SEQUENCE STRATIGRAPHIC EVALUATION OF THE PRUE SANDSTONE IN CREEK COUNTY, OKLAHOMA

By

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OKLAHOMA

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Abstract: The Prue Sandstone is studied extensively across northeastern Oklahoma and Kansas. Previous studies concluded the Prue Sandstone was deposited in a southerly prograding fluvial-deltaic complex with distributary channels and incised valleys. However, the Prue Sandstone is not studied extensively in Creek County, Oklahoma. Also, recent advancements in sequence stratigraphy caused reinterpretation of the Prue Sandstone and support hypotheses that the Prue sediments are estuarine, tidal to fluvial dominated. A combination of regional cross-sections, structure maps, and isopach maps were used to evaluate the regional structure, depositional environments, and sandstone distribution. The depositional paleo dip during Prue time was northwest to southeast. The Prue interval isopach and net isolith maps show that most sand deposition occurred where the interval was thicker in a marine embayment in this area. Core facies determined from 5 wells were described and used to interpret depositional environments. The sandstones in these cores all show tidal influence. Thin section petrographs determine the sandstones are litharenites, with an abundance of quartz and metamorphic rock fragments. The Prue was initially deposited in a tide-dominated, progradational delta that trends west to east across the study area. When the sea level declined, channels incised the delta generating an incised valley complex that may have followed older distributary channels. During subsequent sea level rise, estuaries formed, sediments were reworked, and the channels back filled. A late stage tidal channel eroded the incised valley complex, contributing to lateral discontinuity in reservoirs.

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CHAPTER I

INTRODUCTION

The Pennsylvanian age Prue Sandstone is the youngest siliciclastic interval in the "Cherokee Group" of the Desmoinesian Stage. It is confined to the Cherokee Platform and to shallow shelf areas of the Anadarko Basin, and it was deposited during a series of marine transgressions and regressions attributed to glacial eustasy. There have been various interpretations proposed for the depositional history of the Prue Sandstone such as Ropp (1991) and Andrews (1996). that concluded that the Prue Sandstone was deposited in a fluvial-deltaic environment and/or by channel fill within incised valleys. However, advancements in sequence stratigraphy and the understanding of Pennsylvanian glaciation and cyclothems have resulted in interpretations that the Prue Sandstone may have been deposited in transgressive, marginal marine tidal environments such as estuaries in addition to fluvial-deltaic environments (Dalrymple et al., 2012). Estuarine deposition may have been overlooked because few estuaries are recognized in the geologic record and not widely documented and distinguished from associated fluvial, deltaic, or lagoonal marine deposits (Archer and Feldman, 2006), (Bhattacharya, 2003), (Greb and Martino, 2005).

This study investigates the depositional environments and subsurface sequence stratigraphy of the Prue Sandstone in the Prue interval in Creek County, Oklahoma. It integrates subsurface maps and well logs with core analysis to better understand facies distribution, depositional environments, and geologic history of the Prue interval. Sequence stratigraphic principles were applied in order to better define facies and stratigraphic relationships of the Prue interval. The study extends previous investigations of the Prue Sandstone on the Cherokee Shelf such as Ropp (1991) that concluded that the Prue Sandstone was deposited in fluvial-deltaic settings, and will also investigate whether Prue Sandstone deposition in Creek County, Oklahoma was influenced by transgressive tidal environments active in estuarine settings.

Location of the Study Area

The study area (Figure 1) incorporates the western two-thirds of Creek County in north-central Oklahoma. It encompasses 18 townships that range from Township 14 North to 19 North, and Ranges 7 East to 9 East. The study area was chosen due to the location of Prue distribution patterns and the abundance of data including more than 1400 wells, wireline logs and core. Also, the Prue interval has not been extensively studied in the project area, and recent understanding of sea level fluctuations due to Pennsylvanian glaciation and sequence stratigraphic principles have not been applied to Prue deposition in this area.

Previous Investigations

Numerous investigations on the Pennsylvanian Desmoinesian “Cherokee” Group have been conducted. Green and White (1921) first referenced the Prue Sandstone while working in the Prue Field in Osage County, Oklahoma. They interpreted that Prue Sandstone deposition is confined to the Cherokee Platform and to the shallow shelf of the Anadarko Basin. Oakes (1953) divided the Desmoinesian age “Cherokee” Group into the Krebs Group and Cabaniss Group. He identified the uppermost sandstone in the Cabaniss Group as the Prue Sandstone. Cole (1969) investigated the depositional environments of the “Cherokee” Group on the eastern flank of the Nemaha Ridge, while Berg (1969) investigated it on the western flank. Shipley (1977) reported on depositional trends of the “Cherokee” sandstones in Payne County. Krumme (1981) completed an extensive study on Prue/Calvin sandstones in the McAlester Basin. Ropp (1991) conducted a detailed study on the Prue Sandstone in which she made a facies, diagenetic history, and

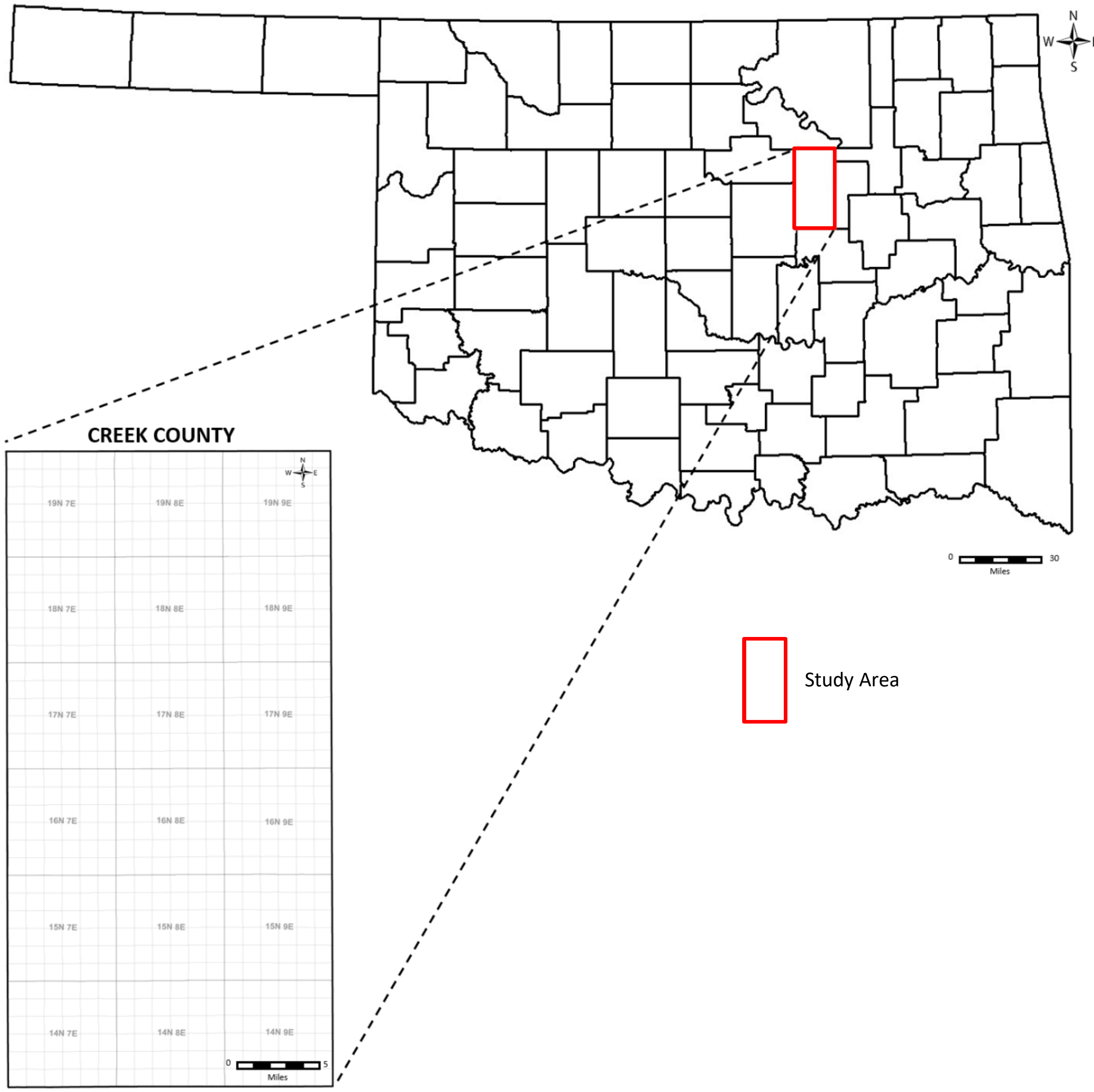


Figure 1. Location of the study area in Creek County within north-central Oklahoma.

structural evaluation of the Prue in Lincoln County, Oklahoma. Andrews (1996) conducted a study for the Oklahoma Geological Survey and determined the Prue Sandstone was fluvial-dominated deltaic deposition. This special publication contains the information on the Prue Sandstone's distribution, stratigraphy, depositional models, maps, and case studies.

Investigations related to the influence of Pennsylvanian glaciation in Oklahoma started with Weidman (1923) when he questioned whether there was any glaciation in the Arbuckle and Wichita Mountains. The theory of relative sea level change during the Pennsylvanian from glacial eustasy by waning and waxing of Gondwanan ice sheets were hypothesized in Wanless and Shepard (1936). Heckel (1977, 1985, 1986) performed extensive studies on Kansas and northeastern Oklahoma cyclothems in the 1980s. Boardman and Nestell (1993) studied and defined glacial eustatic sea-level fluctuation in the North American Midcontinent including Oklahoma. Brenner (1995) studied Cherokee Group sequences and cyclothems in the Mid-Continent. Marshall (2002) recognized and described 28 separate transgressive-regressive (T-R) cycles or cyclothems within the Cherokee Group. Utilizing these 28 cycles, Boardman (2002) established a modern cyclothem succession and sea level curve for Cherokee deposition which was updated by Boardman and others (2004). Johnson (2013) compiled the geologic history of Oklahoma relating to the structural history and glaciation in the region.

Other investigations of note pertaining to the Prue Sandstone include Akmal (1953), Blumenthal (1956), Cole (1956), Benoit (1957), Ferguson (1964), Berg (1969), Candler (1976), Pulling (1979), Verish (1979), Denesen (1985), Joseph (1987), Puckette (1990), Stirling (1998), Broker (2000), Huhnke (2004), and Boucher (2007). These studies mainly focus on the interpretation of depositional environments using subsurface mapping and core analysis.

CHAPTER II

METHODOLOGY

The following procedures and methodology were used to perform and interpret the subsurface evaluation of the Prue Sandstone in the study area. An extensive literature search with regional analysis was conducted that focused on the Prue Sandstone itself, and then developed into a broader analysis of the Prue interval. Subsurface data was compiled from cores, thin sections, wire-line logs, subsurface maps, and production reports obtained from the Oklahoma Geological Survey, the Tulsa Geological Survey, the Oklahoma Petroleum Information Center (OPIC), and Drillinginfo.com.

Petra (IHS) software was used to create nine cross sections and seven subsurface maps across the study area. The study included over 1400 wireline logs which were obtained from the Oklahoma Geological Survey, the Tulsa Geological Survey, Drillinginfo.com, and IHS. The logs were then scanned and depth-registered into the IHS Petra software.

Regional marker beds associated with the Prue interval were correlated using gamma ray, spontaneous potential, resistivity, and neutron-density signatures from wireline logs to establish the regional stratigraphic framework and to determine the geometry and distribution of the sandstone bodies. The stratigraphic units associated with the Prue interval were delineated and used in the construction of structure and thickness maps. Three North-South and six East-West cross sections were constructed using nearby wells in order to make accurate correlations over the

18-township area. Stratigraphic surfaces were identified in order to recognize sequence packages, sandstone distribution, and marine transgression and regressions that can be correlated across the study area (See Appendix G).

Three structure maps were constructed on the top surface of the Verdigris Limestone, Oswego Limestone (consistent transgressive limestones), and Excello Shale to show structural features affecting the geometry of the Prue interval (See figures 42 – 44).

Four isopach maps were constructed to illustrate the thickness and geometry of the Prue interval in the study area (See figures 45 – 48). These maps demonstrate accommodation space and establish the paleogeography during deposition of the Prue interval and associated sediments. A Prue interval isopach map from the Oswego Limestone to the Verdigris Limestone was constructed to determine the thickness of the interval. A net Prue Sandstone isolith map was constructed to show distribution of the sandstone. The sandstone classification was determined using a negative deflection ≥ 25 millivolts of the spontaneous potential curve and a 25 API deflection on the gamma-ray curve from the shale baseline. An isopach of the Skinner Sandstone interval was constructed to determine if the Skinner Sandstone thickness affected accommodation space of the overlying Prue interval. An isopach map from the Verdigris Limestone to the top of the Mississippian Limestone was constructed to show regional depositional relationships affecting Prue interval stratigraphy. A depositional facies map was then constructed from wireline log signature electrofacies to determine trends of like depositional patterns.

Five cores from the Oklahoma Petroleum Information Center (OPIC) in Norman, Oklahoma were described to confirm log electrofacies identification and depositional characteristics of the Prue Sandstone in Creek County, OK (See figures 7 – 32). The cores were used to develop an understanding of the lithology and facies relationships of the Prue interval and were studied for sedimentary structures, textures, and mineralogical constituents. Depositional features in the core were then compared to outcrop descriptions and biostratigraphy investigated by Marshall (2002) and compared to other core descriptions from Ropp (1991), Stirling (1998), Broker (2000), and Huhnke (2004). The cores were then logged and calibrated to gamma ray wireline log signatures in order to confirm wireline electrofacies signatures for depositional environments and facies distribution.

Six thin sections were taken from two cores of the Prue Sandstone for petrographic microscope analysis (See figures 34 – 41). The thin sections were used to establish the mineralogical composition, detrital and authigenic constituents, grain size, and porosity of the core. To determine the diagenetic history and classify the sandstones. these results were plotted on a Folk Ternary Diagram (Figure 33).

CHAPTER III

GEOLOGIC SETTING

Tectonic Framework

The area of investigation lies on the Northeast Oklahoma Platform bounded by the Nemaha Uplift to the west, the Ozark Uplift to the east, and the Arkoma Basin to the south. The Northeast Oklahoma Platform is a tectonically stable depositional platform and is continuous with the Cherokee Basin in Kansas (Krumme, 1981). During the Pennsylvanian, it was divided into two depositional components: the Cherokee Shelf in southeastern Kansas and northeastern Oklahoma, and the Forest City Basin in northeastern Kansas and northwestern Missouri. The strata have a gentle homoclinal dip of about one degree per mile, or around 60 feet per mile to the southwest. Structural patterns in the region resulted from basement movements, occurring along the Nemaha Ridge and in the Ozark Uplift (Hanke, 1967). There are numerous structures that interrupt the gentle homoclinal dip to create small anticlinal closures (Ropp, 1991).

The Nemaha Uplift is a north-south trending belt of faulted anticlines. Movement along the Nemaha Uplift began in the late Ordovician with most major tectonic movement occurring in post-Mississippian/pre-Desmoinesian time (Brenner, 1989). The Nemaha Uplift was gradually onlapped and then completely buried by upper Cherokee sedimentation (Krumme, 1981). The Ozark Uplift to the east persisted during the Paleozoic Era. The tectonic movement began prior to deposition of the Cherokee sediments including the Prue Sandstone. Effects from the Ozark Uplift cannot be determined due to post-Desmoinesian erosion between the study area and the

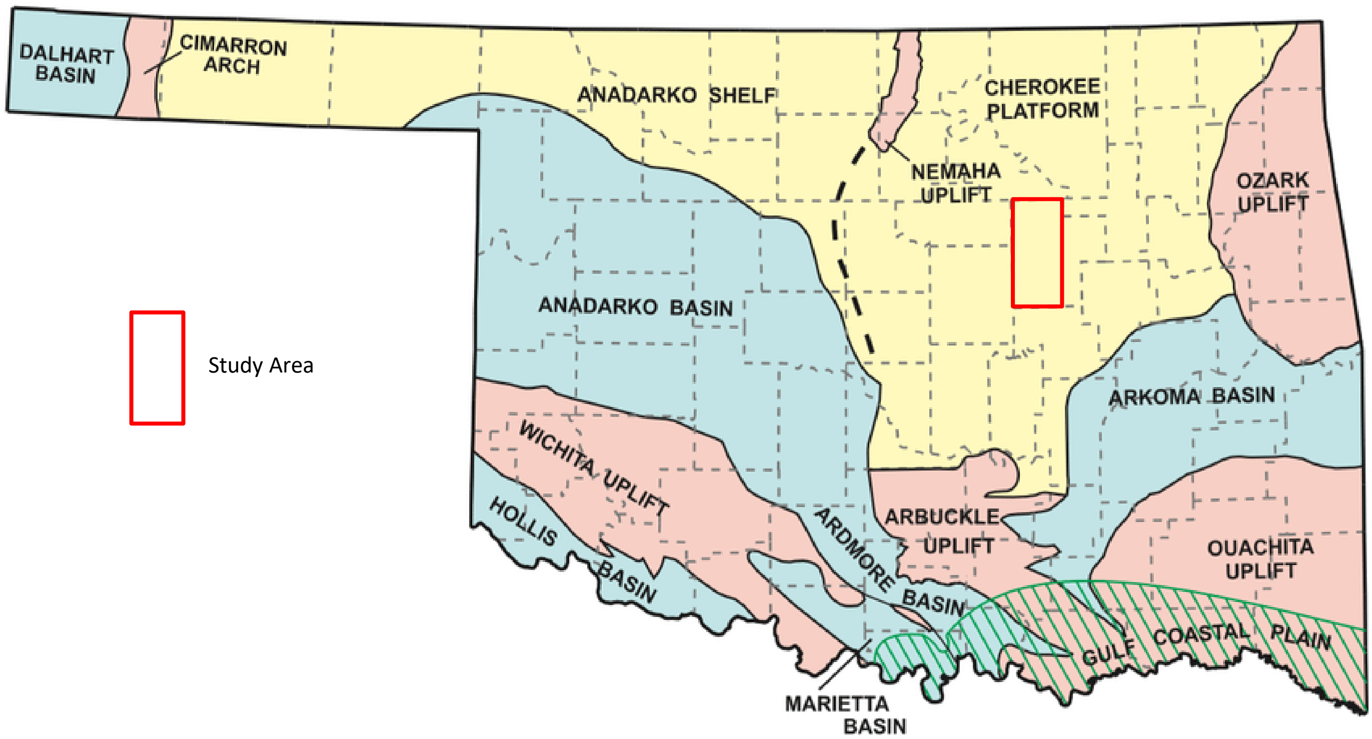
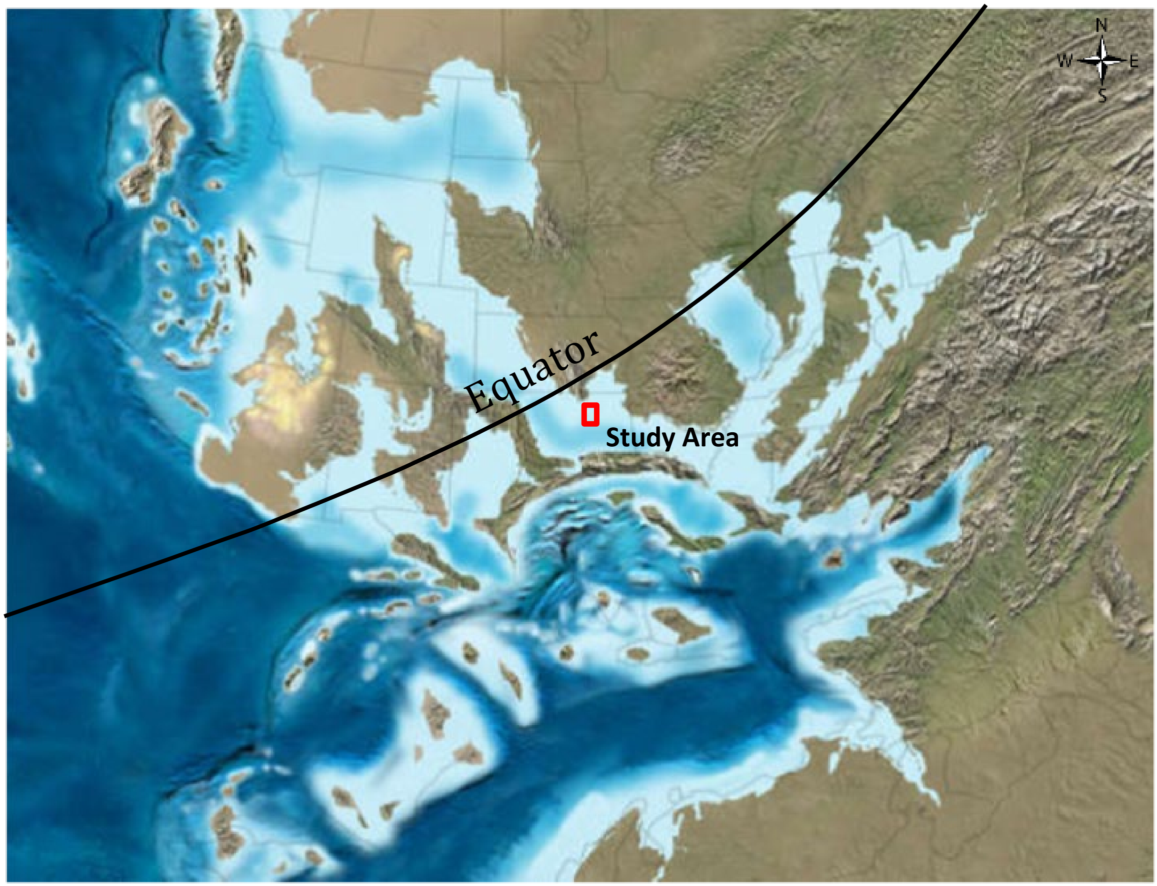


Figure 2. Major structural features and geologic provinces in Oklahoma with study area outlined in red (modified from Johnson, 2008).



Study Area

Figure 3. Middle Pennsylvanian (~307 Ma) paleogeography. Area of study outlined in red. (After Blakey, 2014).

Ozark Uplift (Brenner, 1989). The Arkoma basin to the south is separated from the Anadarko Basin to its west by the Seminole Uplift (Krumme, 1981).

Stratigraphy

This study focuses on the Marmaton and Upper Cabaniss Group with particular attention to the Prue interval defined as the section between the base of the Excello Shale and the base of the Oakley Shale (Figure 4). The Marmaton Group is defined from the top of the Big Limestone to the base of the Oswego Limestone, or top of the Excello Shale. The upper part of the Cabaniss Group is defined as the base of the Oakley Shale to the top of the Excello Shale (Ropp, 1991). This stratigraphic interval also includes the Verdigris, post-Bevier, and Breezy Hill cyclothems or sequences of Marshall (2002). The Cherokee Group formed during a time of cyclic transgressions of the Cherokee Sea, resulting in the deposition of four rock-stratigraphic sequences of sandstone: the Bartlesville, Red Fork, Skinner, and Prue. The recognition of transgressive-regressive cycles is facilitated by cyclic marine intervals including limestones and black fissile shales.

According to Marshall (2002), the Verdigris cyclothem begins at the top of the underclay below the Croweburg Coal and extends to the top of the underclay below the Bevier Coal. The Croweburg Coal marks the beginning of transgression. The Oakley Shale, a back fissile shale, overlies the Croweburg Coal. The Oakley Shale is the basal and oldest stratigraphic unit of this study. The Oakley Shale is characterized by a "hot" high-value gamma ray log signature (≥150 API units), relatively low resistivity, and density porosity value of 20-30%. It is a dark gray to black fissile shale containing dark gray phosphate nodules and deep-water conodonts (Brenner, 1989). Overlying the Oakley Shale is the Verdigris Limestone. The Verdigris Limestone is an important lithostratigraphic marker in the Cherokee Group. The presence of Verdigris Limestone overlying deep-water Oakley Shale indicates that the Verdigris Limestone was a regressive limestone. It is characterized by a low "clean" gamma ray log signature, with high resistivity, and a density porosity of less than 2%. The Verdigris is described as microcrystalline, tan to gray,

SYSTEM	STAGE	GROUP	FORMATION	SURFACE NAMES	SUBSURFACE NAMES	
PENNSYLVANIAN	DESMOINESIAN	MARMATON	FT. SCOTT	Oologah Limestone	Big Lime	
				Labette Shale	Little Osage Shale	
				Ft. Scott Limestone	Oswego Limestone	
		CABANISS	SENORA	Excello Shale	Excello Shale	
				Breezy Hill Limestone	Breezy Hill Limestone	
				Kinnison Shale	Kinnison Shale	
				Iron Post Coal	Iron Post Coal	Prue Interval
				Lagonda Sandstone	Prue Sandstone	
				Bevier Coal	Bevier coal	
				Verdigris Limestone	Verdigris Limestone	
				Oakley Shale	Oakley Shale	
				Croweburg Coal	Henryetta Coal	

Figure 4. Generalized stratigraphic nomenclature of the Cherokee Group in eastern Oklahoma showing subsurface formation names and their surface equivalents (Marshall, 2002).

argillaceous, fossiliferous limestone containing marine fauna including brachiopods, bryozoa, echinoderms, corals, and algal fragments (Cole, 1955 and Brenner, 1989). Marshall (2002) identified crinoids and shallow water conodonts within the formation.

The Post Bevier Coal cyclothem extends from the top of the underclay below the Bevier Coal to the top of the underclay below the Iron Post Coal. The Bevier Coal marks eustatic sea level transgression. Thin limestone units may be present above the Bevier Coal. An unnamed black fissile shale will often be present above the Bevier Coal which may represent a small transgression (Marshall, 2002). The Bevier Coal is sparse in Oklahoma and may not appear in the study area. The Prue Sandstone is stratigraphically the highest of the “Cherokee” Group sandstones. The Prue Sandstone interval involves the stratigraphic interval underlain by the Bevier Coal (when seen) and the Verdigris Limestone and is overlain by the Iron Post Coal and Breezy Hill Limestone. The Prue interval contains shales, silty shales, sandy shales, and sandstone. The sand is characterized by a “clean” gamma ray deflection of ≥ 25 API units, a SP deflection of 25 millivolts, and density porosity of 12-20%. The sandstone is described as tan to gray, very fine to medium-grained, micaceous, and shaley with high-angle cross beds (Hanke, 1967). Sedimentary features from core analysis and petrography of the Prue Sandstone are discussed in Chapter IV.

The Breezy Hill cyclothem extends from the top of the underclay below the Iron Post Coal to the top of the Breezy Hill Limestone. The Breezy Hill cyclothem consists of the Iron Post Coal, Kinnison Shale, and the Breezy Hill Limestone (Marshall, 2002). The Iron Post Coal is located directly above the Prue Sandstone. It is usually less than two feet thick and cannot often be seen in wireline logs. When seen on wireline logs, it is recognizable by a “clean” gamma ray response (≥ 25 API units) and density porosity of 30% or more. In core, it contains carbonaceous shale banding with small layers of pyrite. The Kinnison Shale overlies the Iron Post Coal and underlies the Breezy Hill Limestone. It is a thin-bedded, silty-clay, dark gray shale with

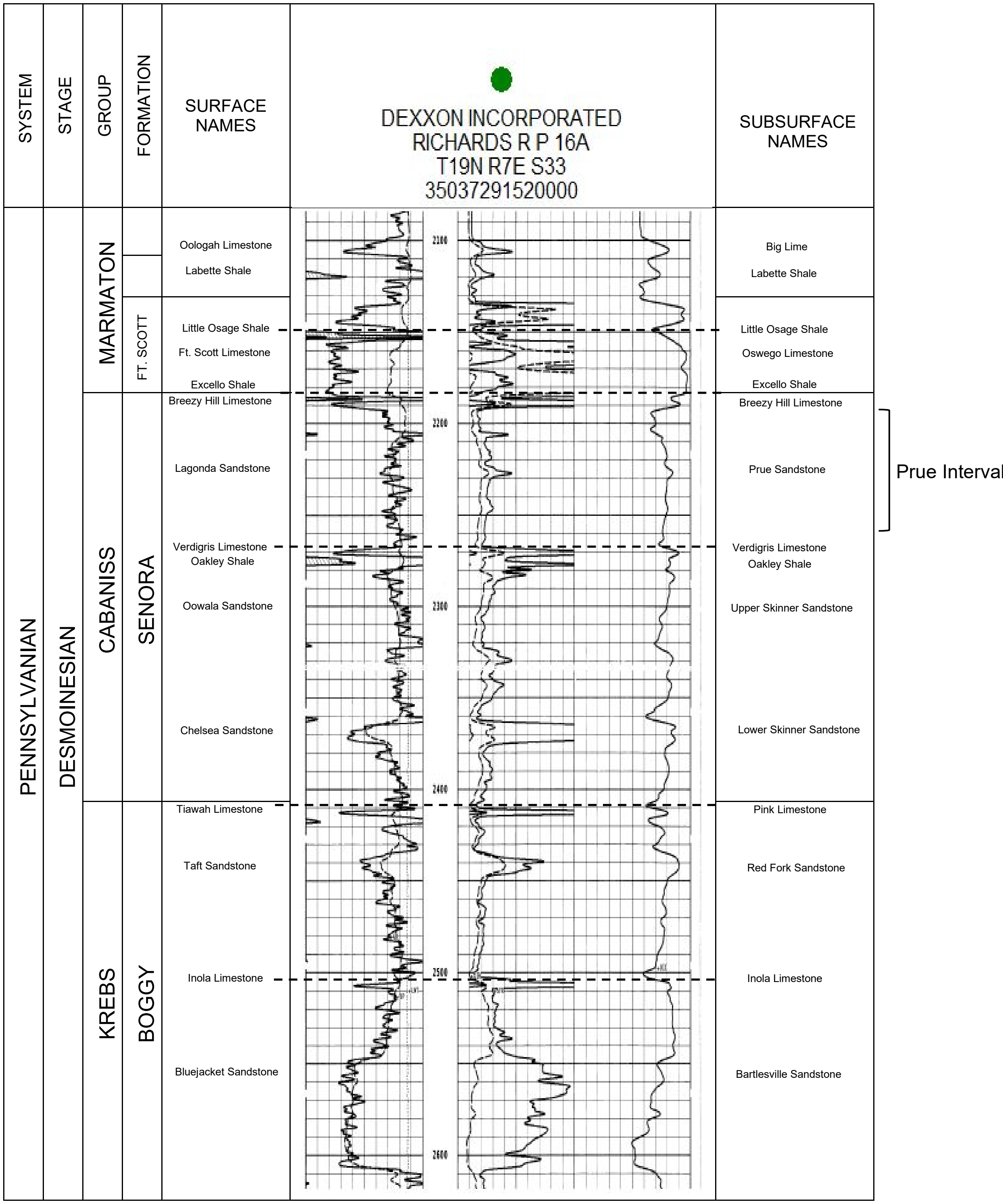


Figure 5. Composite log showing gamma-ray, SP and resistivity curves of the subsurface section including the Bartlesville Sandstone (Krebs Group), Cabaniss Group including the Prue interval and lower part of the Marmaton Group.

brachiopods. It is often fissile, soft, and carbonaceous. The Breezy Hill Limestone overlies the Iron Post Coal and Kinnison Shale and underlies the Excello Shale. It is the point of maximum transgression in the Breezy Hill cyclothem. It is characterized by a thin, relatively “clean” gamma ray log signature, with a density porosity ranging from 0-6%. The Breezy Hill Limestone is a massive crinoidal biosparite that contains archeogastropods, mesogastropods, brachiopods, calcareous foraminifera, crinoids, and conodonts (Marshall, 2002).

The Lower Fort Scott cyclothem extends from the top of the underclay below the Excello Shale to the top of the underclay below the Summit Coal in the Marmaton Group. This cyclothem consists of the Mulky Coal, Excello Shale, Blackjack Creek Limestone, and the underclay below the Summit Coal (Marshall, 2002). The Excello Shale overlies the Breezy Hill Limestone and underlies the Oswego Limestone of the Marmaton Group. It is an excellent continuous marker bed throughout the study area and is easily recognizable, as it is characterized by the very high “hot” gamma ray log signature ($\geq$ 150 API units) and density porosity values exceeding 25%. The Excello Shale is a black, fissile, phosphatic shale that represents a major transgression over the Midcontinent (Marshall, 2002). It also has abundant pyrite, quartz, calcite, organic carbon, and minor amounts of clay minerals (Broker, 2000). The facies contain deep-water conodonts; however, the presence of phosphate nodules and the lack of other fauna suggest that the Excello Shale may have been deposited in anoxic condition (Marshall, 2002).

The Oswego Limestone is the lowest unit of the Marmaton Group. It is located immediately above the Excello Shale and bounded above by the Little Osage Shale. The Oswego Limestone has a “clean” gamma ray log signature ($\leq$ 50 API units), with a high resistivity, and a 0-10% density porosity response. It is a mottled, buff to gray, microcrystalline, fossiliferous limestone often with an abundance of chert and characterized by oolites, calcite veins, and can be slightly dolomitic. It varies in thickness substantially throughout the study area, often being more than 50 feet thick to the north, with rapid thinning and disappearance moving southward. The

Little Osage Shale separates two formations within the Oswego Limestone including the Blackjack Creek and Higginsville Limestones. It is characterized by a “hot” gamma ray log signature ($\geq$ 150 API units), and is described as a black, fissile shale containing an abundance of phosphate nodules (Broker, 2000). The Labette Shale overlies the Oswego Limestone and is the lower boundary for the Big Lime. The Big Lime is an informal stratigraphic rock unit directly above the Little Osage Shale. It is characterized by a “clean” low gamma ray and SP log signatures, and a higher resistivity and is described as white to gray, fine to coarsely crystalline, oolitic, and dolomitic (Ropp, 1991). It also varies in thickness substantially throughout the study area, often being more than 30 feet thick to the north, with rapid thinning and disappearance moving southward, usually in relation with the Oswego Limestone.

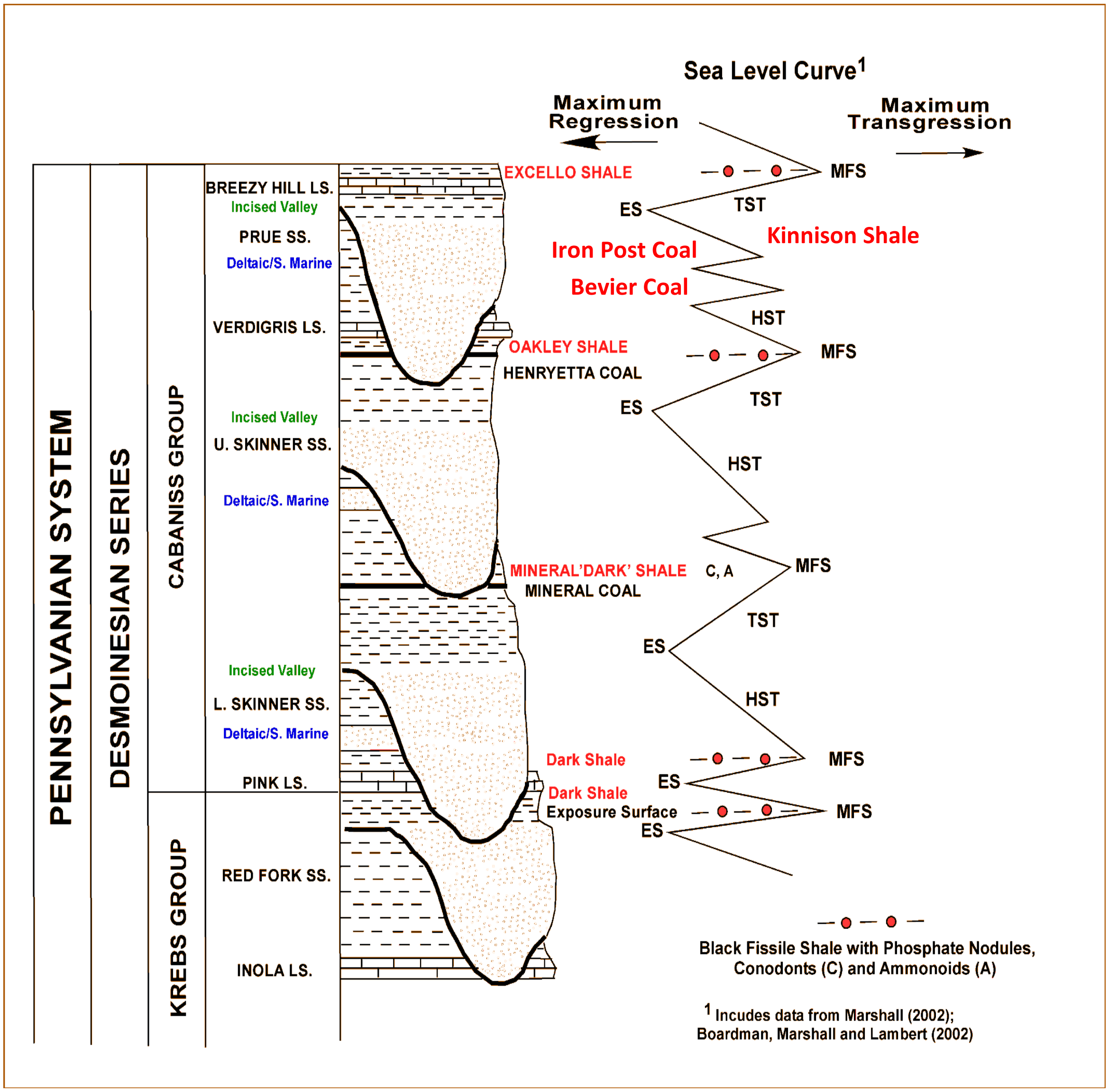
Depositional Framework

The Pennsylvanian sub-period of northeast Oklahoma is characterized by glacio-eustatic cyclic transgressive/regressive depositional patterns called cyclothems or sequences (Heckel, 1977). These transgressions and regressions by the Midcontinent Sea had a profound effect on northeastern Oklahoma and southern Kansas. Most of the area was covered by the sea during times of transgression and was terrestrial to semi-continental during times of regression (Marshall, 2002). Subsidence of the Arkoma Basin combined with glacial-eustatic sea-level changes and highstand deltaic sedimentation attributed to the Cherokee Group thickness (Marshall, 2002).

Many have noted the cyclical nature of deposition of the Cherokee Group including in the Prue interval. Wanless and Weller (1932) created the term cyclothem in the Illinois Basin. Weller (1930) stated that cyclic deposition has been related to tectonism. Wanless and Shepard (1936) and more recently Heckel (1984, 1986; 1987) performed multiple studies relating cyclic deposition to eustatic sea level changes due to glaciation. Heckel (1984) defines cyclothems as marine transgressive-regressive sequences or T-R units or cycles which represent a maximum flooding zone of the shelf, represented by thin, black phosphatic shales. Heckel (1986) described the transgressive-regressive marine cyclothem which consist of in ascending order: near shore "outside" shale, regressive limestone, core shale, transgressive limestone, and nearshore shale. Marshall (2002) determined the number and nature of these cycles within the Cherokee Group from subsurface outcrops based upon faunal assemblages and lithofacies in eastern Oklahoma and Kansas. By describing marine intervals found, he divided the resulting cycles into minor, intermediate, and major depending upon the degree of marine transgression.

After Marshall (2002) identified and characterized all the transgressive-regressive cycles, he drew a generalized sea level curve labeling each cycle. Maximum regressions were placed at subaerial exposures, and maximum transgressions were placed at the deepest marine interval within the cyclothem. The size of the transgressions was determined from the interpretation of the lithofacies and microfossils.

According to Marshall (2002), major marine transgressions, as illustrated by the sea level curve in Figure 6, took place at several points in the Cherokee Group. Major marine transgressions at maximum sea-level highstands occur after deposition of the widespread Oakley and Excello shales. Many minor marine transgressive-regressive cycles were identified within the Prue interval with at least two cycles occurring between the major marine transgressions of the Oakley Shale and Excello Shale (Nelson, 1985). The Oakley Shale is the lower boundary of the Prue interval sequence and represented a maximum transgression of the sequence and anoxic depositional conditions. Minor transgressions and regressions deposited alternating shales and sandstones within the Prue interval. Regression occurred where distributary channels prograded across the delta plain and deposited channel sands. Further regression associated with falling sea level resulted in the incision of major channels within the Prue interval (Marshall, 2002). Transgression resulted in a relative rise in sea level and backfilled the incised valleys with



HST – Highstand Sequence Tract
LST – Lowstand Sequence Tract
TST – Transgressive Sequence Tract
MFS – Maximum Flooding Surface
ES – Exposure Surface

Figure 6. Modified sea level curve for the Cherokee Group (Boardman, Marshall, Lambert, 2002).

sediment. The Excello Shale is the upper boundary of the Prue interval and was deposited during maximum transgression, in stagnant, deeper water, and anoxic conditions (Brenner, 1995).

Source Area

The Prue Sandstone originated from fluvial systems that advanced across the Cherokee Platform from the northeast. Channel systems resulted in large sand bodies accumulating on the Central Oklahoma Platform. These channels drained from sources in Illinois to the northeast (Marshall, 2002). The Prue Sandstone is fine-grained to very fine-grained, subangular to subrounded, with large amounts of suspended clay, silt, abundant muscovite, and very fine-grained sand consisting of mostly quartz and less amounts of metamorphic rock fragments. The predominance of metamorphics, the grain size, and roundness suggest that Prue sand is indicative of long transport, and the source was from cratonic areas far to the northeast, most likely from the Transcontinental Arch (Krumme, 1981). Andrews (1996) constructed a regional isopach map from the top of the Verdigris Limestone to the top of the Pink Limestone across most of Oklahoma, concluding that the Prue's distribution was influenced by the paleotopography of the Cherokee Platform and Nemaha Uplift.

CHAPTER IV

RESULTS

Core Analysis

Five (5) cores within the study area were examined and described to determine lithological facies and depositional characteristics of the Prue Sandstone. The cores were used to develop an understanding of the lithology and facies relationships of the Prue interval, and were studied for lithology, sedimentary structures, textures, and detrital constituents. Wire-line logs were used in conjunction with these cores to correlate log signatures with depositional facies and environments. Petrologic log data and photographs for each of the cores is located in Appendices A-E. The cores were obtained from the Oklahoma Petroleum Information Center (OPIC) in Norman, OK.

Table 1. List of wells with cored interval examined in the study area.

Well Name	Location	County	Formation	Cored Interval (feet)
Peter Brown #9	Sec 33-17N-7E	Creek	Prue Sandstone	2381-2393
Sam Sawyer #20	Sec 22-17N-7E	Creek	Kinnison Shale – Oakley Shale	2384-2413
Stroud Prue Unit Tr. #12-6	Sec 8-14N-7E	Creek	Kinnison Shale – Oakley Shale	2861-2941
Yarhola Royalty Unit Tr. 3 #25	Sec 16-17N-7E	Creek	Prue Sandstone	2294-2321
Watson #1	Sec 35-16N-7E	Creek	Prue Sandstone	2667-2693

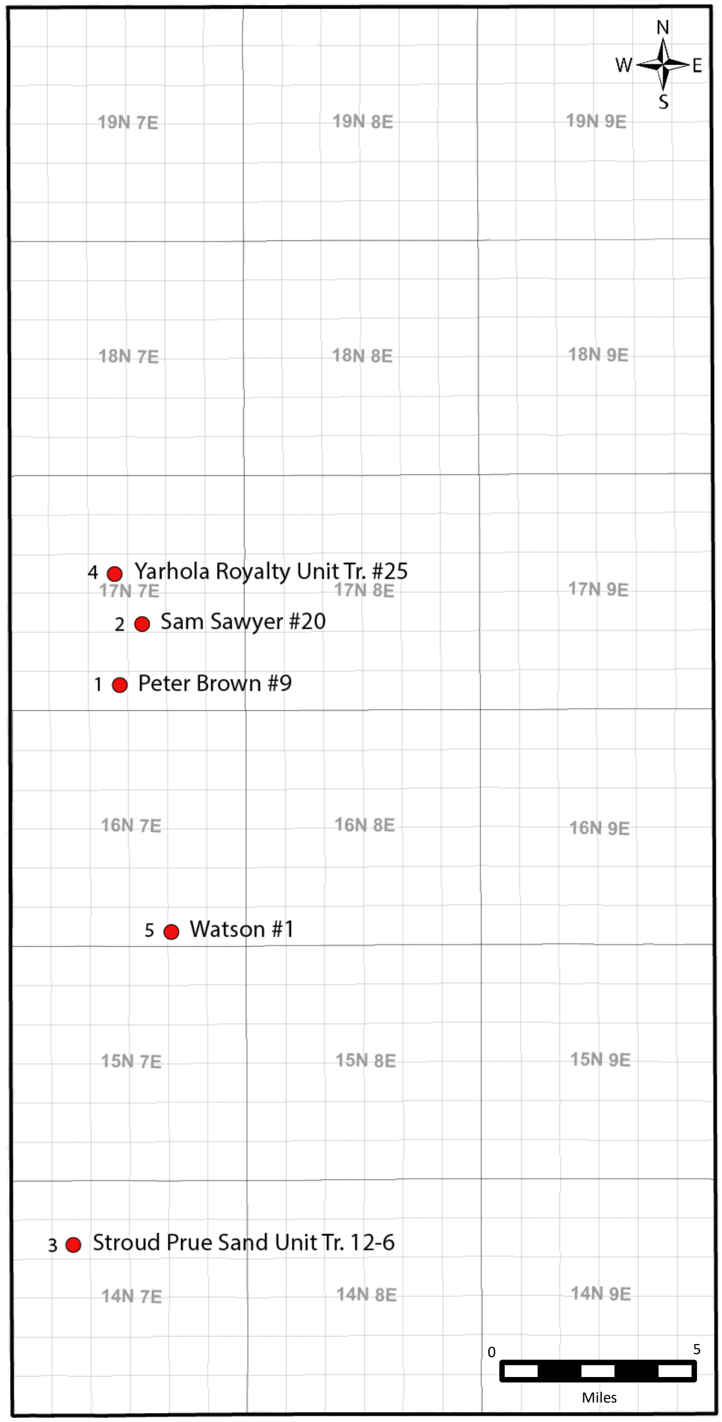


Figure 7. Location of the 5 cores examined within the study area.

Gulf Oil Corp., Peter Brown #9, Section 33, T.17N, R.7E, SW SE NE

The cored interval is from 2381-2393 feet (Figure 10). The core starts just above the Prue Sandstone. At the top of the Prue Sandstone is a mottled, gray limestone with a small amount of fossil debris that was bioturbated and mixed with black shale. Below the limestone is the top of the Prue Sandstone, which is a light gray, very fine to fine-grained sandstone (0.065-0.2 mm), with relatively good sorting. The sandstone shows massive bedding at the top of the interval depth. Interbedded black shales occur throughout the Prue Sandstone. The sandstone shows tidal influx and is rhythmically bedded that includes small-scale cross bedding, flaser bedding, and sand ripples near the bottom of the sand interval. Bioturbation and burrowing are abundant throughout the cored interval, especially in the shale at the bottom of the core at 2389-2392 feet. There are thin shale laminations throughout the core with shale becoming the dominant lithology at its base. A siderite clast is present at 2382 feet. From 2388-2390, there is some discolored red banding likely due to oxidation. Calcite cement occurs in trace amounts. No thin sections were available for this core.

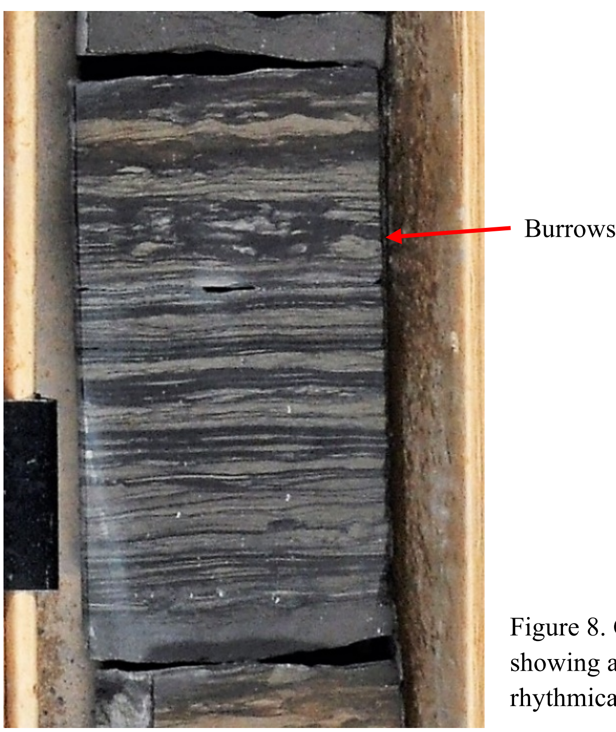


Figure 8. Close up of Peter Brown #9 core showing an abundance of burrows and rhythmically deposition at depth 2390.4.

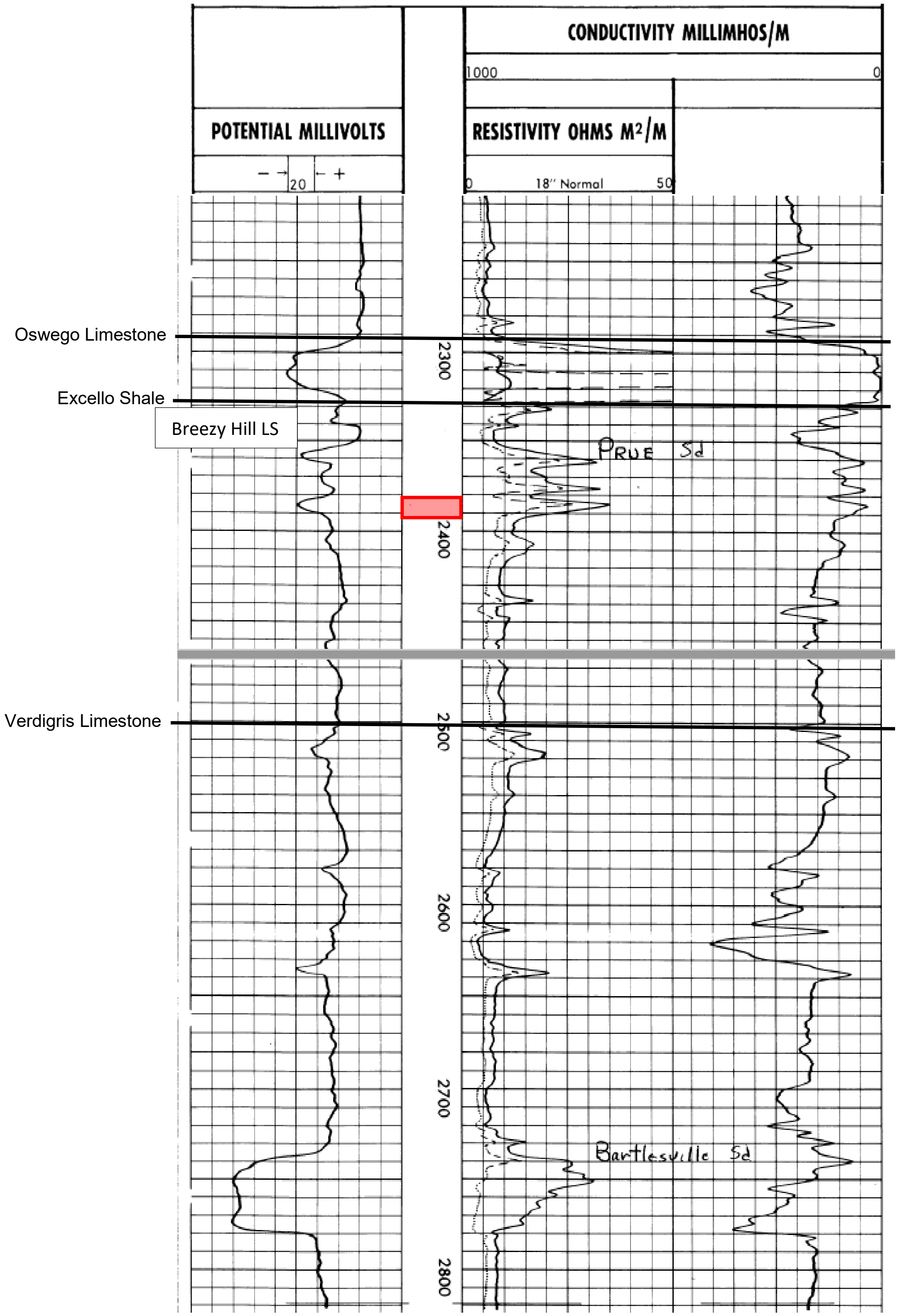


Figure 9. SP and resistivity logs of the Peter Brown #9, Section 33, T.17N, R.7E. The cored interval is from 2381-2393 feet with the shaded box indicating the cored interval. The cored interval only contains a small portion of the Prue Sandstone.

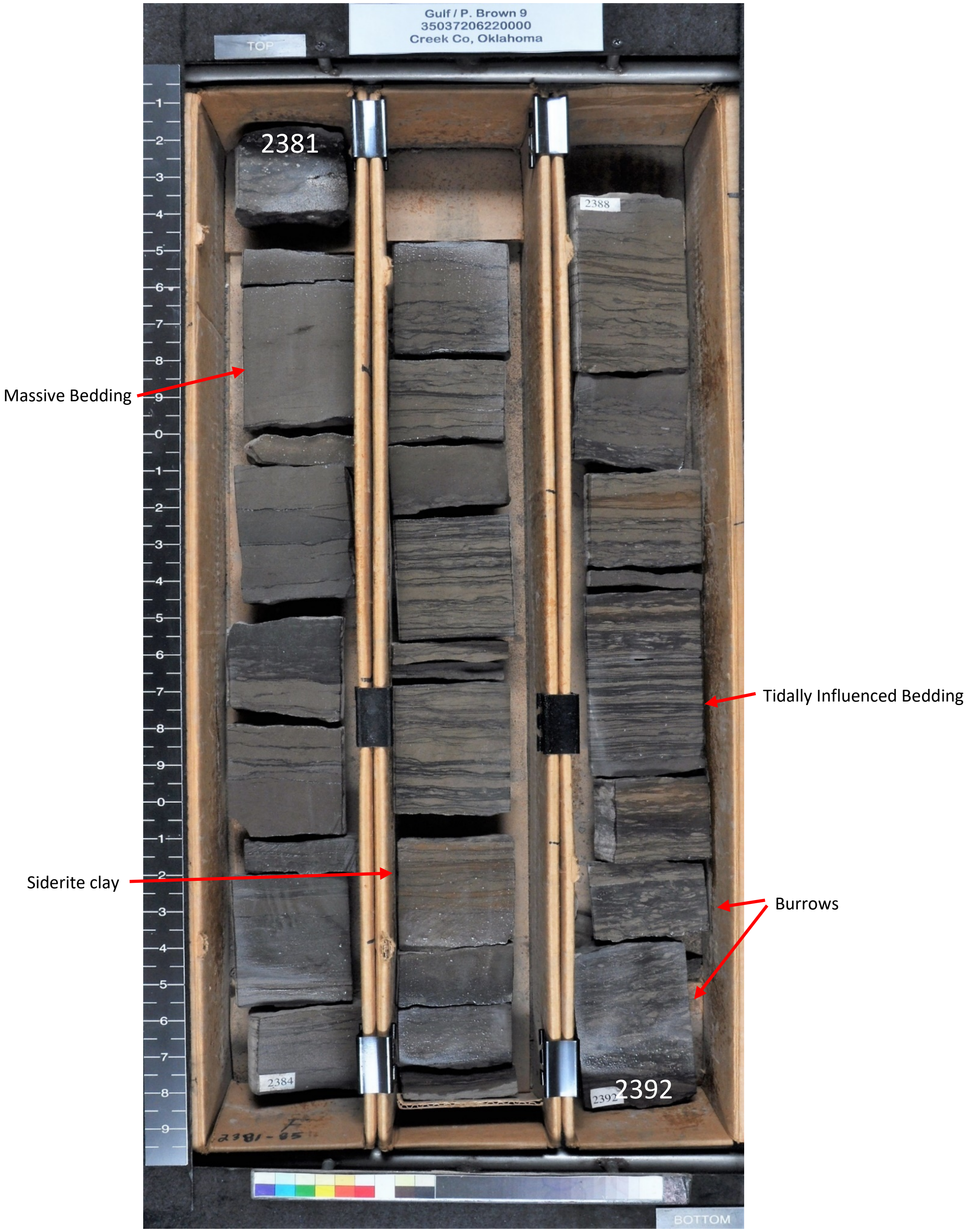


Figure 10. Entire slabbed core of Peter Brown #9 from depth 2381 to 2392 feet. Depth 2387 feet shows red strips of siderite clay. The core is massively bedded near the top, with more rhythmic bedding at the bottom of the core. Burrows are seen throughout, especially closer to the bottom of the core. Scale bar indicates tenths of feet.

Grace Petroleum Corp., Sam Sawyer #20, Section 22, T.17N, R.7E, NE SE SW

The cored interval is from 2384-2413 feet (Figures 13 – 15). The core begins above the Prue Sandstone in the Kinnison Shale, a dark black fissile shale. The Kinnison Shale is followed immediately by a half foot of the Iron Post Coal at 2387.5 feet. The coal is bituminous with a vitreous luster and smooth texture. Below the coal at 2388 feet is a green to gray paleosol with clayey texture and multiple plant remains. Below the paleosol is the start of the Prue Sandstone. The Prue Sandstone is light gray, very fine to fine-grained sandstone, with relatively good sorting. At 2393 feet, the Prue is thinly bedded with thin trough cross bedding. Mud rip up clasts are seen. Shale bands start becoming prominent at 2399 feet. At 2402 feet, some of the shale banding is tidally rhythmically laminated in a low energy environment with ripples and low angle cross bedding. At 2402 feet, soft sediment deformation is apparent. At depth 2407 feet, interbedded shale becomes more prominent at the base of the sand along with bioturbation. At 2409 feet is a sharp contact with an unidentified limestone. The unidentified limestone mottled gray and fossiliferous limestone with abundant brachiopods, dispersed crinoid fragments, other fossil fragments, and large carbonate clasts. The shale at 2411 feet is a highly bioturbated black shale. Thin sections GS 2392.5 and 2404.6 were sampled from this core.

Figure 11. Close up of Sam Sawyer #20 core showing the bituminous Iron Post Coal that lies above the Prue Sandstone at depth 2387.5.

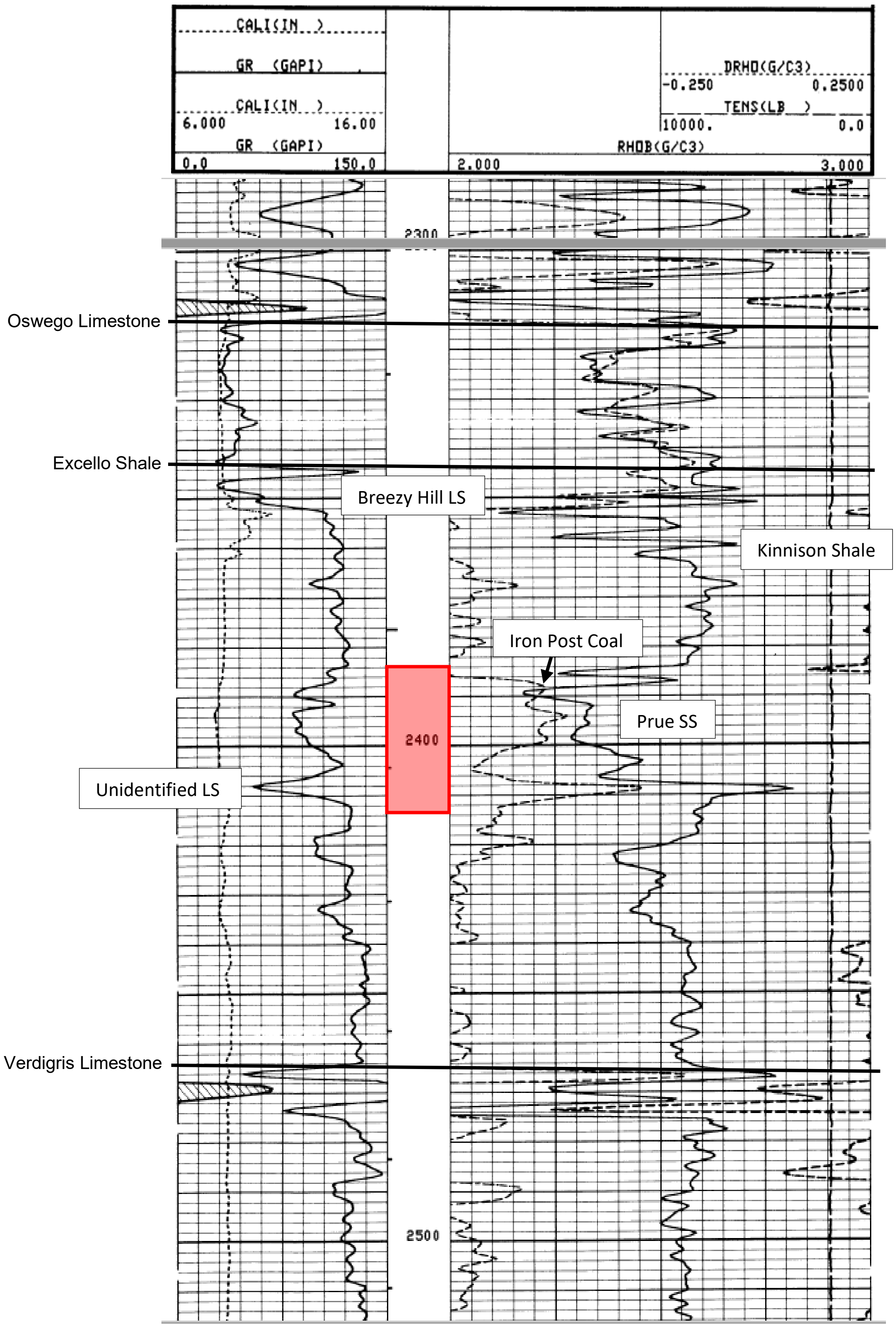


Figure 12. Gamma Ray and porosity logs of the Sam Sawyer #20 well. The cored interval is from 2387-2413 feet. The shaded box indicates the cored interval. The density porosity well log is the only well log of the cored intervals that show the unidentified limestone below the Prue Sandstone and the Iron Post Coal.

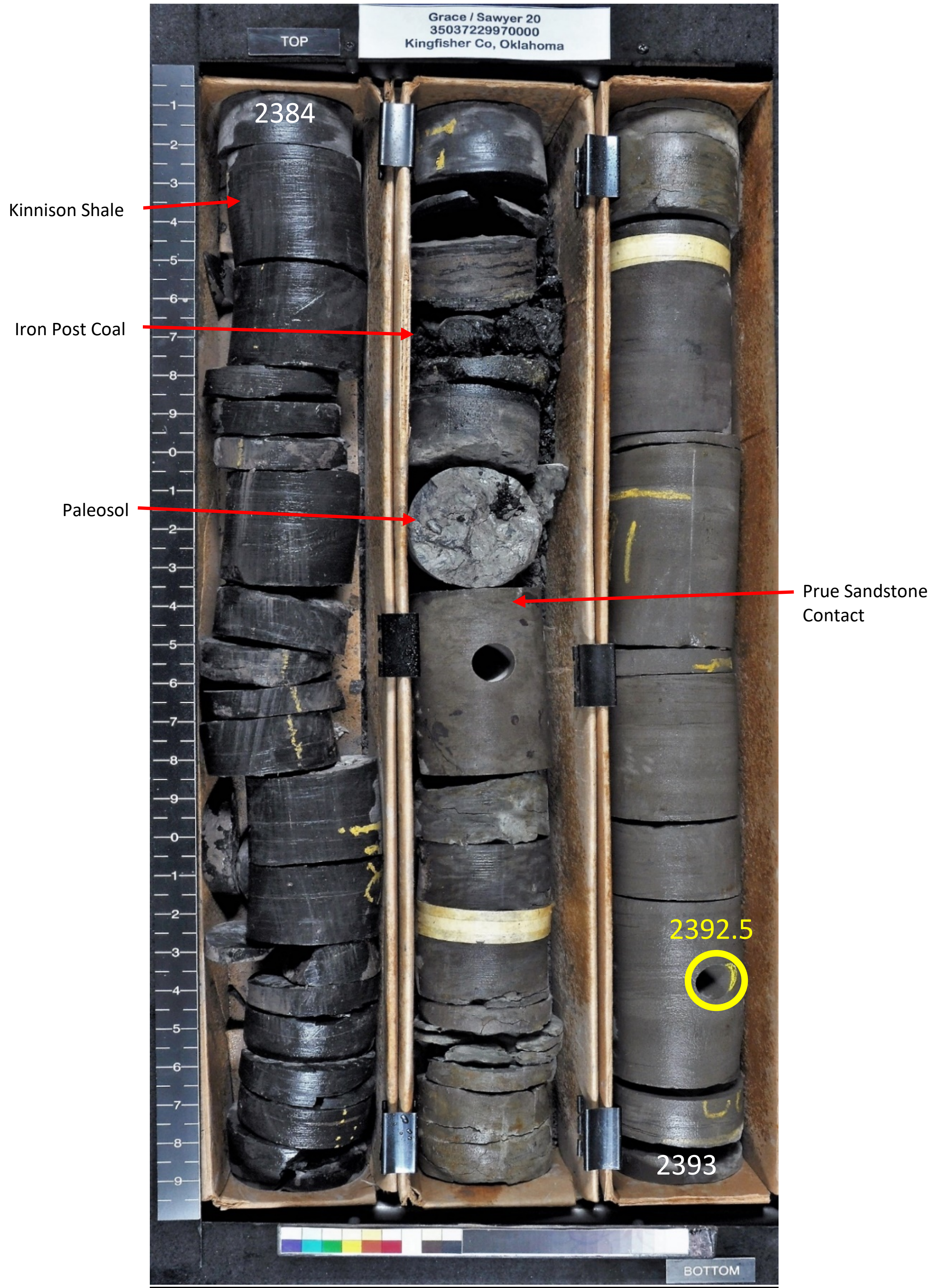


Figure 13. Core of Sam Sawyer #20 from depth 2384 to 2393 feet. Core shows the Kinnison Shale from 2384-2393 feet, and the Iron Post Coal at 2387.3 feet with the paleosol that underlies it. The Prue Sandstone begins at depth 2388.4 feet. Yellow circle indicates thin section GS 2392.5. Scale bar indicates tenths of feet.

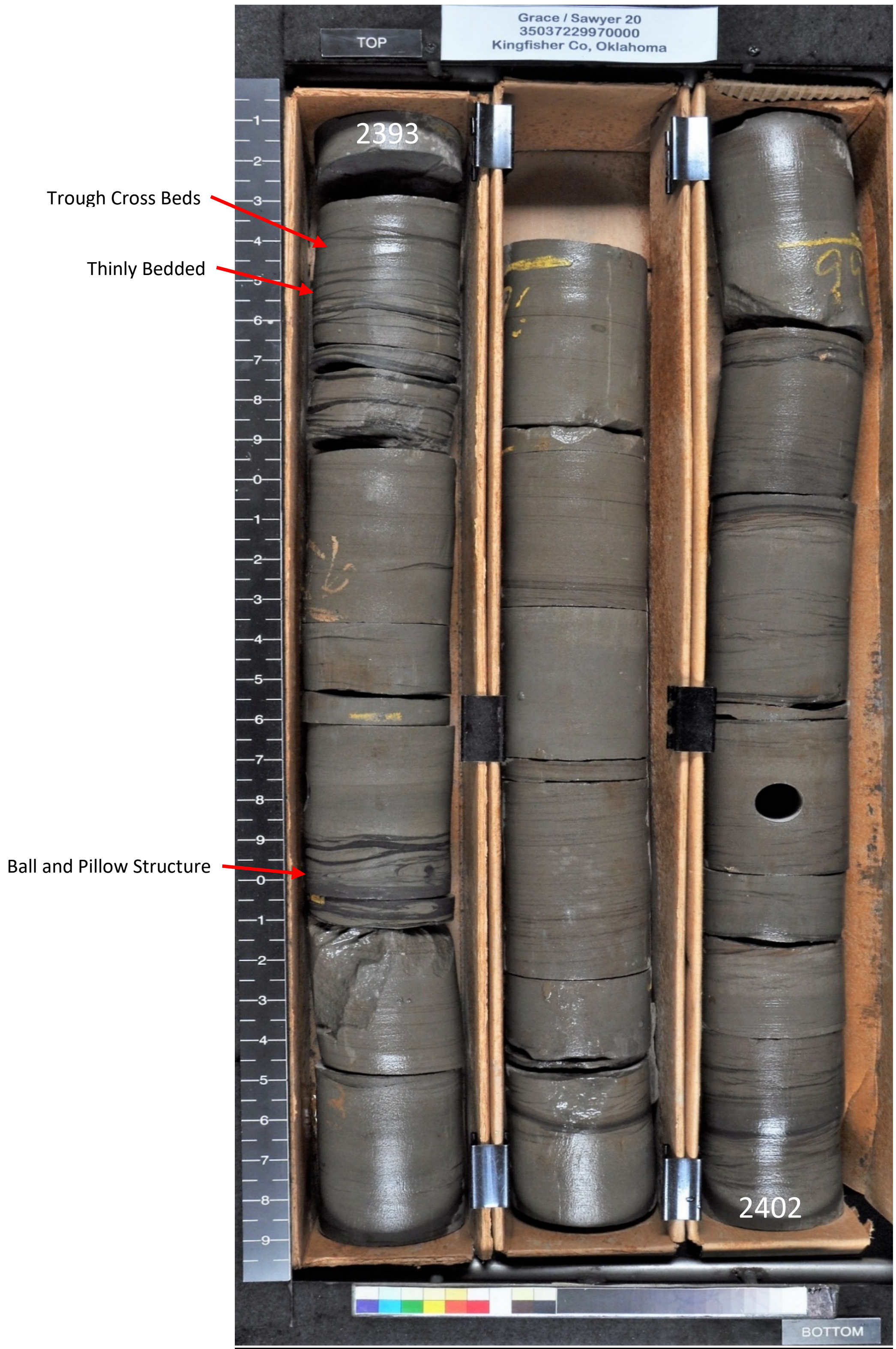


Figure 14. Core of Sam Sawyer #20 from depth 2393 to 2402 feet. The Prue Sandstone is more thinly bedded at depth 2393 feet. Ball and pillow structures are evident at depth 2395 feet. Interbedded shale content increases near the bottom of the interval with low energy, rhythmic wavy beds and low angle cross bedding. Scale bar indicates tenths of feet.

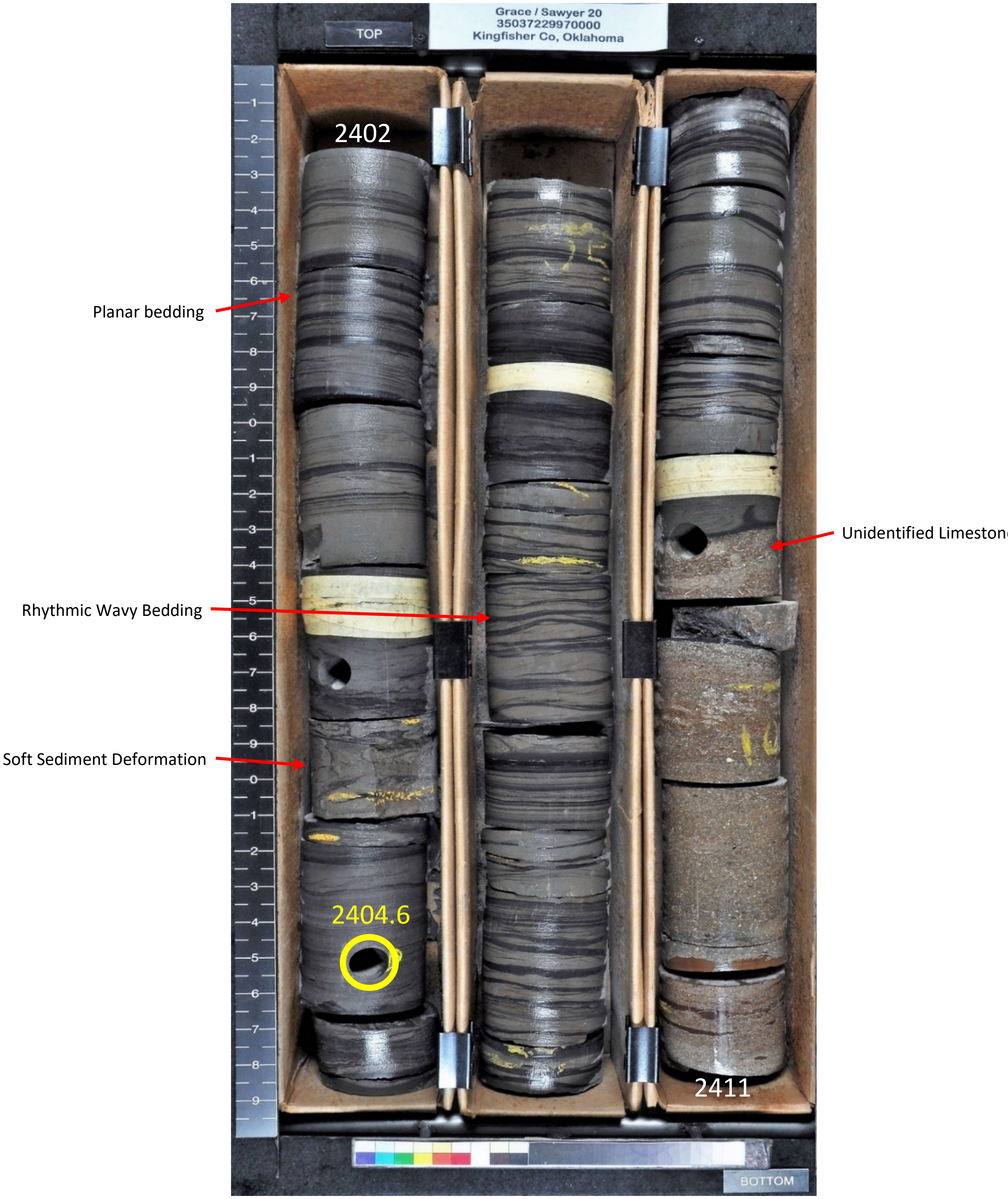


Figure 15. Core of Sam Sawyer #20 from depth 2402 to 2411 feet. Soft sediment deformation is evident. Shale content increases from 2405 to 2409 feet with rhythmic wavy beds and lenticular bedding. A sharp at contact occurs at 2409.3 feet between the Prue Sandstone and an unidentified marine limestone bed. Yellow circle indicates thin section GS 2404.6. Scale bar indicates tenths of feet.

Sun Production Company, Stroud Prue Unit Tr. #12-6, Section 8, T.14N, R.7E, NW NW SE

The Stroud Prue Unit Tr. #12-6 is cored from 2861-2941 feet. The cored interval begins above the Prue Sandstone in the Kinnison Shale, a black shale with iron banding that is in sharp contact with. There is a sharp contact with the Prue Sandstone. The sandstone is light brown, very fine grained (0.065 mm), and moderately sorted. Interbedded shale, burrowing, and bioturbation occur throughout the entire interval. Sedimentary structures include small scale trough cross bedding, wave ripples, and rhythmic bedding. Sandstone is more prominent at the beginning of the interval with increasing shale in the lower half of the core. In the lower half of the core, the sandstone becomes highly burrowed with an abundance of clay. This section of the core is an interval with little to no SP deflection and has a flat gamma-ray log signature. The Verdigris Limestone occurs at 2939 feet and is mottled gray fossiliferous limestone with dispersed brachiopods, crinoid fragments, and other fossil fragments. The Oakley Shale contact is below the Verdigris Lime at depth 2940 feet and is characterized as a very dark black fissile shale. This core is south of the main Prue deposition complex. This represents deposition in a different time frame and different geography than the rest of the cores in the study. No thin sections were sampled from this core.

Figure 16. Close up of Stroud Prue Unit Tr. #12-6 core showing the increasing burrows in the bottom half of the core at depth 2926.9 feet closer to the Verdigris Limestone.

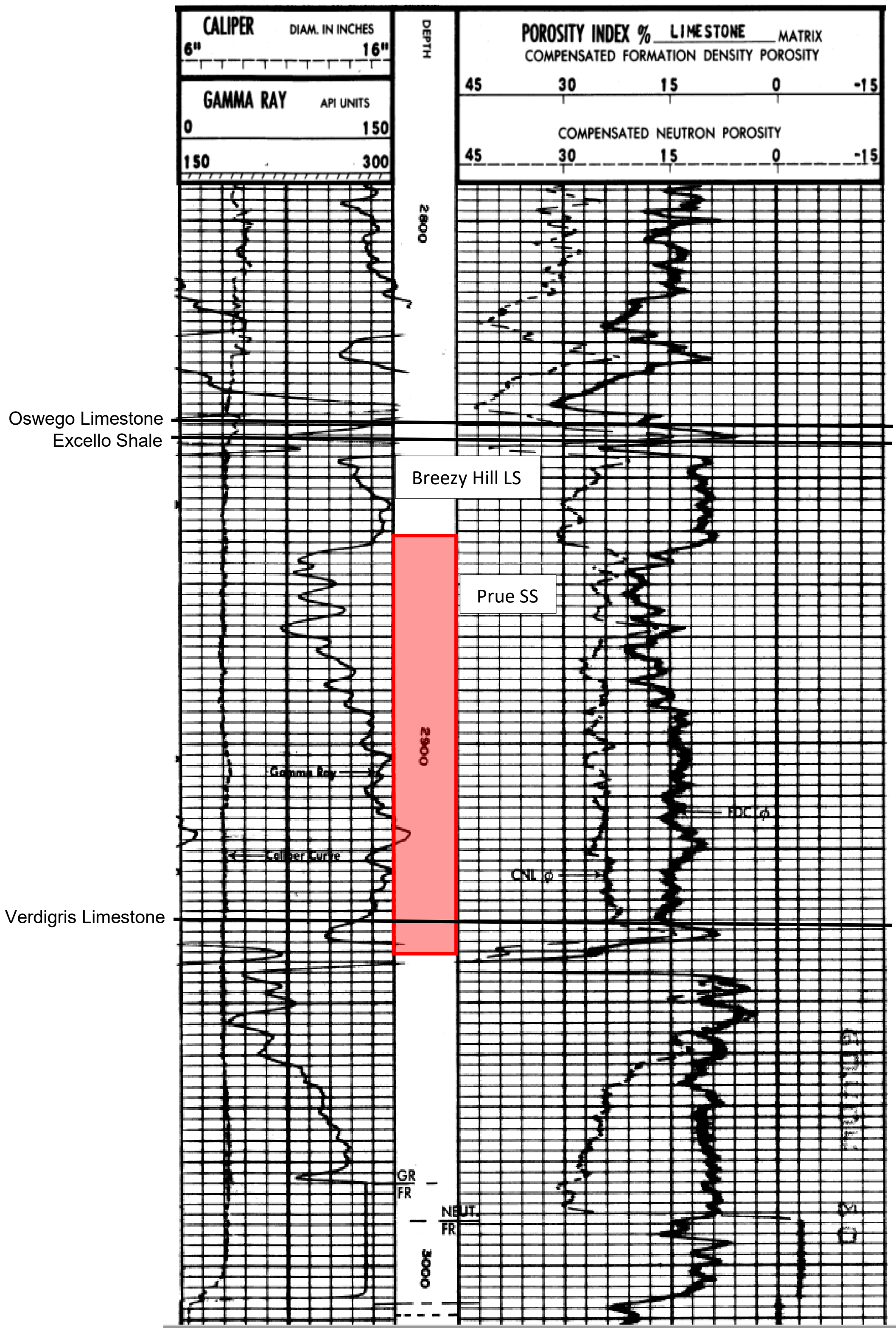


Figure 17. Gamma-ray and porosity logs of the Stroud Prue Unit Tr. #12-6 well. The cored interval is from 2861-2941 feet. The shaded box indicates the cored interval. Gamma-ray and caliper curves are to the left of the depth track, and porosity (neutron-density) curves are to the right of the depth track. Scale bar indicates tenths of feet.

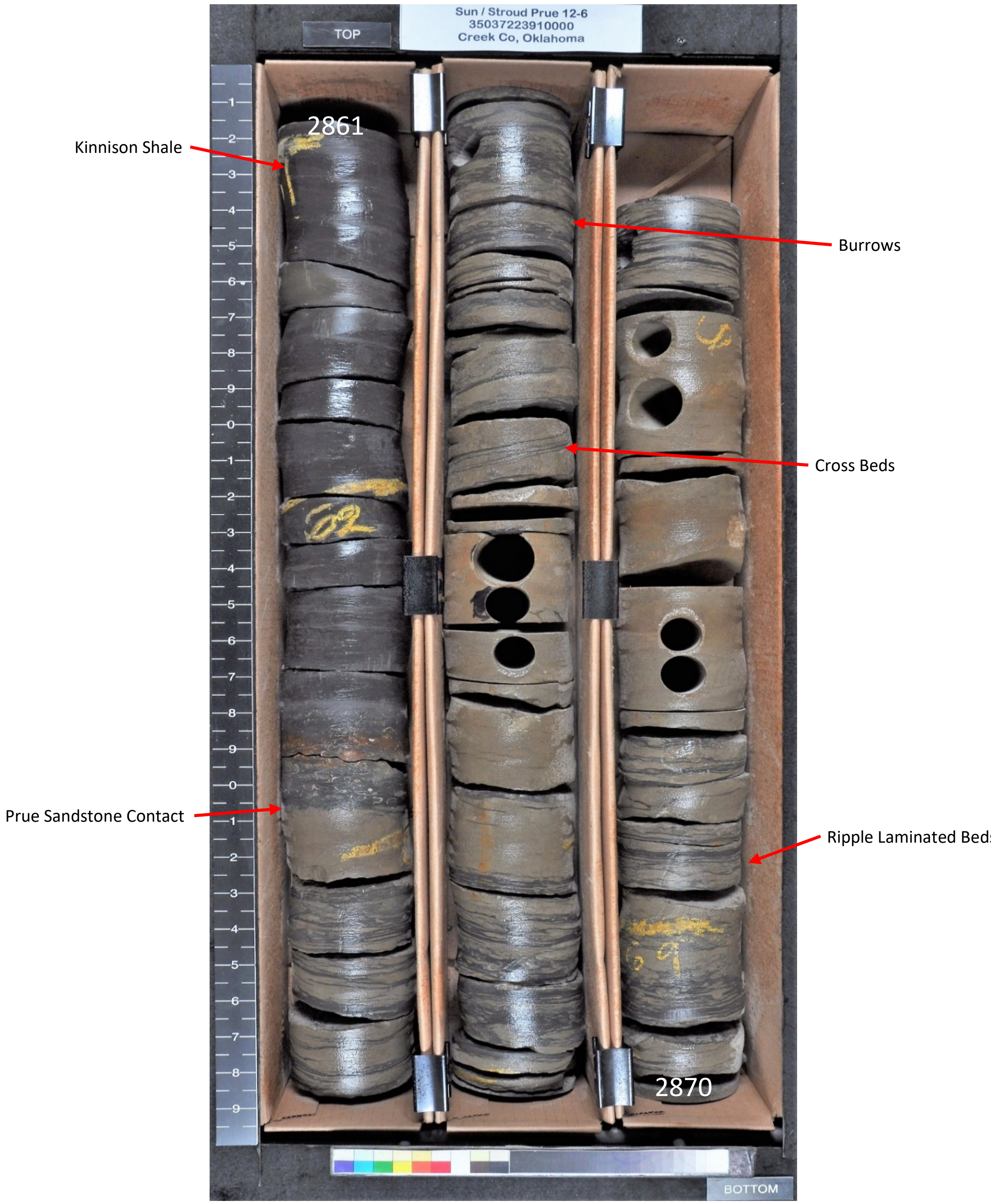


Figure 18. Core of Stroud Prue Unit Tr. #12-6 from depth 2861 to 2870 feet. The interval begins in the Kinnison Shale, a black marine shale with a sharp contact with the Prue Sandstone at 2863.1 feet. Core has an abundance of burrowing and bioturbation with sedimentary structures that include small scale trough cross bedding, wave ripples, rhythmic bedding. Scale bar indicates tenths of feet.

Figure 19. Core of Stroud Prue Unit Tr. #12-6 from depth 2879 to 2887 feet. There is an abundance of rhythmic bedding of sandstone and interbedded shale. Burrowing and bioturbation are also abundant in the interval. Scale bar indicates tenths of feet.

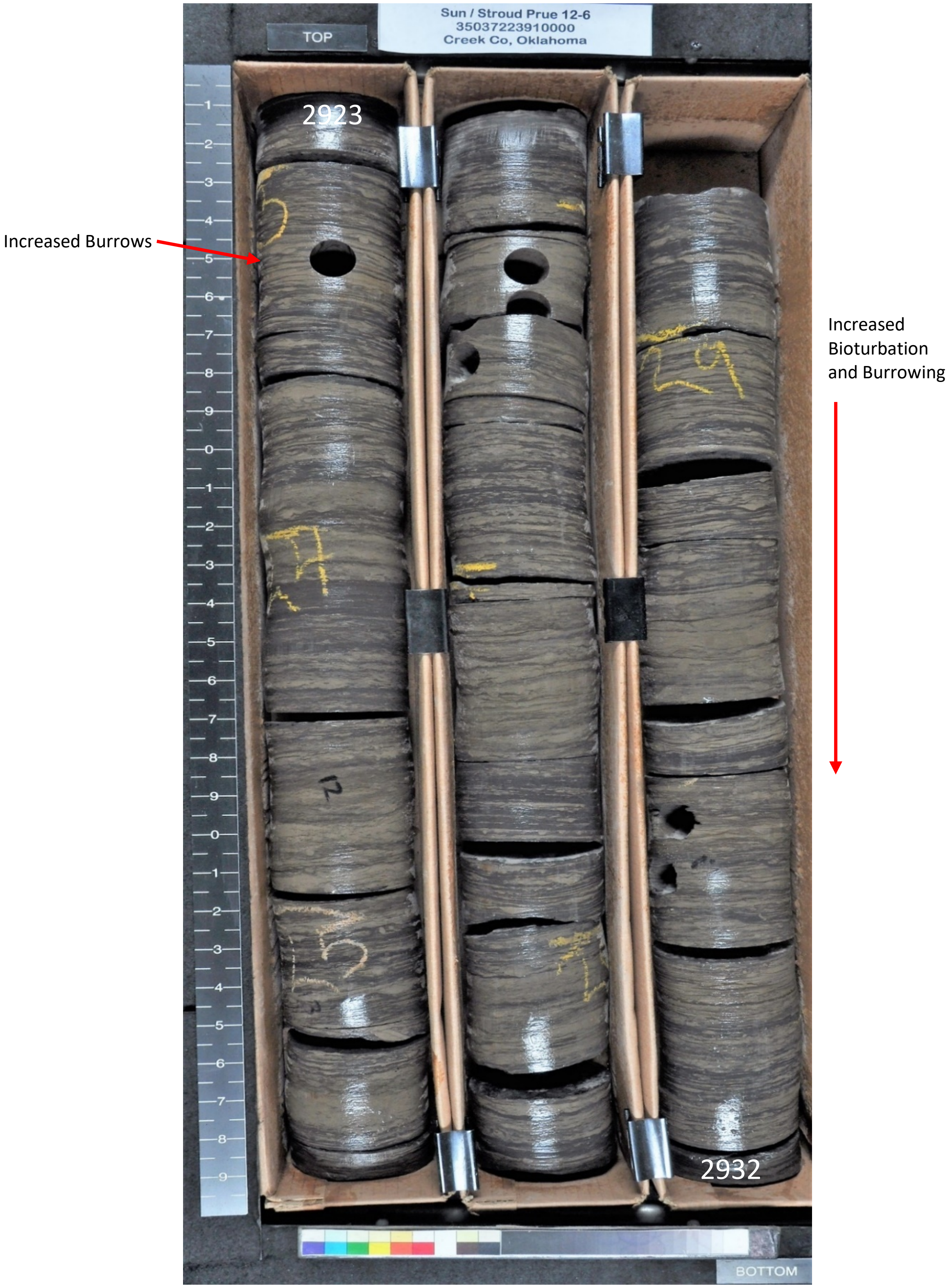


Figure 20. Core of Stroud Prue Unit Tr. #12-6 from depth 2923 to 2932 feet. The interval becomes increasingly more burrowed and has a higher abundance of interbedded shale within the sandstone. Scale bar indicates tenths of feet.

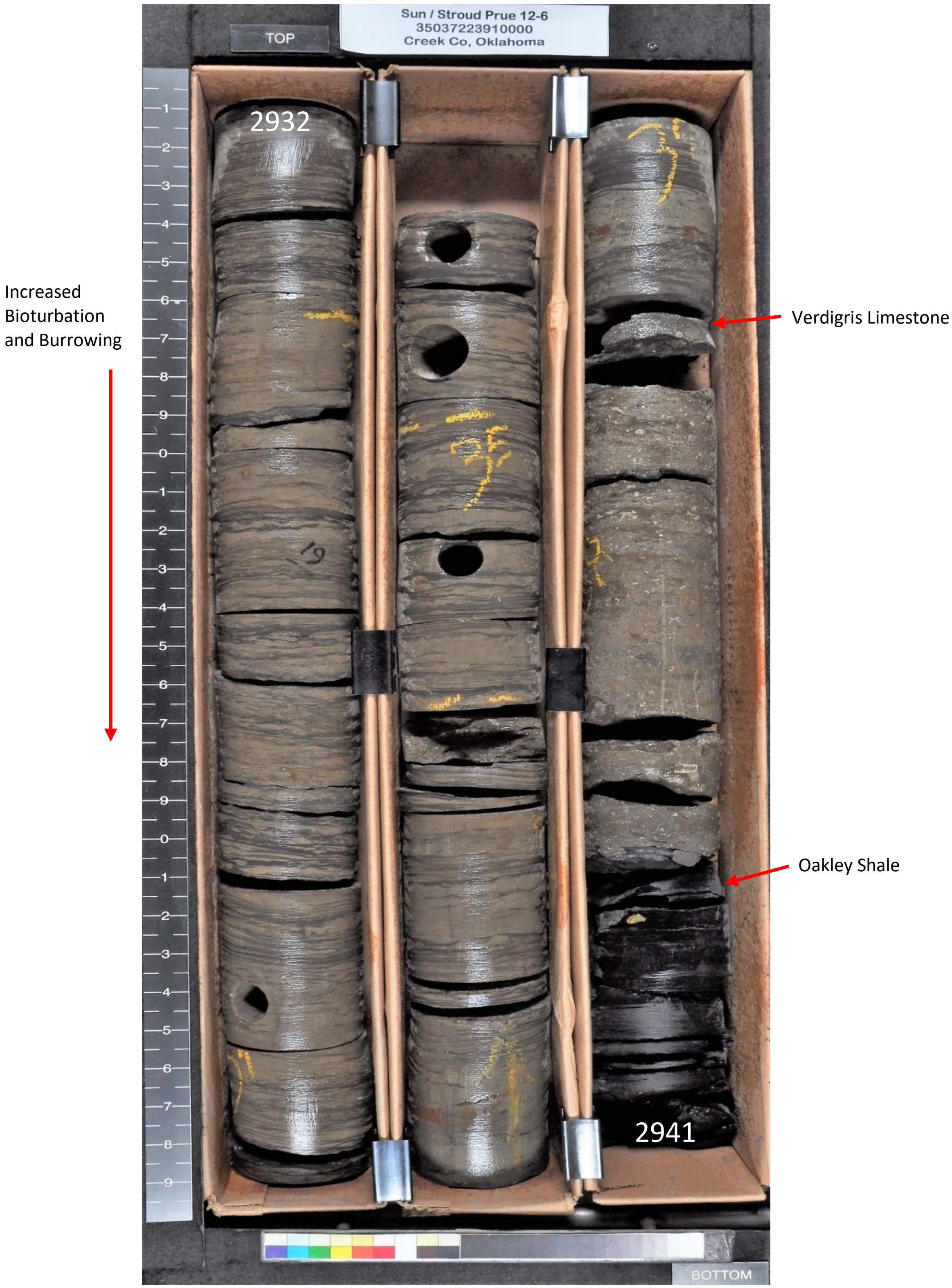


Figure 21. Core of Stroud Prue Unit Tr. #12-6 from depth from 2932 to 2941 feet. The sandstone is highly burrowed with abundant interbedded shale. The Verdigris Limestone occurs at 2938.7 feet and contains dispersed brachiopods, crinoid fragments, and other fossil fragments. The Oakley Shale contact is below the Verdigris Lime at a depth of 2940.1 feet. Scale bar indicates tenths of feet.

Getty Oil Company, Yarhola Royalty Unit Tr. 3 #25, Section 16, T.17N, R.7E, SE SW NE

The cored interval is from 2294-2321 feet and begins in the Prue interval above the Prue Sandstone. The sandstone is light brown to light gray, very fine grained, and has good sorting. The top of the core is interbedded shale and sandstone with sedimentary structures such as iron banding, microfractures, rip up clasts, burrows, and cross bedding. At 2300 feet, soft sediment deformation is seen. Rhythmic flaser and wavy bedding with interbedded shale and sandstone is seen as well until depth 2304 feet; and at 2304 feet, climbing ripples are seen in the sandstone. These sedimentary structures give evidence for tidal influence after deposition. At 2303, the sand was flooded, and soft sediment deformation is seen. There are several thick shale bands at depths 2302 and 2303 feet. At 2313 feet, there is a scour surface with several siderite nodules and rip up clasts. Limestone banding occurs at 2314 feet. At 2318 feet, there are siderite clasts and oxidized cemented sandstone. A very thin limestone band is present at 2320 feet, and then shale becomes the main lithology at 2320 feet. The shale is described as a dark black fissile shale. The sandstone in the latter half of the core (2304-2320 feet) is higher energy environment with apparent cross bedding and mud draping. Thins sections GY-25 2301.5, 2304.4, 2315.7, and 2317 were sampled from this core.

Figure 22. Close up of Yarhola Royalty #25 core showing the abundant cross bedding in the bottom half of the core at depth 2314 feet.

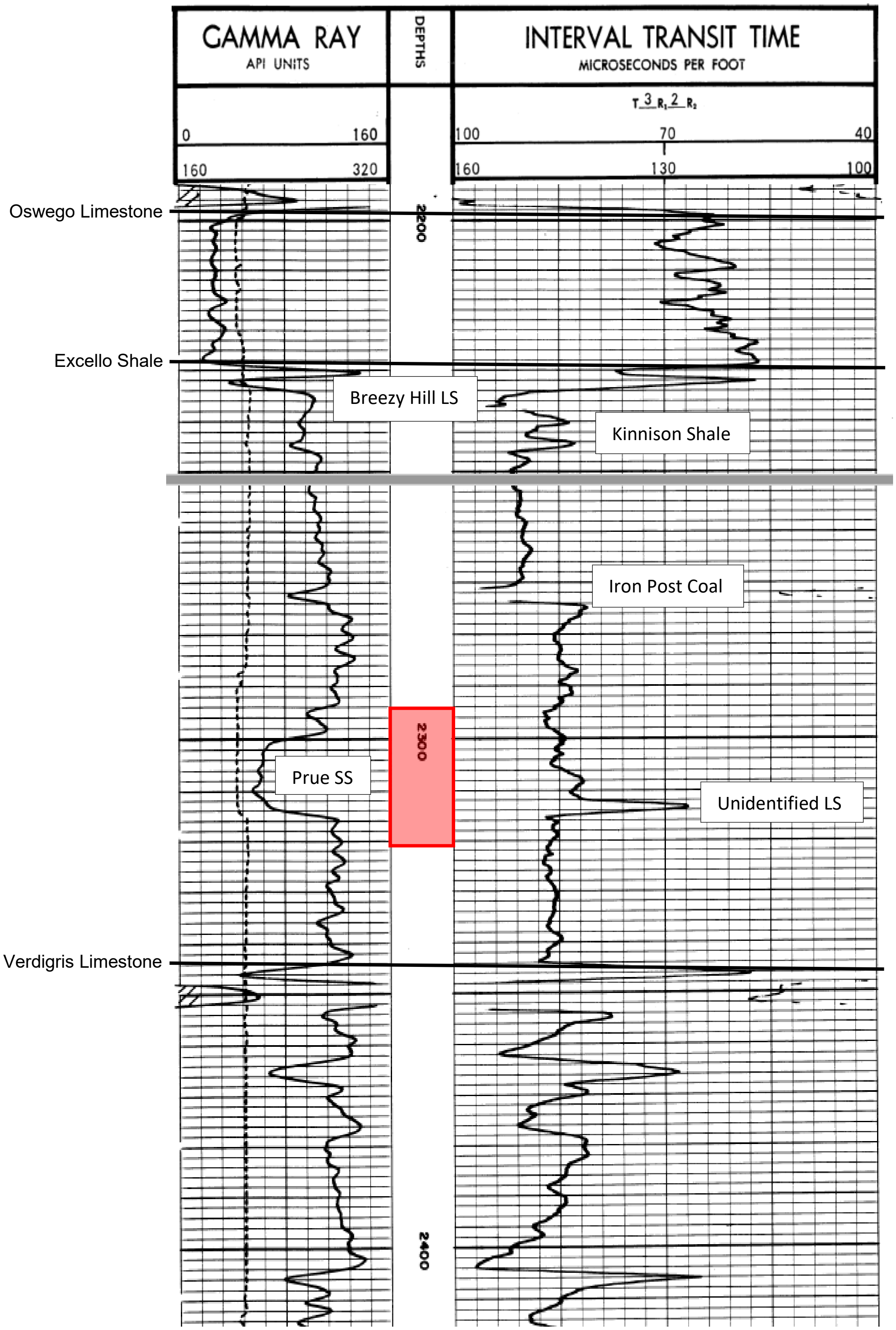


Figure 23. Gamma ray and interval transit time logs of the Yarhola Royalty #25 well. The cored interval is from 2294-2321 feet. The shaded box indicates the cored interval. The blocky-fining upward wire-line log signature has eroded though the unidentified limestone seen on the interval transit time log.

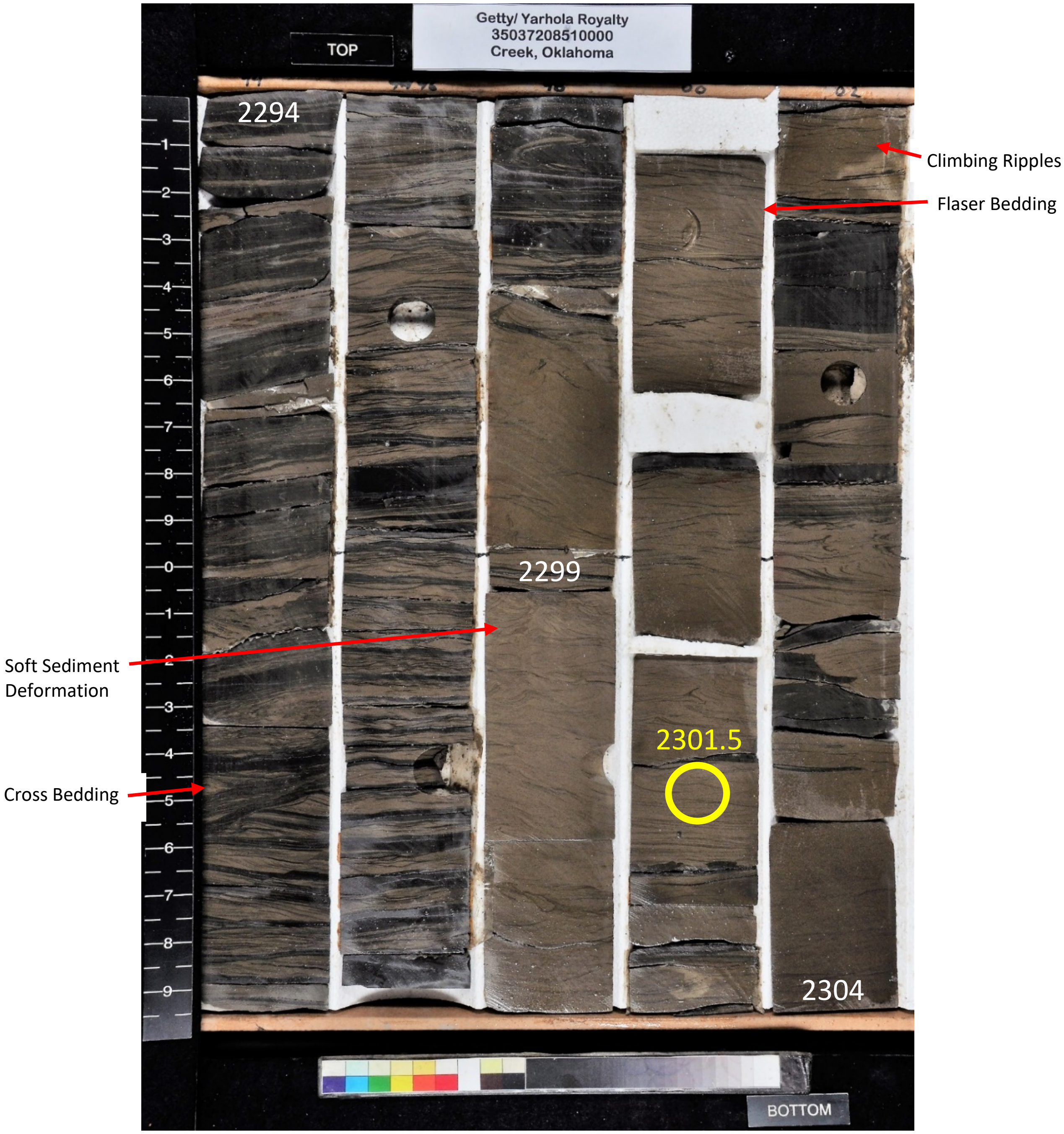


Figure 24. Slabbed core of Yarhola Royalty #25 from depth 2294 to 2304 feet. The top of the core is more rhythmically bedded with sandstone and interbedded shale. Soft sediment deformation, climbing ripples, and cross bedding are evident. Yellow circle indicates thin section GY 2301.5. Scale bar indicates tenths of feet.

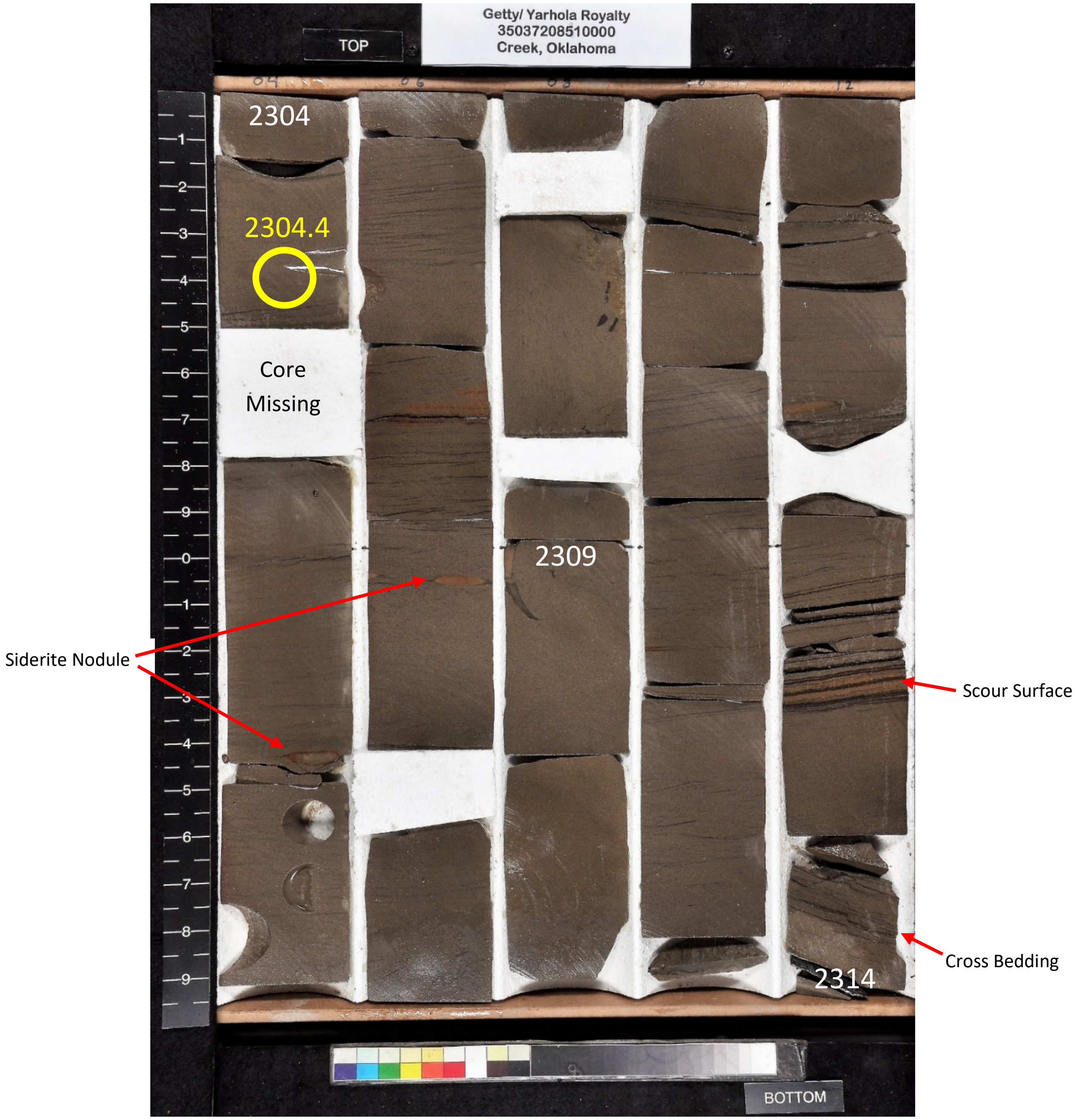


Figure 25. Slabbed core of Yarhola Royalty #25 from depth 2304 to 2314 feet. Several siderite nodules are seen. At 2313 feet are a scour surface and rip up clasts. A thin bed of carbonaceous sediment is seen at depth 2313.3 feet. Yellow circle indicates thin section GY 2304.4. Scale bar indicates tenths of feet.

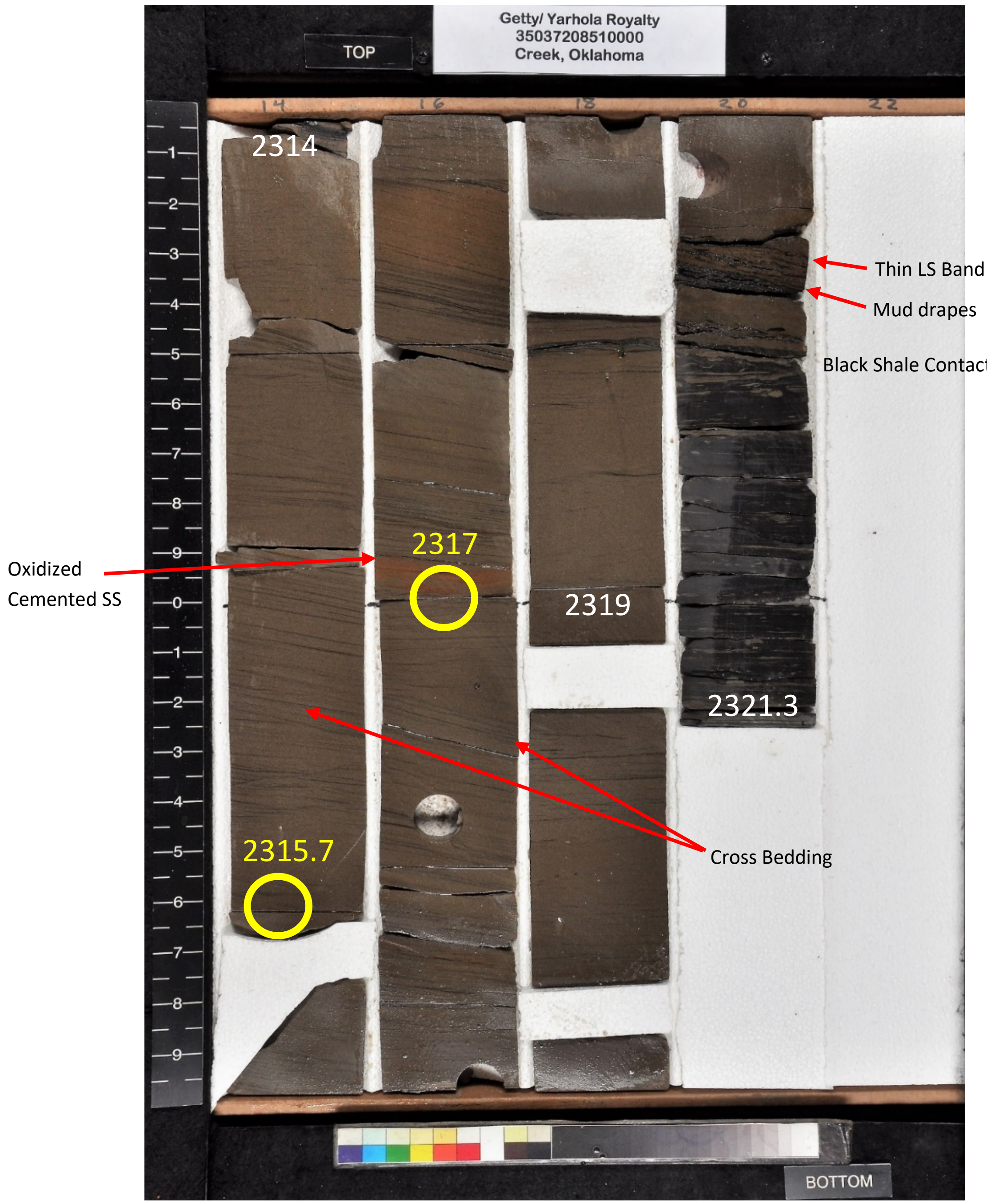


Figure 26. Slabbed core of Yarhola Royalty #25 from depth 2314 to 2321.3 feet. At 2318 feet, there are siderite clasts and oxidized cemented sandstone. A thin limestone band is seen at 2320 feet. A dark gray shale becomes the main lithology at 2320.6 feet. The sandstone at the end of the core interval have cross bedding and mud draping. Yellow circle indicates thin sections GY 2315.7 and GY 2317. Scale bar indicates tenths of feet.

Gulf Oil Corp., Watson #1, Section 35, T16N, R7E, NW NW SW

The cored interval is from 2667-2693 feet. The core begins at the top of the Prue Sandstone. The sandstone is light brown to gray, very fine to fine grained (0.065-0.2 mm), and has good sorting. At the top of the core is a 2-inch-thick black shale followed by another two inches of a yellow to green oxidized claystone. Immediately after the claystone, the Prue Sandstone occurs and is interbedded with black shale throughout. The sandstone is characterized by rhythmic wavy bedding and lenticular bedding. Burrows are consistent throughout the core in areas with lower energy. At 2675 and 2676 feet, soft sediment deformation and rip up clasts occur. Small scale flaser bedding occurs around depth 2680 feet. Interbedded shale occurs throughout most of the core with mostly shale lithology occurring near the bottom of the core and coarsening up with more sandstone at the top of the core. No thin sections were sampled from this core.

Figure 27. Close up of Watson #1 core showing the lenticular bedding at the top of the core at depth 2668.2 feet.

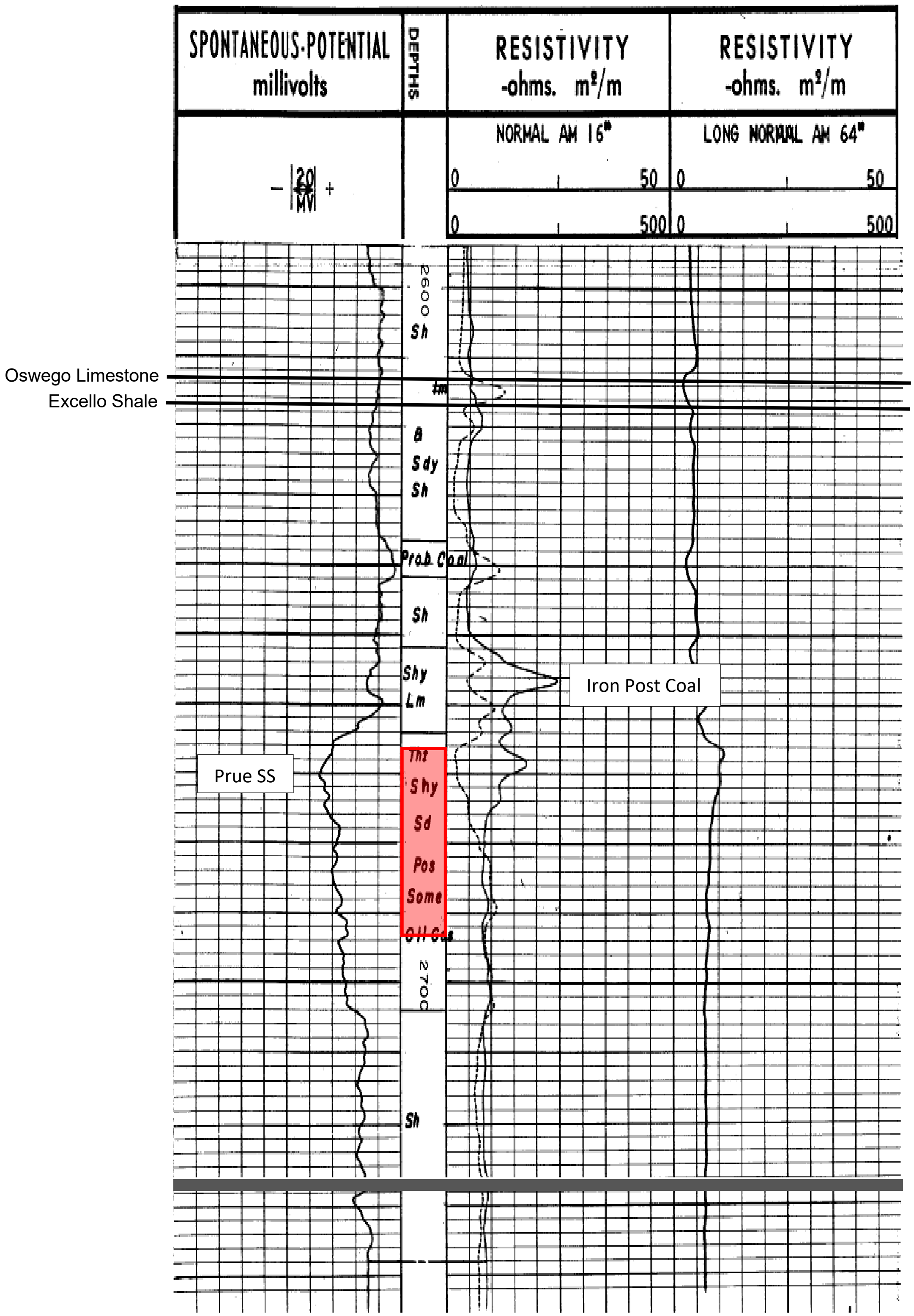


Figure 28. Spontaneous potential and resistivity logs of the Watson #1 well. The cored interval is from 2667-2693 feet. The shaded box indicates the cored interval. The Spontaneous Potential (SP) curve is to the left of the depth track, and resistivity curves are to the right. The wireline log did not log the Verdigris Limestone.

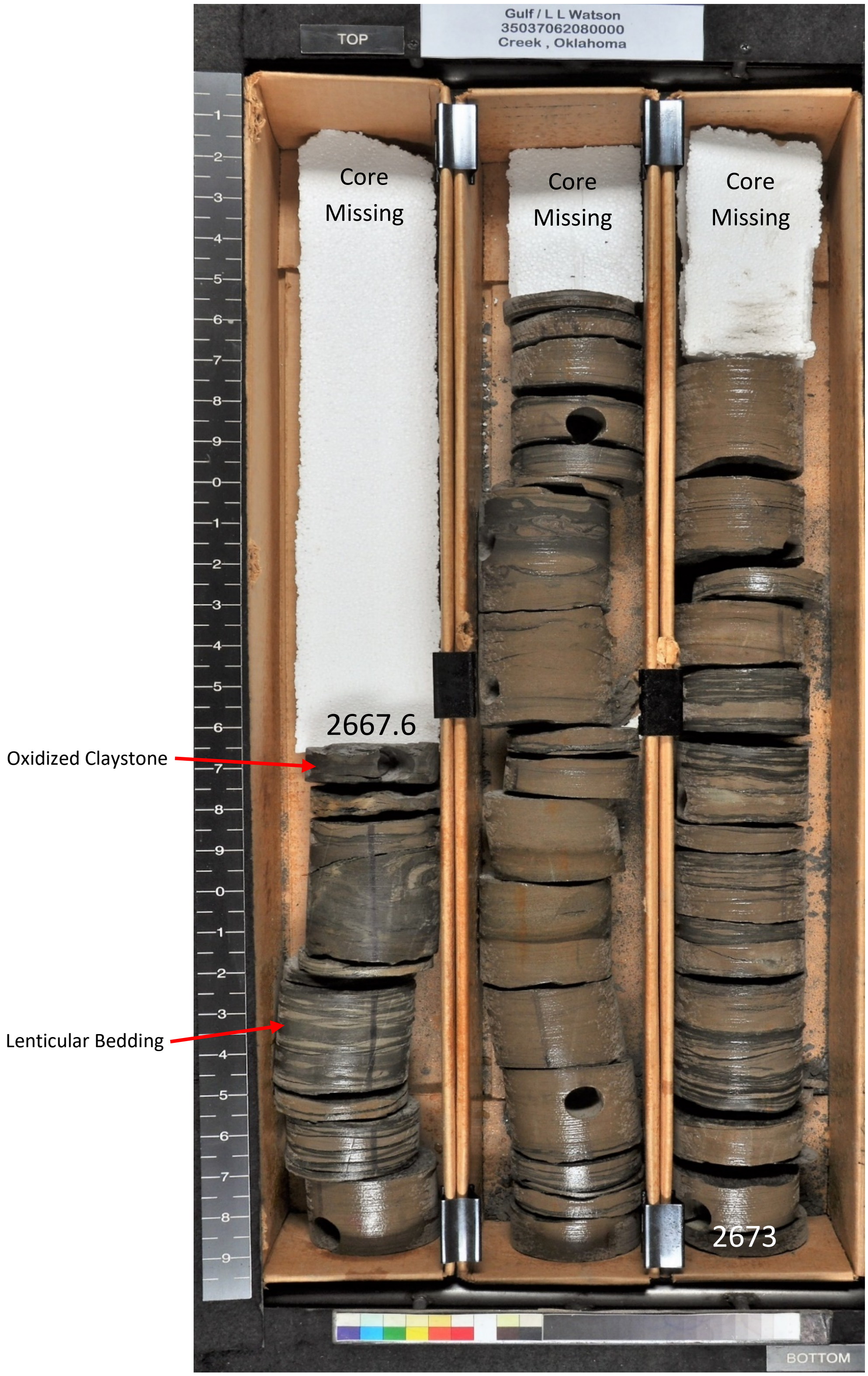


Figure 29. Core of Watson #1 from depth 2667.6 to 2673 feet. The top of the core has two inches of a yellow to green oxidized claystone. The Prue Sandstone below the clay has a coarsening upward profile. The sandstone is characterized by rhythmic wavy and lenticular bedding. Scale bar indicates tenths of feet.

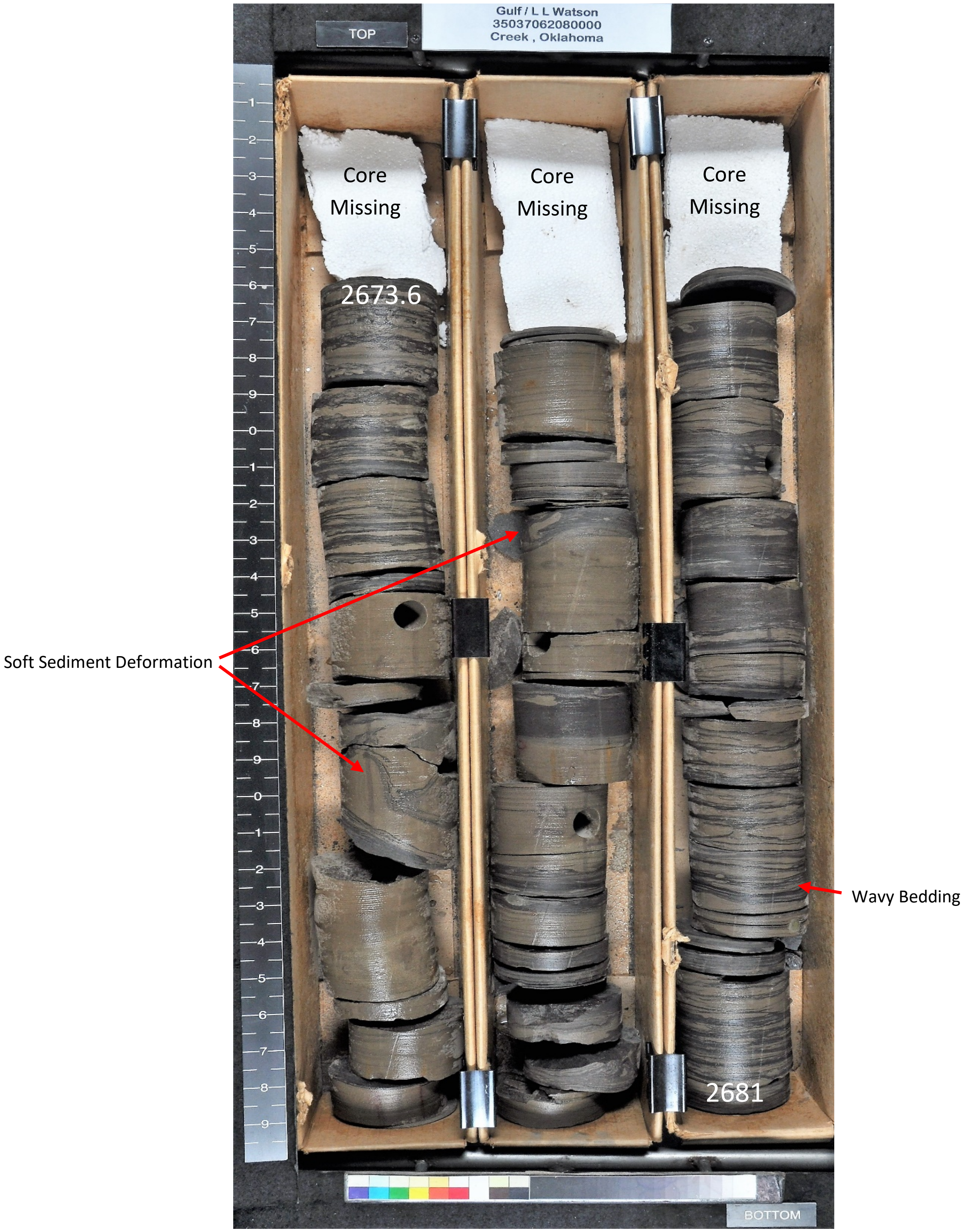


Figure 30. Core of Watson #1 from depth 2673.6 to 2681 feet. The core has soft sediment deformation at 2675 and 2676.3 feet. The sandstone has rhythmic wavy and flaser bedding occurring at 2680.2 feet. Scale bar indicates tenths of feet.

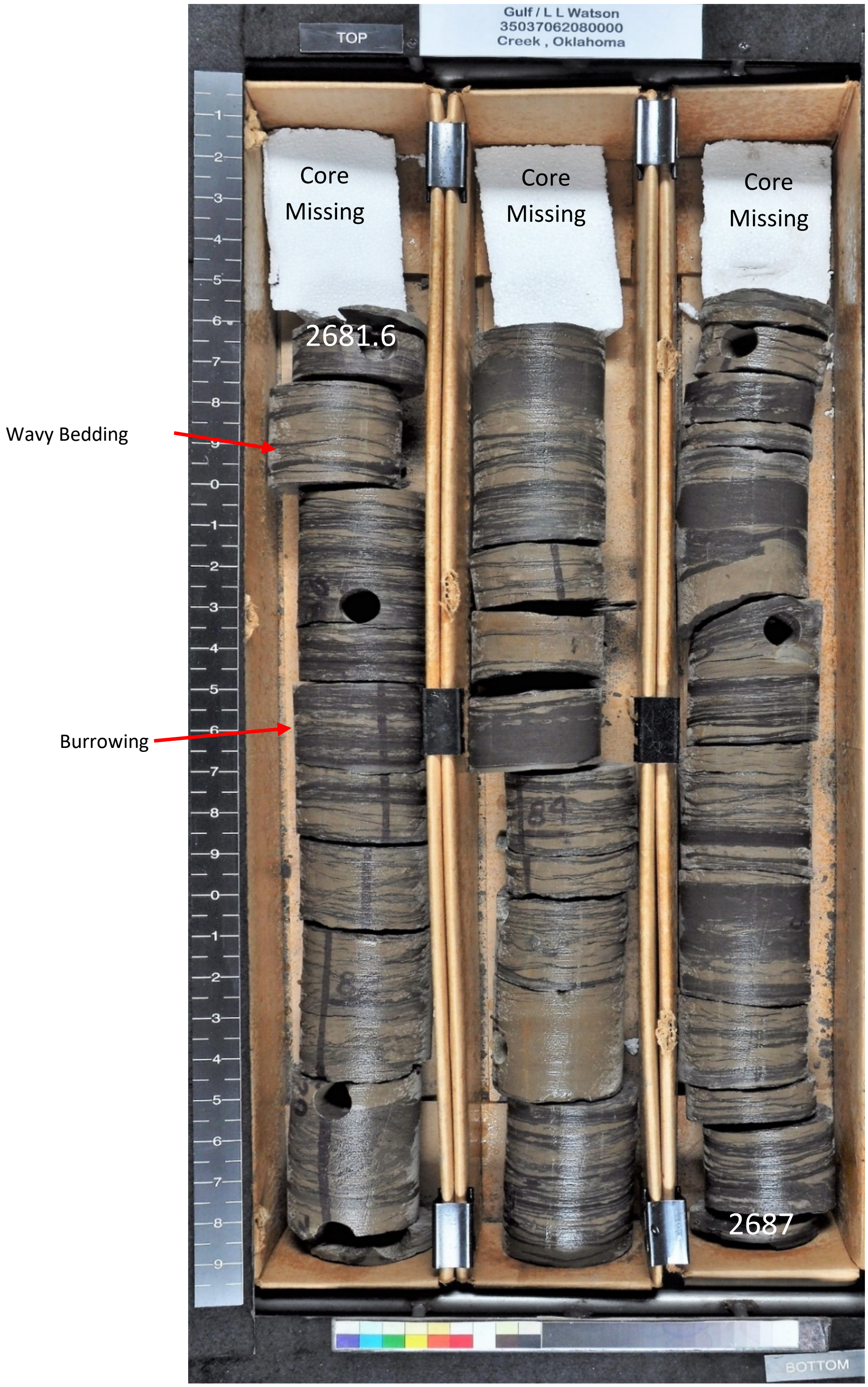


Figure 31. Core of Watson #1 from depth 2681.6 to 2687 feet. The core has abundant interbedded shale in the latter half of the core. The sandstone has rhythmic wavy and lenticular bedding. Burrows are abundant at the bottom of the core. Scale bar indicates tenths of feet.

Figure 32. Core of Watson #1 from depth 2687.7 to 2693 feet. The core has abundant interbedded shale at the bottom of the core. The sandstone has rhythmic wavy and lenticular bedding with small-scale burrowing in the bottom of the core. Shale is the predominant lithology at 2692.1 feet. Scale bar indicates tenths of feet.

Thin Section Analysis

Six thin sections were prepared from two cores for petrographic microscope analysis. Four thin sections were taken from well Yarhola Royalty Unit Tr. 3 #25, and two thin sections were taken from Sam Sawyer #20. These thin sections were used to determine mineralogical composition, detrital and authigenic constituents, and porosity using a standard point-count technique. To classify the sandstone, mineral components were then plotted on a Folk Ternary Diagram (Figure 33), with end-members of quartz, feldspar, and rock fragments.

Monocrystalline quartz is the most abundant constituent, comprising of 43.9% of the detrital constituents. The quartz grains were generally subangular to angular. Original quartz grains may have been preserved by micrite dust rims. Polycrystalline quartz was also observed as sutured composite grains; however, these were far less abundant than monocrystalline quartz at 5.5% overall. Feldspar is present, comprising of 4.9% of the total constituents. The most abundant feldspar was plagioclase, with microcline and orthoclase rarely seen. The feldspars were often observed as partially dissolved of grains, showing a honeycomb like texture or almost altered completely. Rock fragments were the second most abundant constituent comprising of 27.8% of the total. The most common were schistose metamorphic rock fragments that were commonly observed as ductilly-deformed pseudomatrix. Metamorphic rock fragments with distinct grain boundaries were observed. Muscovite was minor and considered a metamorphic rock fragment. Chert grains and other sedimentary rock fragments were observed but were much less common. Siderite was seen in abundance in one slide (GY-25 2301.5) comprising 10% of the slide; however, siderite was only observed in one other thin section (GS 2392.5). Glauconite is a minor constituent that was observed as a full glauconite grain and in the form of pseudomatrix between quartz grains.

Folk Classification

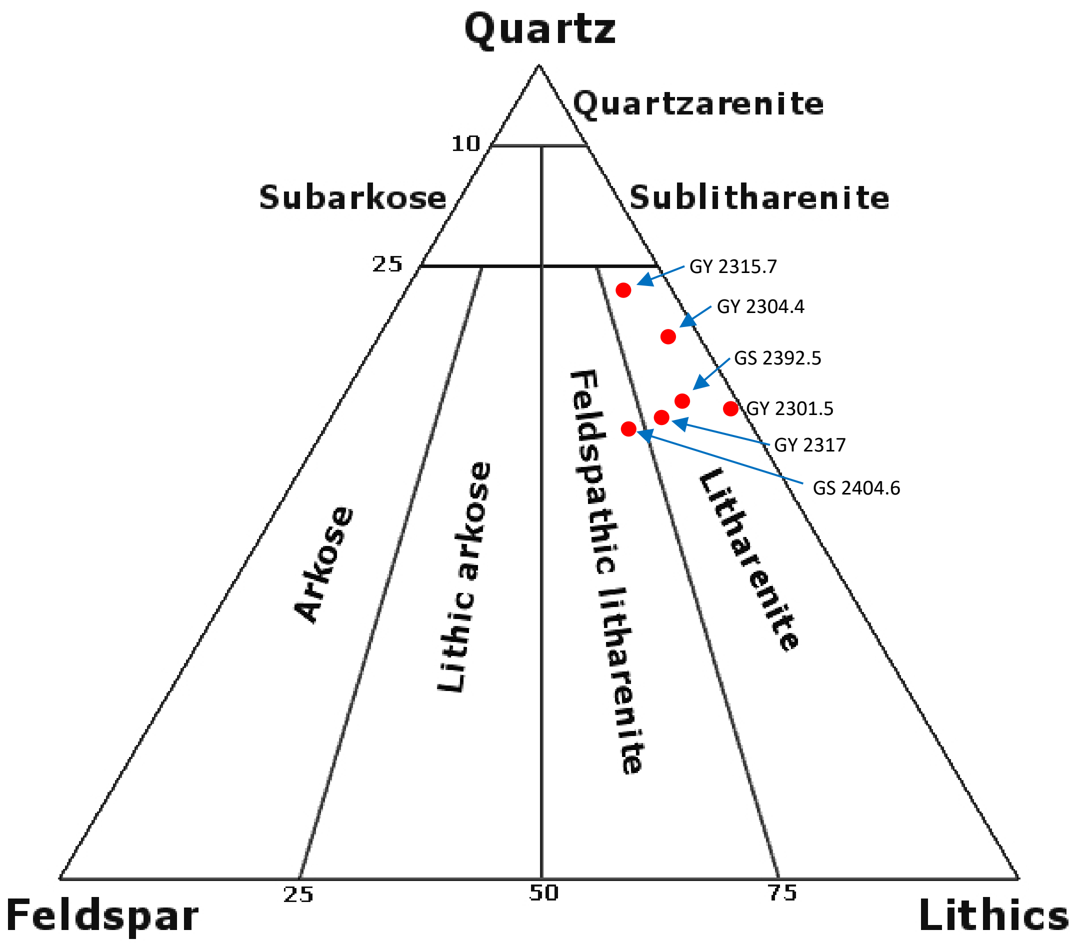


Figure 33. Folk classification ternary diagram showing the detrital composition of the Prue Sandstone in the study area. Five of the six thin sections plotted as a litharenite and one feldspathic litharenite. This is due to the high abundance of quartz grains and metamorphic rock fragments. Samples GY 2301.5, 2304.4, 2315.7, 2317 are from Yarhola Royalty #25 and samples GS 2392.5, 2404.6 are from Sam Sawyer #20. All thin sections are from T.17N R.7E.

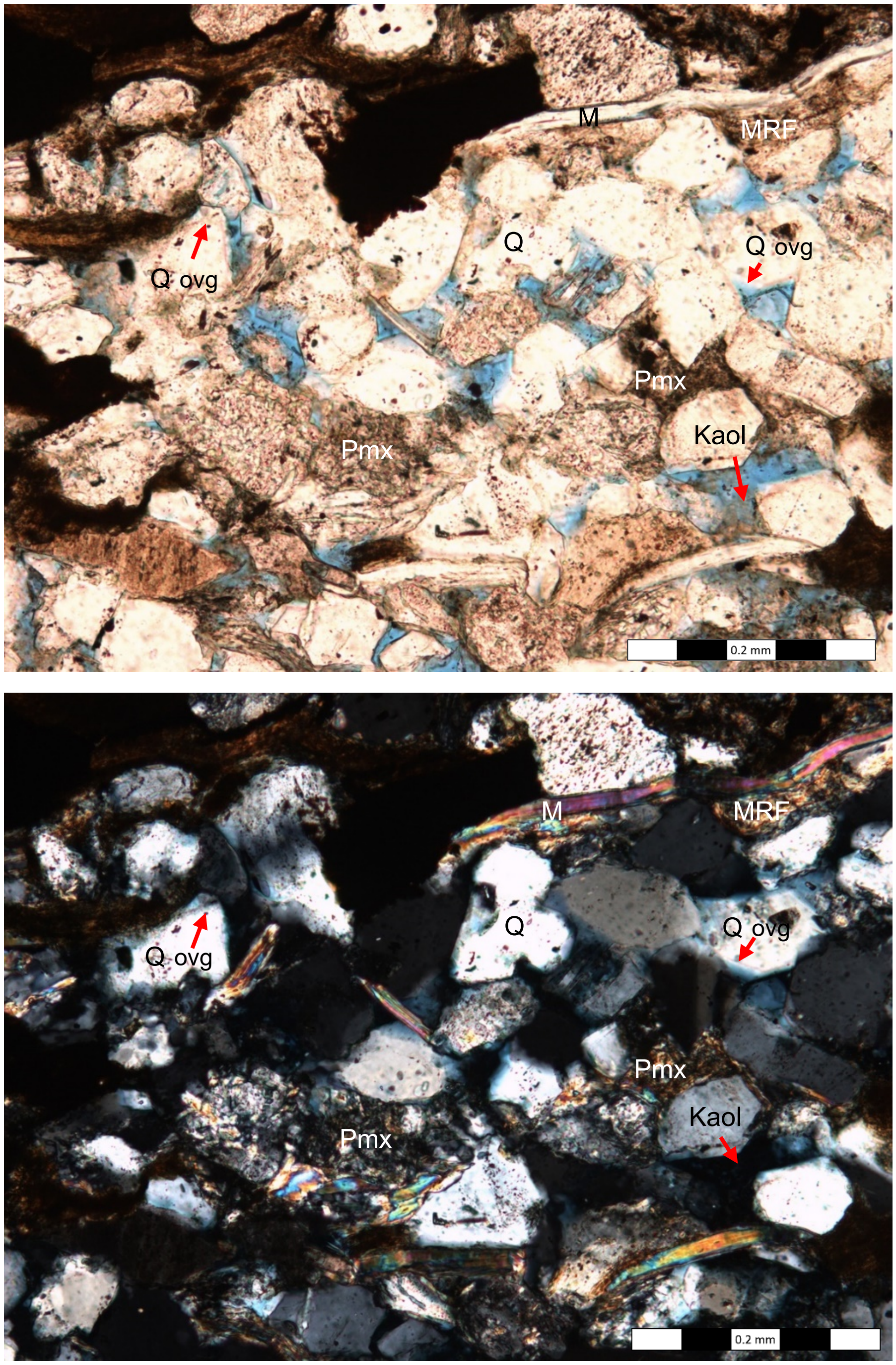


Figure 34. Thin-section petrography of Prue Sandstone from Sam Sawyer #20 (GS), depth 2392.5 feet. Framework grains include quartz (Q), plagioclase feldspar (Plag), metamorphic rock fragments (MRF), and muscovite bands (M). Authigenic constituents include kaolinite (Kaol), and quartz overgrowths (Q ovg). Clay clasts form pseudomatrix (Pmx). Top: 10x PPL. Bottom: 10x CPL. See Appendix F for point counts and ternary diagram.

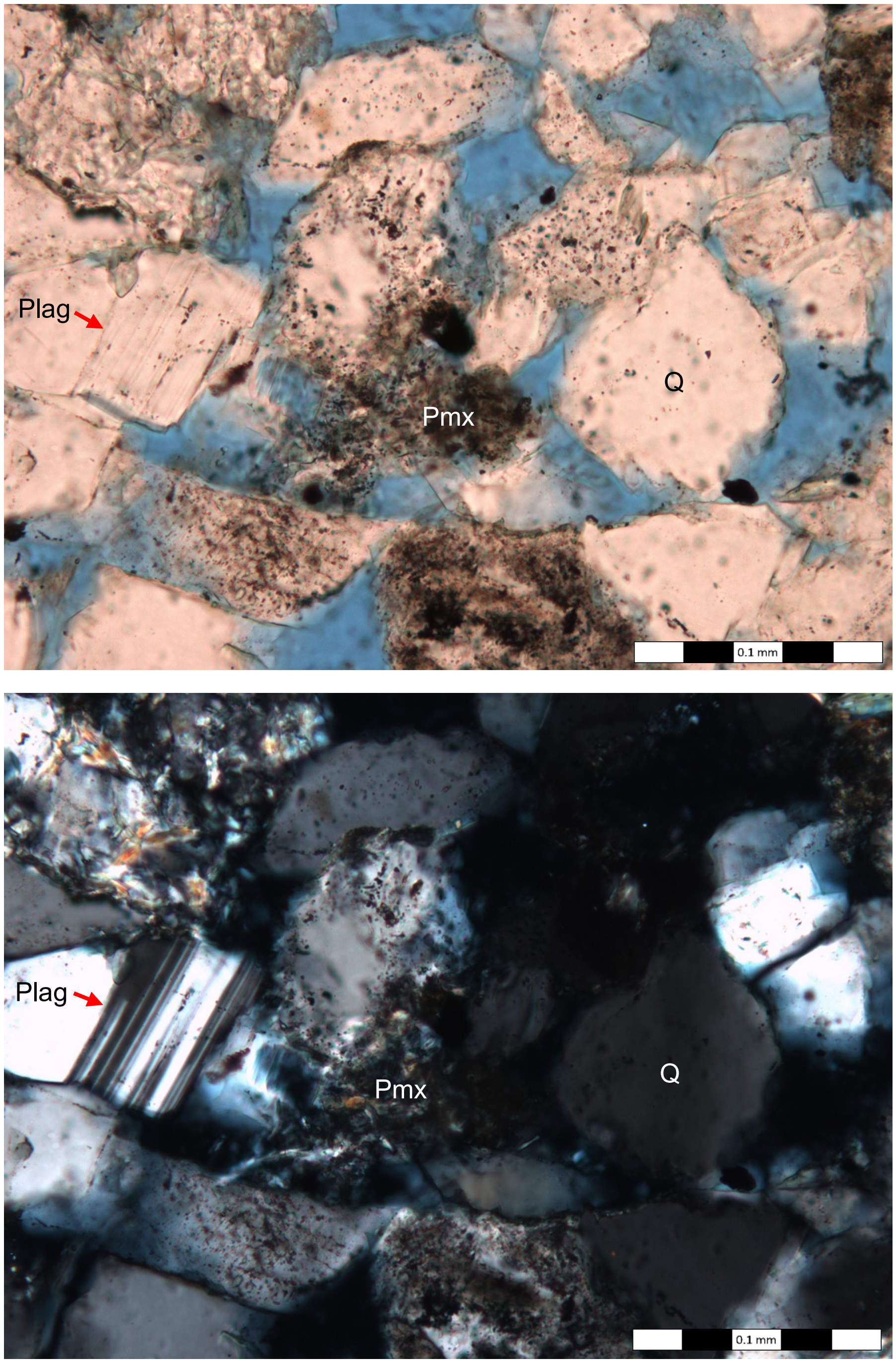


Figure 35. Thin-section petrography of Prue Sandstone from Sam Sawyer #20 (GS), depth 2404.6 feet. Framework grains include quartz (Q) and plagioclase feldspar (Plag). Clay clasts form pseudomatrix (Pmx). Thin section also shows a higher abundance of secondary porosity. Top: 10x PPL. Bottom: 10x CPL. See Appendix F for point counts and ternary diagram.

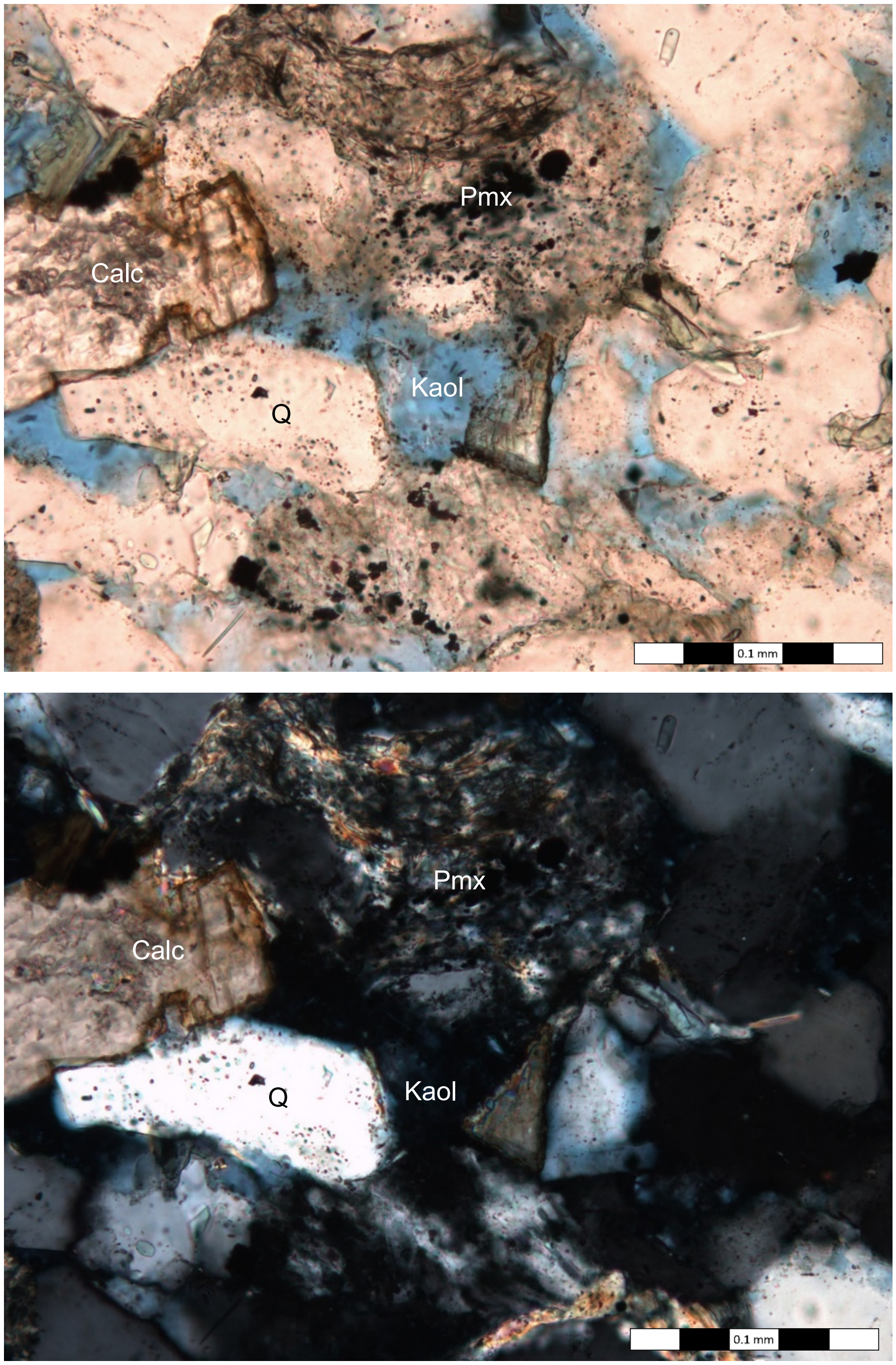


Figure 36. Thin-section petrography of Prue Sandstone from Sam Sawyer #20 (GS), depth 2404.6 feet. The dominant framework grain is quartz (Q). Illitic clay clasts form Pseudomatrix (Pmx). Authigenic clay is kaolinite (Kaol). Calcite (Calc) is seen as cement. Top: 10x PPL. Bottom: 10x CPL. See Appendix F for point counts and ternary diagram.

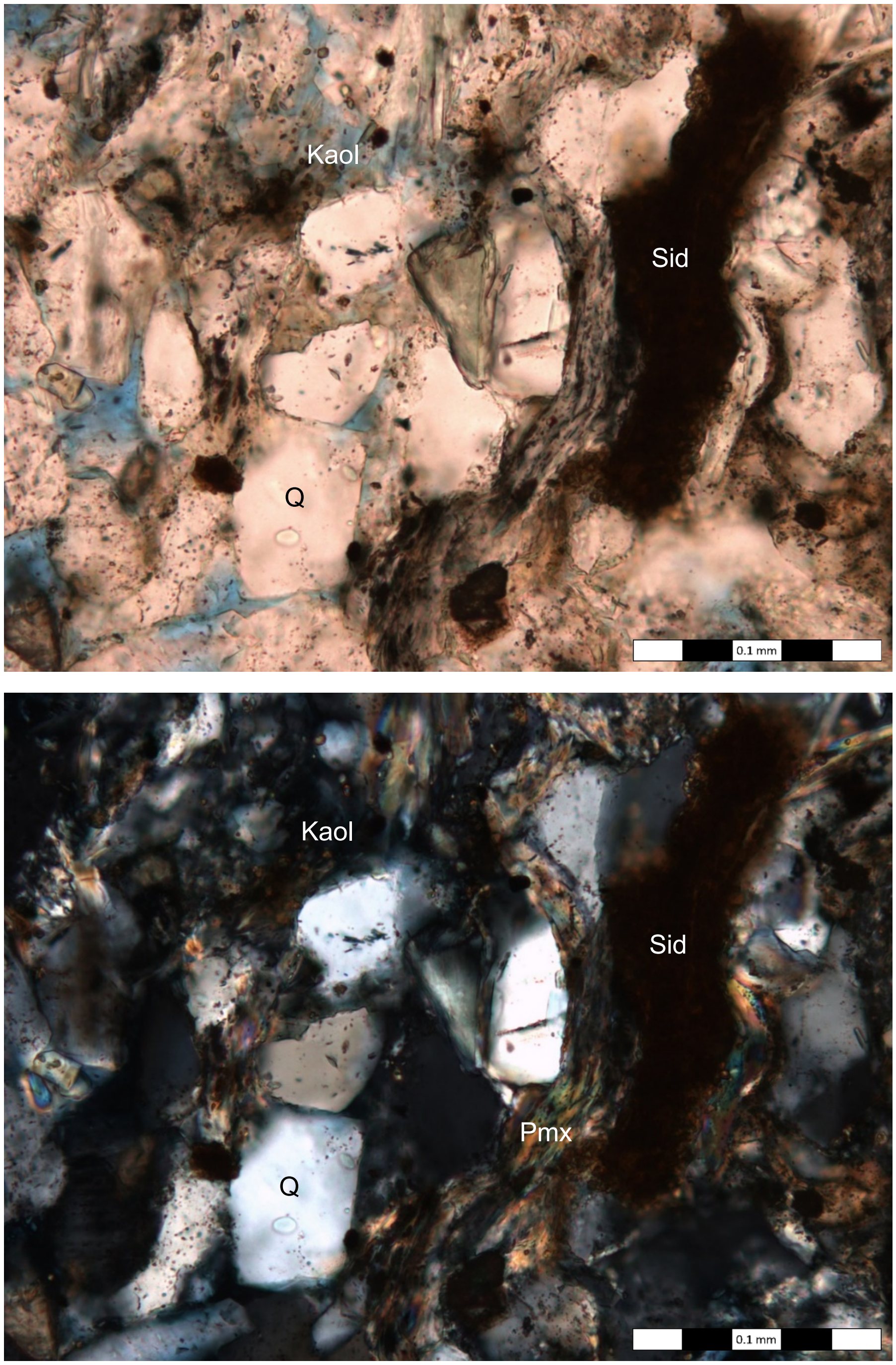
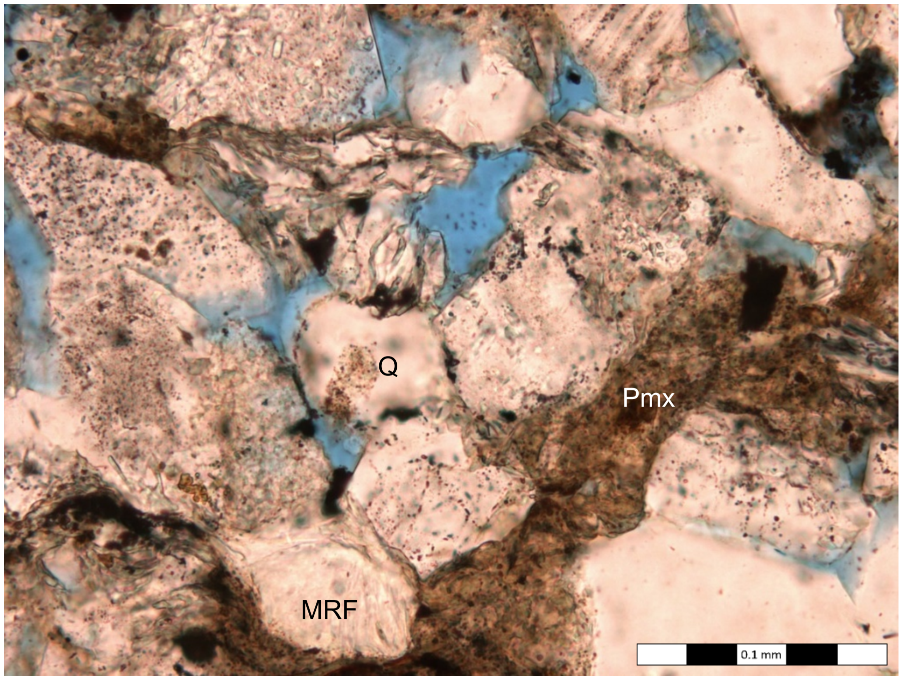


Figure 37. Thin-section petrography of Prue Sandstone from Yarhola Royalty #25 (GY), depth 2301.5 feet. The dominant framework grain is quartz (Q). Authigenic constituents include kaolinite (Kaol), and siderite (Sid). Clay clasts form pseudomatrix (Pmx). Top: 10x PPL. Bottom: 10x CPL. See Appendix F for point counts and ternary diagram.



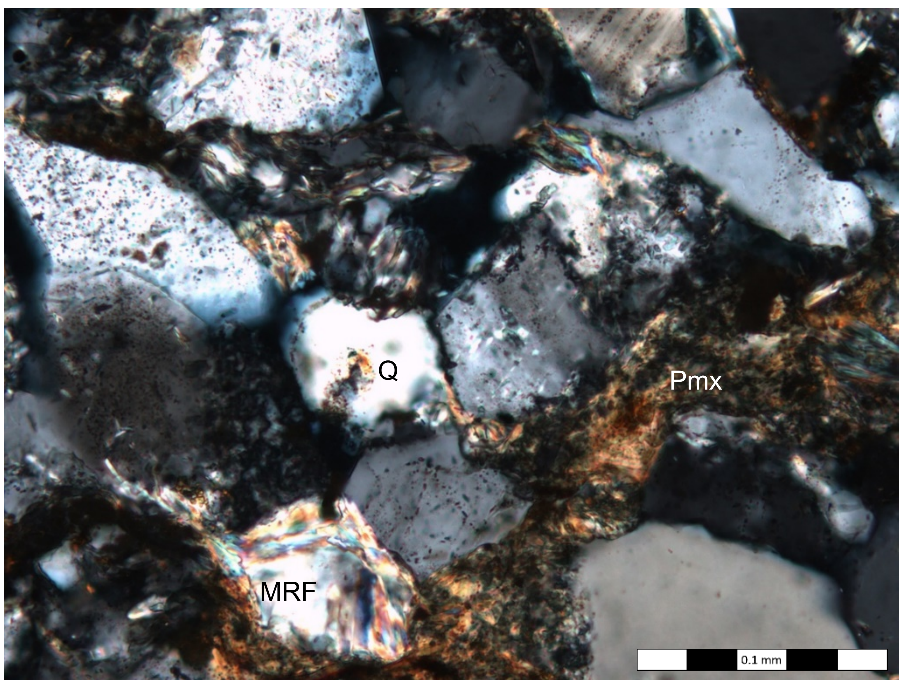


Figure 38. Thin-section petrography of Prue Sandstone from Yarhola Royalty #25 (GY), depth 2304.4 feet. The dominant framework grains include quartz (Q) and metamorphic rock fragments (MRF). The deformed sedimentary rock fragments form pseudomatrix (Pmx). Top: 10x PPL. Bottom: 10x CPL. See Appendix F for point counts and ternary diagram.

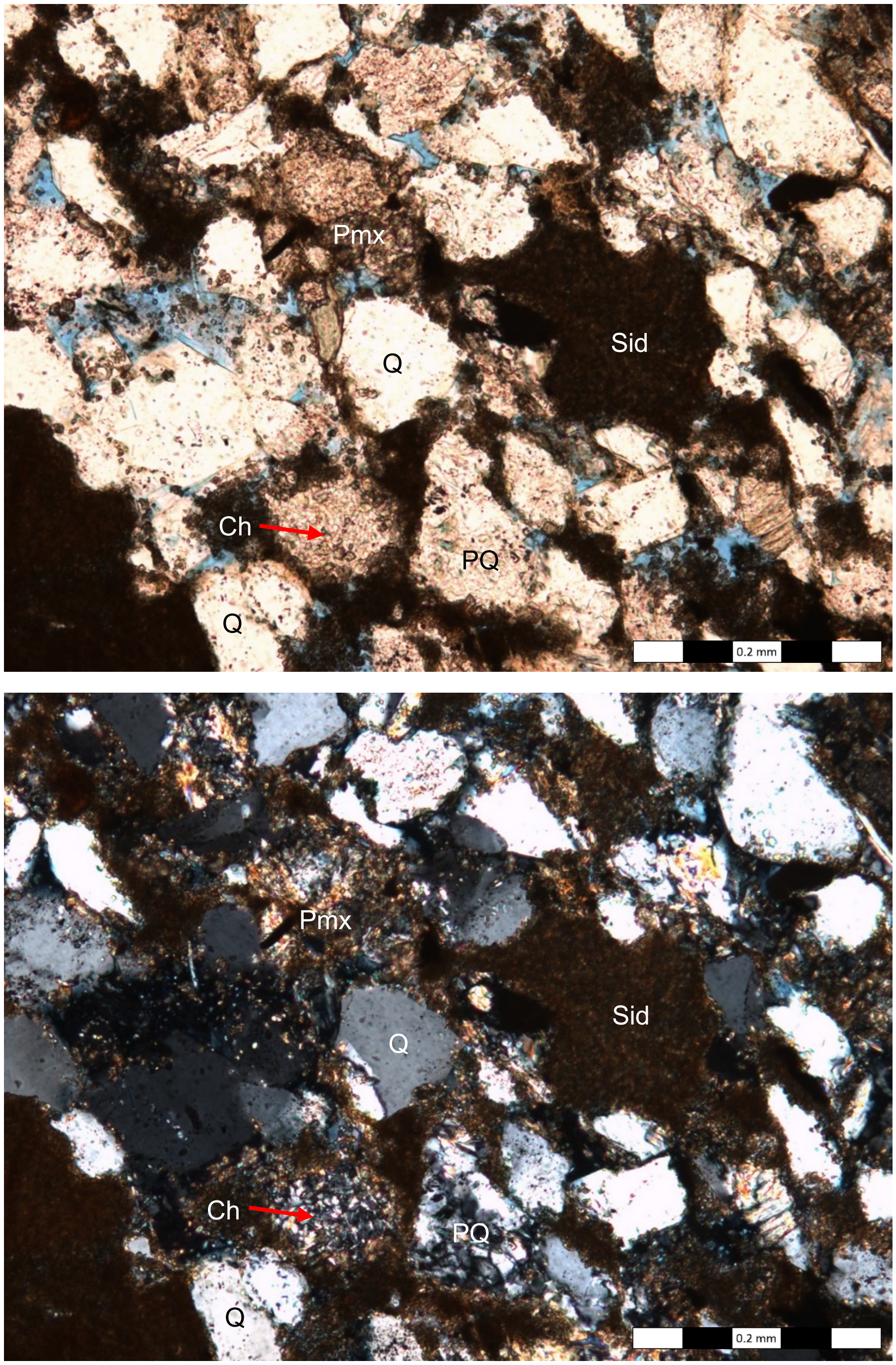


Figure 39. Thin-section petrography of Prue Sandstone from Yarhola Royalty #25 (GY), depth 2315.7 feet. Framework grains include quartz (Q), polycrystalline quartz, and chert (Ch). Other constituents include illitic clay pseudomatrix (Pmx), and siderite (Sid). Top: 10x PPL. Bottom: 10x CPL. See Appendix F for point counts and ternary diagram.

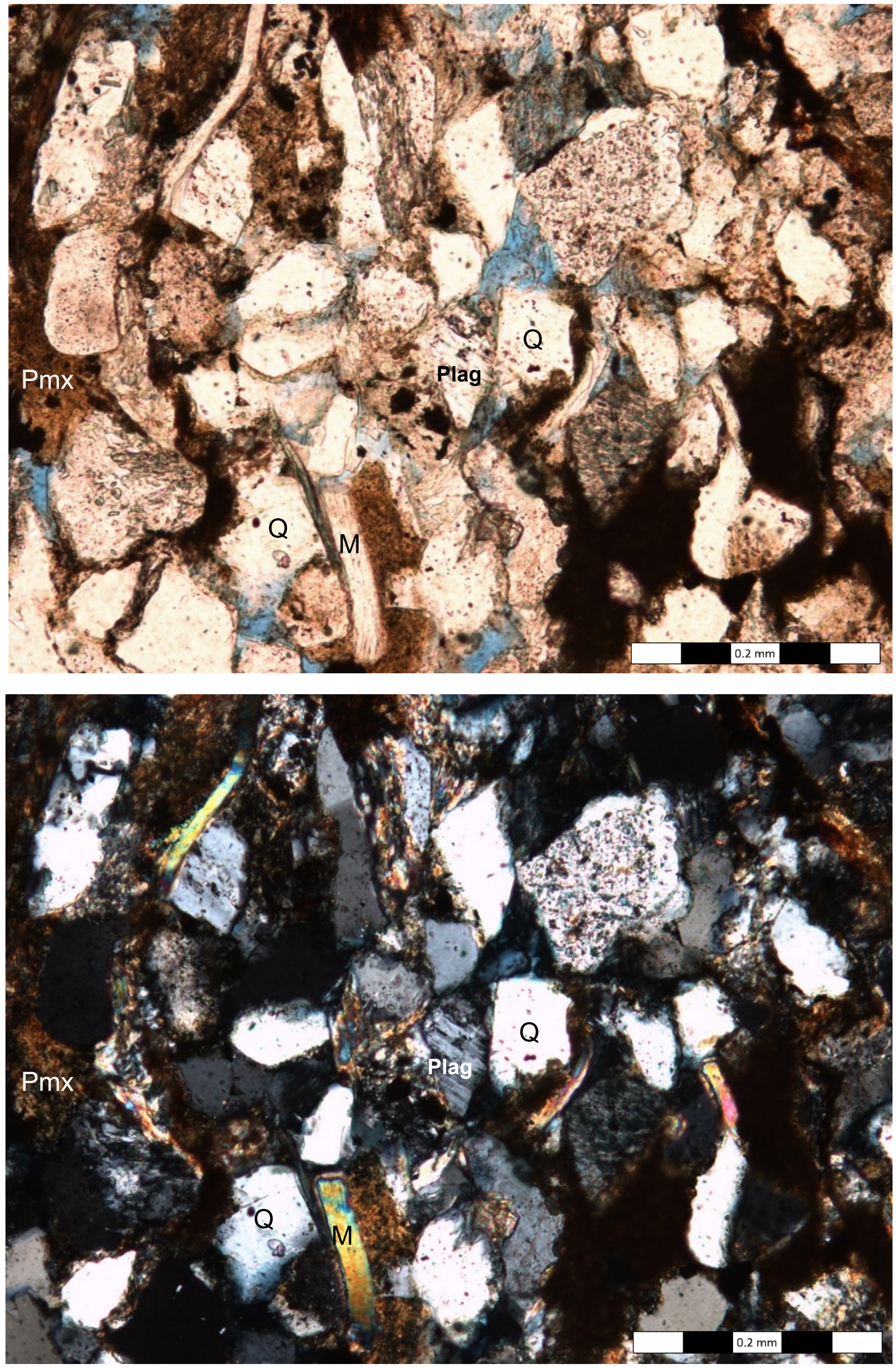
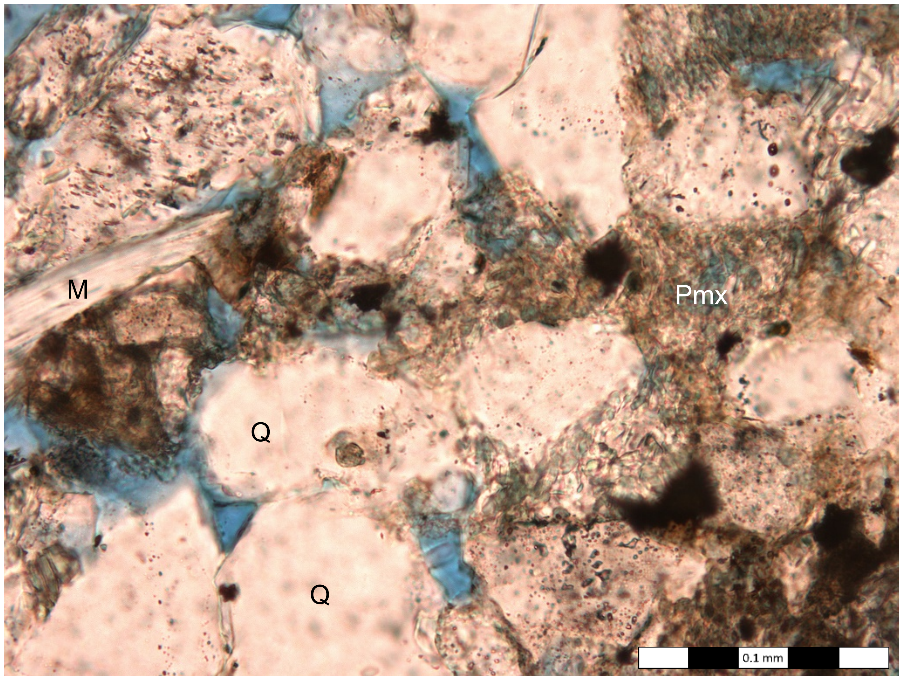


Figure 40. Thin-section petrography of Prue Sandstone from Yarhola Royalty #25 (GY), depth 2315.7 feet. The dominant framework grains include quartz (Q), plagioclase feldspar (Plag), and muscovite (M). Clay clasts form pseudomatrix (Pmx). Top: 10x PPL. Bottom: 10x CPL. See Appendix F for point counts and ternary diagram.



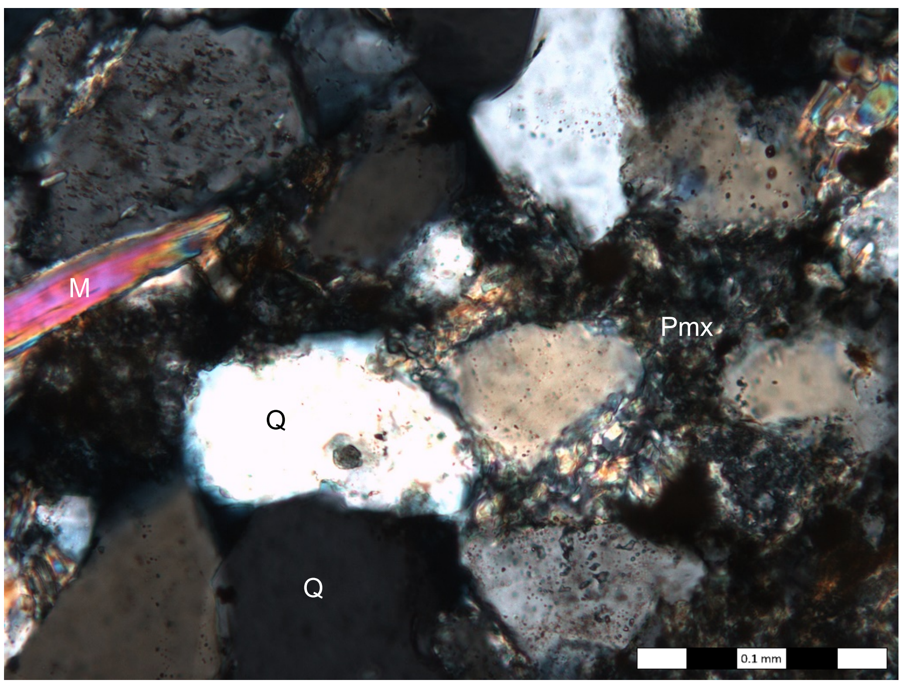


Figure 41. Thin-section petrography of Prue Sandstone from Yarhola Royalty #25 (GY), depth 2317 feet. The dominant framework grains include quartz (Q) and muscovite (M). The main authigenic constituent is silica cement as quartz overgrowths surrounding triangular-shaped pores. Clay clasts form pseudomatrix (Pmx). Top: 10x PPL. Bottom: 10x CPL. See Appendix F for point counts and ternary diagram.

Diagenetic constituents include authigenic clays and cements that were precipitated from water that flowed through the sandstone during the course of diagenesis. Diagenetic constituents that were observed in thin section include quartz overgrowths, kaolinite, illite, chlorite, calcite, micrite, and siderite. Chlorite is present due to the alteration of muscovite and can be seen as part of pseudomatrix. Kaolinite is observed filling pore space in several slides (GS 2392.5, GS 2404.6, GY-25 2301.5). Illite was abundant in the ductilly-deformed clay clasts that form pseudomatrix. Calcite was observed in three of the thin sections (GS 2392.5, GS 2404.6, GY-25 2317). Calcite was not common between quartz grains, and was a cement replacing quartz and feldspar grains.

Secondary porosity was the dominant porosity observed mainly resulting from the dissolution of feldspar and metamorphic rock fragments and made up 7.6% of the thin sections, with porosity ranging from 4.2% to 15.8% overall. Several different types of secondary porosity were observed in the thin sections including partial dissolution, moldic, elongate pores, oversized pores, honeycomb, and intergranular.

Structure Maps

Structural contour maps were prepared in order to interpret the structural attitude of the Prue interval. Structure maps on the tops of the Oswego Limestone, Excello Shale, and Verdigris Limestone show the monoclinal dip to the southwest with faults associated with the Nemaha Uplift to the west of the study area.

The Oswego Limestone structure map indicates that the strike of the beds is slightly northeast-southwest, and the dip is about 50-100 feet or about 70 feet per mile (1.3°) with some increase in dip where faults are present. To the west of the study area in townships 16-18 North and Range 7 East, are steeper bed dips with structural highs that indicate an anticlinal feature that trends north-south. A reverse fault that trends north-south along the east side of the structural high create uplift in the townships.

The Verdigris Limestone and Excello Shale structural maps mimic the Oswego Limestone structural map, with the structural features being similar in all the structure maps. The strike of the Verdigris Limestone and Excello Shale structure maps is slightly northeast-southwest, same as the Oswego Limestone structure, and the dip is about 50-90 feet or about 60 feet per mile (1.1°) with some increase in dip where faults are present. As with the top of the Oswego structure, in townships 16-18 North and Range 7 East, there are steeper bed dips that indicate an anticlinal feature that trends north-south. The same reverse fault that trends north-south east along the east of the structural high, creates the uplift for the top of the Verdigris and Excello structure. There are some minor structural saddles or synclinal features in townships 16 North, 8 East and 17 North, 9 East. The structural contour maps on the Verdigris Limestone, Excello Shale, and Oswego Limestone indicate several common elements which include similar strike of north-south, similar dip angles (1.1°-1.3°), and the same structural features including all tops are influenced by the same fault. This evidence supports the hypothesis that the structural attitude of these formations was the result of tectonic forces. The tectonic forces would have affected all strata between the Oswego Limestone and the Verdigris Limestone, including the Prue interval. Therefore, the structural attitude of the Prue interval is the result of tectonic forces after the deposition of the Oswego Limestone.

Isopach Maps

An isopach map of the interval between the top the Mississippian age carbonates and the top of the Verdigris Limestone shows the paleotopography of the Pre-Desmoinesian unconformity. Pennsylvanian strata lie unconformably over Mississippian carbonates in the study area. Topographic highs occur where the interval thins, and the thicker intervals are in areas where extensive erosion of Mississippian rocks occurred. The Mississippian to Verdigris Limestone interval increases approximately 700 feet from the northwest to the southeast portion of the study area map. The thick sediment trends suggest that Prue Sandstone deposition was

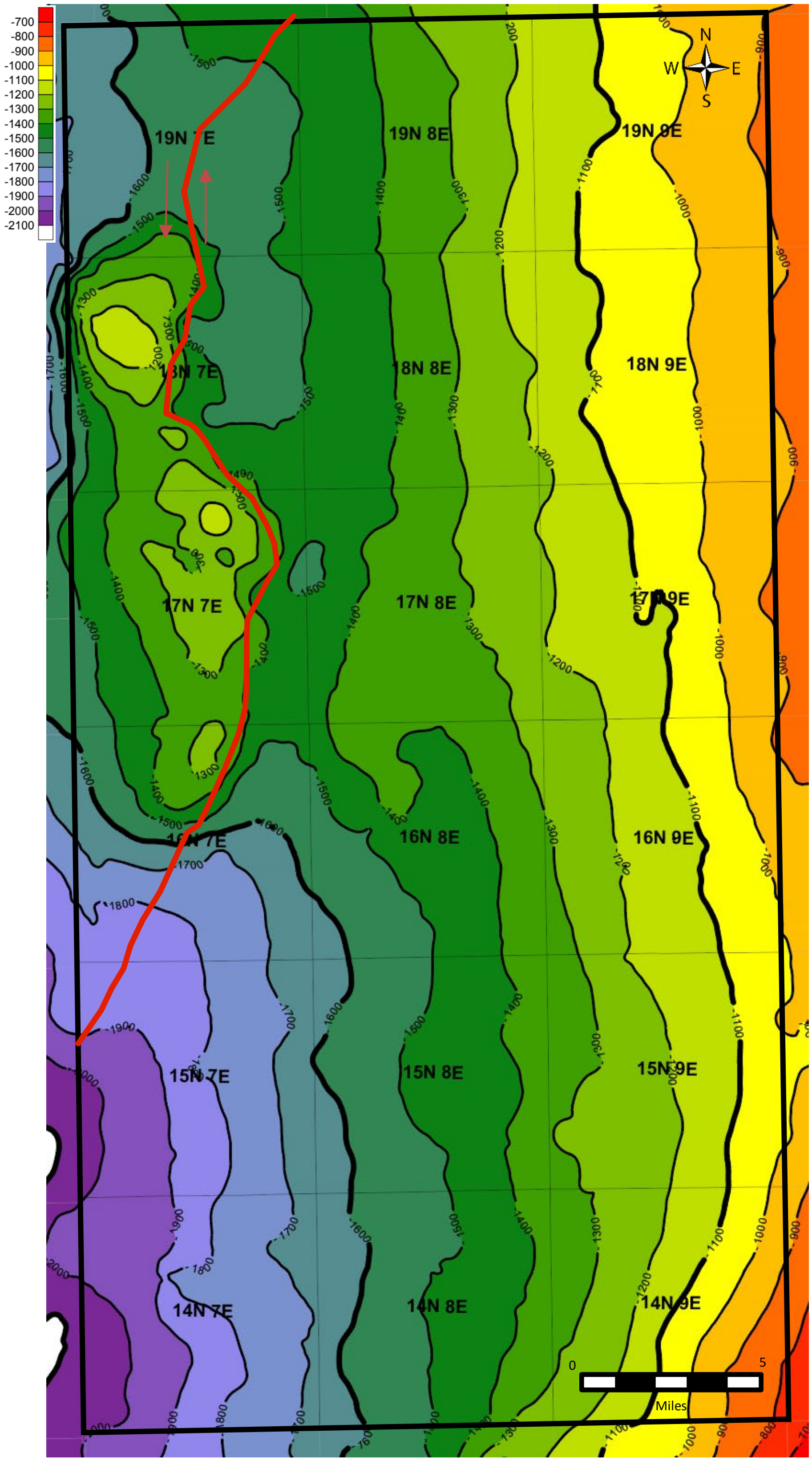


Figure 42. Structural contour map on top of the Oswego Limestone. The contour interval is 100 feet. Reverse fault shown in red.

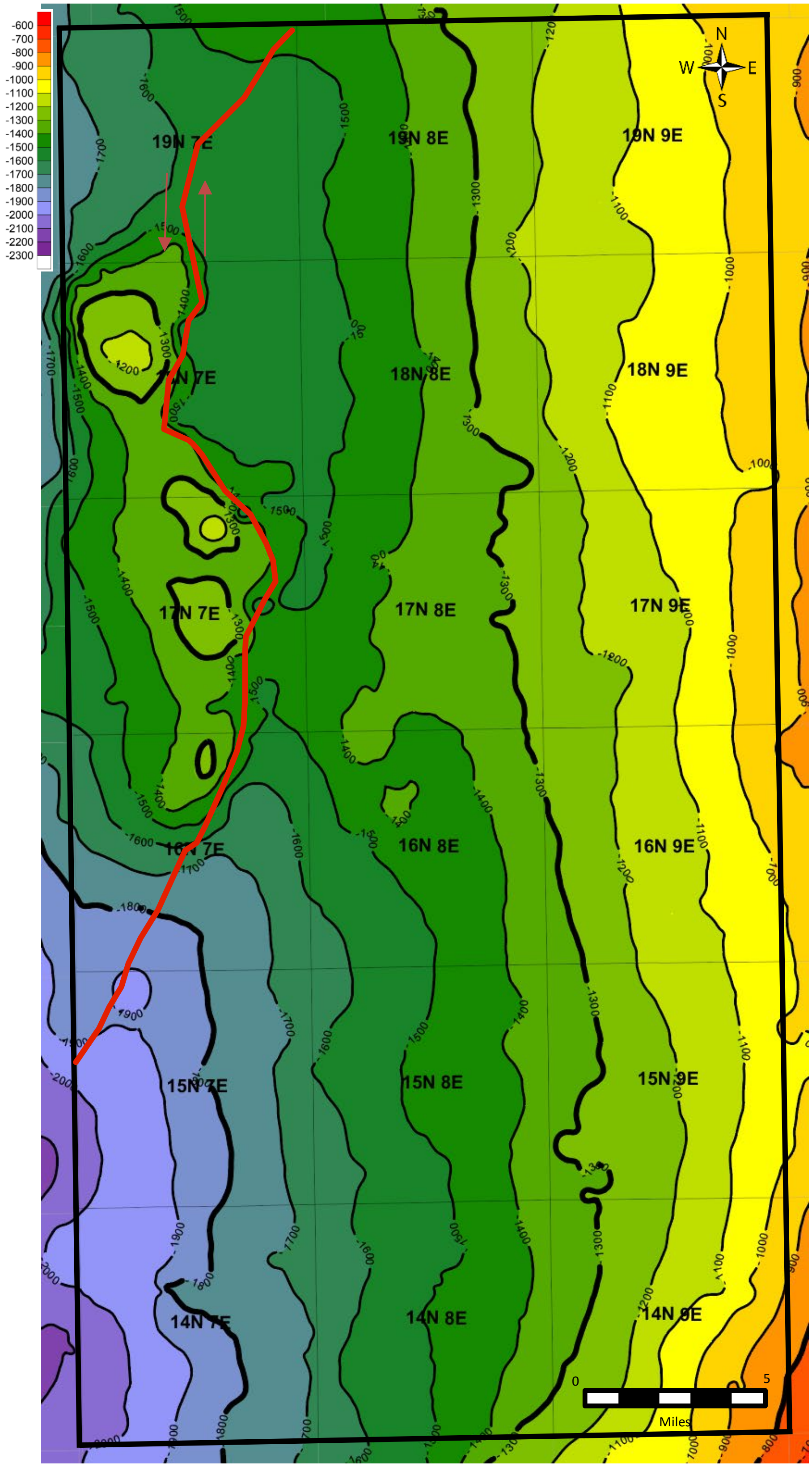


Figure 43. Structural contour map on top of the Excello Shale. The contour interval is 100 feet. Reverse fault shown in red.

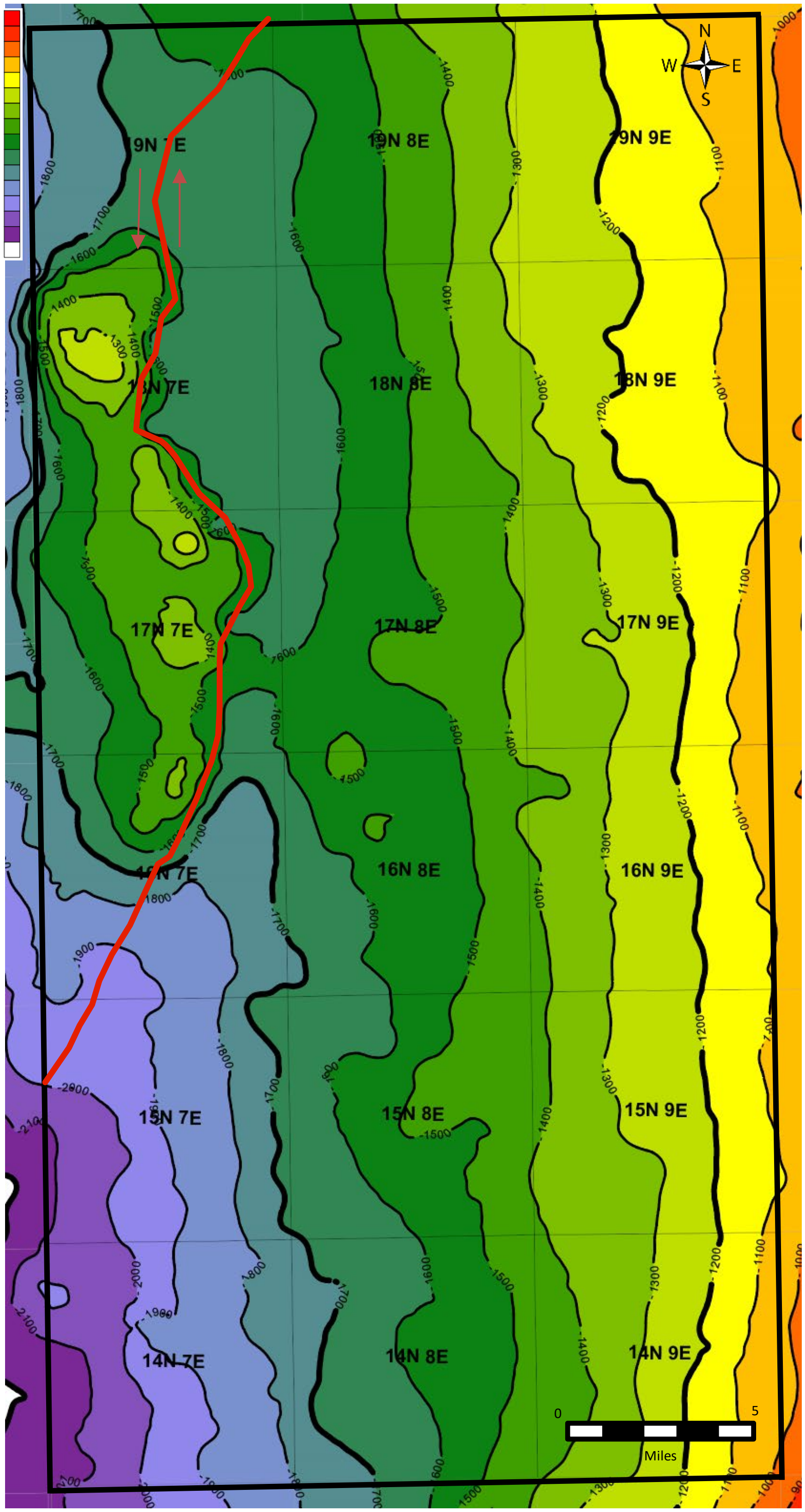


Figure 44. Structural contour map on top of the Verdigris Limestone. The contour interval is 100 feet. Reverse fault shown in red.

from higher elevations in the northwest towards the depocenter lying to the southeast.

An isopach map of the Skinner Sandstone interval from the base of the Verdigris Limestone to the top of the Pink Limestone was prepared to see how trends in Skinner interval thickness may have influenced later Prue Sandstone deposition. The Skinner interval increased approximately 150 feet from the northwest to the southeast portion of the study area map. It is hypothesized that if there were thicker deposits of Skinner Sandstone then there would be less deposition in the overlying Prue interval. However, there seems to be no correlation to Prue deposition. The Skinner Sandstone interval thickens from the northwest to the southeast, while Prue interval sediments are thickest in the center of the study area with very little sediment deposited to the south of the study area. The Skinner interval is similar to the Mississippian to Verdigris Isopach in that the Skinner Sandstone interval increases from the northwest to the southeast portion of the study area map.

An isopach map of the Prue interval was constructed from the top of the Excello Shale to the top of the Verdigris Limestone. The Prue interval isopach values were contoured on a 25 foot interval, with thickness values varying from less than 50 feet in the south-center portion (Townships 15N, R.7-9E) of the study area to over 220 feet in the southeastern portion of the study area (T.14N, R.9E). The Prue interval thickens in the center of the study area, but very rapidly becomes much thinner just to the south. The interval thickens again in the southern portion of the study area especially to the southeast (T.14N, R.9E). The interval isopach values increase when there is more sand present in the interval and decrease when there is less or no sand present in the interval. This could be attributed to the compaction of shales within the isopach interval outside of the channel boundaries (Broker, 2000). This is especially evident in Township 15 North, Ranges 7-9 East, when there is no sand present in the interval and the entire Prue interval is at its thinnest at less than 50 feet. Just north across Township 16, sand is at its most abundant, and there is a rapidly thickening of the overall Prue interval. Variation in thickness reveal the structure of deposition in the northwest, which are expressed by thins on structural highs. In the north to northwest, where homoclinal dip is prevalent, the thins are possibly due to differential compaction. Overall thicker deposition of the interval is represented by channel infill deposits; however, in some areas there is an increase in deposition when channeling is not present.

A net isolith map of the Prue Sandstone was calculated by a 25 API deflection from the shale baseline on the gamma-ray log or by a negative 25 millivolt deflection from the shale baseline on the spontaneous potential curve within the Prue interval. This map shows evidence of several sandstone bodies differentiated by well log character that range in thickness of 0 where the Prue Sandstone is completely absent to 60 feet at its thickest. Most of the thicker Prue Sandstone bodies are in T.18N R.9E with the sandstone bodies trending southwest towards thick sandstone bodies in Townships 17N R.7E and 8E and 16N R.7E and R.8E. These thick sandstone bodies are cut through with a flat area in between them in T.18N R.8E and in the northeast corner of T.17N R.8E. These sand bodies are connected to large sand bodies from outside the study area. Sections in eastern Creek County and further east in Tulsa County (T.16N-18N, R.10E-18E) were studied for well log characteristics and highlighted thick Prue Sandstone bodies and channels coming from the northeast. Prue channels were interpreted to have deposited and connected to the thick sandstone body in the eastern portion of the study area (T.18N R.9E). These Prue channels with thick sandstone bodies (T.16N-18N, R.10E-18E) may have been from the same deposition and were interrupted in deposition by tidal influences in T.18N R.8E. Other sandstone bodies were interpreted to connect to a previous investigation, Ropp (1991), to the west. Ropp (1991) interpreted the Prue Sandstone in Payne County, OK to have thick sandstone bodies in T.17N R.4-7E, correlating to the sand bodies in this study area in T.17N R.7E. The study area has very little or is completely devoid of sand in T.15N R.7-9E which could be attributed to sediments entering a seaway trough that was located at the bottom portion and below the study area. Some thin bodies of sand are present in the lowest portion of the study area as sediment enters the seaway trough, however, these sand bodies do not have distinct well log signatures. Well log characteristics and interpretation will be discussed in Chapter V.

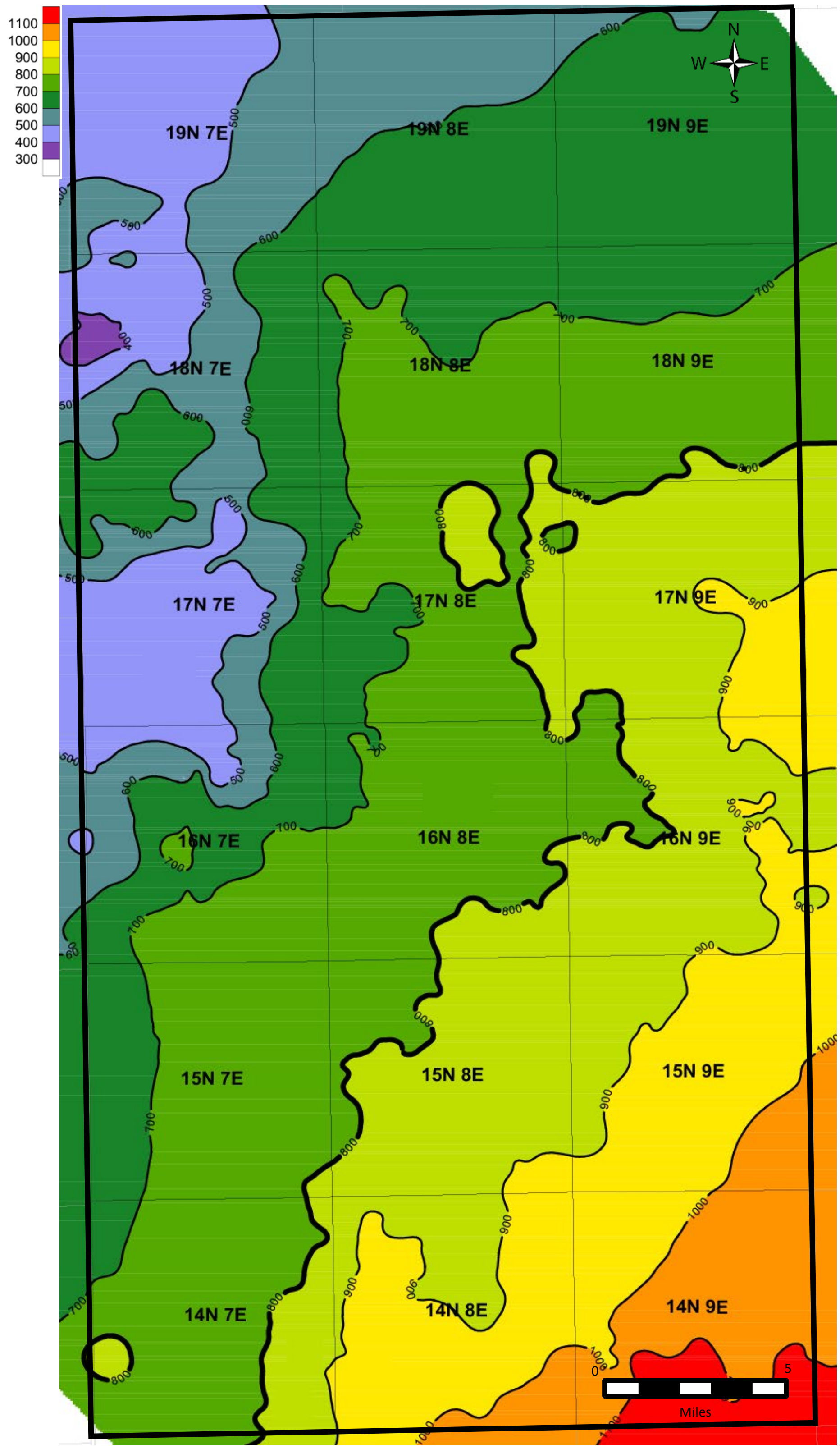


Figure 45. Isopach map from the top of the Verdigris Limestone to the top of the Mississippian Formation. In the study area, Pennsylvanian strata lie unconformably upon Mississippian carbonates. The contour interval is 100 feet.

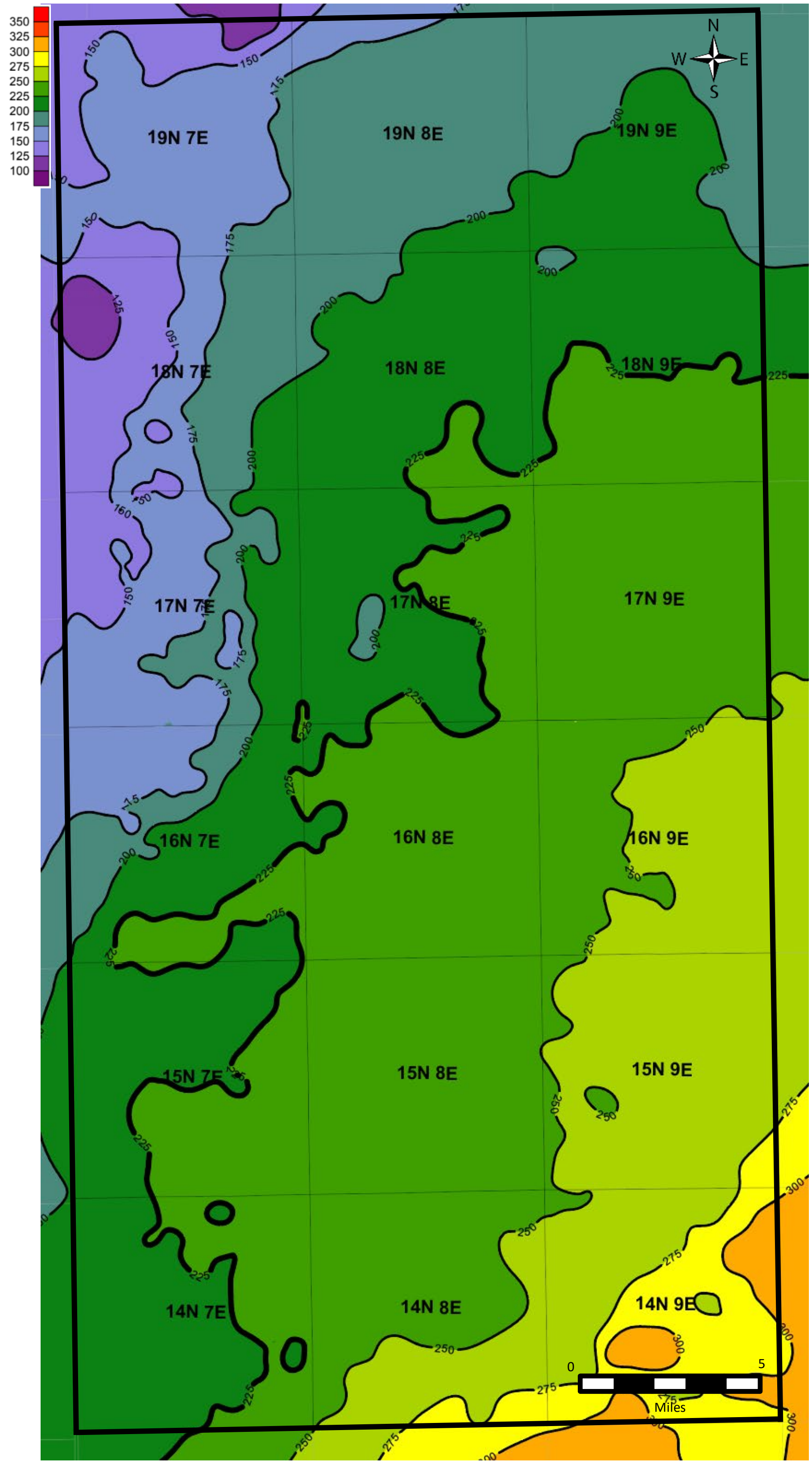


Figure 46. Isopach map of the Skinner Sandstone interval, the interval from the base of the Verdigris Limestone to the top of the Pink Limestone. The contour interval is 25 feet.

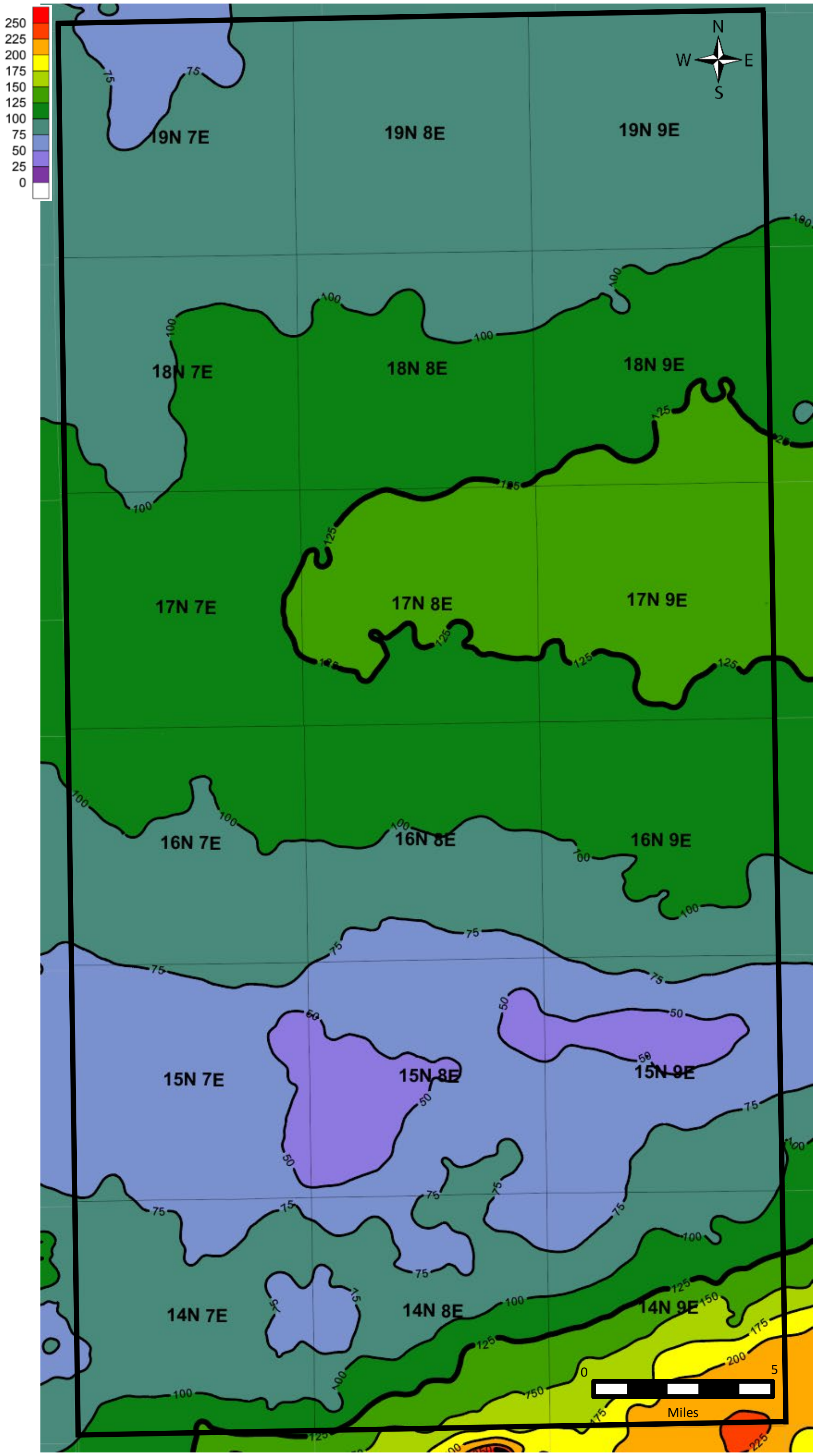


Figure 47. Isopach map of the Prue interval, the interval from the top of the Excello Shale to the top of the Verdigris Limestone. The contour interval is 25 feet.

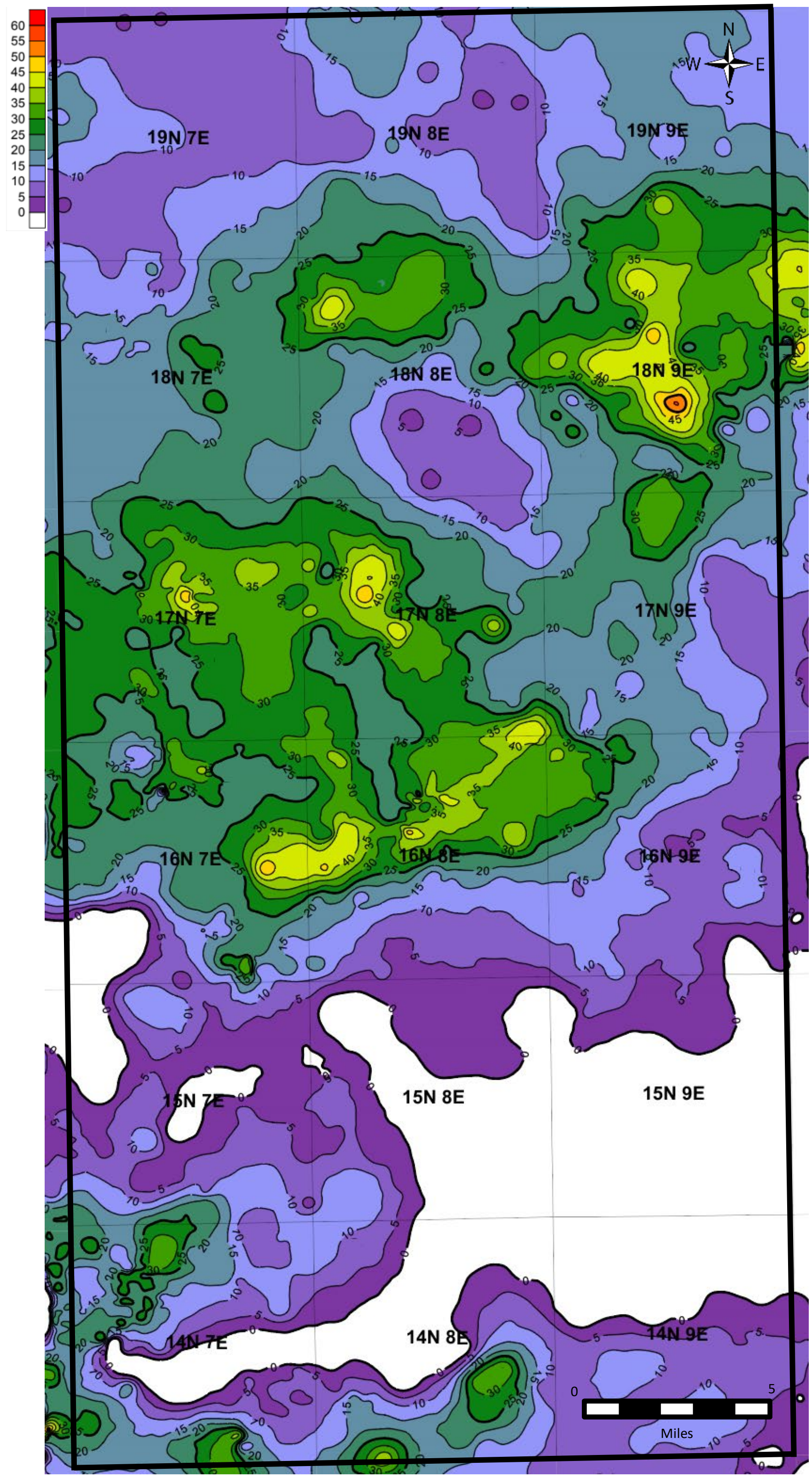


Figure 48. Isolith map of the Net Prue Sandstone. Sandstone was calculated by a 25 API deflection from the shale baseline on the gamma ray log or by a negative 25 millivolt deflection from the shale baseline on the spontaneous potential curve within the Prue interval. The contour interval is 5 feet.

CHAPTER V

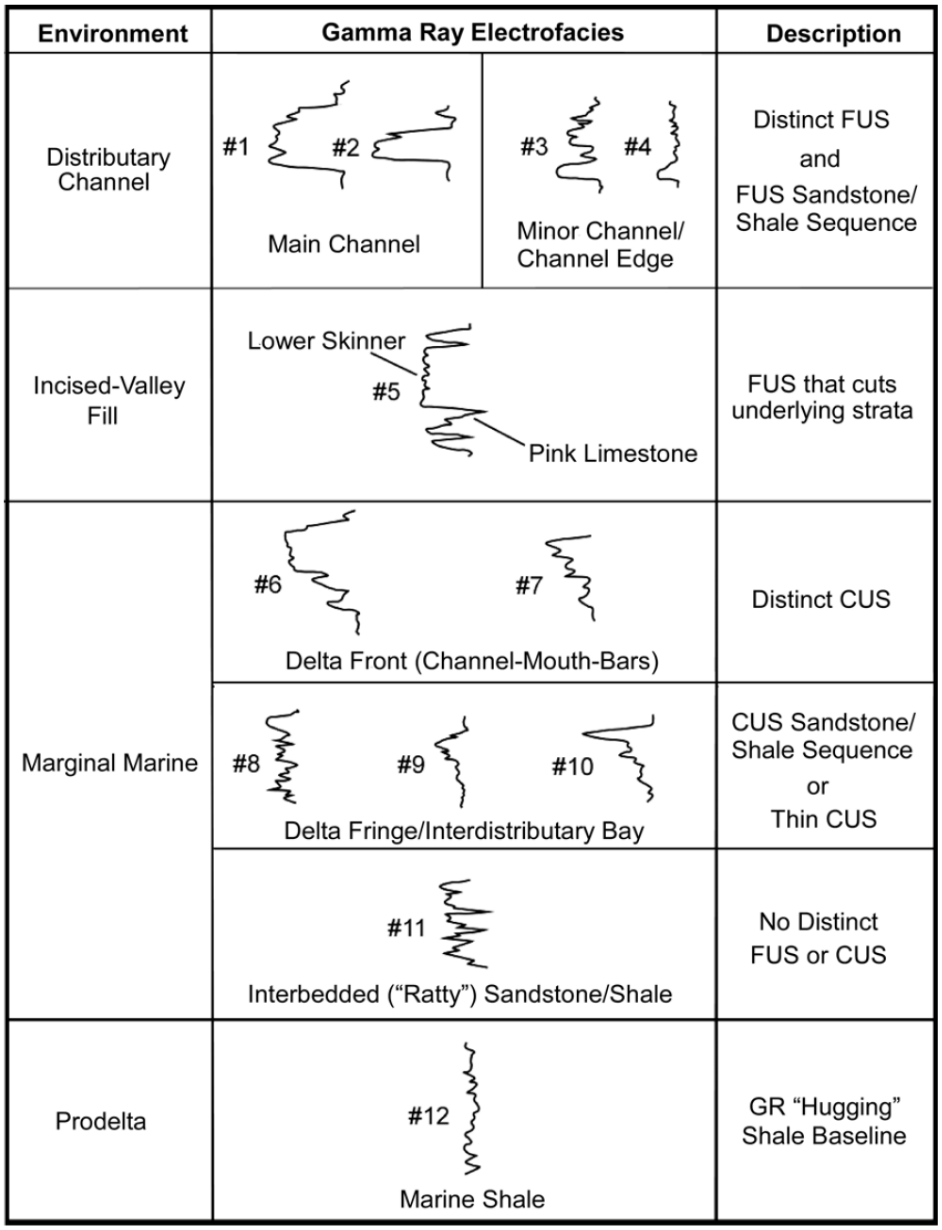
DISCUSSION AND INTEPRETATION

Stratigraphic Analysis

Nine stratigraphic cross sections were constructed for this study using the Excello Shale as a datum of reference. Three north-south cross sections labeled A-A', B-B', and C-C', and six east-west cross sections labeled D-D', E-E', F-F', G-G', H-H', and I-I' were constructed and are shown on a map in figure 50. Figures of cross sections A-A', B-B', C-C', E-E', and F-F' on pages 79-83 are excerpts from their respective full regional cross sections located on Plates in Appendix G. The cross sections were constructed to show the stratigraphic correlations, lithologic distribution, and depositional setting of the Prue interval and associated stratigraphy in the study area.

Interpretation of well log signatures represent evidence for the sequence stratigraphic analysis and depositional model. The individual sandstone bodies in the study area cannot be traced over the entire study area, as there are some disconnections in their distribution patterns. Although the sandstone is traceable in small areas across the cross sections, the sandstone distribution changes markedly within definite stratigraphic intervals.

The thickest sandstone units have sharp basal contacts and bell-shaped fining upwards or blocky log signatures. This suggests constant grain size and sorting indicative of a high energy environment such a distributary channel or incised valley fill. Thinner sandstone units are often funnel shaped or coarsening upward sequences. These signatures are characterized by a sharp



FUS – Fining Upward Sequence
CUS – Coarsening Upward Sequence
GR – Gamma Ray

Figure 49. Electrofacies chart used to help determine depositional environments within the study area (Boucher, 2007).

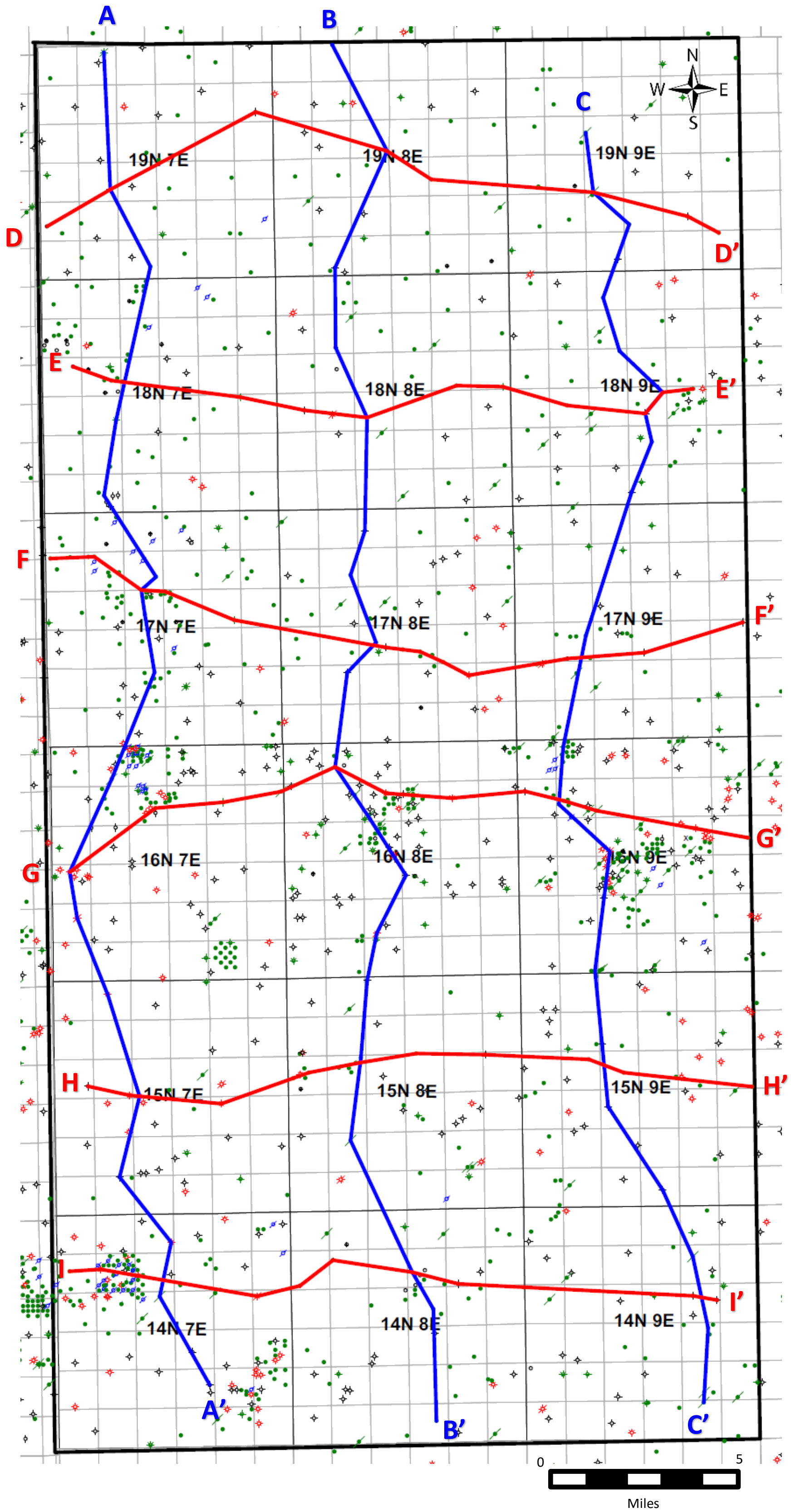


Figure 50. Map showing the location of each cross section.

upper contact with overlying shale and a gradational base. This indicates higher energy at the top of the unit. The patterns of well log signatures suggest that the thicker sandstone deposits represent channel complexes or incised-valley fills; and the thinner more extensive sandstone units with coarsening upward funnel-shaped signatures are indicative of bar complexes. Irregular well log patterns that appear to have no discernible fining upward or coarsening upward signatures and tend to grade laterally, represent interbedded sandstone and shale complexes. A flat log pattern that has small or no change or deflection in SP or gamma ray signature suggests clay-rich marine rock deposition or poorly developed sandstone.

Regional Depositional Setting

Krumme (1981) stated that the source of the Prue sediment originated from cratonic areas to the northeast, most likely from the Transcontinental Arch. Andrews (1996) used an isopach map from the top of the Verdigris Limestone to the top of the Pink Limestone across most of Oklahoma to conclude that the Prue's distribution was the result of the Cherokee Platform and Nemaha fault zone attitudes. This is used to explain the west trending channels that are found in the regional area. It is important to note that the prograding fluvial sediment in the study area trend west-east as the sand source was from a larger channel system to the west of the study area. Ropp (1991) identified a large Prue Sandstone distributary system, with incised valleys cutting south through her study area (T.13N – T.16N, R.4E – R.6E). This study interprets the early prograding sediment in this study area to be an extensional system from the deposited sediments in Ropp's larger fluvial system complex, meaning the original source of the sediment came from the west and trends northeast through prograding channels in the study area. The basinward dip of the Cherokee Platform as seen in the Verdigris to Mississippian isopach map was too small to allow the buildup of thick, prograding deltaic sequences; however, the Prue extends far northeast into Kansas and Iowa and to the southwest towards the Anadarko Basin forming few major channel systems, including no major channel system in the study area.

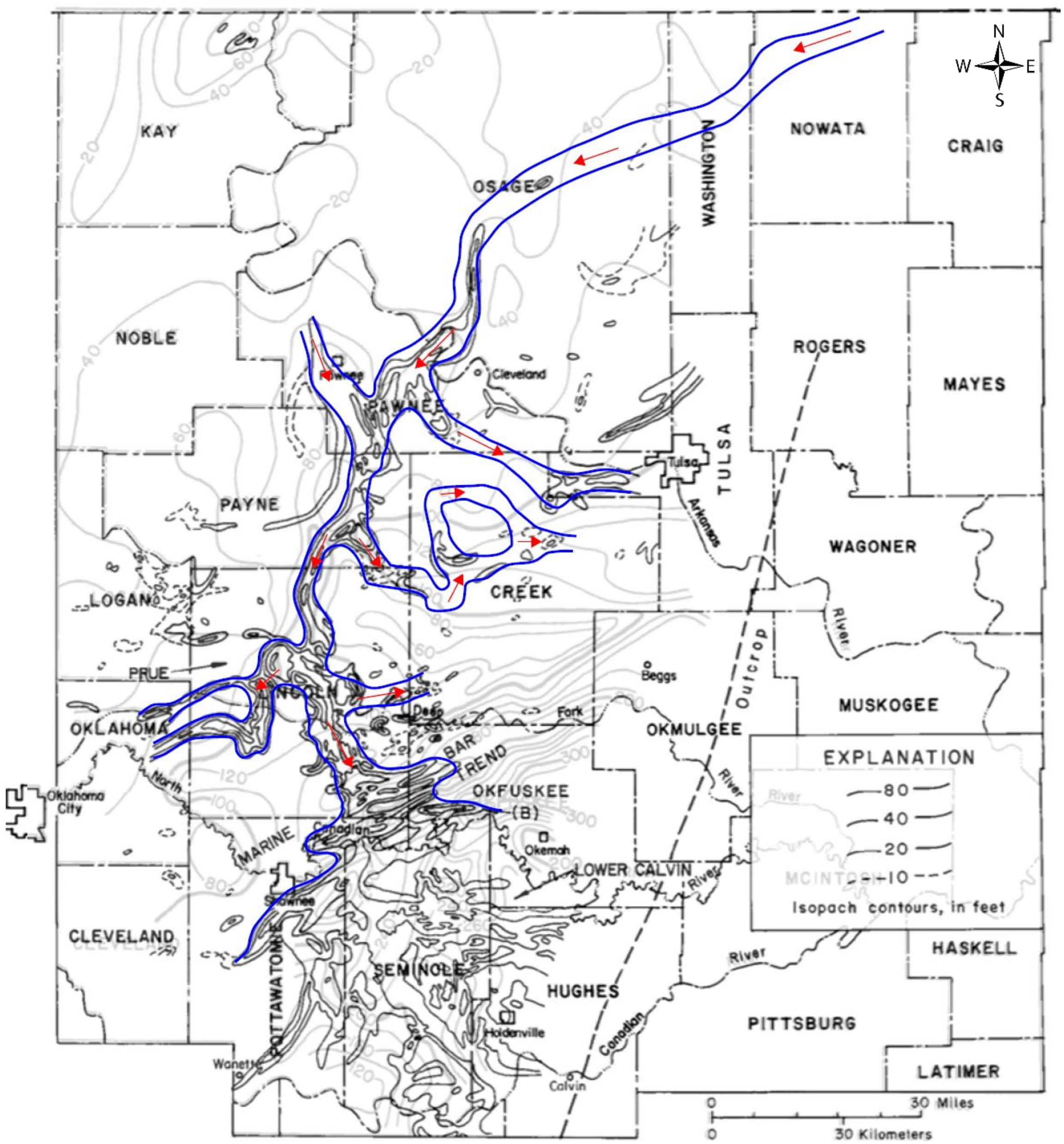


Figure 51. Regional depositional isopach of the Prue Sandstone and the lower Calvin Sandstone overlain upon Prue-Calvin interval isopach in eastern Oklahoma (modified from Krumme, 1981). Blue outlines show general trend of distributary channels in the region, and red arrows indicate direction of dispersal. Interpretations of channel distribution were used from recent studies of the Prue Sandstone including Boucher (2007) in portions of Blaine, Canadian, Custer, Caddo, Grady, and Washita Counties, Broker (2000) in portions of Oklahoma, Cleveland, and Canadian Counties, Huhnke (2004) in Nowata County, and Ropp (1991) in Lincoln County, Oklahoma.

Most of the thick sandstone accumulation within the Prue interval in the region occurred in incised valley complexes. During the Pennsylvanian, the area was located near the paleo-equator allowing fluvial systems to develop when sea level was low, delivering prograding sediment to the coast (Greb and Martino, 2005). Subsequent sea regression resulted in the erosion and ultimately the incision of earlier Prue fluvial deltaic deposits and underlying strata. During the subsequent rise in sea level the incised valleys were flooded and transformed into estuarine systems as marine environments transgressed landward. The flooded estuaries backfilled rapidly from sediments derived from reworked fluvial and marine sources (Archer and Feldman, 1995). In general, the lower portion of incised valleys contain fill that consists of basal fluvial lag, which grades upward into fluvial sandstone and then overlain by marine-influenced estuarine sandstone and mudstones (Dalrymple, 2006). This backfill often filled the incised valleys with large amounts of sand in multiple stacking patterns in the region, however complex multiple stacking patterns are not seen in the study area.

It is unlikely that the Prue Sandstone would have been deposited extensively across the Cherokee Platform without repeated channel abandonment and/or bifurcation (Brenner, 1989). Therefore, the dispersal and merging of the prograding fluvial environment and near-shore tidal environments is likely. During times of high tide, tidal waters spread across the valley, and tidal energy in the estuarine environment reworked the previous fluvial sediment. The tidal reworking of the fluvial sediment formed coarsening upward offshore bars and small marginal marine distributary mouth bars.

Depositional Systems of Study Area

Based on the evidence seen from the well logs, subsurface mapping, and core, the Prue Sandstone in the study area was first deposited in a prograding fluvial system that became incised and backfilled with estuarine sediments and reworked by tidal processes. It is part of a tidal influenced, incised valley system with distal segments consisting of marginal marine and interdistributary facies. The incised valley fill (IVF) deposits trend southwest-northeast across the study area and form the thickest accumulations of the Prue Sandstone; however, non-channel sandstone deposits that have a coarsening upward character often have relatively thick sand deposits alongside the IVF deposits. Tidal influence dominated large portions of the Prue Sandstone deposition especially towards the center of the study area with much of the sandstone deposits being reworked and redeposited in tidal-dominated estuarine settings.

The Prue interval isopach map shows that the study area was a v-shaped incision into a tide dominated coastline. It was located south of the paleo-equator, so that the prevailing winds would have been from the east-northeast. This would enhance wave, tidal and storm action to directly enter and influence deposition in this embayment. In the north of the study area, the Prue interval thins and is represented primarily by shale. To the south, the margin of this embayment is represented by isopach thin in T.15N R.7E – R.9E and T.14N R.7E – R.9E. Here the Prue interval is thin, has no sandstone, consists of shale, and represents low energy open marine shelf environments. This can be seen in the shale-rich log signatures in cross sections H- H' and I-I'. Although there is no core or thin sections from this area, it can be assumed that these were low-energy marine shelf environments and most sediment was deposited from suspension. Farther south of this isopach thin, the stratigraphic section quickly thickens into the open ocean of what would become the Arkoma Basin (southern quarter of T.14N R.8E and south half of T.14N R.9E).

In the central portion of the study area in T.16N R.7-9E, T.17N R.7-9E, and T.18N R.7-9E, the fluvial-deltaic sediments trending slightly southwest to the northeast were incised and backfilled, depositing several thick sandstone bodies into the transformed estuary. During times of lowstand sea-level regression, river valleys often incised through the underlying stratigraphic units of the deltaic systems below the Prue Sandstone. In several studies, such as Ropp (1991) to

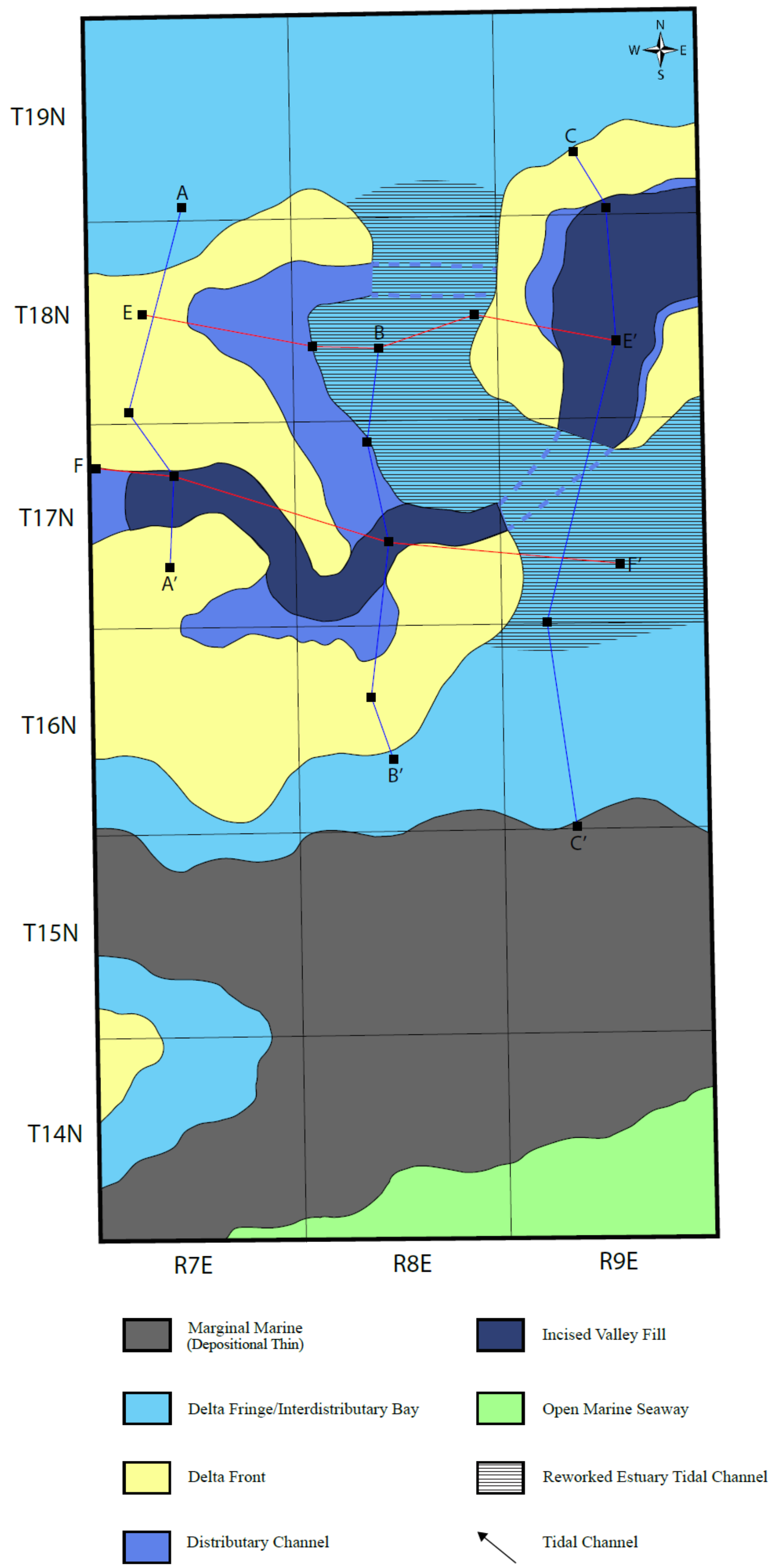


Figure 52. Distribution of electrofacies within the Prue Sandstone interval in the study area.

the west of the study area, incision is deep enough to cut through the underlying Verdigris Limestone and Oakley Shale, however such deep incision was not observed in this study area. The incised paleovalleys were then filled with sediment into the flooded estuary during subsequent rise in sea level. Thick, stacked sand accumulation from the backfill of the IVF is seen in the northeastern portion of the study area in T.19N R.9E and T.18N R.9E. These thick sandstone accumulations are characterized by a thick, blocky fining upward log character within the incised valley complex. The incised valley trending W-E across the study area is often discontinuous and may have been connected to a portion of another major channel complex. Ropp (1991) identified a larger north-south trending incised valley complex to the west of the study area. In that study, the Prue Sandstone isopach shows an incised valley in T.16N R.6E with a channel trend into T.16N R.7E that is interpreted to be the original prograding fluvial source of the sand in this study area. Several fining upward trends represented minor distributary or abandoned channels such as in T.18N R.7E, T.17N R.7E, and T.16N R.7E in cross section A-A'.

The Yarhola Royalty #25 core in T.17N R.7E shows sharp basal contact that incises through an underlying unidentified limestone (seen in the Sam Sawyer #20 core). Only remnants of the bottom of the incised limestone can be seen in the Yarhola Royalty #25 core, but the limestone is seen distinctly in associated well logs as having been eroded. Overall, the core exhibits a sequence of horizontally stratified sandstone, overlain by a cross-bedded sandstone and ripple-laminated sandstones overlain by an erosional surface. This is interpreted as sandy IVF deposits overlain by tidal influenced rhythmically bedded mud and sand. The rising sea levels then reworked the upper portion of the Prue Sandstone and redeposited the sand and marine mud in the flooded estuary evidenced by the rhythmic tidal, ripple-laminated, interbedded characteristics of the sandstone (Brenner, 1995).

These complexes were both fluvial originally and transgressive related, showing evidence of significant tidal influence from tidal erosion and reworked sediments in the center of the study area in T.18N R.8E to T.17N R.9E. This tidal channel separates the incised valley complex and reworks the earlier deposited sediments represented by the reworked coarsening upward trends that cut through the W-E trending complex. Regional cross sections F-F' and G-G' show the trends from west to east that represent the fining upward correlations in T.17N R.7-8E and T.16N R.7-8E in the west and T.18N R.9E to the east with the channel disconnected by a broad zone of tidal reworking. Although no core is available in this portion of the study area, cross sections B-B' trending N-S and E-E' and F-F' trending W-E show evidence of pronounced blocky sandstone to fining upward reworked IVFs adjacent to the earlier sand-filled IVFs. This tidal channel has relatively flat to slight coarsening upward SP and gamma ray log characteristics. This could be interpreted that the incised valley complex trending SW-NE across the study was one large IVF complex that was cut through and reworked by the tidal channel in the middle of the study area.

In between the thicker IVFs, the Prue Sandstone interval is characterized primarily of shale with coarsening upward to thin beds of very-fine grained sandstone or flat shale electrofacies profile. This can be interpreted to be marginal marine or interdistributary areas that are tidally influenced on the edge of the channel systems. The core Watson #1 in T.16N R.7E gives evidence of thin, lenticular interbedded shale and sandstone beds resulting in short periods of high energy sand discharges into the muddy-shelf areas. The core has evidence of soft sediment deformation and rip up clasts possibly from storms. The core interval and well log signatures show strong characteristics of a tidally influenced interdistributary bay in the tidal flat. Marginal marine deposits occur in T.16N R.7-9E through T.15N R.7-9E, and the western sections of T.14N R.7E, and are characterized by shale and small amounts of interbedded sandstone. The Stroud Prue Unit Tr. #12-6 core in T.14N R.7E is characteristic of distal marginal marine or prodelta, with small scale cross bedding, wave ripples, and low energy rhythmic bedding that has an abundance of interbedded shale, bioturbation, and burrowing that reworked the sand bodies. In the western and northeastern portions of the study area, large coarsening upward sand bodies

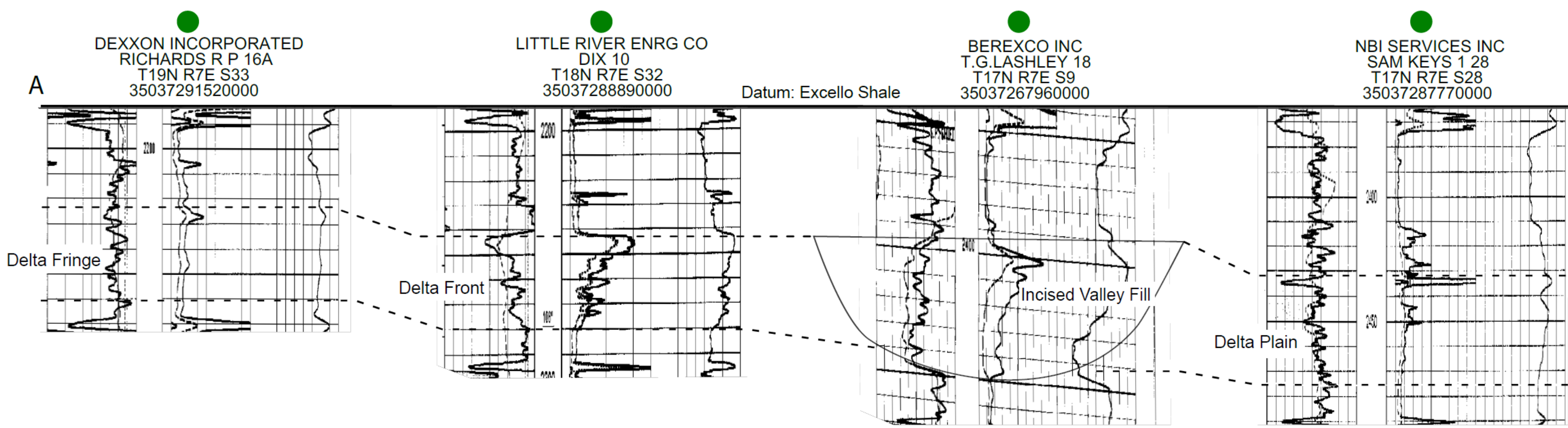


Figure 53. Excerpt from Cross Section A-A’ showing the spatial relationships between environments of the Prue Sandstone vertically along the western portion of the study area.

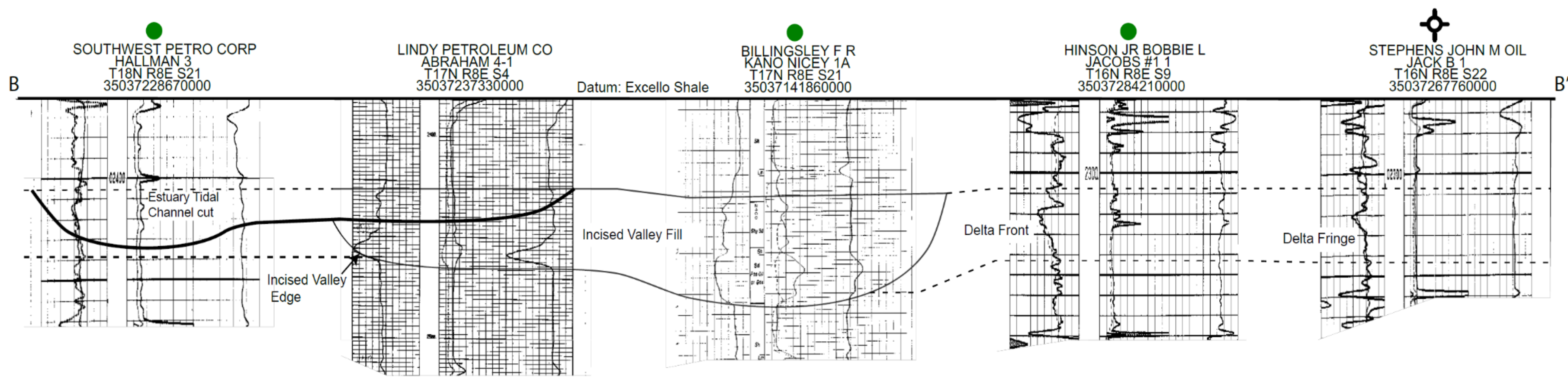


Figure 54. Excerpt from Cross Section B-B' showing the spatial relationships between environments of the Prue Sandstone vertically along the center portion of the study area.

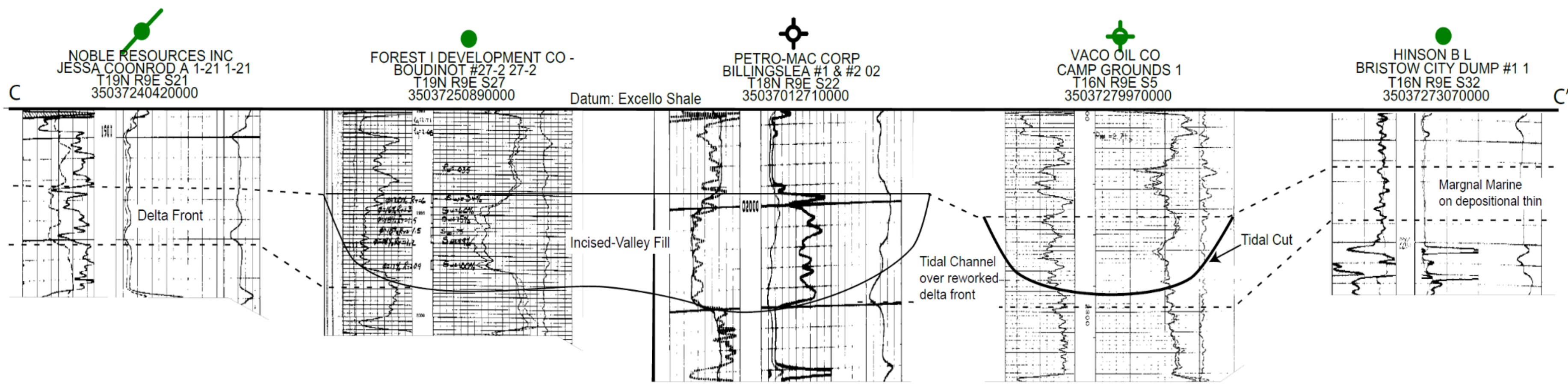


Figure 55. Excerpt from Cross Section C-C' showing the spatial relationships between environments of the Prue Sandstone vertically along the eastern portion of the study area.

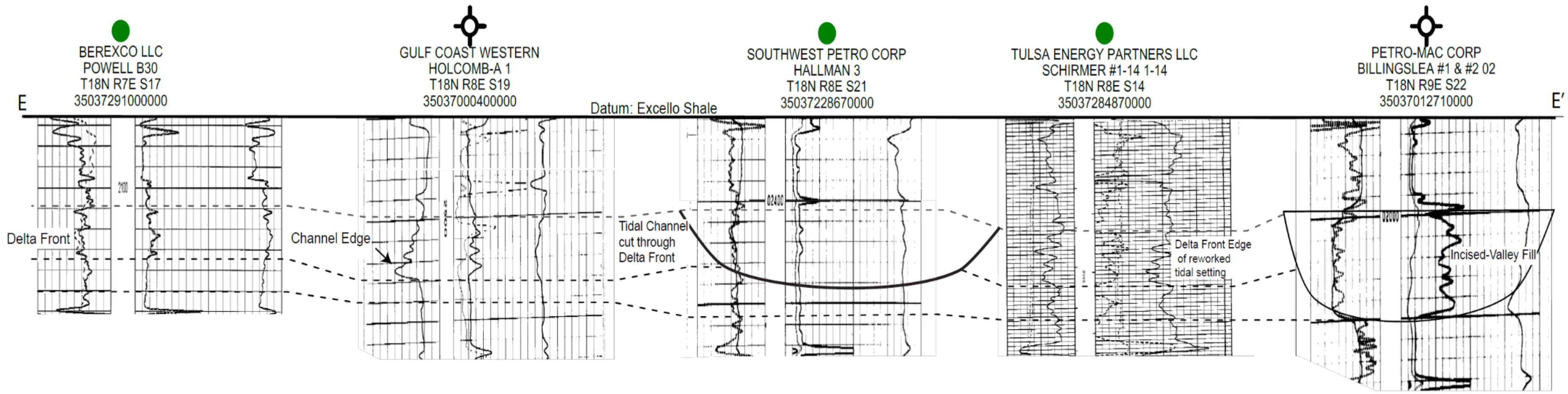


Figure 56. Excerpt from Cross Section E-E' showing the spatial relationships between environments of the Prue Sandstone horizontally across the township 18N.

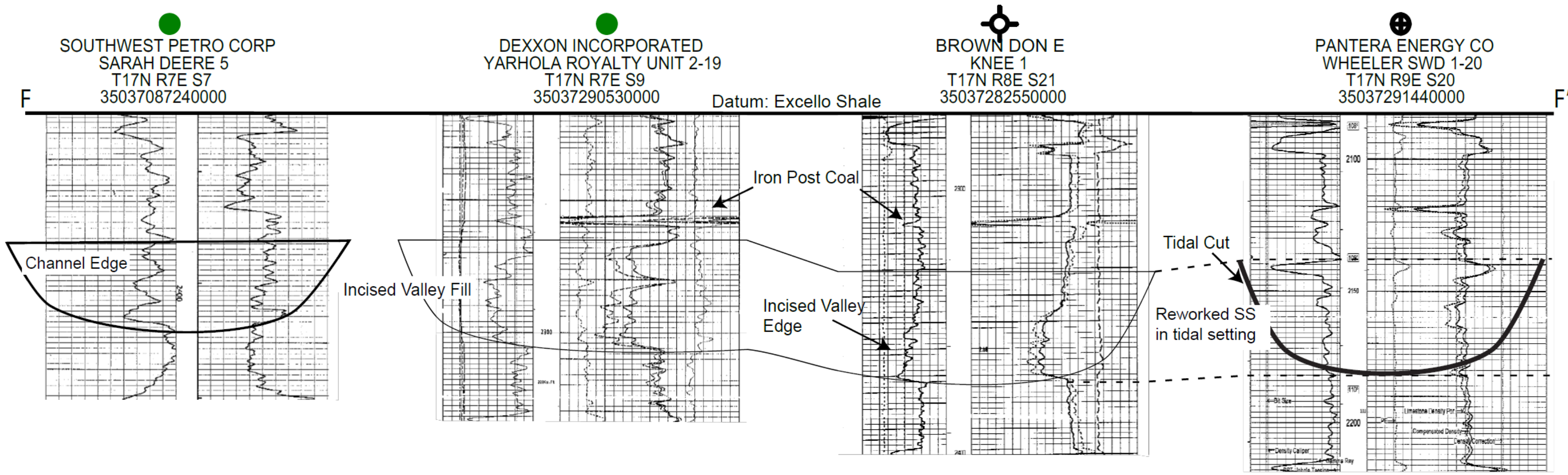


Figure 57. Excerpt from Cross Section F-F' showing the spatial relationships between environments of the Prue Sandstone horizontally across the township 17N.

adjacent to the IVFs are interpreted to be part of the early delta front environment. This is evident in cores Peter Brown #9 in section 33 and Sam Sawyer #20 in section 22 of T.17N R.7E with the sandstone massively bedded at the top of the interval and fining downward with tidal influx and rhythmic bedding that includes small-scale cross bedding, flaser bedding, and sand ripples near the bottom of the sand interval. The Sam Sawyer #20 core was deposited in a higher energy environment near the top of the sand interval with prominent rip up clasts seen, and the sand becomes more fine at the bottom of the sand interval with low angle cross bedding, rhythmically laminated beds, and extensive bioturbation and burrowing deposited in a low energy environment.

The Iron Post Coal and underlying paleosol cap the deltaic complexes as seen in core Sam Sawyer #20 in T.17N R.7E. The Iron Post Coal and paleosol appear laterally extensive throughout the study area and are seen in this core. These paleosols form by plant growth and the weathering of residual sediments, requiring subaerial exposure and seaward regression. It represents erosion and therefore marks a low stand sequence tract in nonmarine interfluve settings. The Iron Post Coal formed as the groundwater table rose due to slowly rising sea levels. There is no associated dark grey marine shale above the Iron Post Coal in this area as is found above other Pennsylvanian coal beds that represent a major transgressive flood event. Therefore, the Iron Post Coal in this study area may have formed on exposed delta lobes as abandonment and subsidence induced local transgressions flooded the delta complexes (Brenner, 1995).

Depositional Model

The deposition of Pennsylvanian age sandstones in central Oklahoma was due to many transgressive-regressive sequences. Glacio-eustatic fluctuations in sea level determined the positions of the siliciclastic point sources and shoreline positions due to the buildup of ice causing the shoreline to retreat (Brenner, 1995). The Cherokee Group’s genetic sequences represent about 400,000 years each, and depositional sequences bounded by paleosols represent transgressive-regressive cycles that approximate 100,000 years each. The tectonic setting of the Mid-Continent during this time period was relatively stable, indicating that the deposition of the Prue interval was caused by glacio-eustatic fluctuation from the waxing and waning of Gondwanan ice sheets, which caused the numerous fluctuations in sediment accumulation rates (Brenner, 1995).

The base of the Oakley Shale is considered the base of the sequence boundary. The Oakley Shale is a widespread, black, phosphatic shale that represents a condensed interval. The Oakley was deposited far from siliciclastic sources, in a low-energy, anoxic marine environment during a major marine transgression before maximum sea-level highstand and represents a maximum flooding surface. Following the deposition of the Oakley Shale, began the cycle of eustatic regression. As the sea regresses, nitrites in the sea oxidized into nitrates, becoming the source of food for plants and organisms and allowing the flourishing of marine life in the area. The Verdigris Limestone was then deposited on the low-energy, carbonate shelf containing an abundance of marine fossils.

Eustatic regression continued, and fluvial-deltaic systems and shorelines prograded seaward ceasing carbonate sedimentation. It is hypothesized that the original sediment source in the study area was from a large incised valley complex to the west. This IVF system was identified by Ropp (1991) with fluvial channels downcutting into the Verdigris Limestone. At least one channel of Ropp's system is shown to connect directly into the current study area, which represents a tide dominated marine embayment in T.16N R.7-9E, T.17N R.7-9E, and T.18N R.7-9E. This clastic influx first resulted in deposition of prodelta muds and sheet sands in a prograding delta system. Over time, southwest to northeast trending distributary channels prograded across the delta plain, extending eastward into the embayment and shifted laterally by flow diversions through small crevasses during storms and floods. This created abandoned channels and portions of the delta system that would subside as the muddy sediments compacted.

Further sea-level regression resulted in coastal areas emerging, and rates of deposition often exceeded accumulation rates. Prograding channels eroded preexisting deposits, which then resulted in the entrenchment of the distributary channels and the eventual erosion of incised paleovalleys into the margin of the existing delta front channel across T.16N R.7-9E, T.17N R.7-9E, and T.18N R.7-9E. During subsequent sea-level rise, the incised valleys were flooded and transformed into estuarine systems as marine environments came more landward. The flooded incised valley estuaries served as sediment sinks and filled rapidly with reworked fluvial and transgressive marine sediments. This would often result in thick facies-stacking patterns controlled by fluvial and tidal influences where rippled sandstones would grade upward into mudstones, reflecting the infilling of the estuaries with silts and clays. These sands were later bioturbated heavily as subaqueous organisms re-established in the environment.

Due to the relative position of the marine shoreline, tidal influence increased in the flooded estuarine environment resulting in the reworking and redistribution of fluvial-deltaic sediments while also depositing transgressive marine sands and muds in the study area. Tidal influence dominated most of the study area with evidence seen in core overlain upon incised valley and fluvial deposits and in interdistributary areas with an abundance of rhythmic tidal bedding. In the middle section of the study area in T.18N R.8E to T.17N R.9E, a wide tidal channel cut across the existing delta plain and incised valley complex which caused the fluvial and estuarine sediments and shoreline to redistribute and displace over the tidal flat environment. Most of the redeposition took place in tidal flat environments that exist in prodeltaic and interdistributary systems. Sand deposition took place during times of high flood and ebb tidal flows, while suspension of mud and organic activities dominated as flow energy slowed during high tides. In the northeast portion of the area in T.18N R.9E, the fluvial sandstone channels were transformed by tidal reworking and backfilling of previously deposited sandstones, to produce some of the thickest sandstone accumulations in the study area. In the study area, sand

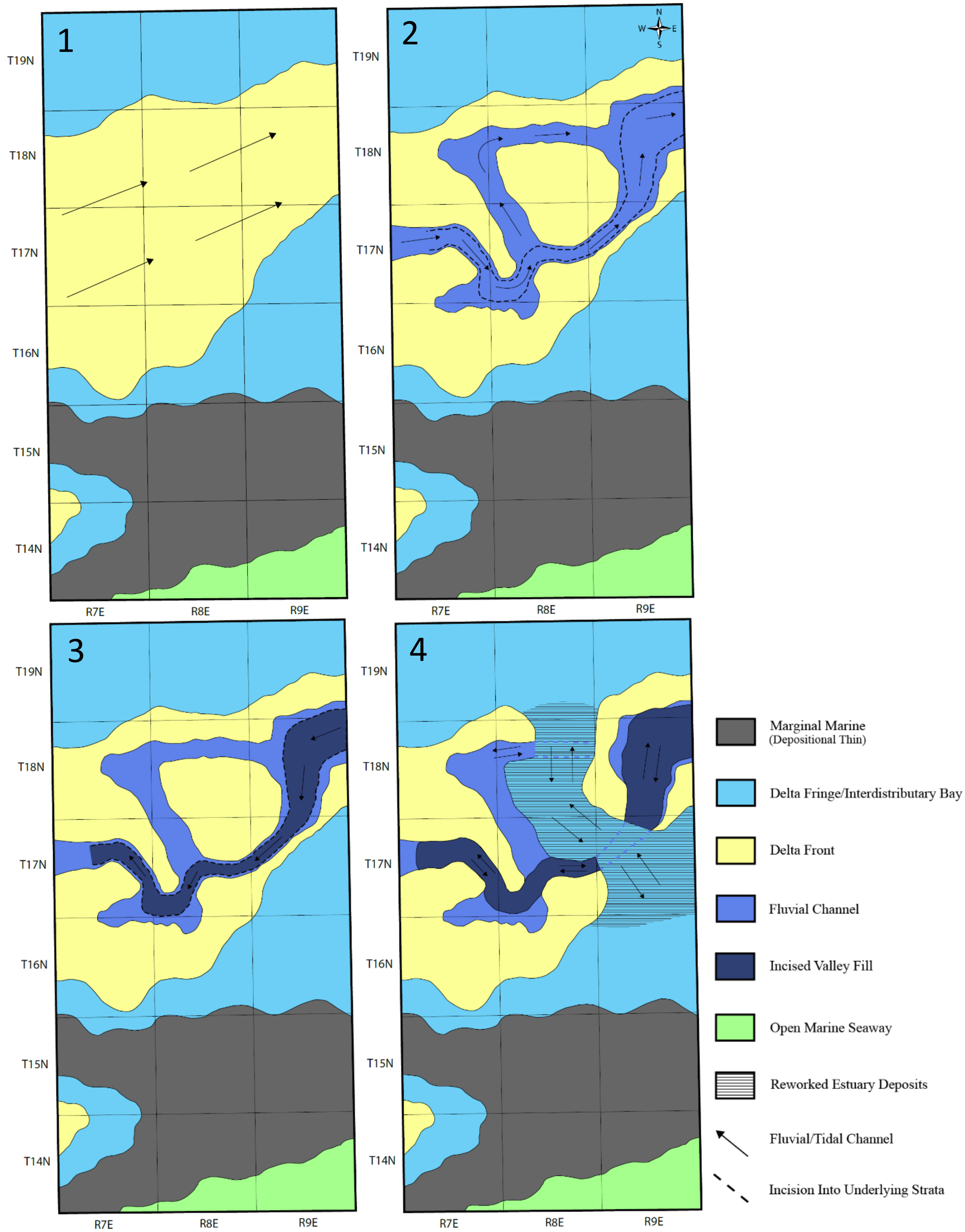


Figure 58. Depositional environment interpretation of the Prue Sandstone in the study area. 1) Deposition of progradational fluvial sediments into tide dominated marine embayment. 2) Fluvial channels develop across the delta plain. Further regression causes the erosion of an incised valley into older deltaic complex. 3) Marine transgression floods the estuarine incised valley and backfills the valley with fluvial and marine sediments. 4) Tidal channel cuts into incised valley complex, depositing and reworking fluvial and marine sands in the flooded estuary.

accumulation reached as high as 60 feet, with sediment accumulation continuing as sea level continued to rise.

Due to sediment supply keeping up with sea level rise, areas of exposure on the coastal plain wetlands became prominent as sediment was carried into the ocean beyond the coastal plain. These represent paleosols formed by plant growth and weathering of residual sediments and indicating subaerial exposure due to withdrawal of the sea, resulting in erosion and nondeposition. A rise in the ground water table flooded the coastal plain and contributed to the formation of bogs and marshes that covered the low-lying coastal plains. This environment produced extensive coal-producing swamps where the ground surface was continuously wet and required a higher water table. This is represented by the deposition of the Iron Post Coal along the marine shoreline. These areas may represent areas of emergence where deltaic sediments accumulated faster than they could be accommodated by subsidence or compaction. The Iron Post Coal caps the sandstone dominated portion of the Prue interval.

The Kinnison Shale and Breezy Hill Limestone, found above the tide dominated deltaic sequence of the Prue interval, represent the final marine transgression in this sequence. The sea continued to transgress over the area, while sediment supply waned over time. The Prue interval was in an open sea environment, where the Kinnison Shale was deposited due to marine mud buildup. Once the sea water cleaned up, this allowed for the conditions available for organisms to thrive and carbonates to deposit, resulting in the deposition of the Breezy Hill Limestone. The sea level continued to transgress over the area, reaching maximum transgression, flooding the midcontinent, and depositing the Excello Shale, capping the Prue interval boundary.

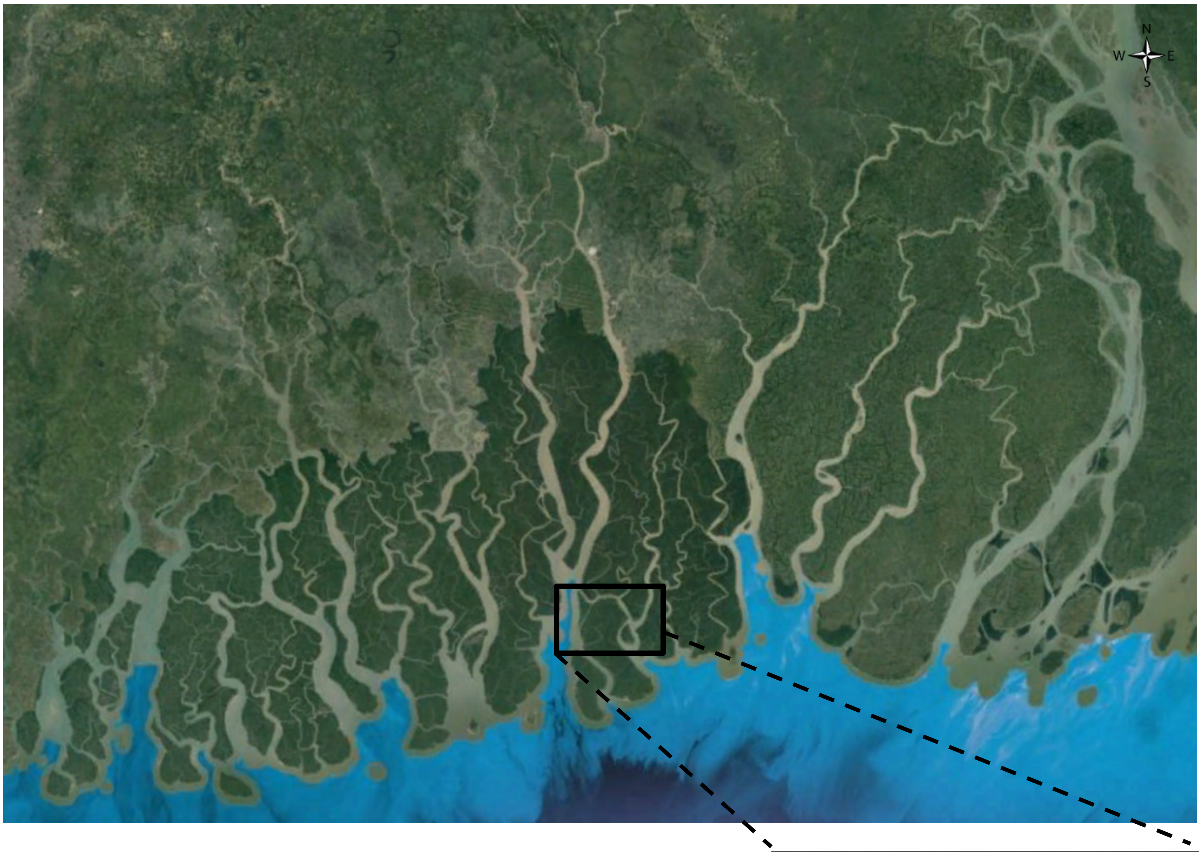
Modern Analog

A modern analog for the Prue Sandstone depositional model best fits the Ganges-Brahmaputra Delta on the eastern edge of India. The delta and offshore fan complex form one of the world's largest depositional systems. Sediments from the Ganges and Brahmaputra Rivers are derived from the Himalayas to the north and are transported across the Indian Plate to the margin of the Bengal Basin, where the sediments are originally deposited as part of the deltaic complex along the delta front or transported into the Bay of Bengal Complex as part of the deep-water fan. Incision of underlying strata, results in estuarine tidal environments such as in the Meghna Estuary (Lindsay et al., 1991). A sequence of 16 km of fluvial-deltaic sediments have filled the basin since the Paleogene, creating a complex delta morphology. Major tidal currents and frequent tropical storms are major contributors in shaping the delta front and the sediment dispersal (Allison, 1998). Fluvial processes dominate the sediment transport in the northern, landward portions of the complex, while tidal processes become the dominant sediment dispersal system seaward (Kuehl et al., 2005). This is similar to the Prue system with the sediment source originating in the north and fluvial complexes dominated the early sediment transport and dispersal to the south-southwest moving seaward. The seaward portions were tide-dominated dispersal systems near a paleo-equatorial region.

The Ganges-Brahmaputra delta is advancing along the delta front in shallow-water deposits off the river-mouth region. It is distinguished by flood-dominated channels and shoals extending from interdistributary islands that were created due to shoreline accretion. This seaward extension of interdistributary islands further into the estuarine settings are cut through by tidal channels, separating the land into islands. The delta front deposits are characteristic of sands and interbedded silty and clay layers. Channel and IVF deposits are fining upward sequences with cross-bedded muddy sands and buried by a shoal-island complex consisting of interbedded sand and mud (Kuehl et al., 2005). The Prue complex is similar in that the delta front deposits are interbedded with fine sand and mud. The distributary channels and IVFs are characterized by fining upward sequences with cross-bedded, fine-grained sandstone and silt.

In the lower delta plain of the Ganges-Brahmaputra deltaic complex, distributary channels of the Ganges River spread across the region in a series of north-south oriented channels, creating elongate peninsulas that are dissected by smaller anastomosing tidal channels. For example, to the far east on the Kuataka Peninsula, the active distributaries that form the Meghna Estuary is cut through by smaller tidal channels causing the distributaries to separate and subdivide the peninsula into smaller islands (Allison, 1998). This is similar to the Prue complex in the study area, where a larger incised valley complex is cut through by a tidal channel in the center portion of the study area.

In the Meghna Estuary region of the Ganges-Brahmaputra Delta, tidal energy is dynamic. Sediments in this region are sandy silts that exhibit mm-scale tidal laminations of silt and micaceous fine sand (Allison, 1998). Sediments are generally silty to clay with some very fine to fine-grained sand. This region has an abundance of primary sedimentary structures that include burrowing and bioturbation with layers of interbedded mud and sand characteristic of tidally influenced sediment (Kuehl et al., 2005). The core Watson #1 in T.16N R.7E and other cores in the region shows evidence of small scale tidally influenced bedding of generally silty to clay and fine-grained sand. Burrowing and bioturbation was abundant in the core especially in Stroud Prue Unit Tr. #12-6 in T.14N R.7E where abundant burrows occur throughout the entirety of the core.



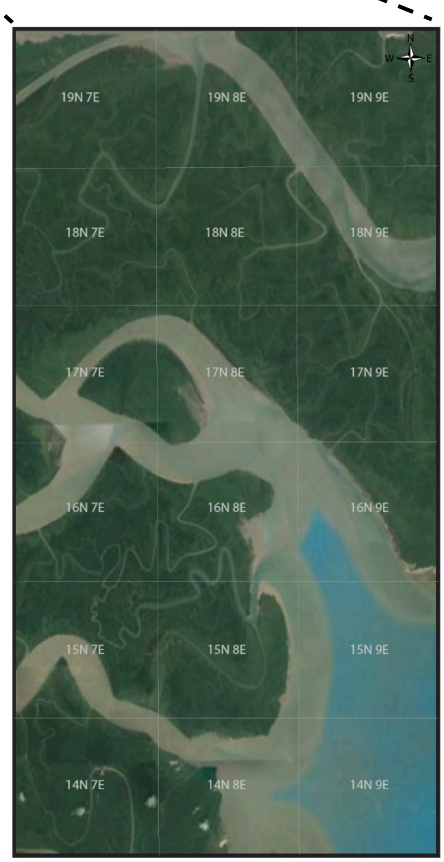


Figure 59. Google Earth satellite image of the Ganges-Brahmaputra Delta, India with (bottom) portion of image mirrored 180° and overlain upon the study area. This shows a representation of the Prue interval system interpreted depositional system in the study area.

CHAPTER VI

CONCLUSIONS

1. Prue Sandstone deposition originally occurred in a fluvial setting prograding in a SW-NE direction into a tide-dominated marine embayment, that was then incised in lower fluvial valleys during eustatic regression and backfilled with both fluvial and marine sediments in estuarine settings as sea level rose during eustatic transgression.

2. It is interpreted that the original sediment source in the study area was from a large incised valley complex to the west. This IVF system was identified by Ropp (1991) with at least one channel of Ropp's system shown to connect directly into the study area.

3. Incised valleys cut across the center portion of the study area in a W-E direction. These incised valley systems had the thickest sandstone accumulations within the study area, due to the backfilling and stacking patterns of sand and mud as the area flooded during sea level transgression.

4. The Prue interval sediments were heavily influenced and redistributed by tidal conditions characterized by cyclic sedimentary sequences that can be correlated across the study area.

5. Tidal reworking of fluvial and marine sediments occurred during eustatic transgressions when the incised valleys filled with fluvial and tidal sands and muds, shifted northward.

6. A tidal channel cutting across the W-E trending incised valley complex reworked and redistributed the previously deposited sediments in the flooded estuary and disconnected the incised valley complex from the eastern and western areas of the study area.
7. The Verdigris Limestone, below the Prue interval, is a thin limestone deposited during marine transgression. The Oakley and Excello Shales, above the Prue interval, were formed during marine highstand systems and represent extensive marine flooding in deep water anoxic conditions. These three formations can be correlated throughout the study area and were used as regional markers.

8. Five cores, along with their associated wireline logs, were correlated and interpreted for depositional processes and rock composition throughout the study area, such as the Iron Post Coal which was often unseen in wireline logs. Core analysis gives evidence of the depositional environments of the Prue Sandstone including the incised valley cutting through the previously deposited limestone and sedimentary features such as rhythmically deposited bedding.

9. Petrographic analysis shows that the Prue Sandstone is predominately litharenite. The detrital constituents are dominantly quartz, schistose metamorphic rock fragments that occur as ductilly-deformed pseudomatrix, muscovite bands, and plagioclase. Authigenic components include pore-filling kaolinite, calcite, and siderite.

10. Glacio-eustatic fluctuation, caused by the waxing and waning of Gondwanan ice sheets, is interpreted to be the main cause of the fluctuations in the sediment accumulation rates during the Mid to Late Pennsylvanian. The Cherokee Shelf in the Mid-Continent is interpreted to be structurally stable during deposition of the Prue interval.

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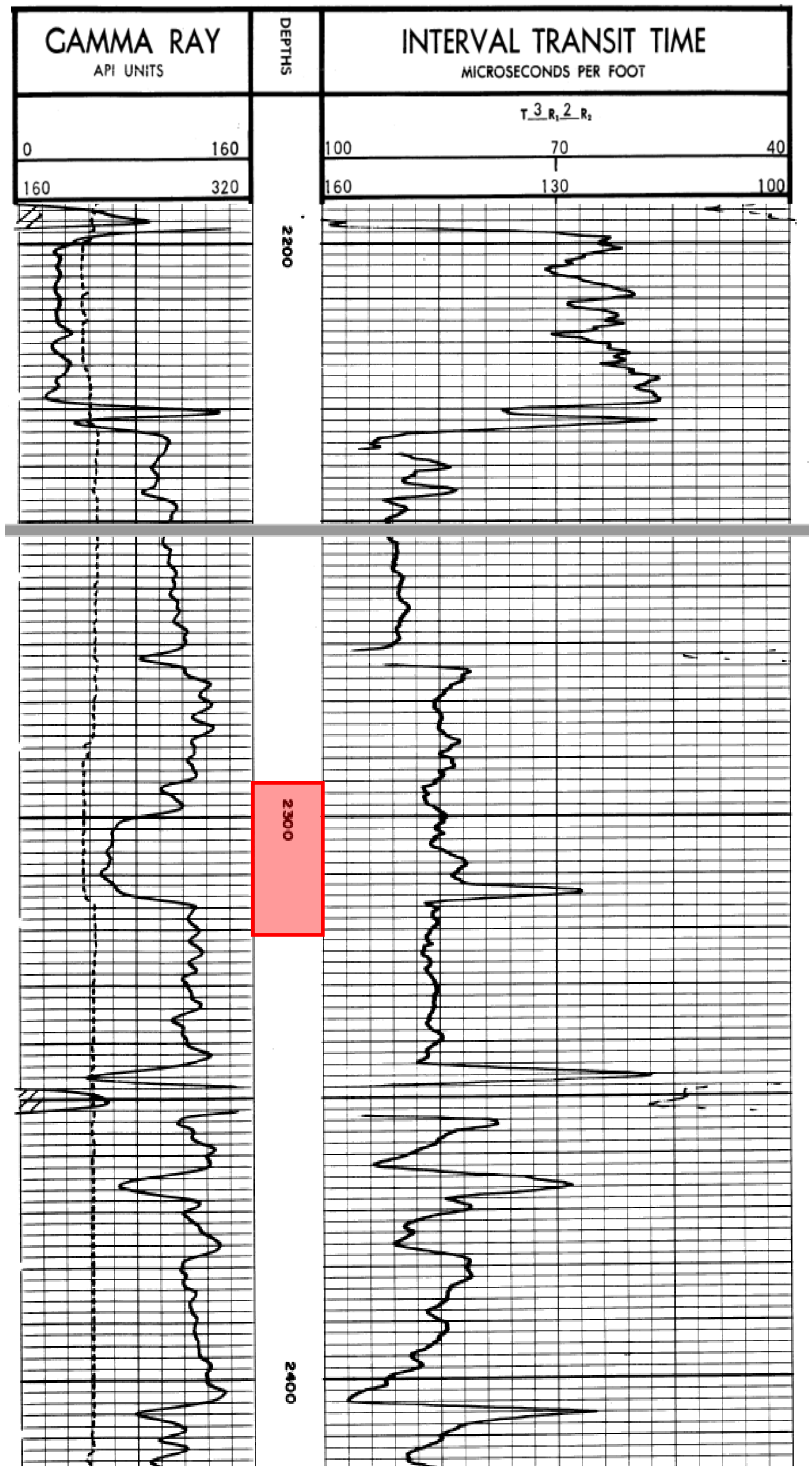
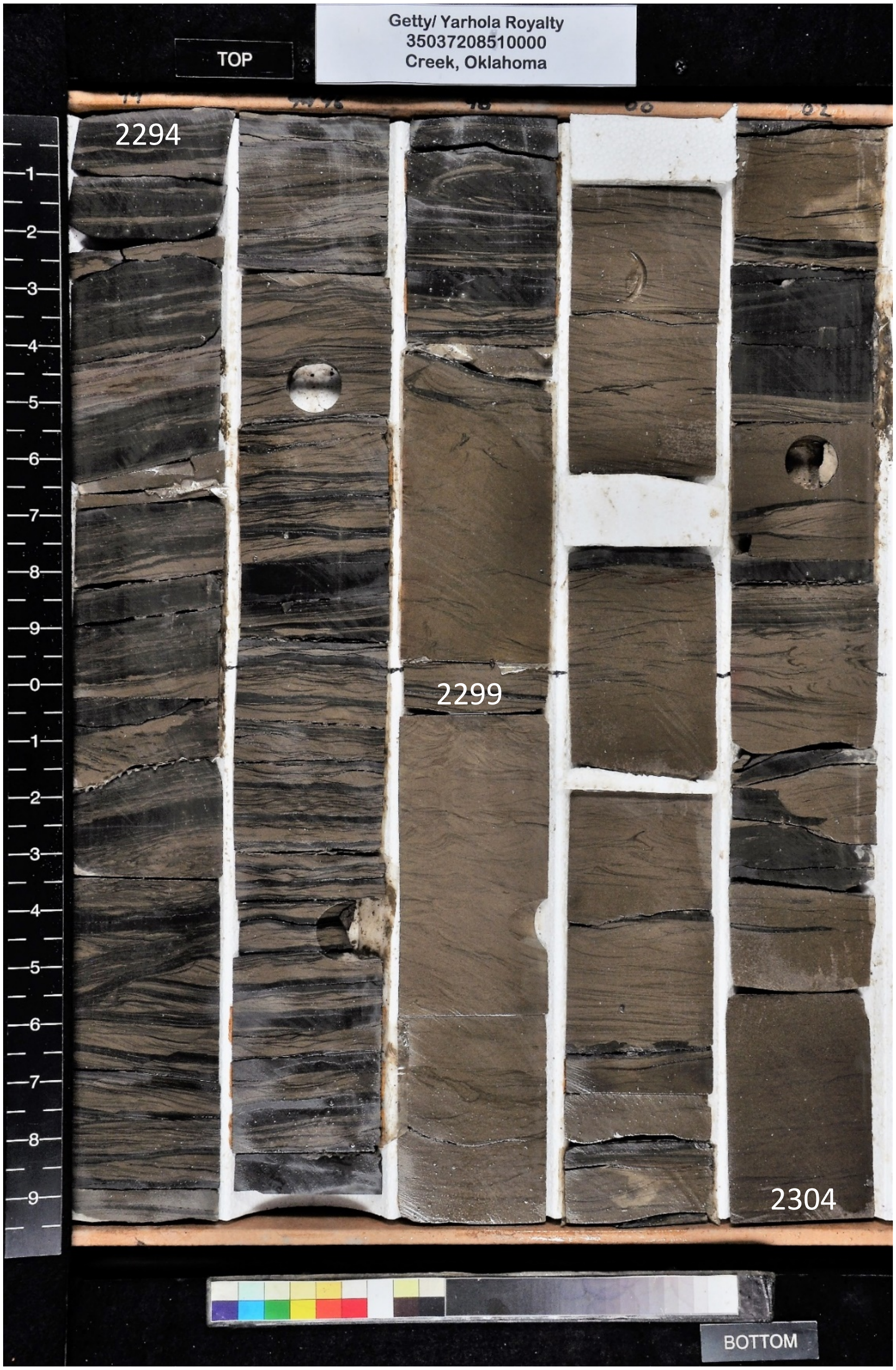
APPENDICES

APPENDIX A

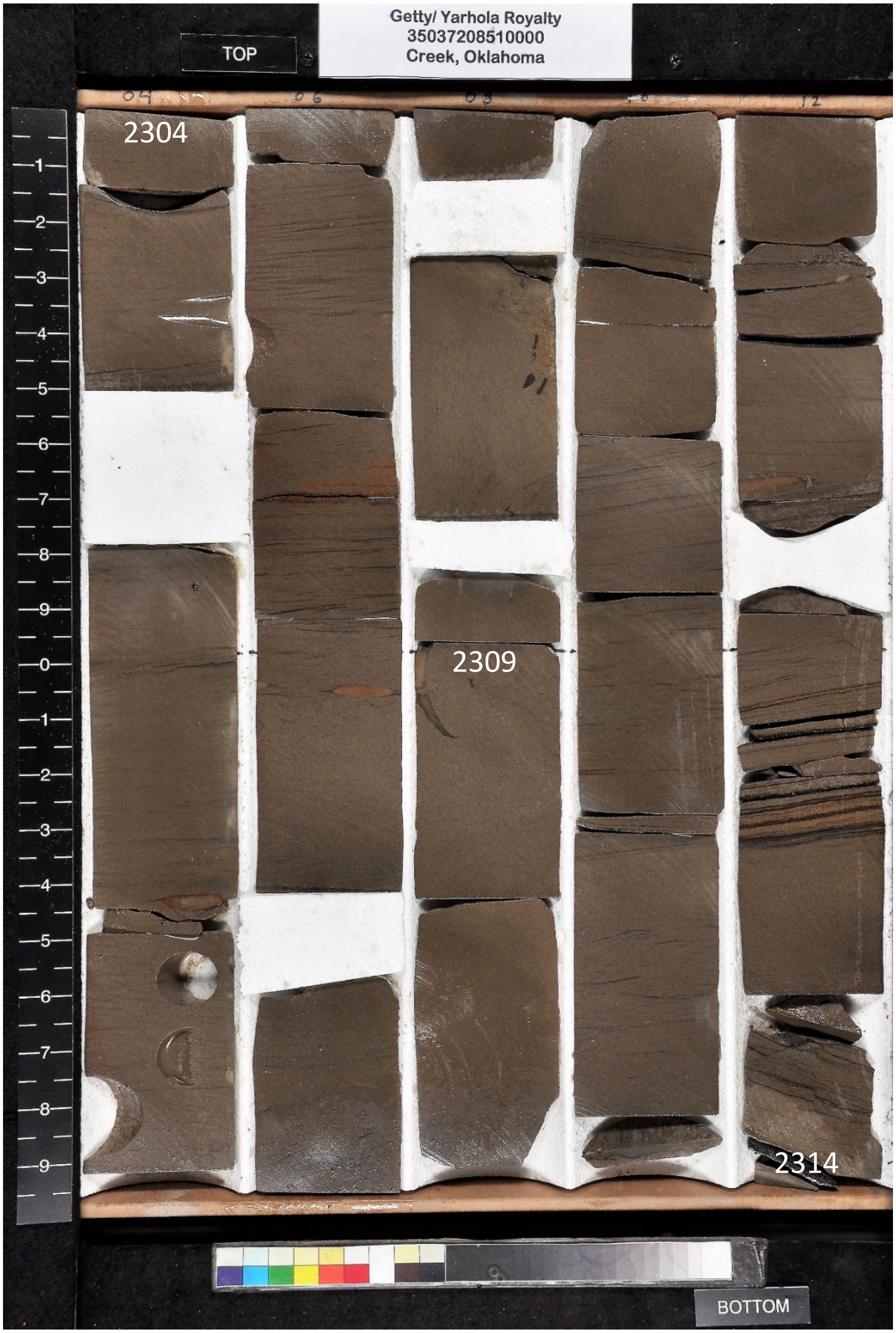
YARHOLA ROYALTY TR. 3 #25 CORE PHOTOGRAPHS

Getty Oil Company, Yarhola Royalty Unit Tr. 3 #25, Section 16, T17N, R7E, SE SW NE

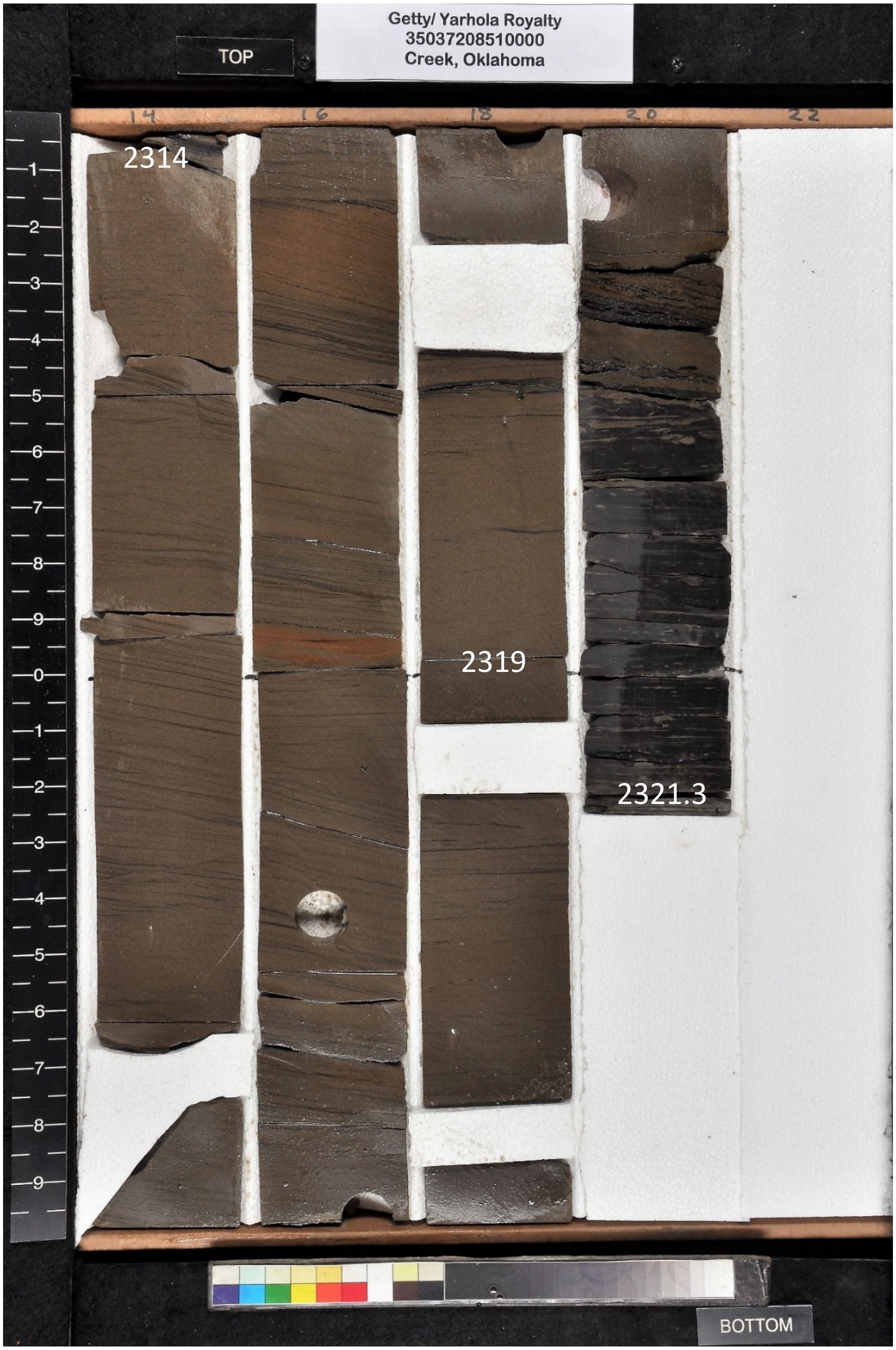




Slabbed core from the Yarhola Royalty Tr.3 #25 covering the interval from 2294 to 2304 feet.



Slabbed core from the Yarhola Royalty Tr. 3 #25 covering the interval from 2304 to 2314 feet.

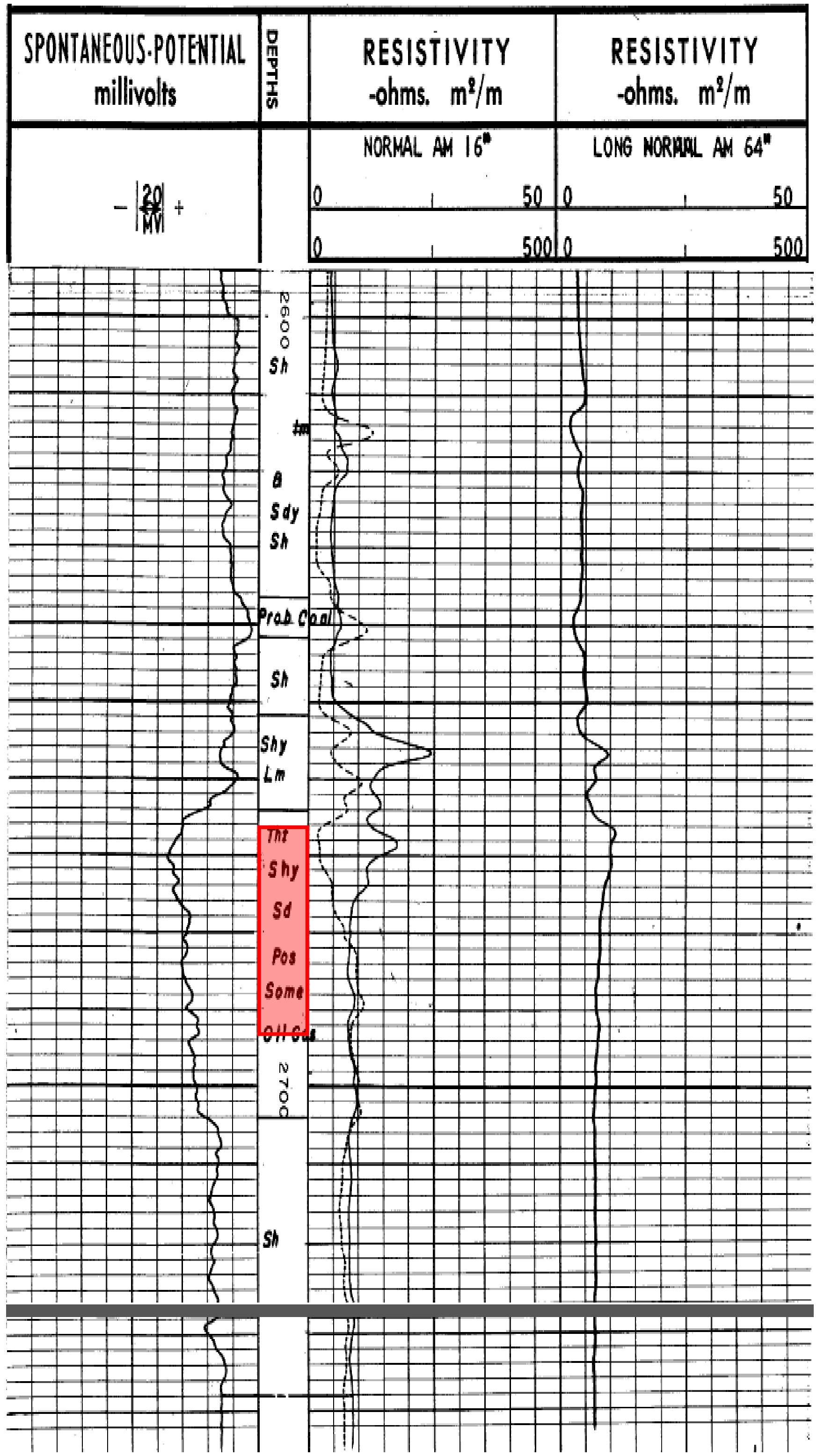


Slabbed core from the Yarhola Royalty Tr. 3 #25 covering the interval from 2314 to 2321.3 feet.

APPENDIX B

WATSON #1 CORE PHOTOGRAPHS

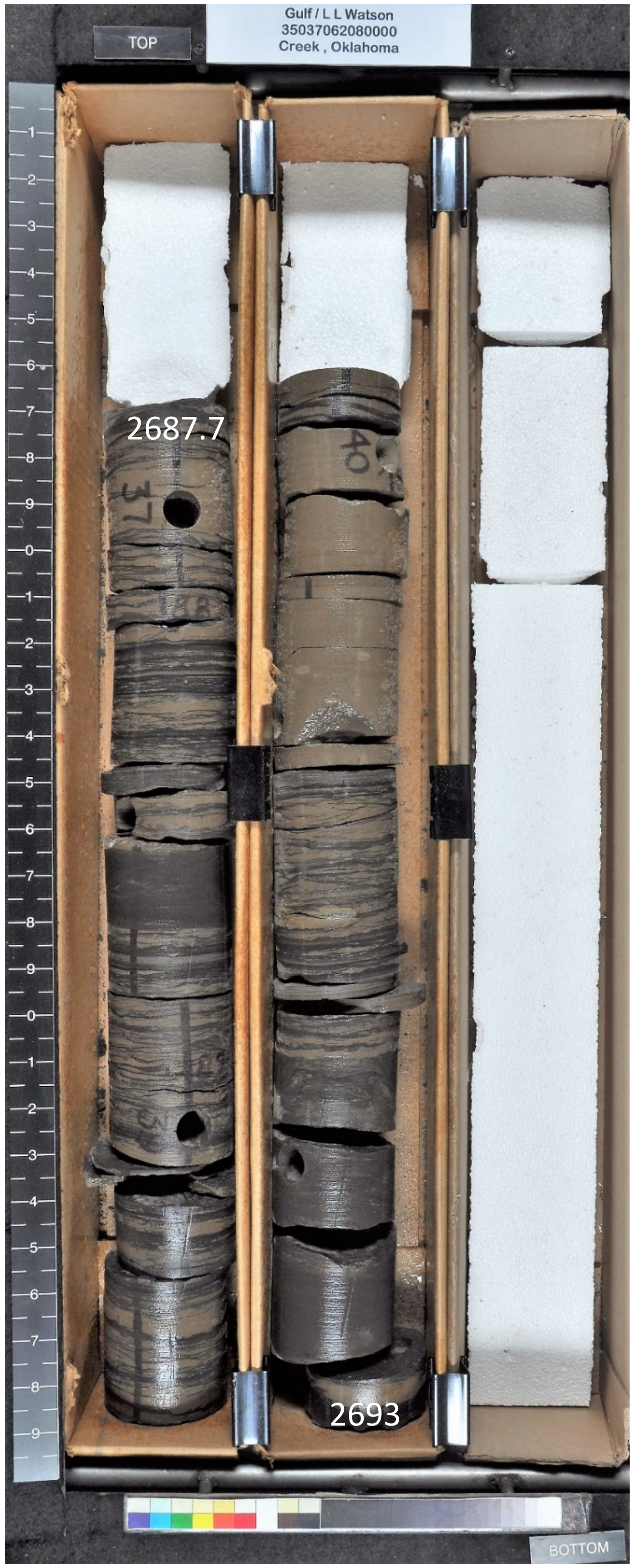
Gulf Oil Corp., Watson #1, Section 35, T16N, R8E, NW NW SW



Core from Watson #1 covering the interval from 2667.6 to 2673 feet.

Core from Watson #1 covering the interval from 2673.6 to 2681 feet.

Core from Watson #1 covering the interval from 2681.6 to 2687 feet.

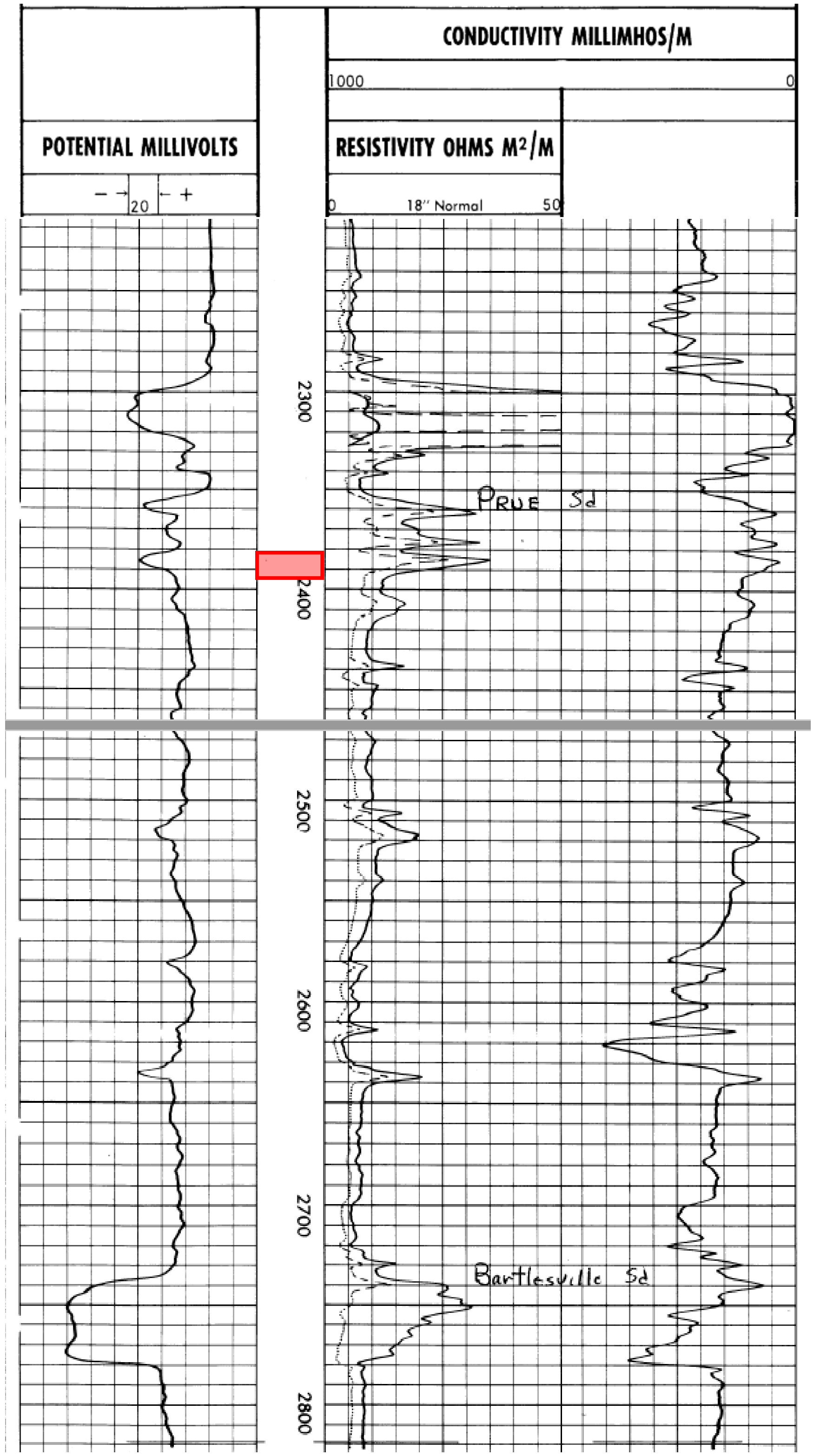


Core from Watson #1 covering the interval from 2687.7 to 2693 feet.

APPENDIX C

PETER BROWN #9 CORE PHOTOGRAPHS

Gulf Oil Corp., Peter Brown #9, Section 33, T17N, R7E, SW SE NE

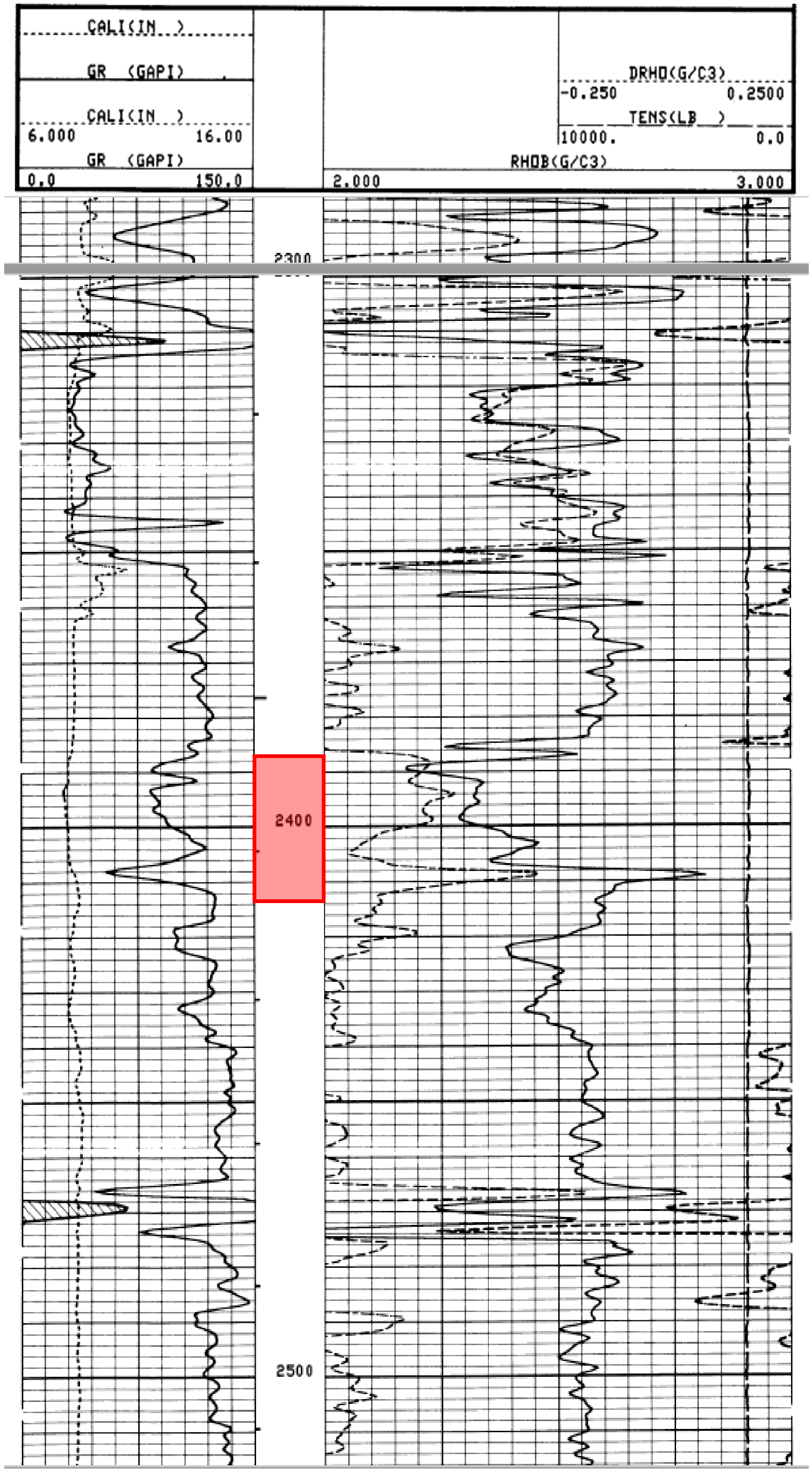


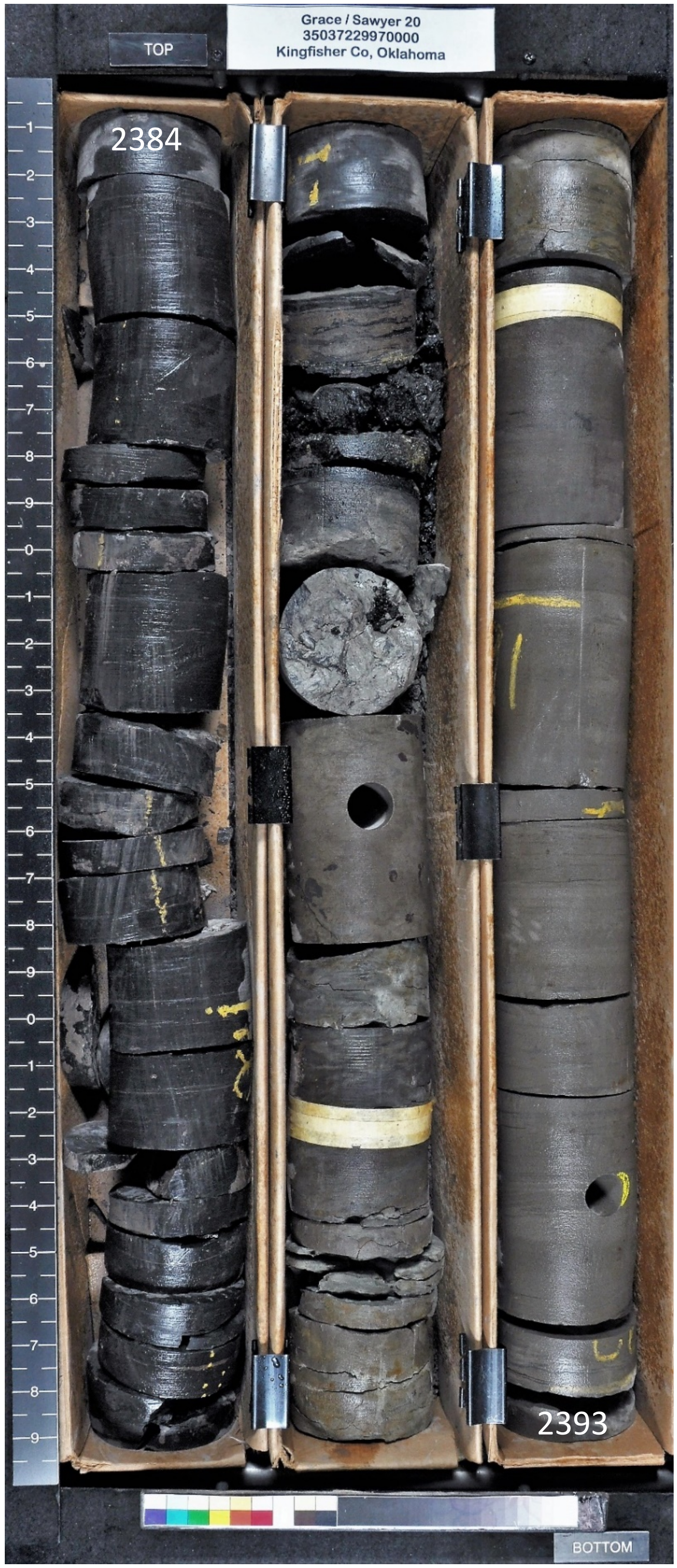
Entire slabbed core from Peter Brown #9 covering the interval from 2381 to 2392 feet.

APPENDIX D

SAM SAWYER #20 CORE PHOTOGRAPHS

Grace Petroleum Corp., Sam Sawyer #20, Section 22, T17N, R7E, NE SE SW





Core from Sam Sawyer #20 covering the interval from 2384 to 2393.

Core from Sam Sawyer #20 covering the interval from 2393 to 2402.

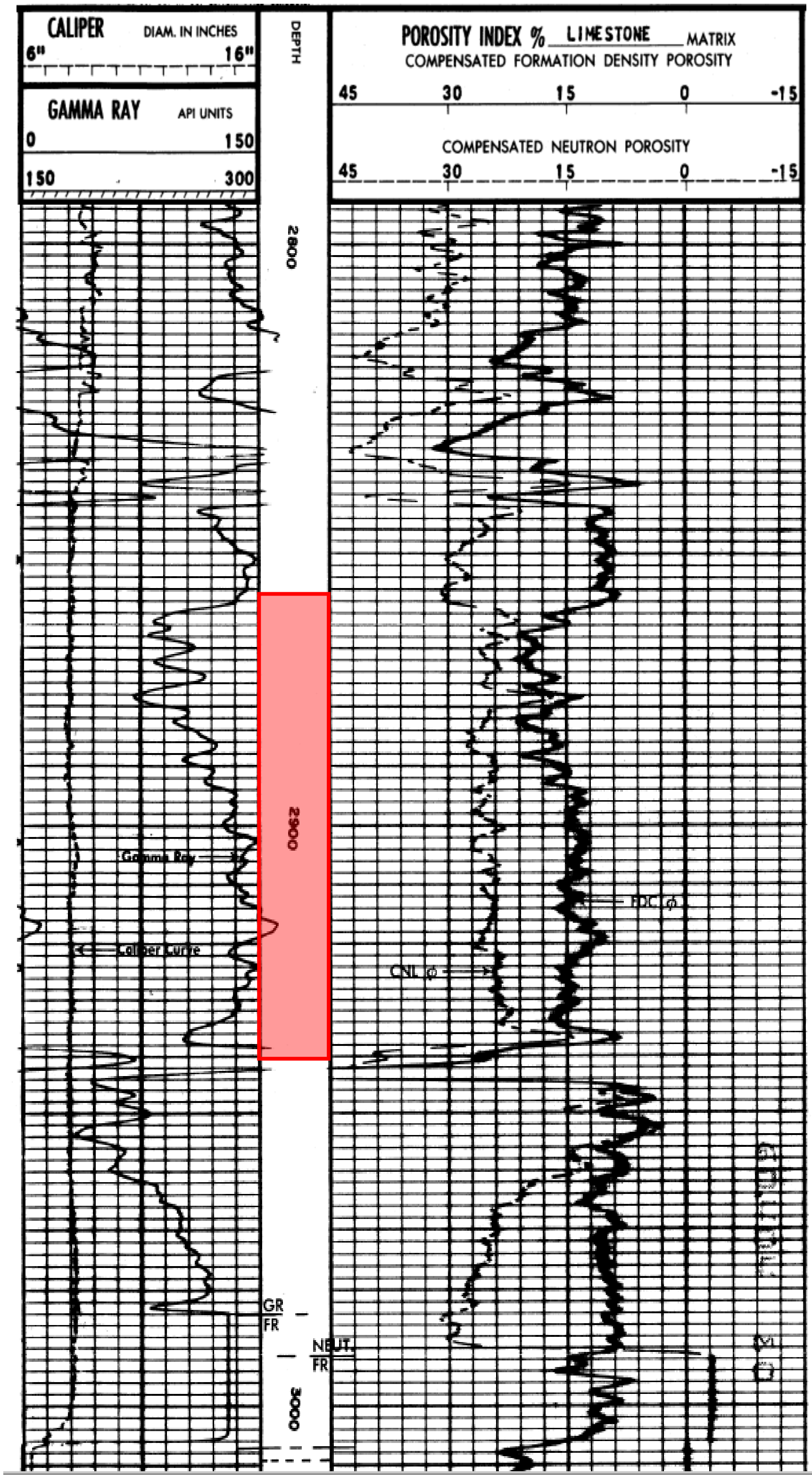
Core from Sam Sawyer #20 covering the interval from 2402 to 2411.

Core from Sam Sawyer #20 covering the interval from 2411 to 2414.

APPENDIX E

STROUD PRUE UNIT TR. #12-6 CORE PHOTOGRAPHS

Sun Production Comp., Stroud Prue Unit Tr. #12-6, Section 8, T14N, R7E, NW NW SE



Core from the Stroud Prue Unit Tr. #12-6 covering the interval from 2861 to 2870.

Core from the Stroud Prue Unit Tr. # 12-6 covering the interval from 2870 to 2879.

Core from the Stroud Prue Unit Tr. #12-6 covering the interval from 2879 to 2887.

Core from the Stroud Prue Unit Tr. #12-6 covering the interval from 2887 to 2896.

Core from the Stroud Prue Unit Tr. #12-6 covering the interval from 2896 to 2905.

Core from the Stroud Prue Unit Tr. #12-6 covering the interval from 2905 to 2914.

Core from the Stroud Prue Unit Tr. #12-6 covering the interval from 2914 to 2923.

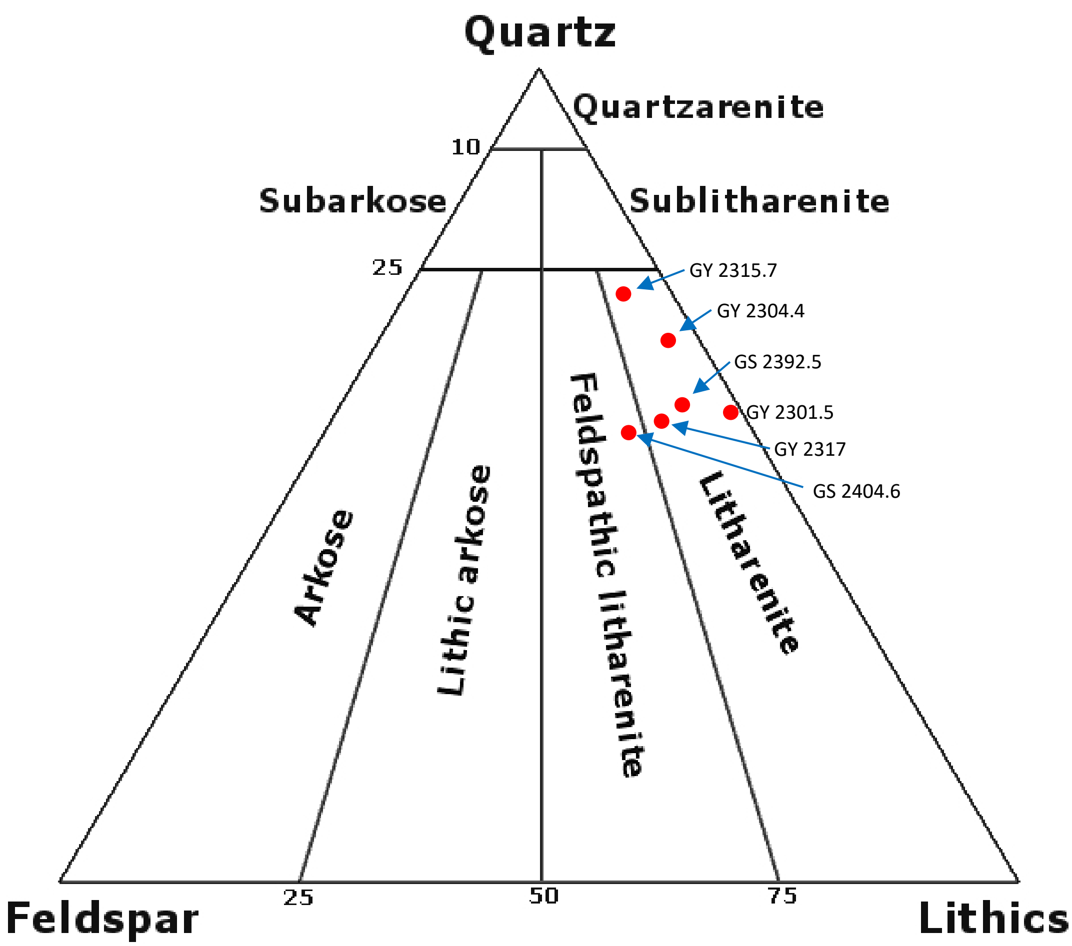
Core from the Stroud Prue Unit Tr. #12-6 covering the interval from 2923 to 2932.

Core from the Stroud Prue Unit Tr. #12-6 covering the interval from 2932 to 2941.

APPENDIX F

POINT COUNTS AND TERNARY DIAGRAM

Folk Classification



Folk classification ternary diagram showing the detrital composition of the Prue Sandstone in the study area.

GS 2392.5, Sam Sawyer #20

SANDSTONE PETROGRAPHY and DIAGENESIS

THIN SECTION NUMBER: GS 2392.5 PETROGRAPHER: Alexander Ahmadian
LOCATION: OSU DATE: 4-24-18

I. Detrital Constituents	%	Size mm (0.01 – 0.1 mm)	Remarks (Magnification 10x)
1. QUARTZ			
A. Monocrystalline: Main grain		0.02 – 0.1 mm	
B. Polycrystalline: A little more abundant		0.01 – 0.05 mm	
C.			
2. FELDSPAR			
A. Microcline			
B. Orthoclase			
C. Sanidine			
D. Plagioclase: Some		0.02 – 0.08 mm	
E.			
3. ROCK FRAGMENTS			
A. Shale			
B. Chert: Very little			
C. Sandstone			
D. Carbonate			
E. Siltstone			
F. Metamorphic: Very Abundant. Almost as much as quartz		0.04 – 0.14 mm	
G. Plutonic			
H. Volcanic			
I.			
J.			
4. OTHER GRAINS			
A. Glauconite: None here			
B. Shell Fragments			
1.			
2.			
3.			
C. Phosphate			
D. Muscovite: Very long bands, Very abundant throughout			
E. Biotite			
F. Pyrite			
G. Hematite			
H. Zircon			
I. Rutile			
J.			

II. Detrital Matrix	%	Size	Remarks
1. Clayey			
2. Silty			
3. Limy			
4. Other			

III. Diagenetic Constituents	%	Size	Remarks

1. Cement
   - A. Quartz
     1. Overgrowth A little more noticeable
     2.
   - B. Opal
   - C. Chalcedony
   - D. Feldspar
   - E. Carbonate
     1. Calcite
     2. Dolomite
     3. Siderite
   - F. Hematite
   - G. Limonite
   - H. Phosphate
   - I. Gypsum
   - J. Anhydrite
   - K. Barite
   - L. Pyrite
   - M.

2. Authigenic Clays
   - A. Kaolinite-Dickite Very little
   - B. Illite
   - C. Smectite
   - D. Chlorite
   - E. Mixed-layered
   - F.
3. Others
   - A. Zeolites
   - B.

IV. Porosity	%	Size	Remarks

1. Primary Little bit
2. Secondary Yes.
   - A. Moldic
   - B. Oversized
   - C. Micro (Intragrain)
3. Micro (Interclay)

V. Classification
1. Name
2. Plot on attached page

VI. Texture
1. Sphericity Sub angular to Angular
2. Sorting Well
3. Maturity
4. Very fine

VII. Description

Point Counting Table

	Qtz	Poly Quartz	Plag	Micro	Ortho	Gran RF	Sed RF	Met RF	Matrix P-Mat	Chert	Siderite	SiO_2	Calcite	Dol	Kaol	Glauc	Por ϕ	Sec ϕ	Musc
38.3			8.3				8.3	15	6.7						5			5	13.3
36.7		5							43.3		10							5	
30		16.7							31.7		10								11.7
50		8.3						5	16.7									13.3	1.6
40		6.7							45								3.3	5	
25			8.3				11.7		28.3		5				3.3			5	13.3
	132	25	10				12	12	103		15				5		2	20	23

	%	NORM. %
MATRIX:	28.6	
Q:	43.6	49.5
F:	2.8	3.2
R:	13.1	47.3
	88.1	100

GS 2404.6, Sam Sawyer #20

SANDSTONE PETROGRAPHY and DIAGENESIS

THIN SECTION NUMBER: GS 2404.6 PETROGRAPHER: Alex Ahmadian
LOCATION: OSU DATE: 4-27-18

I. Detrital Constituents	%	Size mm	Remarks
		0.02 - 0.1 mm	20 x mag
1. QUARTZ			
A. Monocrystalline Most abundant. Subangular		0.02 - 0.1 mm	
B. Polycrystalline Some in certain areas			
C.			
2. FELDSPAR			
A. Microcline			
B. Orthoclase			
C. Sanidine			
D. Plagioclase A little more abundant			
E.			
3. ROCK FRAGMENTS			
A. Shale			
B. Chert			
C. Sandstone			
D. Carbonate			
E. Siltstone			
F. Metamorphic Very abundant, Lots of muscovite also			
G. Plutonic			
H. Volcanic			
I.			
J.			
4. OTHER GRAINS			
A. Glauconite			
B. Shell Fragments			
1.			
2.			
3.			
C. Phosphate			
D. Muscovite Good amount			
E. Biotite			
F. Pyrite			
G. Hematite			
H. Zircon			
I. Rutile			
J.			

II. Detrital Matrix	%	Size	Remarks
1. Clayey			
2. Silty			
3. Limy			
4. Other			

III. Diagenetic Constituents | % | Size | Remarks

1. Cement
   - A. Quartz
     - 1. Overgrowth Abundant
     - 2.
   - B. Opal
   - C. Chalcedony
   - D. Feldspar
   - E. Carbonate
     - 1. Calcite Very little but it is present
     - 2. Dolomite
     - 3. Siderite
   - F. Hematite
   - G. Limonite
   - H. Phosphate
   - I. Gypsum
   - J. Anhydrite
   - K. Barite
   - L. Pyrite
   - M.
2. Authigenic Clays
   - A. Kaolinite-Dickite Less than other slides
   - B. Illite
   - C. Smectite
   - D. Chlorite
   - E. Mixed-layered
   - F.
3. Others
   - A. Zeolites
   - B.

IV. Porosity | % | Size | Remarks

1. Primary Some
2. Secondary Most abundant
   - A. Moldic Yes pretty abundant compared to others
   - B. Oversized
   - C. Micro (Intragrain)
3. Micro (Interclay)

V. Classification
1. Name
2. Plot on attached page

VI. Texture
1. Sphericity Subangular to angular
2. Sorting Well
3. Maturity
4. Very fine grained

VII. Description

Point Counting Table

Qtz	Poly Quartz	Plag	Micro	Ortho	Gran RF	Sed RF	Met RF	Matrix P-Mat	Chert	Siderite	SiO_2	Calcite	Dol	Kaol	Glauc	Por φ	Sec φ	Musc
56.7								26.6						3.3			3.3	
23.3		18.3						25						6.7			13.3	13.3
36.7							31.7										33.3	
23.3	15.3	28.3						18.3									11.7	
58.3								13.3				15					21.7	
55		16.6						16.6									11.7	
157	11	33					19	60				9		6			57	8

MATRIX: 16.7 %

Q: 46.7

F: 9.2

R: 7.5

NORM.

58.3 %

11.5

30.2

100 %

GY-25 2301.5, Yarhola Royalty #25

SANDSTONE PETROGRAPHY and DIAGENESIS

THIN SECTION NUMBER: GY 25 2301.5
LOCATION: OSU

PETROGRAPHER: Alexander Ahmadian
DATE: 4-27-18

I. Detrital Constituents	%	Size mm	Remarks
		0.02 - 0.1mm	Mag 20x
1. QUARTZ			
A. Monocrystalline Most abundant			
B. Polycrystalline More abundant than other thin sections			
C.			
2. FELDSPAR			
A. Microcline			
B. Orthoclase			
C. Sanidine			
D. Plagioclase Low Amount			
E.			
3. ROCK FRAGMENTS			
A. Shale			
B. Chert			
C. Sandstone			
D. Carbonate			
E. Siltstone			
F. Metamorphic Abundant			
G. Plutonic			
H. Volcanic			
I.			
J.			
4. OTHER GRAINS			
A. Glauconite			
B. Shell Fragments			
1.			
2.			
3.			
C. Phosphate			
D. Muscovite Less than other thin sections			
E. Biotite			
F. Pyrite			
G. Hematite			
H. Zircon			
I. Rutile			
J.			

II. Detrital Matrix	%	Size	Remarks
1. Clayey			
2. Silty			
3. Limy			
4. Other			

III. Diagenetic Constituents	%	Size	Remarks
1. Cement			
A. Quartz			
1. Overgrowth Very abundant			
2.			
B. Opal			
C. Chalcedony			
D. Feldspar			
E. Carbonate			
1. Calcite			
2. Dolomite			
3. Siderite			
F. Hematite			
G. Limonite			
H. Phosphate			
I. Gypsum			
J. Anhydrite			
K. Barite			
L. Pyrite			
M.			
2. Authigenic Clays			
A. Kaolinite-Dickite Low Amount			
B. Illite			
C. Smectite			
D. Chlorite			
E. Mixed-layered			
F.			
3. Others			
A. Zeolites			
B.			

IV. Porosity	%	Size	Remarks
1. Primary Some			
2. Secondary Very Abundant			
A. Moldic			
B. Oversized			
C. Micro (Intragrain) Very abundant			
3. Micro (Interclay)			

V. Classification
1. Name
2. Plot on attached page

VI. Texture
1. Sphericity Subangular
2. Sorting Well
3. Maturity
4.

VII. Description

Point Counting Table

	Qtz	Poly Quartz	Plag	Micro	Ortho	Gran RF	Sed RF	Met RF	Matrix P-Mat	Chert	Siderite	SiO_2	Calcite	Dol	Kaol	Glauc	Por ϕ	Secϕ	Musc
33.3		20					11.7	3.3			15						8.3		6.7
46.7								36.7			13.3							3.3	
53.3									36.7							5			5
53.3	53.3								25		15							6.7	8.3
28.3		8.3							35		16.6							11.7	
46.7								28.3									3.3	21.7	
	157	17					7	41	58		36					3	7	26	12

		NORM.
MATRIX:	16.1 %	
Q:	48.3	59.6 %
F:	0	0.0
R:	16.7	40.4
	81.1	100 %

<u>GY-25 2304.4, Yarhola Royalty #25</u>

SANDSTONE PETROGRAPHY and DIAGENESIS

THIN SECTION NUMBER: GY 25 2304.4
LOCATION: OSU

PETROGRAPHER: Alex Ahmadian
DATE: 4-27-18

I. Detrital Constituents	%	Size mm	Remarks
		0.02 - 0.1mm	

1. QUARTZ
   - A. Monocrystalline Most abundant
   - B. Polycrystalline More abundant than other thin sections
   - C.
2. FELDSPAR
   - A. Microcline
   - B. Orthoclase
   - C. Sanidine
   - D. Plagioclase Very little
   - E.
3. ROCK FRAGMENTS
   - A. Shale
   - B. Chert
   - C. Sandstone
   - D. Carbonate
   - E. Siltstone
   - F. Metamorphic Abundant
   - G. Plutonic
   - H. Volcanic
   - I.
   - J.
4. OTHER GRAINS
   - A. Glauconite
   - B. Shell Fragments
     1.
     2.
     3.
   - C. Phosphate
   - D. Muscovite Less than other thin sections but still present
   - E. Biotite
   - F. Pyrite
   - G. Hematite
   - H. Zircon
   - I. Rutile
   - J.

II. Detrital Matrix	%	Size	Remarks

1. Clayey
2. Silty
3. Limy
4. Other

III. Diagenetic Constituents	%	Size	Remarks

1. Cement
   - A. Quartz
     1. Overgrowth Very abundant
     2.
   - B. Opal
   - C. Chalcedony
   - D. Feldspar
   - E. Carbonate
     1. Calcite
     2. Dolomite
     3. Siderite
   - F. Hematite
   - G. Limonite
   - H. Phosphate
   - I. Gypsum
   - J. Anhydrite
   - K. Barite
   - L. Pyrite
   - M.
2. Authigenic Clays
   - A. Kaolinite-Dickite Little
   - B. Illite
   - C. Smectite
   - D. Chlorite
   - E. Mixed-layered
   - F.
3. Others
   - A. Zeolites
   - B.

IV. Porosity	%	Size	Remarks

1. Primary Some
2. Secondary Very
   - A. Moldic
   - B. Oversized
   - C. Micro (Intragrain) Very abundant
3. Micro (Interclay)

V. Classification
1. Name
2. Plot on attached page

VI. Texture
1. Sphericity Subangular
2. Sorting Well
3. Maturity
4.

VII. Description

Point Counting Table

	Qtz	Poly Quartz	Plag	Micro	Ortho	Gran RF	Sed RF	Met RF	Matrix P-Mat	Chert	Siderite	SiO_2	Calcite	Dol	Kaol	Glauc	Por ϕ	Sec ϕ	Musc
83.3								5										11.6	
45								30					11.6		3.3			10	
58.3								16.7	13.3							3.3		8.3	
53.3								11.7	23.3	10								1.7	
20		28.3	13.3						23.3									8.3	6.7
48.3		8.3						16.7	11.7				15						
	185	22	8					48	43	6			17		2	2		24	4
								13.3	11.9	1.7			4.7		.06	.06		6.7	1.1

MATRIX: 6.1 11.9 2.2 % NORM.

51.4 Q: 57.5 66.8 %

F: 6.1 2.6

R: 13.3 30.6

88.8 100 %

GY-25 2315.7, Yarhola Royalty #25

SANDSTONE PETROGRAPHY and DIAGENESIS

THIN SECTION NUMBER: GY-25 2315.7
LOCATION: OSU

PETROGRAPHER: Alexander Ahmadian
DATE: 4-24-18

0.04 - 0.1 mm   Magnification 10x

I. Detrital Constituents	%	Size mm	Remarks

1. QUARTZ
   - A. Monocrystalline Subangular to angular. Most abundant grain. 0.04 - 0.1 mm
   - B. Polycrystalline Rare. Subangular to angular 0.02 - 0.05 mm
   - C.
2. FELDSPAR
   - A. Microcline Small amounts. Twinning. 0.04 - 0.08 mm
   - B. Orthoclase
   - C. Sanidine
   - D. Plagioclase Most abundant feldspar. 0.04 - 0.1 mm angular
   - E.
3. ROCK FRAGMENTS
   - A. Shale
   - B. Chert Small amounts. 0.02 - 0.06 mm
   - C. Sandstone
   - D. Carbonate
   - E. Siltstone
   - F. Metamorphic Abundant. 0.04 - 0.14 mm
   - G. Plutonic
   - H. Volcanic
   - I.
   - J.
4. OTHER GRAINS
   - A. Glauconite 2 small grains 0.01 - 0.02 mm
   - B. Shell Fragments
     1.
     2.
     3.
   - C. Phosphate
   - D. Muscovite Long bands Abundant
   - E. Biotite
   - F. Pyrite
   - G. Hematite
   - H. Zircon
   - I. Rutile
   - J.

II. Detrital Matrix	%	Size	Remarks

1. Clayey Kaolinite filling pores
2. Silty
3. Limy
4. Other

III. Diagenetic Constituents | % | Size | Remarks

1. Cement
   - A. Quartz
     - 1. Overgrowth Some
     - 2.
   - B. Opal
   - C. Chalcedony
   - D. Feldspar
   - E. Carbonate
     - 1. Calcite
     - 2. Dolomite
     - 3. Siderite
   - F. Hematite
   - G. Limonite
   - H. Phosphate
   - I. Gypsum
   - J. Anhydrite
   - K. Barite
   - L. Pyrite
   - M.
2. Authigenic Clays
   - A. Kaolinite-Dickite Yes. Abundant
   - B. Illite
   - C. Smectite
   - D. Chlorite
   - E. Mixed-layered
   - F.
3. Others
   - A. Zeolites
   - B.

IV. Porosity | % | Size | Remarks

1. Primary Didn't find any
2. Secondary ✓
   - A. Moldic ✓
   - B. Oversized ✓
   - C. Micro (Intragrain) ✓
3. Micro (Interclay) ✓

V. Classification
1. Name
2. Plot on attached page

VI. Texture
1. Sphericity Subangular to Angular
2. Sorting Well
3. Maturity
4. Very fine grained

VII. Description

Point Counting Table

Qtz	Poly Quartz	Plag	Micro	Ortho	Gran RF	Sed RF	Met RF	Matrix P-Mat	Chert	Siderite	SiO_2	Calcite	Dol	Kaol	Glauc	Por ϕ	Sec ϕ	Musc
43.3								23.3		33.3								
26.6	5	3.3						16.7		20				18.3	3.3		8.3	
46.7	6.7	13.3						6.7		11.7				1.7			5	
55	5						10			13.3				3.3			3.3	11.7
63.3	3.3								3.3	21.7							6.7	1.7
45			11.7					16.7		10				10			1.7	5
168	12	10	7				6	38	2	66				20			15	10

		NORM.
MATRIX:	10.6 %	
Q:	50	71.7 %
F:	4.7	6.8
R:	4.4	21.5
	69.7	100 %

GY-25 2317, Yarhola Royalty #25

SANDSTONE PETROGRAPHY and DIAGENESIS

THIN SECTION NUMBER: GY 25 2317 PETROGRAPHER: Alexander Ahmadian
LOCATION: OSU DATE: 4-27-18

I. Detrital Constituents	%	Size mm	Remarks
		0.04-0.1 mm	Mag 20x
1. QUARTZ			
A. Monocrystalline	Most abundant	0.02-0.08 mm	
B. Polycrystalline	A little more abundant	0.02-0.5 mm	
C.			
2. FELDSPAR			
A. Microcline	Didn't find		
B. Orthoclase			
C. Sanidine			
D. Plagioclase	Some	0.04-0.08 mm	
E.			
3. ROCK FRAGMENTS			
A. Shale			
B. Chert			
C. Sandstone			
D. Carbonate			
E. Siltstone			
F. Metamorphic	More abundant, High in muscovite		
G. Plutonic			
H. Volcanic			
I.			
J.			
4. OTHER GRAINS			
A. Glauconite			
B. Shell Fragments			
1.			
2.			
3.			
C. Phosphate			
D. Muscovite	Quite a bit. Long bands		
E. Biotite			
F. Pyrite			
G. Hematite			
H. Zircon			
I. Rutile			
J.			

II. Detrital Matrix	%	Size	Remarks
1. Clayey			
2. Silty			
3. Limy			
4. Other			

III. Diagenetic Constituents | % | Size | Remarks

1. Cement
   - A. Quartz
     - 1. Overgrowth Some
     - 2.
   - B. Opal
   - C. Chalcedony
   - D. Feldspar
   - E. Carbonate
     - 1. Calcite Started to see in spots. Not completely surrounding grains but apparent
     - 2. Dolomite
     - 3. Siderite
   - F. Hematite
   - G. Limonite
   - H. Phosphate
   - I. Gypsum
   - J. Anhydrite
   - K. Barite
   - L. Pyrite
   - M.

2. Authigenic Clays
   - A. Kaolinite-Dickite Some filling pores
   - B. Illite
   - C. Smectite
   - D. Chlorite
   - E. Mixed-layered
   - F.

3. Others
   - A. Zeolites
   - B.

IV. Porosity | % | Size | Remarks

1. Primary
2. Secondary More abundant but still low
   - A. Moldic
   - B. Oversized
   - C. Micro (Intragrain)
3. Micro (Interclay)

V. Classification
1. Name
2. Plot on attached page

VI. Texture
1. Sphericity Subangular to angular
2. Sorting well
3. Maturity
4. Very very fine grained

VII. Description

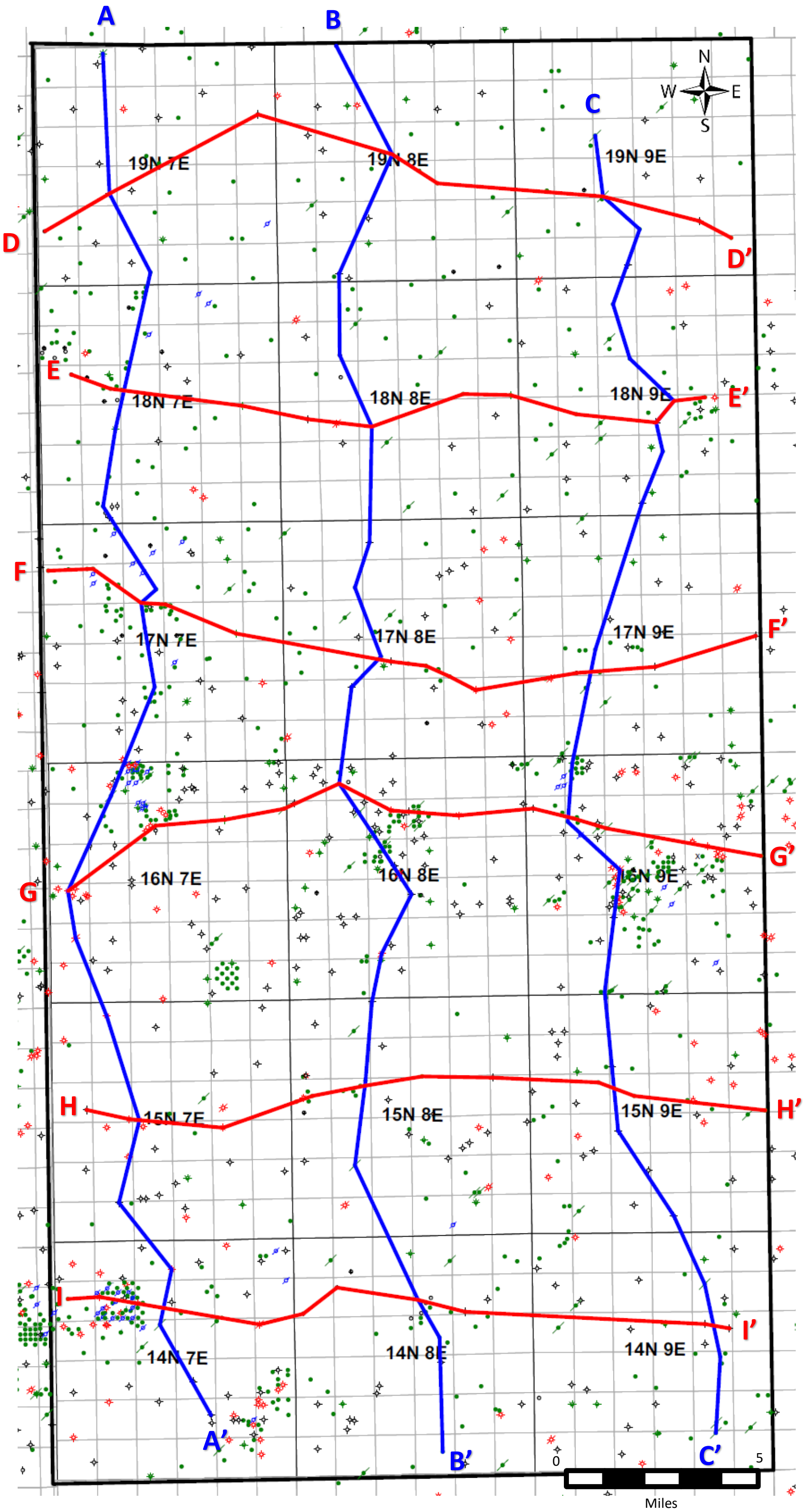
Point Counting Table

Qtz	Poly Quartz	Plag	Micro	Ortho	Gran RF	Sed RF	Met RF	Matrix P-Mat	Chert		SiO_2	Calcite	Dol	Kaol		Por ϕ	Secϕ
55								38.3									6.7
33.3							46.7	11.7						5			3.3
6.7		18.3						10									5
	31.7	21.7						5				33.3		1.7			6.7
55.3								8.3						20			13.3
33.3	20							46.7									
148	31	24					28	72				20		16			21

		NORM.
MATRIX:	20.6 %	
Q:	49.7	59.1 %
F:	6.7	7.9
R:	7.8	33
	84.8	100 %

APPENDIX G

PLATES/CROSS SECTIONS


A
B
C
N
W
E
S
19N 7E
19N 8E
19N 9E
D
D'
E
18N 7E
18N 8E
18N 9E
E'
F
17N 7E
17N 8E
17N 9E
F'
G
16N 7E
16N 8E
16N 9E
G'
H
15N 7E
15N 8E
15N 9E
H'
I
14N 7E
14N 8E
14N 9E
I'
A'
B'
C'
0
5
Miles

A

A-A'

A'

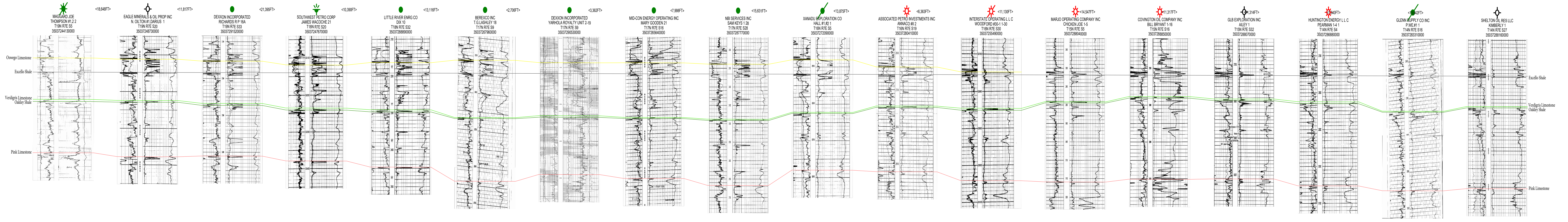


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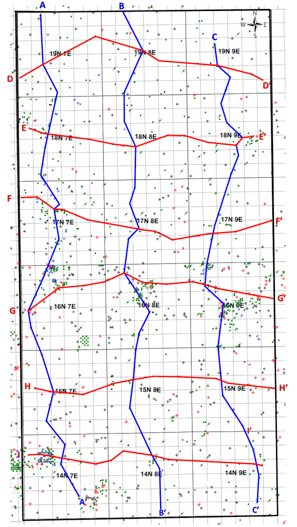
Plate 1



B B-B' B'

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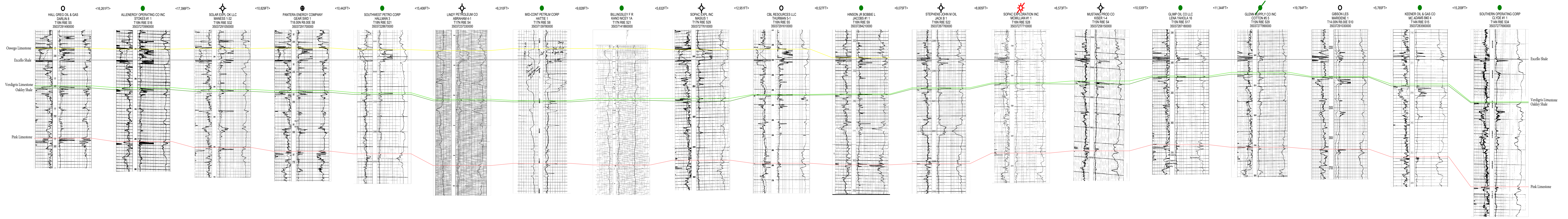

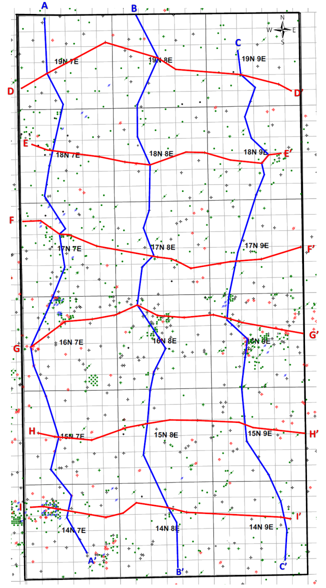

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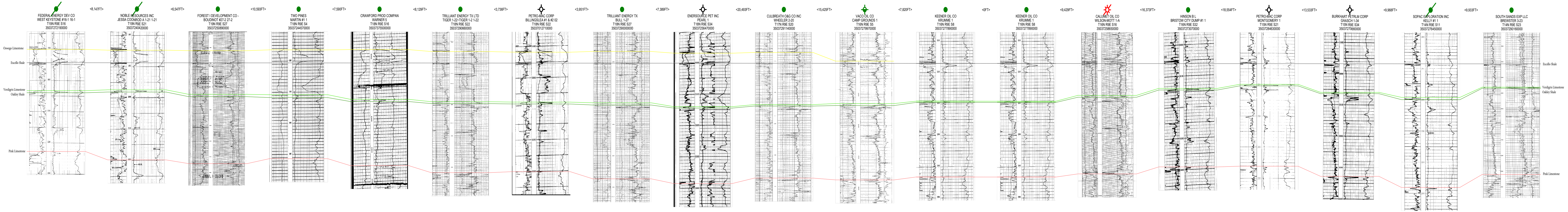
C-C'

C

C'



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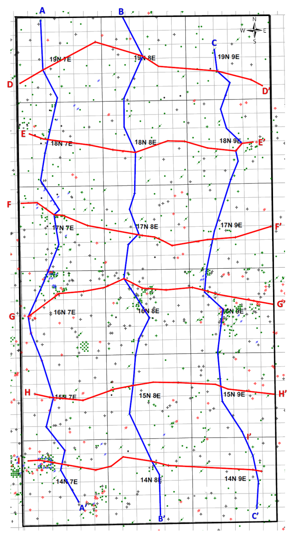

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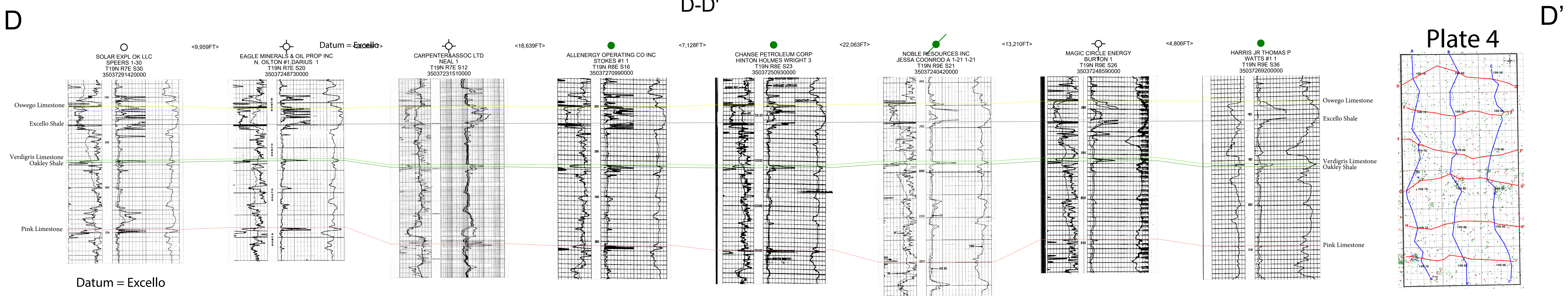

D
D-D'
D'
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N. OILTON #1,DARIUS 1
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CARPENTER&ASSOC LTD
NEAL 1
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BURTON 1
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WATTS #1 1
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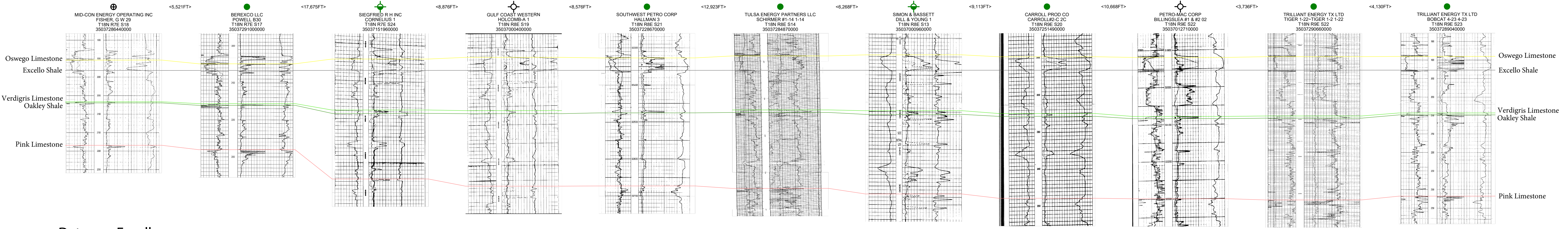
E-E'

E

E'



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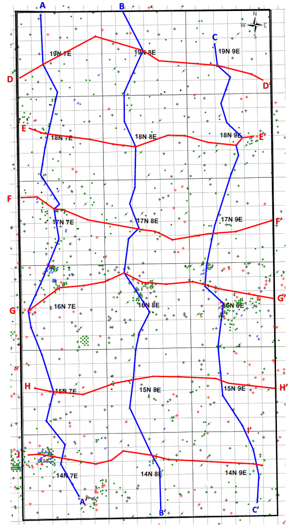

F

F-F'

F’

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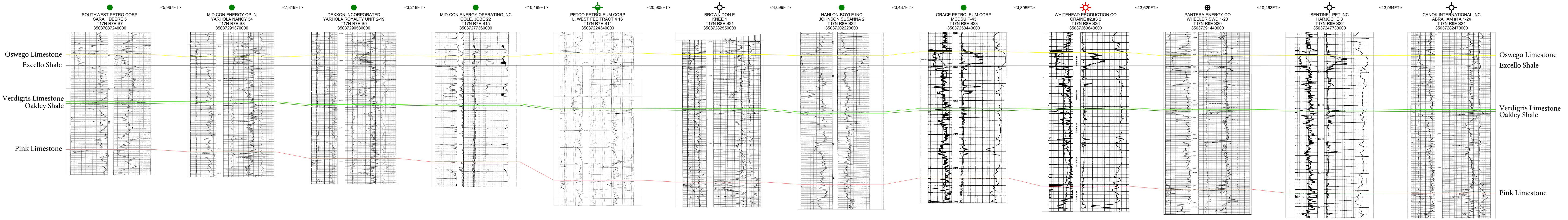

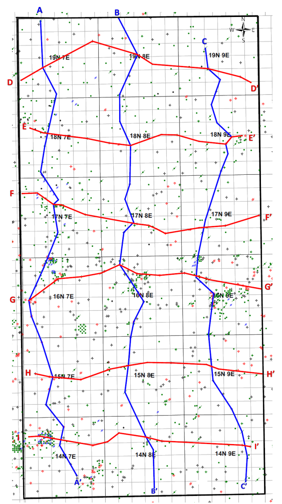

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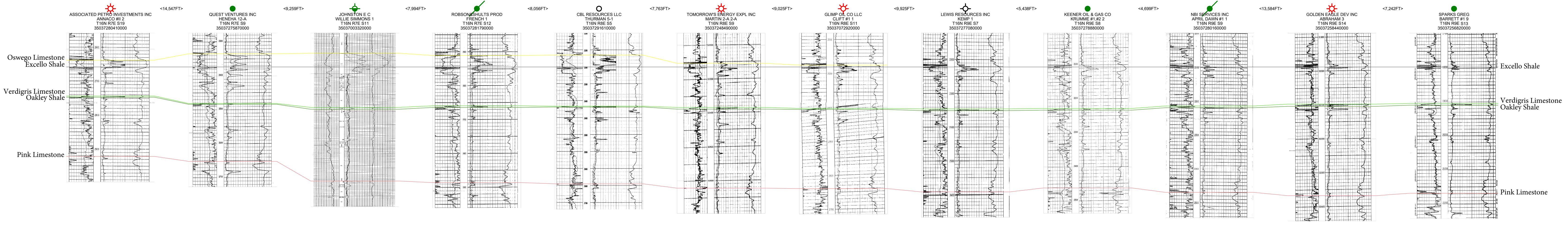
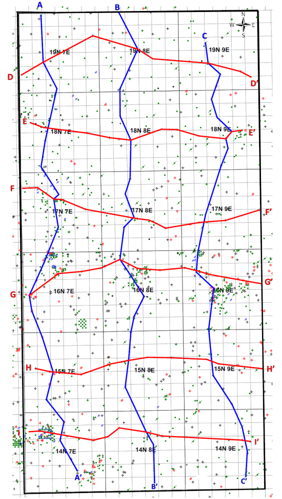
G-G'

G

G'

Plate 7





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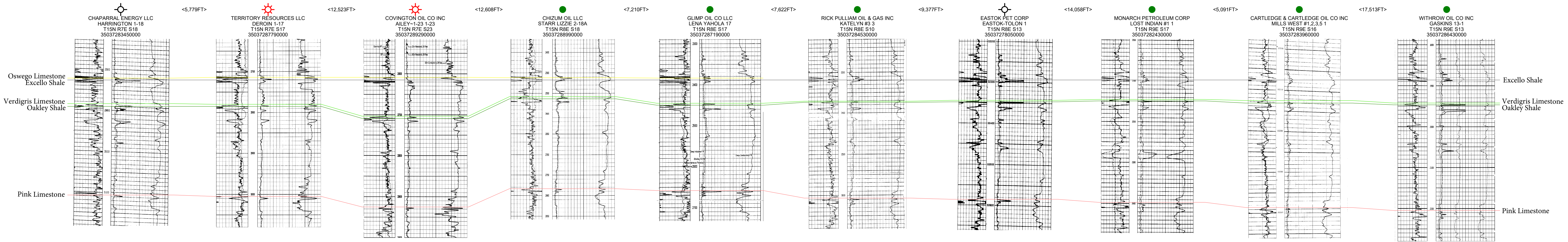
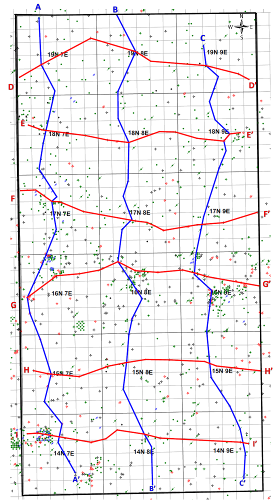
H

H-H'

H’

Plate 8





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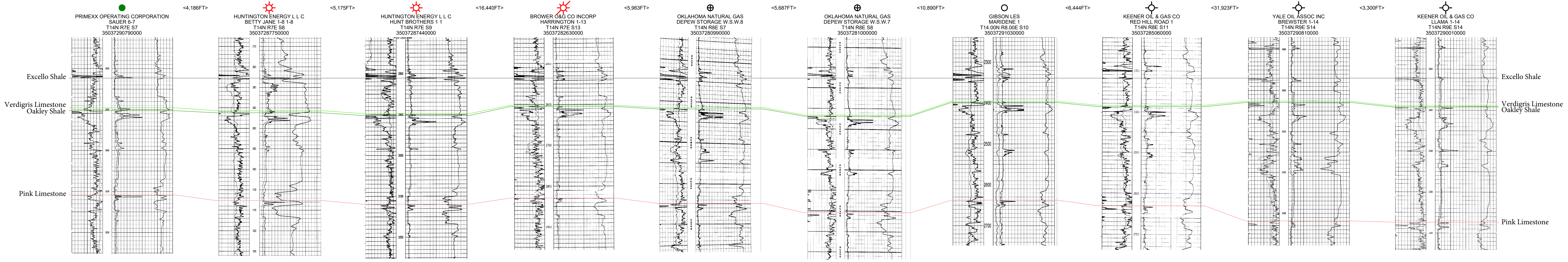
I-I'

I

I'



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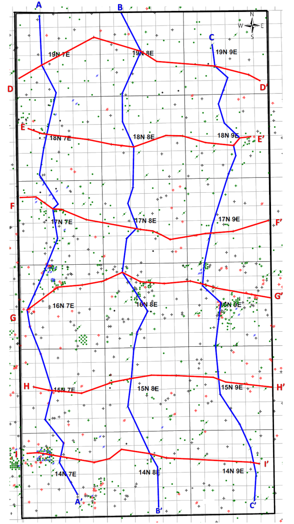

VITA

Alexander Joshua Ahmadian

Candidate for the Degree of

Master of Science

Thesis: SEQUENCE STRATIGRAPHIC EVALUATION OF THE PRUE SANDSTONE IN CREEK COUNTY, OKLAHOMA

Major Field: Geology

Biographical:

Education:

Completed the requirements for the Master of Science in Geology at Oklahoma State University, Stillwater, Oklahoma in December, 2019.

Completed the requirements for the Bachelor of Science in Geology at the University of Oklahoma, Norman, Oklahoma in 2012.

Experience:

Field Geologist for Nomac Services, March 2013 to October 2014
Field Camp Teaching Assistant at Oklahoma State University, Summer 2018
Geosteering Geologist for Hoss Geosciences, November 2018 to Present
Formation Analyst for Hoss Consulting Services, October 2019 to Present

Professional Memberships:

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Geological Society of America (GSA)
Oklahoma City Geological Society (OCGS)
Society of Petrophysicists and Well Log Analysts (SPWLA)
Tulsa Geological Society (TGS)