FACIES, DIAGENETIC, AND SUBSURFACE EVALUATION OF THE PRUE SANDSTONE ON THE CENTRAL OKLAHOMA PLATFORM

By

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TABLE OF CONTENTS

TABLE

LIST OF FIGURES

Figure		Page

LIST OF PLATES

CHAPTER I

INTRODUCTION

Location of Study Area

The area of this thesis study includes approximately 432 square miles in 12 townships in northeastern Lincoln County, Oklahoma, on the Central Oklahoma Platform. Specifically, Township(s) 13 through 16 North, Range(s) 4 through 6 East (Figure 1) were studied in detail.

The purpose of this study is to investigate the subsurface characteristics, diagenetic history, and facies distribution of the Desmoinesian Prue sandstone interval. This study was selected due to the wealth of data, and economic importance of the Prue Sandstone.

Objectives

The objectives of this study include:

1. Establishing the depositional framework of the Prue interval.
2. Delineating Prue stratigraphy and calibrating core lithology to wire-line log response.
3. Determining the distribution and the geometry of the sandstone reservoirs.

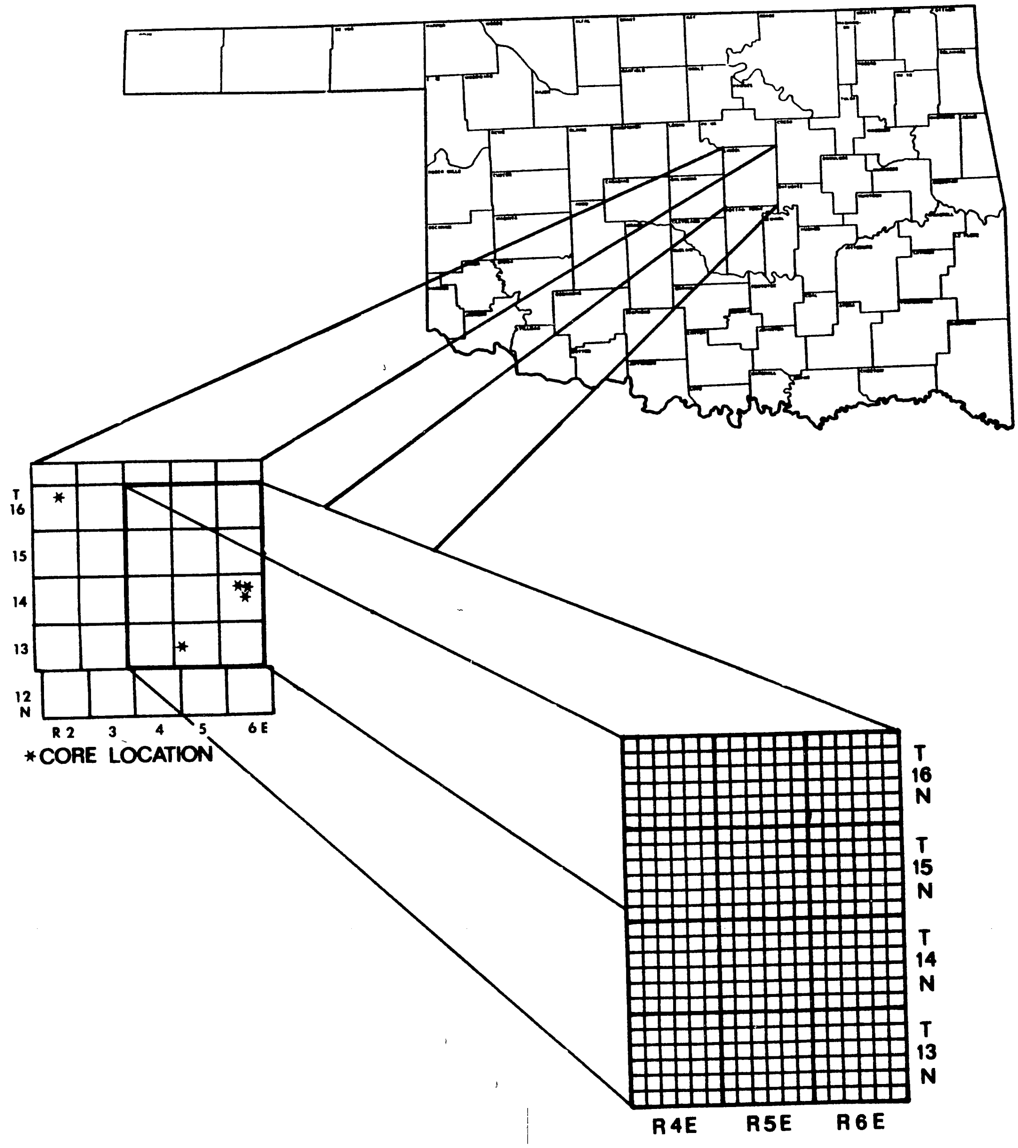


Figure 1. Map Showing Location of Study Area and Cores Examined (after Cole, 1956)

4. Determining the Prue sandstone environments of deposition.
5. Evaluating the petrographic and diagenetic characteristics of the Prue Sandstone.
6. Investigating the trapping mechanisms of hydrocarbon accumulations in the Prue sandstone reservoirs.

Methods of Investigation

Subsurface well data were compiled primarily from electrical well logs, scout tickets and current and historical (plugged) production books, obtained from the Oklahoma City Geological Society Log Library and the Oklahoma State University Geological Log Library. All values used in construction of the subsurface maps came solely from the electrical well logs. Delineation of the various field boundaries and producing zones was obtained from the scout tickets. The production information of the various fields was obtained from Petroleum Information Publications (Plate VIII).

A series of stratigraphic cross sections were constructed in order to establish accurate correlations throughout the entire 12-township area (Plates IX, X, XI). These consisted of two east-west sections and a north-south section. The cross sections were tied with common wells to improve correlations. The top of the Checkerboard

Limestone, which is a continuous stratigraphic time marker, was used as a datum reference in order to filter the affects of post-Prue tectonics.

After the correlations were completed, stratigraphic units were delineated by their resistivity, gamma ray and spontaneous potential log signatures. These characteristic log signatures were used in the construction of structure and thickness maps (Plate I, II, III, IV and V).

The upper and lower limits of the Prue sandstone body were determined by a negative deflection of -20 mv or more of the spontaneous potential curve (Plate VI) from the shale base line. This criterion was confirmed by the calibration of core lithofacies to log signature. An SP signature map was constructed by tracing the SP signature from the top of the Excello Shale to the top of the Verdigris Limestone (Plate VII).

Four cores were analyzed within the area of investigation. In addition, one core to the west of the area was obtained and studied. All cores were logged and their sedimentary structures and petrographic features described. The descriptions can be found in the Appendix.

Twenty-eight thin sections were prepared from the cores of the Prue Sandstone. Thin sections were used to study the petrography and establish the diagenetic history of the Prue reservoir. The results of the petrographic/diagenetic aspect of the study are presented in Chapter V. Analysis of bulk X-ray diffraction runs were utilized to help determine mineralogy. X-ray diffraction was run on all twenty-eight bulk powdered samples. The clay mineral fraction was extracted on 13 of the 28 samples, and analyzed to determine clay composition.

Previous Investigations

Numerous investigations of the Pennsylvanian Desmoinesian "Cherokee" Group have been conducted. Although the term "Cherokee" is no longer recognized as a formal geological unit, it is used frequently in subsurface studies. Oakes (1953) divided the "Cherokee" Group into the Krebs and Cabaniss Groups. The uppermost sandstone interval of the Cabaniss Group is recognized as the Prue Sandstone. Only those investigations that pertain directly to the Prue Sandstone or Lagonda Sandstone (surface nomenclature) are referenced. These studies include Akmal (1953), Albano (1975), Astarita (1975), Benoit (1957), Berg (1969), Blumenthal (1956), Candler (1976), Cole (1956 and 1969), Denesen (1985), Ferguson (1964), Joseph (1987), Lojeck (1983), Puckette (1990), Pulling (1979), Shipley (1977), Verish (1979).

Most of these studies contributed to the interpretation of Prue depositional environments through subsurface mapping. Ware (1955) correlated surface to subsurface stratigraphy of the Senora Formation in Northeastern Oklahoma. Krumme (1981) did an extensive regional study of the Prue/Calvin sands in Oklahoma Platform and McAlester Basin. Wade (1985) carried out a petrographic and diagenetic study of a Prue Sandstone core in northwestern Lincoln County. Puckette (1990) investigated cycles in the Cabaniss Group of western Oklahoma.

CHAPTER II

STRATIGRAPHY

Introduction

The Desmoinesian sedimentary record in the Central Oklahoma Platform is characterized by cyclic carbonate-shale-sandstone sequences that are easily correlatable over most of the Platform area. Widespread thin carbonate units such as the Pink and Verdigris Limestones have traditionally been used to define the boundaries of format units. Format defined in general terms as a rock unit which is related at one point (or in one area) to a unit of formal stratigraphy, but which crosses facies boundaries and cutoffs to reach other areas where other formal units are employed. Formats are useful for correlations (particularly in the subsurface) between areas where the stratigraphic section is divided into different formations that do not correspond in time value (Gary et al., 1972). In this study, the Prue interval was constructed using marker beds and were complimented with "core" shale correlations. Heckel (1977) defines "core" shale as typically a thin, nonsandy, gray to black, phosphatic shale deposited under conditions of near sediment starvation. The "core" shale forms at maximum transgression. These shale correlations were especially useful in the region where the carbonate beds were not recognizable.

Figure 2 illustrates the electrical characteristics of the Desmoinesian rock in the study area. The commonly accepted subsurface nomenclature is also shown in this figure.

Upper Cabaniss Group

The upper Cabaniss Group is defined for this study as all stratigraphic units between the Oakley Shale and the Excello Shale. The "core" shales were also used to define the boundaries of the Prue Sandstone interval, since the traditional format-bounding stratigraphic markers (Verdigris and Breezy Hill Limestones) were not always mappable.

Oakley Shale

The Oakley Shale lies directly beneath the Verdigris Limestone (Figure 2). It is characterized by a "hot" high gamma-ray log signature and relatively low resistivity compared to the overlying carbonate. It is a black fissile shale, which contains numerous pea-sized phosphatic concretions (Ware 1955).

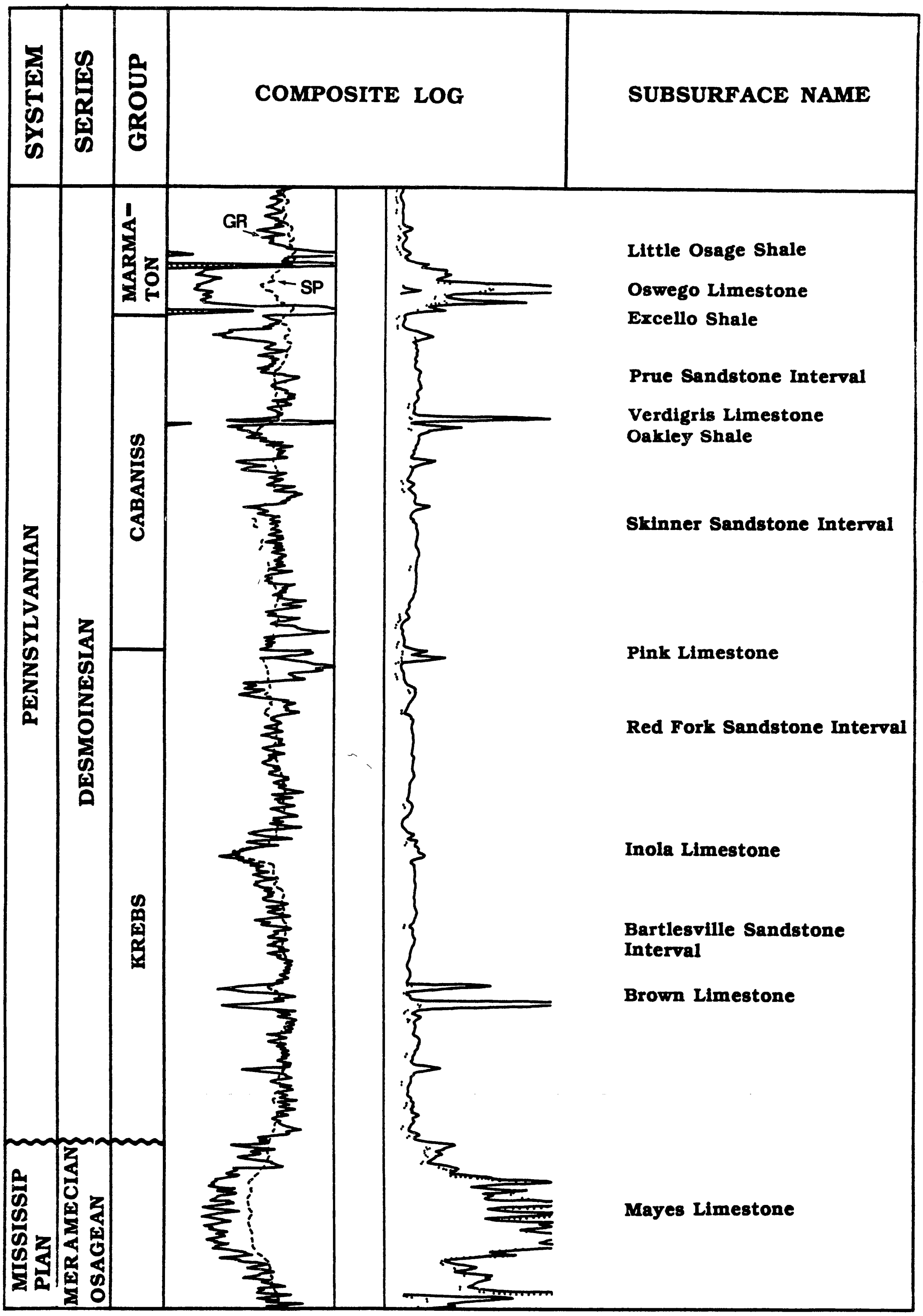


Figure 2. Composite Log Showing Wire-line Log-Signatures.

Verdigris Limestone

Immediately overlying the Oakley Shale is the Verdigris Limestone. The Verdigris exhibits "clean" (low shale) gamma-ray and high resistivity curve signature. Cole (1956) describes it as a microcrystalline, tan to gray, sometimes mottled, dolomitic limestone that is 5 to 8 feet thick. It is persistent throughout the investigated area except where it has been incised by the Prue channel. It is also difficult to identify the Verdigris when it is overlain by calcareous shales.

Prue Sandstone

The Prue Sandstone Interval (Figure 2) is delineated by the Verdigris Limestone at its base and the Breezy Hill Limestone at its top. The Breezy Hill Limestone often is not mappable in the study area and the Excello Shale was used to define the upper boundary of the Prue interval. The Prue interval contains shales, sandy-shale and sandstone. The Prue Sandstone has been described in previous investigations as a tan to gray, very fine to medium-grained, shaley, micaceous sandstone of deltaic origin (Astarita, 1975). It ranges from 0 to 127 feet thick in the area of study. The petrography and diagenetic character of the Prue Sandstone is discussed in Chapter V.

Inola

Breezy Hill

The Breezy Hill Limestone is directly above the Prue interval and beneath the Excello Shale. It is not persistent in the study area. It is a massive crinoidal biosparite. As illustrated in Figure 10, it is present from 4276 to 4283.6 feet in the Quintle No. 1 Sec. 9, T.16N, R.2E. The Breezy Hill when present is identified on electric log as a thin relatively "clean" stratigraphic unit immediately below the Excello Shale.

Excello Shale

The Excello Shale is a black, fissile, thinly-laminated shale, which contains phosphate nodules. These very abundant nodules, which are one of the most diagnostic features of the Excello, also contain pyrite, quartz, calcite, organic carbon, and minor amounts of clay minerals (Ece, 1989). The Excello is recognized on electrical survey (Figure 2) by its "hot" high gamma-ray log signature. The conformable boundary between the Marmaton and Cabaniss Groups is recognized as the top of the Excello Shale (Puckette, 1990).

Lower Marmaton Group

The Lower Marmaton Group is defined for this study as the Oswego Limestone and Little Osage shale.

Oswego Limestone

The Oswego Limestone ranges from 0 to 57 feet thick in the study area. Cole (1956) describes it as being tan to gray, microcrystalline limestone with occasional fossiliferous portions, and it is slightly dolomitic.

Little Osage Shale

Directly above the Oswego Limestone is the Little Osage Shale, a black, fissile shale which contains phosphate nodules. The Little Osage Shale is recognized on electrical survey (Figure 2) by its "hot" high gamma-ray log signature.

CHAPTER III

DEPOSITIONAL FRAMEWORK

Tectonic Setting

The area of investigation lies on the Central Oklahoma Platform between the Nemaha ridge to the west, the Ozark Uplift to the east, the Seminole Uplift to the south and the McAlester Basin to the southeast (Figure 3). The Central Oklahoma Platform is a tectonically stable area that is continuous with the Cherokee basin of Kansas. The strata of the platform have a gentle (one degree per mile) homoclinal dip to the southwest. Numerous local structures interrupt this homoclinal dip to generate small anticlinal closure and nosings. The isopach map of the Verdigris/Mayes interval (Plate III) exhibits uniform contour line density across the study area, suggesting a generally stable setting for Prue format deposition.

The Pennsylvanian System was marked by two major orogenies (Jordan, 1967). The orogenies were the pre-Desmoinesian (late Mississippian through Atokan) Wichita Orogeny, and the (post-Missourian, pre-Vanoss) Arbuckle Orogeny. The Wilzetta Fault, which is an extension of the Seminole Uplift, was active in Prue time. This is

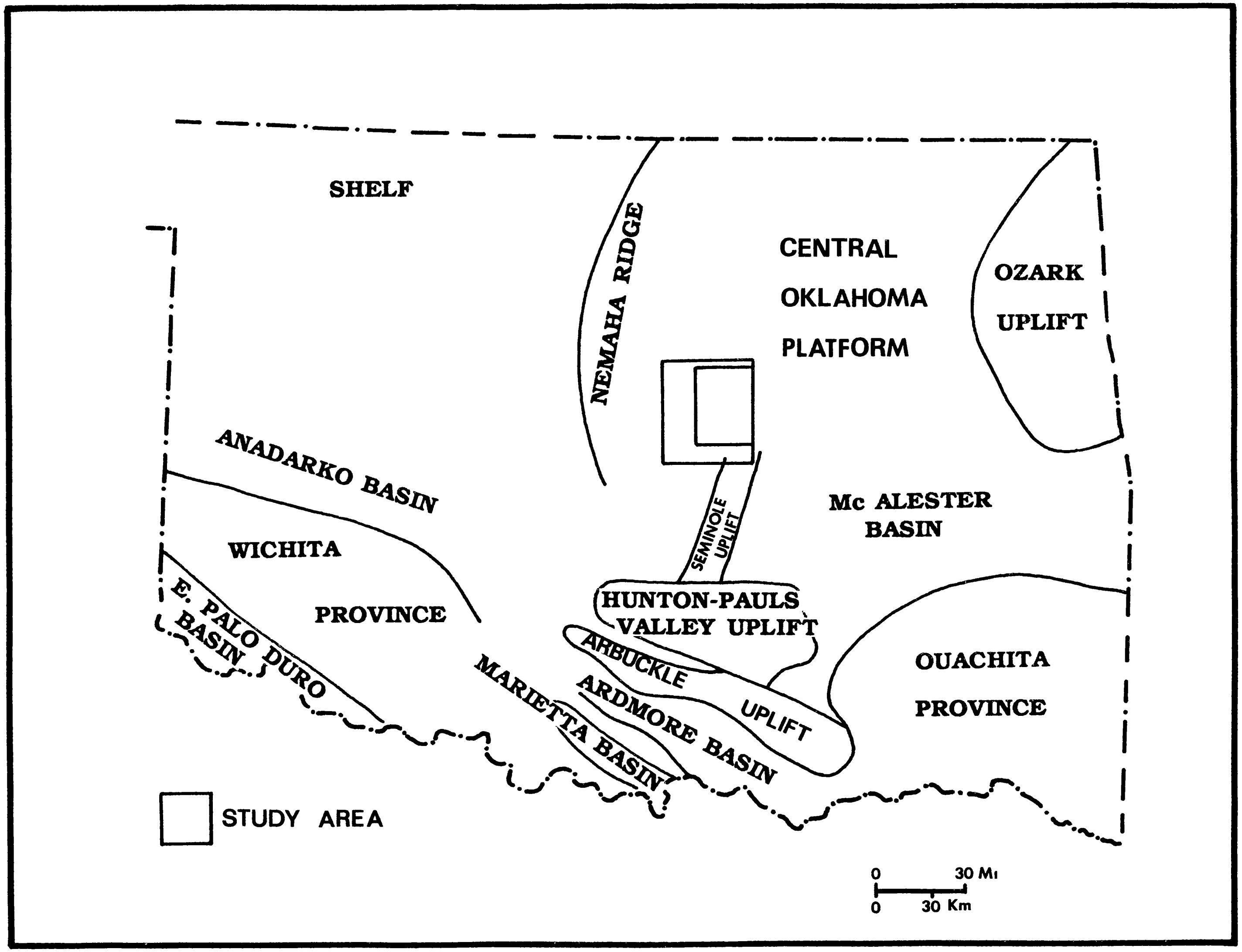


Figure 3. Map Showing Major Structural Features and Provinces of Oklahoma (Modified from Jordan, 1967)

evidenced by syndepositional thickening on the downthrown side of the fault (Plates III and IV).

Source Area

The Prue Sandstones of the Platform are fine to very fine grained subangular to subrounded, quartz-arenite, sublitharenite, or subarkose with muscovite-bearing metamorphic rock fragments. These metamorphics suggest the Prue source was the Transcontinental Arch to the north. The grain size and roundness indicate long transportation distances from the cratonic source. Krumme (1981) showed that the paleogeography of the central Midcontinent region during deposition of the Prue sands and indicated that they were from a north-northeast cratonic source (Figure 4).

Depositional Cycles

For many years examples of cyclic change have been noted from geologic history. Wanless and Weller (1932) applied the term cyclothem for repeating rock types in the Illinois basin. Cyclic deposition has been related to tectonism (Weller, 1930) eustatic changes in sea level by glaciation (Wanless and Shepard, 1936) and more recently by Heckel (1984, 1986 and 1987). Heckel defines cyclothems as marine transgressive-regressive sequences,

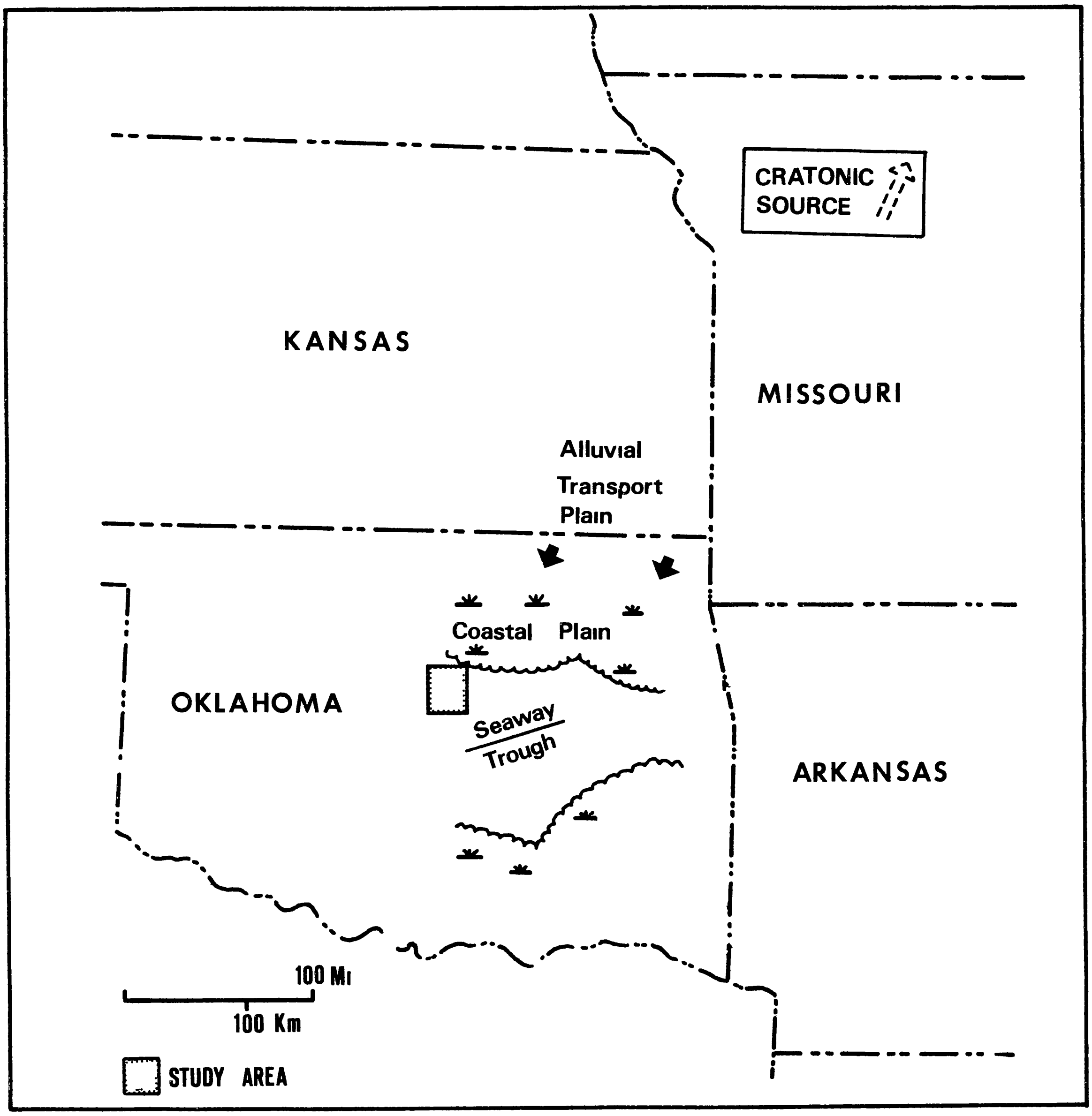


Figure 4. Map Showing Paleogeography During Deposition of the Prue Sandstone in the Central Midcontinent Region (Modified from Krumme, 1981).

centered on thin, nonsandy, black phosphatic ("core") shales which represent maximum inundation of the shelf.

Heckel (1986) has described the basic transgressive-regressive ("Kansas") cyclothem of the Pennsylvanian in the Midcontinent (Figure 5). This cyclothem consists of in ascending order: 1. Near shore (outside) shale; 2. Regressive Limestone; 3. ("core") shale; 4. Transgressive Limestone; 5. Nearshore (outside) shale. Ordered cycles have been applied to sea-level changes and associated depositional sequences. Along with glaciation as the cause of relatively short term sea-level changes, other larger term causes are suspected. These may relate to timing and rates of plate motion, mid-oceanic ridge construction and orogenic events (Ross and Ross, 1987). The Middle and Upper Pennsylvanian cyclic sea level charts are shown in Figure 6. Often only parts of classic cyclothems formed. Partial cyclothems are called cycles.

Bennison (1984) noted that the term "outside shale" is suitable for Kansas platform sequences; but it is probably inadequate for the shelf to trough environment of the Desmoinesian sequences of Oklahoma. Figure 7 is an experimental model of a well developed Pennsylvanian sedimentary cycle on opposite shores of the Arkoma seaway in

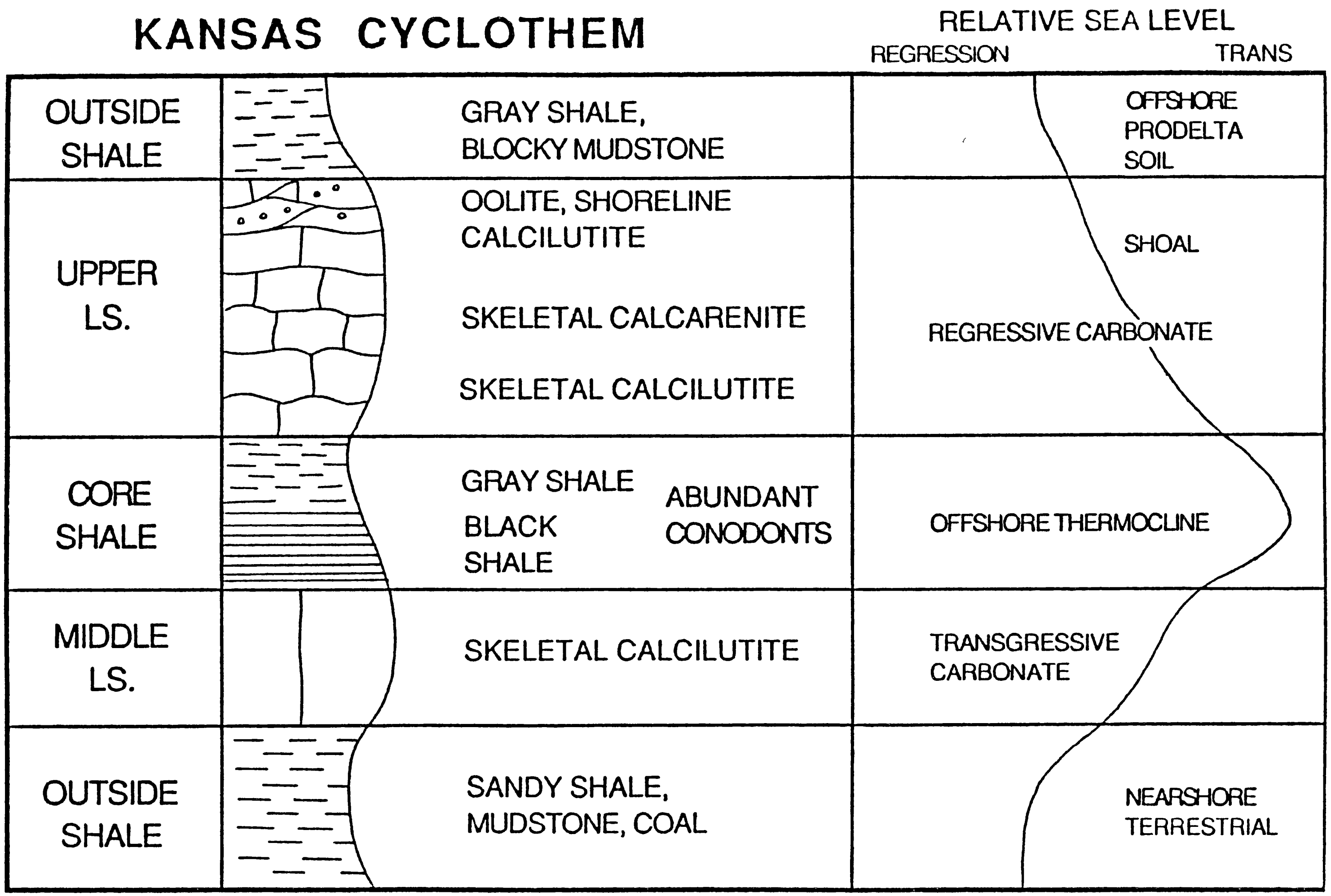


Figure 5. Classic "Kansas" Cyclothem (after Heckel, 1986)

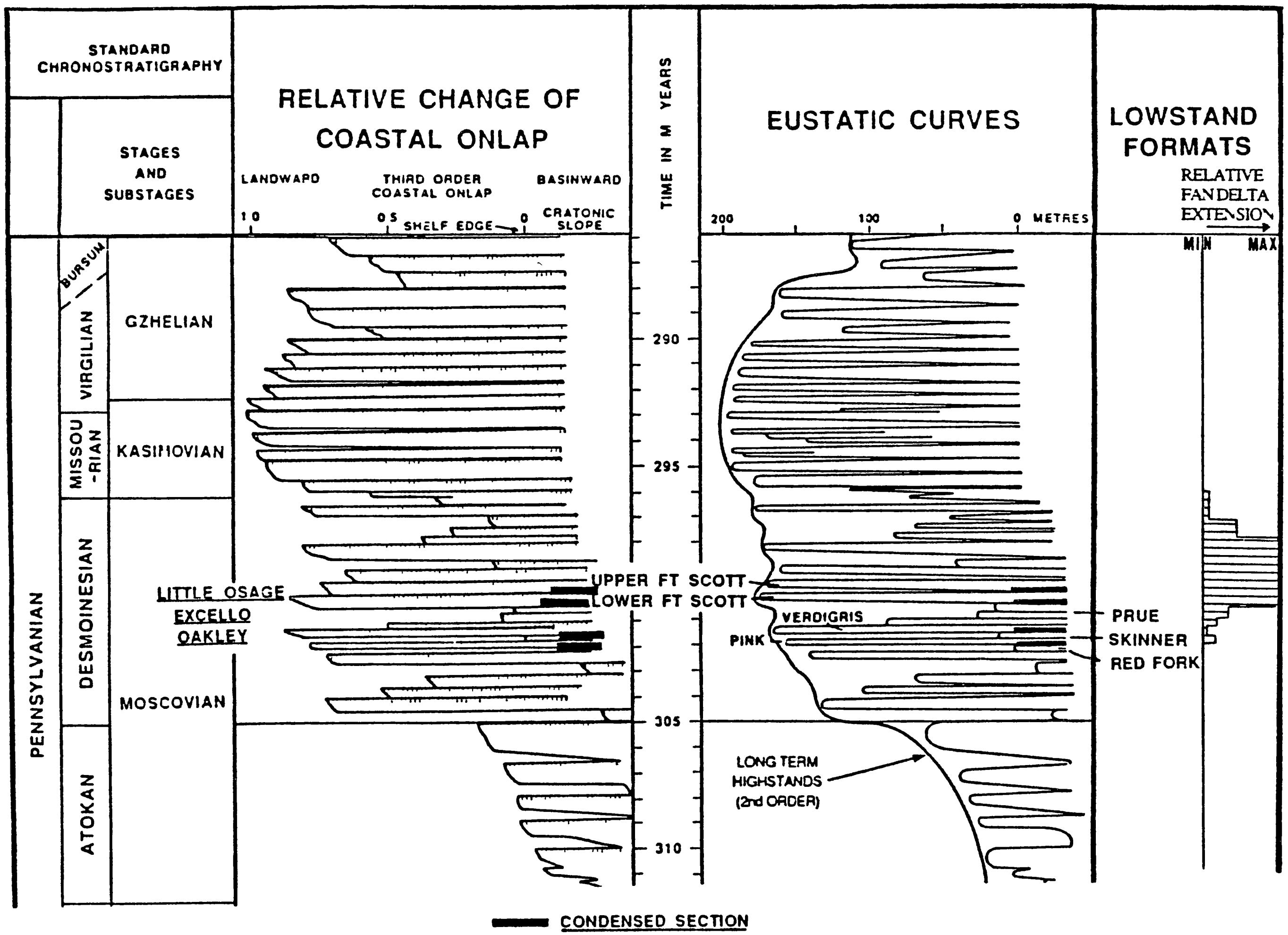


Figure 6. Major Pennsylvanian sea level cycles (after Puckette, 1990; Ross and Ross, 1987)

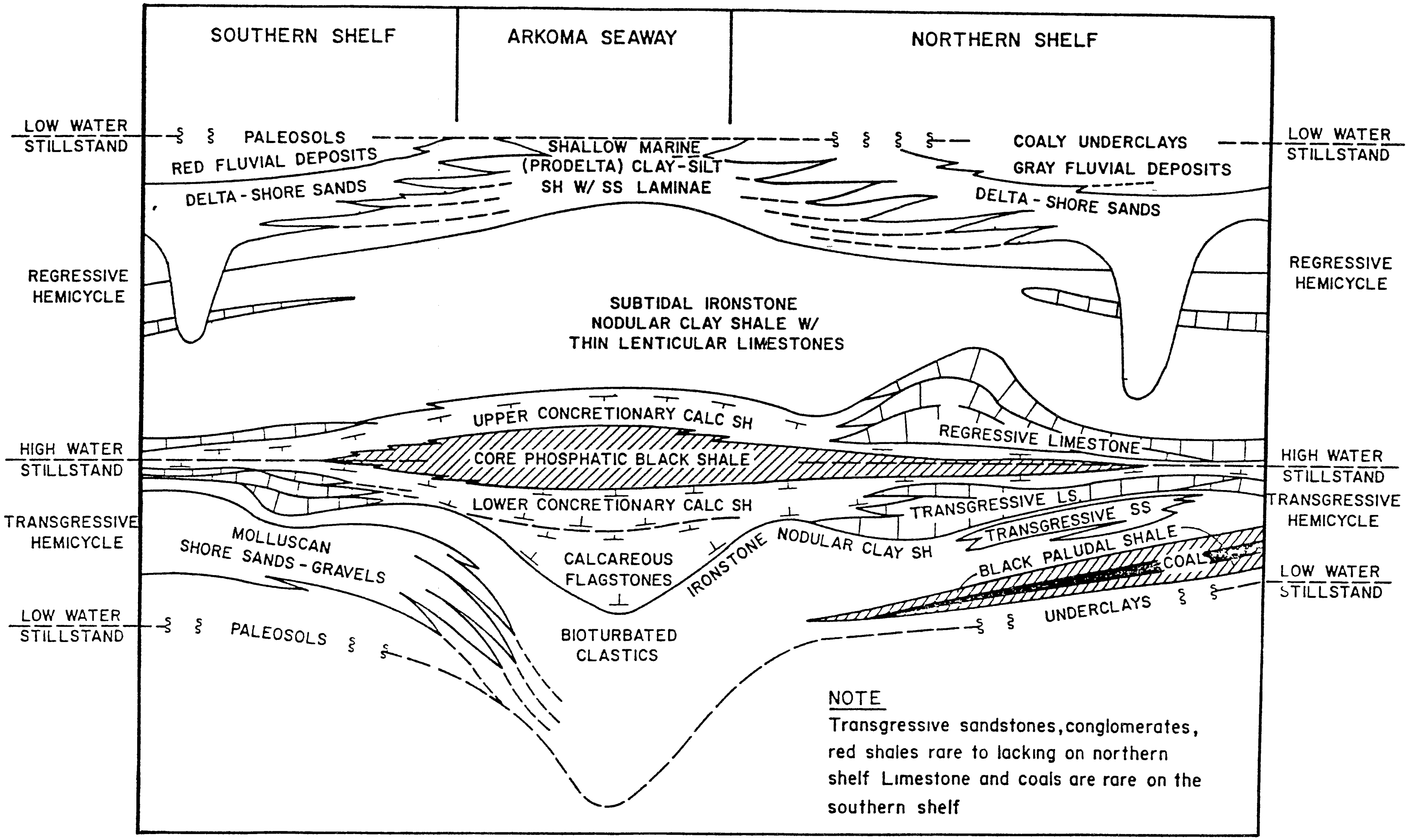


Figure 7. Experimental model of a well developed Pennsylvanian sedimentary cycle on opposite shores of the Arkoma Seaway, (after Bennison 1984).

Oklahoma. This model in the Northern Shelf portion of the figure represents the Prue Sandstone deltaic deposition more accurately than the Heckel cyclothem.

Wire-line logs were used to correlate components of the two cycles that can be identified in the Upper Cabaniss and Lower Marmaton Groups of the study area (Figure 8). The first cycle was initiated with the rapid transgression of the Oakley ("core") Shale. Sea level stabilized resulting in the deposition of the Prue deltaic system. A further drop in sea level resulted in incision of the Prue deltaic system and the underlying Verdigris Limestone to form an incised valley. Valley fill deposits form when sea level begins to rise and causes stream gradient to decrease drastically. A second cycle was initiated with the transgressive Breezy Hill Limestone. This transgression culminates with deposition of the Excello ("core") shale. The next sea level then dropped and stabilized, resulting in the deposition of the Oswego Limestone.

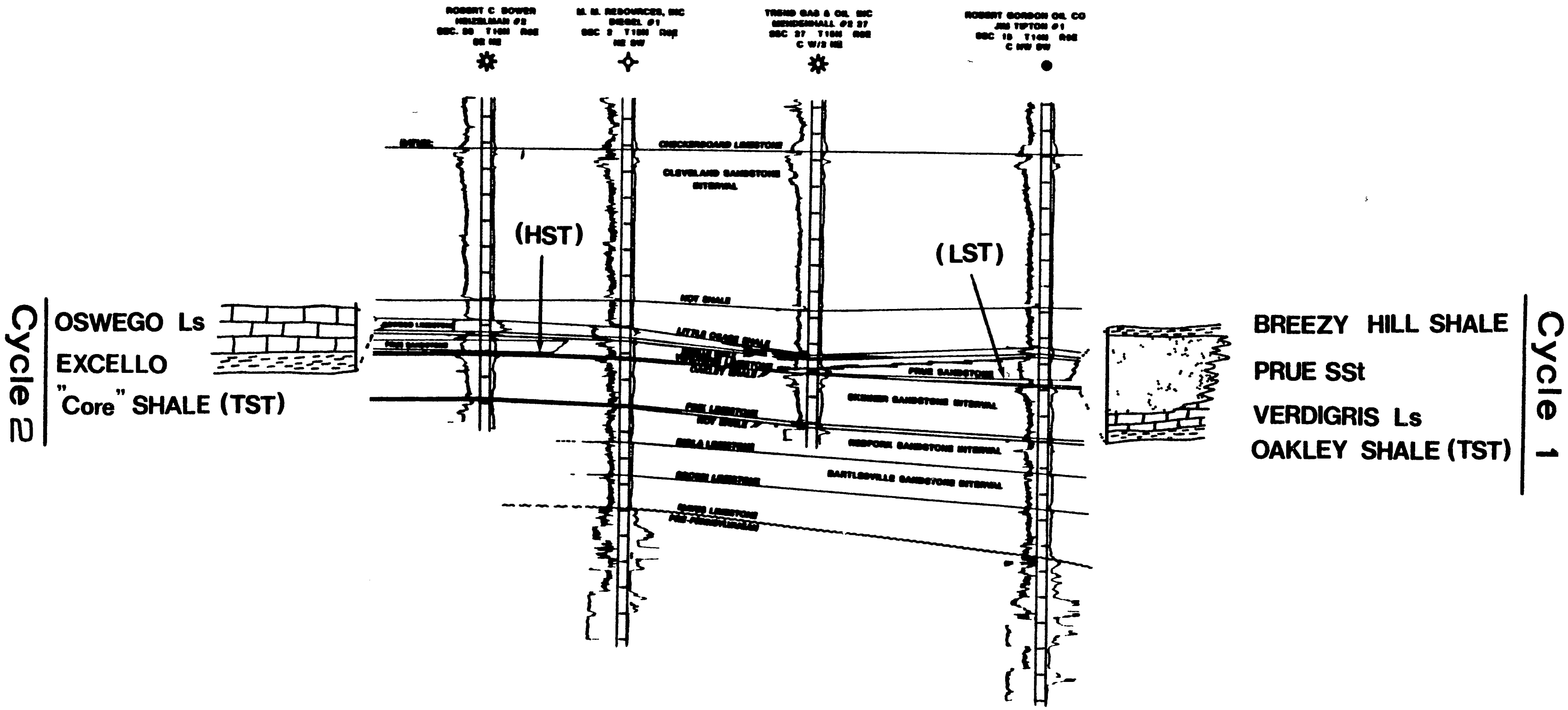


Figure 8. Stratigraphic Cross-section from Central Oklahoma Platform showing Upper Cabaniss and Lower Marmaton Groups sea level cycles

CHAPTER IV

SUBSURFACE ANALYSIS

Subsurface Mapping

Eleven plates were prepared to delineate the Upper Desmoinesian stratigraphy and petroleum geology in the area of investigation. The intitial step involved preparation of three cross-sections in order to establish accurate correlations of the stratigraphic intervals to be mapped. Two structural contour maps, three thickness maps, a log signature map and a field boundary/Prue cumulative production map were prepared in order to examine structural, sedimentalogical and production aspects of the Prue Sandstone.

Local Structural Geology

Structural contour maps were prepared on the base of the Marmaton Group and the top of the Verdigris Limestone (Plates I and II) to determine the present structural attitude of the Prue interval. In areas where the Verdigris was absent, the top of the Oakley Shale was used as the mapping marker. The Verdigris has a maximum thickness of 5 feet and rests on the top of the Oakley

Shale. This close stratigraphic positioning minimizes the discrepancy that results when this technique is employed where incision is observed (Figure 9).

The internval between the base of the Marmaton Group and the top of the Verdigris ranges from 60 to 140 feet thick, except in the faulted areas where it reaches a maximum thickness of 177 feet (Plate IV). The two structure maps mimic each other, and the structural features discussed below apply to both the Verdigris and Marmaton maps.

Present structural strike of beds is north-northwest with a west-southwest dip of 50 to 125 feet per mile. Some increase in dips is noted in the areas where faults are present. Local variation in dip direction defines structural noses, saddles, and closure adjacent to faults. An en echelon fault pattern mapped at the surface in eastern Lincoln, western Creek, eastern Pawnee, and Osage counties, to the north-northeast of the study area is thought to reflect general fault trends within the study area and indicate strike-slip components in the regional pattern of deformation (Verish, 1979). The trend of the faults seen in the Prue stratigraphic interval is north-northeastward. In Sections 19, 20, 29, 30 and 31, Township 14 North, Range 6 East, a graben is observed on the structure maps. This graben is substantiated by the thickness maps that show the interval from the top of the Verdigris to the top of the

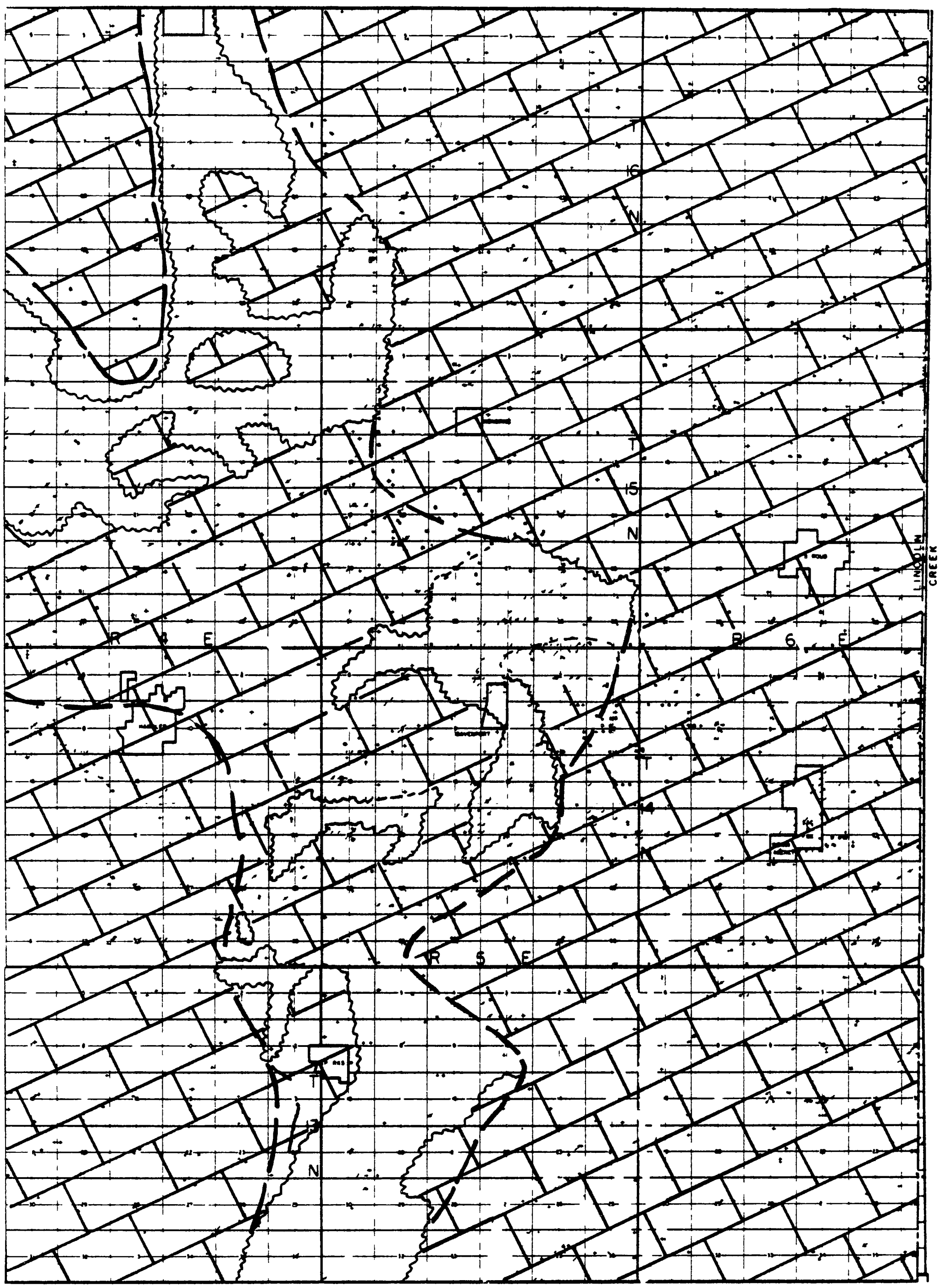


Figure 9. Map Showing Incised Area of the Verdigris Limestone.

Mayes thickening to over 200 feet (Plate III). The interval from the base of the Marmaton Group to the top of the Verdigris Limestone has a thickness of over 100 feet in the downthrown area and thins to approximately 60 feet on either side of the graben (Plate and IV). This thickness differential indicates the basic structure of the area was developing before and during deposition of Pennsylvanian rocks.

Paleotopography

Within the study area, Pennsylvanian strata lie uncomformably upon Mississippian carbonates of Meramecian-Osagean age, except where these carbonates are locally absent. Paleotopography of the pre-Desmoinesian unconformity is expressed by a thickness map (Plate III) of the interval between the top of the Mayes Limestone and the top of the Verdigris Limestone. Topographic highs are represented by areas where the interval thins, whereas the thickest intervals are interpreted to have been areas were the most extensive erosion of Mississippian rocks occurred.

Thickness of the Mayes/Verdigris interval increases approximately 450 feet from the northwest to the southeastern part of the area mapped. Localized thickening on the downthrown side of faults increases the Mayes/Verdigris interval to as much as 650 feet. Trends of thick sediment suggest that the drainage course of the Prue channels was to flow from higher elevations in the north towards a southeasterly lying depocenter.

Geometry

Three stratigraphic cross sections were constructed using the Checkerboard Limestone as a datum of reference (Plates IX, X, and XI). Cross-sections were prepared to demonstrate stratigraphic correlations, lithologic distribution, and depositional relationship of the Prue Sandstone and the underlying Verdigris Limestone.

Cross-section A-A' (Plate IX) is a north-south section across the central part of the study area. Seven wells were utilized in this cross section. Two sandstone bodies are represented. The northernmost sandstone units has SP signatures that suggest a sharp basal contact and a fining upward character (these signatures are discussed in detail under depositional framework). The sandstone in the northern area is 30 to 40 feet thick. It is separated from the Verdigris Limestone by a 10 to 15 feet thick shale interval. The southernmost sandstone shown on this cross section is incised into the underlying Verdigris Limestone in some wells. This incision is evident in the Trend, Mendenhall 2-27. The southern sandstone deposit thickens to 80 feet in the Gordon, Tipton No. 1. Two episodes of sand deposition separated by shale are evident in the Hill, Beck No. 1. In the Mega, Duncan No. 1 to the south, the sandstones are absent, and the Prue interval is represented by shale facies.

Cross-section B-B' (Plate X) is a west to east cross-section across township 16 North, Ranges 4, 5 and 6 East. Five wells were utilized in this cross-section. The Prue Sandstone shown in the western part of the study area is 10 feet thick (Confed, Grimm No. 2) and the log signature suggests that the interval coarsens upward. This upper Prue sandstone is absent in the Indian, State 1-A well to the east. This well contains a sandstone within the channel that completely erodes the underlying Verdigris Limestone. This 50 ft. thick sandstone has a SP signature that suggests a sharp basal contact and a fining upward character. The incised channel is approximately 2.5 miles wide and is delineated by the lateral change from sandstone to shale or interbedded sandstone/shale sequences. The Brown, Herzelman No. 2 in Section 28, T16N, R5E is the well that ties the two cross sections together. Laterally there is a shale facies for approximately 6 miles. A 10 foot sandstone is present in the top of the interval in the Steckler No. 1.

Cross-section C-C' (Plate XI) is a west - east trending cross-section across Township 14 North, Ranges 4, 5 and 6 East. Five wells were utilized in this cross-section. The Prue Sandstone shown in the western part of the study area (Van Horn, Kennedy 19-1 and Sullivan, Berry 1) is approximately 10 feet thick. The log curve suggests the interval coarsens upward. The upper Prue sandstone is absent in the Gordon, Tipton 1 in Section 15, Township 14 North, Range 5 East the well ties with the north-south cross-section A-A'. The incised channel is approximately 6.5 miles wide, to the east an interbedded sand and shale lithofacies change occurs. The upper Prue sandstone is developed in the Park Roads, Edith 1. The deltaic facies is 2 miles wide and 25 feet thick. The Prue interval is represented by shale lithofacies eastward in the Scott, Todd 1-A.

The variation in thickness of the Prue interval is illustrated by the Verdigris/Mayes isopach map (Plate III). This map indicates a general thickening of the Prue interval from the northwest to the southeast. The varying thickness ranges from 55 to 177 feet. Variations in thickness reveal structure on the surface of deposition in the southeast, expressed by thins on the structural highs. In the north and northeast parts of the map, where homoclinal dip is prevalent, the thins are due possibly to differential compaction. Thicker deposition of the interval is represented by channel deposits; however, an increase in deposition is reflected where channeling is not present.

The area in the southern portion, where sediments are thicker, demonstrates that the rate of subsidence and deposition was greater in the southeastern area than in the northern area of the study.

The Prue Sandstone thickness map (Plate VI) is defined by a negative 20 millivolt deflection of the Spontaneous Potential curve from the shale base line. The corresponding resistivity curves were utilized to confirm sandstone presence by negative SP deflection. High resistivities (tite or hydrocarbon bearing) and low resistivities (water bearing) sandstones were observed. The general trend of the Prue Sandstone incised valley fill deposits is southeastward. Minor deltaic channels show a southwestern trend. The thickness ranges from 0 to 127 feet.

The Spontaneous Potential Map (Plate VII), portrays the interval from the base of the Oswego Limestone/top of the Excello Shale to the top of the Verdigris Limestone/top of the Oakley Shale. The "core" shales were used as markers when the limestones were absent. SP log signatures serve as a major type of evidence used to interpret Prue sedimentary facies. The signature is an indicator of vertical trends in grain size. Different sedimentary facies are developed by depositional processes reflected by SP log shape patterns. After analysis of the subsurface maps and calibrating cores examined with SP signatures in the area of investigation an interpretation was made based on overall character of the SP patterns. This is discussed in detail in under depositional framework.

The lower boundary of the Prue interval is the Verdigris Limestone, except where it has been removed by channel incision. The Breezy Hill Limestone is the upper boundary of the interval, except where the limestone facies is not prevalent in the area of study. Above the Breezy Hill is the Excello "core" shale which was deposited at maximum transgression. Above the Excello Shale is the Oswego Limestone. In the area of study the Oswego Limestone has a maximum thickness of 64 feet in the extreme northwestern part of the study area (Plate V). The Oswego thins abruptly to 10 feet in approximately 8 miles from the northwest corner of the mapped area. Strike is northeast-southwest. The Oswego is absent in the southern portions of the area shown in cross-sections A-A' and C-C' (Plates IX and XI).

Description of Cores

Five cores of Prue Sandstone were described and sampled. Plate VII and Figure 1 show locations of the cores. Petrologic logs of the cores are in the Appendix. The cores were examined for lithology, grain size, sedimentary structures and detrital constituents. Wire-line logs were calibrated to core in order to associate SP signatures with environments of deposition and facies distribution in the Prue Interval.

Gulf Oil Corp. Hamm No. 1, Section 19, T13N, R5E

The cored interval is from 3698 - 3715 feet, in the Prue Sandstone (Figure 10). The rock is light brown, moderately-sorted to well-sorted sandstone. Grain size varies from very fine to fine-grained sand. Sedimentary structures include medium-scale tabular planar cross-bedding, small-scale trough cross-bedding, as well as massive and planar bedding. Bioturbation is present in the top 2 feet of the cored interval in a finely laminated sandy shale. The sandstone contains siderite clasts that were apparently transported and reworked. The sandstone contains muscovite, carbonaceous laminae, and calcite cement. Comparison of the above depositional features with wire-line log patterns suggest the Hamm core repesents channel fill deposition.

General American Oil Co. Potter No. 5, Section 10, T14N, R6E

The cored interval is from 2940-2998.7 feet. This well is located in the area of relatively flat SP log character

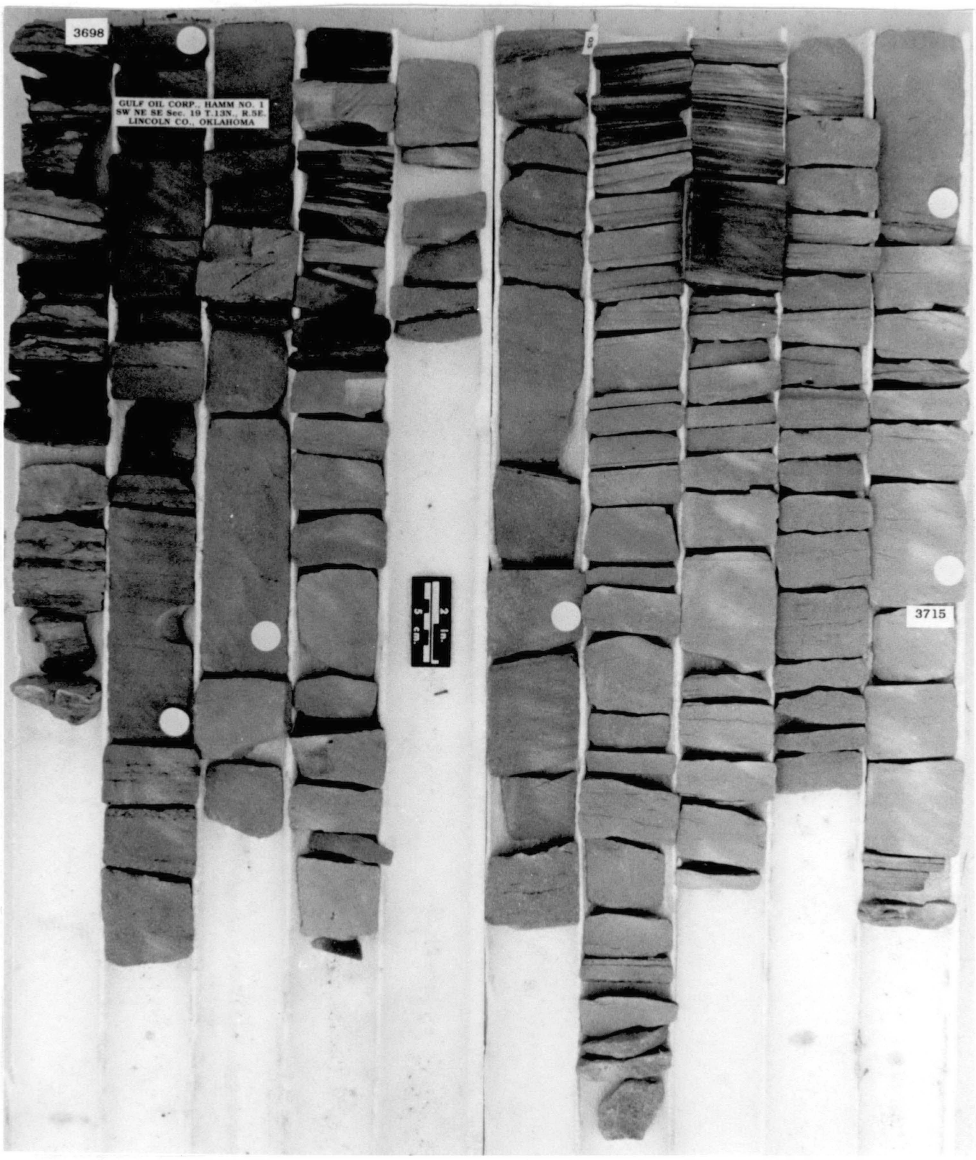


Figure 10. Photograph of Core, Gulf Oil, No. 1 Hamm, Section 19, T13N, R5E, Interval from 3698 to 3715 feet.

(Plate VII). The rock consists of interbedded sandstone/mudstone, siltstone, fossiliferous marine shale, and thin sandstone units (Figure 11). Sandstones are very fine to fine-grained and well sorted. Sedimentary structures include small scale trough crossbedding, streaky bedding, and extensively bioturbated carbonaceous laminae. These rocks are interpreted as delta fringe facies that are characterized by intercalated very fine-grained sand, silt and shale. A sharp contact is seen at 2944.9 feet between the sandstone and an overlying fossiliferous shale. This latter unit is interpreted as a transgressive marine shale due to the abundance of fossils.

General American Oil Co. May No. 3,
Section 10, T14N, R6E

The cored interval is from 2898-2956 feet and contains silty shale with minor sandstones (Figure 12). The sandstone is moderately to well sorted and very fine to fine-grained. Sedimentary structures include small-scale trough cross-bedding and large scale tabular planar cross-bedding. Sedimentary structures include flowage, wavy bedding, abundant burrows, ripples, small-scale trough cross-bedding, mud chips and horizontal and vertical burrows, and soft sediment deformation. Carbonaceous laminae are abundant. Abrupt contacts occur at 2906.8 and

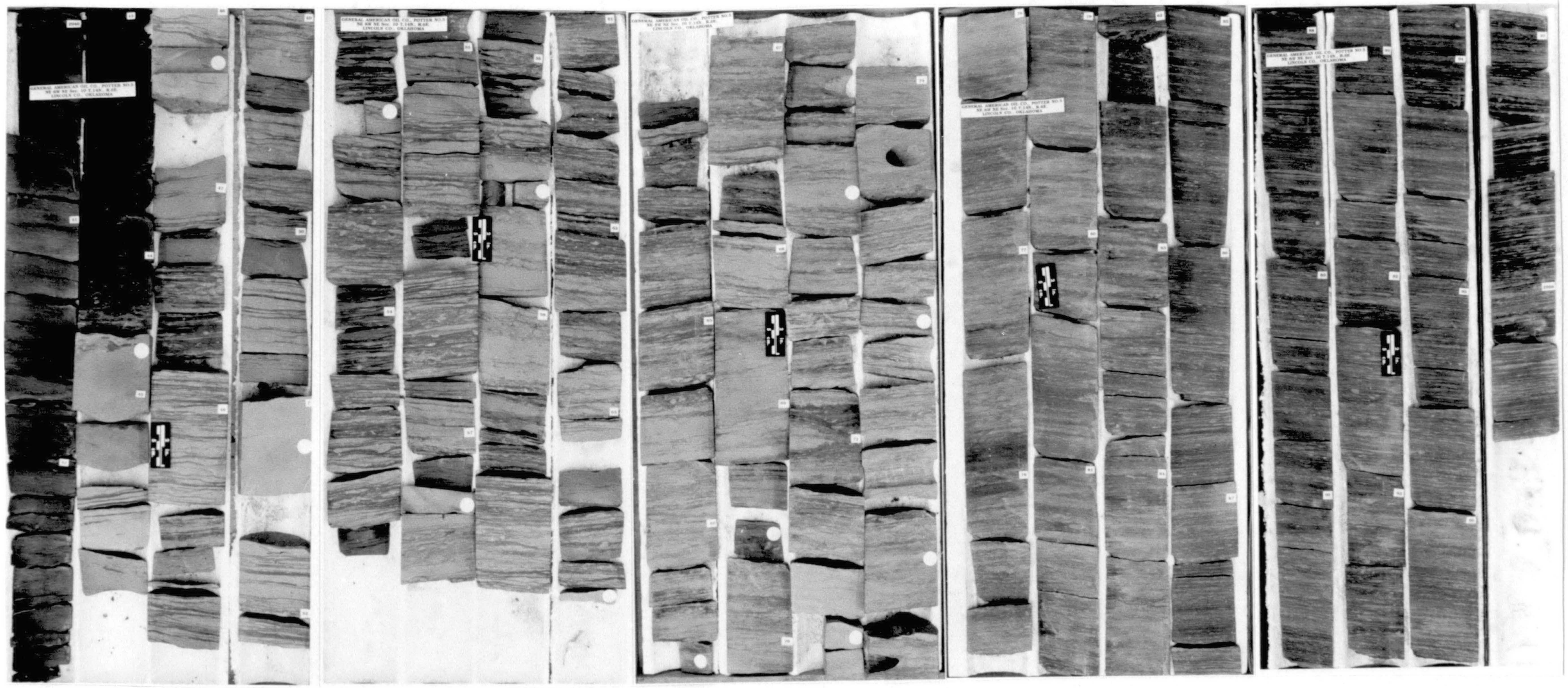


Figure 11. Photograph of Core, General American, No. 5 Potter, Section 10, T14N, R6E, Interval from 2940 to 2998.7 feet

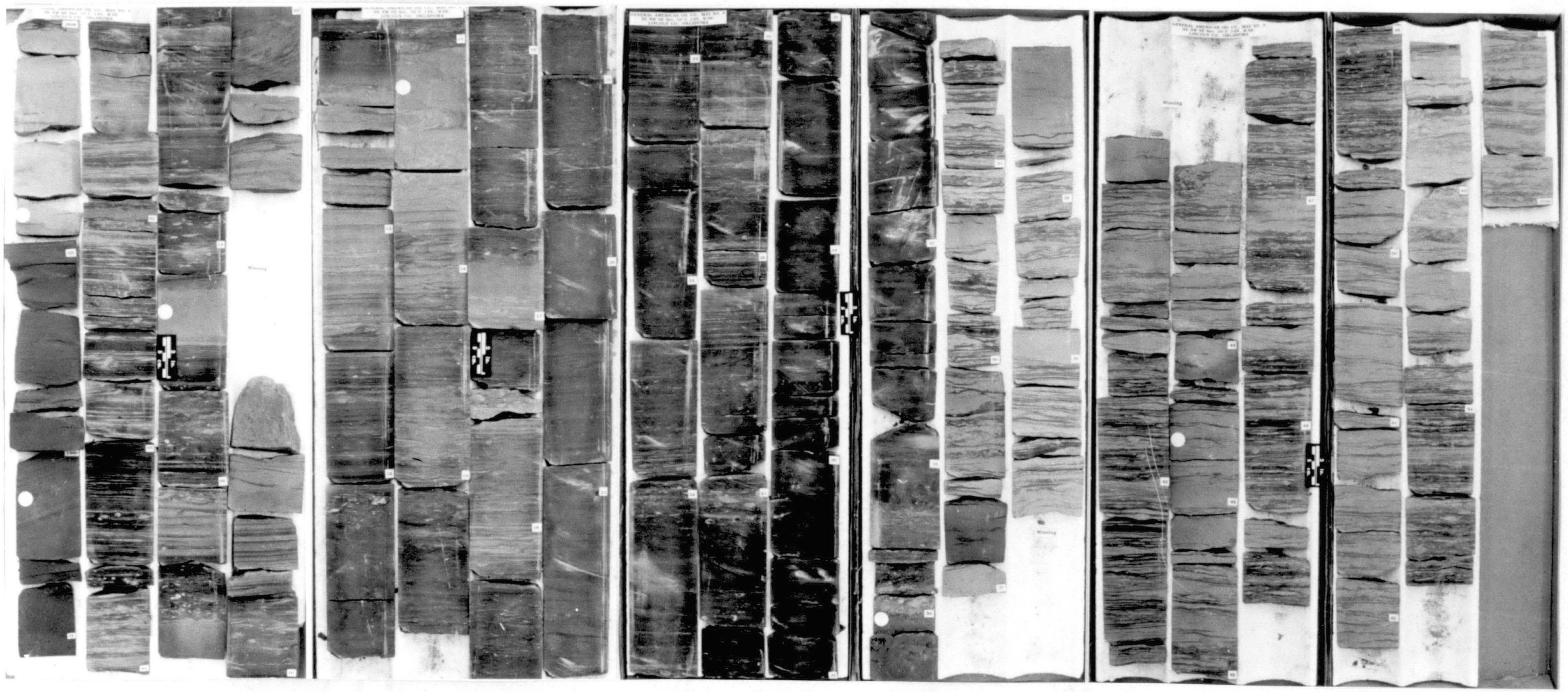


Figure 12. Photograph of Core, General American, No. 3 May, Section 10, T14N, R6E, Interval from 2898 to 2956 feet

2934 feet. The contact at 2906.8 feet is between a sandstone and an overlying shale with abundant fossils (brachiopods and crinoids). A sharp contact is present at 2934 feet between a fossilferous shale and a sandstone containing mud rip-up clasts. These sandstone depositional features suggest a periodic high energy environment (tidal or storm) within a typically low energy setting. This core may represent deposition within a deltaic interdistributary bay.

Tenneco Oil Co. Sac and Fox No. 126,
Section 15, T14N, R6E

The cored interval is from 2960-3018.3 feet, and is dominated by siltstone, sandstone, and shale (Figure 13). The rock consists of interbedded sandstone/mudstone, silty clay stone/mudstone, shale, and thin clean sandstones. The sandstones are moderately sorted to well sorted. Interbedded sandstone/mudstone are poorly sorted. Sedimentary structures include ripples, small-scale trough cross-bedding, and wavy bedding. Carbonaceous laminae and bioturbation are abundant. The sandy facies of this core are interpreted as indicating delta fringe deposition. The delta fringe facies are characterized by intercalated fine to very fine-grained sand, silt and shale.

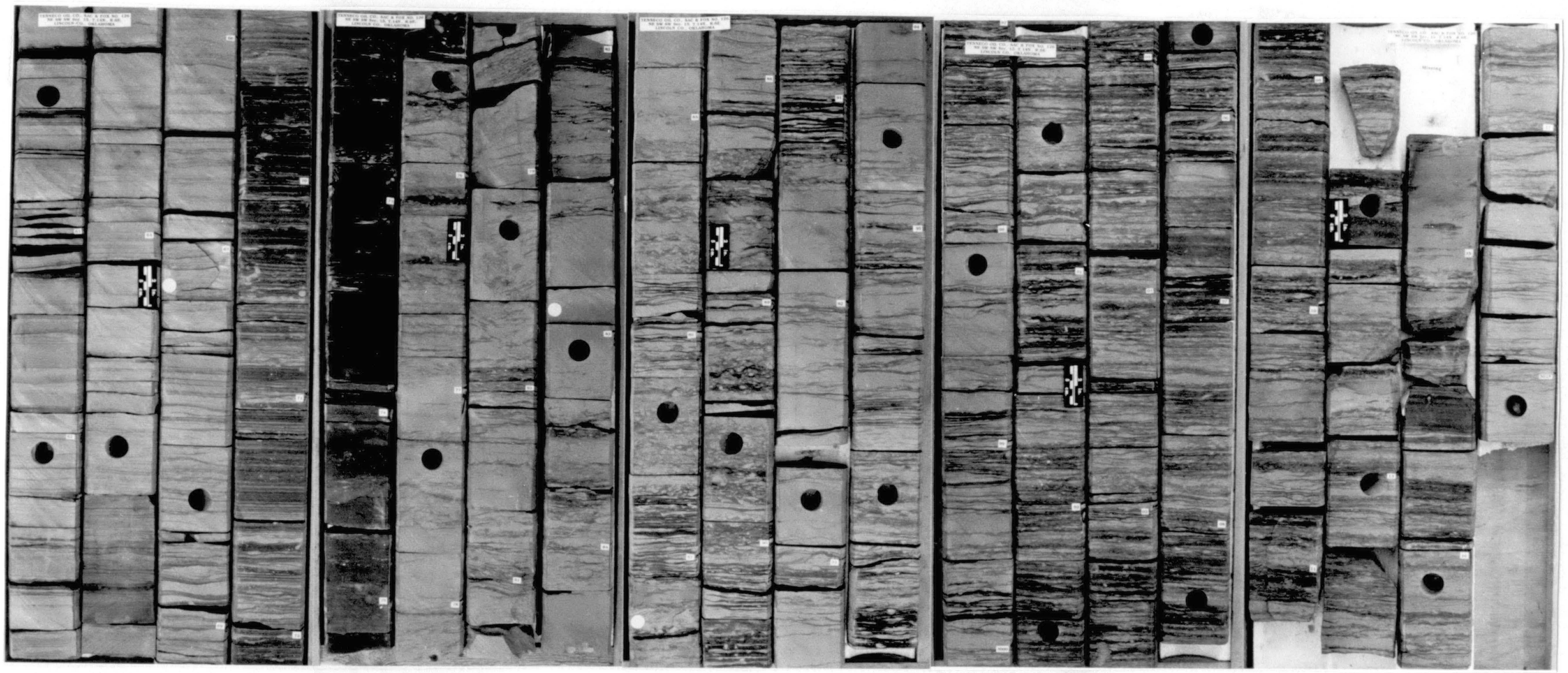


Figure 13. Photograph of Core, Tenneco Oil, No. 126 Sac and Fox, Section 15, T14N, R6E, Interval from 2960 to 3018.3 feet

This core also contains a massive fossiliferous black shale. The black shale contains siderite, soft sediment deformation (flowage), fossils (brachiopods and crinoids) and some horizontal burrows. This black shale is interpreted as a deeper water prodelta shale.

<u>Phillips Oil Operating Co. Quintle</u>
<u>No. 1 Section 9, T16N, R2E</u>

The cored interval is from 4276 - 4333.5 feet and includes the entire interval from the Prue Sandstone through the Breezy Hill Limestone (Figure 14). The base of the core is planar-bedded, very fine-grained sandstone. An abrupt scour contact with abundant fossil hash occurs near the base of the core. The sandstone is a fine-grained and moderately well to well sorted. Sedimentary structures include massive bedding, large scale tabular planar cross-bedding, and small scale trough cross-bedding. Carbonaceous laminae are abundant, siderite nodules and calcite cement are also present. Grain-size decreases toward the top of the core suggesting a waning of energy. This sandstone is interpreted as a channel fill deposit. The fossil hash is believed to represent reworking of marine sediments after abandonment of the channel. The fining upward character of the sandstone suggests the beginning of channel abandonment.

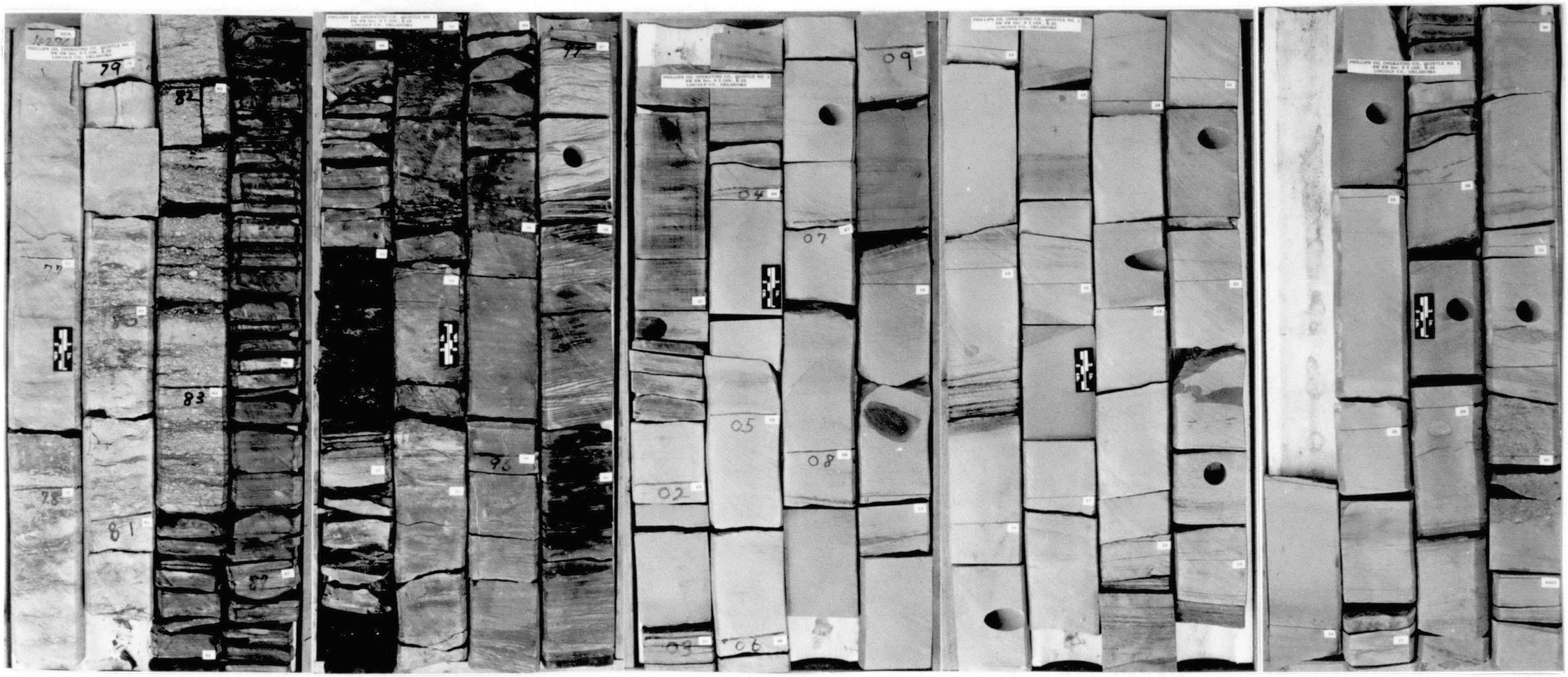


Figure 14. Photograph of Core, Phillips Oil, No. 1 Quintle, Section 9, T16N, R2E, Interval from 4276 to 4333.5 feet

Plant fossils are observed at 4299 feet. These indicate that the shales and sandstones above the channel-fill sandstone represent abandoned channel or marsh deposition (Figure 15). Muddy sandstones at 4296 and 4298 exhibit small-scale trough cross-beds.

The black shale above the sandstone and muddy sandstone interval contains two coal beds. This shale interval is overlain by the fossiliferous Breezy Hill Limestone (Figure 14). These units are interpreted as deposition resulting from the flooding of the Prue interval.

Depositional Model

A combination of the works of Heckel (1977, 1984, and 1986), Bennison (1984), and Brown, Solis-Iriarte, and Johns (1990), served as a foundation for the interpretation of the depositional environments of the Prue interval. Both works address relative rise and fall of sea level and their associated environments of deposition. The Prue Sandstone was interpreted utilizing sequence stratigraphy and cyclothemic concepts.

A transgressive systems tract (TST) represents a time of maximum flooding. It is bounded below by the transgressive surface and above by the downlap surface or maximum-flooding surface (Van Wagner, Mitchum, Campion and

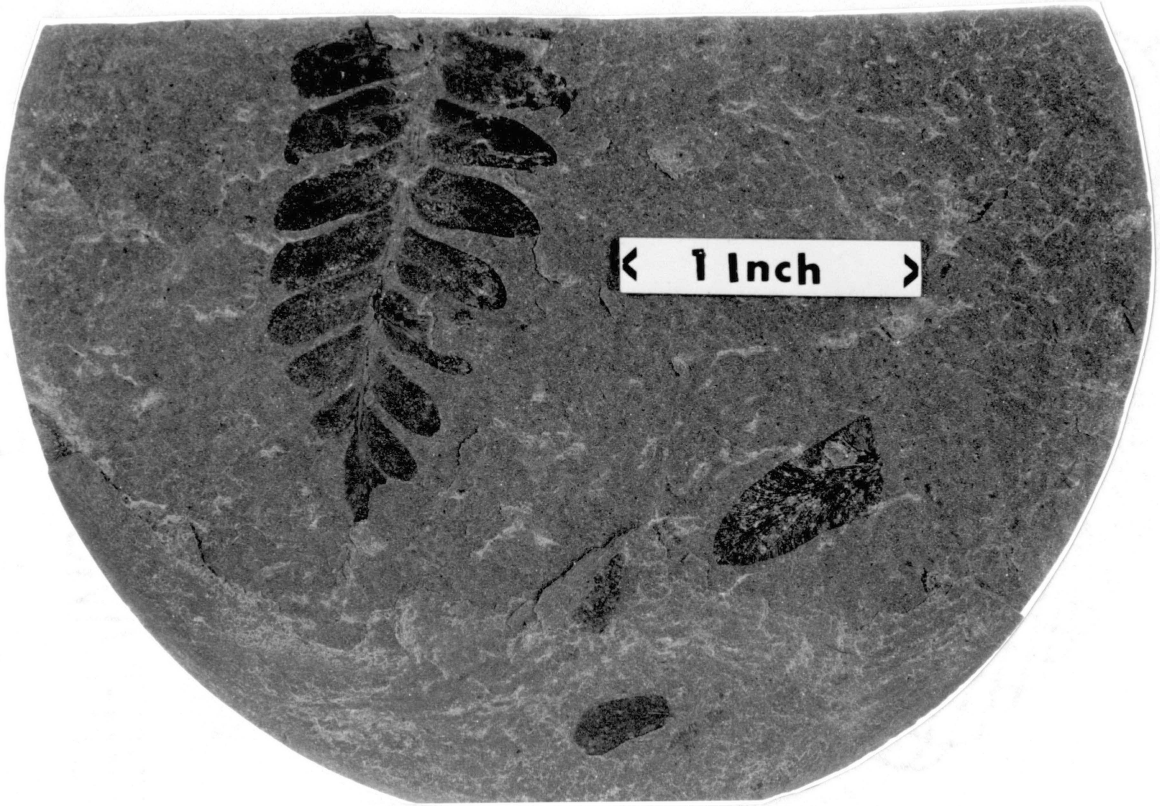


Figure 15. Photograph of Plant Fossils, from No. 1 Quintle at 4299 feet, indicating interdistributary environment

Rahmanian, 1990). Highstand systems tracts (HST), are deposited when relative sea level is high. Lowstand systems tracts (LST), form when sea level rapidly falls below the depositional shoreline break (Brown, Solis-Iriarte and Johns, 1990). These depositional systems tracts were evident in the Upper Cabaniss Group on the Northeastern Oklahoma Platform (Figures 16 and 17).

The Oakley Shale is interpreted as being deposited during the time of maximum sea level rise (TST), followed by a relative minor withdrawal of the sea allowing for the Verdigris Limestone deposition. Continued waning of sea level during the highstand (HST), allowed for the deposition of the deltaic sandstones and delta fringe facies of the Prue Sandstone interval. In late Prue time, a rapid fall is sea level caused incised valleys to develop during the lowstand (LST).

Incised valleys form and fill in two phases. The first phase consists of erosion. Evidence of erosion is indicated by incision of the deltaic systems of the Prue Sandstone and underlying Verdigris Limestone. Most sediments bypass the shelf through the eroded valleys and are carried to the shelf edge. The second phase consists of deposition within the valleys in response to relative rise in sea level. Backstepping channel fill may have occurred during this time. Glauconite grains present in

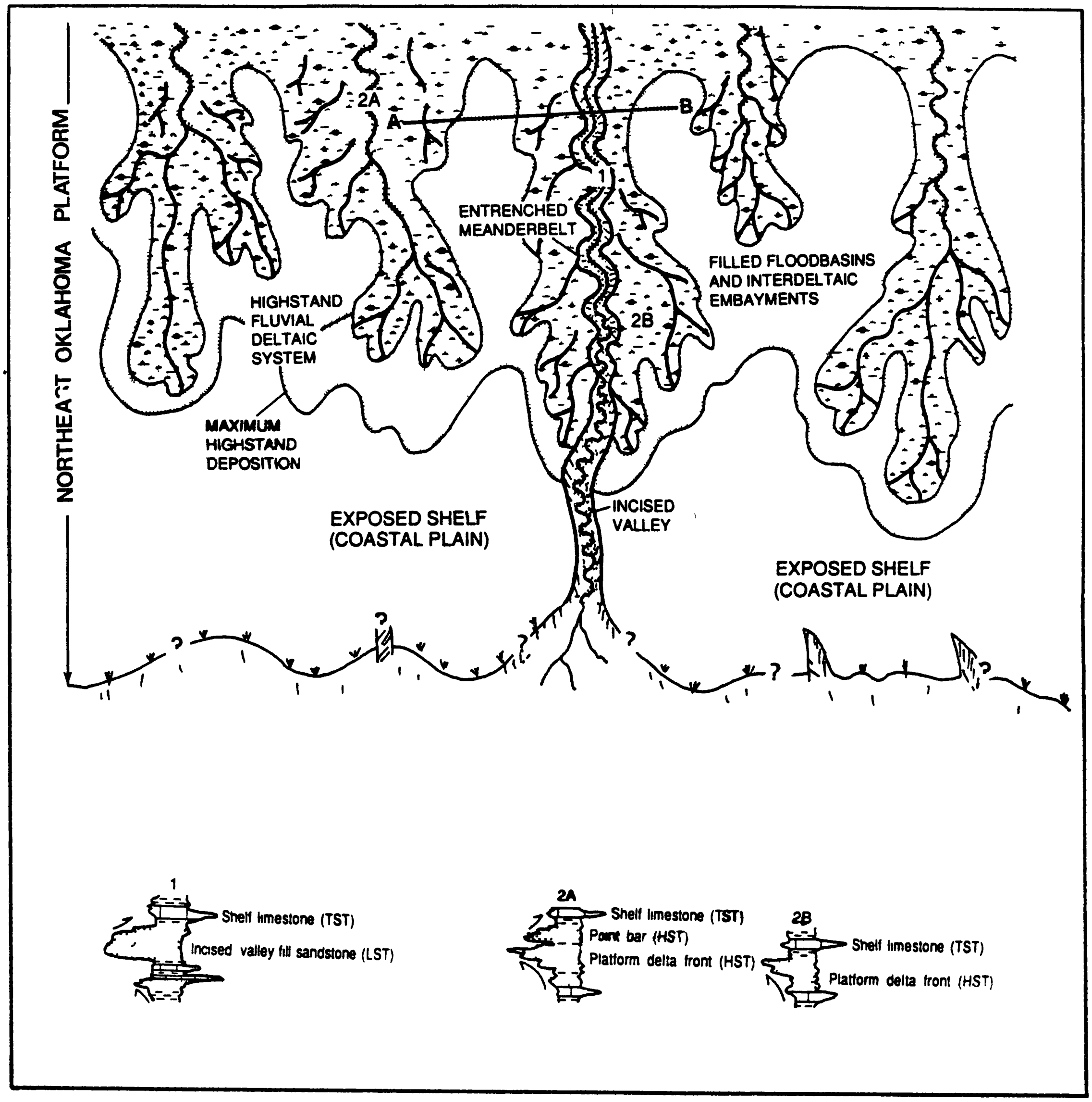


Figure 16. Depositional System at Maximum Progradation of the Prue Sandstone (Modified from Brown, Solis-Iriarte, & Johns, 1990)

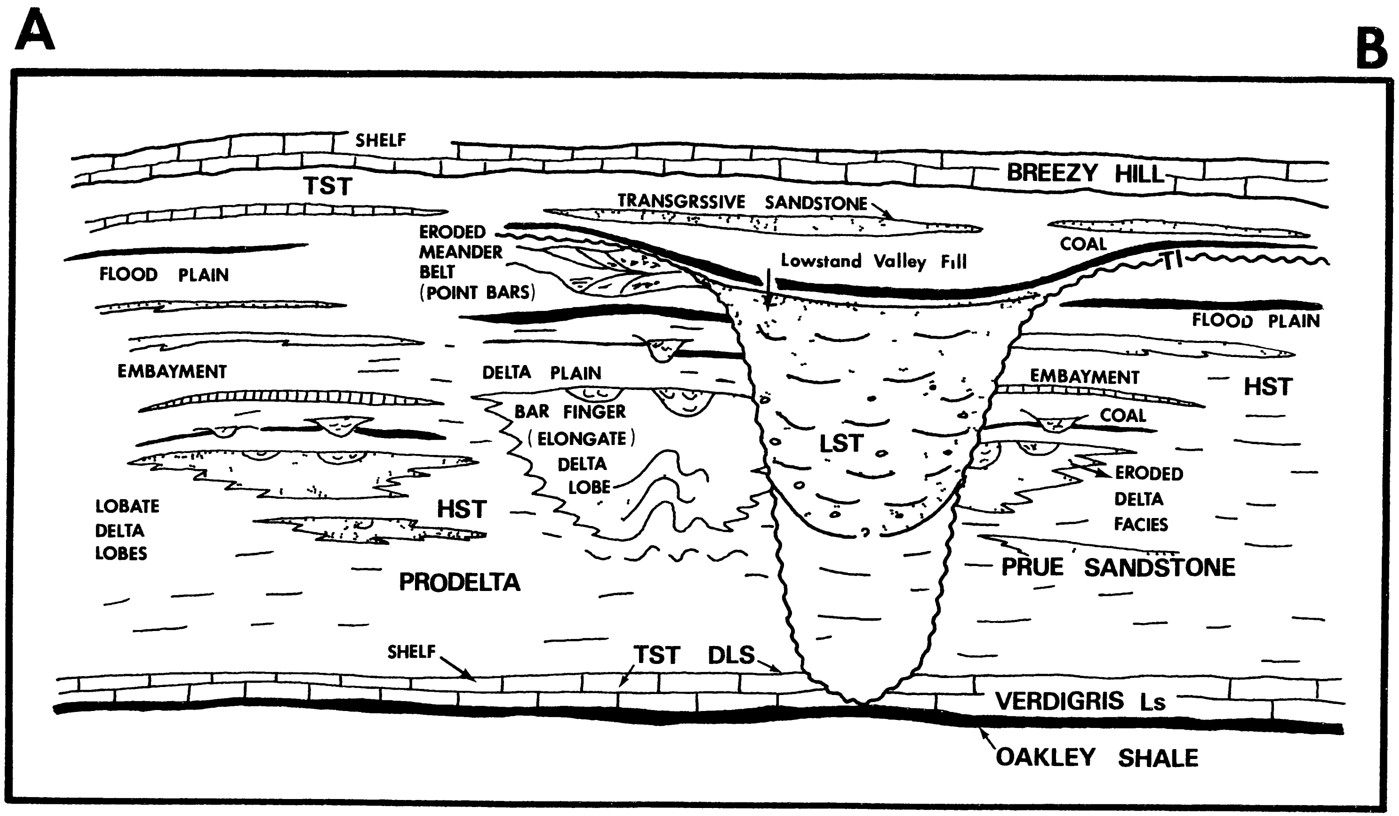


Figure 17. Idealized Cross-section showing Depositional Relationship of Cycle 1 (Modified from Brown, Solis-Iriarte, & Johns, 1990)

the incised channel fill in the Gulf, Hamm 1 (Figures 25 and 26, Chapter V) seem to support this hypothesis. However, the glauconite may be the product of recycling older shallow marine deposits during the incision. Further rise in sea level enabled deposition of the Breezy Hill Limestone. In the area of investigation, the limestone lithofacies is not prevalent. Carbonate was deposited in the Tenneco, Quintle 1 (Figure 13), but deeper marine shale and muddy carbonate was deposited in the area of investigation.

The generalized depositional history of the Oakley Shale through Oswego Limestone interval is shown in Figure 18. This figure describes the two depositional cycles with a related sea level changes that were established for the study stratigraphic interval.

SP Signatures and Possible Depositional Environments

The Central Oklahoma Platform is characterized by cycles of the Upper Cabaniss and Lower Marmaton Groups outlined in Chapter III. Subsurface mapping, examination of cores calibrated with SP signatures and geographical location represent the evidence for the depositional facies model. This concept was further developed through the interpretation of SP signatures and their possible environments of deposition.

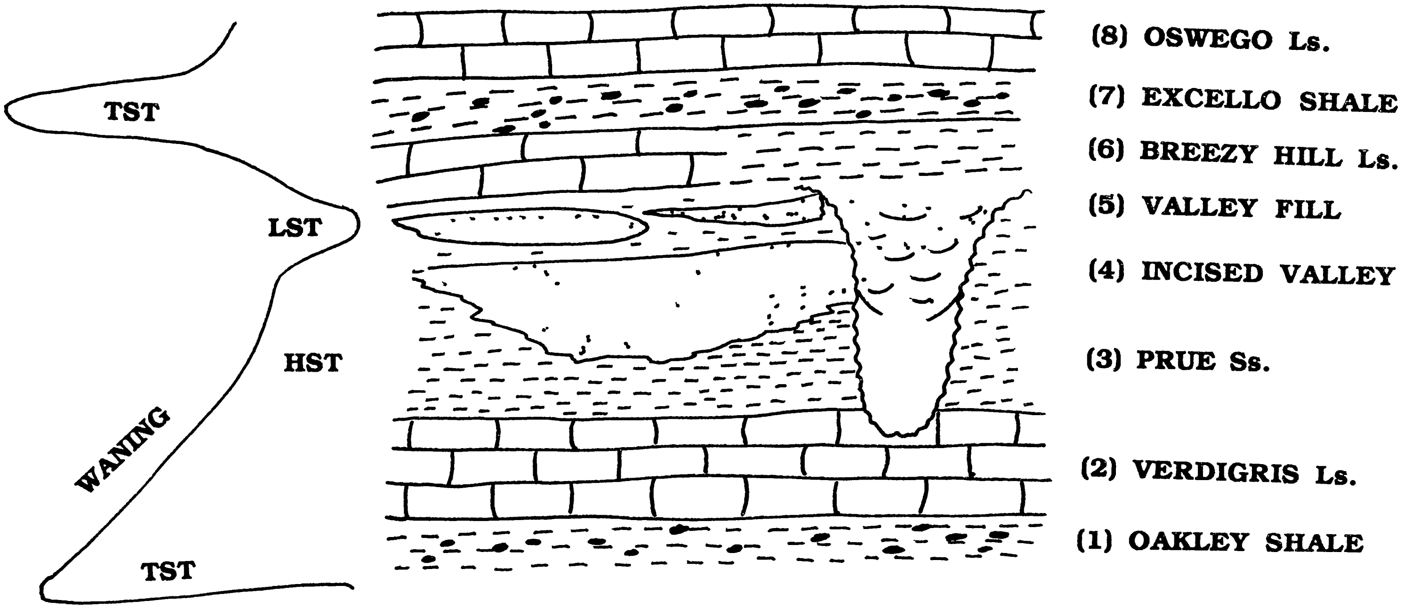


Figure 18. Generalized Depositional History of the Oakley Shale through the Oswego Limestone Interval.

Four general electrofacies were recognized in the study area, bocky (B), flat (F), fining upward (FU), coarsening upward (CU). Due to the dynamic nature of a delta system, shifts in environments of deposition cause hybrid patterns of the four basic signatures (Figure 19). The mapped SP log signatures are segregated in order to infer possible environments of deposition based on overall SP patterns. Figure 20 and Plate VII show the electrofacies segregation and log signaures of the Prue interval, respectively. Sandstone SP patterns fine upward, coarsen upward, are serrated and are blocky. The sandstones may appear in the center, top and or bottom of an overall flat SP pattern.

Blocky (B) patterns with a relatively sharp scoured base, suggest constant grain size and sorting indicative of a high energy environment such as a distributary channel or incised valley fill.

Flat (F) patterns have virtually no discernible change in SP character. This pattern suggests clay-rich rocks of the prodelta, delta fringe or interdistibutary bay.

Finning upward (FU) is characterized by a gradational top and sharp scoured base. Grain size appears to decrease upward. Possible environments of deposition are distributary channel with abandoned channel fill or incised valley fill with waning energy toward the top.

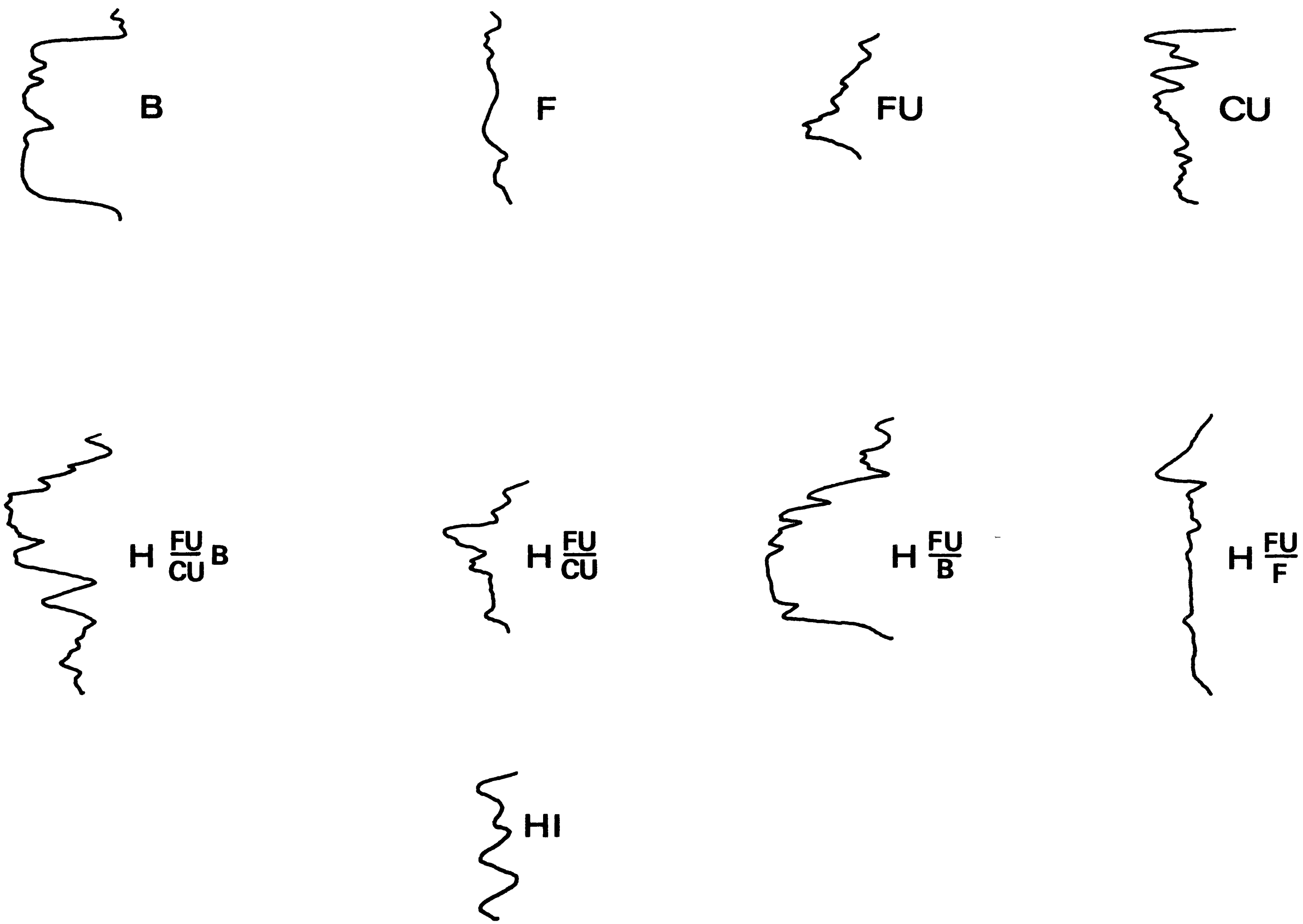


Figure 19. Observed SP Patterns in the Prue Sandstone Interval

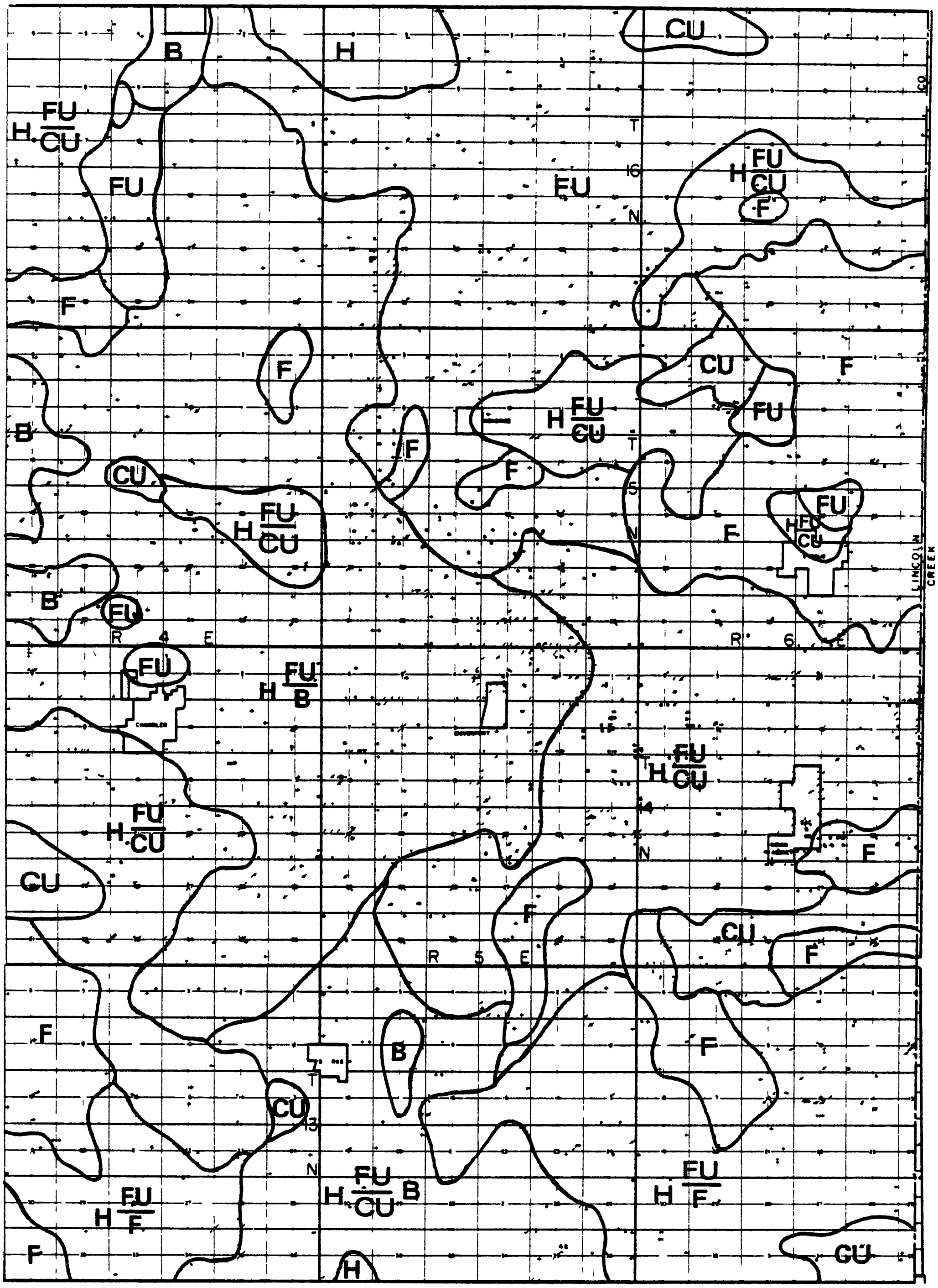


Figure 20. Electrofacies Distribution Map

Coarsening upward (CU) is characterized by a sharp upper contact with the overlying shale and a gradational base. Grain size appears to increase upward indicating higher energy toward the top of the unit. Possible environments of depositions include delta stream mouth bar or possible barrier island shoreface sequence.

Hybrid log signatures are also common in the Prue interval. These include the H FU/CU B that represents a blocky pattern that has a coarsening up component on the bottom and a fining upward component toward the top. A H FU/CU has the same characteristics of the previous hybrid signature except for the blocky nature. These signatures are believed to represent channel fill on top of delta front or fringe sediments.

Another signature that appears to represent abandoned channel fill is the H FU/B. This signature has a blocky base that is overlain by a fining upward interval that represents waning energy and abandonment. The flat signature with a minor fining upward interval at the top is named H FU/F. This signature is believed to represent channel fill overlying interdistributary or prodelta deposition.

The HI signature appears to have no discernible fining upward or coarsening upward characteristics. It appears to be interbedded sandstones and shales that represent interdistributary deposition.

One of the major aspects of this study is the delineation of the depositional environments of the Prue Sandstones. Integration of the electrofacies distribution map (Figure 20) and core data led to the interpretation shown on the depositional facies distribution map (Figure 21).

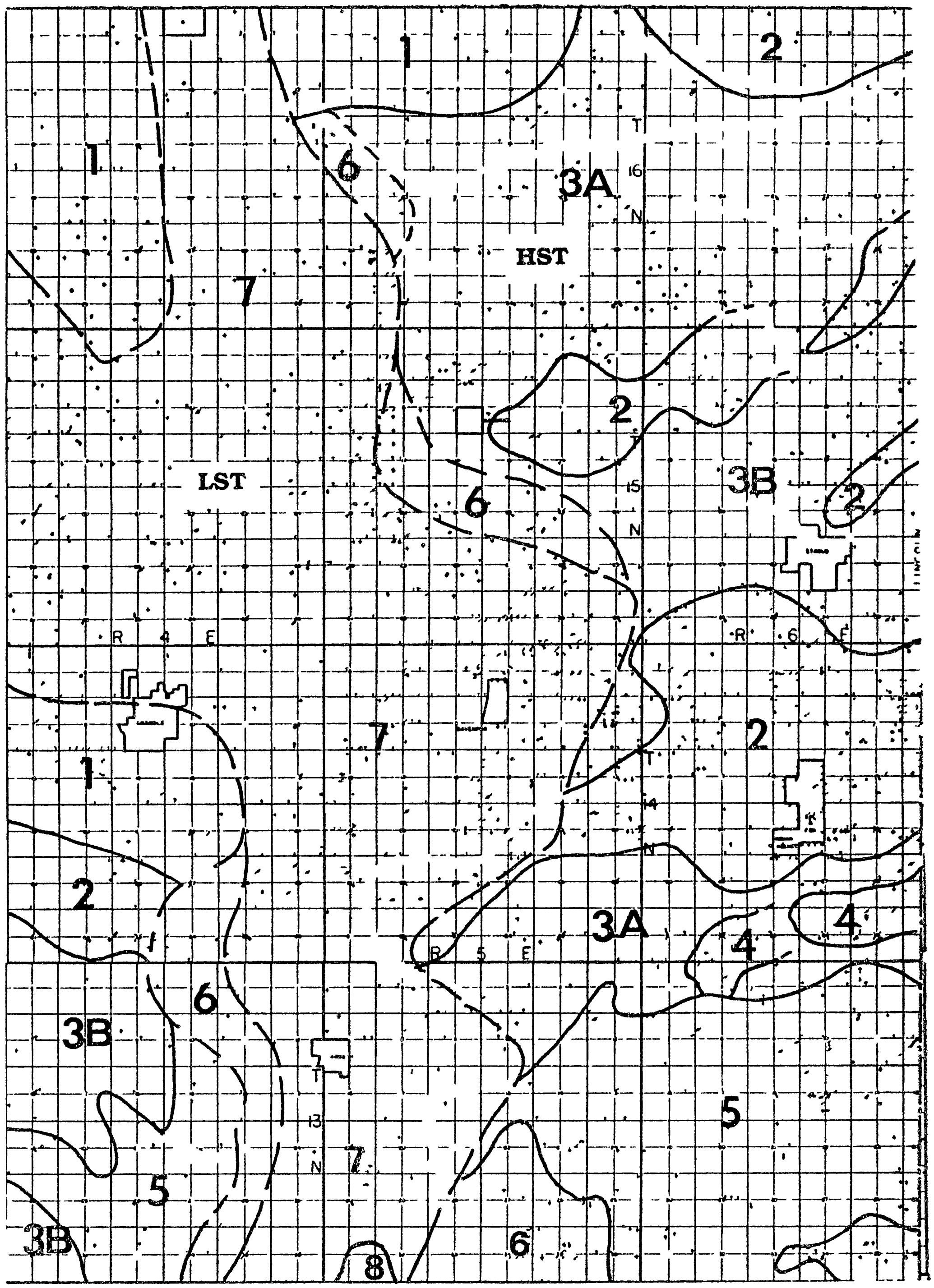


Figure 21. Depositional Facies Distribution Map
1) Interdistributary Bay 2) Channel-fill overlying Delta Front
3A) Distributary Channel 3B) Prodelta
4) Delta Front 5) Interdistributary Bay or Prodelta overlain by minor Channel Fill 6) Abandoned or Incised Valley Fill 7) Incised Valley Fill
8) Distal Delta Front

CHAPTER V

PETROLOGY AND DIAGENESIS

Methodology

The methodology utilized to determine detrital and authigenic constituents in the Prue Sandstone, included 1) thin-section petrography and 2) x-ray diffraction of natural and clay-extracted powdered samples. The clay extraction involved removal of organic, iron-oxide, and carbonates from the sample.

Thin-section petrography was used to determine mineralogical composition and timing of diagenetic events. X-ray diffraction was used to determine the types and crystallinity of clay minerals.

Detrital Constituents

Thin-sections from four of the five cores were examined for quantitative mineralogy (Figure 22) and plotted on a ternary quartz, rock-fragment, and feldspar (QRF) diagram (Folk 1974). The majority of the 28 thin-sections plotted as sublitharenite and subarkose.

Monocrystalline quartz is the most abundant constituent, comprising 55% of the detrital constituents.

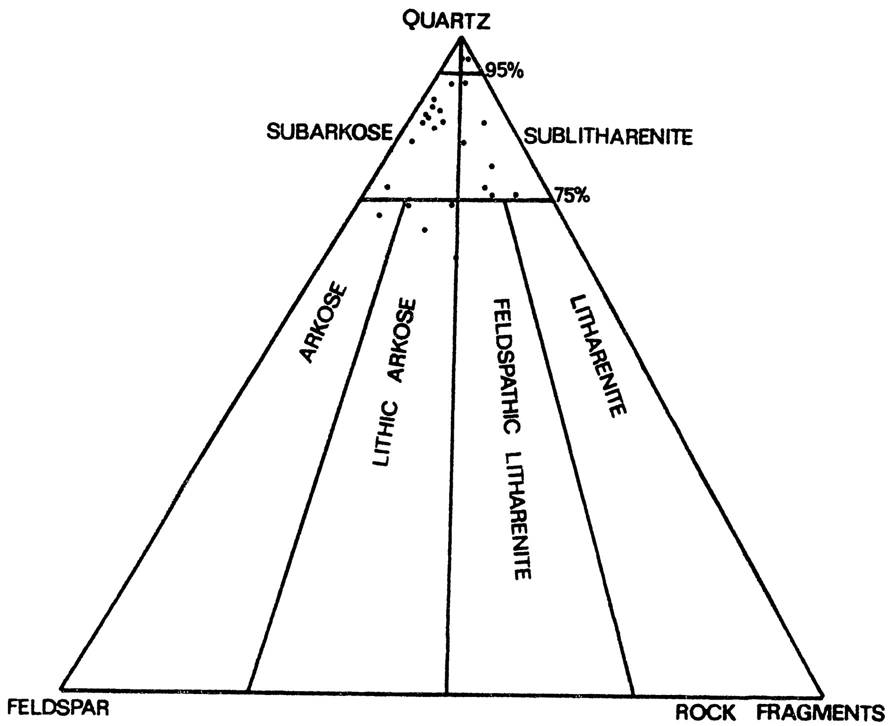


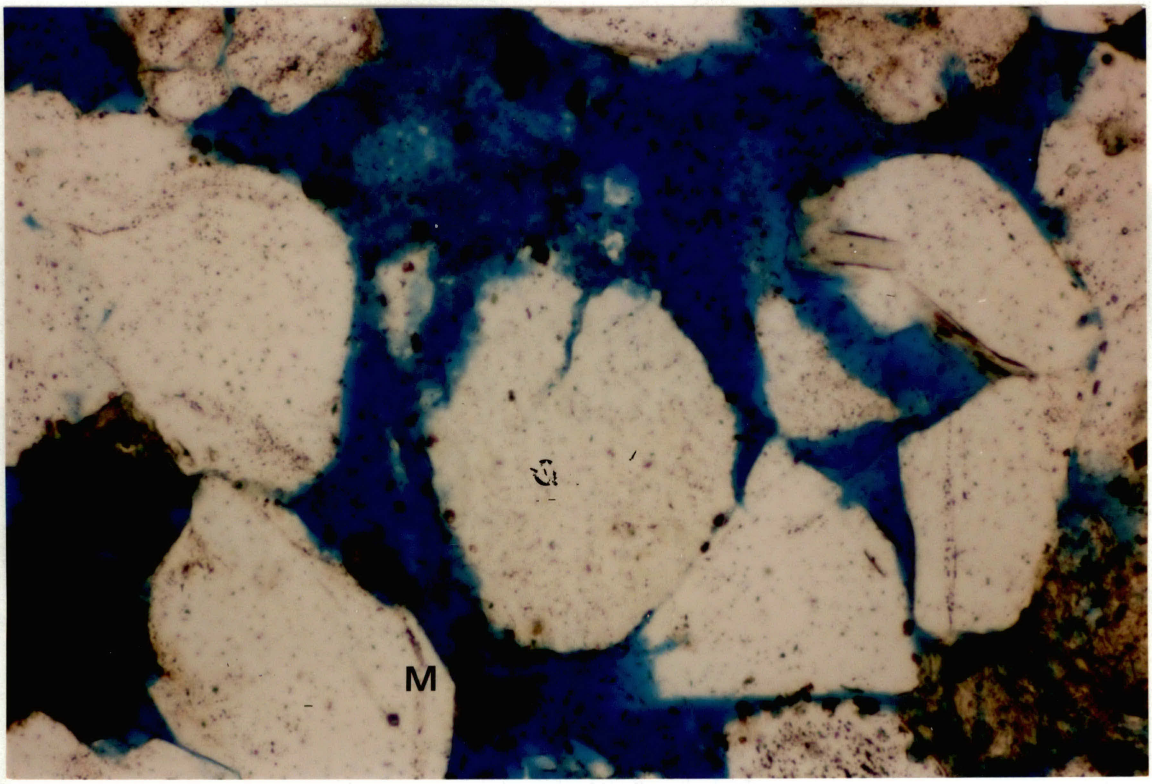
Figure 22. Detrital Composition of the Prue Sandstone (after Folk 1974)

Grains are subrounded to subangular. Original quartz grain shapes may be preserved by micrite dust rim observed in Figure 23. This figure shows a dust rim on a quartz grain with quartz overgrowth. Polycrystalline quartz, seen as sutured composite grains, comprises 1%.

Feldspar is present, comprising 8% of the total grains present. It is present as plagioclase, microcline, and less abundant orthoclase grains. Feldspars often show dissolution of grains.

Rock fragments typically include schistose metamorphic and shale clasts. These grains are commonly observed as ductilly deformed psuedomatrix. Figure 24 shows an illitic rock fragment forming psuedomatrix. Chert grains are also seen but are not common.

Muscovite involves as much as 2.4% of detrital constituents and is observed altered to chlorite (Figure 25). Glauconite is a minor constituent. Two types are observed throughout the thin sections. A "cleaner" glauconite grain appears in the May 3, Sac & Fox 123, Potter 5, and the Hamm 1 wells. Figure 24 shows "cleaner" glauconite grain (G). Figure 25 shows "dirty" altered glauconite grain forming psuedomatrix between quartz grains. Figures 25 and 26 are photos from thin sections of the Hamm 1. Minor amounts (<1%) of glauconite, phosphate, detrital chlorite, and accessory heavy minerals, including



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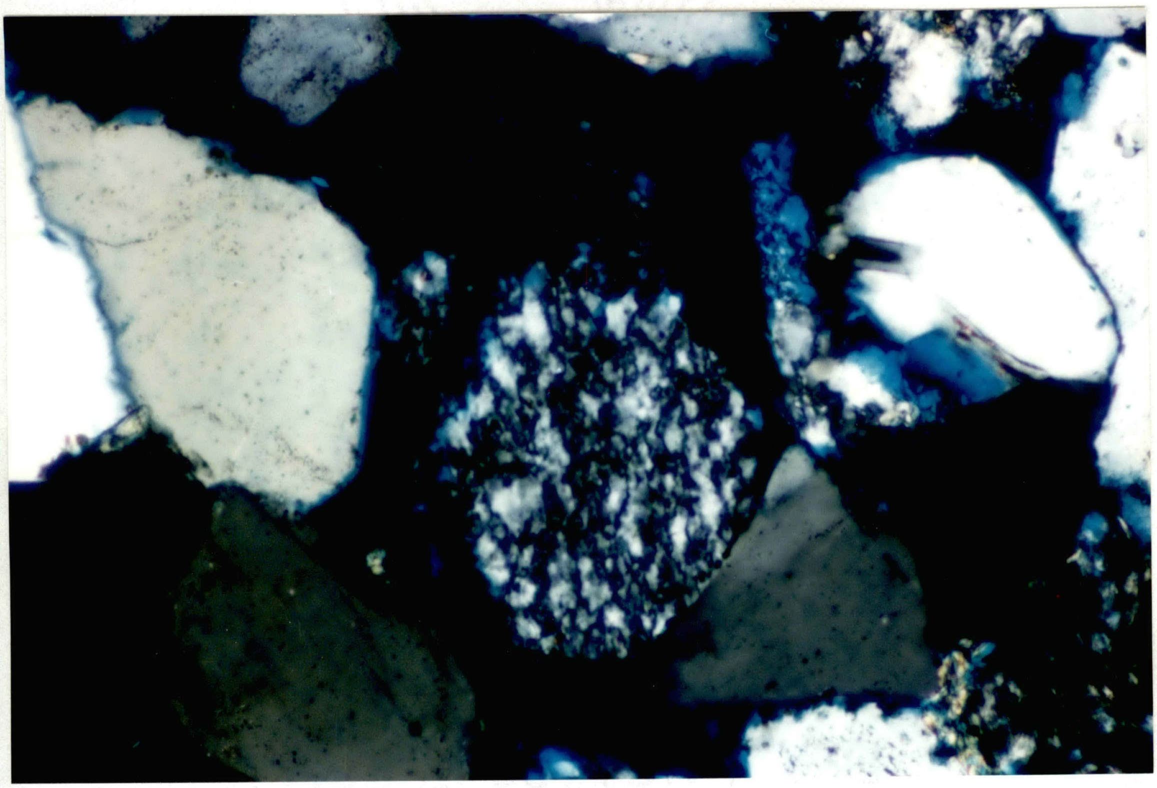


b

Figure 23. Monocrystalline quartz (Q), with micrite dust rim (M), showing quartz overgrowth. a) PPL b) XN (10X)

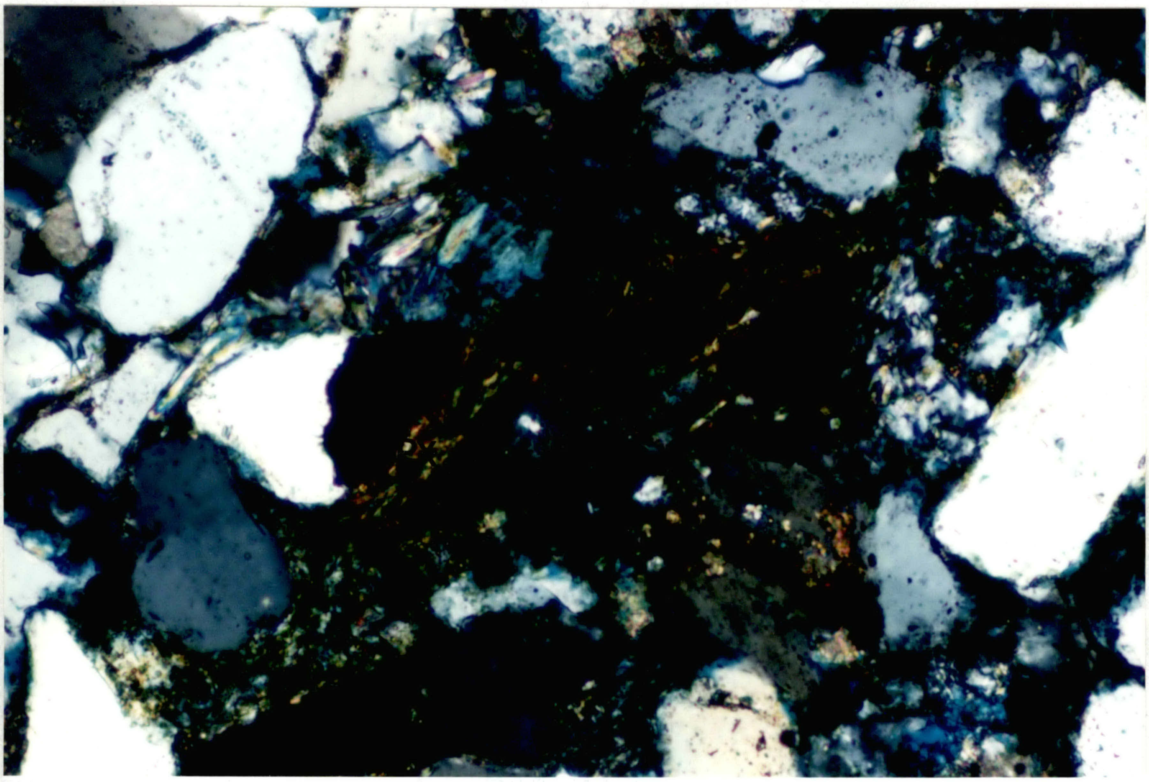
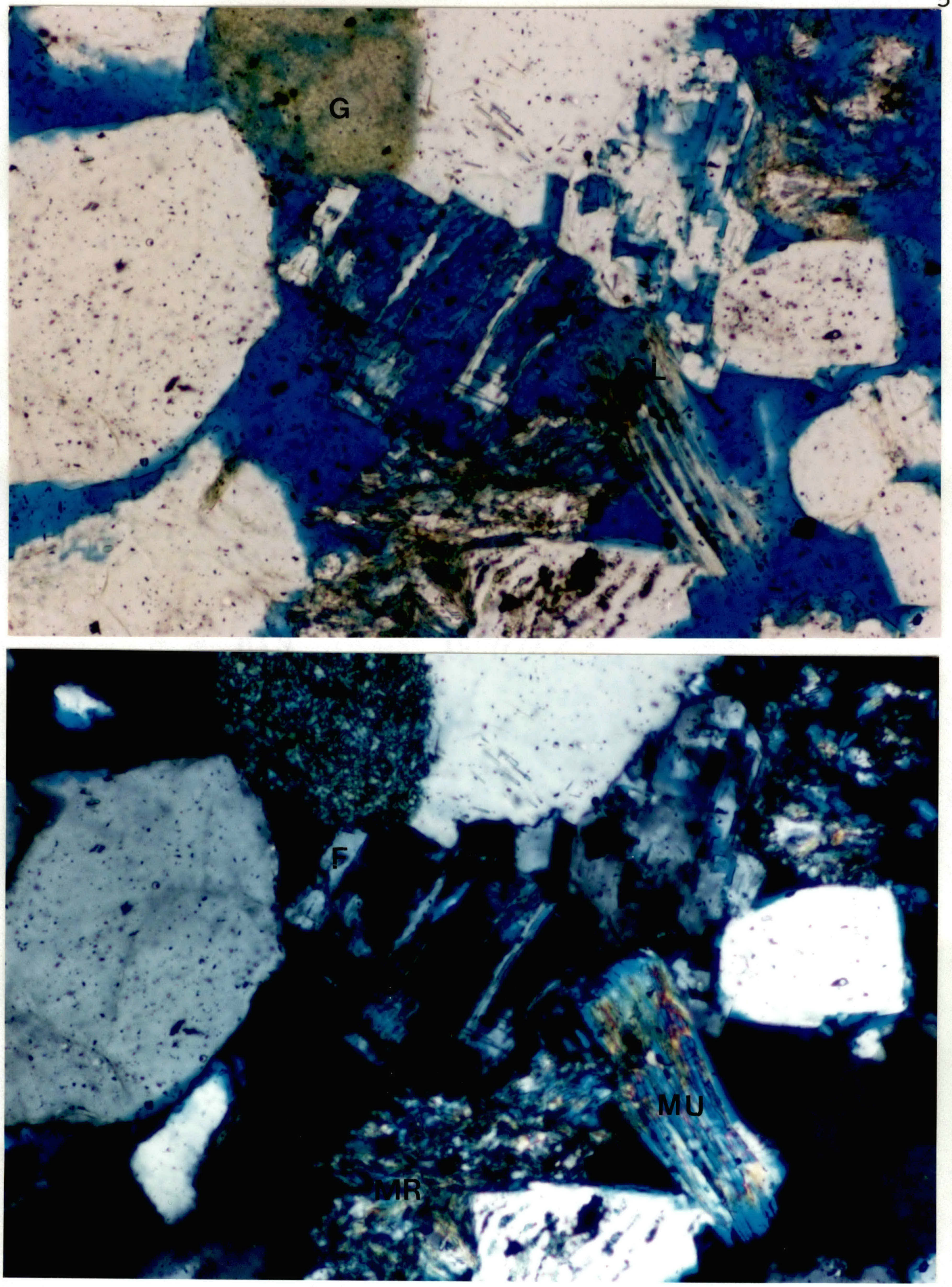


Figure 24. Pseudomatrix (PX), formed as a result of ductile deformation of illitic rock fragment. (XN) (10X)



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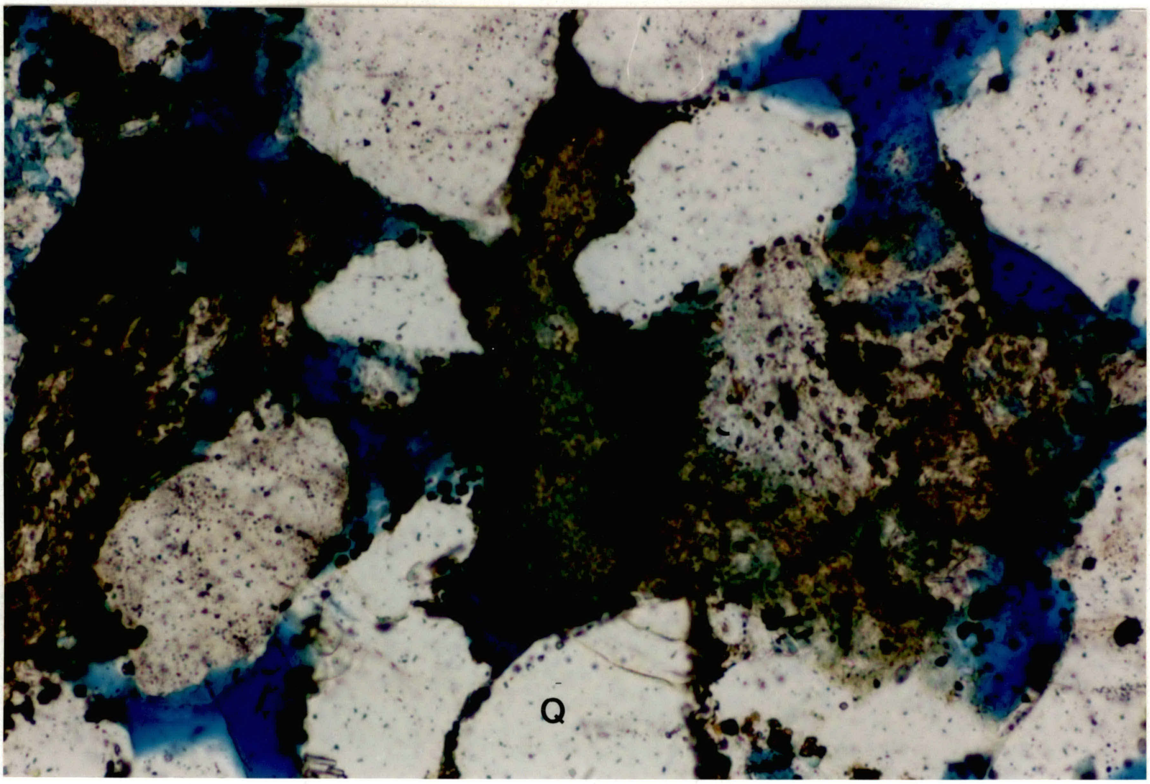
b

Figure 25. Secondary porosity formed from dissolution of detrial constituents: feldspar (F) metamorphic rock fragment (MR) muscovite (MU) altered to chlorite (CL) and "clean" glauconite (G). a) PPL b) XN (10X)



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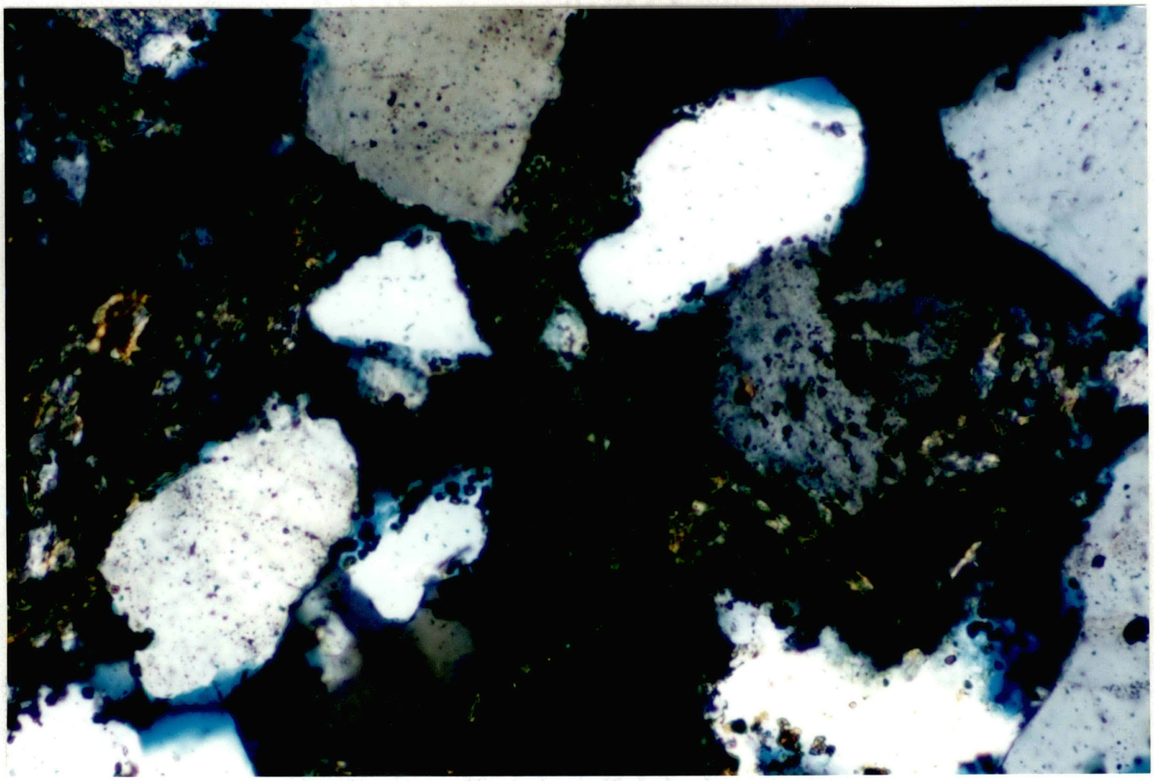

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Figure 26. Ductilly deformed, altered glauconite grain (G) forming pseudomatrix (PX) between quartz grains (Q), exhibiting quartz overgrowth. a) PPL b) XN (10X)

tourmaline and zircon are observed in thin-sections. Pyrite and carbonaceous material occur as accessory constituents. Fossil fragments observed in the Potter 5, May 3, and Sac & Fox 123 include echoniderm plates and spines, brachiopods, bryozoans and crinoids.

Diagenetic Constituents

Diagenetic constituents include cements and authigenic clays chemically precipitated from waters that flowed through sandstones during the course of diagenesis. Diagenetic constituents documented in the Prue Sandstones were quartz overgrowths, chlorite, kaolinite, illite, calcite, micrite, siderite and pyrite.

Authigenic silica occurs as syntaxial quartz overgrowths (Figures 23 and 26). Chlorite is present due to alteration of muscovite (Figure 25). Kaolinite is shown filling pores in Figure 27. Authigenic clays recognized in thin-section were confirmed by x-ray analysis (Figure 28). Figure 29 shows micritic matrix and illite lining detrital grains. Calcite cement is observed replacing quartz and feldspar grains (Figure 30).

Porosity

Primary porosity is observed as trace amounts of the total rock porosity. Secondary porosity is dominant,

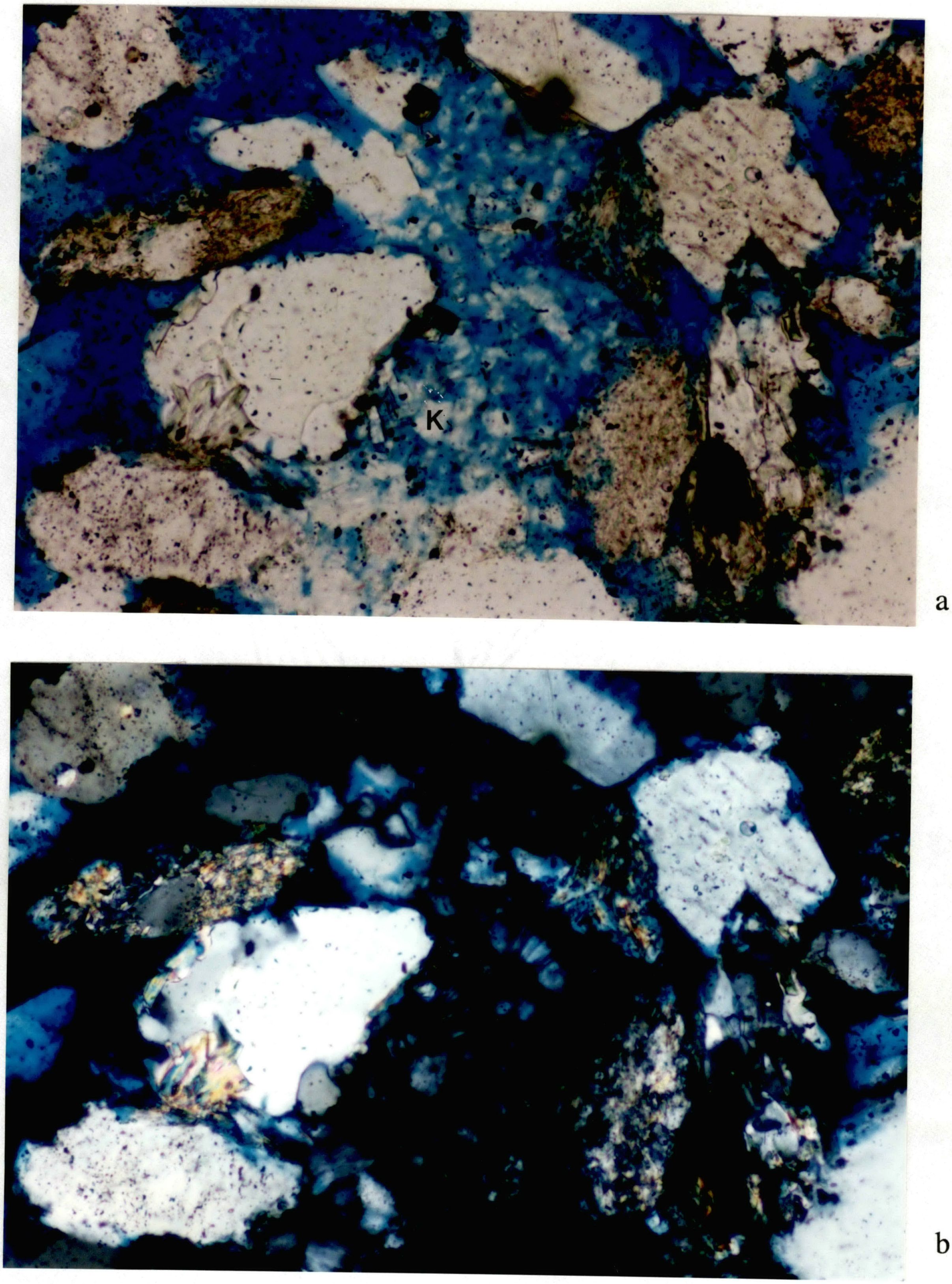


Figure 27. Kaolinite (K) occluding enlarged intergranular secondary porosity. a) PPL b) XN (10X)

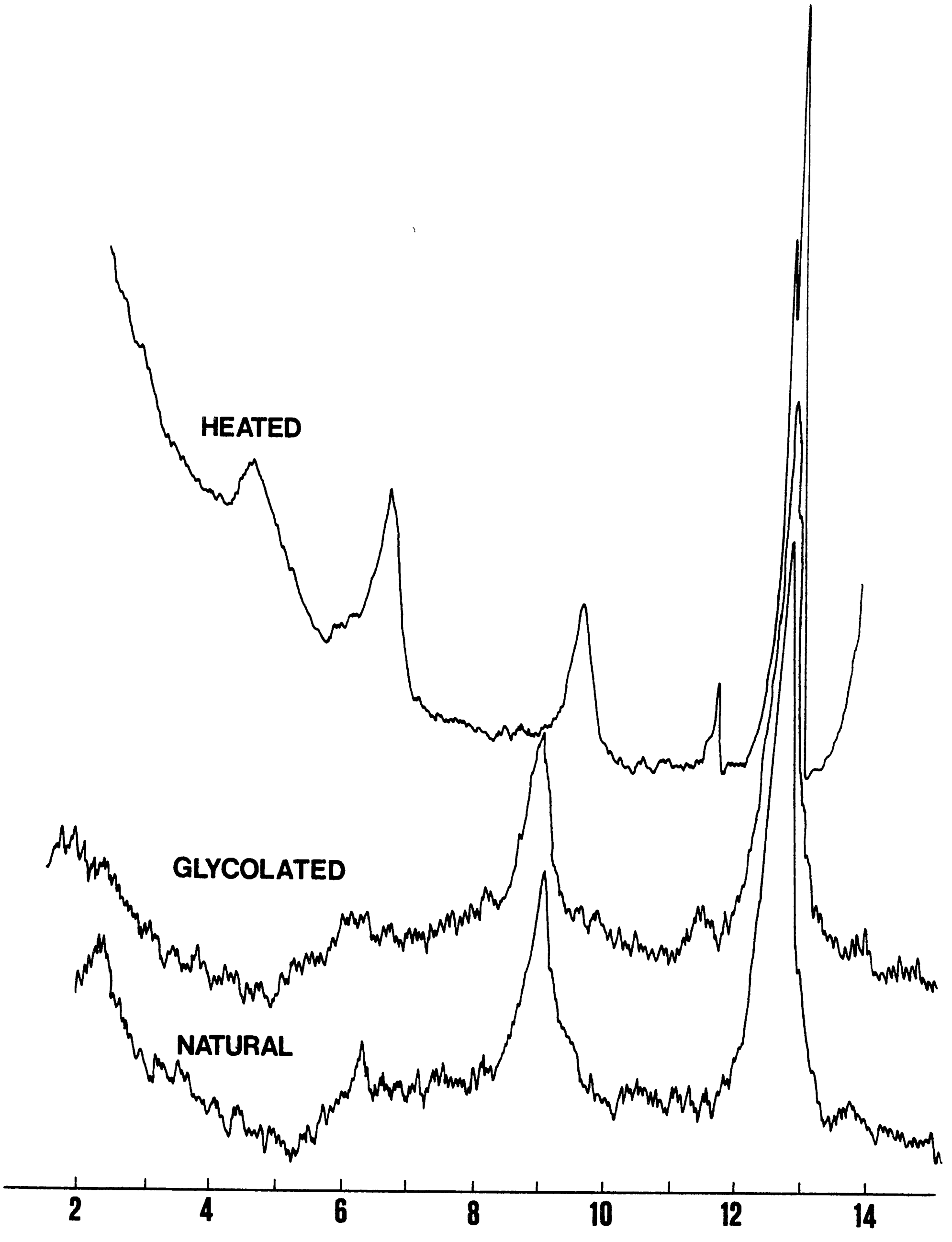
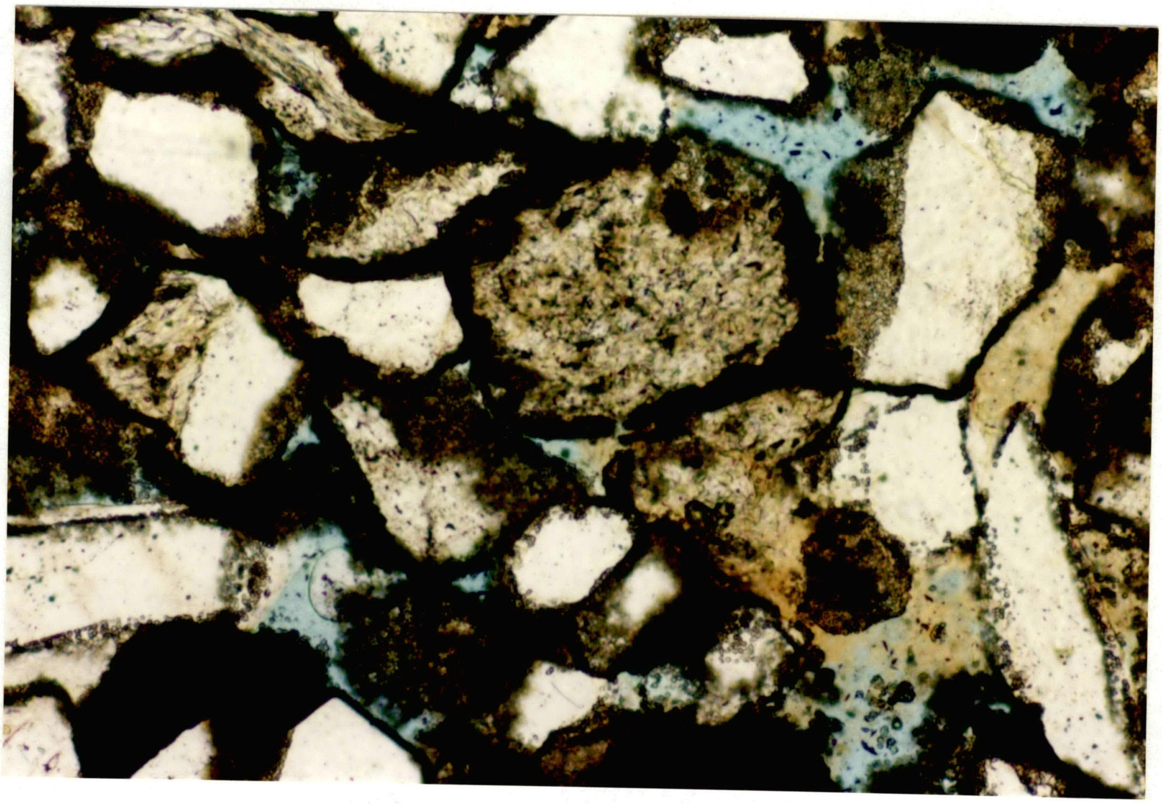


Figure 28. X-ray diffractogram of authigenic clay fractions from Prue Sandstone.



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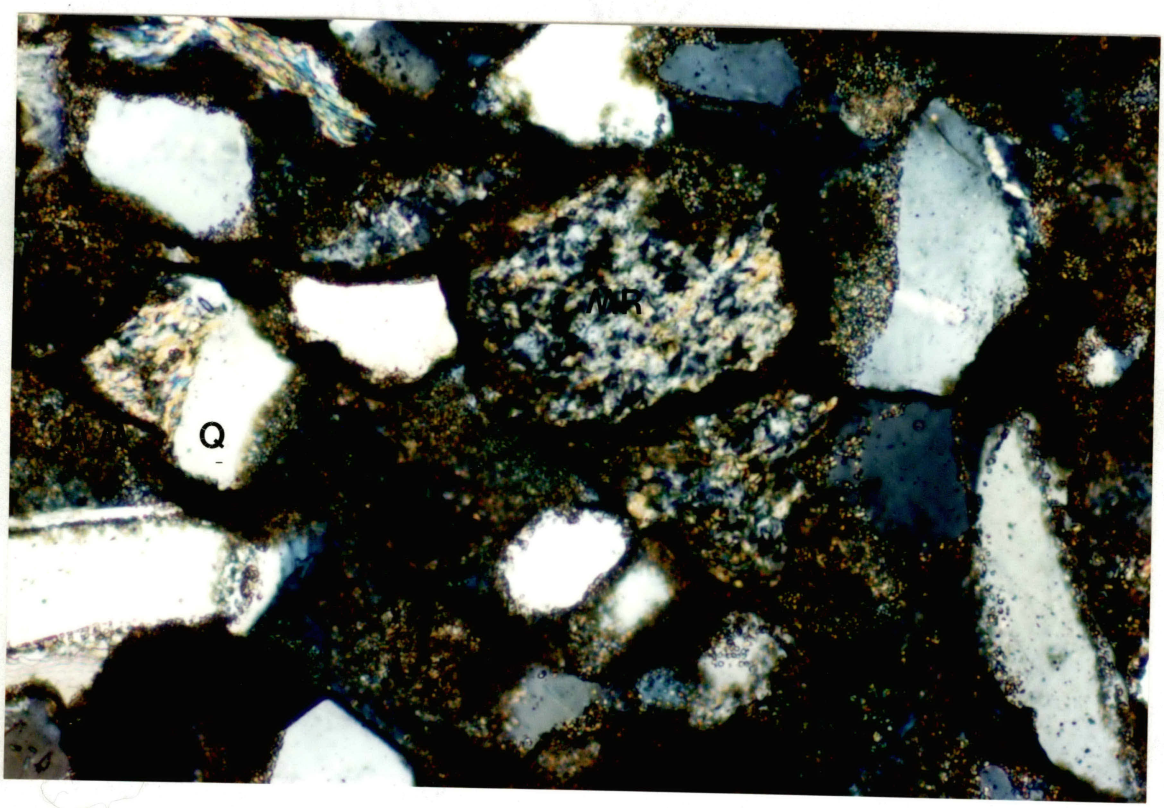

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Figure 29. Micritic matrix (MM) and micrite coating quartz grains (Q) and metamorphic rock fragments (MR) a) PPL b) XN (10X)

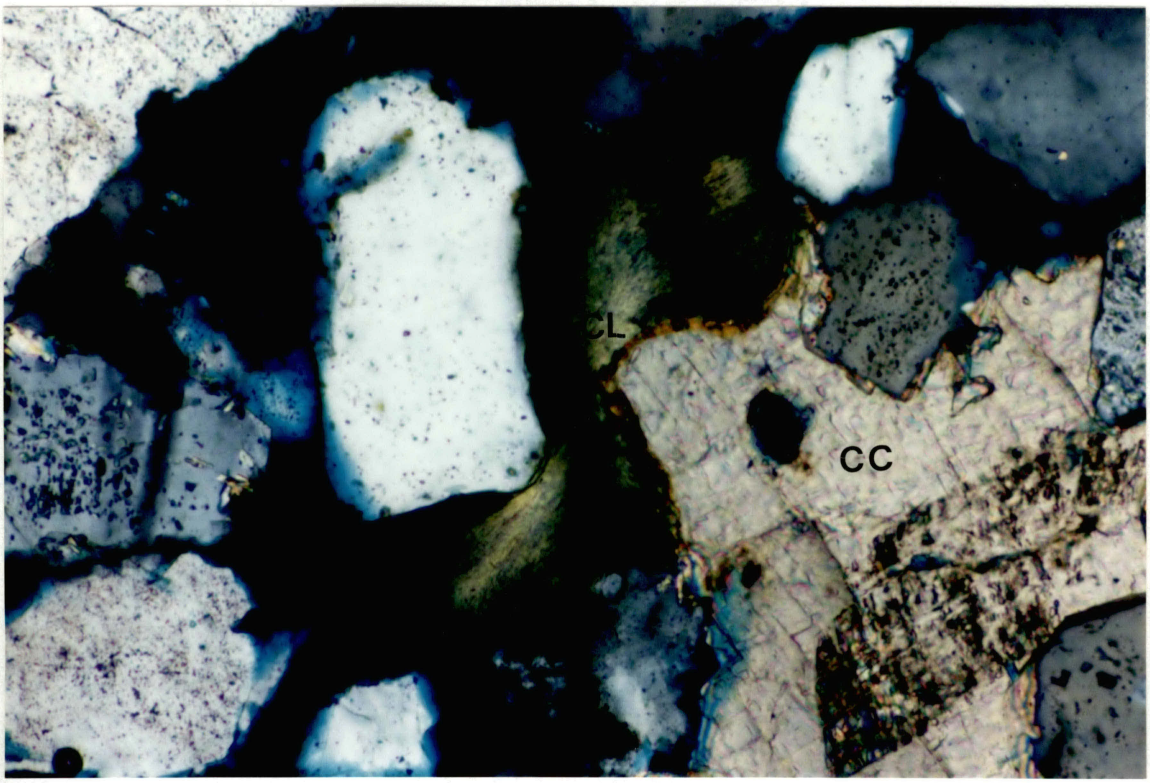


Figure 30. Ductilly deformed detrital chlorite (CL) forming pseudomatrix. Calcite cement (CC) replacing quartz and feldspar grains (XN) (10X)

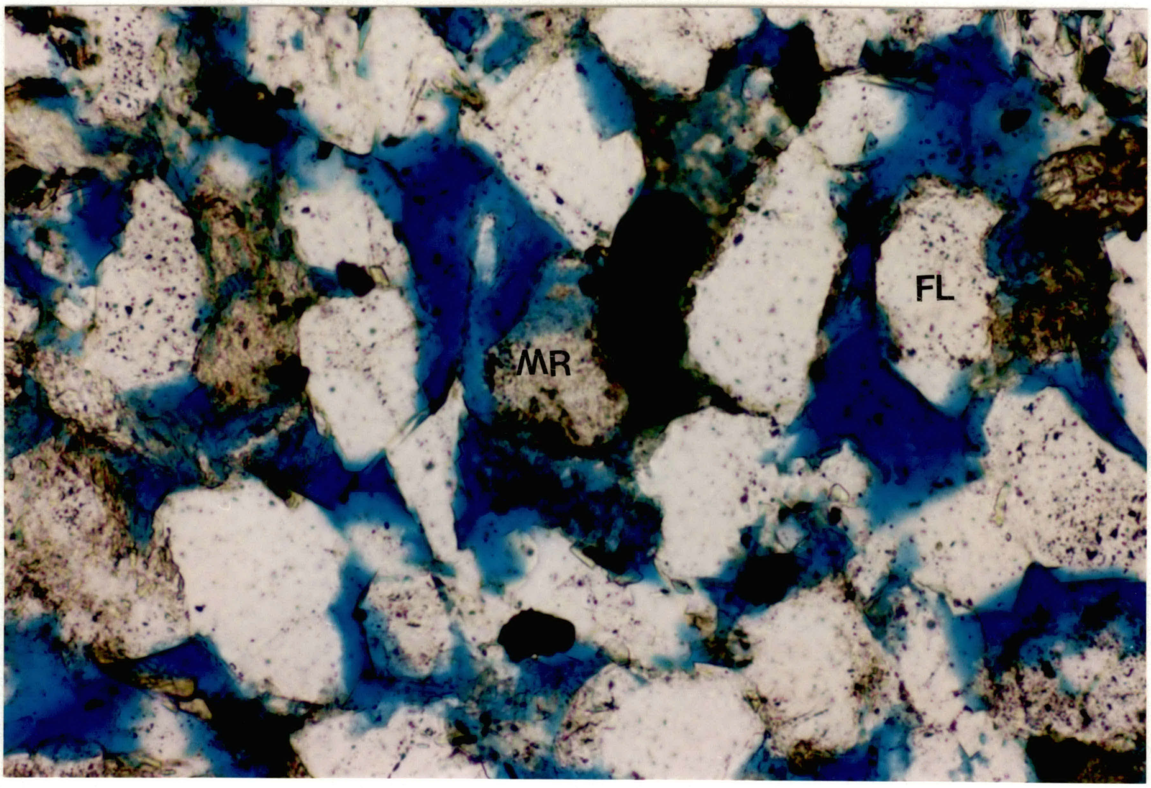
resulting from dissolution of rock constituents, especially in feldspar and metamorphic rock fragments (Figure 25). Secondary porosity as determined from thin-sections ranges from 0% to 25%, and the mean is 7%. The porosity increases with increase in grain size. Several types of porosity are observed in the Prue Sandstone including (1) partial dissolution, 2) moldic, 3) elongate pores, 4) oversized pores and "floating" grains, 5) honeycomb and 6) intragranular.

Partial dissolution of detrital grains and oversized pores is shown in Figure 31. Dissolution occurs due to geochemical reactions and is a common feature.

Moldic porosity shows shape and size of original detrital grain (Figure 32). As dissolution advances grain molds form oversized pores.

Elongate pores (Figure 33) originate as intergranular dissolution features. Oversized pores and "floating" grains suggest dissolution of detrital grains, matrix and authigenic cement.

Honeycombing is characteristic of feldspars; dissolution occurs along cleavage or twin planes. Intragranular porosity shows partial dissolution within the grain (Figure 33).



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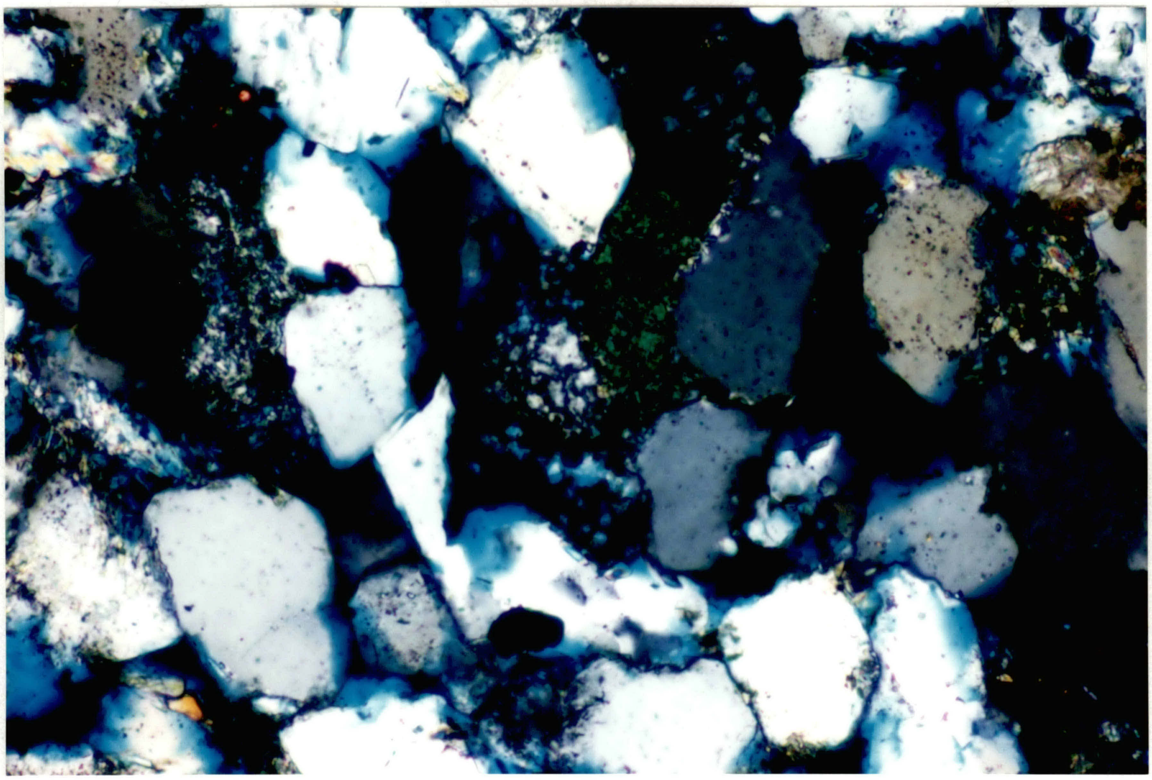

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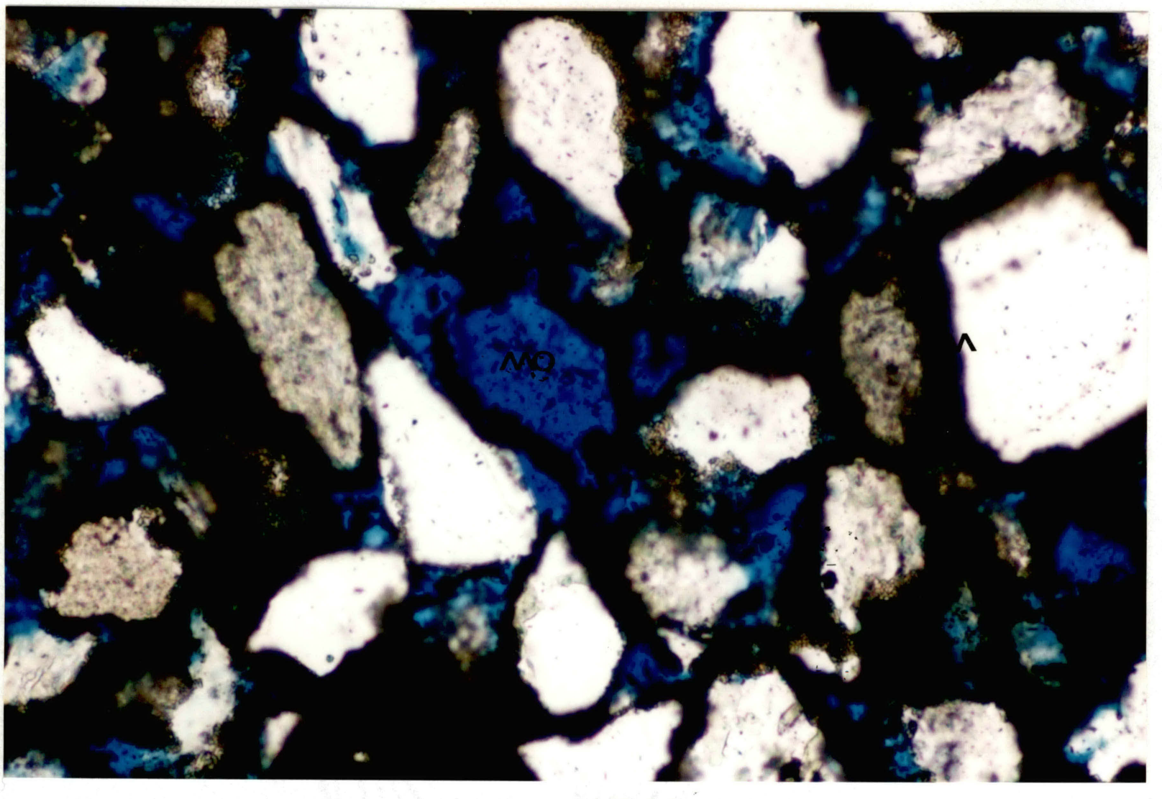
Figure 31. Partial dissolution of metamorphic rock fragment (MR) and "floating" grain (FL) in oversized pore. a) PPL b) XN (10X)



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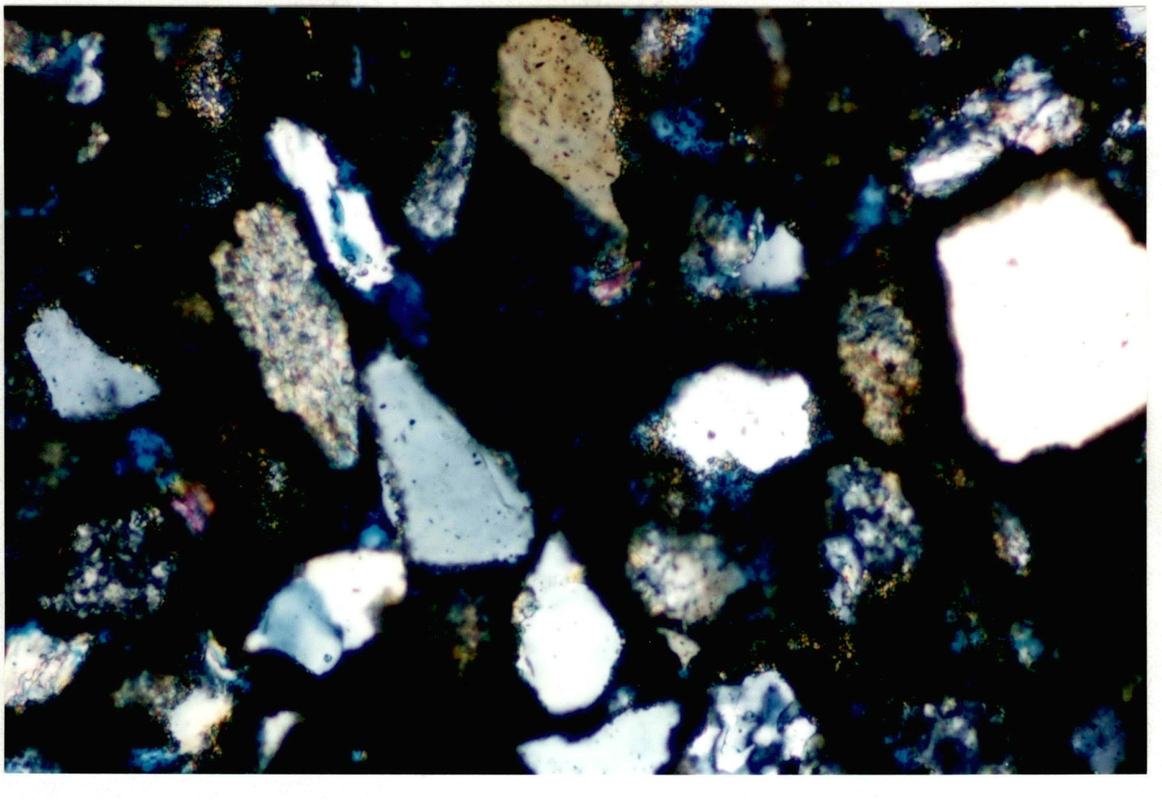

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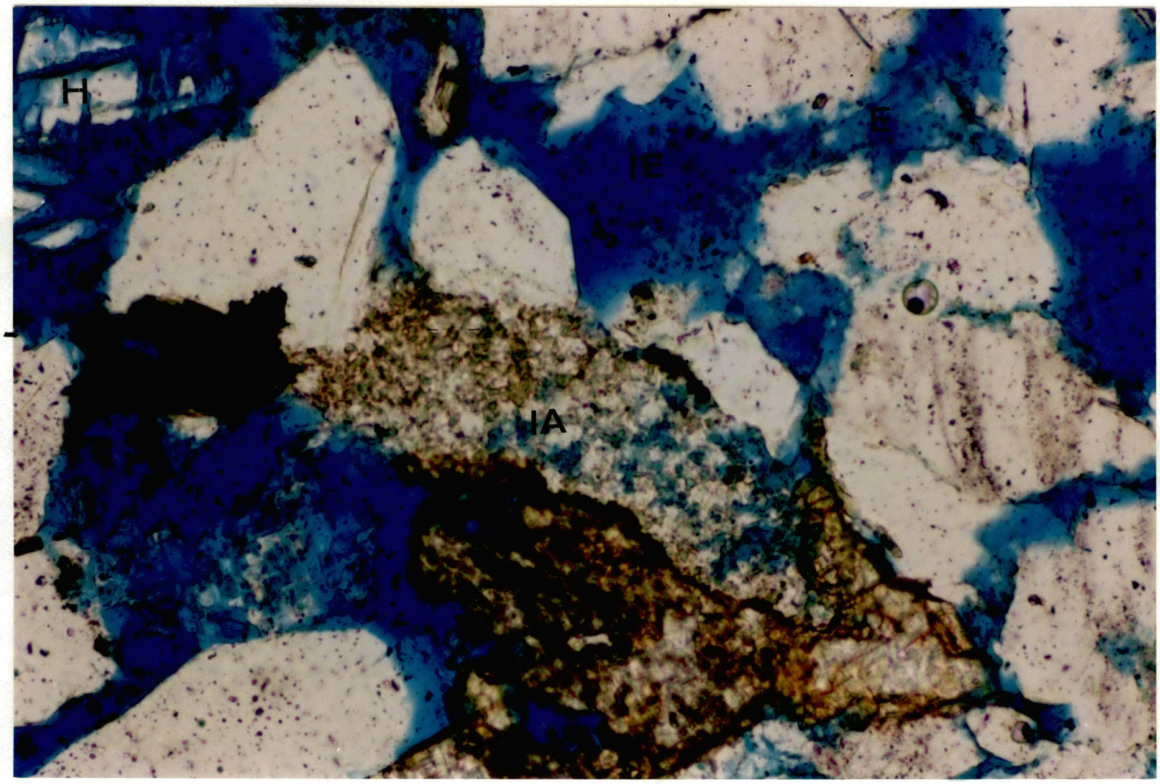
Figure 32. Micrite (M) coating grains. Moldic porosity (MO) developed as a result of dissolution of detrital grains. a) PPL b) XN (10X)



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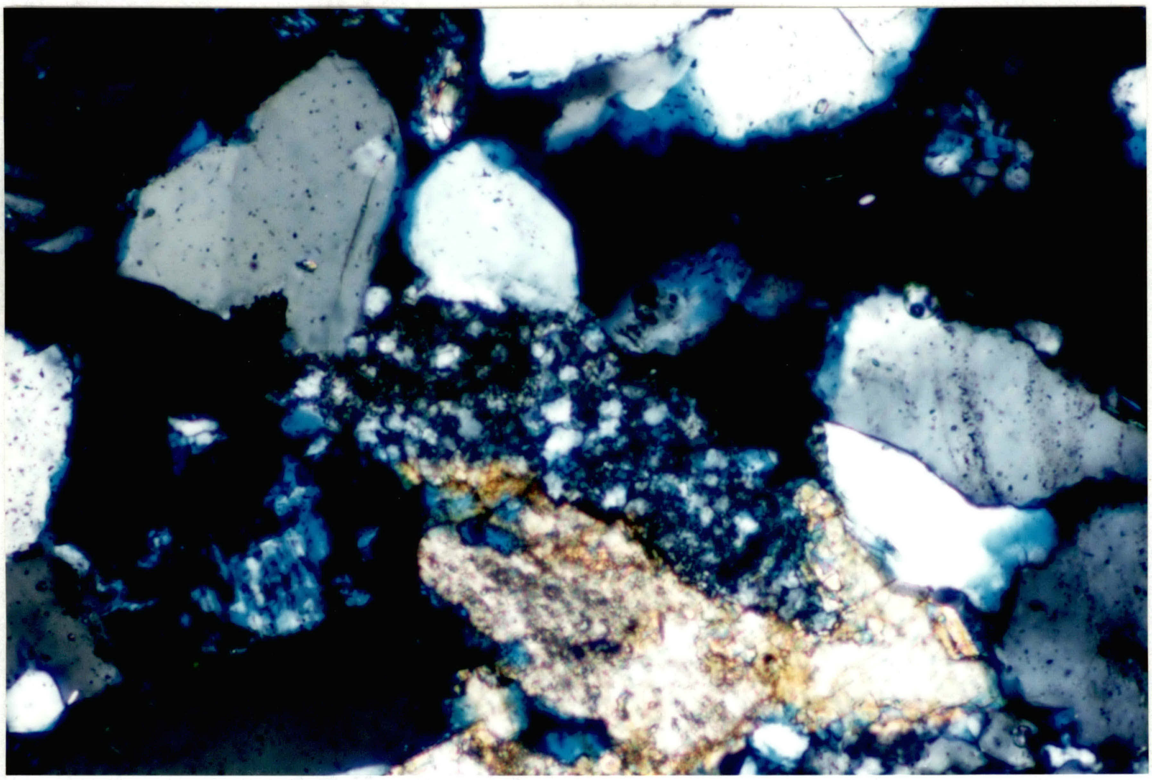

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Figure 33. Enlarged intergranular (IE), Intragranular (IA), honeycomb (H), and elongate (E) porosities formed by dissolution of grains. a) PPL b) XN (10X)

Diagenetic History

Figure 34 summarizes the diagenetic history of the Prue Sandstones. The sequence of events was determined by cross-cutting relationships observed in thin-section.

Micrite appears as a thin layer on the edges of quartz grains, forming a dust rim. A period of acidic ph followed, allowing for the precipitation of quartz over-growths. Siderite derived from altered iron rich detrital constituents precipitated in the form of cement. Generation of secondary porosity occurred due to dissolution of feldspars and metamorphic rock fragments.

Authigenic clays are precipitated due to excess K^+ ions present from dissolution of feldspar. Kaolinite and illite appear as pore filling and lining clays. Chlorite derived from alteration of muscovite, is a later precipitant that coats open pores.

Calcite cement in the sandstones fills pores and replaces feldspar and quartz grains (Figure 35).

Finally pyrite is observed as nodules and in carbonaceous material.

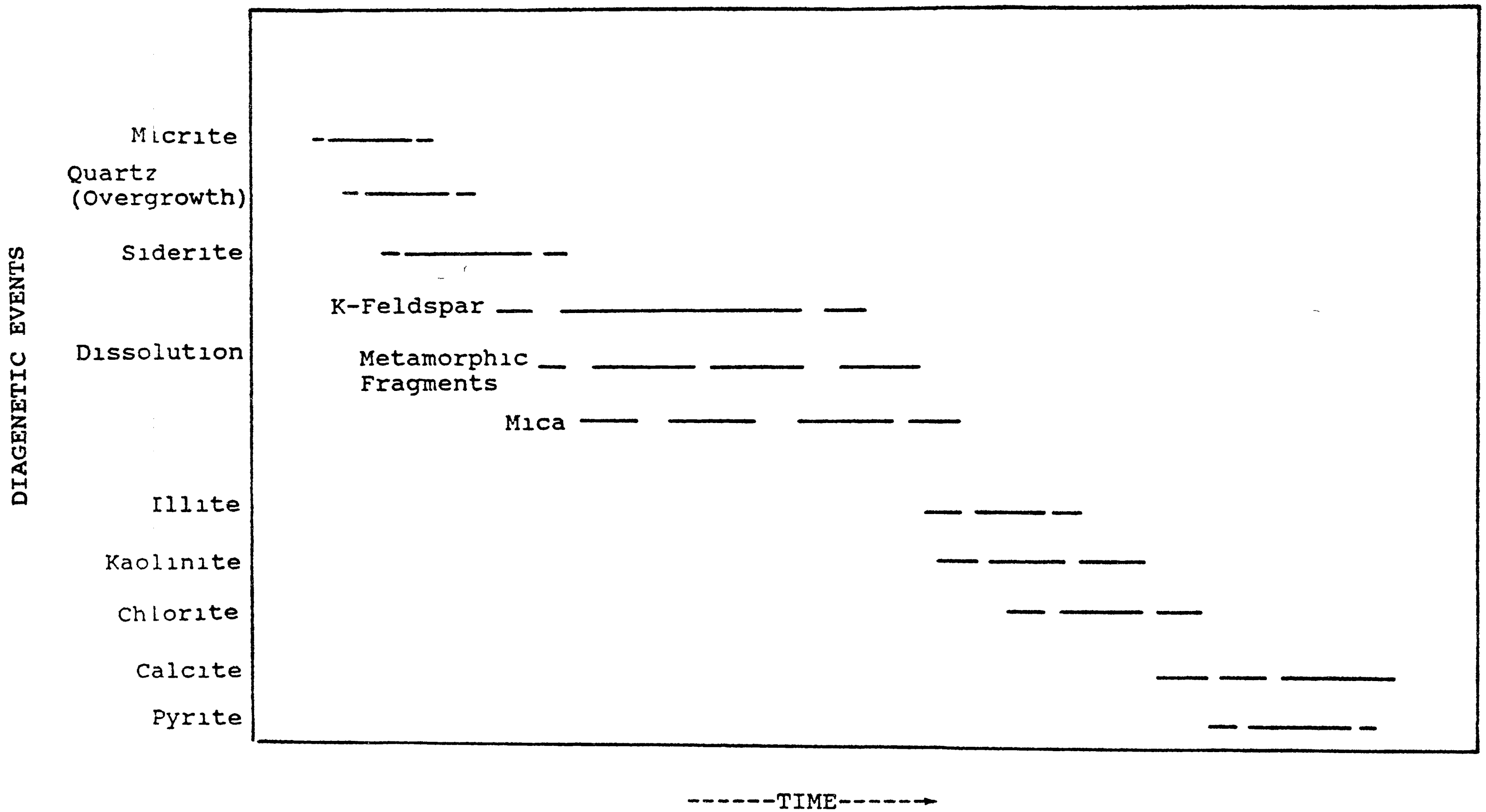

Figure 34. Diagenetic History of the Prue Sandstone

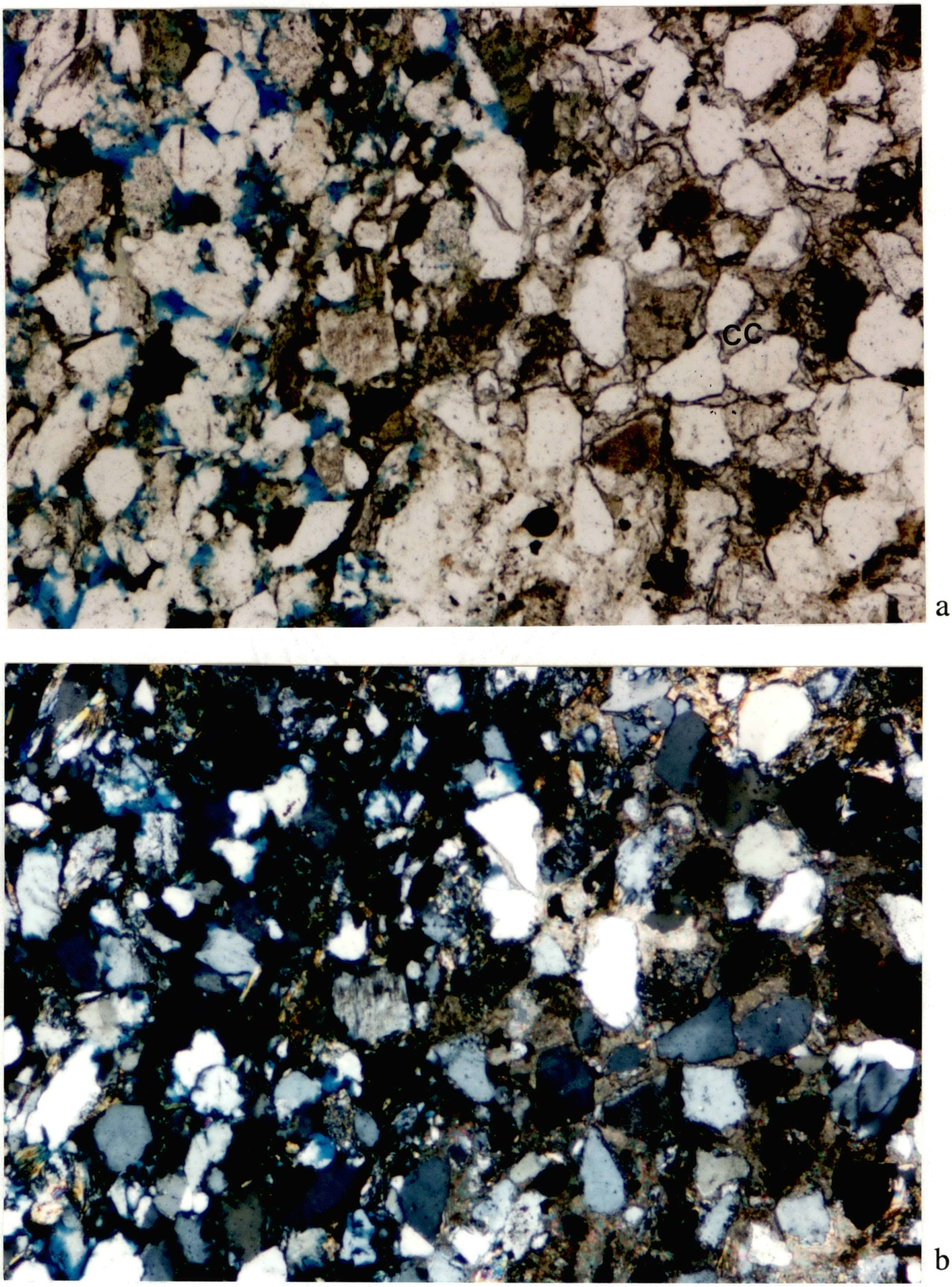

Figure 35. Sharp deliniation between porous and nonporous calcite cemented (CC) zone. a) PPL b) XN (4X)

CHAPTER VI

PETROLEUM GEOLOGY

Occurrences

In the study area there are several fields that produce oil and gas from the Prue Sandstones. Production data is commingled and reported by leases in many areas; therefore, exact values cannot be determined. Only those fields with 85% or greater production from the Prue Sandstone are recorded (Plate VIII). Field boundaries were delineated from scout tickets. Production data of fields examined (Figure 36) was recorded by individual field; however, incomplete data on Davenport listed only the North and West fields. This was recorded as the Davenport area.

Table 1, located on the following page, shows field names, discovery dates, number of active wells in field, cumulative production values for oil and gas (as of March 1991, if available) and the present status of the field.

TABLE I

DATA OF FIELDS PRODUCING FROM PRUE SANDSTONE

	Disc Date	Active Wells	Cum. Crude	Cum. Gas
North & East Sparks	6/50	31	8,166,021	N/A
Peck	4/24	19	4,709,975	53,353
West Peck	5/50	18	5,751,216	N/A
Northeast Midlothian	3/83	2	24,395	5,661
Stone	3/55	1	123,704	27,908
Davenport Area	12/40	58	6,287,419	796,653
East Parkland	3/46	6	871,253	424,136
North Parkland	12/79	6	105,701	66,275
Northeast Parkland	8/53	0	298,274	56,570

Trapping Mechanisms

Many of the fields that produce from the Prue Sandstone in the study area are from traps controlled by structural, stratigraphic, and combination traps.

Peck and West Peck show a coarsening upward SP signature believed to be delta front environment that is trending south-southwest. Both fields are on the upthrown side of the fault (Plates I and II). Closure and anticlinal nosing are exhibited.

North and East Sparks and the Davenport area are within the incised valley fill developed as channel sands. Anticlinal nosing is present and updip lithofacies change occurs. A flat to fining upward SP character occurs in the northeast direction of the North And East Sparks field. Davenport facies change has a H FU/CU log signature interpreted as channel fill overlying delta front deposits. This lithofacies is productive in the Prue Sandstone, Stroud field produces from several zones.

North, East and Northeast Parkland are believed to be incised valley fill deposits with H FU/CU SP character. A fining upward log signature is observed in the homoclinal updip direction.

Figure 36 shows Prue production (circled) in relation to the depositional facies model. Clearly not all production is related to incised valley fill; however, in the area of study, the Prue Sandstone is a prolific producer in the valley fill deposits.

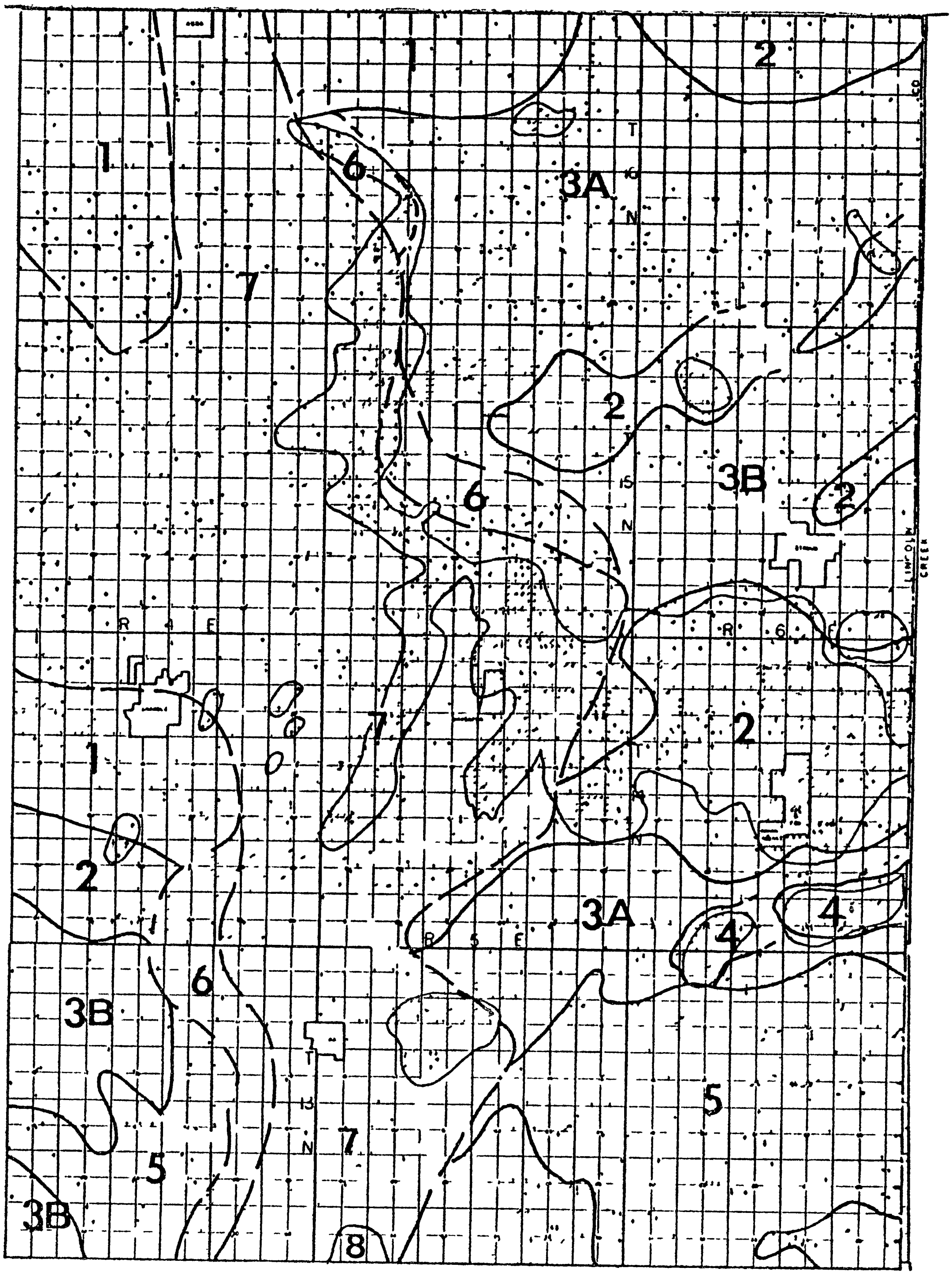

Figure 36. Prue Production Related to Depositional Facies Map

CHAPTER VII

CONCLUSIONS

The principal conclusions of this study include:

1. The Upper Cabaniss Group depositional framework was established by calibrating core lithology to wire-line log response and the generation of a Spontaneous Pontential log signature map.

2. The Verdigris Limestone is persistent throughtout the investigated area except where it has been incised by the Prue channel.

3. The Prue Sandstone interval is characterized by two environments of deposition, which include deltaic and incised valley fill deposits.

4. The Oakley shale and Excello shale are time stratigraphic markers correlatable across most of the study area.

5. The Central Oklahoma Platform is characterized by cyclic sedimentary sequences that are easily correlatable over most of the Platform area.

6. Two cycles (Oakley shale, Verdigris limestone, Prue sandstone, Breezy Hill shale and Excello shale, Oswego limestone) were evident in the area of study.

7. Oswego deposition based on log signature represents a clean carbonate facies in the northern portion of the study and an apparent deeperwater muddy electrofacies in the southern portion of the study.

8. Detrital constituents in the Prue Sandstone indicate a northerly source in the area of study.

9. Dissolution of detrital grains, mainly feldspar and metamorphic rock fragments, created most of the porosity observed in the Prue Sandstone.

10. Fields producing from the Prue Sandstone reservoirs are stratigraphic and structural-stratigraphic traps.

11. Production from the Prue Sandstone reservoirs occur in deltaic and incised valley fill deposits.

12. Prolific hydrocarbon accumulation occurs in the incised valley fill deposits associated with an updip facies change to an impermeable barrier in the Prue Sandstone interval.

13. All Pennsylvanian Sandstones on the Central Oklahoma Platform should be further investigated for a possible association with incised valley fill deposits.

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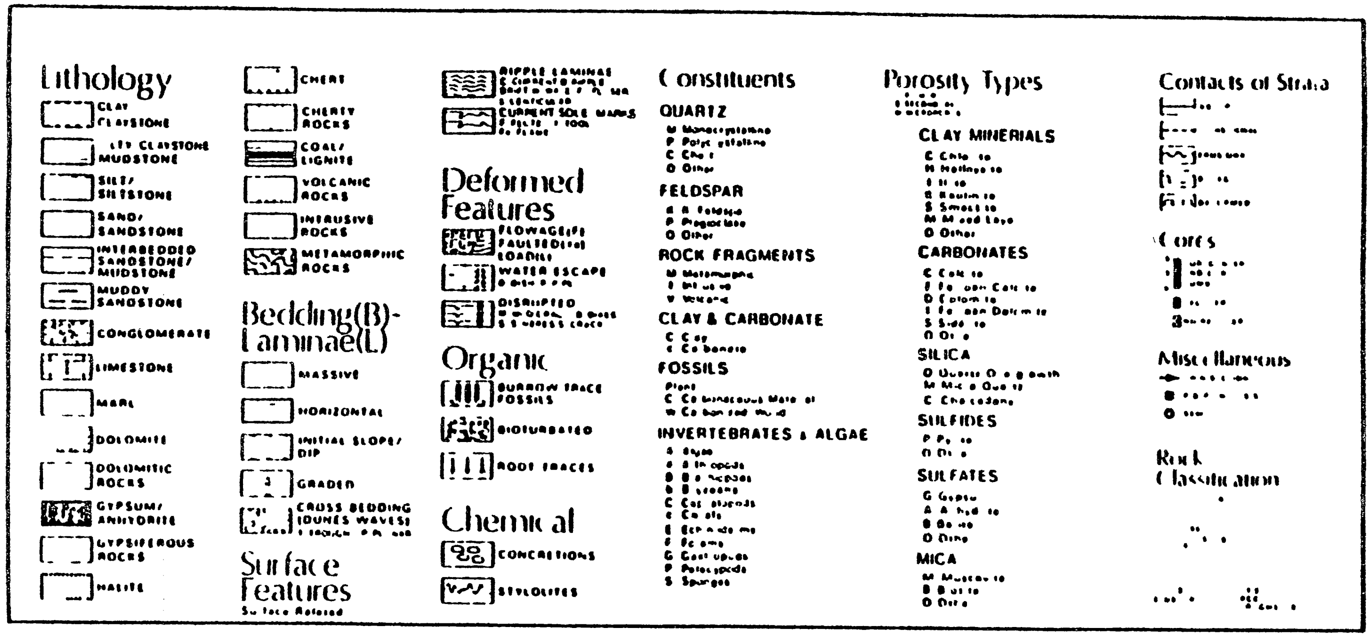
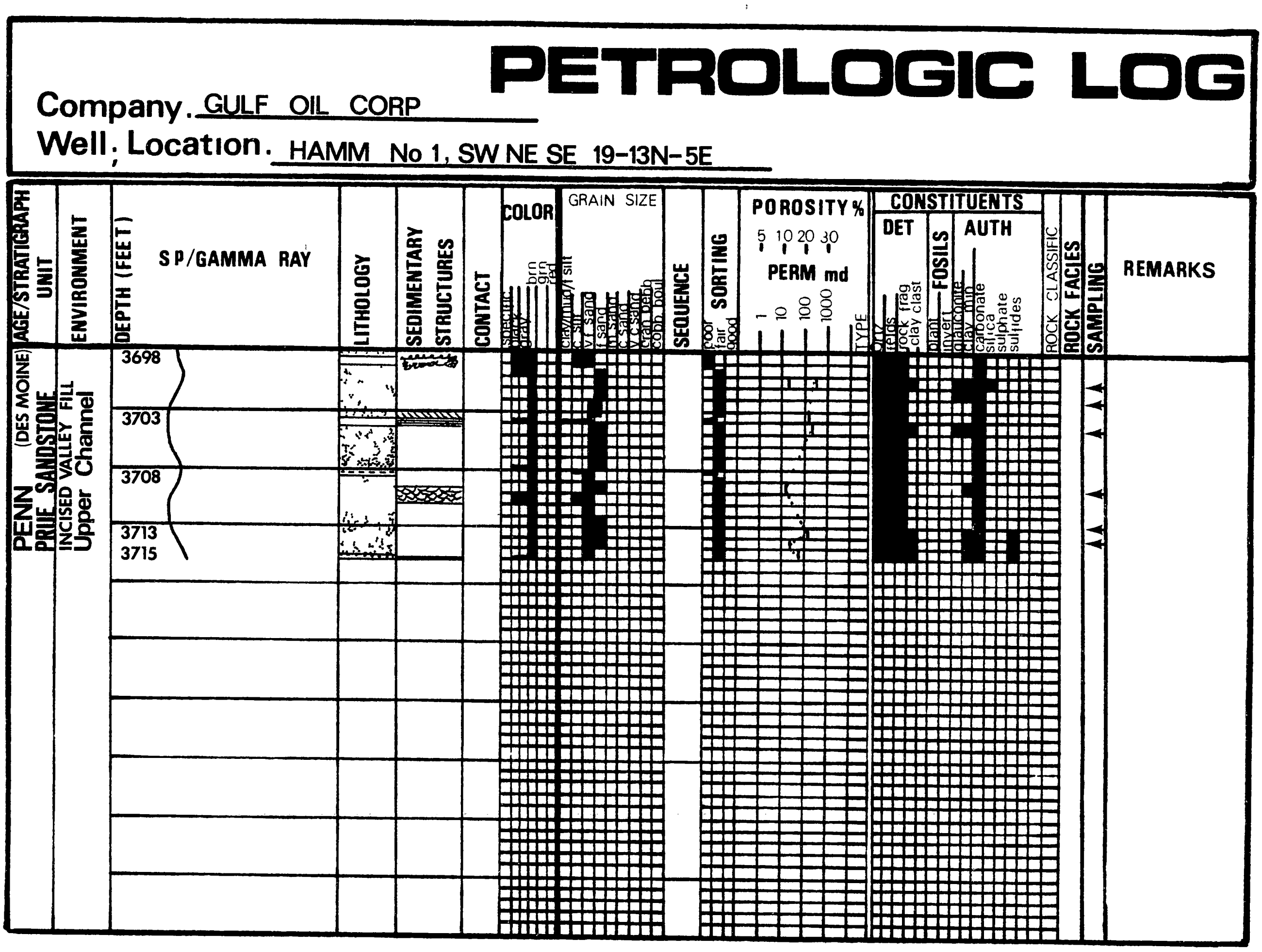
APPENDIX

CORE DESCRIPTIONS

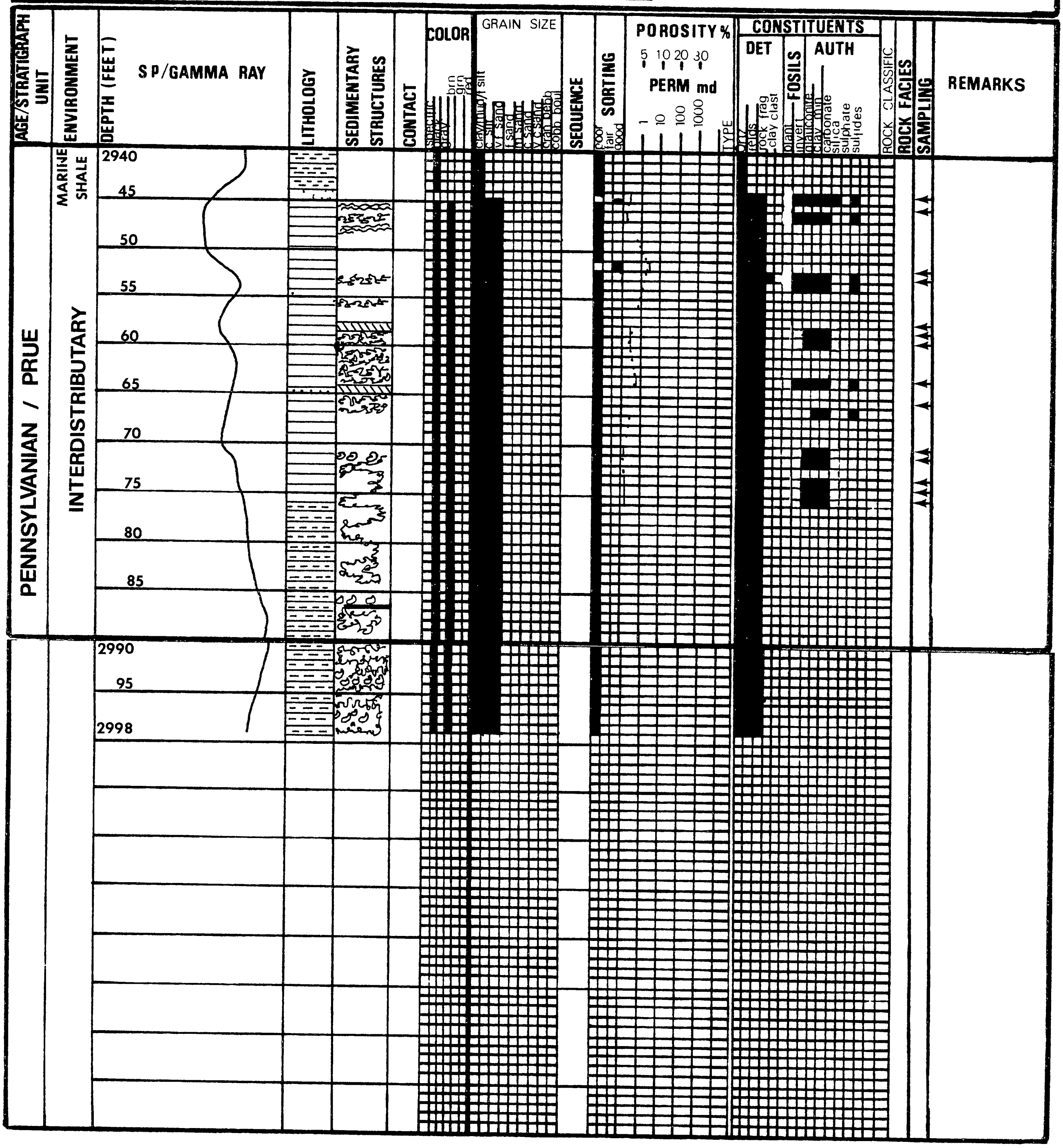

Lithology
CLAY/CLAYSTONE
MUDSTONE
SILT/SILTSTONE
SAND/SANDSTONE
INTERBEDDED SANDSTONE/MUDSTONE
MUDDY SANDSTONE
CONGLOMERATE
LIMESTONE
MARL
DOLOMITE
DOLOMITIC ROCKS
GYPSUM/ANHYDRITE
GYPSIFEROUS ROCKS
HALITE
CHERT
CHERTY ROCKS
COAL/LIGNITE
VOLCANIC ROCKS
INTRUSIVE ROCKS
METAMORPHIC ROCKS
Bedding(B)-Laminae(L)
MASSIVE
HORIZONTAL
INITIAL SLOPE/DIP
GRADED
CROSS BEDDING
Surface Features
CURRENT SOLE MARKS
Deformed Features
WATER ESCAPE
DISRUPTED
Organic
BURROW TRACE FOSSILS
BIOTURBATED
ROOT TRACES
Chemical
CONCRETIONS
STYLOLITES
Constituents
QUARTZ
FELDSPAR
ROCK FRAGMENTS
CLAY & CARBONATE
FOSSILS
INVERTEBRATES & ALGAE
Porosity Types
CLAY MINERALS
CARBONATES
SILICA
SULFIDES
SULFATES
MICA
Contacts of Strata
Cores
Miscellaneous
Rock Classification


PETROLOGIC LOG
Company. GULF OIL CORP
Well; Location. HAMM No 1, SW NE SE 19-13N-5E
AGE/STRATIGRAPH UNIT
ENVIRONMENT
DEPTH (FEET)
SP/GAMMA RAY
LITHOLOGY
SEDIMENTARY STRUCTURES
CONTACT
COLOR
GRAIN SIZE
SEQUENCE
SORTING
POROSITY %
5 10 20 30
PERM md
1 10 100 1000
TYPE
CONSTITUENTS
DET
FOSILS
AUTH
ROCK CLASSIFIC
ROCK FACIES
SAMPLING
REMARKS
PENN (DES MOINE)
PRUE SANDSTONE
INCISED VALLEY FILL
Upper Channel
3698
3703
3708
3713
3715

PETROLOGIC LOG

Company GENERAL AMERICAN OIL Co

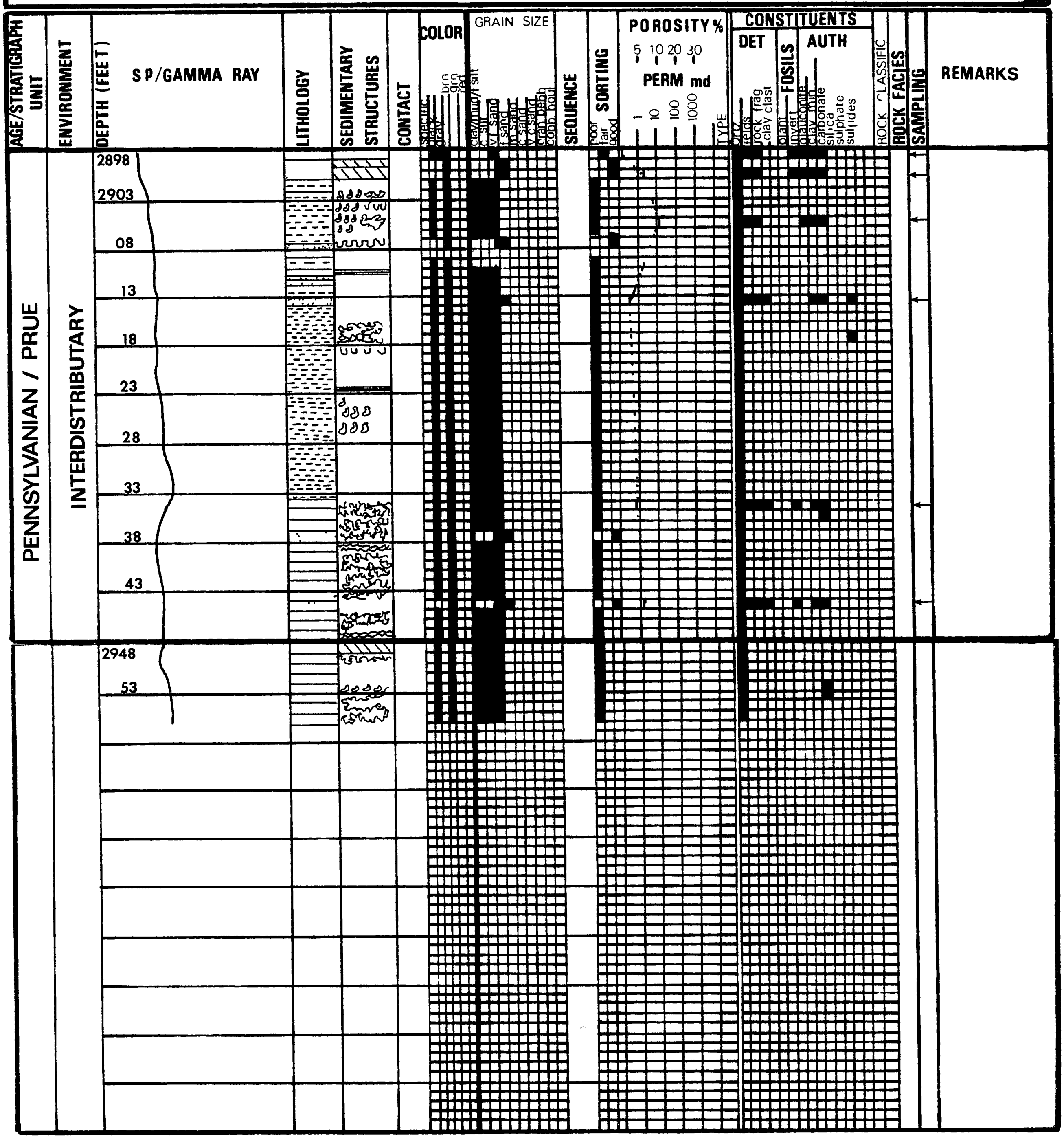
Well, Location. POTTER No 5, 10-T14N-R6E



PETROLOGIC LOG

Company GENERAL AMERICAN OIL Co

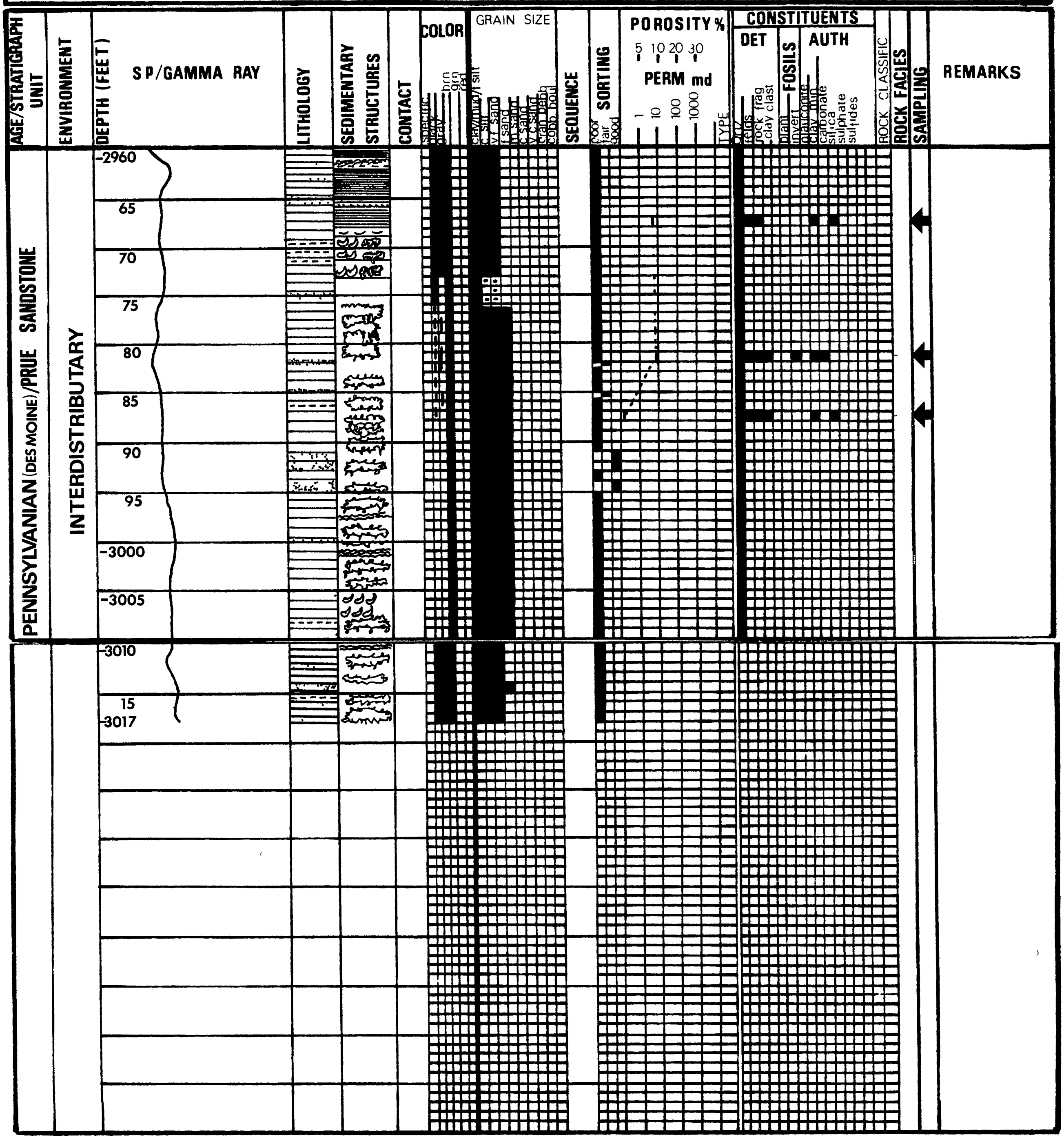
Well, Location: MAY No 3; 10-T14N-R6E



PETROLOGIC LOG

Company TENNECO OIL Co

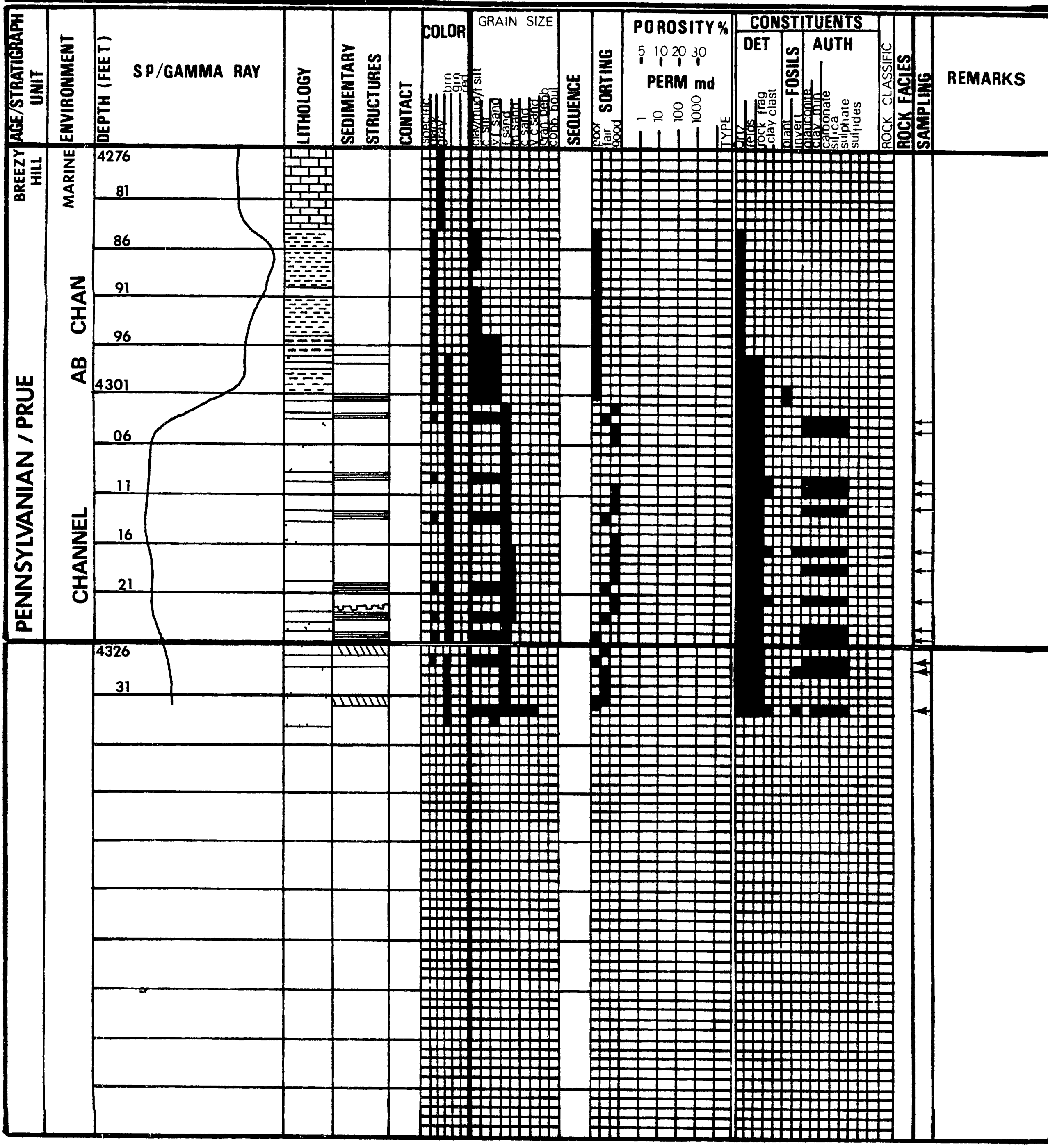
Well, Location. SACTFOX No 126, NE SW SW Sec 15-14N-6E



PETROLOGIC LOG

Company PHILLIPS OIL OPER Co

Well, Location. QUINTLE No 1; 9-T16N-R2E



2

VITA

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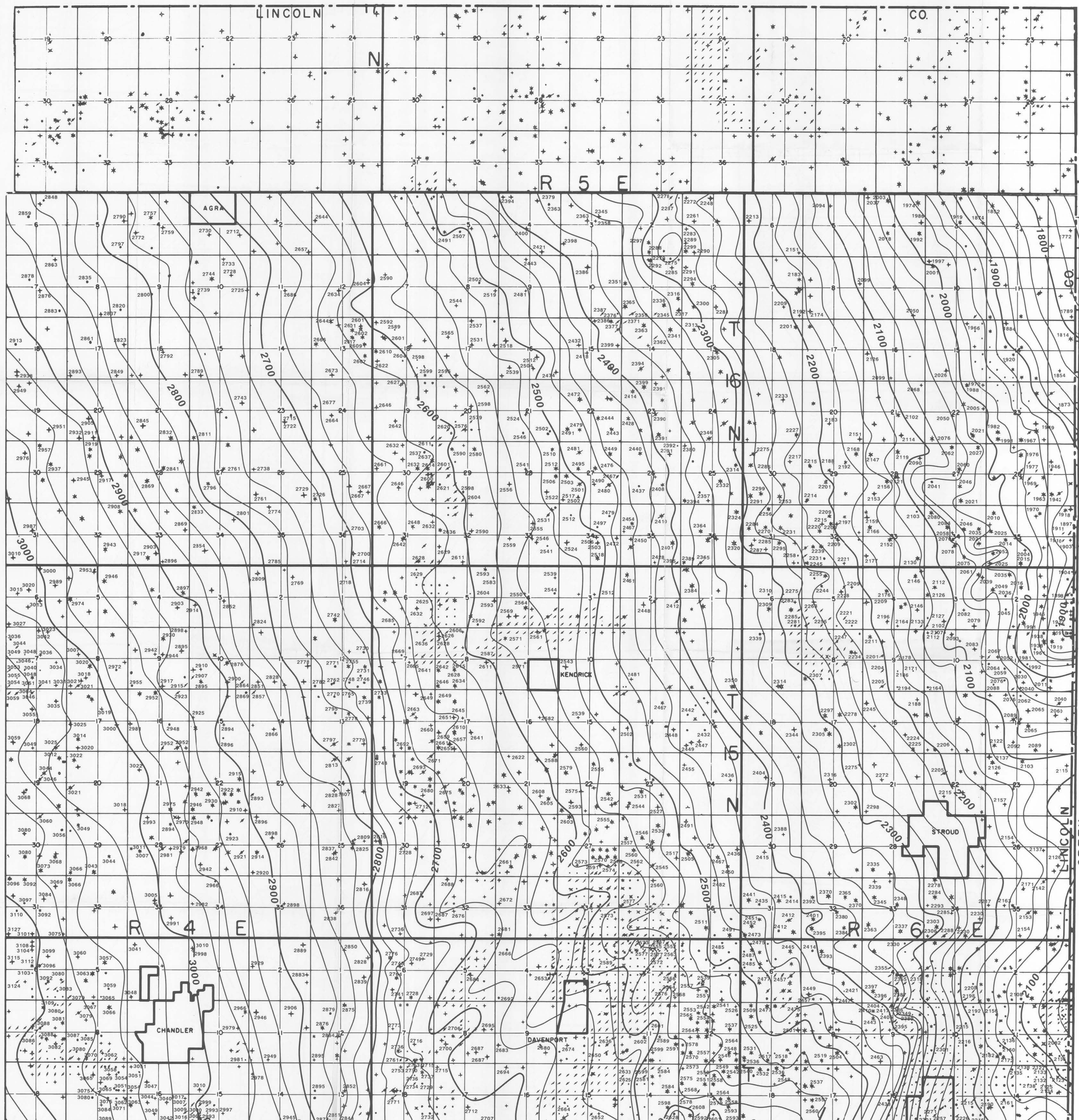

PLATE II

STRUCTURAL CONTOUR MAP
TOP OF VERDIGRIS LIMESTONE

NOTE: ALL ELEVATION VALUES ARE NEGATIVE (-) ON PLATE II

C.I. = 25'

0 .5 MILE 1 MILE
SCALE: 1" = 2640'

CHERYL R. ROPP M.S. THESIS 1991
OKLAHOMA STATE UNIVERSITY

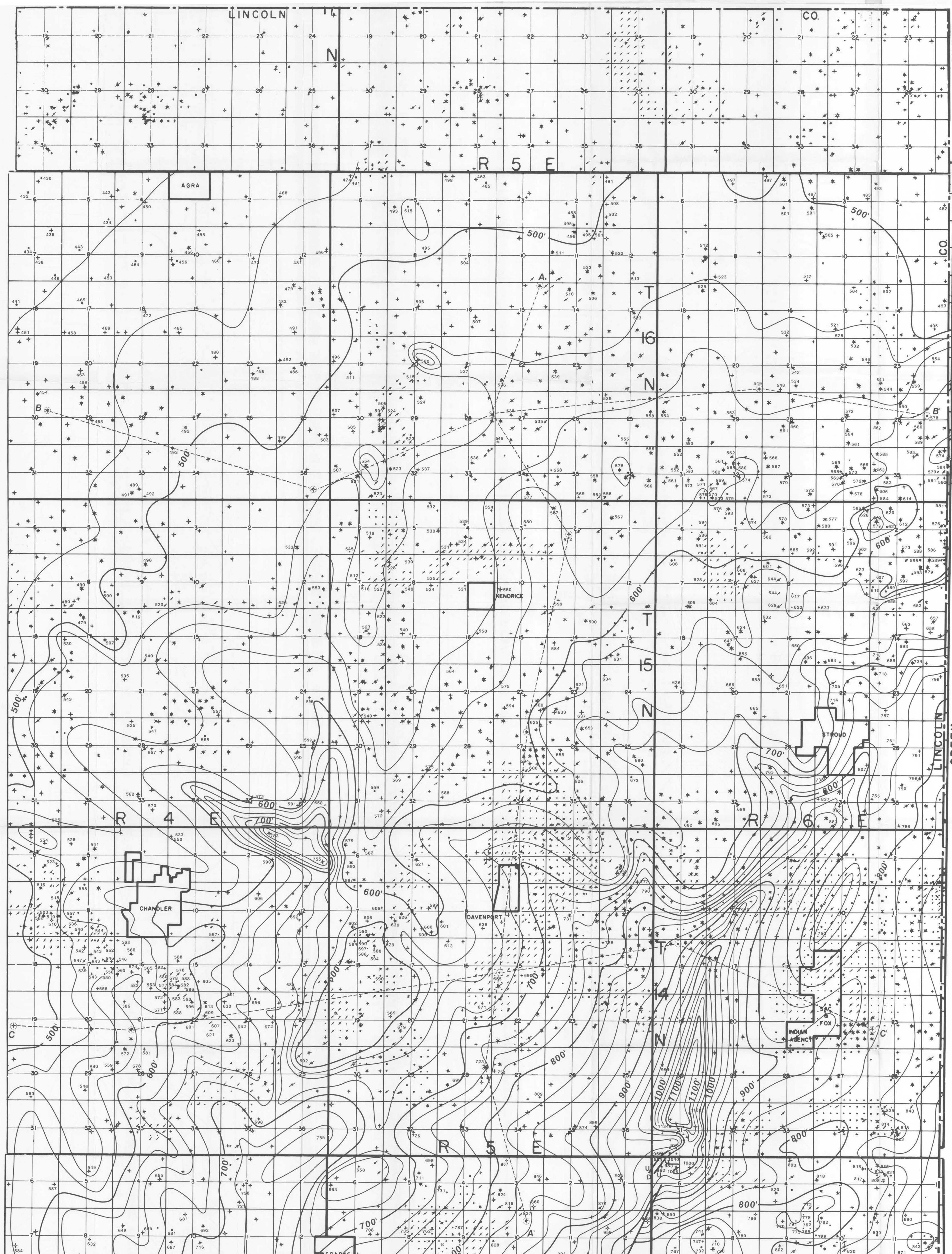

PLATE III

ISOPACH MAP
TOP VERDIGRIS / TOP MAYES

C.I. = 25'

0 .5 MILE 1 MILE
SCALE: 1" = 2640'

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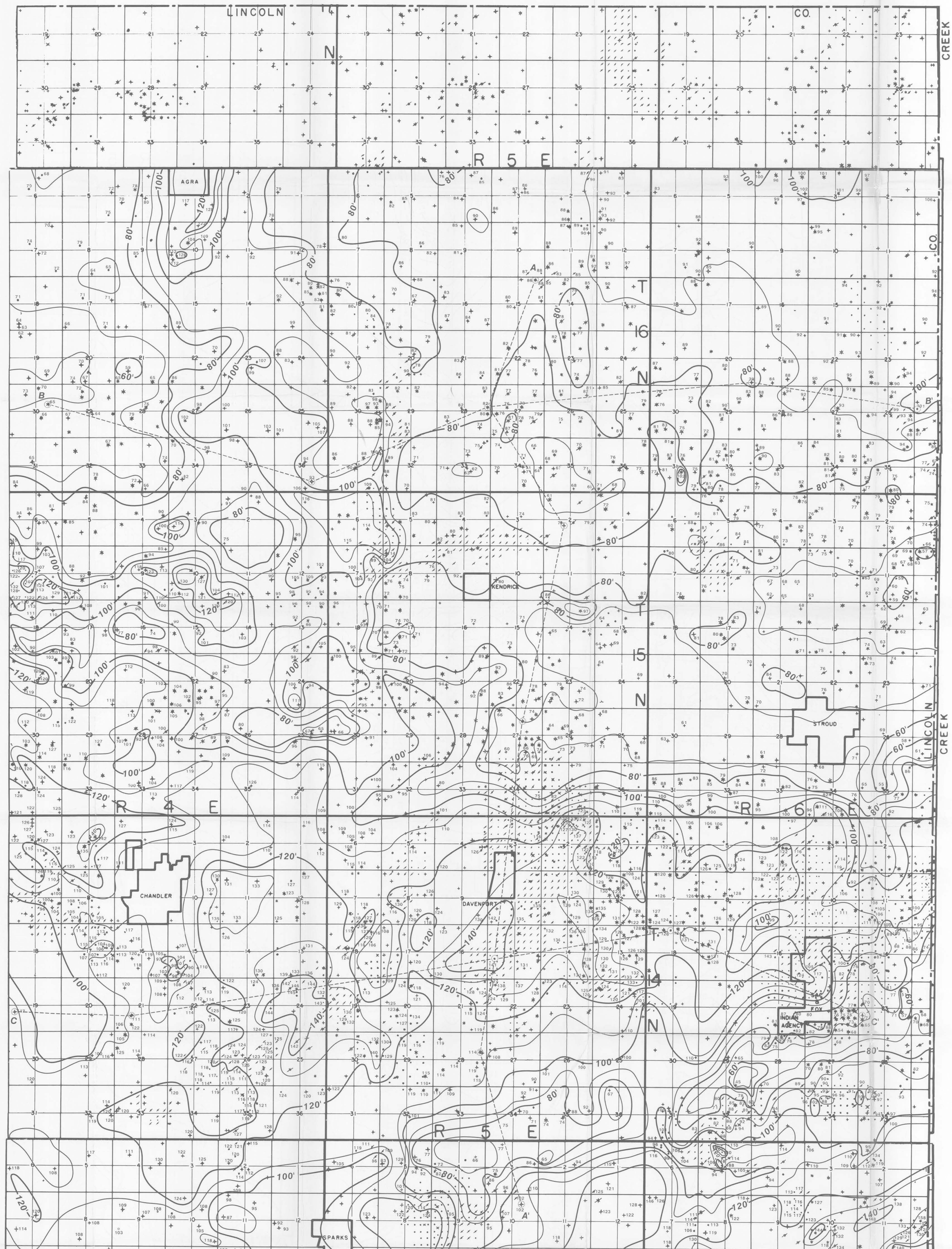

PLATE IV

ISOPACH MAP

BASE OF MARMATON / TOP OF VERDGRIS

C.I. = 10'

0 .5 MILE 1 MILE
SCALE: 1" = 2640'

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OKLAHOMA STATE UNIVERSITY

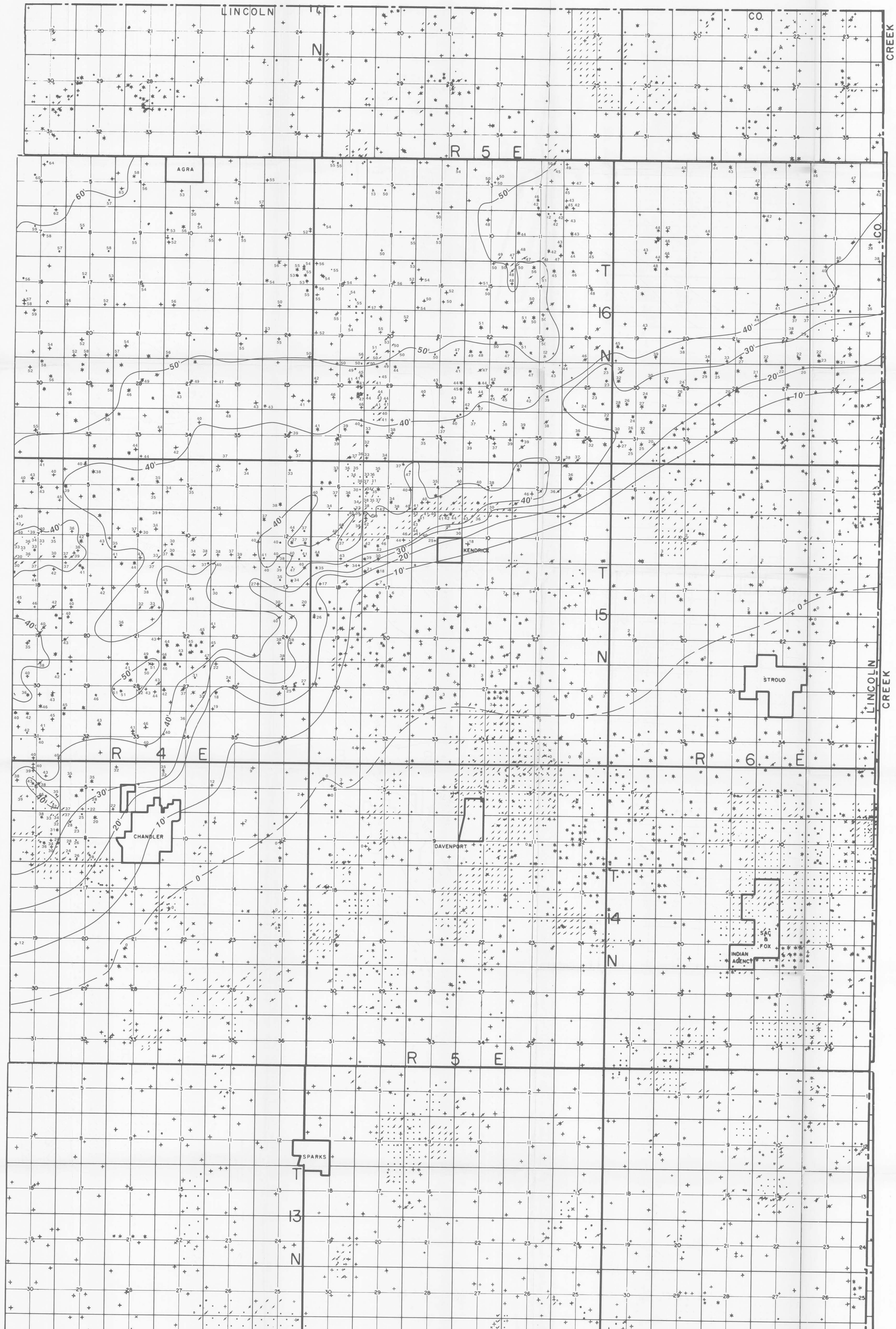

PLATE V

ISOLITH MAP
NET OSWEGO LIMESTONE

C.I. = 10'

0 .5 MILE 1 MILE
SCALE: 1" = 2640'

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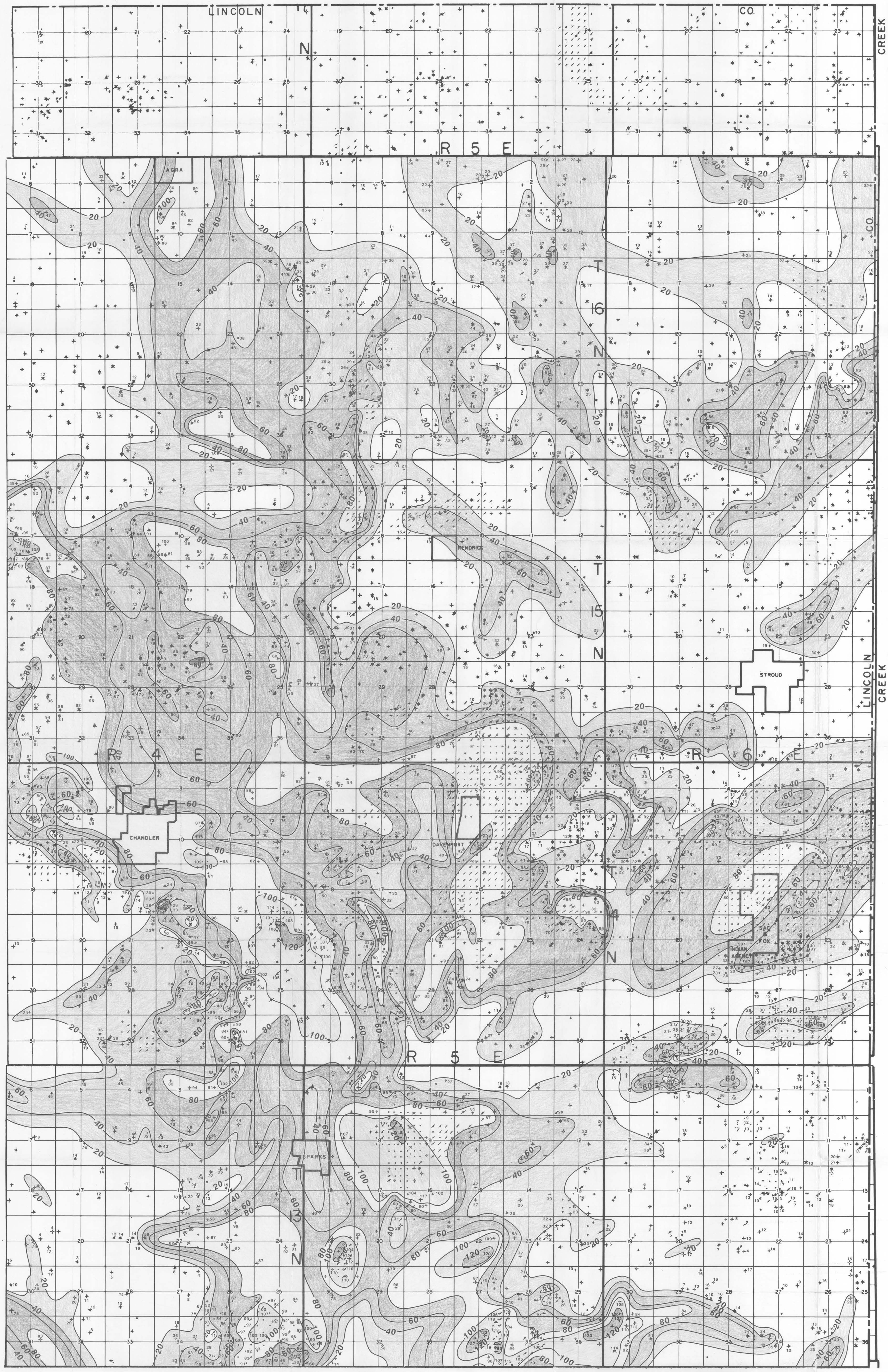

LEGEND

- 120' - ABOVE
- 100' - 120'
- 80' - 100'
- 60' - 80'
- 40' - 60'
- 20' - 40'
- BELOW 20'

PLATE VI

NET ISOLITH
PRUE SANDSTONE

C.I. = 20'

0 .5 MILE 1 MILE
SCALE: 1" = 2640'

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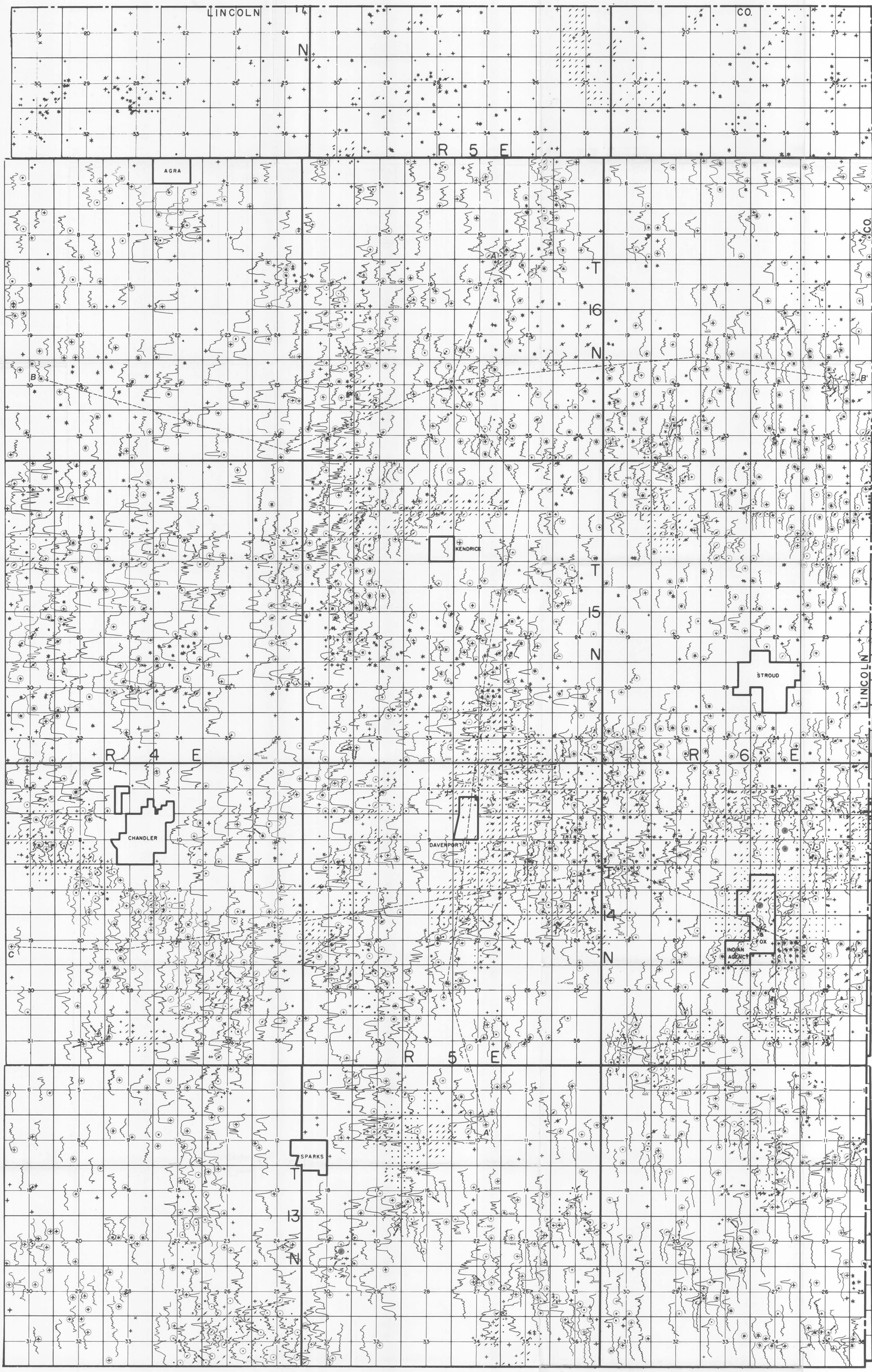
OKLAHOMA STATE UNIVERSITY



LEGEND

● CORE
---- NDE (NOT DEEP ENOUGH)

PLATE VII

SPONTANEOUS POTENTIAL MAP
PRUE ZONE

0 100' 200'
VERTICAL SCALE: 1" = 100'

0 .5 MILE 1 MILE
HORIZONTAL SCALE: 1" = 2640'

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LEGEND

BARRELS OF OIL
MILLION CUBIC FEET OF GAS
NR - (NOT REPORTED)
MARCH 1991

PLATE VIII

PRODUCTION MAP
FIELD BOUNDARIES
AND PRUE SANDSTONE PRODUCTION

0 .5 MILE 1 MILE
SCALE: 1" = 2640'

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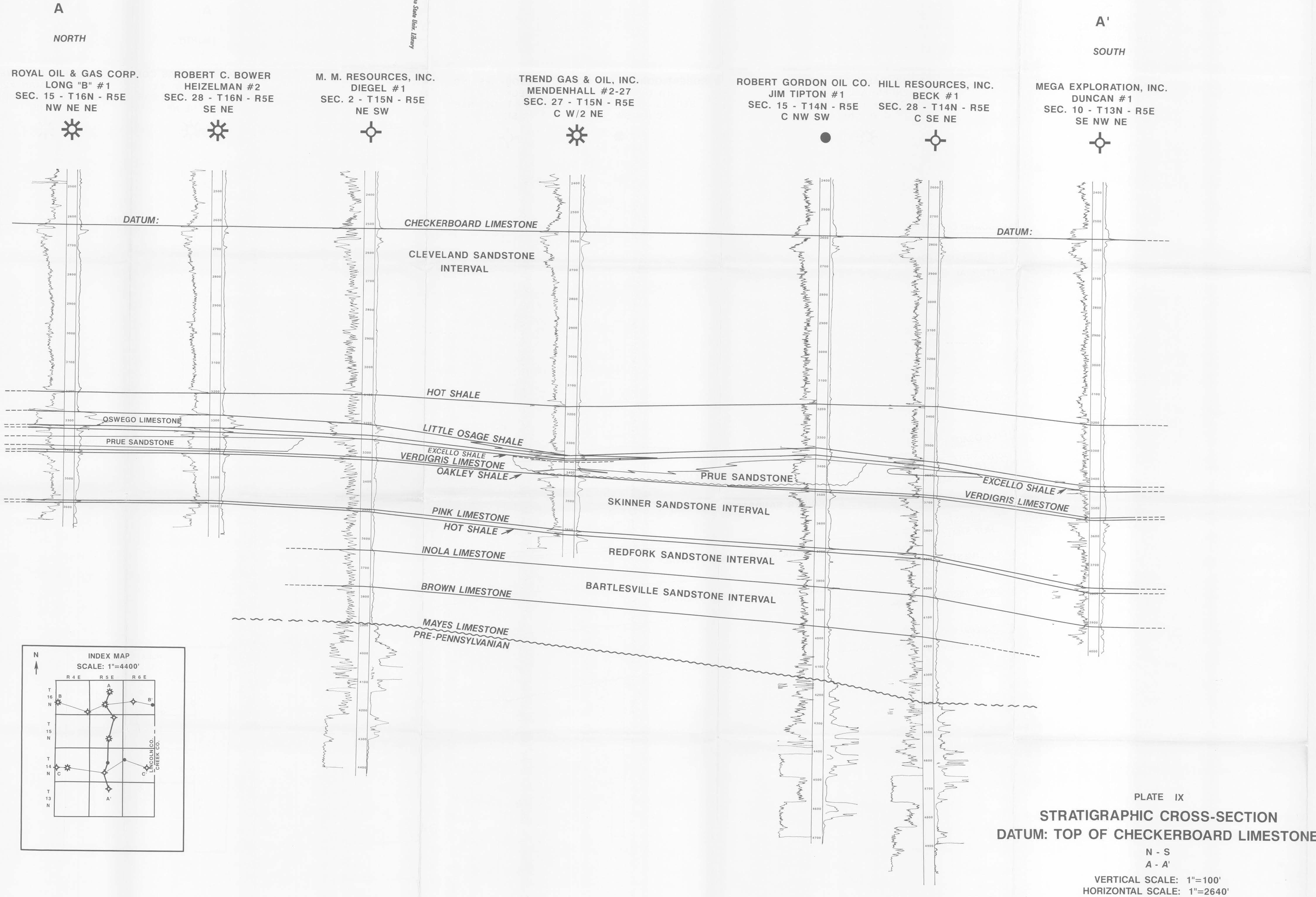

PLATE IX

STRATIGRAPHIC CROSS-SECTION
DATUM: TOP OF CHECKERBOARD LIMESTONE

N - S
A - A'

VERTICAL SCALE: 1"=100'
HORIZONTAL SCALE: 1"=2640'

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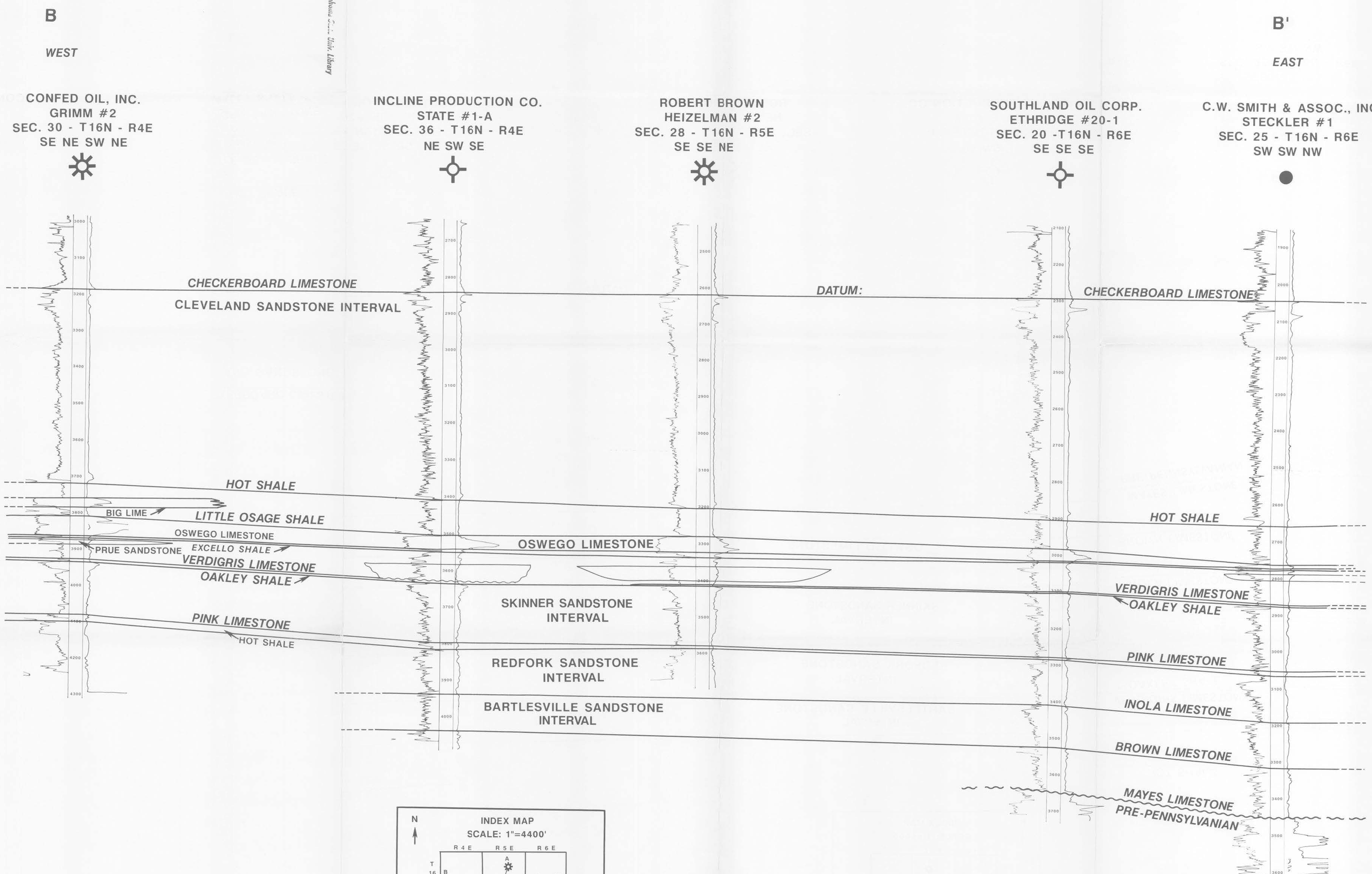

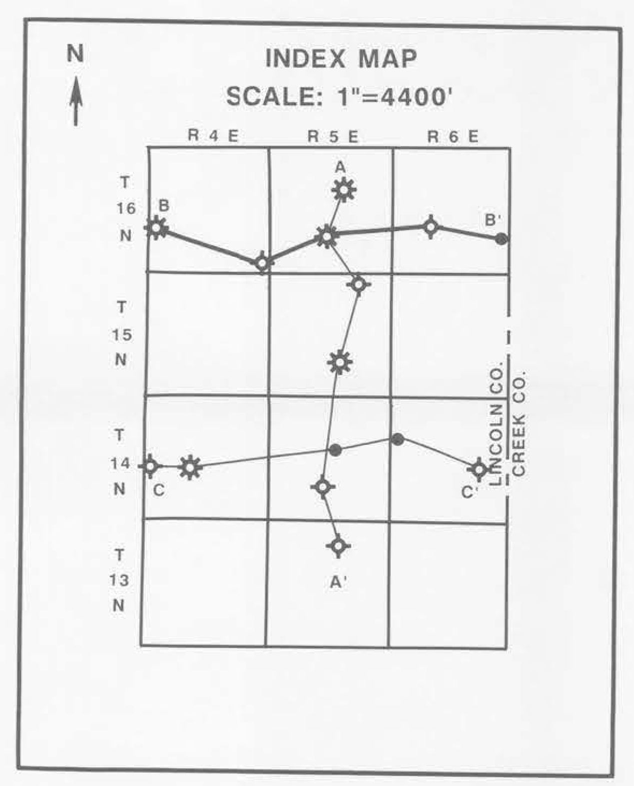

PLATE X

STRATIGRAPHIC CROSS-SECTION
DATUM: TOP OF CHECKERBOARD LIMESTONE

W - E

B - B'

VERTICAL SCALE: 1"=100'
HORIZONTAL SCALE: 1"=2640'

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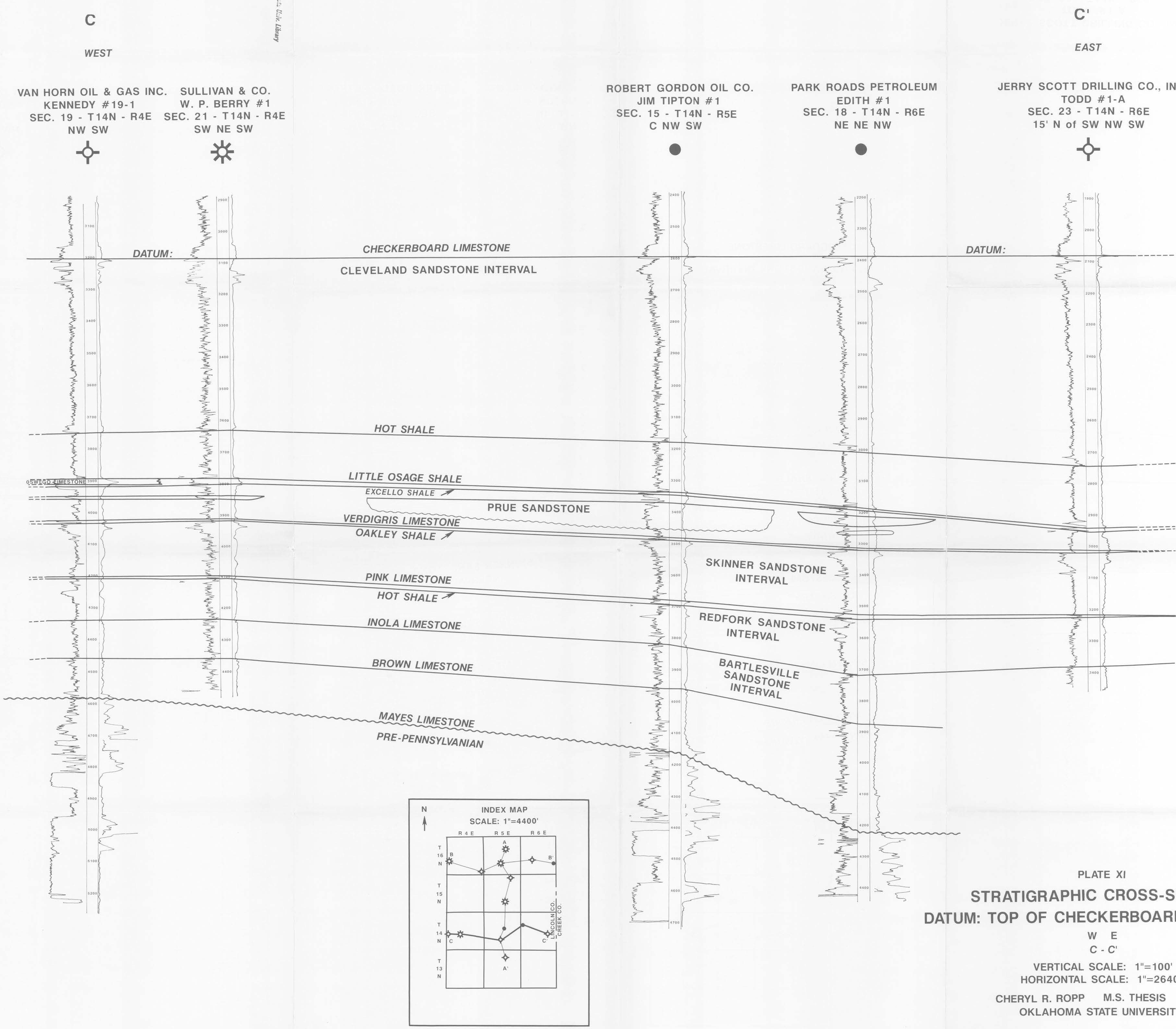

PLATE XI

STRATIGRAPHIC CROSS-SECTION
DATUM: TOP OF CHECKERBOARD LIMESTONE

W E

C - C'

VERTICAL SCALE: 1"=100'
HORIZONTAL SCALE: 1"=2640'

CHERYL R. ROPP M.S. THESIS 1991
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