigenic clays (Figures 67, 68 and 69) (Based on Schmidt and McDonald, 1979).

Evolution of Porosity

Based on empirical observations, the general order of diagenetic events responsible for the evolution of porosity are as follows:

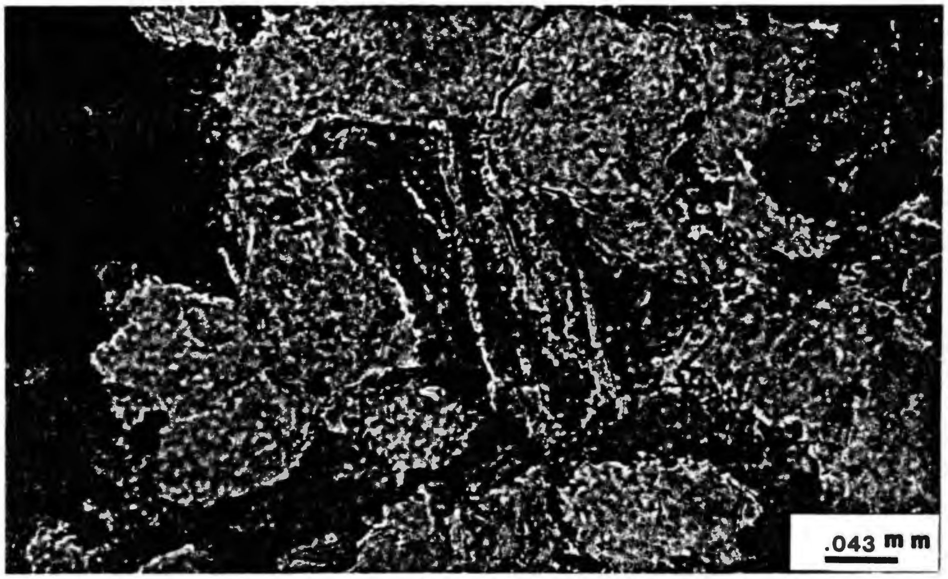


Figure 67. Photomicrograph Illustrating Partial-dissolution Porosity Owing to Leaching of A Feldspar Grain (200X, PPL)

Figure 68. Photomicrograph Illustrating Honey-combed Grains, Fractured Grains, and Corroded Grains (200X, PPL)

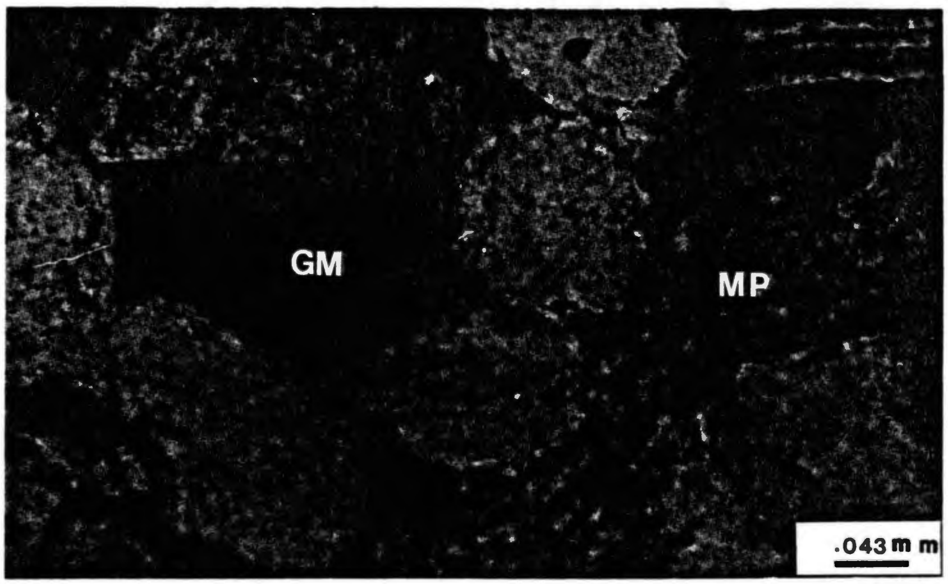


Figure 69. Photomicrograph of Grain Mold and Microporosity Associated with Authigenic Kaolinite (200X, PPL)

1. Before effective burial, processes affecting porosity were probably minimal. Dissolution of sedimentary constituents by migrating surface waters might have been a minor contributor to secondary porosity.

2. Deposition of sediments upon the Red Fork Sandstone and associated subsidence resulted in mechanical processes that led to compaction of soft, argillaceous rock fragments to produce a pseudomatrix, which greatly reduced initial primary intergranular porosity (Figure 70).

3. Precipitation of quartz overgrowths (Figure 71) and calcite cement resulted in final reduction of primary, intergranular porosity to 0 to 3 percent.

4. Next, maximal evolution of secondary porosity began. The majority of the secondary porosity created is due to decarbonization (Schmidt and McDonald, 1979), which is the result of decarboxylation of organic matter contained within adjacent shales during organic maturation. The process of decarboxylation leads to the generation of carbon dioxide, which, when present with water, produces carbonic acid. Carbonic acid is responsible for the dissolution of calcite cement, feldspars, rock fragments, and detrital matrix, which has created secondary porosity (Figures 72 and 73).

5. Carbonic acid, relatively low in pH (acidic solution), is also responsible for the acidic environment favorable for precipitation of kaolinite. Kaolinite has

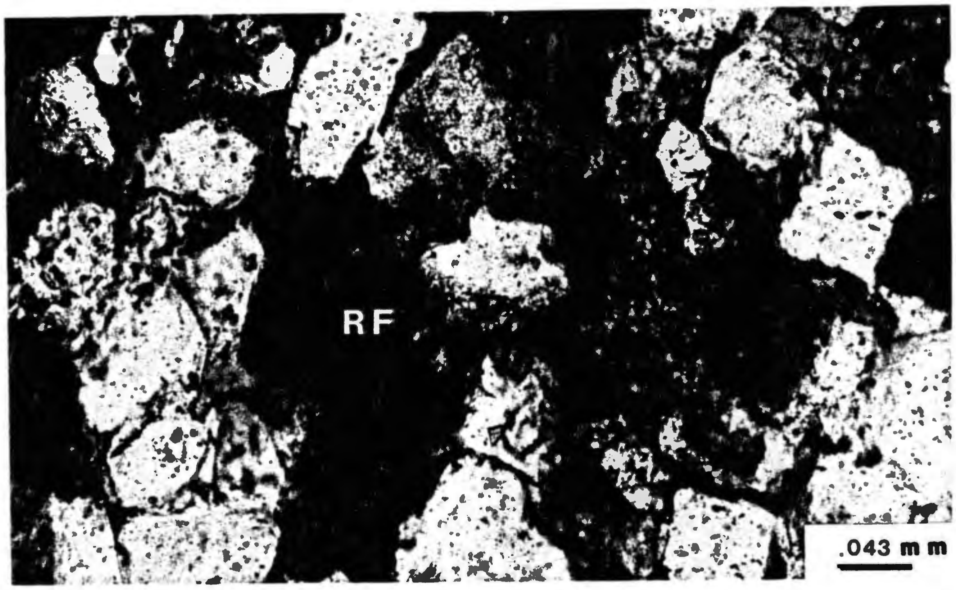
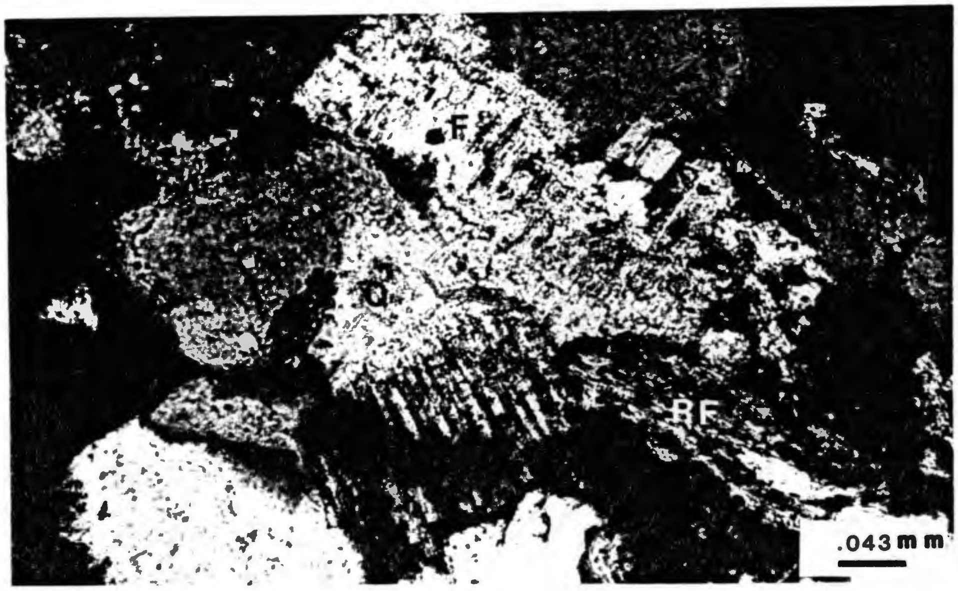


Figure 70. Photomicrograph Illustrating Compacted Rock Fragments Resulting in Reduced Primary Porosity (200X, PPL)

Figure 71. Photomicrograph of Porosity-reducing Quartz Overgrowths (400X, PPL)



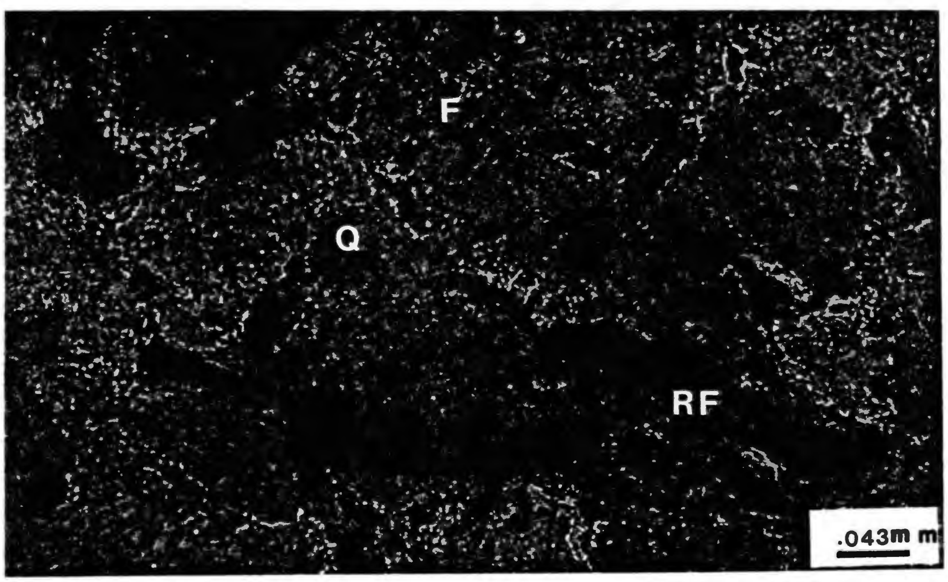


Figure 72. Photomicrograph Illustrating Secondary Porosity Owing to Dissolution of Quartz, Feldspars, and Rock Fragments (200X, XN-top, PPL-bottom)

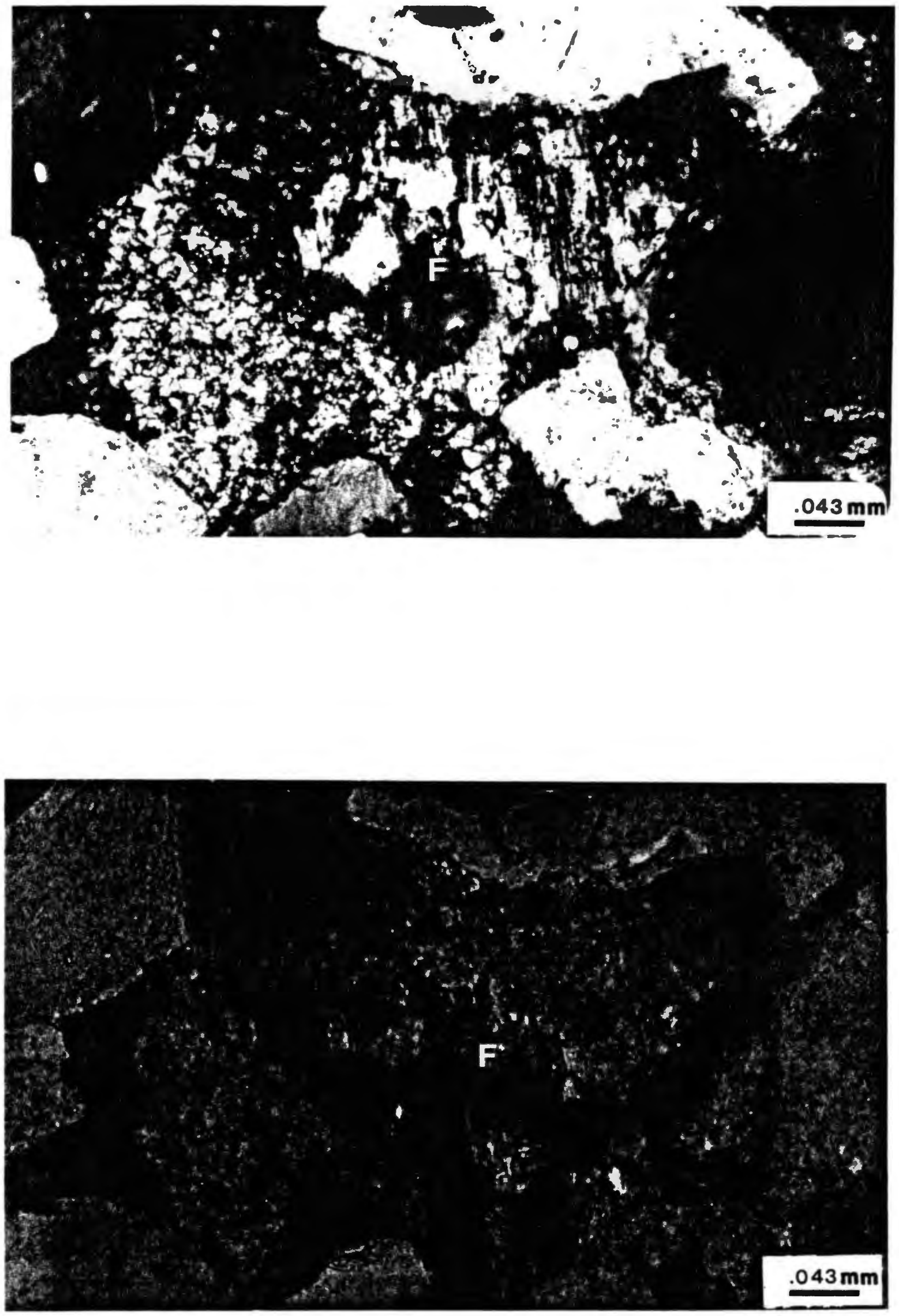


Figure 73. Photomicrograph Illustrating Secondary Porosity Owing to the Dissolution of A Feldspar Grain (200X, XN-top, PPL-bottom)

appreciable microporosity, thus reducing effective secondary porosity (Figures 74 and 75).

6. As dissolution of calcite, feldspars, and rock fragments continued, pH of the migrating pore fluid gradually increased. The increase in pH of pore fluid resulted in an alkaline environment, which led to dissolution of quartz and precipitation of illite (Figure 76) and dolomite cement (Figure 77). Dissolution of metastable quartz grains and overgrowths resulted in an increase of secondary porosity, whereas illite precipitated in pore throats reduced effective porosity. Dolomite cement, seen replacing quartz, feldspars, and rock fragments, resulted in a decrease of effective porosity.

7. Finally, hydrocarbons migrated into the secondary porosity developed in the Red Fork Sandstone (Figures 78, 79 and 80). This kind of event is discussed by Schmidt and McDonald (1979, p. 175).

> "Primary migration of hydrocarbons commonly follows closely after the secondary porosity has been formed, because in the maturation of organic matter, the main phase of hydrocarbon generation follows after the culmination of decarboxylation. This close association of source and reservoir in time and space favours the accumulation of hydrocarbons in secondary porosity."

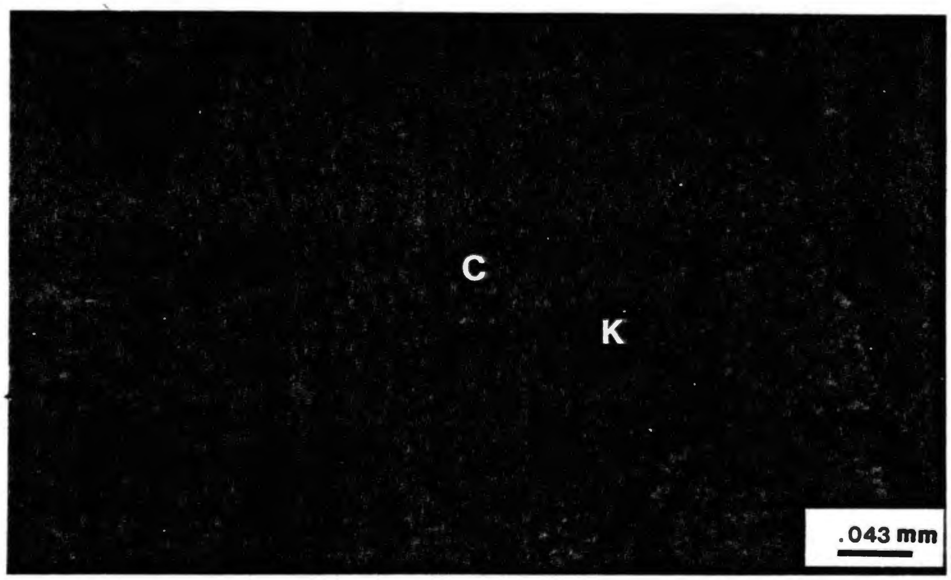


Figure 74. Photomicrograph Illustrating Dissolved Calcite Cement and Pore-filling Authigenic Kaolinite (200X, XN-top, PPL-bottom)

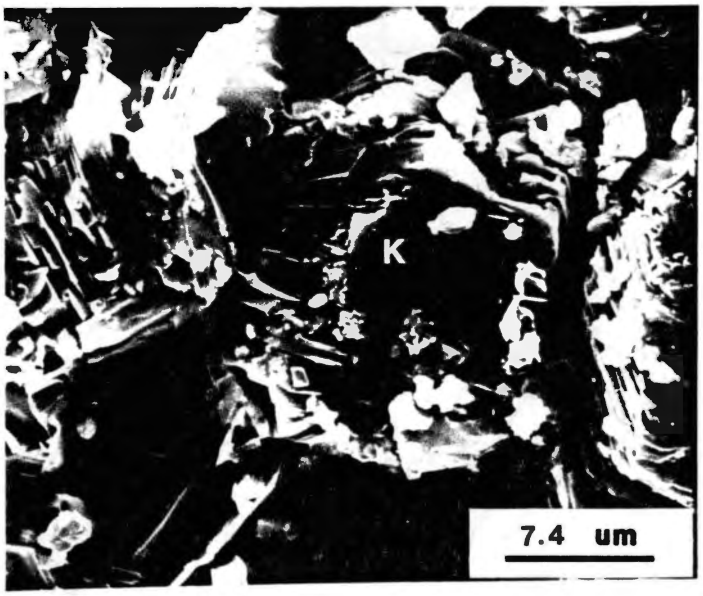


Figure 75. SEM Photomicrograph Illustrating Partially Corroded Booklets of Kaolinite (2700X)

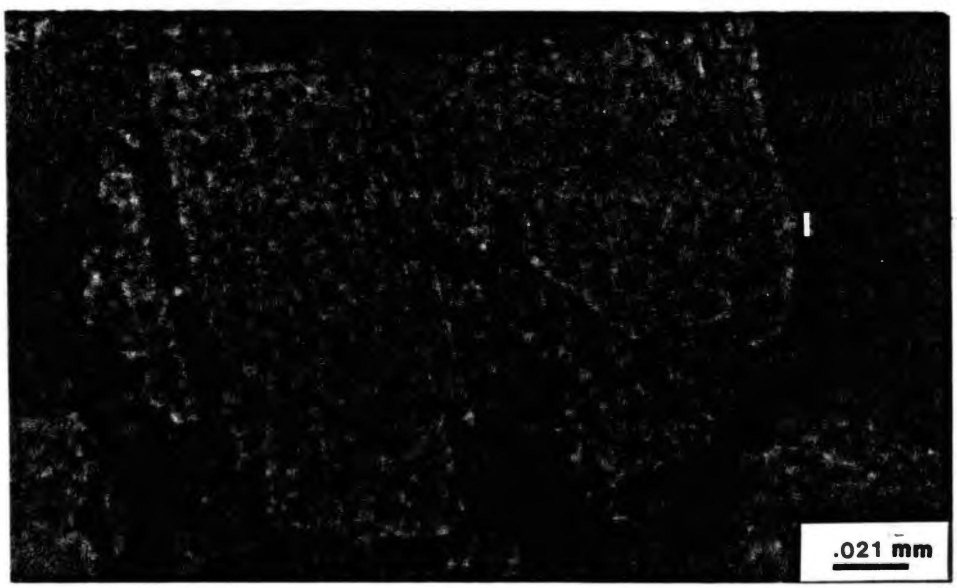


Figure 76. Photomicrograph of Authigenic Illite Coating Feldspar Grain, Which Reduces Effective Porosity (400X, PPL)

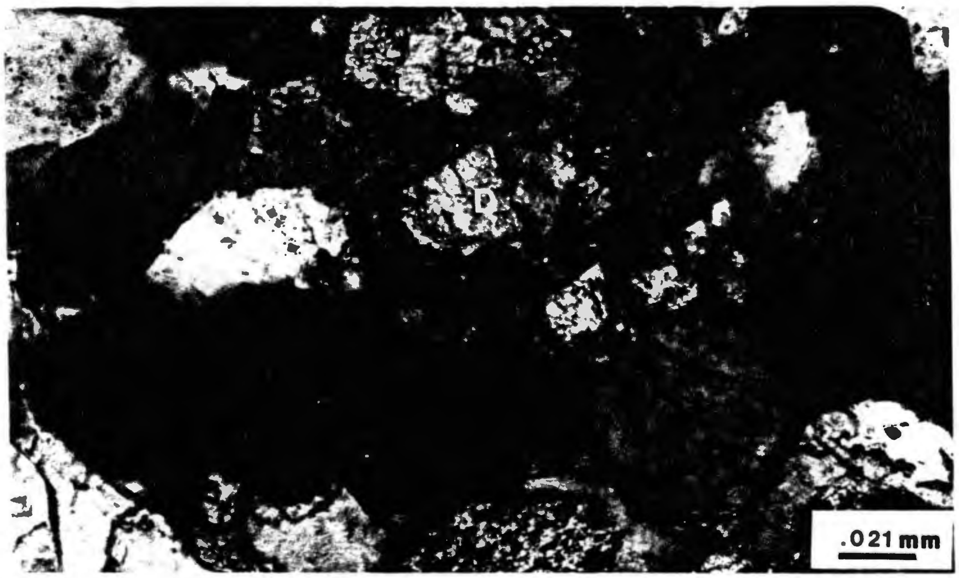


Figure 77. Photomicrograph of Dolomite Cement That Decreased Effective Porosity (200X, XN)

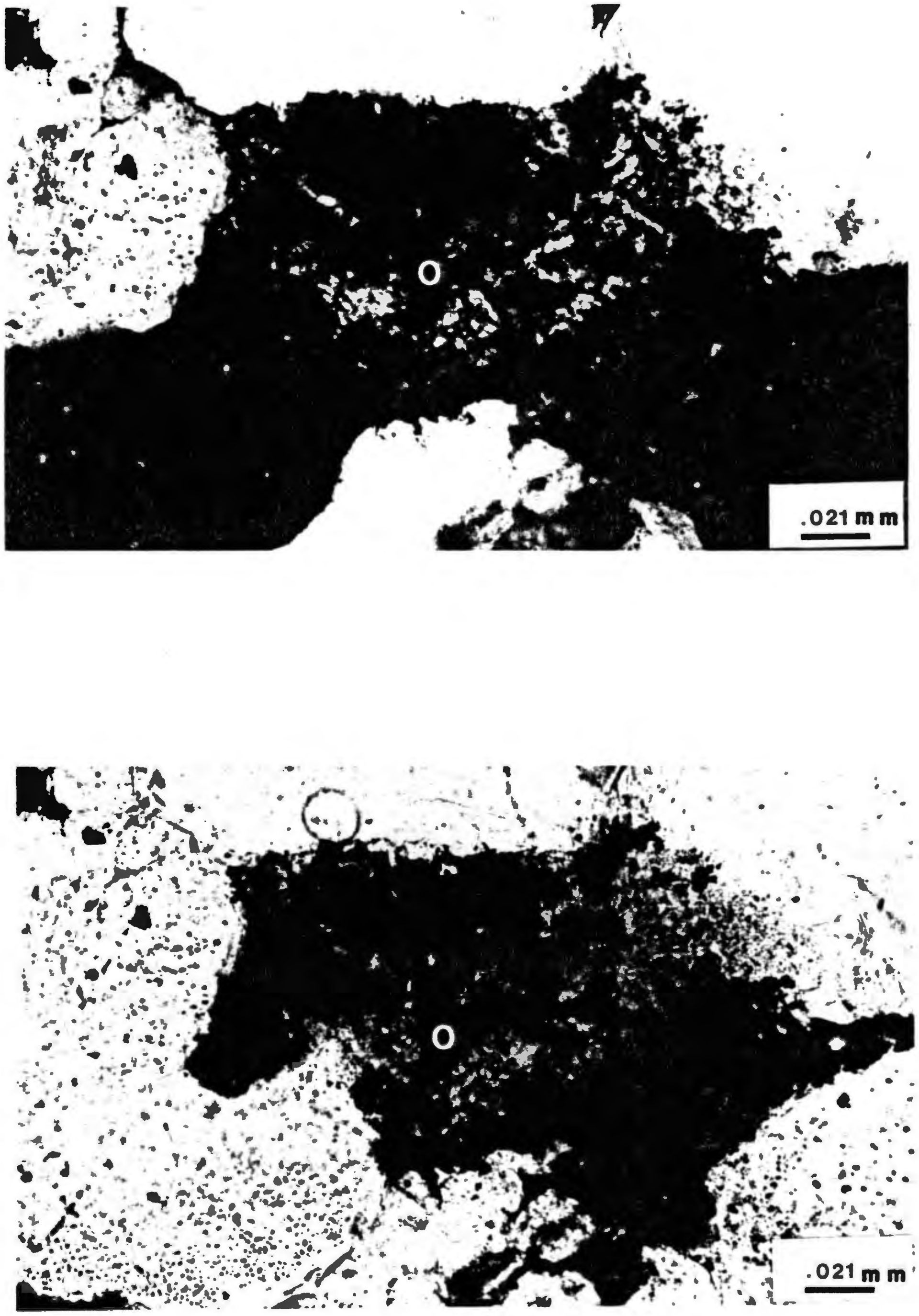


Figure 78. Photomicrograph of Oil Within Microporosity (400X, XN-top, PPL-bottom)

Figure 79. Photomicrograph of Oil Within Microporosity Associated with Precipitation of Kaolinite (400X, PPL)

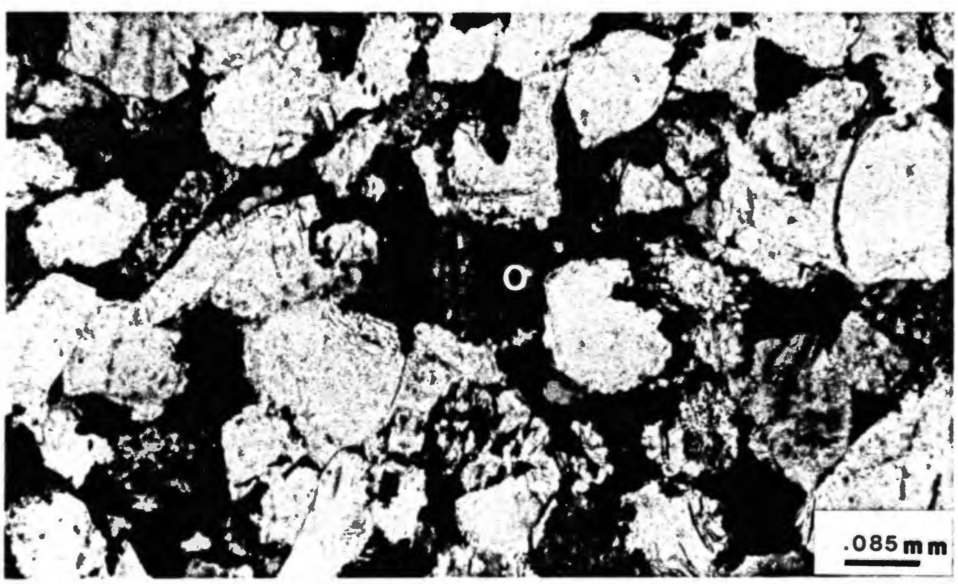


Figure 80. Photomicrograph Illustrating Association of Oil with Secondary Porosity (100X, PPL)

CHAPTER IX

RELATIONSHIP BETWEEN PETROLOGY AND LOG SIGNATURES

Introduction

Well-log signatures (gamma ray, spontaneous potential, and compensated neutron-compensated density porosity) (Figure 81) were related to petrology and diagenesis of the Red Fork Sandstone in the Andover Oil, Kurtz 32-2A core, located in T.10N., R.3E.. In order to determine and illustrate relationships between log signatures and rock composition, graphs were prepared from various data (i.e., gamma ray log, SP log, porosity-log values and percentages of constituents measured from thin sections and X-ray diffraction). These data were processed by entry into a Lotus spreadsheet on an IBM personal computer.

Response of Gamma Ray Log

Response of the gamma ray log is directly related to the abundance of rock fragments. As the amount of rock fragments increases, so does the gamma ray response in standard API units (Figure 82). Relative percentage of illite and gamma ray response show a positive correlation.

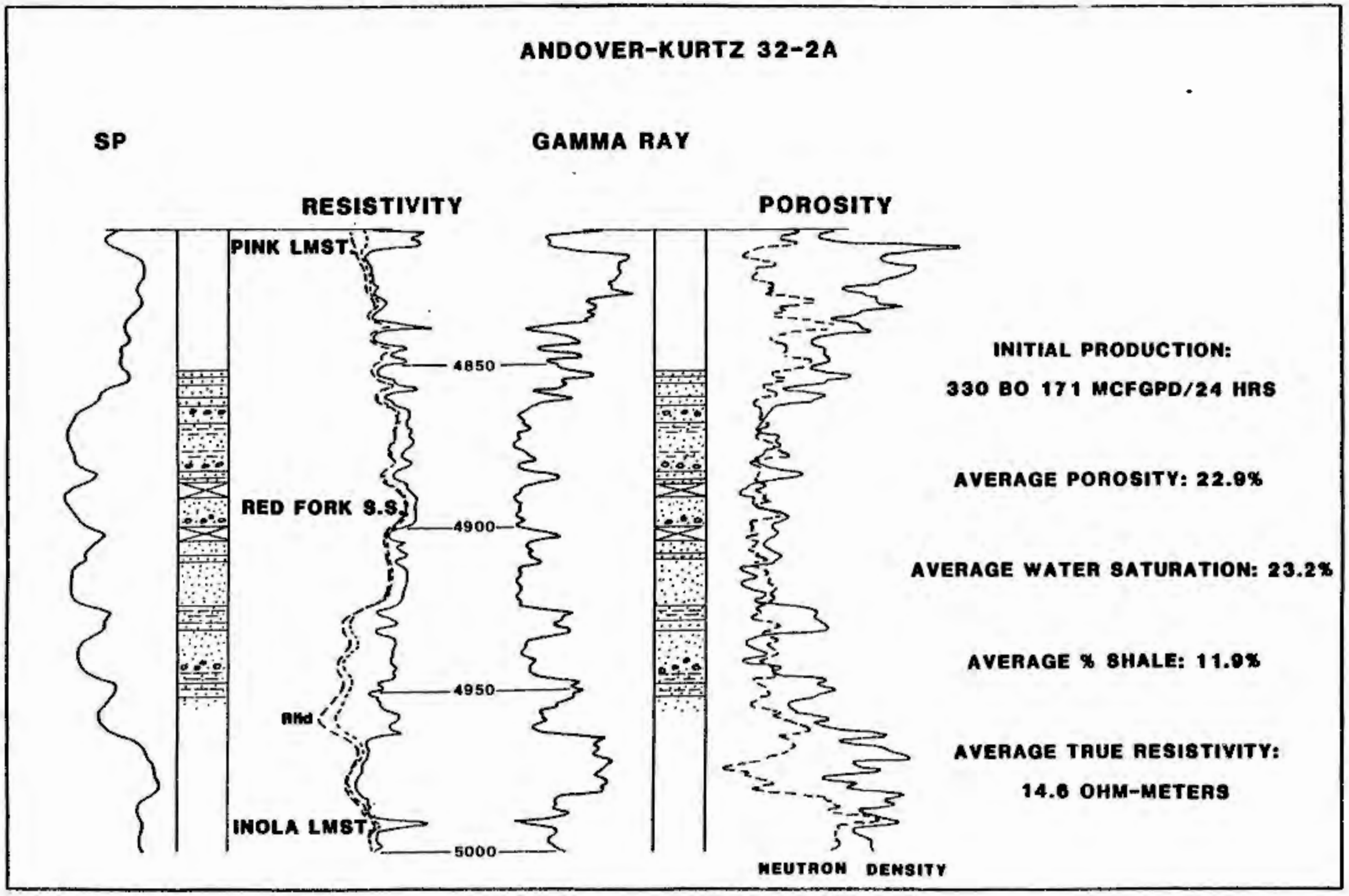


Figure 81. Well Logs Illustrating the Red Fork Sandstone, Andover Oil, Kurtz 32-2A

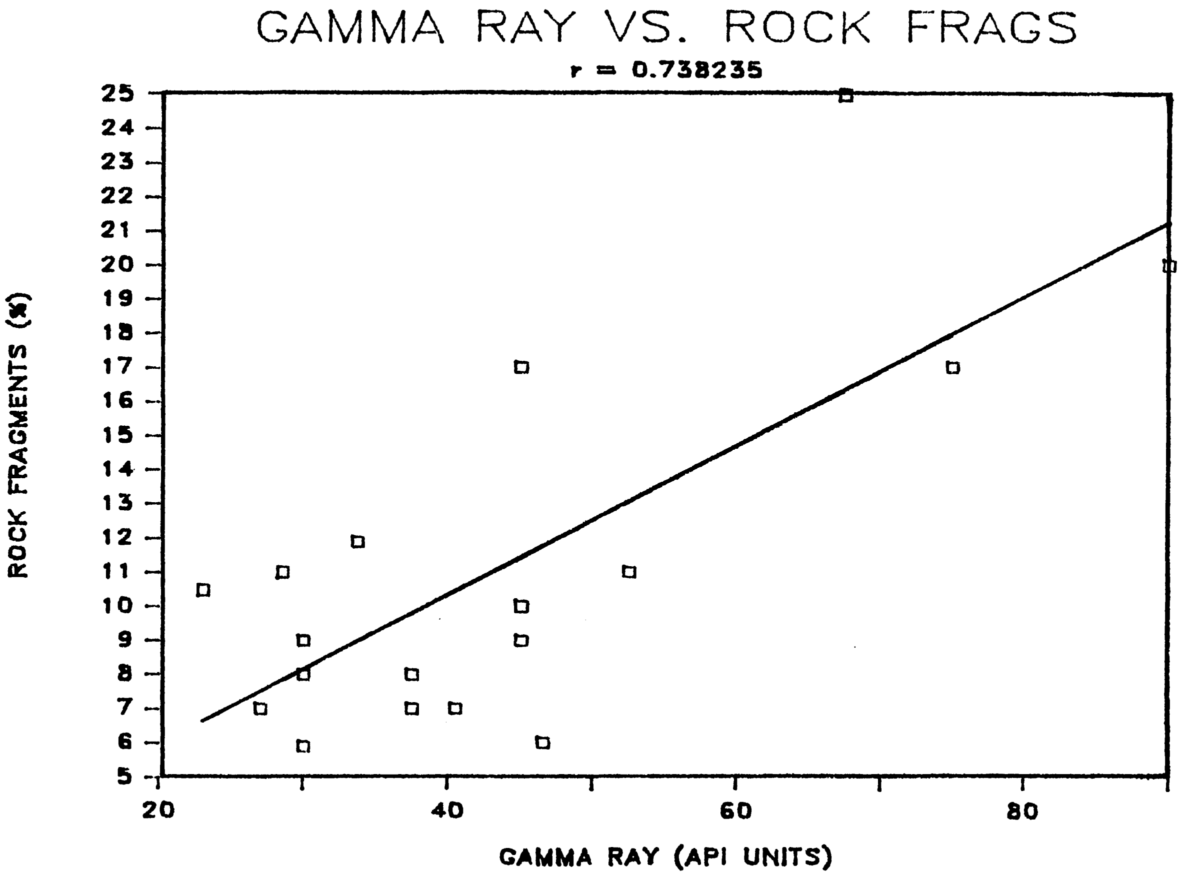


Figure 82. Standard API Units, Gamma Ray Log vs. Percentage of Rock Fragments

As the percentage of illite increases, so does the gamma ray response in standard API units (Figure 83). This relationship is due to the response of the gamma ray tool to K^+ (Asquith, 1982), which is contained within the lattice of illite. This also explains the gamma ray curve's positive relationship to rock fragments, because many of the rock fragments contain illite (Figure 84).

Because kaolinite does not contain the radioactive K^+ ion, the gamma ray log does not respond to kaolinite. However, Figure 85 illustrates an inverse relationship between the amount of kaolinite and gamma ray response. This relationship is due to the inverse relationship between the relative percentages of illite and kaolinite (Figure 86). As the percentage of kaolinite increases, the percentage of illite decreases. An increase in the percentage of kaolinite is the result of diagenesis within the sandstone reservoir. It is highly probable that migration of fluids within the sandstone body, in association with hydrocarbon generation, has flushed the K^+ ion from the interlayer position within the illite clay lattice, which resulted in the replacement of illite and rock fragments by kaolinite.

Finally, no correlation exists between the percentage of chlorite and gamma ray log response because no K^+ ions are contained within the chlorite lattice (Figure 87).

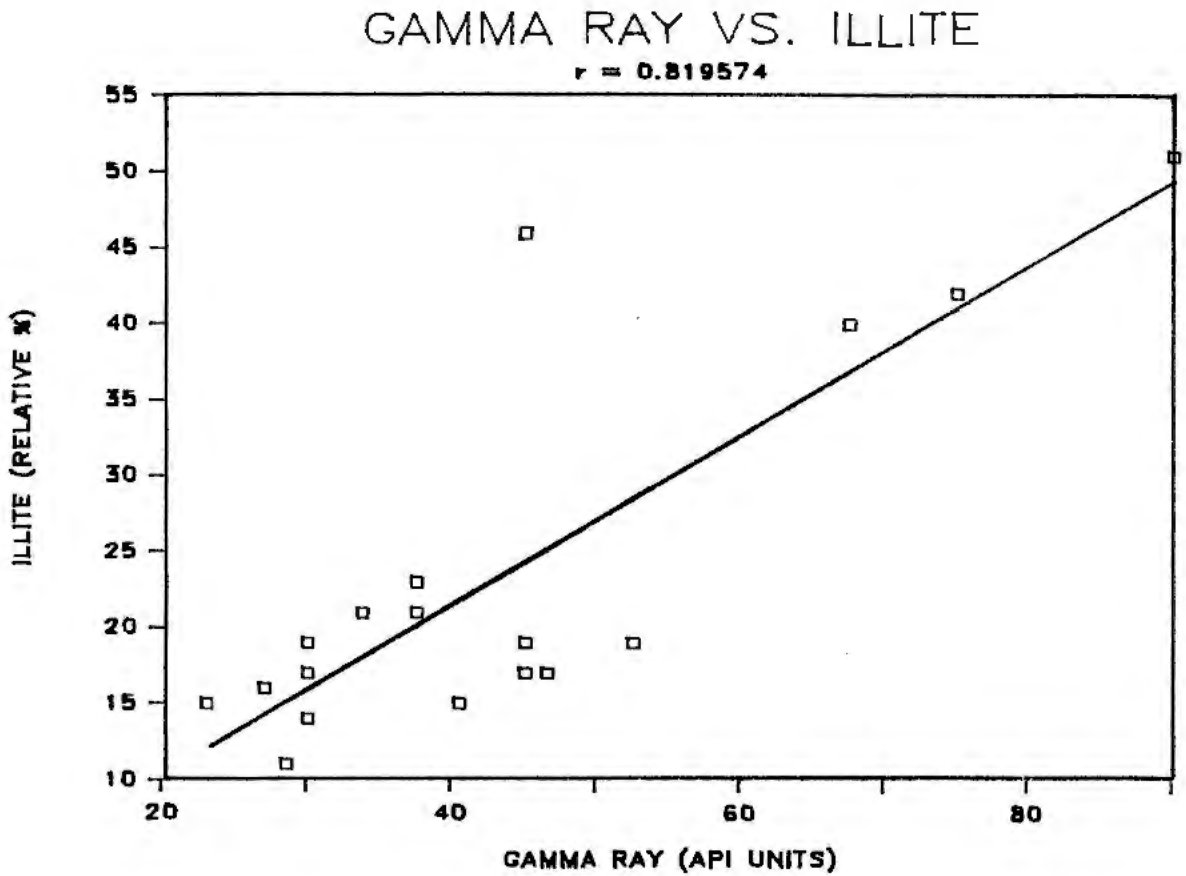


Figure 83. Standard API Units, Gamma Ray Log vs. Relative Percentage of Illite

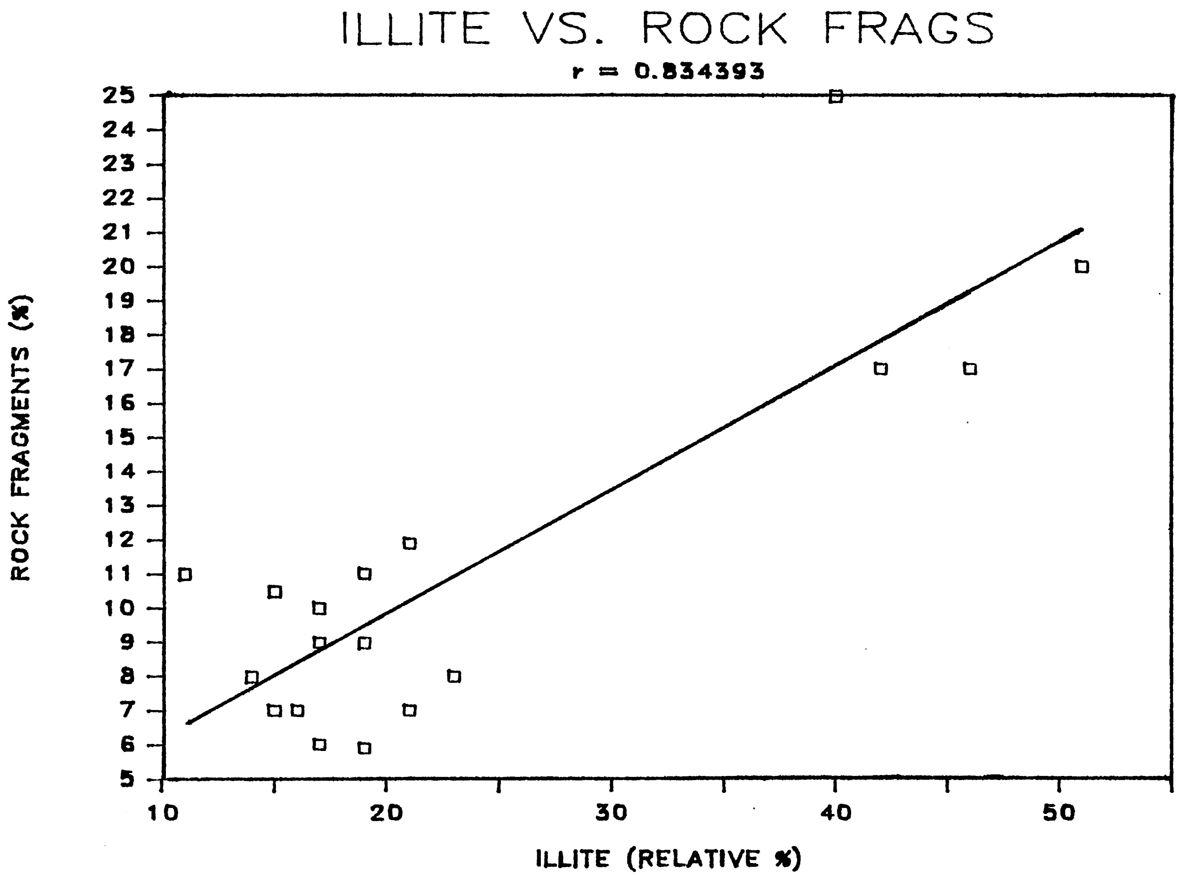


Figure 84. Relative Percentage of Illite vs. Percentage of Rock Fragments

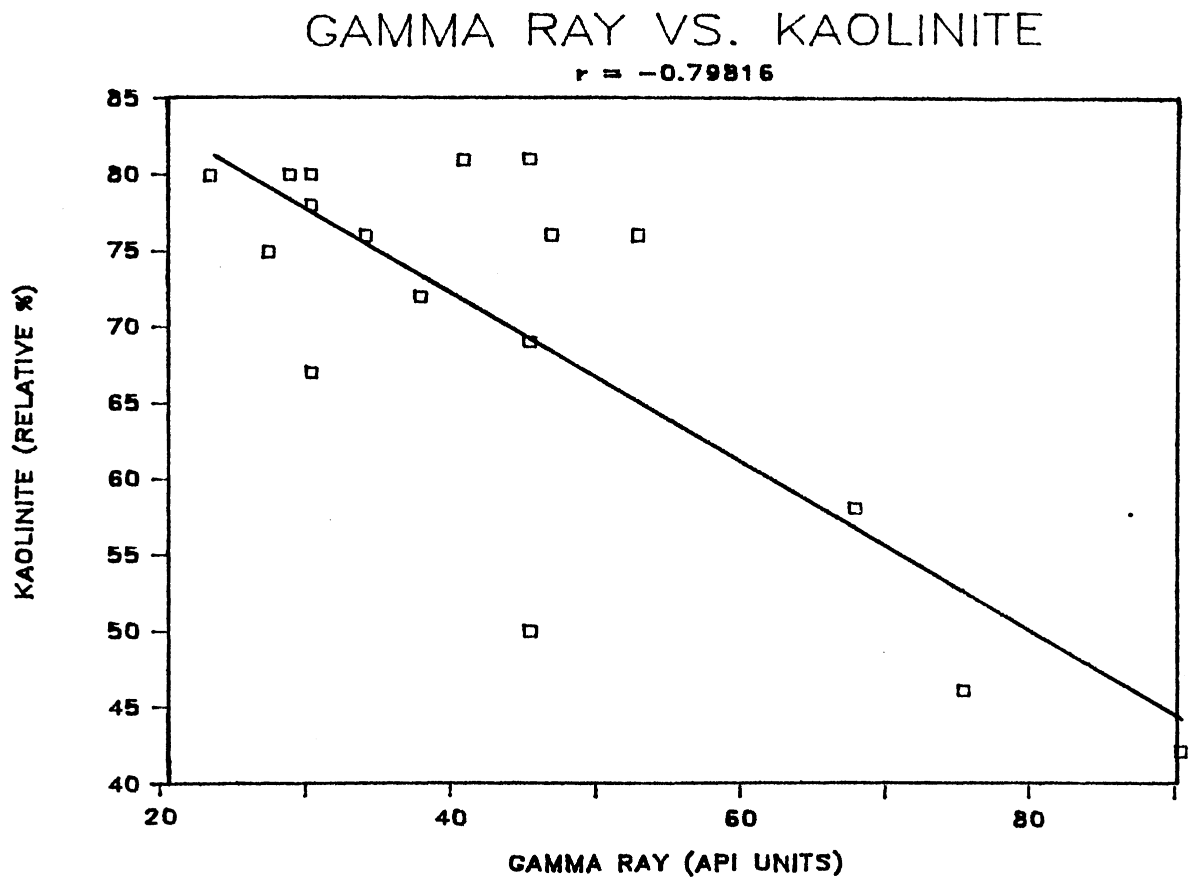


Figure 85. Standard API Units, Gamma Ray Log vs. Relative Percentage of Kaolinite

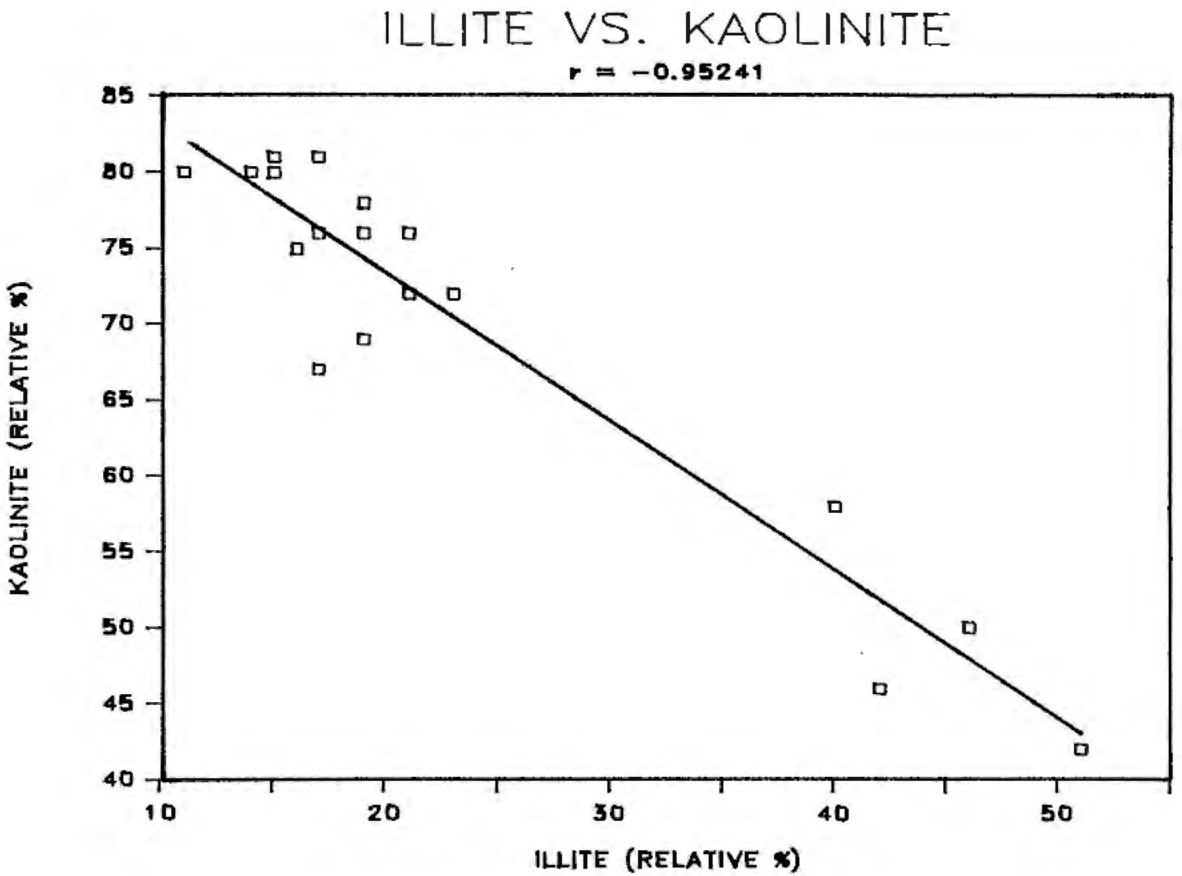


Figure 86. Relative Percentage of Illite vs. Relative Percentage of Kaolinite

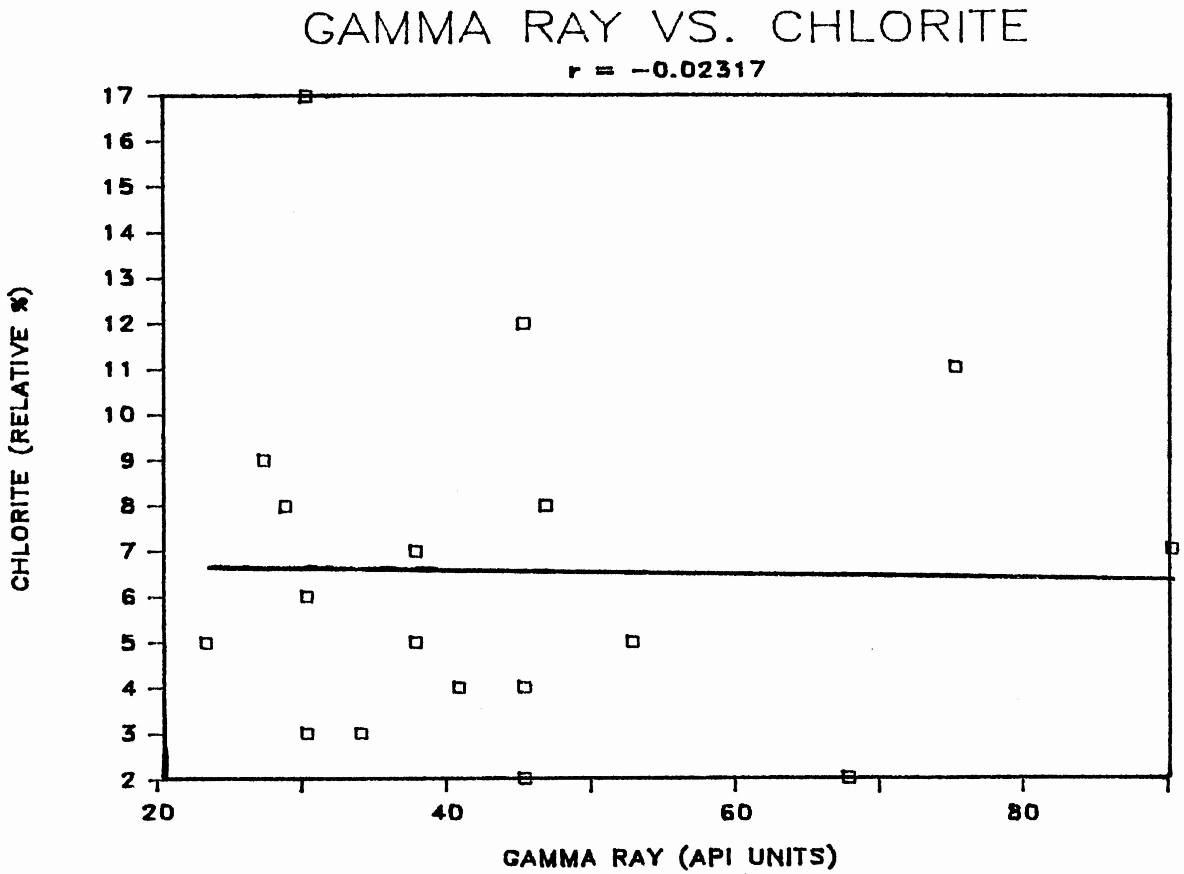


Figure 87. Standard API Units, Gamma Ray Log vs. Relative Percentage of Chlorite

Response of Spontaneous Potential Log

The spontaneous potential log or SP log detects permeable beds (Asquith, 1982). An inverse relationship is observed between the spontaneous potential log and the gamma ray log (Figure 88). Therefore, an inverse relationship is observed between the spontaneous potential log and the percentage of illite and rock fragments (Figure 89).

Response of Porosity Log

Decrease in the negative deflection of the SP log (millivolts), and subsequent increase in the API units of the gamma ray log indicates reduction of the effective porosity by illite (Figures 90, 91, 92 and 93). As the percentages of illite and rock fragments increase, the porosity values from the neutron-density log decrease due to the relatively large matrix density of illite and the hydrogen content of illitic clays (Stewart, 1984).

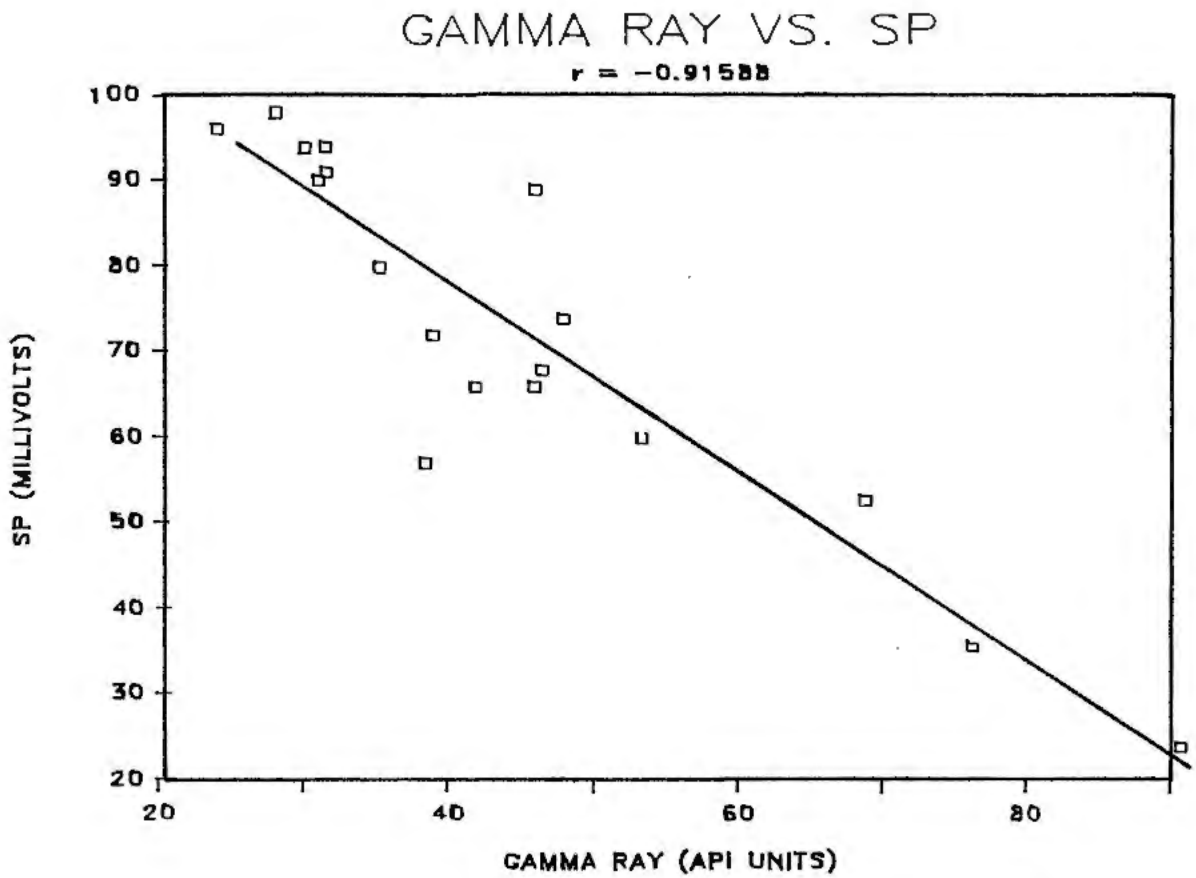


Figure 88. Standard API Units, Gamma Ray Log vs. Millivolts of Deflection from Shale Base Line, Spontaneous Potential Log

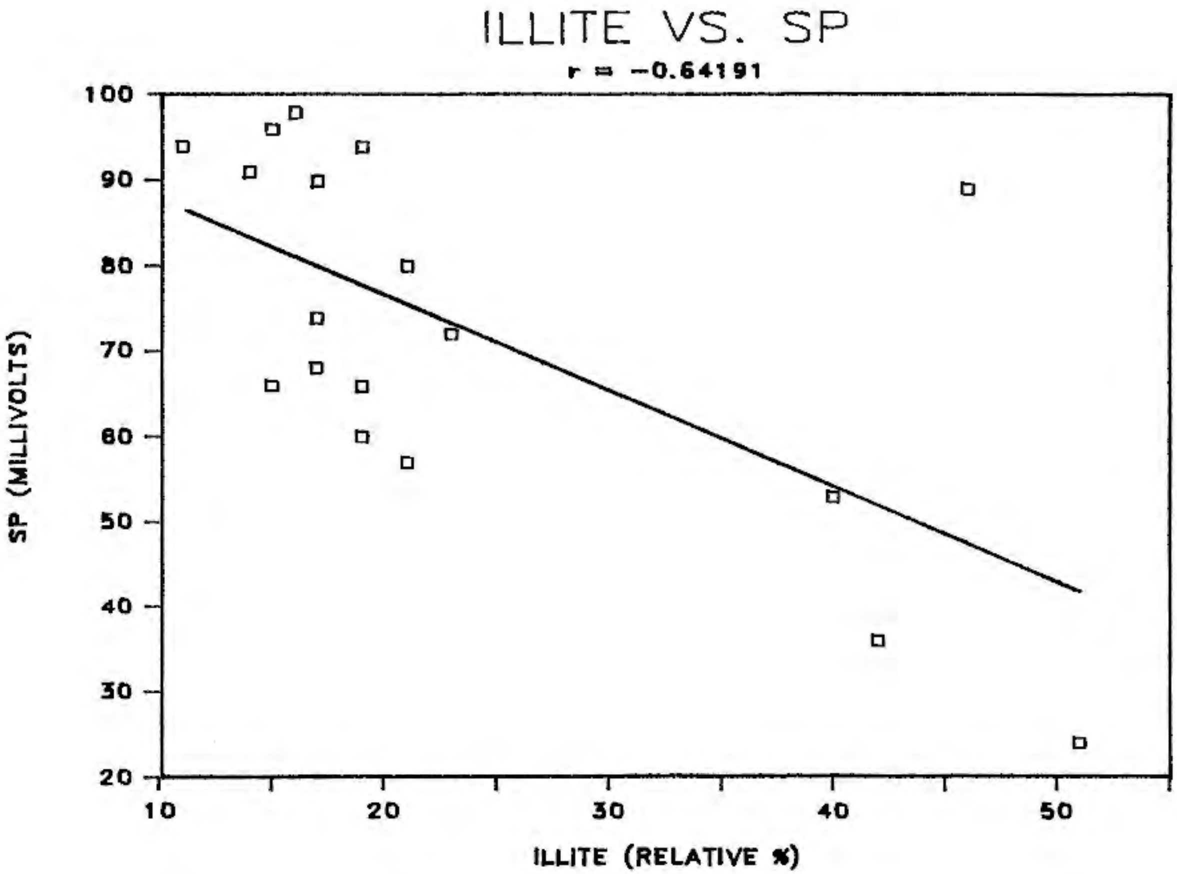


Figure 89. Relative Percentage of Illite vs. Millivolts of Deflection from Shale Base Line, Spontaneous Potential Log

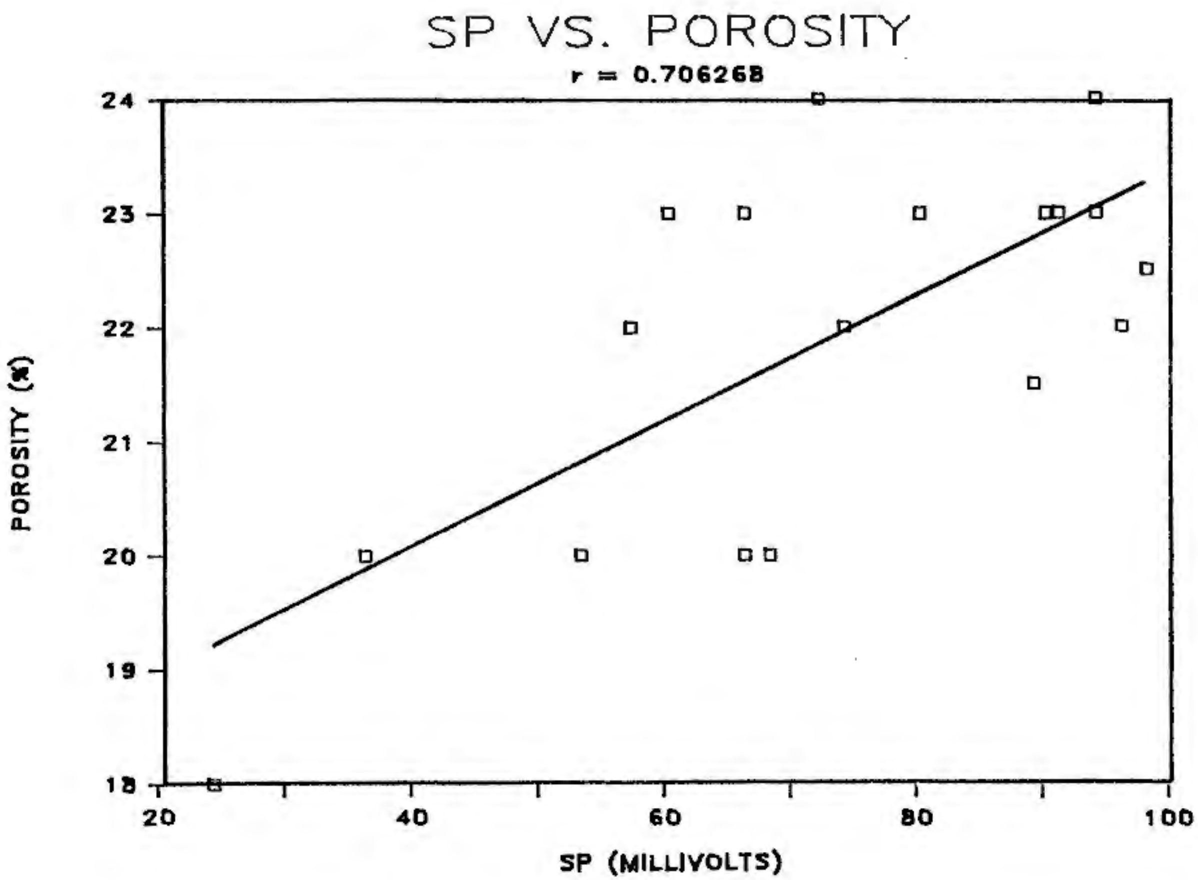


Figure 90. Millivolts of Deflection from Shale Base Line, Spontaneous Potential Log vs. Porosity

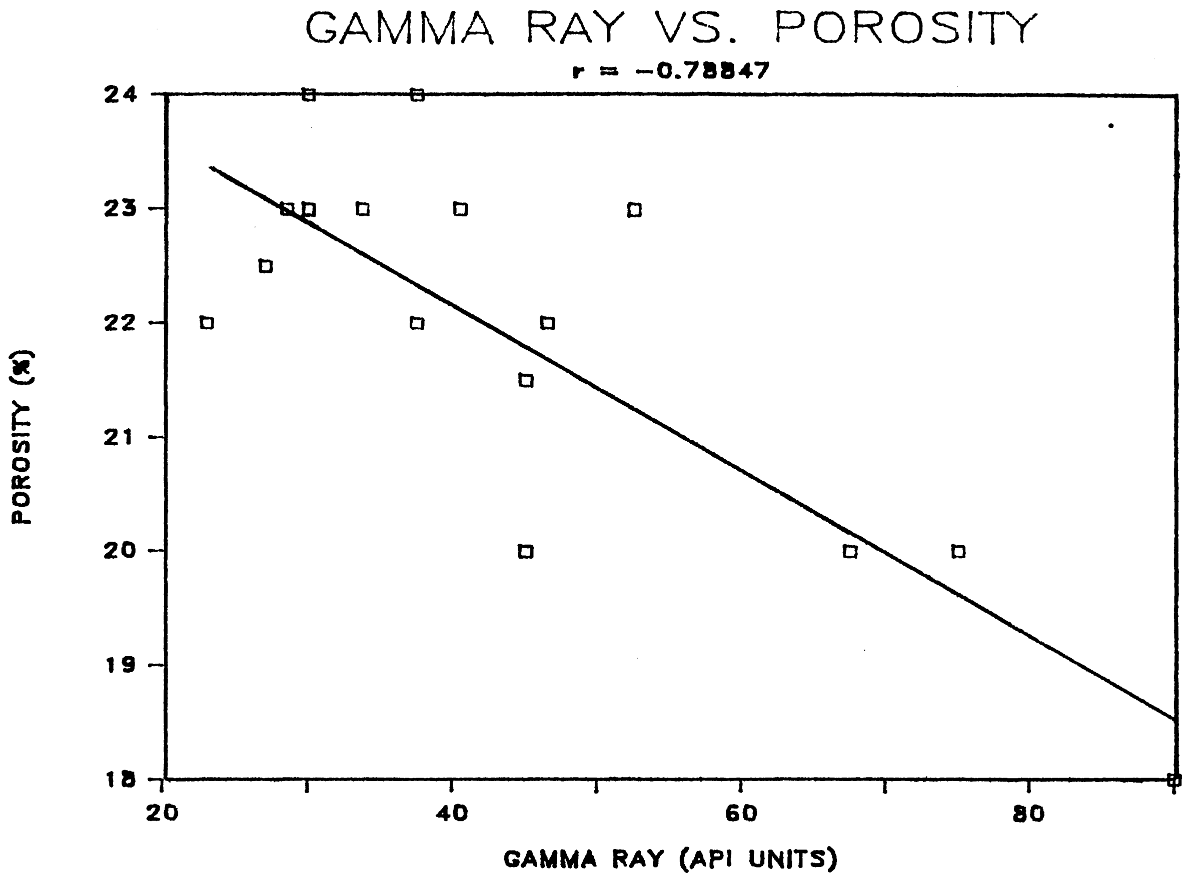


Figure 91. Standard API Units, Gamma Ray Log vs. Porosity

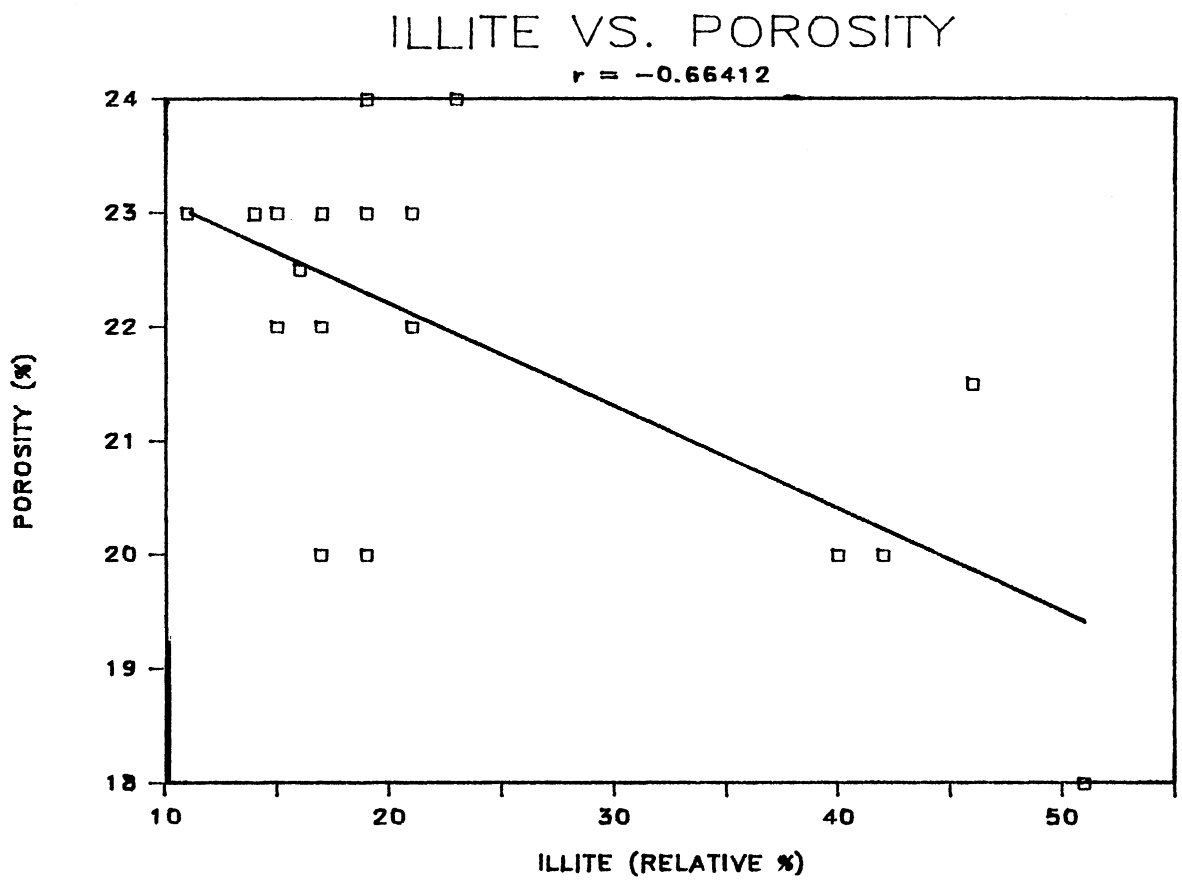


Figure 92. Relative Percentage of Illite vs. Porosity

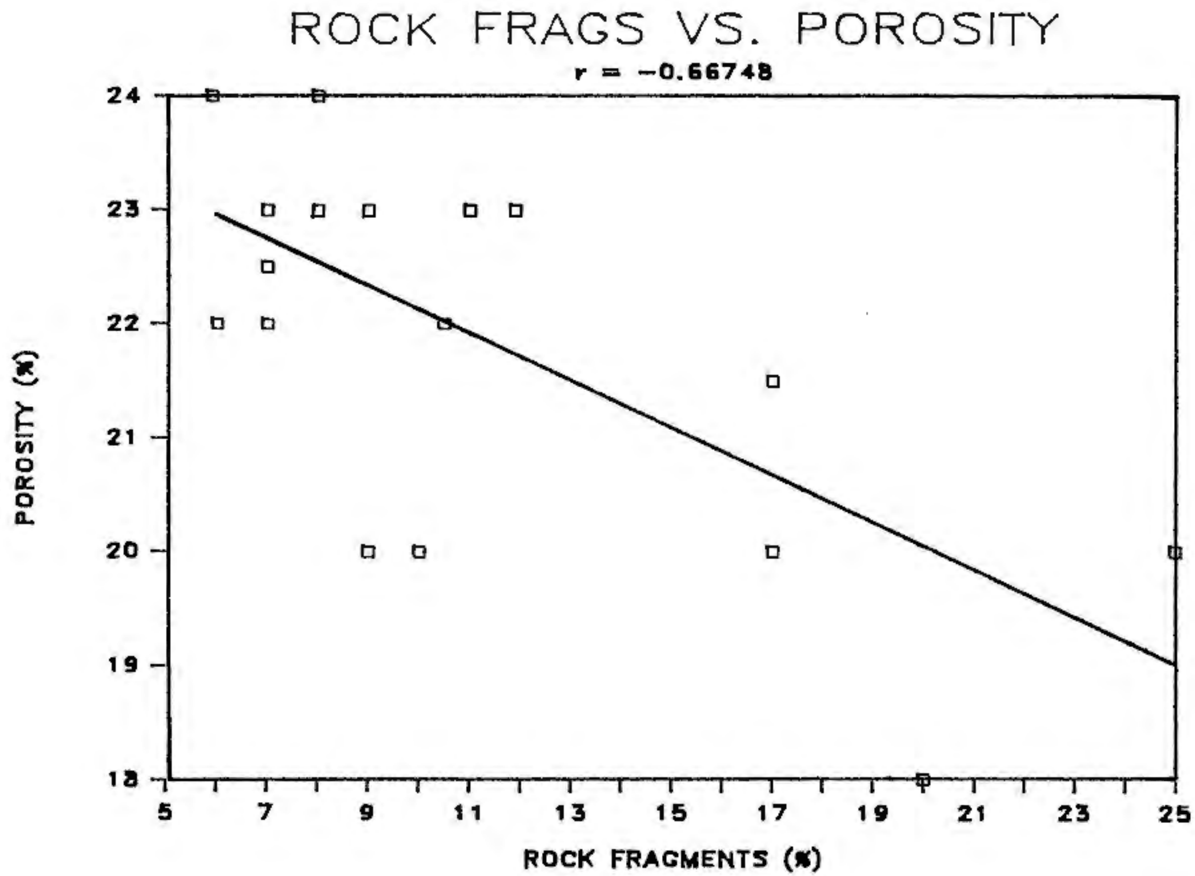


Figure 93. Percentage of Rock Fragments vs. Porosity

CHAPTER X

PETROLEUM GEOLOGY

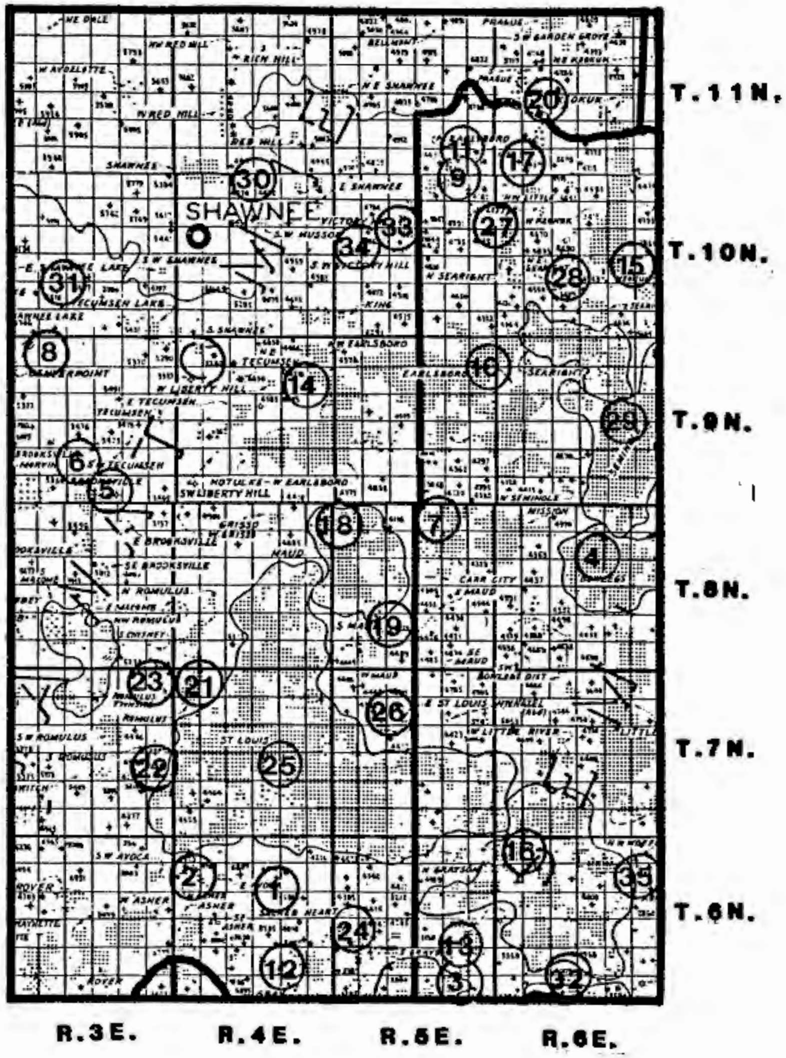
Introduction

The Red Fork (Earlsboro) Sandstone is productive in more than 400 wells in 35 fields in the study area (Figure 94). This fact makes a study of the reservoir characteristics and trends not only interesting but potentially economic as well. Therefore, the purpose of this chapter is to interpret the relationship of stratigraphy, structural geology, depositional environment, and diagenesis in regard to entrapment of oil and gas in the Red Fork Sandstone in the study area.

Two fields that produce from the Red Fork Sandstone, the Northwest Tecumseh Field and the North Searight Field, were studied in order to interpret the relationships discussed above. These studies are followed by a discussion of an area for future exploration, which was based upon relationships observed in the field studies.

Northwest Tecumseh Field

The Northwest Tecumseh Field is located in Sections 9, 16, 17, 20, 21, 27, 28, 29, 31 and 32, T.10N., R.3E..



1 ASHER EAST
2 ASHER NORTH
3 BEBEE - KONAWA SOUTHWEST
4 BOWLEGS
5 BROOKSVILLE
6 BROOKSVILLE NORTH
7 CARR CITY
8 CENTERPOINT
9 DILL SOUTH
10 EARLSBORO
11 GARDEN SOUTHWEST
12 GRAY
13 GRAYSON SOUTH
14 HOTULKE SOUTH
15 KEOKUK
16 KONAWA - DORA
17 LITTLE NORTHWEST
18 MAUD
19 MAUD EAST
20 PRAGUE SOUTH
21 ROMULUS
22 ROMULUS SOUTH
23 ROMULUS TOWNSITE
24 SACRED HEART
25 ST. LOUIS
26 ST. LOUIS EAST
27 SEARIGHT NORTH
28 SEARIGHT NORTHEAST
29 SEMINOLE
30 SHAWNEE
31 TECUMSEH NORTHWEST
32 TYROLA NORTHEAST
33 VICTORY HILL
34 VICTORY HILL SOUTHWEST
35 WOFFORD NORTHWEST

Figure 94. Index Map of Fields with Production from Red Fork Sandstone

Cumulative production of the Red Fork (Earlsboro) Sandstone in the Northwest Tecumseh Field, as of June 1984, is 4,482,725 barrels of oil from 60 producing wells.

Reservoir Characteristics

Reservoir quality of the Red Fork Sandstone in the Northwest Tecumseh Field has been affected severely by diagenetic processes that were discussed in Chapter VII. The two most important reservoir characteristics affected by diagenetic processes are porosity and permeability. Diagenetic clays and cements have major influence on porosity, permeability, and water saturation, in addition to drilling fluids, stimulation fluids, and recovery fluids used in well completion activities (Almon and Davies, 1978). The relationship between reservoir characteristics and clay mineralogy is evident in data recorded from 3 cores from the Northwest Tecumseh Field (Figures 95, 96, and 97). Porosity and permeability decrease as the percentage of illite increases.

Reservoir Trends

In order to illustrate and predict reservoir trends of the Red Fork Sandstone in the Northwest Tecumseh Field, a suite of subsurface maps were constructed. Log calculations used in the subsurface mapping of the Northwest Tecumseh Field are illustrated in Table II.

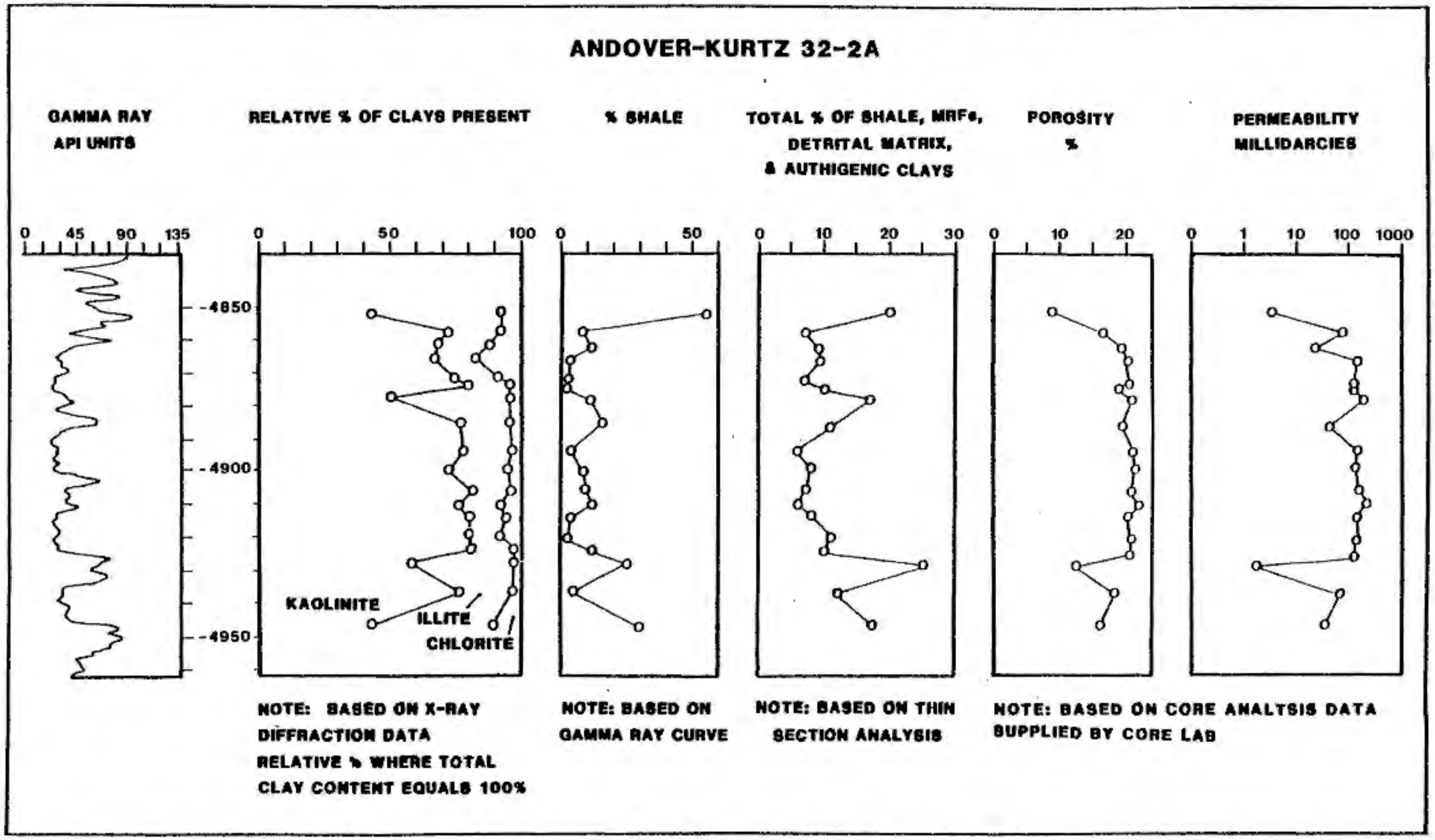


Figure 95. Relationship Between Reservoir Characteristics and Clay Mineralogy in the Core from Andover Oil, Kurtz 32-2A

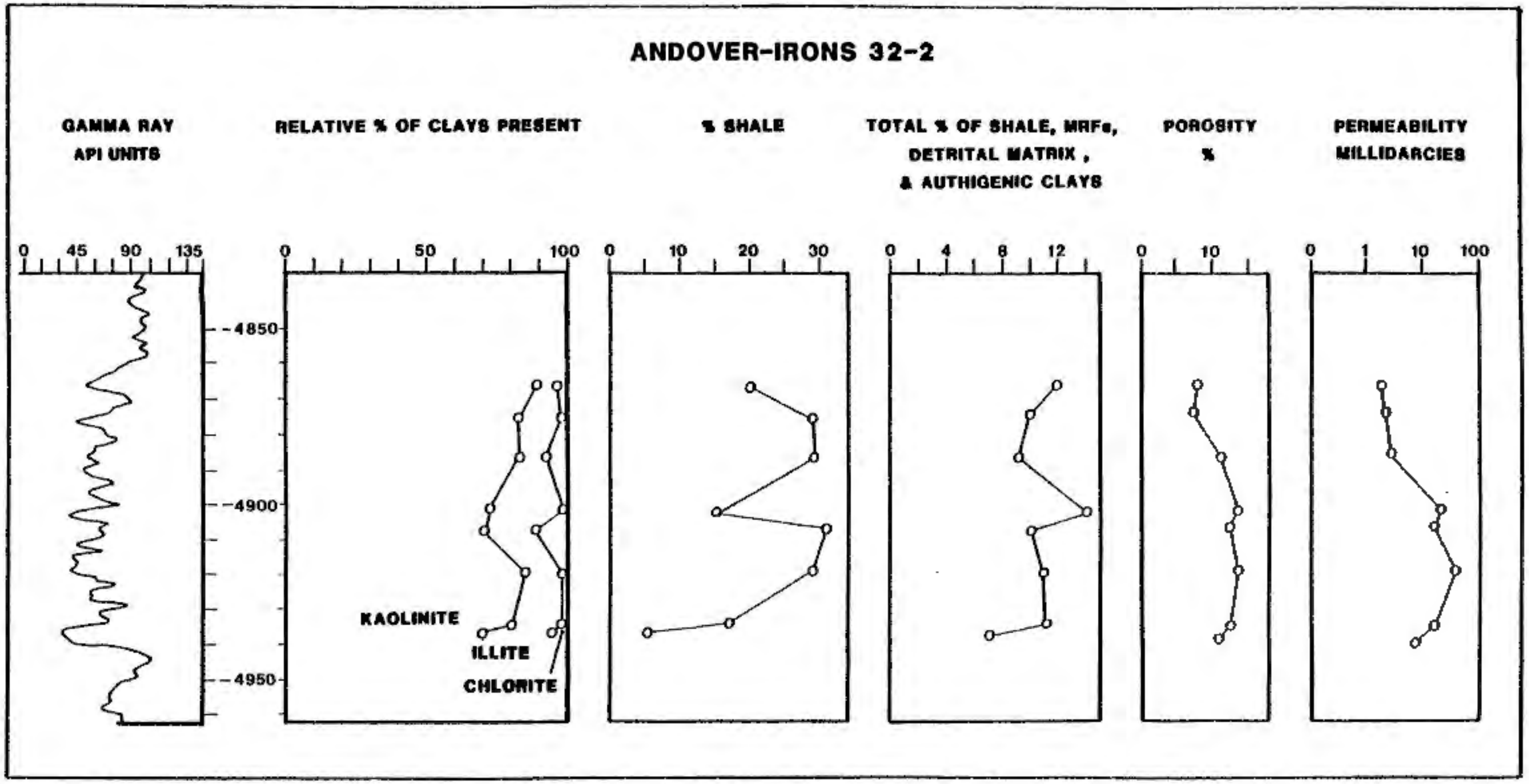


Figure 96. Relationship Between Reservoir Characteristics and Clay Mineralogy in the Core from Andover Oil, Irons 32-2

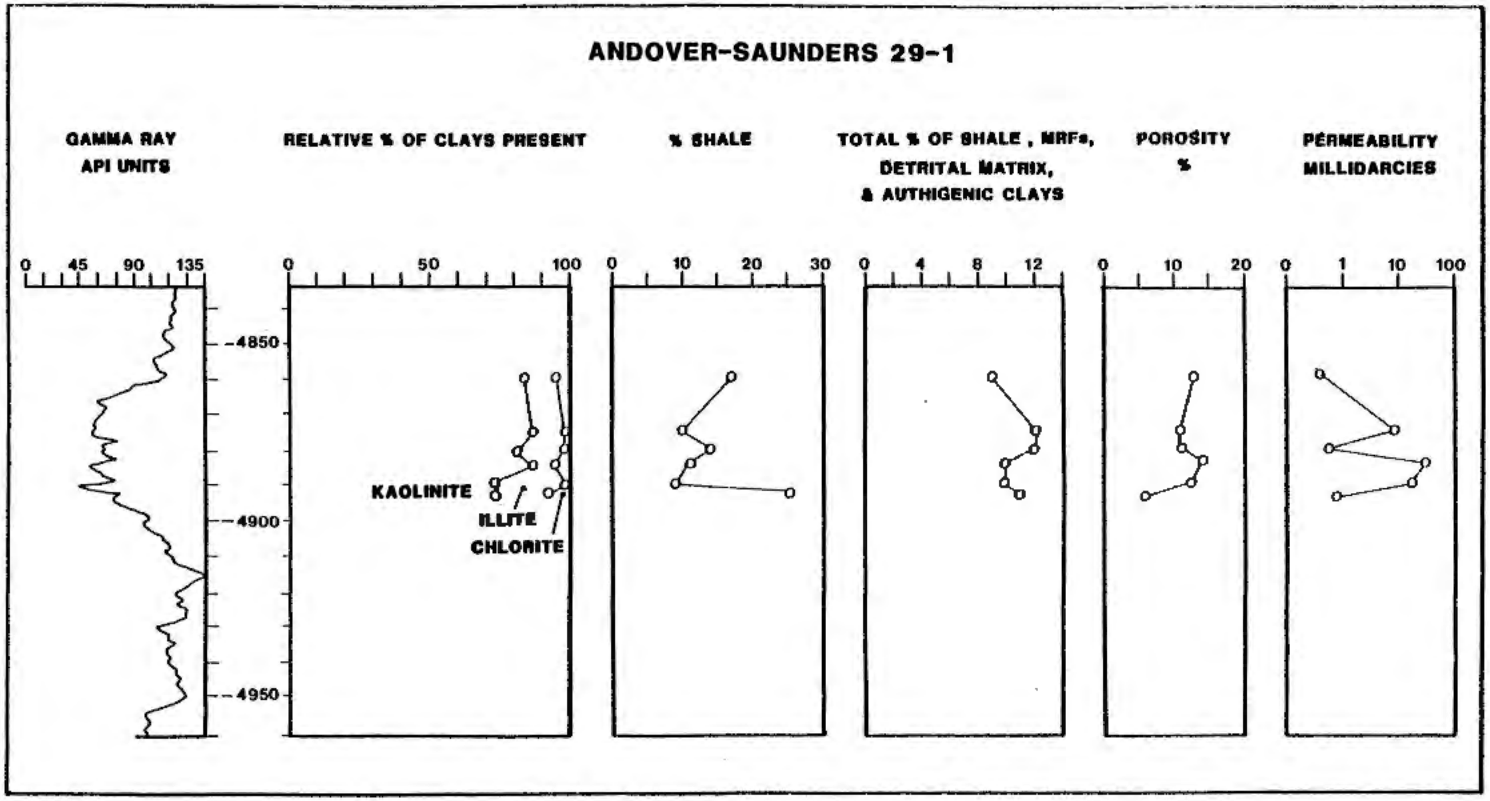


Figure 97. Relationship Between Reservoir Characteristics and Clay Mineralogy in the Core from Andover Oil, Saunders 29-1

TABLE II

LOG CALCULATIONS

Porosity Calculation

$$\text{Neutron-Density Porosity} = \sqrt{\frac{\phi N^2 + \phi D^2}{2}}$$

Where:

ϕN = Neutron porosity
ϕD = Density porosity

(Read straight from combination Neutron-Density Log)

Water Saturation Calculation

$$Sw = \sqrt{\frac{(F)(Rw)}{(Rt)}}$$

$$F = \frac{.62}{\phi^{2.15}}$$

Where:

Sw = Water saturation
F = Formation factor
Rw = Resistivity of formation water (Assumed constant Rw = 0.04 ohm - meters in this study.)
Rt = True resistivity (uninvaded zone, read from deep induction curve)
Oil saturation = 1.0 - Sw

Percent Shale Calculation

$$I(GR) = \frac{GR(Log) - GR(Min)}{GR(Max) - GR(Min)}$$

Where:

I(GR) = Gamma Ray Index
GR(Log) = Gamma Ray reading of formation
GR(Min) = Minimum Gamma Ray (clean sand)
GR(Max) = Maximum Gamma Ray (shale)

Note: Once I(GR) is calculated, Dresser Atlas Chart is used to calculate percent shale. (Asquith, 1982, p. 94)

(From Asquith, 1982)

Structural features in the Northwest Tecumseh Field are illustrated by two structural contour maps (Figures 98 and 99). These maps were constructed using the top of the Verdigris Limestone and the top of the Red Fork Sandstone as mapping planes of reference. The Verdigris Limestone structural geologic map (Figure 98) shows homoclinal westward dip that ranges from 80 to 100 feet per mile. A prominent structural nose is in the southern part of the study area (sections 29 and 32, T.10N., R.3E.). The Red Fork Sandstone structural geologic map (Figure 99) basically is featureless when compared to Verdigris Limestone structure. This probably is due to variations in the thickness and stratigraphic position of the Red Fork Sandstone.

A net-sandstone isolith[4] map of the Red Fork Sandstone (Figure 100) was constructed in the area of the Northwest Tecumseh Field. This map shows evidence of a well-developed distributary channel that trended southward. Two major channels, displaying a bifurcating pattern, are separated by an interdistributary bay.

The trends developed in the porosity map (Figure 101) follow the trends of the distributary channel. There is a

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[4]As illustrated in Cross sections B-B' (Plate III) and F-F' (Plate VII), stacking of the Lower Skinner Sandstone and Red Fork Sandstone combine as the reservoir rock in the northern part of the Northwest Tecumseh Field (Sections 8, 9, 16, 17, 18, 19, 20, 21). Therefore, net-sandstone refers to the reservoir sandstone in the Northwest Tecumseh Field. In the southern part of the Northwest Tecumseh Field the reservoir rock is the Red Fork Sandstone, but in the northern part of the Field the reservoir rock is both the Lower Skinner Sandstone and the Red Fork Sandstone.

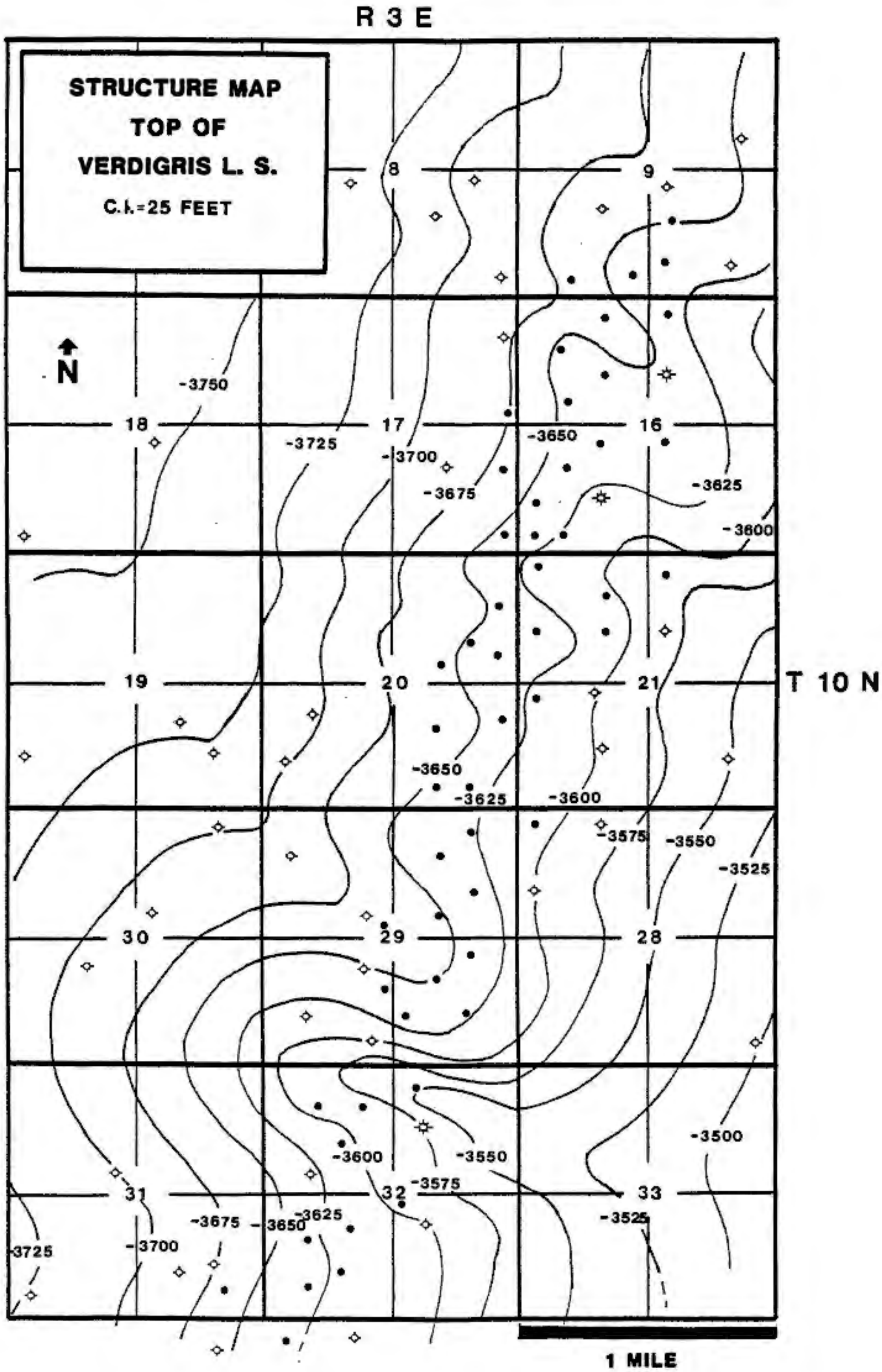

Figure 98. Northwest Tecumseh Field, Structural Geologic Map, Top of Verdigris Limestone

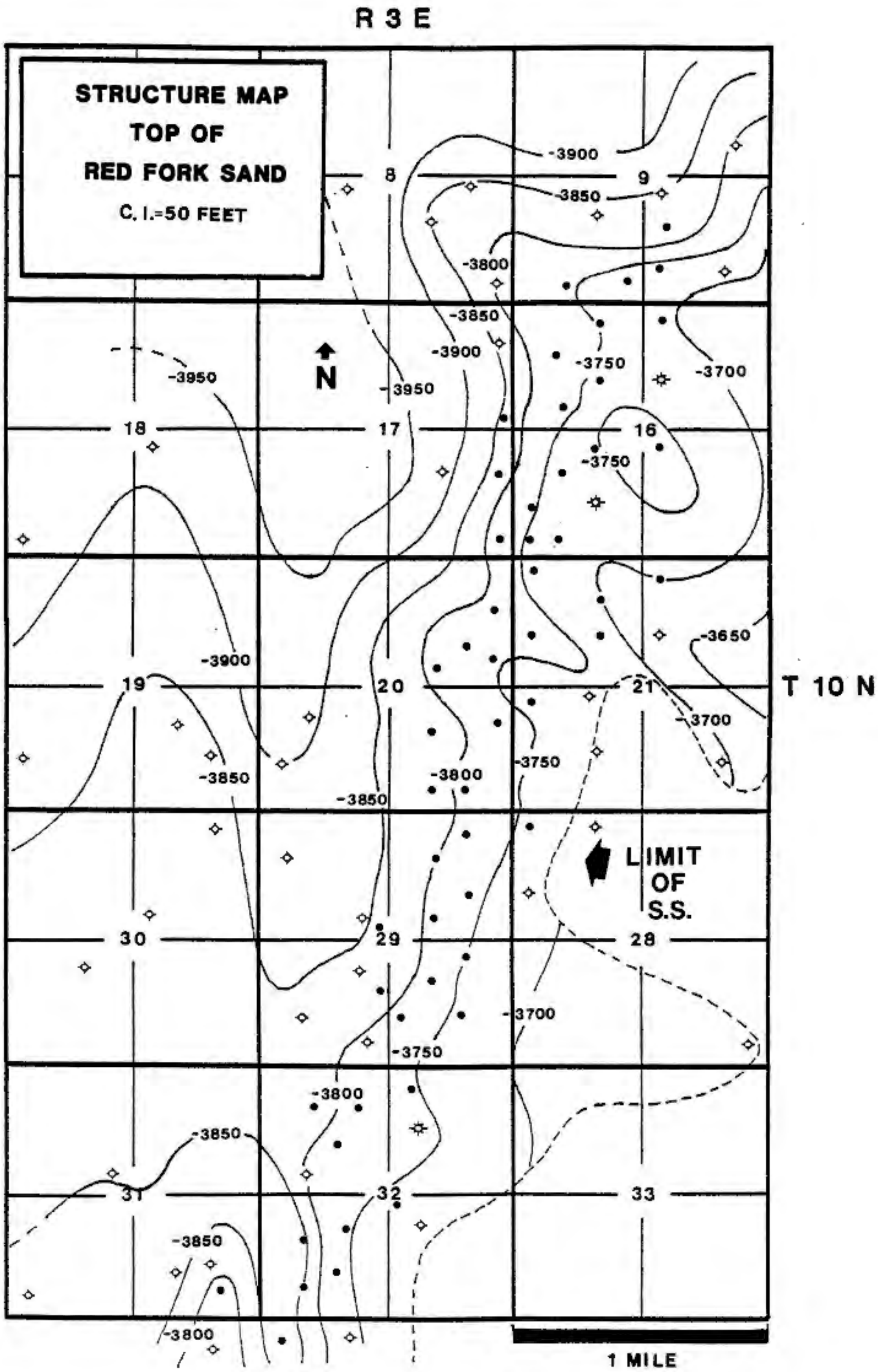

Figure 99. Northwest Tecumseh Field,
Structural Geologic Map,
Top of Red Fork Sandstone

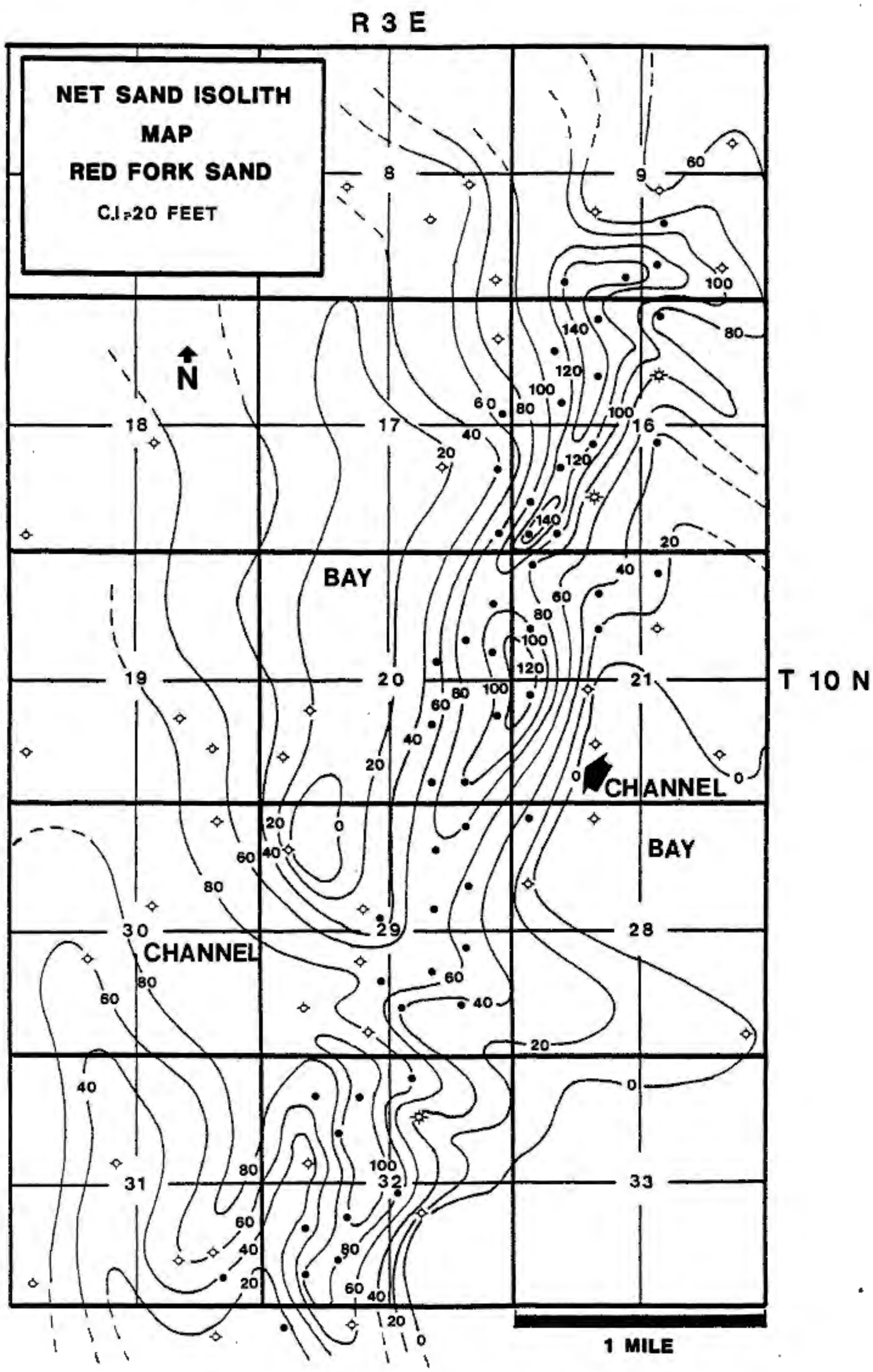

Figure 100. Northwest Tecumseh Field,
Net-sandstone Isolith Map,
Red Fork Sandstone

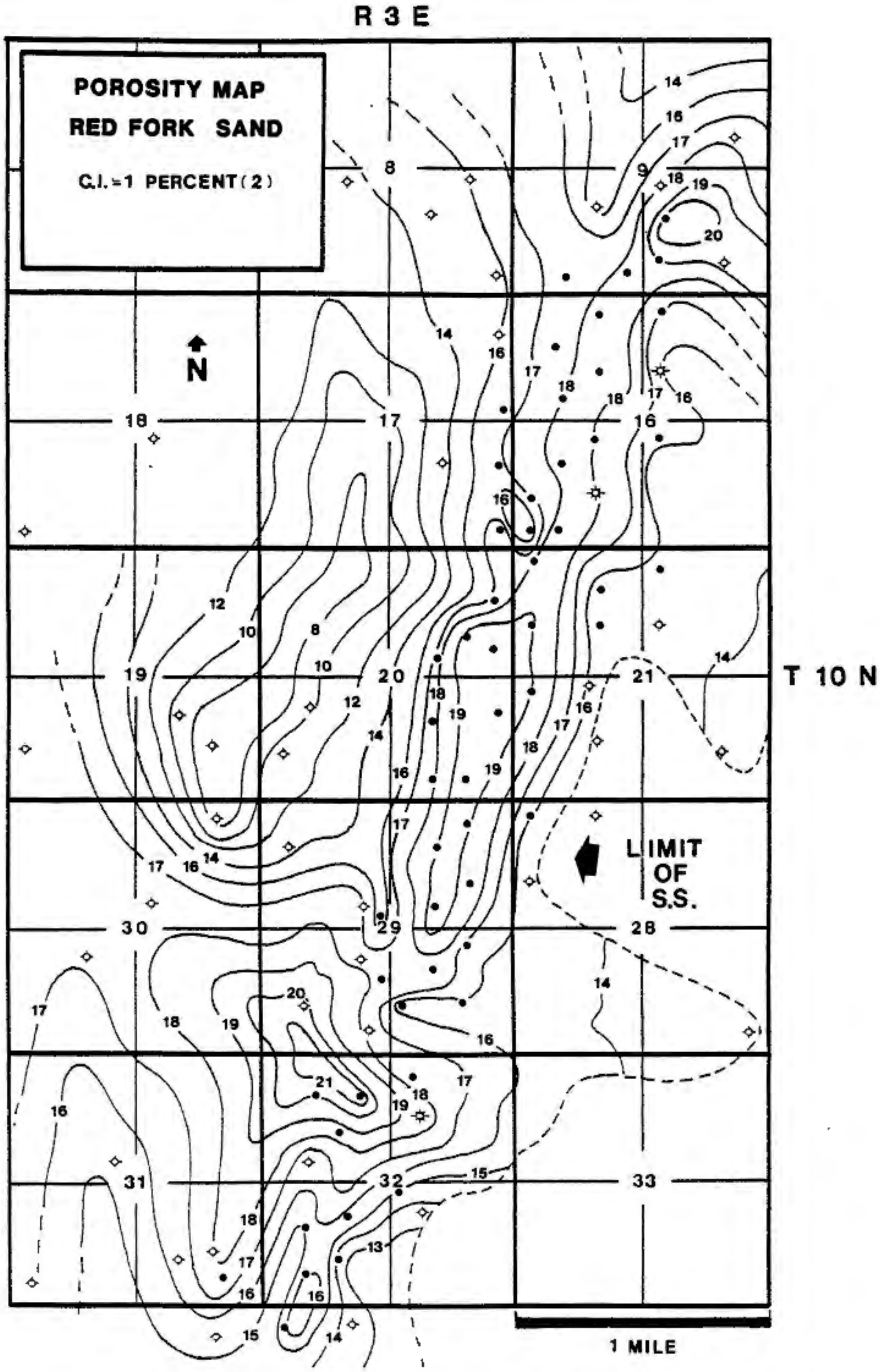

Figure 101. Northwest Tecumseh Field,
Porosity Map,
Red Fork Sandstone
(Porosity Map is Based on
Average Porosity per Well)

direct relationship between porosity and reservoir thickness. The thicker the sandstone reservoir, the greater the porosity. This greater secondary porosity probably is developed because of greater volume and rate of fluid movement through the reservoir prior to emplacement of hydrocarbons. Permeability trends probably also follow the trends established by the porosity map.

Trends shown in the percent-shale map (Figure 102), as would be predicted, follow the depositional trends of sandstone. The lower the percent shale, the thicker the sandstone deposited. These trends can be important when determining what clays are predominant in a certain area of the reservoir. Because this map is based on data from gamma-ray logs, which are sensitive to illite, areas of greater percent shale will indicate areas containing more illite.

Trends shown by the initial production map (Figure 103) illustrate the mechanism that resulted in entrapment of oil and gas in the Northwest Tecumseh Field. Initial production values are higher in the thickest part of the distributary channel where secondary porosity is well developed and where percent shale is low. Oil migrated updip (from the west and south) and was trapped in this thick Red Fork channel. Therefore, structural geology plays an important role in the updip migration of oil, whereas siltstones and shale present to the east of the main channel (interdistributary bay) stratigraphically trapped the hydrocarbons.

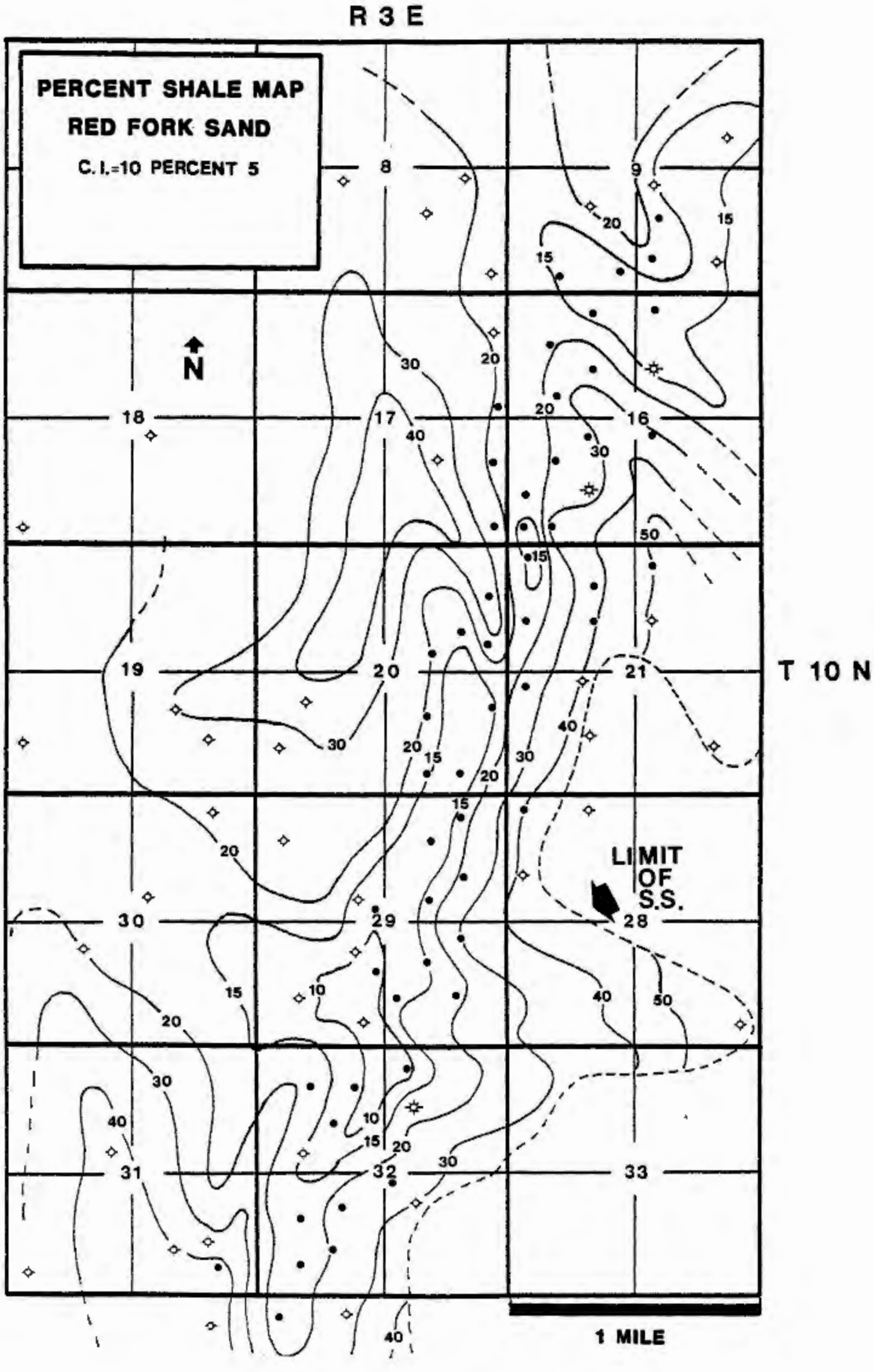

Figure 102. Northwest Tecumseh Field, Percent Shale Map, Red Fork Sandstone

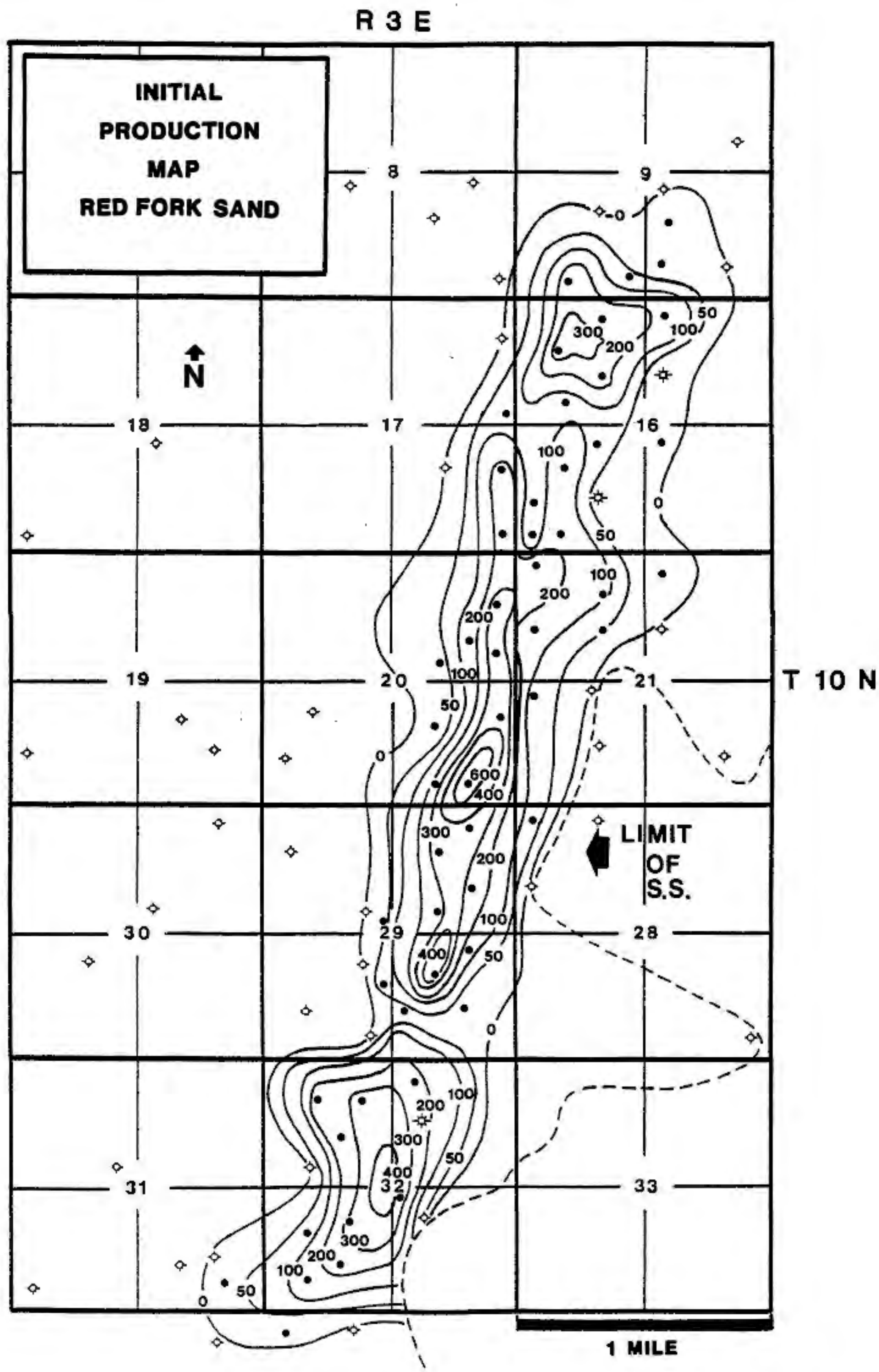

Figure 103. Northwest Tecumseh Field, Initial Production Map, Red Fork Sandstone (Contour Interval = 50, 100, or 200 B.O./day)

In the extreme northern part of the field, updip termination of Lower Skinner Sandstone and upper part of Red Fork Sandstone stratigraphically trapped the hydrocarbons.

Trends established in the initial production map follow the trends of oil saturation (Figure 104) and consequently the major sandstone trend.

"True" resistivity (Figure 105) basically follows the trends established in the other maps constructed. The greater the oil saturation, the greater the resistivity, initial production, porosity, and sandstone thickness, and the lesser the percent shale.

Conclusion from Maps

Construction of the suite of maps helped to define and illustrate reservoir trends and characteristics in the Northwest Tecumseh Field. The development of diagenetic secondary porosity and consequent permeability in the Red Fork distributary channel, followed by the migration of hydrocarbons into a structural-stratigraphic trap, have provided the appropriate reservoir characteristics for the production of oil and gas in the Northwest Tecumseh Field. A Red Fork Sandstone prospect in the Northwest Tecumseh Field is illustrated in Figure 106.

North Searight Field

The North Searight Field is located in Sections 12 and 13, T.10N., R.5E., and in Sections 7 and 18, T.10N.,

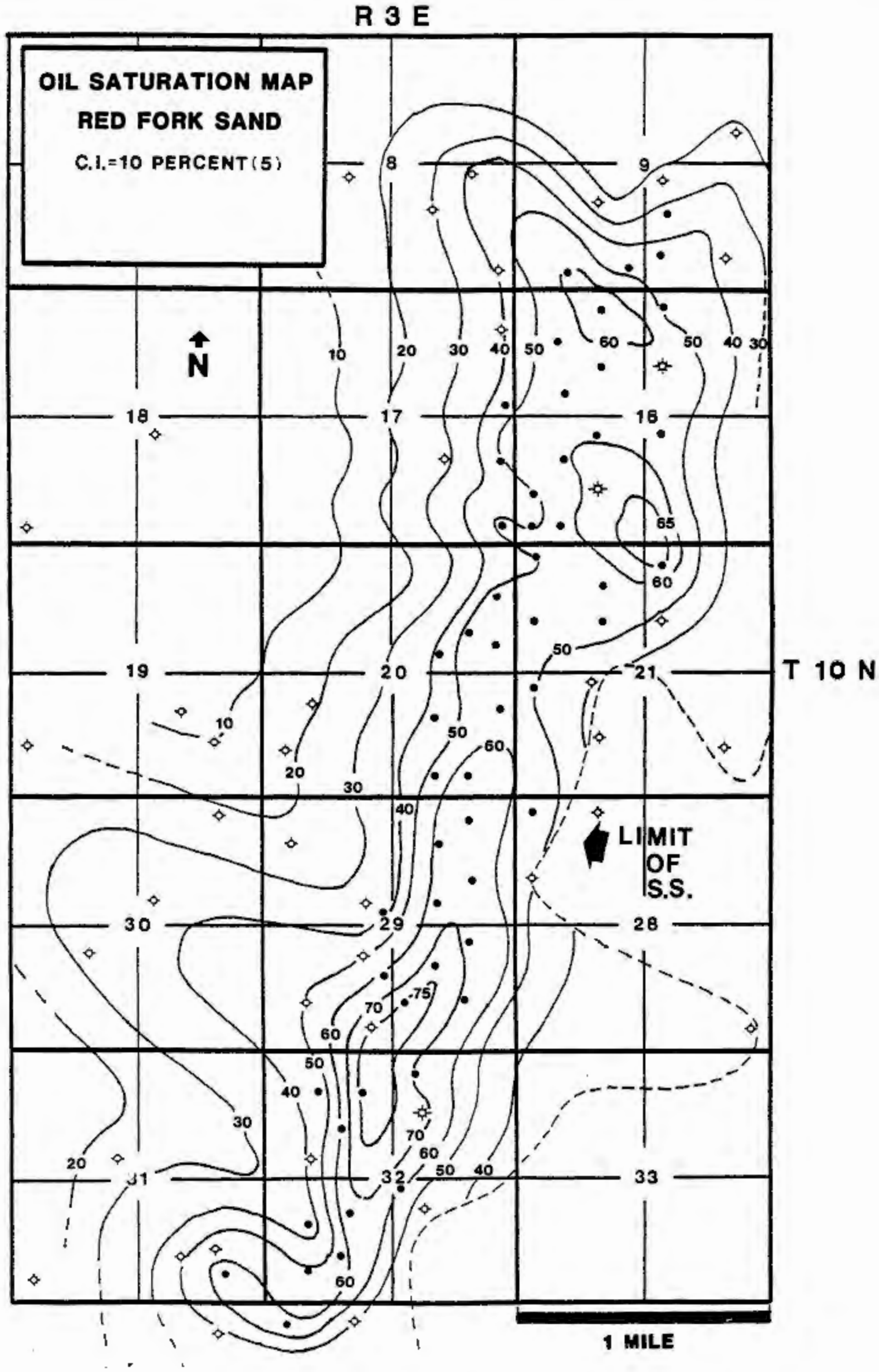

Figure 104. Northwest Tecumseh Field,
Oil-saturation Map,
Red Fork Sandstone

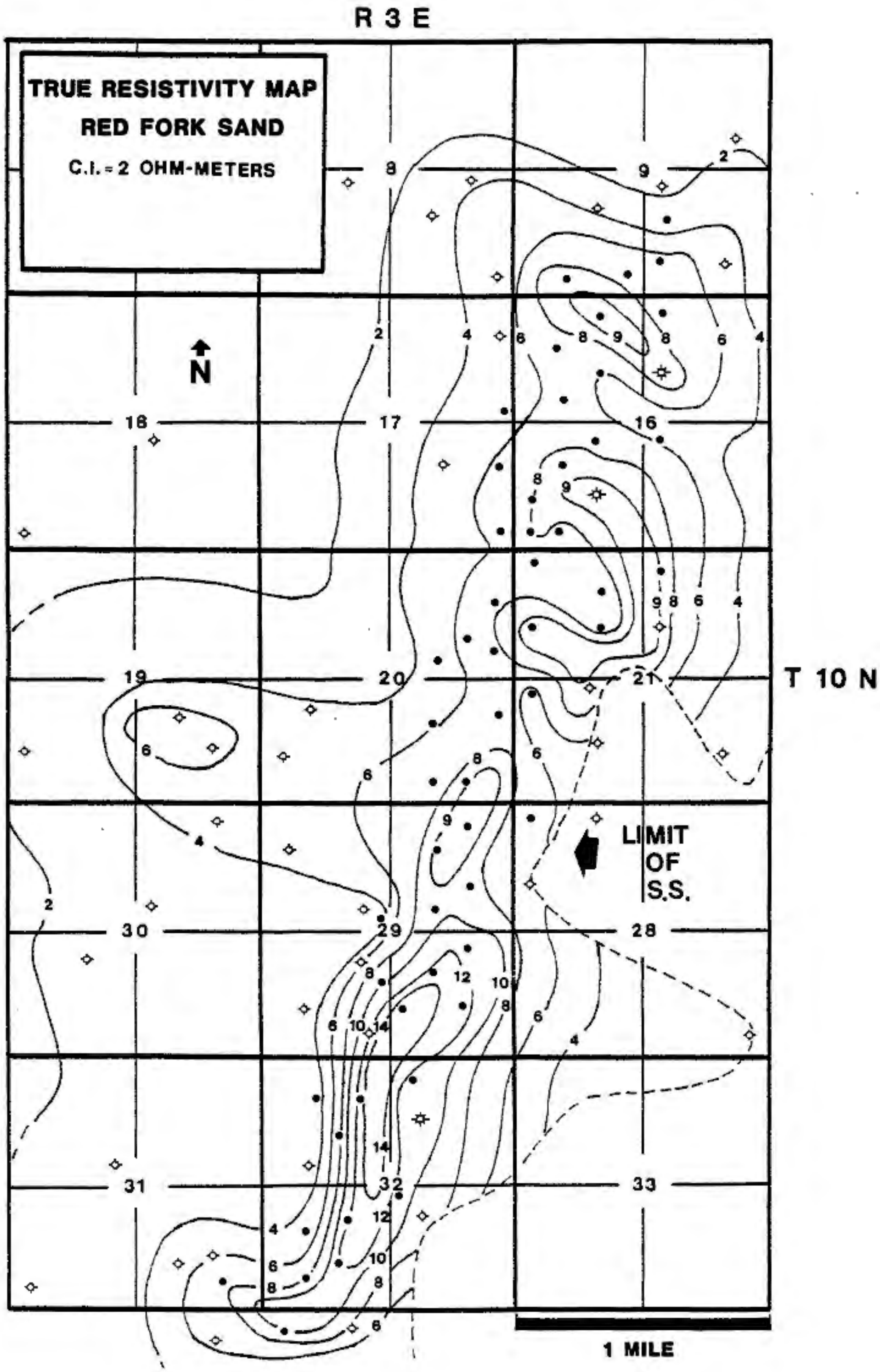

Figure 105. Northwest Tecumseh Field, "True"-resistivity Map, Red Fork Sandstone

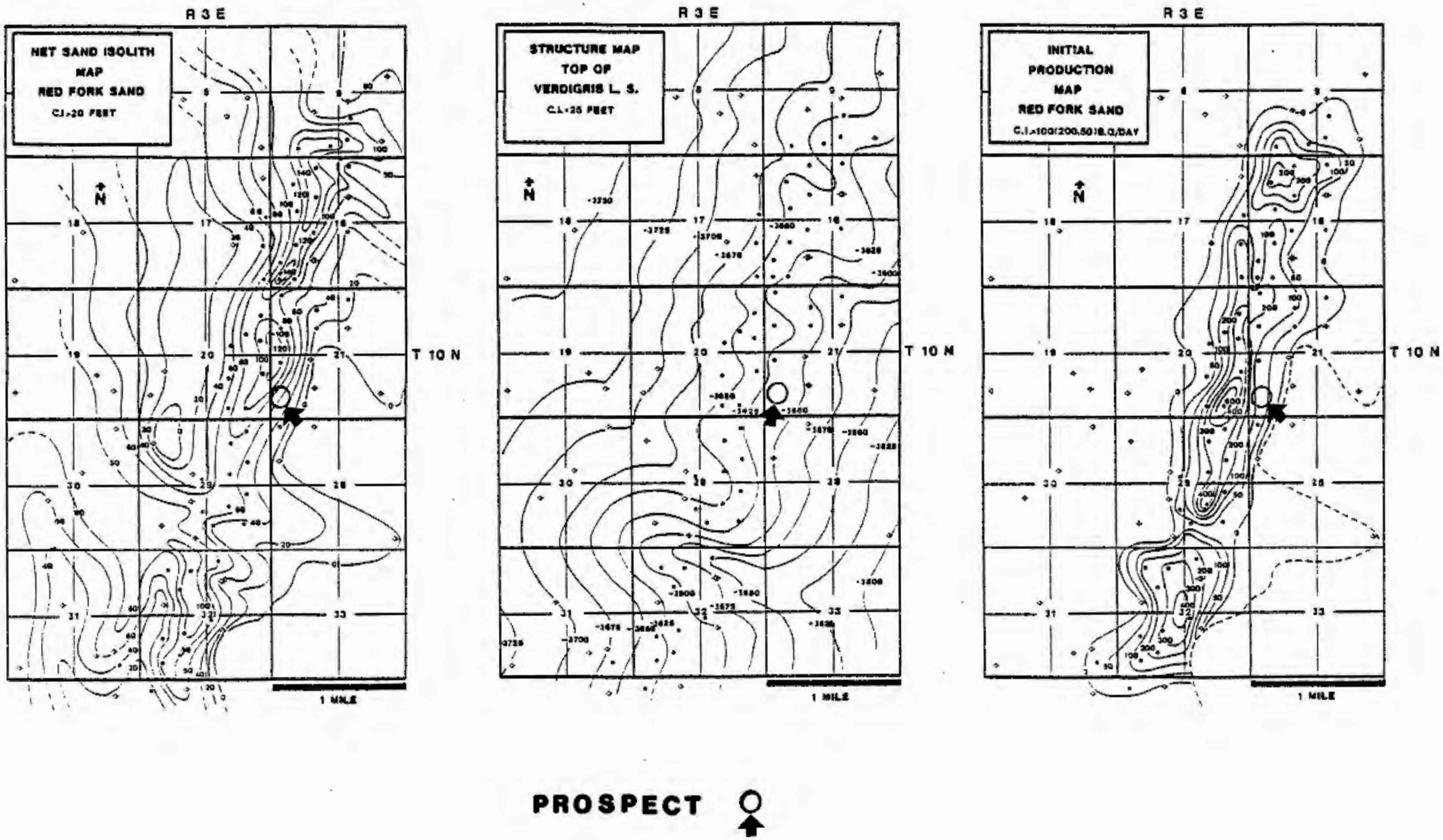

Figure 106. Red Fork Sandstone Prospect in the Northwest Tecumseh Field

R.6E.. Cumulative production of the Red Fork Sandstone in the North Searight Field, as of June 1984, was 278,689 barrels of oil from 23 producing wells.

Reservoir Trends

Structural features in the North Searight Field are illustrated by a structural contour map, which was constructed using the top of the Red Fork Sandstone as a mapping datum. The Red Fork Sandstone structural geologic map (Figure 107) shows homoclinal westward dip that ranges from 80 to 100 feet per mile. Minor anticlinal noses and synclines are the principal structural features. A major anticlinal feature trends northwestward from NW, Sec. 18, T.10N., R.6E. to NW, Sec. 12, T.10N., R.5E..

The Red Fork Sandstone isolith map (Figure 108) shows a well-developed major sandstone trend oriented primarily from north to south. The Red Fork Sandstone in the North Searight Field was deposited probably in a deltaic distributary channel. An interdistributary bay deposit is located to the east and northeast of this major sandstone trend.

The trends developed in the initial production map (Figure 109) illustrate the mechanism which resulted in entrapment of oil in the North Searight Field. Oil migrated updip (from west) and was trapped in this thick Red Fork channel by the northwest to southeast trending anticlinal

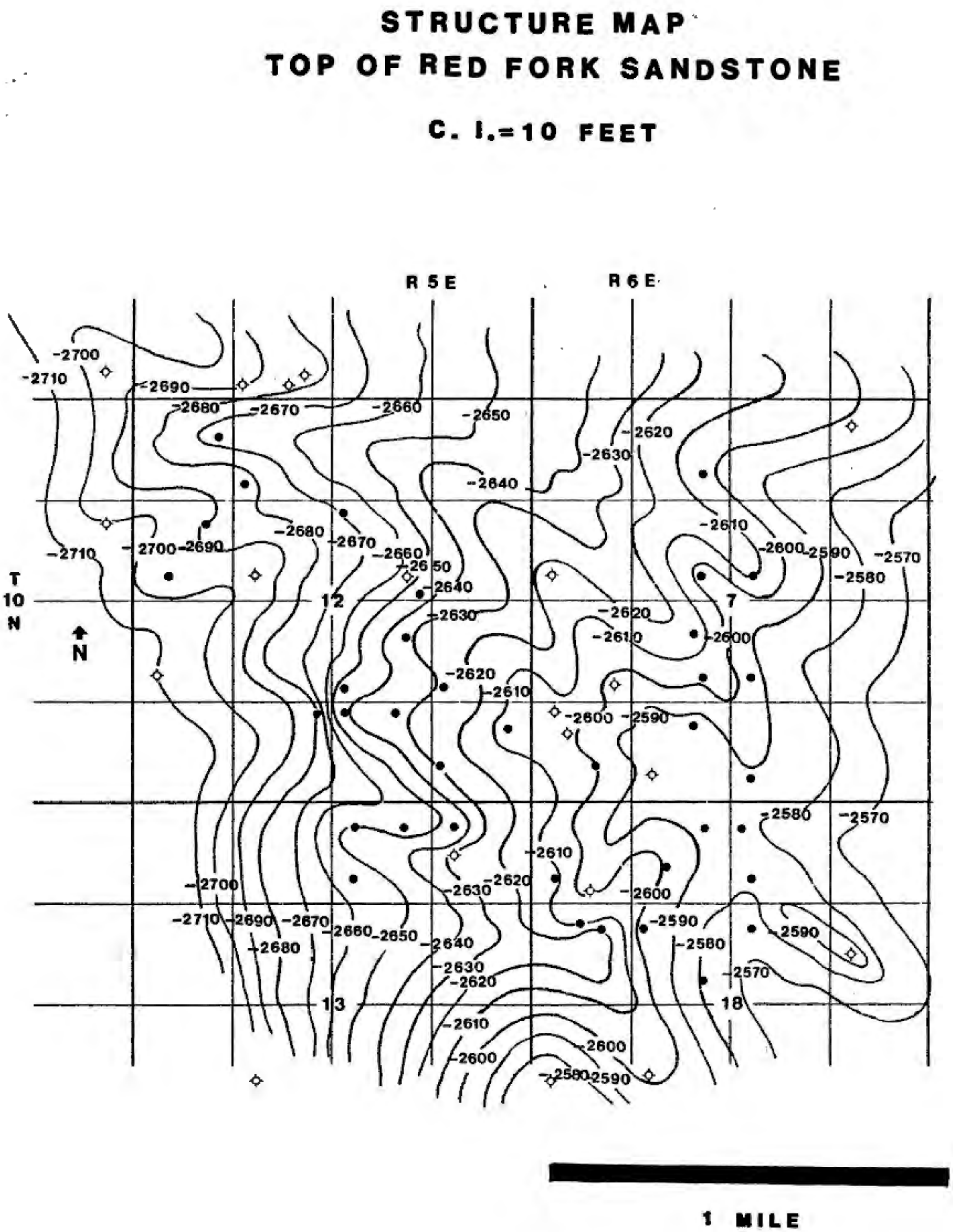

Figure 107. North Searight Field, Structural Geologic Map, Top of Red Fork Sandstone

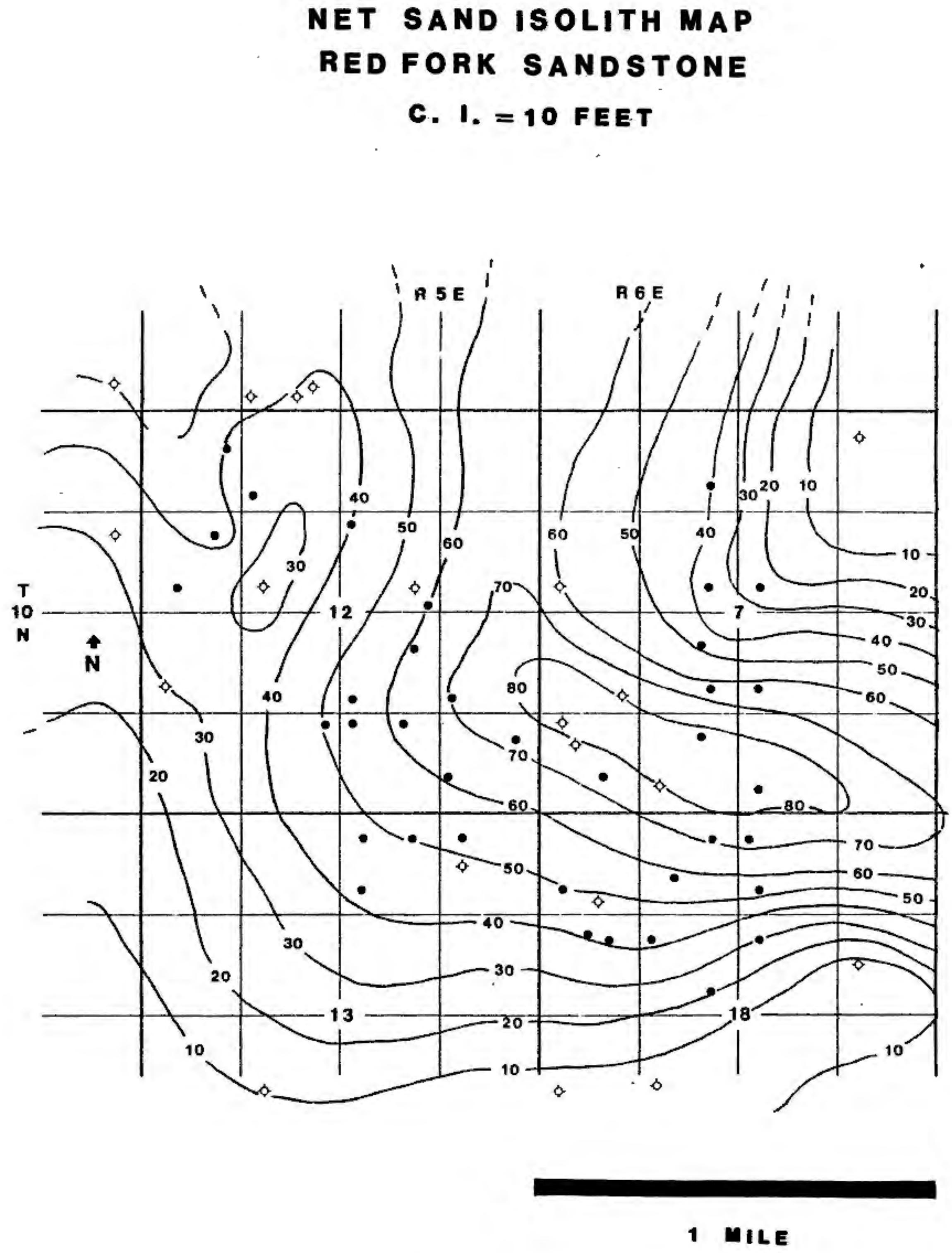

Figure 108. North Searight Field, Net-sandstone Isolith Map, Red Fork Sandstone

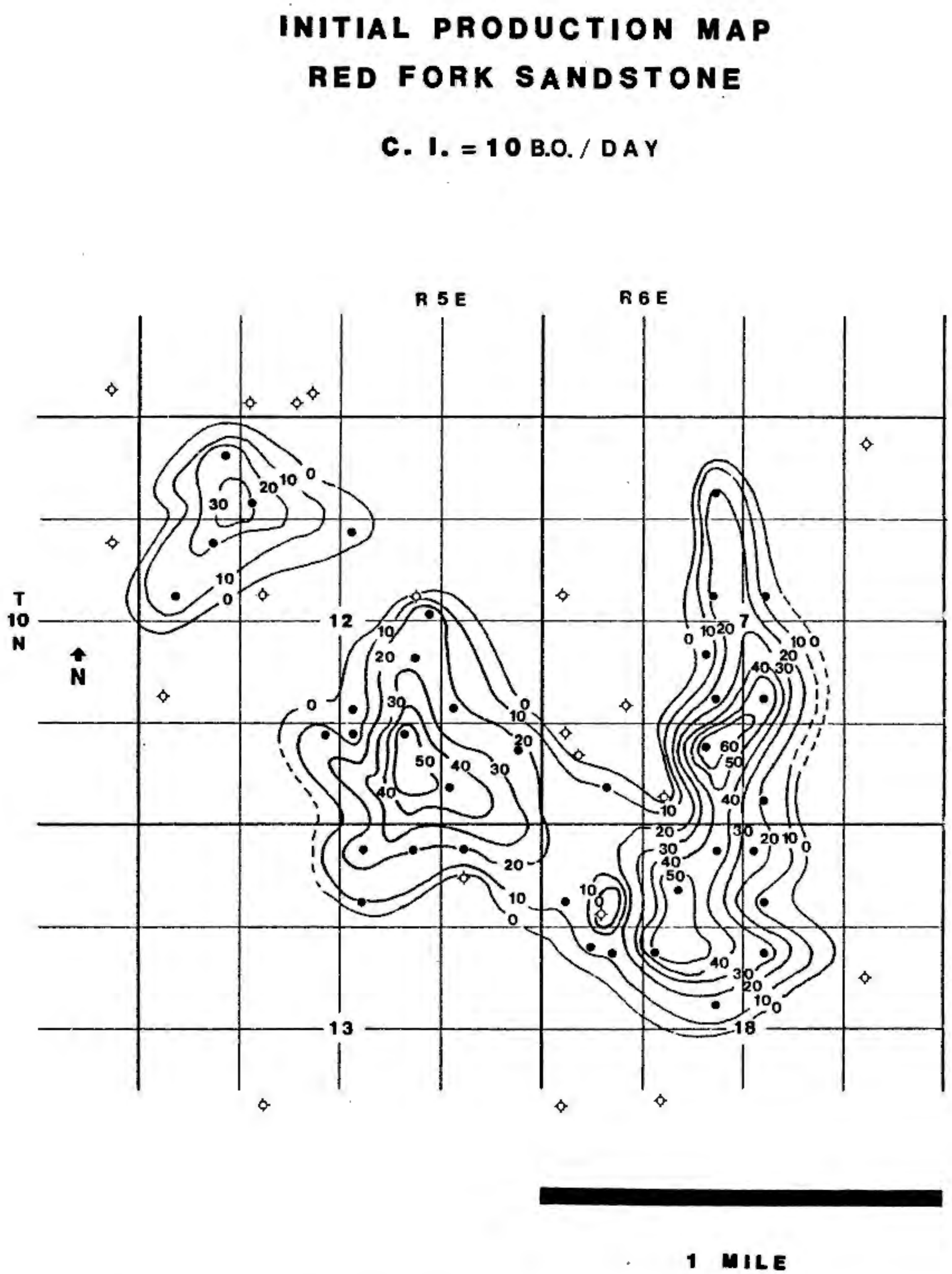

Figure 109. North Searight Field, Initial Production Map, Red Fork Sandstone

feature discussed above. Minor anticlinal features and siltstones and shales to the east (interdistributary bay) also have influenced entrapment of oil. Therefore, the Red Fork Sandstone reservoir in the North Searight Field is a structural-stratigraphic trap. Red Fork Sandstone prospects in the North Searight Field are shown in Figure 110.

Future Exploration

Prospective traps were delineated through the use of structural and stratigraphic criteria similar to trapping relationships observed in the Northwest Tecumseh Field and the North Searight Field. In the study area, several areas show evidence of possible structural "highs" in association with linear trends of Red Fork sandstone. Most of these areas already produce from the Red Fork Sandstone. In Sec. 29 and 32, T.11N., R.5E., a possible structural high in association with a major Red Fork Sandstone trend has not been tested. Figure 111 illustrates a prospective structural-stratigraphic trap which might produce from the Red Fork Sandstone.

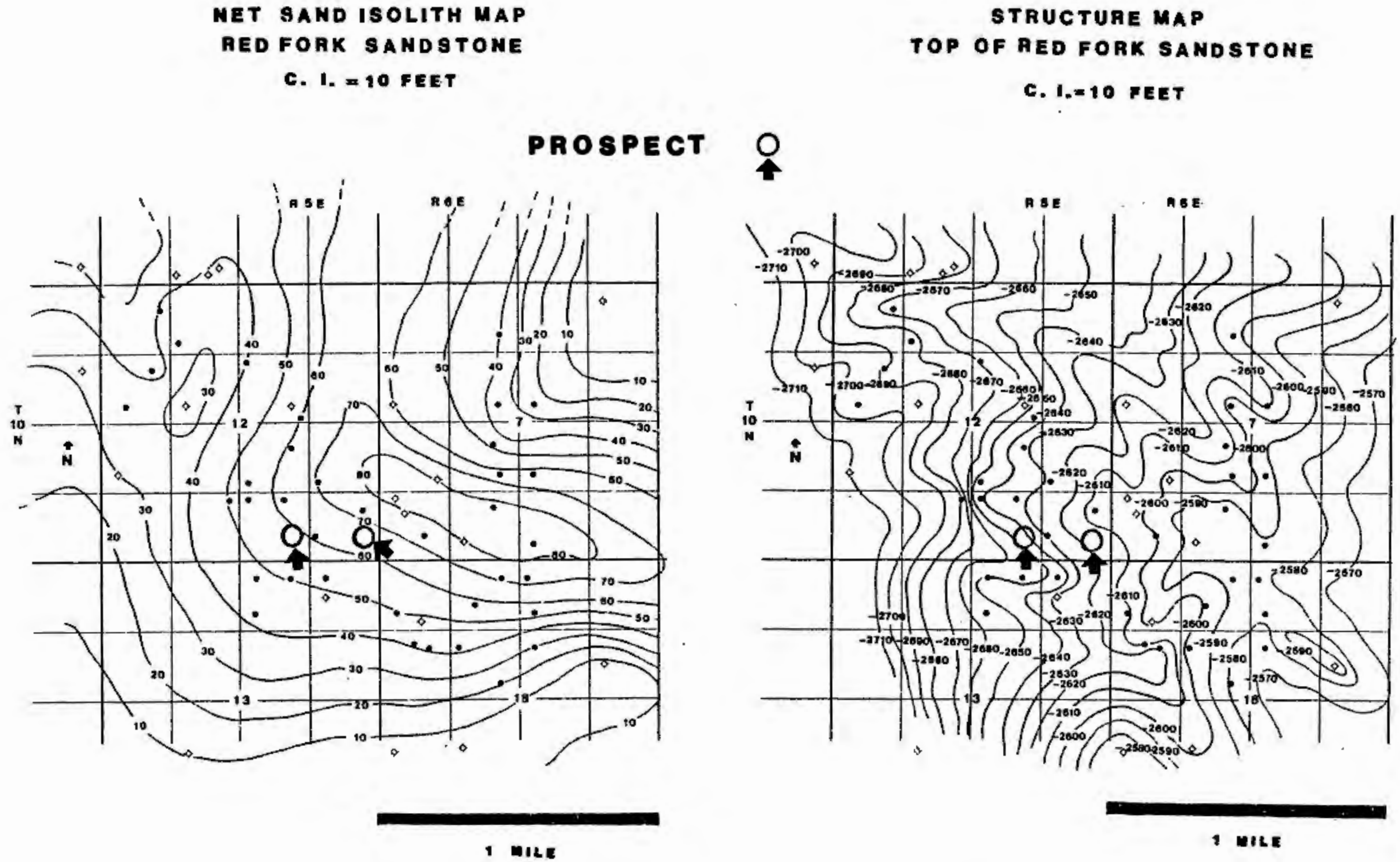

Figure 110. Red Fork Sandstone Prospects in the North Searight Field

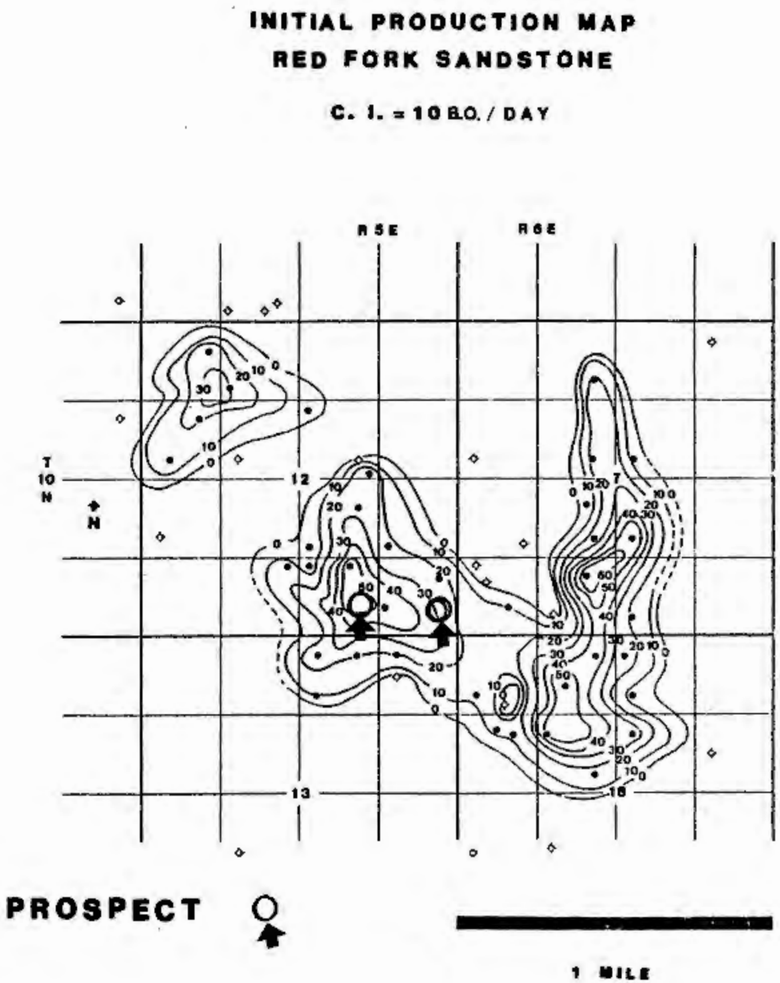

Figure 110. (Continued)

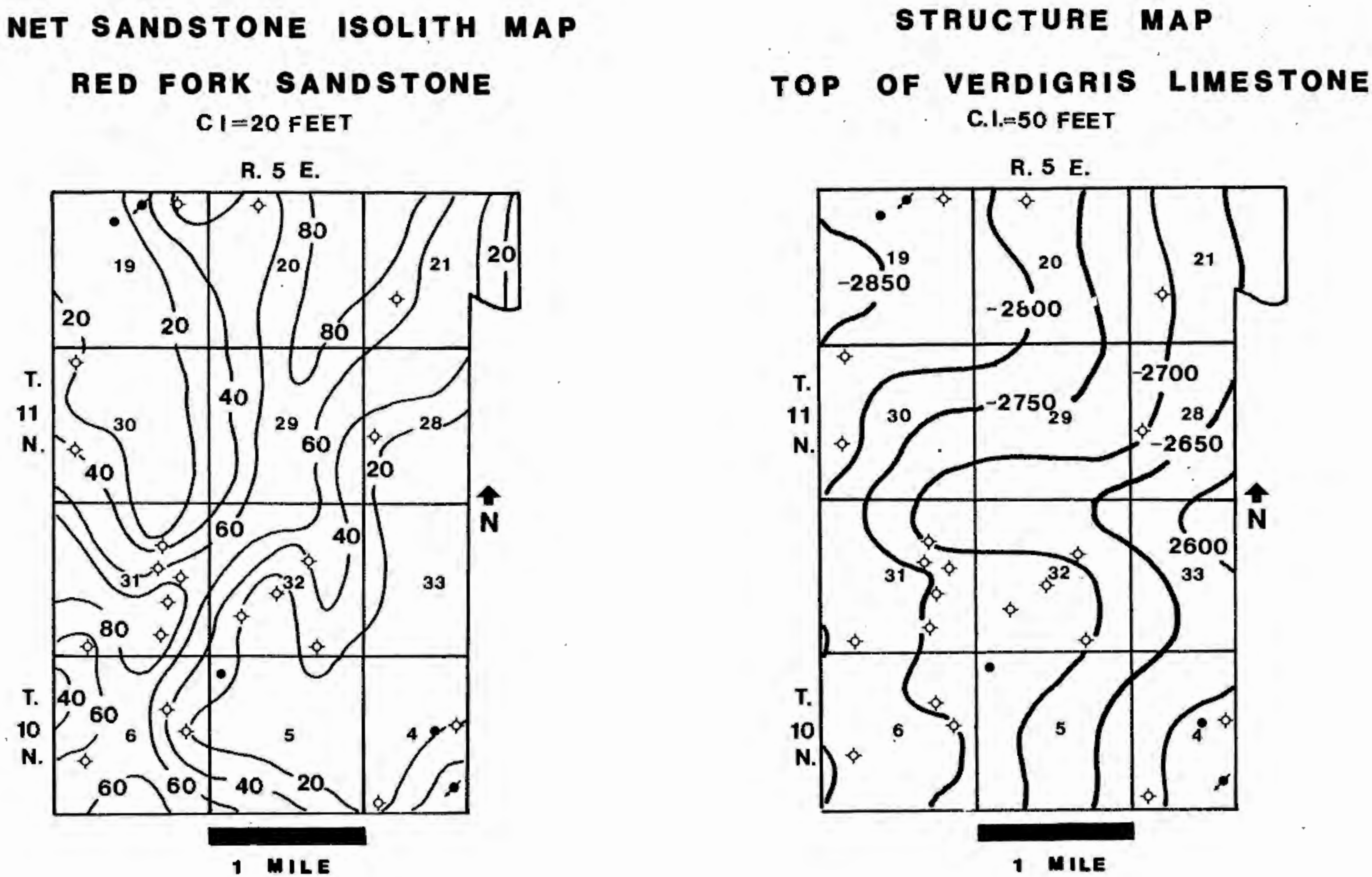

Figure 111. Red Fork Sandstone Prospect in the Study Area.

CHAPTER XI

CONCLUSIONS

The following conclusions have been made from evidence set out in this study:

1. The study area is located on the southermost portion of the stable Central Oklahoma or "Cherokee" Platform. Major tectonic features include the Seminole Uplift in the eastern part of the study area, the Nemaha Uplift to the west, the Pauls Valley Uplift to the south, and the Arkoma Basin to the southeast.

2. Major structural features in the study area, as illustrated by the contour map of Verdigris Limestone, consist of a) a homoclinal westward dip that ranges from 80 to 100 feet per mile, b) anticlinal noses and synclines, and c) the north-northeast-trending Wilzetta Fault, which bounds the west flank of the Seminole Uplift.

3. The Red Fork Sandstone format (Krebs Group, Desmoinesian Series, Pennsylvanian System) is defined as the interval between the base of the Pink Limestone and the top of the Inola Limestone.

4. In parts of the study area, the subsurface equivalent of the Red Fork Sandstone is the Earlsboro Sandstone,

which name in the past has been applied incorrectly to both the Bartlesville and Lower Skinner Sandstones.

5. Evidence from previous investigations, distribution of the sandstone as based on subsurface maps and stratigraphic cross sections, internal sandstone features observed in cores, and depositional and facies models indicate that the Red Fork Sandstone probably was deposited in a deltaic distributary channel environment in the study area.

6. Red Fork Sandstone channel-fill deposits are illustrated by blocky or bell-shaped log patterns with characteristic sharp basal contacts and stacking of individual channels. Nonchannel and/or overbank (bay-fill) deposits have characteristic sharp basal contacts and gradational upper contacts which are illustrated by a poorly developed or serrated log pattern.

7. Based on sandstone trends illustrated by the net-sandstone isolith map, and on thinning of the Red Fork Sandstone interval to the south, illustrated by stratigraphic cross sections, it seems highly probable that the deltaic distributary channels in which the Red Fork Sandstone was deposited had a source to the north of the study area.

8. In the study area, the Red Fork Sandstone is a very fine to fine grained, moderately to well sorted, subrounded, submature to mature, sublitharenite to litharenite.

9. Detrital constituents of the Red Fork Sandstone are monocrystalline and polycrystalline quartz, feldspars, metamorphic-rock fragments, shale fragments, chert, muscovite, detrital matrix, zircon, rutile, chlorite, glauconite, and organic matter.

10. Authigenic constituents are dolomite, calcite, siderite, quartz overgrowths, kaolinite, illite, chlorite, hematite, pyrite, and leucoxene.

11. Two major diagenetic processes have changed the morphology and mineral composition of the Red Fork Sandstone: mechanical processes resulting in compaction of rock fragments to produce a pseudomatrix, and chemical processes such as dissolution, precipitation, alteration, and replacement.

12. The diagenetic history of Red Fork sandstone can be summarized as follows: (a) precipitation of syntaxial quartz overgrowths followed by precipitation of calcite and siderite cement, (b) dissolution of calcite cement, feldspars, rock fragments, and detrital matrix and precipitation of kaolinite, chlorite and illite, (c) dissolution of quartz, precipitation of dolomite cement, and dolomitization of calcite cement, (d) oil migration, precipitation of pyrite, and alteration of pyrite to hematite.

13. In the Red Fork Sandstone, primary porosity (0 to 3%) is of minor importance in development of effective porosity. Secondary porosity ranges from 3 to 27 percent

in thin sections and averages 16 percent. Secondary porosity consists of partial dissolution, grain molds, oversized pores, corroded grains, honeycombed grains, fractured grains, and microporosity associated with authigenic clays.

14. In the Andover Oil, Kurtz 32-2A core, decrease in the negative deflection of the SP log (millivolts) and increase in the API units of the gamma ray log indicate reduction of the effective porosity by illite. As the percentage of illite and rock fragments increase, porosity from the neutron-density log decreases, due to the relatively large matrix density of illite and the hydrogen content of illitic clays.

15. The Red Fork Sandstone is productive in more than 400 wells in 35 fields in the study area.

16. Reservoir quality of the Red Fork Sandstone has been affected severely by diagenetic processes. Of course, the two most important reservoir characteristics affected are porosity and permeability. Diagenetic minerals such as cements and clays have a major influence on porosity, permeability and water saturation, in addition to drilling fluids, stimulation fluids, and recovery fluids used in well completion activities (Almon and Davies, 1978).

17. In the Northwest Tecumseh Field, initial production values are greater in the thickest part of the distributary channel where secondary porosity is well developed and where percent of shale is small. Oil migrated

updip (from the west and south) and was trapped in a thick Red Fork channel. Structural geology is important in the updip migration of oil but siltstones and shales present to the east of the main channel (interdistributary bay) stratigraphically trapped the hydrocarbons. The development of diagenetic secondary porosity and subsequent permeability in the Red Fork distributary channel in conjunction with a structural-stratigraphic trapping mechanism have provided the appropriate reservoir characteristics for the production of oil and gas in the Northwest Tecumseh Field.

18. In the North Searight Field, oil migrated updip (from west) and was trapped in a thick Red Fork channel by a northwest-trending anticlinal feature. Minor anticlinal features and siltstones and shales to the east of the main channel also resulted in entrapment of oil.

19. Exploration for prospective traps in the Red Fork Sandstone should be delineated through the use of structural and stratigraphic criteria similar to trapping relationships observed from the Northwest Tecumseh Field and the North Searight Field.

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VITA

William Lewis Tate

Candidate for the Degree of

Master of Science

Thesis: THE DEPOSITIONAL ENVIRONMENT, PETROLOGY, DIAGENESIS, AND PETROLEUM GEOLOGY OF THE RED FORK SANDSTONE IN CENTRAL OKLAHOMA

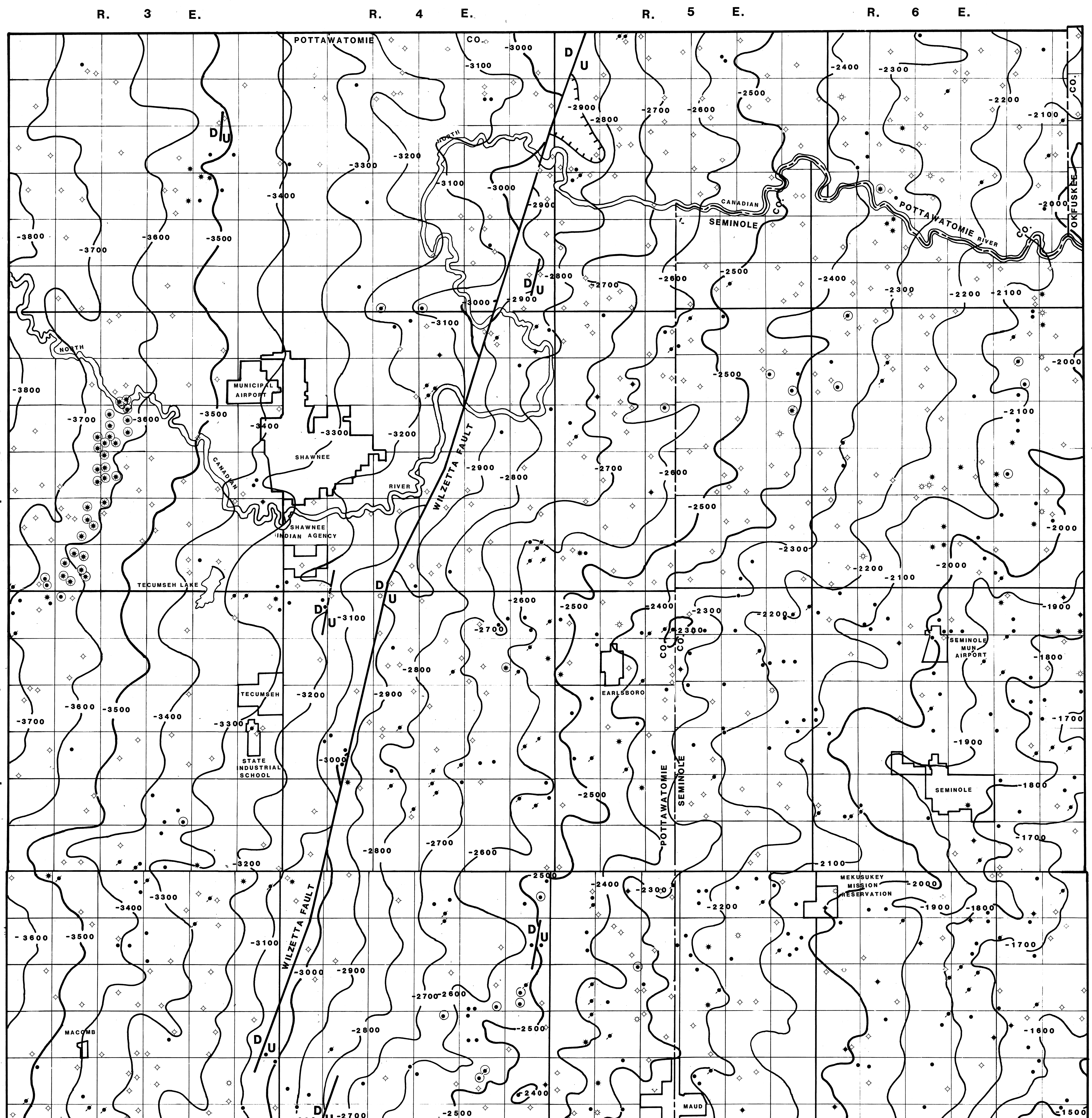
Major Field: Geology

Biographical:

Personal Data: Born in St. Louis, Missouri, April 17, 1960, the son of William F. and Hattie V. Tate.

Education: Received Bachelor of Science degree in Geology, December, 1982, from Oklahoma State University; completed requirements for the Master of Science degree at Oklahoma State University in May, 1985.

Professional Experience: Geologist, M & S Oil Company, summer 1983; Research Assistant, Department of Geology, Oklahoma State University, 1983-1985.



LEGEND

DRY HOLE	GAS WELL
OIL WELL	OIL & GAS WELL
ABANDONED OIL WELL	ABANDONED GAS WELL
RED FORK PRODUCER	INJECTION WELL

0 1/2 1 2 3

SCALE IN MILES

CONTOUR INTERVAL : 100 FEET

N

PLATE I

STRUCTURAL CONTOUR MAP

TOP OF VERDIGRIS LIMESTONE

WILLIAM LEWIS TATE , 1985

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PLATE II

EAST - WEST STRATIGRAPHIC CROSS SECTION

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HORIZONTAL SCALE: 1 INCH = 1/2 MILE

VERTICAL SCALE: 100' – 0'

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PLATE III

EAST - WEST STRATIGRAPHIC CROSS SECTION

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Thesis 1985

C-C′

PLATE IV

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EAST - WEST STRATIGRAPHIC CROSS SECTION

HORIZONTAL SCALE : 1 INCH = 1/2 MILE

VERTICAL SCALE: 100′ – 0′

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PLATE V

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EAST - WEST STRATIGRAPHIC CROSS SECTION

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PLATE VI

EAST - WEST STRATIGRAPHIC CROSS SECTION

HORIZONTAL SCALE: 1 INCH = 1/2 MILE

VERTICAL SCALE: 100′ – 0′

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PLATE VII

NORTH - SOUTH STRATIGRAPHIC CROSS SECTION

HORIZONTAL SCALE : 1 INCH = 1/2 MILE

VERTICAL SCALE: 100′ – 0′

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PLATE VIII

NORTH - SOUTH STRATIGRAPHIC CROSS SECTION

HORIZONTAL SCALE: 1 INCH = 1/2 MILE

VERTICAL SCALE: 100′ 0′

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PLATE IX

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NORTH - SOUTH STRATIGRAPHIC CROSS SECTION

HORIZONTAL SCALE: 1 INCH = 1/2 MILE

VERTICAL SCALE: 100′ – 0′

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PLATE X

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NORTH - SOUTH STRATIGRAPHIC CROSS SECTION

HORIZONTAL SCALE: 1 INCH = 1/2 MILE

VERTICAL SCALE: 100′ – 0′

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J-J'

PLATE XI

NORTH - SOUTH STRATIGRAPHIC CROSS SECTION

HORIZONTAL SCALE: 1 INCH = 1/2 MILE

VERTICAL SCALE: 100′ – 0′

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PLATE XII

NORTH - SOUTH STRATIGRAPHIC CROSS SECTION

HORIZONTAL SCALE: 1 INCH = 1/2 MILE

VERTICAL SCALE: 100′ – 0′

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PLATE XIII

NORTH - SOUTH STRATIGRAPHIC CROSS SECTION

HORIZONTAL SCALE: 1 INCH = 1/2 MILE

VERTICAL SCALE: 100′ – 0′

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PLATE XIV

NORTH - SOUTH STRATIGRAPHIC CROSS SECTION

HORIZONTAL SCALE: 1 INCH = 1/2 MILE

VERTICAL SCALE:

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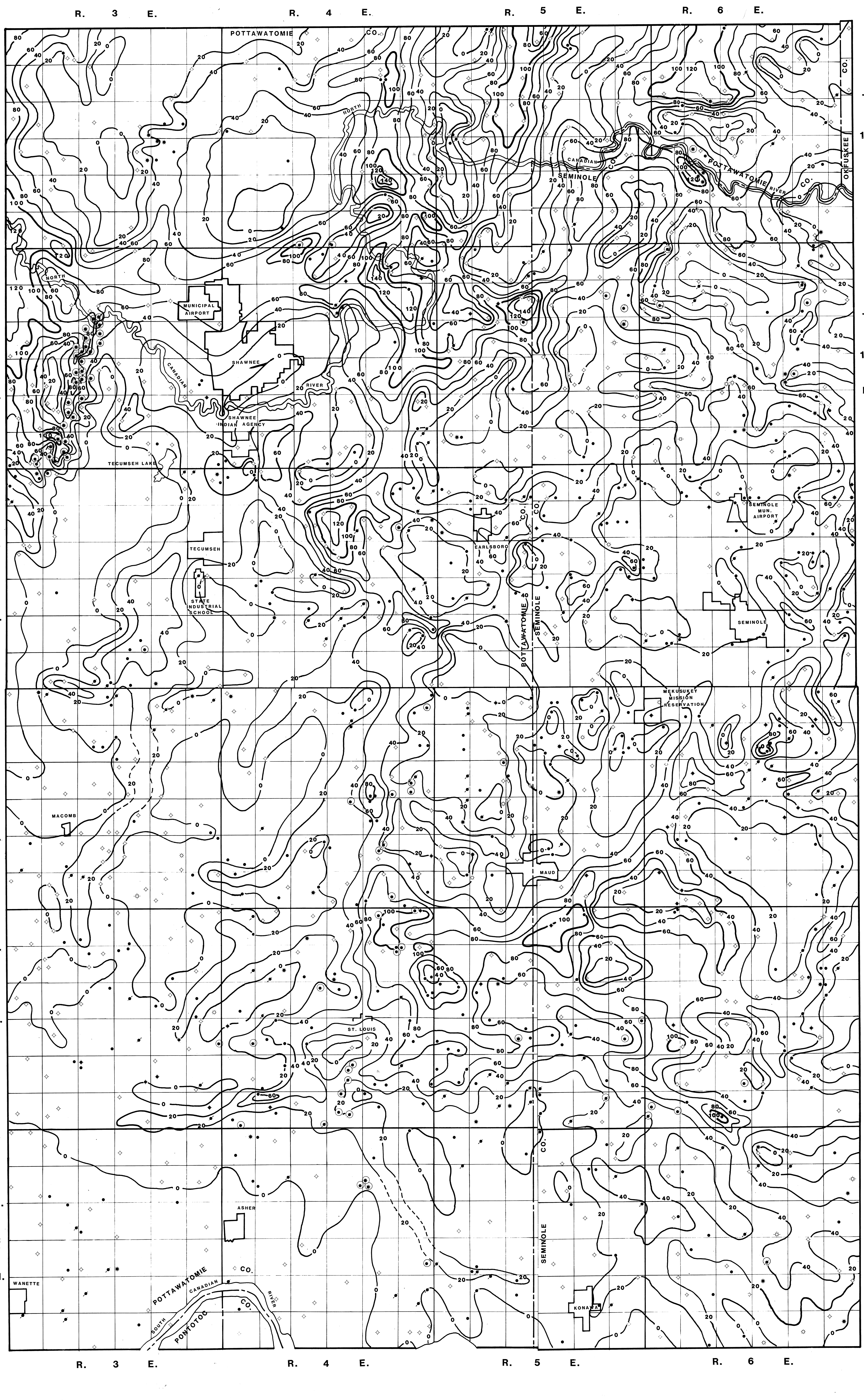

LEGEND

- DRY HOLE
- OIL WELL
- ABANDONED OIL WELL
- RED FORK PRODUCER
- GAS WELL
- OIL & GAS WELL
- ABANDONED GAS WELL
- INJECTION WELL

0 1/2 1 2 3

SCALE IN MILES

CONTOUR INTERVAL : 20 FEET

N

PLATE XV

NET SANDSTONE ISOLITH MAP

RED FORK SANDSTONE

WILLIAM LEWIS TATE , 1985

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PLATE XVI

LOG SIGNATURE MAP

RED FORK SANDSTONE

WILLIAM LEWIS TATE , 1985

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