Analysis of Lithofacies and Producing Zones in the J&J (Caddo) Field, Nolan County, West Texas

M.S. in Geoscience Final Project

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ABSTRACT

Nolan County is an oil and gas producing county in north central Texas. Major oil and gas reserves in this region are produced from reservoirs of Permian, Pennsylvanian, and Ordovician age. Pennsylvanian-age reservoirs consist mainly of Lower to Middle Desmoinesian units, including the Caddo Limestone, Odom Limestone and Strawn reefs, along with some Strawn, Canyon, and Cisco sands. This study describes the stratigraphic units and oil and gas production in a portion of NE Nolan County, Texas, including an analysis of the Caddo Limestone oil reservoir from the J&J Field. The Caddo Limestone studied here is from a conventional core within field, described using petrographic analysis through optical microscopy techniques. The Caddo oil reservoir in the J&J Field is placed in a stratigraphic context via construction of a detailed geologic cross-section using the available wire-line logs utilizing Petra software. Results from this work provide insight into Caddo oil reservoir with broader implications for finding analog production in other areas of the Eastern Shelf.

I. BACKGROUND

The Permian Basin of west Texas and SE New Mexico is the largest petroleum-producing basin of the United States, with a cumulative oil production of nearly 40 billion barrels (Bbbl; Ruppel, 2019). Oil and gas reservoirs in the Permian Basin range from Ordovician to Permian age. Over 70% of oil production is from Permian reservoirs, specifically middle Permian Guadalupian (54%) and lower Permian Leonardian (18%); Pennsylvanian-aged reservoirs comprise approximately 13% of cumulative production, (~3.8 Bbbl), and is the third largest producing zone (Dutton et al. 2005).

Nolan County is located on the western side of the Eastern Shelf adjacent to the Midland Basin, directly west of the city of Abilene (Figure 1). It is bordered by Mitchell County to the west, Fisher County to the north, Taylor County to the east, and Coke County to the south. Nolan County is square in shape, with dimensions of approximately 30 mi x 30 mi. According to the Enverus data base, a total of 4999 wells have been drilled in Nolan County for production of oil and gas or for use as salt-water injection or disposal.

Oil and gas production in Nolan County is dominated by conventional reservoirs of Pennsylvanian to early Permian (Strawn, Canyon, Cisco) and Ordovician (Ellenburger) age. Pennsylvanian-age reservoirs are most numerous (Figures 2 and 3). Drilling and production from these intervals continue today. Some notable oil and gas fields include Nena Lucia, Lake Trammel, Lake Sweetwater, White Flat, and many smaller fields. Main reservoir targets include carbonate bioherms primarily composed of phylloid algae, but there are also large sandstone fields in the area. These carbonates and sandstones are excellent oil and gas producers in part because they are encased organic-rich shales (Wright, 2020; Harris, et al. 1990).

II. PURPOSE AND OBJECTIVES

This study has two main objectives. The first is to better understand lower Strawn lithofacies, specifically the Caddo Formation, based on study of two conventional core samples from the R.L. Foree #2 Aycock well, Section 58, Block 21, T&P RR Co. Survey, API # 42-353-31237 (Fig. 2). These core samples were studied petrographically utilizing an optical microscope together with petrographic thin sections. The Caddo Formation constitutes the stratigraphic base of many carbonate buildups such as in the Nena Lucia and White Flat fields which are some of the biggest fields in Nolan County.

The second objective is to use available wire-line log data to better understand the structural and stratigraphic nature of the Caddo producing zone in J&J Field. In this manner, the producing zone for the J&J Field can be compared with other major fields in the region such as Nena Lucia, White Flat and Lake Sweetwater. A better understanding of the structural-stratigraphic nature of the Caddo Limestone in NE Nolan County will hopefully aid in future exploration and producing efforts within the Eastern Shelf region.

III. GEOLOGIC SETTING

The Permian Basin (Figure 4) has a complex tectonic and geologic history. This includes a precursor intracratonic basin known as the Tobosa Basin, which was tectonically differentiated during Early Pennsylvanian time into the Delaware and Midland basins. Other structures include the Diablo Platform, Central Basin Platform, Eastern Shelf, Ozona Uplift, and the Marathon - Ouachita fold and thrust belt. These features largely result from tectonic movements associated with assembly of the Pangea supercontinent. Pennsylvanian to Early Permian stratigraphic units in the region are the product of the long-term transgression of an epeiric seaway and superimposed short-term changes in sea level during the Pennsylvanian to Early Permian due to glaciation of Gondwana. This resulted in icehouse climate-driven depositional sequences (cyclothems).

Cyclothems were first recognized in Pennsylvanian rocks in the 1930's and were associated with Gondwana's glacial eustatic fluctuations of sea level (Wanless and Shepard,1936). Even though a glacial-eustatic origin of cyclothems was challenged, this explanation is now largely accepted (Heckel 1994, 2002, 2008). Cyclothem sequences vary by location, but in most cases consist of alternating marine and terrestrial strata separated from younger and older cyclothems by terrestrial strata that include paleosols (Figure 5; Joeckel 1994, 1999, Heckel 2008). The development of paleosols indicates rapid regression of sea level at a rate that is compatible with glacial drawdown (Heckel, 1994, 2008). Support for this interpretation is provided by diagenetic patterns in limestones (Heckel 1983), including decreasing porosity going down each cycle with the highest porosity at the top due to micro-karsting.

Cyclothems are commonly divided into four different facies system tracts: transgressive (during large-scale glacial melting), highstand (during interglacial periods), forced regressive (during glacial buildup; Heckel 2008 after Posamentier and Morris 2000) and lowstand (during glacial maximum ice volume; Heckel, 2008). Pennsylvanian stratigraphy along the western margin of the Eastern Shelf can be explained as a series of carbonate depositional sequences developed during transgressive and regressive cycles. Included in these cycles are the deposition of organic-rich shales formed during times of maximum transgression (Figure 5). During lowstands, carbonate units experience brief periods of exposure, accompanied by erosion and micro-karstification (Reid and Mazzullo, 1987). It is not uncommon to have sand deposition during low-stands due to delta progradation that in some instances extended to the western margin of the Eastern Shelf. Dominant sources of terrigenous clastic sediment were in the north (Arbuckle and Amarillo-Wichita uplifts) and east (Ouachita Structural Belt) (Thomas et al., 2021; Tomlinson and McBee 1962).

The Pennsylvanian Period is divided into four global stages, including, from oldest to youngest, Bashkirian, Moscovian, Kasimovian and Ghezelian (Figure 6). In North America five regional stages are recognized, including, from oldest to youngest, Morrowan, Atoka, Desmoinesian, Missourian and Virgilian. These regional stages divided further into lithostratigraphic units (Groups and Formations): Morrow (Morrowan), Atoka (Atokan), Strawn (Desmoinesian), Canyon (Missourian) and Cisco (Virgilian).

A paleogeographic reconstruction for the Lower Strawn is displayed in Figure 7. At this time the Permian Basin and most of Texas including the Eastern Shelf was submerged under shallow-water marine conditions. Some areas to the east towards the Ft. Worth Basin show alternating carbonates and terrigenous detrital deposition (Heckel 2008). During deposition of the Lower Strawn, Texas was in the transition zone between humid equatorial and drier tropical trade-winds belts, fostering shallow marine carbonate deposition (Heckel 2002, 2008). Carbonate buildups thrived in this setting in the absence of detritus clouding the water with fine sediments.

Lower Strawn limestones (Figure 8) were generally deposited on an eroded Ellenberger surface but may also overlie eroded Mississippian or even Atokan rocks preserved in topographic lows on the Ellenburger (Reid and Mazzullo, 1987). At this time most of Texas was underwater (deep to shallow water depths) with some exceptions such as the Ouachita Mountain Belt and various basement highs of the Ancestral Rockies, which were topographic highs that shed terrigenous clastics across the Bend Arch and onto the Eastern Shelf.

The Caddo Limestone is one of many Strawn (Desmoinesian) carbonate units present in the eastern part of the Midland Basin and on the Eastern Shelf (Reid and Mazzullo, 1987). Many Strawn limestone units, including the Caddo Limestone, serve as excellent oil and gas reservoirs (Reid and Mazzullo, 1987). The Caddo Limestone is commonly considered the stratigraphically lowest major Strawn limestone over large areas of the Eastern Shelf and is overlain by alternating shales (with some intercalated sandstone) and limestone of younger Desmoinesian age. These include the Odom, Goen and Capps formations (Reid and Mazzullo, 1987).

There are some uncertainties about the precise stratigraphic age and correlation of the Caddo Formation the Eastern Shelf and Midland Basin (Reid and Mazzullo, 1987). Due to its extremely complex depositional patterns and a general lack of biostratigraphic control, exact temporal correlations of the Caddo remain uncertain, and the same holds true for other Strawn limestones (Reid and Mazzullo, 1987). The Caddo and Odom limestones are thought to be early Strawn in age corresponding to the "Lower Cherokee" as defined by the Hollingworth Palaeontologic Laboratory. The Goen is early Strawn ("Upper Cherokee"), and the Capps is late Strawn ("Marmaton") in age. Recent studies by Reid and Mazzullo (1987), however, further subdivided the three Hollingworth zones into eight fusulinid biozones, making it possible to compare the ages of individual limestone units in a regional sense and subdivide each limestone into more than one fusulinid defined zone. Reid and Mazzullo (1987) divided the Lower Cherokee into three expanded fusulinid zones: Early Early Strawn, Middle Early Strawn, and Late Early Strawn. Their work demonstrates the time-transgressive nature of the Caddo Limestone with ages ranging from Middle Early Strawn in Glasscock County to the west and Late Early Strawn in Stephens County to the east. This suggests a long-term, eastern encroachment of the Caddo seas due to a combination of eustatic sea-level rise and basin subsidence.

Interpretation of the number and type of Strawn carbonate facies on the Eastern Shelf varies regionally from worker to worker. In Stephens County west of the Fort Worth Basin, Fu et al. (2017) identified 9 different lithofacies in the Caddo Formation which they split into 4 major and 5 minor lithofacies. The 4 major lithofacies include *Komia* wackestones and packstones, phylloid-algal wackestones and packstones, echinoderm wackestones and packstones, and bioclast packstones and mudstones. Minor lithofacies include *Komia* grain-dominated packstones and grainstones, *Komia* bafflestones, ooid peloid packstones and grainstones, fusilinid wackestones and packstones, and intraclast packstones. *Komia* is currently thought to have been a twig like red algae, but it has also been described as a sponge-like reef-building organism. The current belief is that distribution is limited to the Bend Arch region.

In Nolan and Coke Counties on the Eastern Shelf, Brant (2018) identified nine different lithofacies in Strawn Reef cores from the Nena Lucia and Jameson fields. The nine lithofacies include crinoidal grainstones, mud-to-grain dominated crinoidal packstone; argillaceous crinoidal wackestone-packstones, phylloid algal wackestone-packstones, cortoidal grainstones, crinoidal-lithoclast rudstones, quartz-bearing lime mudstones, fine grained skeletal wackestone-packstones, and skeletal grainstones. The two major constituents in these fields are phylloid algal plates and crinoids.

IV. DATA

The current data we have obtained include a total of 189,956 wells for our Petra database, with an array of information per item, which includes but is not limited to well information (location, name, field, etc.), geology (tops) and production information. Of these 189,956 wells, 6,180 are in Nolan County. We also obtained all available raster logs for Nolan and Fisher counties from MJ logs (a commercial company which sells depth registered Raster and LAS – file type well logs). For Nolan County there are 4,131 available MJ raster logs, and approximately 900 of these are for deeper wells that penetrate the Ellenberger and are therefore most useful in this study.

The other MJ logs include the Strawn but are not deep enough to penetrate the Caddo formation, and thus are not as useful for this study.

V. METHODOLOGY

We obtained two Caddo core samples that were donated to the UTD Permian Basin Research Lab by UTD alumnus Jerry Berghold (former geologist of R. L. Foree Oil Company who drilled the well and obtained the core samples in 1981). The samples were obtained from the R. L. Foree #2 Aycock well, Section 58, Block 21, T&P RR Co. Survey, NE Nolan County, Texas, API # 42-353-31237. The approximate location of these cores is from a measured depth of 6066 - 6076 feet. The two cores were cut using a rock saw, and three thin sections made from representative samples were made.

Petrographic analysis was done using the Dunham (1962) and Embry and Klovan (1971) classifications for hand samples, and the Folk classification (Folk 1959, 1962) for thin sections. Descriptions focused on major constituents and matrix. Optical microscopy was used to identify major fossiliferous components and physical carbonate grains (e.g., ooids) to constrain the paleoenvironment. Cementation of carbonate constituents and other diagenetic features were also noted.

Petra is IHS Markit software to manage, manipulate and visualize geologic well data. This program can be used to create customizable cross section displays using well data and raster logs. In the present study, Petra was used to build a geologic cross-section across the J&J Field. Stratigraphic tops were defined for both the Caddo Limestone and the Ellenburger and the plotting of these tops on the cross-section defines subtle stratigraphic thinning and thickening of the Caddo across the study area. The top Caddo pick was also used to make a map that shows the present structural elevation of the unit.

VI. OBSERVATIONS

1. Visual Description of Core Samples (2 cores)

Core #1 (Figure 9) is a grain supported, skeletal-ooid grainstone. Under low-magnification using a stereoscopic microscope, the main fossil constituents appear to be predominantly skeletal fragments and possibly ooids. Visible porosity on the sample is variable, mostly developed as interparticle porosity, but there is also presence of intraparticle porosity.

Core #2 is very different, consisting of a mud supported, skeletal packstone. While neither core sample is homogeneous the second core is more heterogeneous in color and texture. This can be observed in Figure 10 where two predominant colors are present., A dull white color dominates, owing to the mud-supported nature of the skeletal packstone texture. A darker greyish color is also present, showing a vitreous luster. These darker zones appear to contain a crystalline carbonate matrix, possibly indicating recrystallized material. Porosity within sample #2 is also variable, due to mud-supported nature of the rock, and is likely due to secondary porosity, via dissolution and recrystallization of the rock.

2. Thin Section Description

A total of three thin sections were analyzed, one from Core #1 and two from Core #2. Two thin sections were taken in Core #2 because of the two prominent zonations on the rocks in terms of color and texture as described above.

Thin section #1 (Figure 11-A) includes many different allochems, mostly broken bryozoan fragments and algal plates which are coated in calcite. Ooids are also present along with these skeletal fragments. The skeletal fragments are mostly broken and rounded, which suggests that these were deposited on a high-energy, open marine environment. Core #1 was identified as a grain supported carbonate, and the skeletal-ooid grainstone texture observed in thin-section supports this interpretation. Minor skeletal material observed in thin section #1 include fusilinids, ostracods, trilobites, and echinoderms including crinoid fragments and spines. Porosity is variable throughout the thin section, with both interparticle and intraparticle porosity in areas of high and low cementation.

Thin section 2A and 2B have a very different appearances than thin section 1. Organic allochems are present, but positive identification is difficult due to recrystallization and diagenetic leaching (Figure 11-B and 11-D). Skeletal fragments consisting of calcite appear less altered than those composed of aragonite. Some aragonite skeletons have been converted into voids and in some cases, later refilled by calcite. Based on level of recrystallization and remanent morphology, most allochems appear to be bryozoans (easily identifiable), phylloid algae or brachiopods (hard to differentiate) and fusilinids (easily Identifiable). The areas where mud matrix is present in thin section corresponds to areas in the core that are lightest in color. Evidence of recrystallization and other diagenetic processes in these two thin sections include dolomitization, which can be seen in the previous figures but not as clearly as in Figure 11-C and 11-E. Areas of dolomitization correspond to greyer-colored areas in core #2.

3. Log-based Cross Section

A log-based stratigraphic cross section (Figure 12) was constructed using Petra's cross section tool with the available raster logs. The cross-section extends from the Lake Sweetwater Field area on the east and passes westward across the J&J Field. When flattened on the top of the Ellenburger, it shows localized positive relief thickening within the Caddo Limestone of the J&J field. The thickening ranges from ten to thirty feet, relative to less than ten feet on either side of the field. The core samples were from a local thin region between these thicker areas. The skeletal material and ooids observed in the core samples may have washed down from higher sections within the field, thus explaining why many of the grains are broken. If this interpretation is correct, the presence of shoals consisting of ooids and rounded grains may exist within the thicker Caddo sections of the J&J Field.

4. Structure Map

A structure map of the present-day top of the Caddo Formation in the region of the J&J Field (Figure 13), was constructed using the formation top picks made by the author. It shows the presence of a positive structural feature over the J&J Field consisting of a V-shape nose sitting between the 3840 ft and 3850 ft depth contours. This positive nose feature extends eastward to a depth of 3870 ft. The Caddo deepens rapidly to the west of the J&J Field and shallows to the east, consistent with the regional westward dip of the Eastern Shelf into the Midland Basin.

VII. INTERPRETATIONS AND CONCLUSIONS

Available core and log data from the Caddo Limestone in the vicinity of the J&J Field in NE Nolan County support previous interpretations that the Caddo represents a broad, shallow-water, open marine platform that developed along the western margin of the Eastern Shelf during Early Strawn time. Visual analysis and description under low magnification of two core samples and three thin-sections indicate the presence of a clean, grain-supported carbonate comprised primarily of a diverse, open-marine assemblage of skeletal allochems as well as ooids. A majority of the skeletal grains are rounded and coated; together with the presence of ooids, this assemblage indicates a high-energy, wave-affected marine environment such as a carbonate shoal. Varying rates of cementation are present along with some areas of dolomitization, with the development of both inter- and intraparticle porosity. Enlarged pores indicate the development of secondary porosity, most likely associated with periods of subaerial exposure soon after deposition, shallow burial diagenesis, or perhaps a combination of both. A second, more mud-dominated facies is also present, suggesting a period of deep-water, less energetic wave conditions. Due to the fact that the exact stratigraphic location of the two core samples is uncertain, the muddier facies either represent the bottom portion of a single, upward-shoaling depositional cycle (cyclothem), or a slightly deeper, offshore portion of the Caddo platform.

A slight stratigraphic thickening of Caddo Limestone in the J&J Field area as shown by cross-section analysis together with development of a pronounced structural nose indicated by the top Caddo structural map suggests the local development of a north-south oriented, skeletal-ooid shoal deposited at or near sea-level. The presence of such a shoal is consistent with both the depositional facies as observed in both sample and thin-section, and the porosity observed within. The widespread development of significant secondary porosity within the Caddo shoal explains the oil production at J&J Field. Other Caddo shoals exist along the western margin of the Eastern Shelf, and more regional mapping and delineation of additional shoals may help explain other Caddo production and/or identify additional targets for drilling.

VIII. FIGURES:

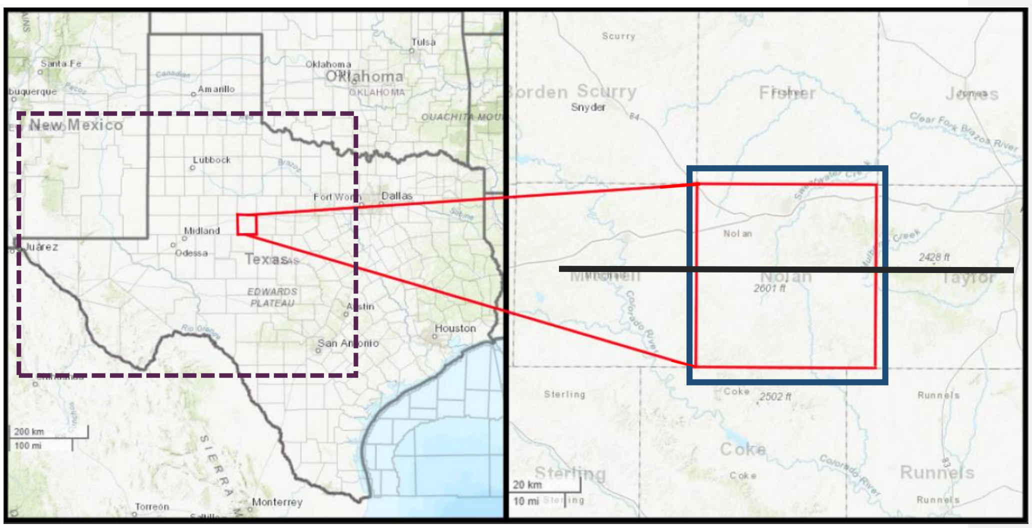


Fig 1: Index map highlighting the location of Nolan County. The map images are modified from Enverus drilling info. The map on the right shows the major rivers, creeks, and roads as well as the names of the surrounding Counties. Each map has its own scale bar in miles and kilometers. The dark blue box shows the location of Figure 2. The dashed purple box shows the location of Figure 7. The black line shows the cross section on Figure 8.

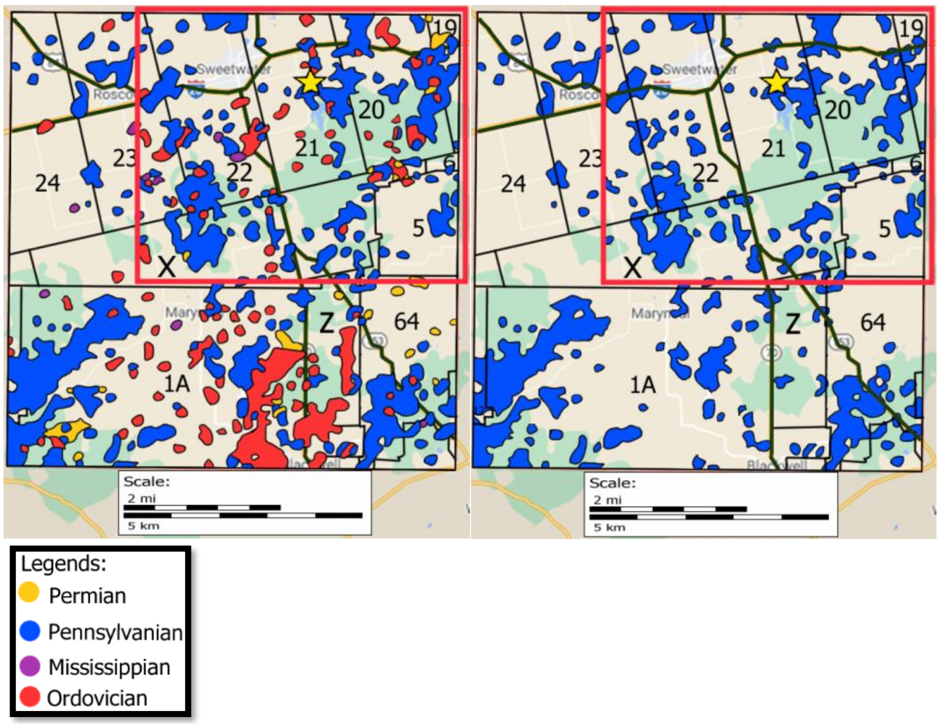


Figure 2. Oil and Gas fields in Nolan County showing the general age of the reservoirs. The yellow star shows the location of the core sample and behind it is also the J&J field. The general background map is from Google maps and was modified to show the field data, redrafted from Villalobos and Johnson (2016). The map on the right highlights the Pennsylvanian-age fields. The red box shows the location of the Caddo structure map (Figure 13).

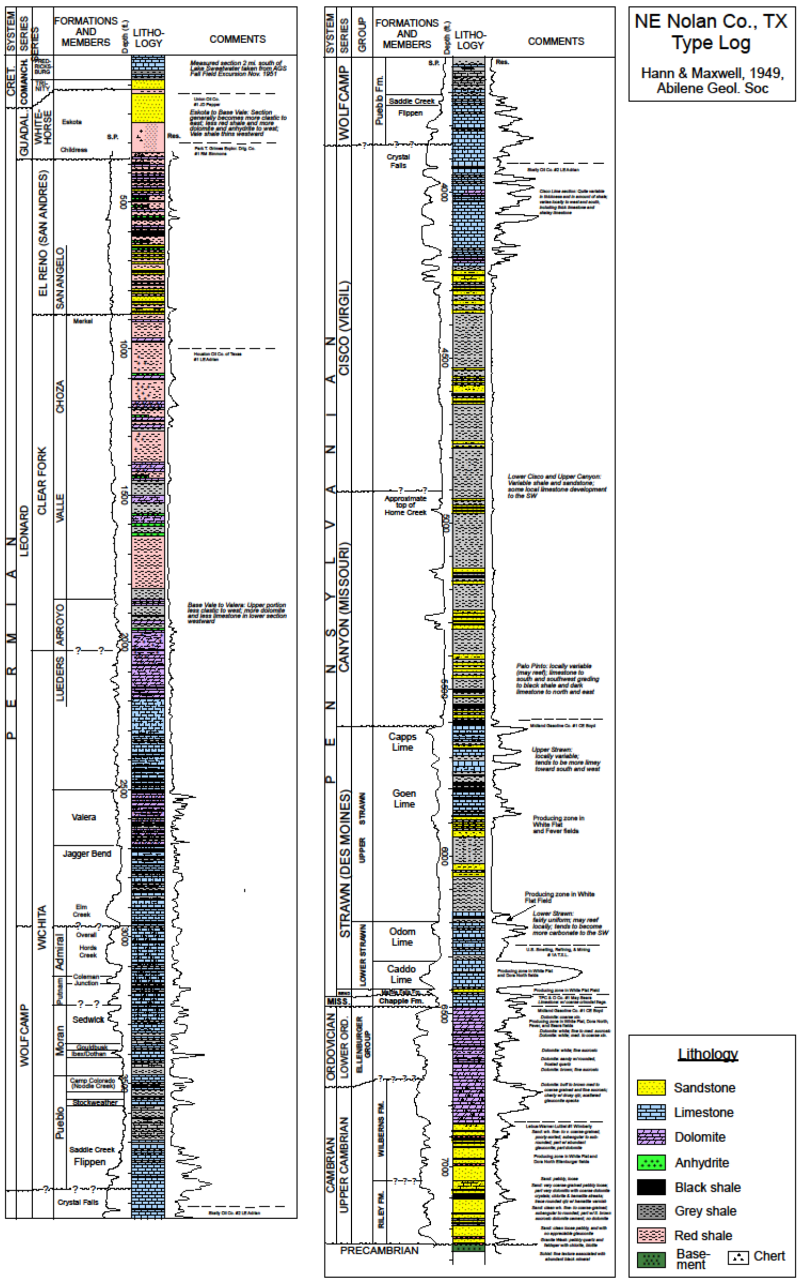

NE Nolan Co., TX
Type Log
Hann & Maxwell, 1949,
Abilene Geol. Soc
SYSTEM
SERIES
FORMATIONS AND MEMBERS
LITHO-LOGY
COMMENTS
GROUP
CRET.
COMANCH.
TRINITY
GUADAL.
WHITE-HORSE
Eskota
Childress
EL RENO (SAN ANDRES)
SAN ANGELO
Merkel
CHOZA
CLEAR FORK
VALLE
LEONARD
ARROYO
LUEDERS
P E R M I A N
Valera
Jagger Bend
Elm Creek
WICHITA
Admiral
Overall
Horde Creek
Coleman Junction
Putnam
Sedwick
Moran
Camp Colorado
Bluckweather
Pueblo
Saddle Creek
Flippen
Crystal Falls
WOLFCAMP
S.P.
Res.
Pueblo Fm.
Saddle Creek
Flippen
Crystal Falls
CISCO (VIRGIL)
Approximate top of Home Creek
CANYON (MISSOURI)
P E N N S Y L V A N I A N
Capps Lime
Goen Lime
UPPER STRAWN
STRAWN (DES MOINES)
Odom Lime
Caddo Lime
LOWER STRAWN
MISS.
Chapple Fm.
ORDOVICIAN
LOWER ORD.
ELLENBURGER GROUP
CAMBRIAN
UPPER CAMBRIAN
WILBERNS FM.
RILEY FM.
PRECAMBRIAN
Measured section 2 mi. south of Lake Sweetwater taken from AGS Fall Field Excursion Nov. 1951
Eskota to Base Vale: Section generally becomes more clastic to east; less red shale and more dolomite and anhydrite to west; Vale shale thins westward
Base Vale to Valera: Upper portion less clastic to west; more dolomite and less limestone in lower section westward
Lower Cisco and Upper Canyon: Variable shale and sandstone; some local limestone development to the SW
Palo Pinto: locally variable (may reef); limestone to south and southwest grading to black shale and dark limestone to north and east
Upper Strawn: locally variable; tends to be more limey toward south and west
Producing zone in White Flat and Fever fields
Producing zone in White Flat Field
Lower Strawn: fairly uniform; may reef locally; tends to become more carbonate to the SW
500
1000
1500
2000
2500
3000
4000
4500
5000
6000
6500
7000
Lithology
Sandstone
Limestone
Dolomite
Anhydrite
Black shale
Grey shale
Red shale
Basement
Chert

Figure 3. Type log for northeast Nolan county (from Hann and Maxwell, 1949 and redrafted by Lowell Waite, 2021). The depth scale is in feet.

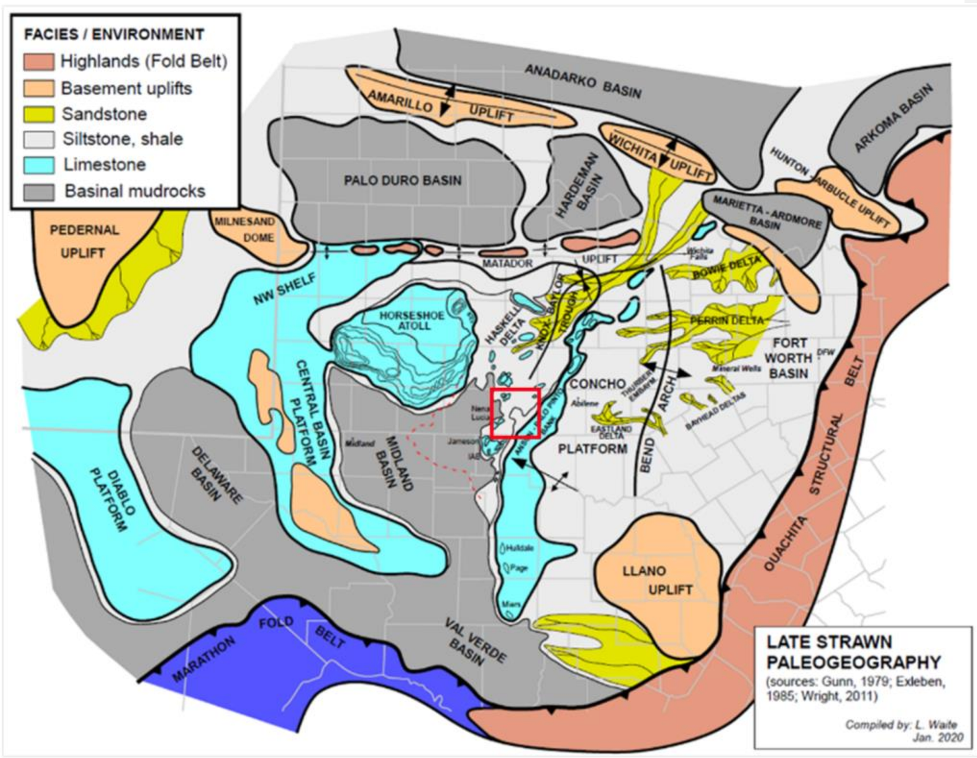


Figure 4: Regional Permian Basin map showing the different geologic and tectonic features present in the Permian Basin. The red box identifies the location of Nolan County. Obtained from Lowell Waite, 2020.

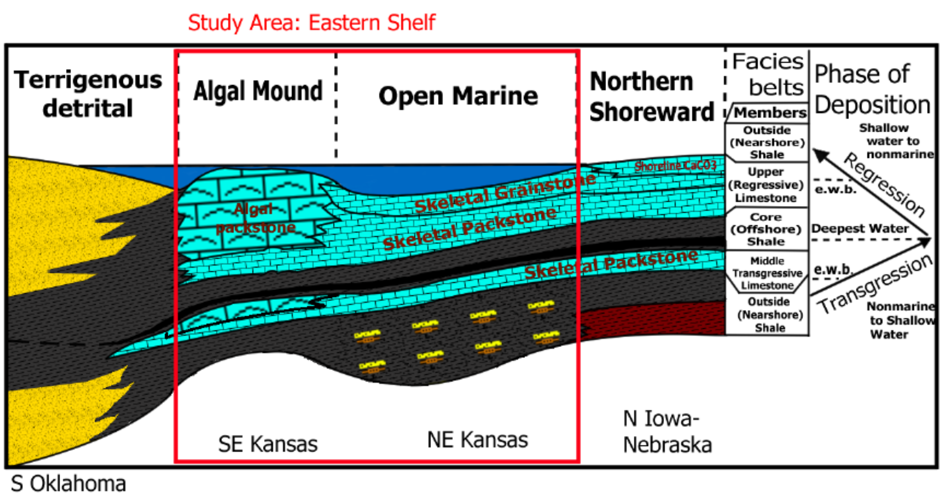


Figure 5: Transgressive (rising sea level) and regressive (descending sea level) stages for a single cycle (cyclothem), illustrating how cyclothems change regionally and are facies dependent. The deepest water phase (sea level maxima) represents the time when highly organic phosphatic black shales are deposited, whereas carbonate deposition is mostly relegated to the regressive phase when photic zone and water conditions (clear water) are optimal. The Eastern Shelf region is located within the Algal Mound and Open Marine setting throughout Strawn time. (redrafted from Heckel, 1994).

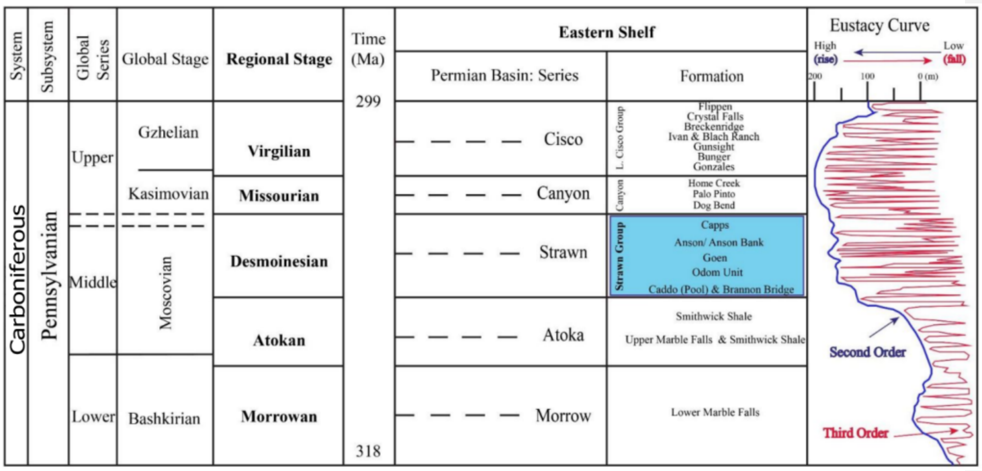


Figure 6. Pennsylvanian chronostratigraphic chart showing Global Stages and North American Regional Stages. The stratigraphic chart and associated eustatic sea-level curve for the Eastern Shelf of the Permian Basin is also shown. Major Eastern Shelf Strawn Group carbonate stratigraphic units are highlighted in blue. Eustatic sea-level curve shows representative of third-order cycles imprinting signatures on second order sequences (which were adapted from Ross and Ross, 1987). This image is from Brant (2018) redrafted from Wright (2011).

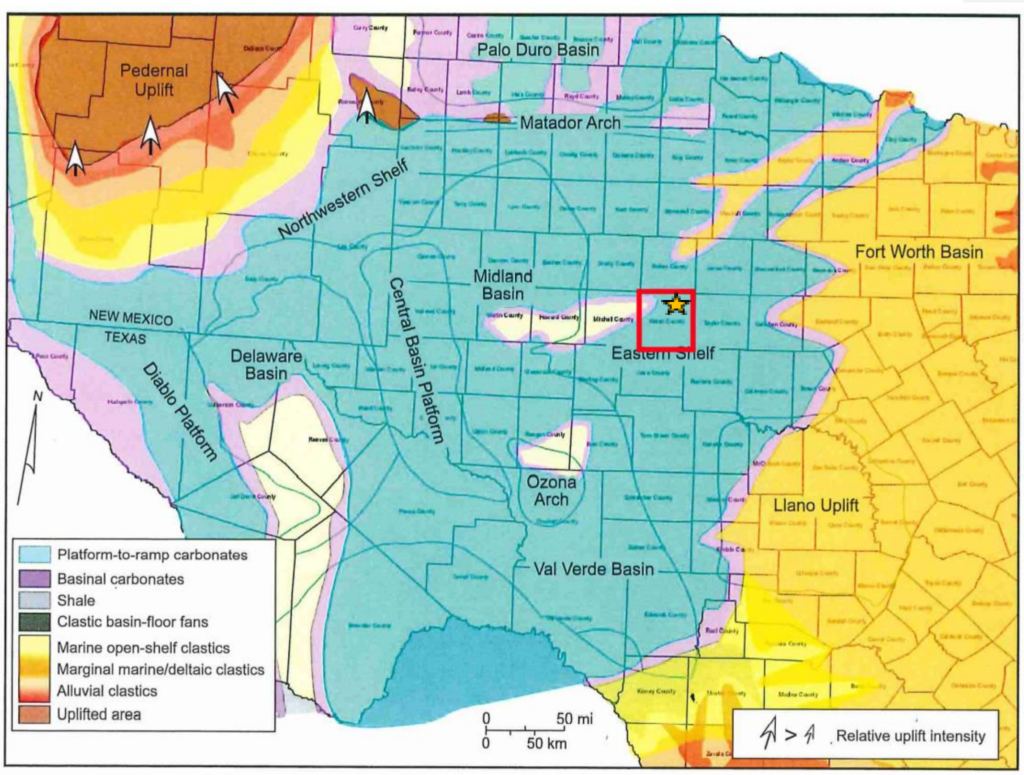


Figure 7. Paleogeographic reconstruction for Early Strawn time. At this time most of the Eastern Shelf and Concho Platform as well as the Permian Basin was submerged and was suitable for depositing shallow water carbonates from (Wright, 2020). Nolan County is outlined with a red square. The J&J field is located at the yellow star.

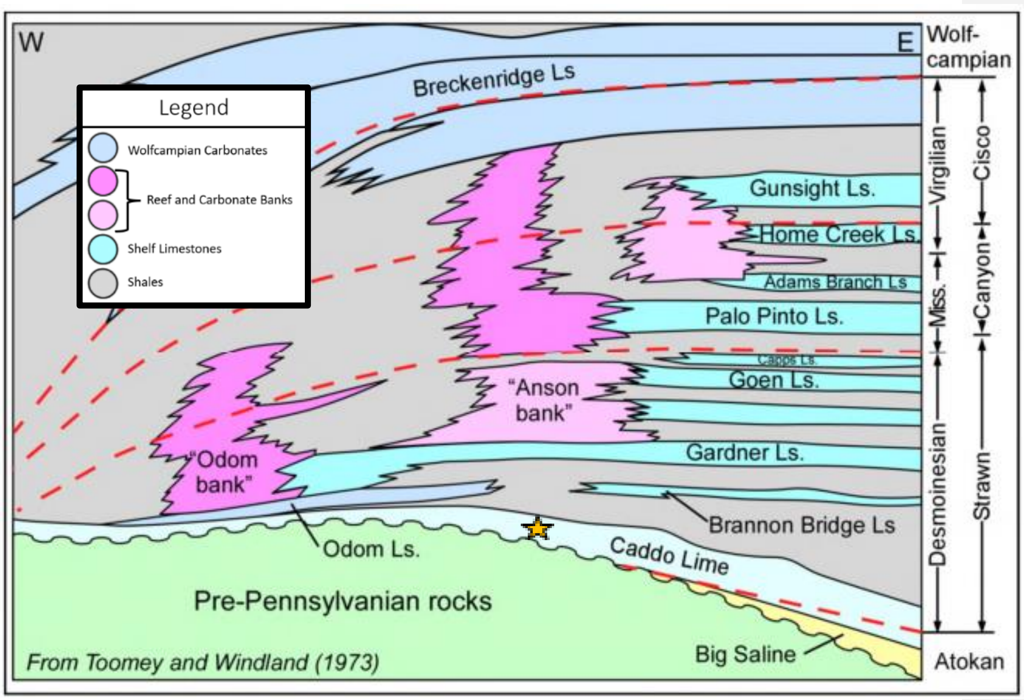


Figure 8. Schematic west-east cross section through Mitchell-Taylor County. Nolan County is located approximately in the middle portion of this cross-section. This image was modified by Alton Brown from Toomey and Winland (1973) and added red dashed lines to indicate the approximate stage boundary; the carbonate bank names were obtained from Cleaves (1975). The approximate location of the J&J field is on the yellow star.

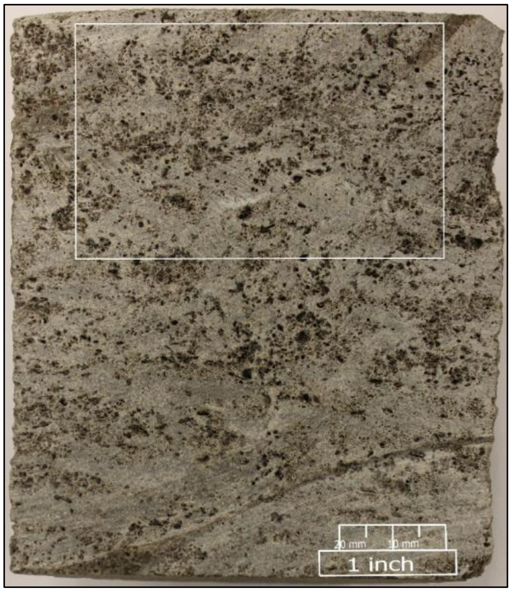


Figure 9. Photograph of Core sample #1. The white box shows where Thin Section #1 was taken from. The porosity changes can be seen easily on this samples, related to different rates of cementation.

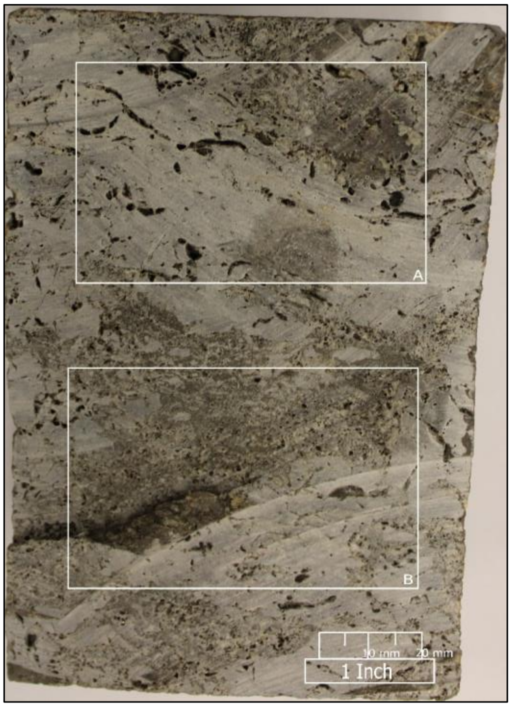
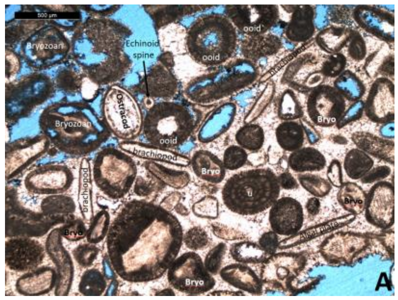
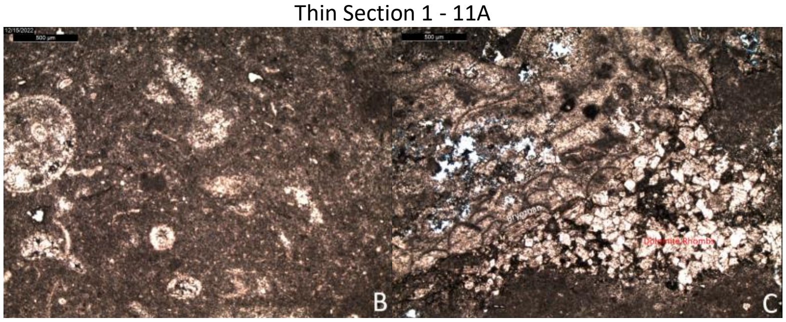


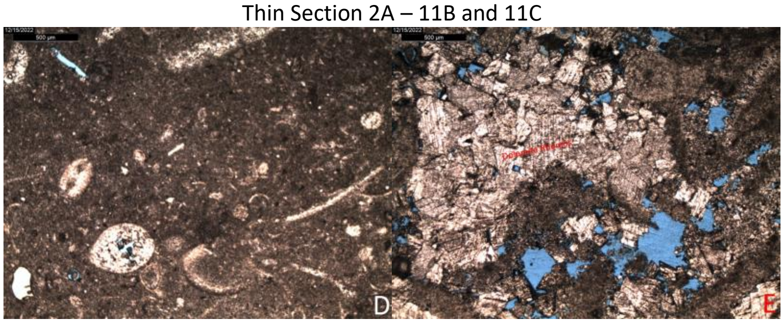
Figure 10. Photograph of Core sample #2. The two white boxes are where Thin Section 2A and Thin Section 2B were taken from. This sample has two predominant colors, a dull white color is the most predominant in this sample, owing to the mud-supported nature of the skeletal packstone texture. A darker greyish color is also present, showing a vitreous luster.



Thin Section 1 - 11A



Thin Section 2A – 11B and 11C



Thin Section 2B – 11D and 11E

Figure 11. Sample A shows a representative sample for Thin Section 1, showing a clean (no mud present) grain supported carbonate, known as grainstone, with an array of allochems, including bryozoans (Bryo) and ooids, these grains are broken and rounded. Other grains include fusilinids (u), brachiopods and/or algal plates and ostracods and echinoderm fragments. Image 11B and 11D show similar composition and texture, consisting of a grain-supported texture in mud matrix, known as packstone for Thin Section 2A and 2B, representing the pale white areas in Core#2. The skeletal material in Thin Section #2 seems to be similar to what is seen on Thin Section #1, but in a mud matrix and lacking in identifiable feature due to leaching of the sample. Image 11C and 11E show areas of higher porosity in some cases show the presence of rhombohedral dolomite crystals, corresponding to areas of vitreous gray color in Core #2. Some skeletal fragments like bryozoan and fusilinids can be seen near or inside these areas.

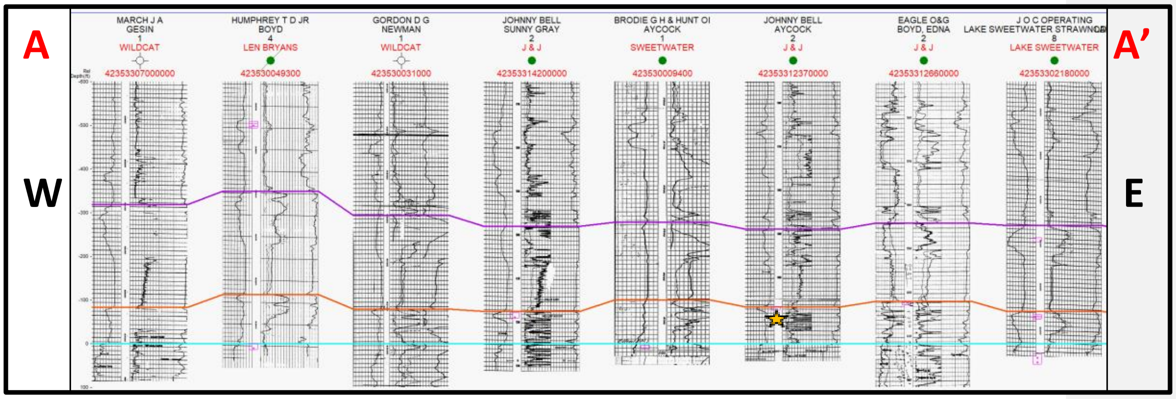


Figure 12: Stratigraphic Cross Section of the J&J field, flattened on the Ellenberger datum. The cross section extends west to east horizontally for a distance of 2 miles. The vertical scale is indicated along the left side of the section, from zero to six hundred feet (zero represents the top of the Ellenberger/base of the Caddo Formation). The location of the Cross Section is indicated on Figure 13. See text for discussion.

Commented [LW1]: Need to add "A" and "A'" on the section

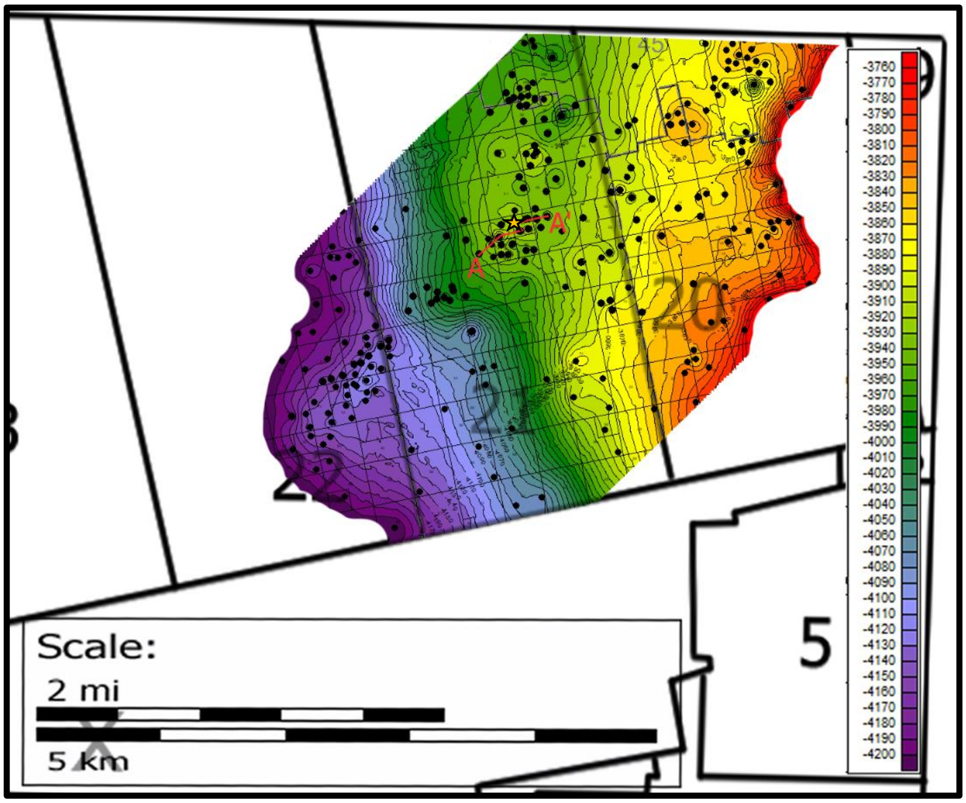


Figure 13: Structure map on top of the Caddo Limestone. See Figure 2 for location. The cross section (Figure 12) is highlighted red on the map, the control points (black dots) below the line are the wells that are shown on the cross section. A positive structural nose together with stratigraphic thickening of the Caddo shown in Figure 12 indicated the presence of an ooid shoal. Contour interval is 10 feet; control points are indicated by the black dots. The cores are located at the yellow star. The yellow star shows the core sample location and the positive structure surrounding it is the J&J field.

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