AUSTIN CHALK STRATIGRAPHY, GIDDINGS FIELD TO THE SAN MARCOS ARCH, CENTRAL TEXAS

A Thesis

by

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ABSTRACT

The Late Cretaceous Austin Group contains a petroleum play fairway that spans across east and south Texas. This unit is composed of shallow to deep-water carbonate and marl, which were deposited along the southeast margin of the Cretaceous Interior Seaway, during the latest Turonian through earliest Campanian. Giddings Field in east-central Texas is one of the most prolific oil and gas fields producing from the Austin Chalk. As such, Austin research to date in east-central Texas has focused on the immediate Giddings Field area. However, the area west of Giddings Field, in Bastrop, Fayette, and Lee Counties, where the Austin Group approaches the San Marcos Arch, has received little subsurface scrutiny in comparison to the Giddings area to the east, or the shallower subsurface and outcrop regions toward the north. Through detailed examination and correlation of wireline well logs and a partial core, a new understanding of the chronostratigraphic framework defining depositional and post-depositional influences in the distribution and thickness variations within the Austin Group was determined. This new understanding sheds light on potential petroleum reservoir and play distributions across the study area.

The Austin Group in the study area is unconformably bound by the Eagle Ford Group below and Taylor Group above. Within the Austin Group a major maximum flooding (downlap) surface, and underlying Sequence Set Boundary (SSB), were used to sub-divide the Austin Group into two major sequence sets.   These sequence sets respectively define the Lower Austin Chalk (LAC), which is interpreted as a transgressive sequence set, and Upper Austin Chalk (UAC), which is interpreted as highstand sequence set.

The LAC is bound at the base by the Austin Group and Eagle Ford Group contact and above by the SSB. It is composed of four high-frequency sequences (S1, S2, S3, and S4), readily identified by their associated maximum flooding surfaces. These high-frequency maximum flooding surfaces, along with the upper and lower LAC boundaries, were used as correlation markers that constrained five correlation units within the LAC. These correlation units indicate the westward thinning of the LAC is a result of onlap at the base and stratal convergence to the west. The LAC correlation units also highlight a central paleo-topographic high in the area identified as an ancillary, or relict feature of the San Marcos arch. The depositional influence of this ancillary high is most evident in the lower units of the LAC, indicates minimal influence in the overlying LAC units, and has no influence directly above in the UAC units. The San Marcos Arch proper expresses a dramatic depositional influence further west in the UAC, where there is little to no influence directly below in the LAC.

The UAC is bound by the SSB at its base, and the unconformity at the base of the Taylor Group at its top. The UAC is composed of eight high-frequency sequences (S5 - S12), readily defined by the associated eight high-frequency maximum flooding surfaces. The uppermost seven maximum flooding surfaces, combined with the UAC upper and lower boundaries, were used as correlation markers that constrained eight correlation units within the UAC. These units thin considerably as they approach the San Marcos Arch to the west and lap-out on to the downlap surface directly above the SSB in the middle of the Austin Group. The east-southeast corner of the study area records substantial eastward thinning of the UAC caused by the erosion of the five uppermost units through incision from the overlying Waco Channel, which defines the base of the Taylor Group in the eastern part of the study area.

Onlap of the lower LAC units against the ancillary San Marcos Arch at the base of the Austin Group, downlap of UAC units just above the SSB in the middle of the Austin Group, as well as truncation beneath the Waco Channel at the top of the Austin Group, control the thickness and distribution of the various chronostratigraphic units within the Austin. These factors impact the plays, play fairways, and traps within the Austin Group where units terminate against the Waco Channel, San Marcos Arch, the paleo topographic high in the LAC, or where structural highs occur, and need to be considered for further exploration and exploitation activities within the study area and beyond.

DEDICATION

To my parents, for their unwavering support and inspiring my interest in the world around me.

To my brothers, for fostering my love of science and curiosity though their examples.

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NOMENCLATURE

LAC	Lower Austin Chalk
UAC	Upper Austin Chalk
TX	Texas
KWIS	Cretaceous Western Interior Seaway
m	Meters
ft	Feet
mV	Millivolts
MD	Measured Depth
Ma	Million Years
API	American Petroleum Institute (Gamma Ray wireline curve scale)
GR	Gamma Ray wireline curve
Res	Resistivity wireline curve
SP	Spontaneous Potential Wireline Curve
SSB	Sequence Set Boundary
HST	Highstand Systems Tract
TST	Transgressive Systems Tract
TOC	Total Organic Content

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1. INTRODUCTION

The Upper Cretaceous, especially the Cenomanian through the Coniacian, were characterized by enhanced greenhouse conditions, caused largely by the abundance of atmospheric carbon dioxide from volcanism, resulting in some of the warmest global temperatures in Earth's history (Falzoni et al., 2016; Huber et al., 1995). By the Late Santonian, however, these elevated temperatures began to decrease (Falzoni et al., 2016; Huber et al., 1995). Eustatic sea levels rose with temperatures, enhanced by tectonic influences, such as more rapid oceanic seafloor spreading and foreland subsidence, forming vast, relatively shallow epicontinental seas across North America (Figure 1), as well as globally. High temperatures, broad marine environments, and abundant carbon sources generated ideal conditions for prolific chalk production from the Latest Turonian through the Earliest Campanian (Weeks, 1945; Ewing and Caran, 1982; Jackson and Laubach, 1988; Fullmer and Lucia, 2006). The concurrence of these events provided the sediments and accommodation for widespread chalk deposition, and the formation of the Austin Group across Texas.

The Late Cretaceous Austin Group (Figure 2) represents about 9 million years of the earth's history. It is a complex stratigraphic unit, consisting of cyclic alternations of carbonate and marl, that contain prolific petroleum reservoirs, historically as fractured chalk plays across Texas (Hovorka and Nance, 1994; Dravis, 1991). Due to the resource potential of the Austin Group, as well as underlying (older) exploitation plays, there is abundant subsurface (well log) data. This information, combined with outcrop studies, provide a broad characterization of this unit throughout the region.

One area where the Austin Group has received relatively little attention is the study area of Bastrop, Fayette, and surrounding counties in central Texas (Figure 3). Interestingly, this area is just west of the Giddings Field, a productive oil and gas field covering an area approximately 80 miles by 20 miles extending through Fayette, Lee, Burleson, and several other counties in east Texas (Durham and Hall, 1991). The Austin Group thins to the southwest as it approaches the San Marcos Arch, a structural extension of the Precambrian Llano Uplift that resisted subsidence during the Cretaceous (Dravis, 1981). The Austin Group sediment along the eastern flank of the northwest to southeast trending San Marcos Arch has yet to be fully described and organized within its sequence stratigraphic framework, including the depositional environments in this region.

This study utilizes well-log correlation of the Austin Group west of Giddings Field toward the San Marcos Arch, to define the depositional environments and sequence stratigraphy of the Austin Group. This study also characterizes the depositional processes of the Austin Group, as well as the underlying San Marcos Arch and overlying Waco Channel (Durham and Hall, 1991; Young, 1986), as syndepositional and post-depositional influences on the stratigraphy of the Austin Group. Finally, this study assesses the continued economic development and expansion of the Giddings Field westward, towards the San Marcos Arch; specifically, in the lower “A Zone” (Figure 4), which historically is the primary pay zone in Giddings, and other Austin Chalk fields across Texas.

2. GEOLOGIC HISTORY

The unique global greenhouse environment that occurred during the Late Cretaceous resulted in high atmospheric and oceanic temperatures, periodic shallow Oceanic Anoxic Events (OAEs), and a readily available supply of carbon, producing both an abundant proliferation, and high turnover rate of planktonic and benthic foraminifera and coccolithophores (Falzoni et al., 2016; Tessin et al., 2019). These events, coupled with some of the highest sea levels in the earth's history, provided the conditions for significant pelagic carbonate deposition (Figure 3) across the Cretaceous Western Interior Seaway (KWIS). Pelagic coccolithophores and forams provided the bulk of the calcareous sediments deposited across most of Texas during the latest Turonian through earliest Campanian. Along with sedimentary infill and subsidence, local accommodation and basin topography was controlled through marginal wrenching faulting and subsidence associated with; 1) the Late Triassic to Late Cretaceous opening and continued extension of the Gulf of Mexico (GOM) basin (Weeks, 1945; Ewing and Caran, 1982; Jackson and Laubach, 1988; Fullmer and Lucia, 2006), and potentially 2) foreland tectonics (Jackson and Laubach, 1991). These tectonic, sedimentary, and igneous activities provided additional depositional controls in the study area; specifically, relative to the San Marcos Arch, Balcones Fault zone, and, potentially, the Luling and Mexia fault zones.

The Late Cretaceous (latest Turonian – earliest Campanian) Austin Group (Figure 2) was deposited unconformably above the Eagle Ford Group in a shallow to deep shelf environment on the northwest rim of the Gulf of Mexico basin during a span of ~ 9 million years (90.3 - 81.6 Ma ±0.3 Ma, International Chronostratigraphic Chart, 2020) and biostratigraphy from Young and Mark (1952), Adkin (1933), Young (1963), Dawson and Reaser (1985), Young and Woodruff

(1985), and Dawson and Reaser (1990). The Austin Group in the study area is unconformably overlain by the Taylor Marl, or the Pecan Gap Chalk when the Taylor Marl is not present. Deposition of the Austin Group coincides with the deposition across the shallow KWIS (Figure 1) that stretched from the Boreal Sea to the Gulf of Mexico (Wright, 1987). The Late Cretaceous also was marked by an abundance of local volcanic activity in south-central Texas associated with the Balcones Fault zone, and the ashfall from this volcanism was likely a source of some clay material within the marl units of the Austin Group (Durham, 1957).

The Austin Group outcrops in Williamson and Travis counties, TX, striking northeast and dipping very gently southeasterly. Historically, in outcrop the Austin Group was sub-divided into six main biostratigraphic and lithological units from the base upward (Figure 2): the Atco Formation, Vinson Chalk, Jonah Formation, Dessau Chalk, Burditt Marl, and Pflugerville Formation (Young and Woodruff, 1985). These stratigraphic units are defined by lithological and paleontological marker beds, including ammonites and pelagic microfauna and combines field work with outcrop description and nomenclature that was developed for the Austin Group over more than the last 100 years (i.e., Adkins, 1933; Dumble, 1890; Durham, 1955; Durham, 1957; Shumard, 1860; Taff, 1892; Young, 1963; Young, 1977; Jiang, 1989; Lundquist, 2015; Cooper et al., 2020).

In outcrop, eight Austin Chalk “zones” were delineated through direct association with the uniquely concentrated, but not entirely zone-specific fossils in each unit (Young and Marks, 1952). The separation of zones also was represented by the lack of a certain species in adjoining zones since some species appear in other units within the Austin Group. These paleontological zones are a close correlation to the six units previously mentioned but lack the more distinct depositional and stratigraphic boundaries. These units, or zones (Figure 2), from base to top are;

the *Inoceramus subqudraius* zone, associated with the Lower Atco Formation; the *Gryphaea wratheri* zone, associated with the Upper Atco Formation and Lower Vinson Chalk; the *Inoceramus undulatoplicatus* zone, associated with the Upper Vinson Chalk; the *Hemiaster texanus*, associated with the Lower Jonah Formation the *Texanites internodusus* zone, associated with the Upper Jonah Formation; the *Gryphaea aucella* zone, associated with the Dessau Chalk; and the two remaining upper zones, *Ostrea centerensis* and *Ostrea travisana*, which may represent both the Burditt Marl and Pflugerville Formation.

This study correlates Austin Group picks from areas surrounding Austin (Lundquist, 2015; Cooper et al., 2020) to the subsurface to the southeast near Giddings Field; using unit designations based on significant sequence stratigraphic markers identified in well log signatures (Figure 2), then correlated to those lithostratigraphic designations used in Cooper et al. (2020). The combined thickness of these Austin Group units ranges from 150 to 800 ft (50 m to 250 m) across the Giddings field and surrounding area (Durham and Hall, 1991).

The Atco Formation (latest Turonian and Coniacian) at the base of the Austin Group is approximately 115 ft (35 m) thick in the study area and was deposited unconformably on the Eagle Ford Group below. The Atco Formation is predominantly a massive skeletal wackestone, interbedded with thin beds of fissile, skeletal wackestone commonly containing *Peroniceras* ammonite variants, with a significant bentonite bed near its base (Dawson and Reaser, 1990; Durham, 1957; Durham and Hall, 1991; Hovorka and Nance, 1994; Young and Woodruff, 1985). Although the exact height and subsurface extent of the bentonite bed is uncertain, it is generally considered a regional feature useful as a correlative marker for outcrops, well logs, and cores. The lower part of the Atco Formation is massively bedded and contains local horizons of glauconite and phosphate grains, and iron ooids (Durham, 1957; Cooper et al., 2020). Two main intermittent facies occur within the Atco Formation, both contain fragmented molluscs, but one contains a calcisphere microfacies and inoceramid prisms, and the other contains no calcispheres (Young and Woodruff, 1985). The Atco Formation correlates to the units between the Austin Chalk base and the Major Flooding Surface 20 (MFS20) identified in this study (Figure 4).

The Atco Formation is 90 - 130 ft (27 - 40 m) thick and transitions upward into the Vinson Chalk (lower Santonian) across a gradational boundary (Young and Woodruff, 1985) that indicates a deeper depositional environment with fewer, thinner, fissile marl beds, and thicker skeletal wackestone beds (Durham, 1957; Young and Woodruff, 1985). Occasional ripped-up limestone clasts and shingled inoceramid fragments were interpreted as storm-wave reworking in outcrops in Travis County (Young and Woodruff, 1985). The upper boundary of the Vinson Chalk is a hardground “corrosion zone” (Young and Woodruff, 1985). Similar to the Atco Formation, the Vinson Chalk is dominated by calcareous marine detritus with, or without forams (Young and Woodruff, 1985). Unlike the Atco Formation, the Vinson Chalk contains occasional beds of shell fragments of *Phyrygia aucella*, anomalinids, echinoid spines, and molluscs (Young and Woodruff, 1985). Bioturbation is not as common in the Vinson Chalk as in the Atco Formation, and the environments recorded in the Vinson Chalk outcrop were likely more anoxic at the sediment interface (Young and Woodruff, 1985). The Vinson Chalk upper boundary is identified as MFS30 in this study (Figure 4).

The upper Santonian Jonah Formation was deposited conformably above the hardground capping the Vinson Chalk (Durham and Hall, 1991) and commonly consists of thickly bedded skeletal packstone/grainstone at the base and top, with a lower overall concentration of carbonate marl, compared to the Vinson Chalk below and Dessau Chalk above. The Jonah Formation contains glauconitic and fragmental fossiliferous limestone interbedded with fissile shale

(Durham, 1957; Young and Woodruff, 1985). The fragmental limestone and skeletal packstone lithologies in outcrops along the banks of the San Gabriel River near Jonah in Williamson County indicate a very shallow and higher energy depositional environment near the north flank of the San Marcos Arch (Durham, 1957). The Jonah Formation contains abundant bioturbation, indicating a more open marine environment with oxic waters than the Vinson Chalk (Dawson and Reaser, 1990; Hovorka and Nance, 1994; Young and Woodruff, 1985). The upper boundary of the Jonah Formation is a glauconitic corrosion zone, indicating a flooding surface (Young and Woodruff, 1985). The Jonah Formation is 13 – 26 ft (4 - 8 meters) thick in the study area. The Jonah Formation is separated into an upper and lower unit by a subaerially exposed unconformity identified in outcrop (Cooper et al., 2020). The Jonah Formation is bounded by surfaces designated in this study as MFS30 and the Sequence Set Boundary (SSB), with the Lower and Upper units (Cooper et al., 2020) separated by the surface designated MFS40 (Figure 4).

The Dessau Chalk (late Santonian - earliest Campanian) is composed of massive marl beds interbedded with skeletal wackestone. This unit is approximately 75 - 100 ft (23 - 30 m) thick and contains three distinct oyster banks in up-dip outcrops, each ranging from one to two feet (0.3 to 0.6 m) thick; the lower bank, composed of *Gryphaea aucella*, is situated near the middle of the unit, and the upper two banks, *Exogyra laeviuscula* overlain by *Exogyra tigrina*, are nearer the top (Durham, 1957; Lundquist, 2015; Young and Woodruff, 1985). Unlike the underlying fragmental limestone of the Jonah Formation, the massive skeletal wackestone of the Dessau Chalk was deposited across the San Marcos Arch (Durham, 1957). The upper boundary of the Dessau Chalk is characterized as an unconformity. The top of the Dessau Chalk was previously postulated to contain glauconitic grains, but these were later identified as pyroclastic components from local volcanic eruptions, such as Pilot Knob in the Austin area (Young and Woodruff, 1985). The Dessau Chalk upper boundary is designated in this study as MFS90 (Figure 4).

The Early Campanian Burditt Marl and Pflugerville Formation are correlated together as a single unit in this study, maintaining correlative consistency to the most recent study incorporating outcrop and subsurface wireline data (Cooper et al., 2020); they are bounded by the surface designated MFS90 at the top of the Austin Group (Figure 4). The Burditt Marl, deposited unconformably above the Dessau Chalk, is an approximately five meters thick limestone containing no more than 15% clay (Young and Woodruff, 1985). The Early Campanian Pflugerville Formation, also referred to as the Big House Formation (Durham, 1957), gradationally overlies the Burditt Marl and represents the uppermost unit of the Austin Group. In Travis County outcrops, the lower half of the Pflugerville Formation is composed of a white chalk, the upper half a chalky marl that transitions gradationally upward into the Taylor Group above (Durham, 1957). Total thickness of the Pflugerville Formation is 39 – 72 ft (12 - 22 m). The Pflugerville Formation is relatively unfossiliferous when compared to the remainder of the Austin Chalk (Durham, 1957). The Burditt Marl and Pflugerville Formation do not appear in outcrop in counties north of the Travis County outcrops; instead, the Taylor Group directly overlies the Dessau Chalk, thus the Burditt Marl and Pflugerville Formation pinch-out or were truncated in Travis and Hays counties, where they occur in subsurface well logs, and to a limited extent in outcrop, to thin up-dip to the north, and as they approach the San Marcos Arch to the west (Durham, 1957; Young and Woodruff, 1985; Cooper et al., 2020).

Finally, it should be noted that in the subsurface, the Austin Group (Figure 2) is commonly divided into three informal lithostratigraphic lower, middle, and upper units (Dawson and Reaser, 1985; Durham and Hall, 1991; Hovorka and Nance, 1994). These units were sub-divided further, defining sub-units, A through L, based largely on variations in subsurface gamma-ray well log values (Hovorka and Nance, 1994). The separation of these units was based on well log signatures, core analysis, and association with previous outcrop studies (e.g., Young and Woodruff, 1985). The Lower Austin includes the Atco Formation and Vinson Chalk, with the upper boundary between the Lower and Middle Austin being a hardground, separating the Vinson Chalk from the Jonah Formation. The Middle Austin corresponds to the Jonah Formation, and is bounded at its top by the disconformity separating the Jonah Formation from the Dessau Chalk (Durham and Hall, 1991). The Upper Austin includes the Dessau Chalk, Burditt Marl, and the Pflugerville Formation.

3. METHODS

3.1. Data

3.1.1. Wireline Logs

Subsurface data from 229 wells across Bastrop, Fayette, Lee, Travis, and Caldwell counties (TX) was procured through a DrillingInfo© account provided to Texas A&M University Geology & Geophysics Department by Enverus, Inc. These data included raster well log images of various wireline tools, geographical locations, and bore geometries. Most relevant to this study were the Gamma Ray (GR), Resistivity (Res), and Spontaneous Potential (SP) wireline curves. The patterns of the GR signatures were used to determine likely facies associations, lithological shifts, depositional changes related to sea level change, and potential ash beds that were useful in correlating wells across the study area. The Res and SP curves were used to supplement correlations, or as correlative alternatives where GR was not available or not characteristic because of a variable signature.

Data saturation of the study area is directly associated with local petroleum exploration and development trends, as well as freshwater production wells. Well concentration is heaviest to the southeast, where the Austin Chalk and Buda formations were targeted as trend extensions from the Giddings Field during regional development of the East Texas Field. To the northwest, many of the available wells were targeting sandstone beds of the overlying Taylor Group or shallow freshwater reservoirs, so many of the wells and wireline logs in this area did not reach sufficient depths to record much of the Austin Group, if it was penetrated at all. Included in the final selected wells are three used in the recently published work by Cooper et al (2020), which tie the two studies' works together in an extended examination of the Austin Group through the subsurface east of the San Marcos Arch, toward Giddings Field.

3.1.2. Well Core

A partial core of the Lower Austin Chalk (LAC), including the Atco Formation, Vinson Chalk, and a portion of the lower Jonah Formation, from the Cities Services Co. (Sage Energy Co.) Ivy B #1 42-149-30568 well was examined at the Texas Bureau of Economic Geology in Austin, Texas (Figure 5). Sampling of the core was restricted, as the core was heavily sampled in the past and its preservation is prioritized. Well logs were provided by Doug Toepperwein of Sage Energy Co., the current operator of the Ivy B #1. The core was taken from 8305 ft to 8492 ft (2531.4 to 2588.4 m) MD, which includes 144.8 ft (44.1 m) of the Austin Group, from 8305 ft (2531.4 m) to the Austin Group base/Upper Eagle Ford Group contact at 8450 ft (2575.5 m). Of the 144.8 ft (44.1 m) core of Austin Chalk, a total of 11.5 ft (3.5 m) of core is missing, leaving 133.3 ft (40.6 m) of intact core material. The core was examined through both unaided and magnified visual inspection using a 10x hand lens. Examination focused on describing sedimentary characteristic and lithological shifts, presence and degree of bioturbation, fossil identification, mineralogical characteristics, and color. These details were observed and recorded in one-foot intervals between 8305 ft and 8450 ft (2531.4 and 2575.5 m).

3.2. Processing

3.2.1. Wireline Logs

Well log data was interpreted with IHS Petra® geologic subsurface software provided to Texas A&M University Geology & Geophysics Department by IHS Markit™. All well log data was imported into the software and refined through quality control and relevancy to the study area. Of the 229 imported wells, 51 were selected for use in the subsurface correlation

(Appendix). Any wells that did not include gamma ray logs were generally removed from the project. Wells also were dropped from the project if they had insufficient Austin Group depth coverage, poor quality raster log images, missing significant well data (i.e., ground level height, surface and bottom hole coordinates, deviation survey, etc.), or if they were considered redundant, in which case the best well in the immediate location was chosen.

The Austin Group boundaries (Figure 4) are easily identified in most areas by a clear and consistent contrast in GR and Res curve properties from the muddy Upper Eagle Ford Group below and the muddy Lower Taylor Group above. The average radioactivity of approximately 30 API observed in the Austin Group is well below the >100+ API of the Lower Taylor Group and the >150+ API of the underlying Upper Eagle Ford Group (Figure 4). In confirmation of the GR trend, the Res curve at the upper and lower bounds would inversely shift to a near-zero value in both the Eagle Ford Group and Taylor Group, outside the depths of the Austin Group.

Two significant, generally field-wide markers were used to correlate units within the Austin Group across the study area; the Three Wise Men and Two Finger GR markers (Figure 4). The Three Wise Men marker occurs between the MFS60 and MFS70 surfaces, and the Two Fingers marker is bound by the SSB and MFS50 surfaces (Figure 4). Another distinct high-GR marker that occurs in the southeast and southwest corners of the project area is identified as an ash bed just below the MFS10 marker. This ash bed is used as a reliable correlation and drilling marker and for the A Zone in Giddings Field to the east. However, the A Zone is not widely present in the study area, and as such does not provide significant correlation value in this study.

After establishing a broad correlation of the Austin Group based on the Three Wise Men and two Fingers markers, repeating GR, Res, and SP patterns and trends were correlated as units in cross section (Figures 6 - 9) that reflect high-frequency stacking of depositional sequences.

These units were isolated with high-GR, low-Res, and high-SP signatures identified as major flooding surfaces (MFS) markers (Figure 4), with distinct “bell-shaped” GR characteristics above and “funnel-shaped” GR characteristics below the selected surfaces (Donovan, 2016). These shifts are associated with variability in organic content related to sea level change and the resulting cycles of proximal and distal sedimentary compositions. Using these log signature pattern qualifiers, as opposed to simply focusing on isolated log values, limits the possibility of misinterpreting ash beds or other high-GR/low-Res events as major flooding surfaces. Once units were identified and correlated across the study area, isochore maps were produced to represent the thickness variations and determine the implications of paleotopographic depositional surfaces and other depositional constraints.

3.2.2. Well Core

The Cities Services Co. (Sage Energy Co.) Ivy B #1 42-149-30568 well core data was used to correctly identify the sequence boundary separating the Eagle Ford Group from the Austin Group in the associated well logs (Figure 5). The most applicable data collected from the core examination consisted of depositional and post-depositional sedimentary and bioturbation facies shifts. The Austin Group facies consisted of 1) massively-bioturbated mudstone, 2) bioturbated-laminated mudstone, and 3) well-laminated mudstone deposits (Figure 5). These facies observations were recorded then contrasted and correlated with observed trends in the well logs (Figure 5). These facies descriptions are similar to lithofacies described in other recent works (e.g., Loucks et al., 2020) in the area that sub-divide the descriptions based on depositional and post/syn-depositional fabrics, but divide the massively-bioturbated facies into two different categories based on total organic content (TOC) and contrasting volumes of siliciclastic sediments, producing a total of four lithofacies defined as 1) highly bioturbated, low TOC, argillaceous, lime wackestone to packstone, 2) similar to the first, but higher TOC and greater siliciclastic content, 3) bioturbated-laminations, and 4) well-laminated (Loucks et al., 2020). The facies in this study were simplified by eliminating the differentiation in TOC and siliciclastic content between Facies 1 and Facies 2 and combining them into a single facies classified as 1) massively-bioturbated mudstone.

4. RESULTS

4.1. Wireline Logs

Examination of the major flooding surfaces correlated across the study area indicate the Austin Group can readily be sub-divided into two distinct groupings of high-frequency sequence sets separated by a Sequence Set Boundary (SSB), defined by the regional downlap onto its overlying maximum flooding surface. An interpreted transgressive sequence set, defined as the Lower Austin Chalk (LAC), is bounded by the Austin Group/Eagle Ford Group contact below and the SSB above. The highstand sequence set, defined as the Upper Austin Chalk (UAC), is bounded by the SSB at its base and the Austin Group/Taylor Group contact above.

The LAC consists of five shallowing-upward sequences, each approximately 30-100 ft (9-30 m) thick, bounded by the Austin Group base and the SSB, and separated by the major flooding surfaces MFS10, MFS20, MFS30, and MFS40. These units collectively thin gradually from east to west (Figure 8), and all but the lowest unit (Figure 7), representing the Giddings Field “A Zone,” occur across the study area. This thinning indicates westerly depositional influence by the San Marcos Arch, whereas the beds individually display onlap and stratal convergence geometries indicative of a transgressive cycle.

The UAC is bounded by the SSB (below), and the unconformity at the base of the Taylor Group (above). consists of eight shallowing-upward sequences, also approximately 30-100 ft (9-30 m) thick each, and separated by the major flooding surfaces MFS50, MFS60, MFS70, MFS80, MFS90, MFS100, and MFS110. The UAC also occurs in cross sections A-A’ (Figure 6) and B-B’ (Figure 7) and thins westerly toward the San Marcos Arch. Post Austin Group erosion produced a sharp easterly thinning at the southeast corner of the study area, where the uppermost five units were erosionally truncated.

4.2. Facies

Three significant facies were identified in the core as 1) massively-bioturbated mudstone, 2) bioturbated-laminated mudstone, and 3) well-laminated mudstone deposits (Figure 5). While logging the occurrence of these facies, a repeating trend was identified in which the facies shifted abruptly from massively-bioturbated to well-laminated, then transitioned gradually to bioturbated-laminated, then to massively-bioturbated before another abrupt shift back to well-laminated. These cycles correlated with the high-frequency sequence set trends identified in wireline well log cross section (Figure 7) correlations in the LAC depths present in the core (Figure 5). This reinforced the interpretation methods used to identify the major flooding surfaces picked throughout the rest of the study area.

The core data also confirmed the depth of the Austin Group/Eagle Ford Group contact, and corroborated the technique applied in wireline well log correlation to identify the major flooding surfaces, especially, MFS20 and MFS30. These flooding surfaces separated the identified high-frequency sequence units used in establishing stratigraphic geometries and depositional associations (Figure 5).

4.3. Cross Sections

Four cross sections were constructed in west to east, and northwest to southeast orientations to illustrate the stratal geometries of the units within the Austin Group. Cross sections A-A' (Figure 6) and B-B' (Figure 7) reflect the approximate strike orientation of the beds and the influence of depositional and post-depositional topographic features and erosional events. Cross sections C-C' (Figure 8) and D-D' (Figure 9) are oriented approximately along depositional dip of the Austin Group to emphasize depositional geometries associated with onlap and downlap, and provide additional dimensional perspective of the depositional and post-depositional features affecting the stratigraphic geometries.

The cross sections are referenced on the SSB datum surface across the field to distinguish the distinct lapout (onlap & downlap) geometries of the LAC and UAC, respectively. These two sequence sets also have independent depositional responses to topographic features associated with the San Marcos Arch. In the Lower Austin Chalk, a topographic high, or saddle, in the south-central portion of the study area segments the lowest unit of the Lower Austin Chalk, the "A Zone," yet this feature does not have an impact on the geometries of the Upper Austin Chalk. Conversely, the Upper Austin Chalk converges against the San Marcos Arch to the west with more exaggerated westward thinning than what is observed in the Lower Austin Chalk (Figures 6-8).

The southeastern extent of the study area exposes a large erosional feature identified as the Waco Channel in the Upper Austin Chalk (Durham and Hall, 1991). This feature is imaged in cross sections B-B' (Figure 7) and D-D' (Figure 9).

4.4. Isochore Maps

Three isochore maps were constructed based on stratigraphic distinctions and structural influences. This first isochore map (Figure 10) is of the Giddings Field A Zone production interval, the lowest unit of the LAC bounded by the Austin Group/Eagle Ford Group boundary below and the flooding surface MFS10 above. The A Zone isochore map expresses the depositional influence of a topographic high which formed a saddle segmenting the A Zone into separate east and west occurrences in the field.

The second isochore map (Figure 11) represents the total vertical thickness of the LAC, with the Austin Group/Eagle Ford Group contact at the base, and the SSB datum as the top. The LAC isochore map shows a gradual thinning from east to west, and includes an isolated area of thinning and subsequent isolated thickening directly west of the saddle formed by the paleotopographic high segmenting the A Zone below. The features associated with this saddle in the LAC map (Figure 11) correlate well with the thickness changes in the A Zone map (Figure 10).

The third isochore map (Figure 12) represents the vertical thickness of the UAC between the SSB datum at the base and the Austin Group/Taylor Group boundary at the top. Like the LAC, the UAC thins westward across the field, but at a greater rate. Sharp eastward thinning is observed in the UAC isochore at the east corner of the study area, but no isolated thinning or thickening events occur centrally in the UAC isochore, reflecting little or no influence of the paleotopographic saddle effects observed in the LAC.

5. DISCUSSION

5.1. Facies

Based on core control, three facies were recognized. These facies are: 1) massively-bioturbated mudstone, 2) bioturbated-laminated mudstone, and 3) well-laminated mudstone deposits (Figure 5). These three facies are based on sedimentary changes that indicate depositional shifts as related to environmental changes brought on by change in water depth. The massively-bioturbated sediments represent oxic, proximal conditions more hospitable to burrowing organisms that are dependent on the presence of oxygen for respiration. In contrast, the well-laminated deposits indicate a sediment interface inhospitable to burrowing organisms, and likely related to anoxia or near-anoxia in distal basin conditions (Young and Woodruff, 1985), whereas the bioturbated-laminations indicate a transitional environment from proximal to basinal and the gradual environmental change from oxic to anoxic, or hospitable to inhospitable for organisms. Facies cycles were observed in the core where massively-bioturbated deposits would shift sharply to well-laminated deposits, which would gradually transition to bioturbated-laminated facies, and eventually massively-bioturbated before abruptly shifting back to well-laminated deposits. Two of the more significant shifts corresponded with the major flooding surface MFS20 and MFS30 picked in the wireline well log associated with the core (Figure 5).

5.2. Sequence Stratigraphy

Through detailed correlation of wireline well logs and analysis of cross section geometries, it was determined that the Austin Group in the region between Giddings Field and the San Marcos Arch consists of two high-frequency sequence sets, comprised of a total of twelve high-frequency sequences (S1 – S12), separated by a major lapout (interpreted downlap) surface (SSB) within sequence S4 (Figure 4). The lower sequence set, designated the LAC, is composed of four high-frequency sequences, S1-S4, and is sub-divided into five correlation units separated by major flooding surfaces. The five LAC correlation unit boundaries are defined by 1) the Austin Group – Eagle Ford Group boundary to MFS10, 2) MFS10 to MFS20, 3) MF20 to MFS30, 4) MFS30 to MFS40, and 5) MFS40 to SSB (Figure 4). The LAC is bounded at the base by the Austin Group and Eagle Ford Group contact, and at the top by the major downlap surface (Figure 4), directly underlain by the Sequence Set Boundary (SSB). The upper sequence set, designated the UAC, is composed of eight high-frequency sequences, S5-S12, and sub-divided into nine correlation units. The nine UAC correlation unit boundaries are defined by 1) SSB to MFS50, 2) MFS50 to MFS60, 4) MFS60 to MFS70, 5) MFS70 to MFS80, 6) MFS80 to MFS90, 7) MFS90 to MFS100, 8) MFS100 to MFS110, and 9) MFS110 to the Austin Group – Taylor Group boundary (Figure 4). S12 and MFS110 are not present in the type log. The UAC is bound below by the SSB, and above by the Austin Group and Taylor Group contact (Figure 4).

Identifying the SSB and distinguishing the LAC from the UAC identified a pattern in the SP log curve that corresponds to the TST and HST sequence sets (Figure 4). The LAC transgressive sequence set is characterized by a broad, bell-shaped SP characteristic, starting with an SP value of 22 mV at the Austin Group and Eagle Ford Group contact, decreasing to -47 mV near the top of the high frequency sequence S1, and increasing to -4 mV at the SSB at the sequence boundary separating S4 and S5 (Figure 4). Inversely, the UAC highstand sequence set is characterized by a broad, funnel-shaped SP trend that decreases from the -4 mV value at the SSB to -42 mV near the upper boundary of S9, then increasing to 3 mV at the Austin Group and Taylor Group contact. The bell-shaped and funnel-shaped characteristics are similar to the GR log characteristics that are interpreted to indicate an increase or decrease in relative sea level depths, respectively, related to the increase or decrease in values of preserved radioactive elements (potassium, thorium, and uranium) associated with the corresponding depositional environments (Donovan et al., 2016). Basically, the high gamma ray, and high SP, bentonite-rich marls used for correlation in this study are interpreted to occur directly above and below the interpreted maximum flooding surface in each of the high frequency sequences within the Austin. Thus, the SP trends are likely a result of formation permeability characteristics attributed to gradual facies shifts associated with contemporaneous sea level conditions and the resulting sediment input and changes in the depositional environment. Lower SP values indicate larger-grained near-shore, or more proximal facies which generally produce more permeable lithology, whereas higher SP values represent smaller-grained basinal, or more distal facies with little to no permeability. The overlapping association of the identified SP pattern with recognized bell-shaped and funnel-shaped GR pattern characterization occurs when considering that low and high GR and SP values can both reflect low to high sea level depths during deposition. Numerous factors, including formation fluid type and primary vs. secondary porosity and permeability can influence SP values dramatically, and so some wells presented SP log patterns incongruous with other wells in the study area. Understanding the limitations of those factors, the observations made in this study recognize a repeating SP trend that corresponds to the transgressive and highstand sequence sets of the LAC and UAC, with an inflection point at the SSB. This trend is well imaged in the type log (Figure 4); the Hopper, James A Unit, Weimken Unit (type log), and Tye wells in cross section B-B’ (Figure 7); the Holland, Ring A, and Wiseman-Novak Unit wells in cross section C-C’ (Figure 8); and the Tyra and Margie wells in cross section D-D’ (Figure 9).

The stratigraphic framework of the Austin Group in this area can be described as one composite sequence composed of numerous high-frequency sequences. The LAC, which is interpreted as a transgressive sequence set, is composed of high-frequency sea level fluctuations with an overall deepening trend beginning at the Austin Group/Eagle Ford Group sequence boundary at the base, culminating in a maximum flooding surface above the SSB (Figure 4), and the UAC being a highstand sequence set similarly composed of high-frequency sea level fluctuations recording an overall shallowing trend, culminating in a large-scale eustatic sea level drop at the Austin Group/Taylor Group sequence boundary at the top of the Austin Group.

5.3. Structures

At the base of the LAC, the lowest unit, the Giddings Field “A Zone,” bounded by the Austin Group/Eagle Ford Group contact below and MFS10 above, is separated by a paleotopographic high in the south-central portion of the study area and sub-divided into west and east segments, as seen in cross section B-B’ (Figure 7) and the “A Zone” Isochore Map (Figure 10). The overlying LAC units were then deposited across this topographic high and “A Zone” infill with only minor thinning across the saddle, as seen in cross section B-B’ (Figure 7) and the LAC Isochore Map (Figure 11). This topographic high is interpreted to be a relict or ancillary structure of the San Marcos Arch, which emerges as a more dramatic depositional constraint further west after the LAC deposition, and during deposition of the UAC units. The depositional geometries of the LAC sequences show onlap at the base and stratal convergence causing gradual thinning of the sequences to the west onto the San Marcos Arch, indicate the LAC is a transgressive sequence set.

The lowest unit of the UAC, bounded by the SSB below and MFS50 above, designated the Two Fingers Marker (Figure 4), correlates across the majority of the area until it laps-out against the SSB downlap surface to the west, as seen in cross section A-A’ (Figure 6). The correlation marker designated the Three Wise Men Marker (Figure 4) also laps-out against the SSB in a similar fashion as the Two Fingers marker (Figure 6). The westward onlap of the UAC units, and significant thinning of the UAC, as seen in cross sections A-A’ (Figure 6), B-B’ (Figure 7), and C-C’ (Figure 8), and the UAC Isochore Map (Figure 12), indicate a significant influence of the more pronounced San Marcos Arch, west of the relatively minor paleotopographic influence observed in the LAC. These onlap geometries also indicate the UAC is a highstand sequence set. At the western extent of the study area, all but the uppermost two units of the UAC lap-out against the San Marcos Arch.

The eastern thinning of the UAC, as observed in cross sections B-B’ (Figure 7) and D-D’ (Figure 9), and the UAC Isochore Map (Figure 12), is attributed to post-depositional erosion of the Waco Channel, which likely occurred following the depositional conclusion of the Austin Group and before deposition of the Taylor Group. The downcutting of the Waco Channel truncates the five uppermost units of the UAC within the study area, causing the dramatic thinning seen in cross section and the UAC isochore map.

The precise timing of the Waco Channel erosional event remains in question. Some studies conclude that a depositional hiatus occurred after deposition of the Austin Group, and before deposition of the Taylor Group, and downcutting of the Waco Channel through the upper Austin Group occurred in response to a regional uplift termed the Belton High (Stephenson, 1936; Seewald, 1967; Durham and Hall, 1991). Alternatively, other outcrop and subsurface studies indicate that the Burdett Marl and Pflugerville Formations (collectively, MFS90, MFS100, and MFS110) overlie an erosional surface and conclude the Waco Channel is a submarine channel that formed after deposition of the Dessau Chalk, prior to deposition of the Burdett Marl and Pflugerville Formation (Durham and Hall, 1991). The interpretations of this study do not indicate that any units of the Austin Group are younger than the Waco Channel event. However, further study of the Waco Channel is needed to more accurately determine when and how this erosional feature was formed.

5.4. Petroleum Applications

Several observations were made which apply to the prediction of petroleum reservoirs and play fairways in the Austin Group of the region. These observations consist of play extensions or re-emergence, and the potential for structural reservoir traps. The western extent of Giddings Field production unit known as the “A Zone,” identified as the lowest unit of the LAC in this study, truncates against the eastern flank of the central high observed in the “A Zone” Isochore Map (Figure 10). It was discovered that the “A Zone” unit continues from the western flank of the saddle or paleotopographic high and extends eastward across the western borders of Bastrop and Fayette Counties and into Caldwell and Gonzales Counties, and possibly into Lavaca County. The truncation of UAC units on the SSB downlap surface as they approach the eastern flank of the San Marcos Arch and truncation of units by the Waco Channel at the east end of the study area may provide structural traps that impede lateral petroleum migration through the units in these respective locations.

The lack of major faulting in the study area could be a potential benefit considering reservoir isolation; i.e., preservation of reservoir pressures and reduced formation water inundation. It could also limit the migration of hydrocarbons from remote source rocks, if no sufficient source rock is immediately available to the potential reservoirs in the Austin Group. The resolution of this study precluded the identification of any local fracture networks or minor fault systems, which are a significant factor in reservoir quality within Giddings Field (Drake, 1991; Horstmann, 1987; McGhee, 1991).

6. CONCLUSION

Detailed log correlations of the top of the Late Cretaceous Eagle Ford Group, Austin Group, and basal overlying Taylor Group, and integration of a partial Austin Group core provide a new chronostratigraphic framework to define depositional and post-depositional influences, as well as explain and predict petroleum reservoir distributions within the Austin Group in Bastrop, Fayette, and Lee Counties and the immediate surrounding counties. The Austin Group is an unconformity-bounded Composite Sequence bounded by pronounced sequence boundaries at its base and top. Both these sequence boundaries are defined by stratal truncation below and stratal onlap above. A major regional downlap surface (SSB) within the Austin Group was identified in this study. This surface defines a LAC transgressive sequence set below, from an UAC highstand sequence set above. The LAC thins due to onlap at the base, as well as stratal convergence, to the west onto the San Marcos Arch. Onlap patterns at the base of the Austin Group, compared to thickness variations within it, suggests that influence of the San Marcos Arch may have migrated westward in the lower Coniacian.

The distribution and thickness variations of the Giddings Field “A Zone” reservoir at the base of the LAC can be explained and predicted by the onlap patterns at the base of the Austin Group. The UAC thins from downlap, as well as stratal convergence, to the west; and thins to the southeast by incision from the overlying Waco Channel prior to Taylor Group deposition. The Waco Channel truncates reservoir zones in the uppermost Austin Chalk, and may be a key factor in defining the trap, play, and play fairway for these reservoirs where it may form structural traps along its flanks.

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Figure 1 Paleogeographic map of the Cretaceous Western Interior Seaway, mid-Santonian, 84.9 Ma (Used with permission ©2014 Colorado Plateau Geosystems Inc). Study area indicated on map by black outlined irregular polygon.

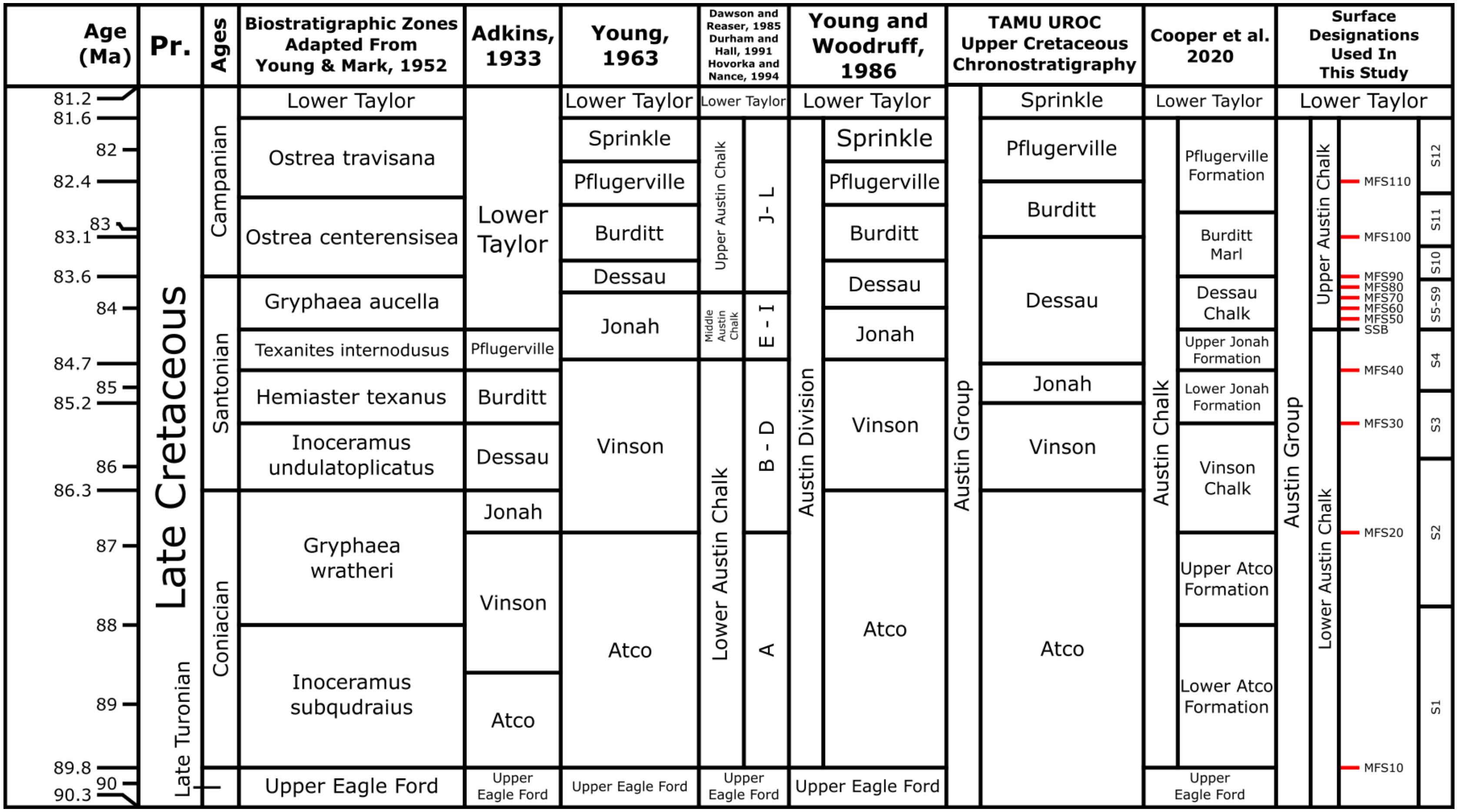


Figure 2 Austin Group lithostratigraphy compared across previous works. Adapted from Young and Woodruff, 1985. This study most closely follows the work of Cooper et al., 2020. The maximum flooding surfaces and sequences identified in this study are indicated in the last column. (Texas A&M University Unconventional Reservoir Outcrop Characterization Consortium Upper Cretaceous Chronostratigraphy used with permission of A.D. Donovan, 2021).

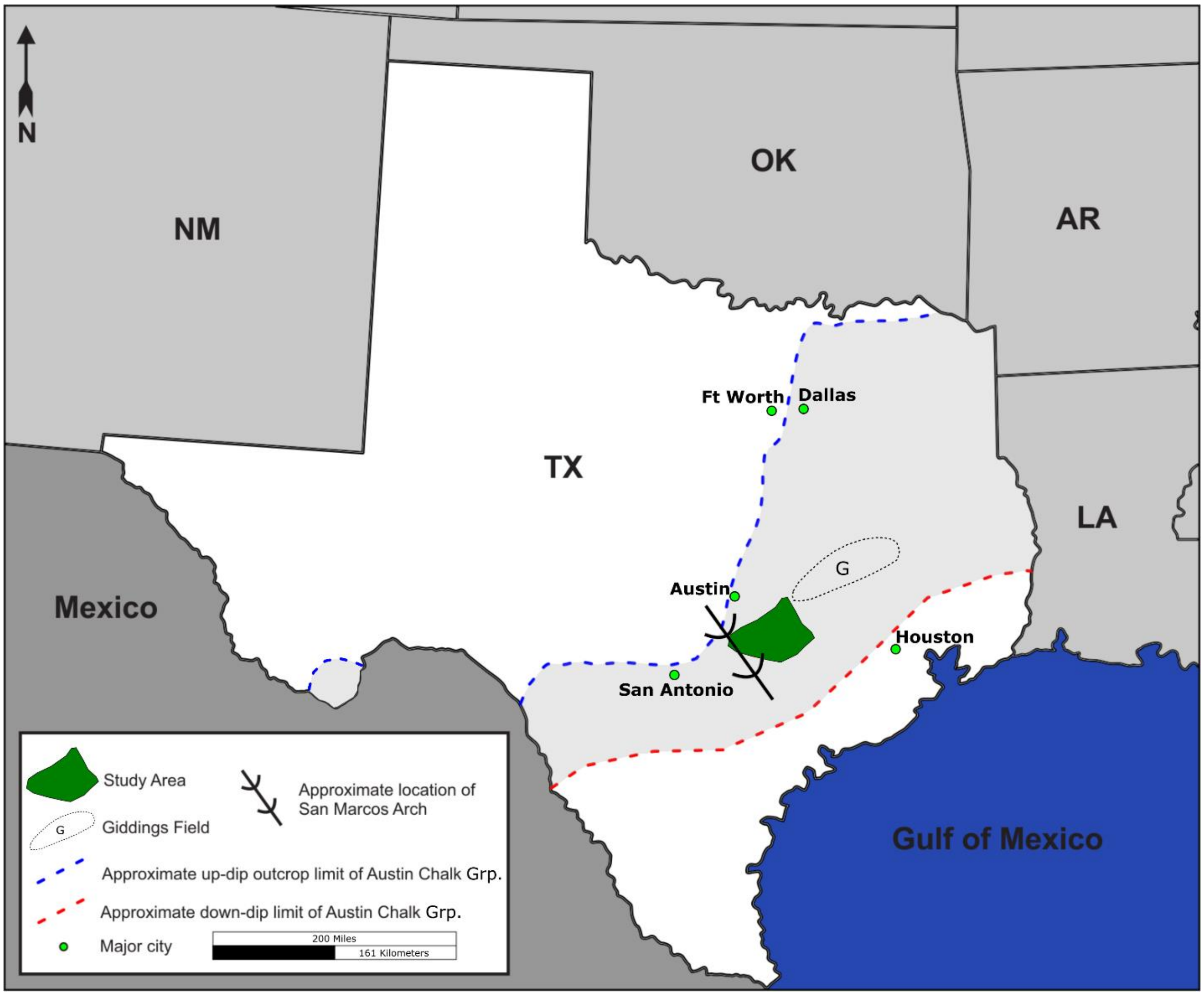


Figure 3 Map of the study area (outlined) in relation to several Texas cities, Giddings Field, and the approximate limits and location of the Austin Group.

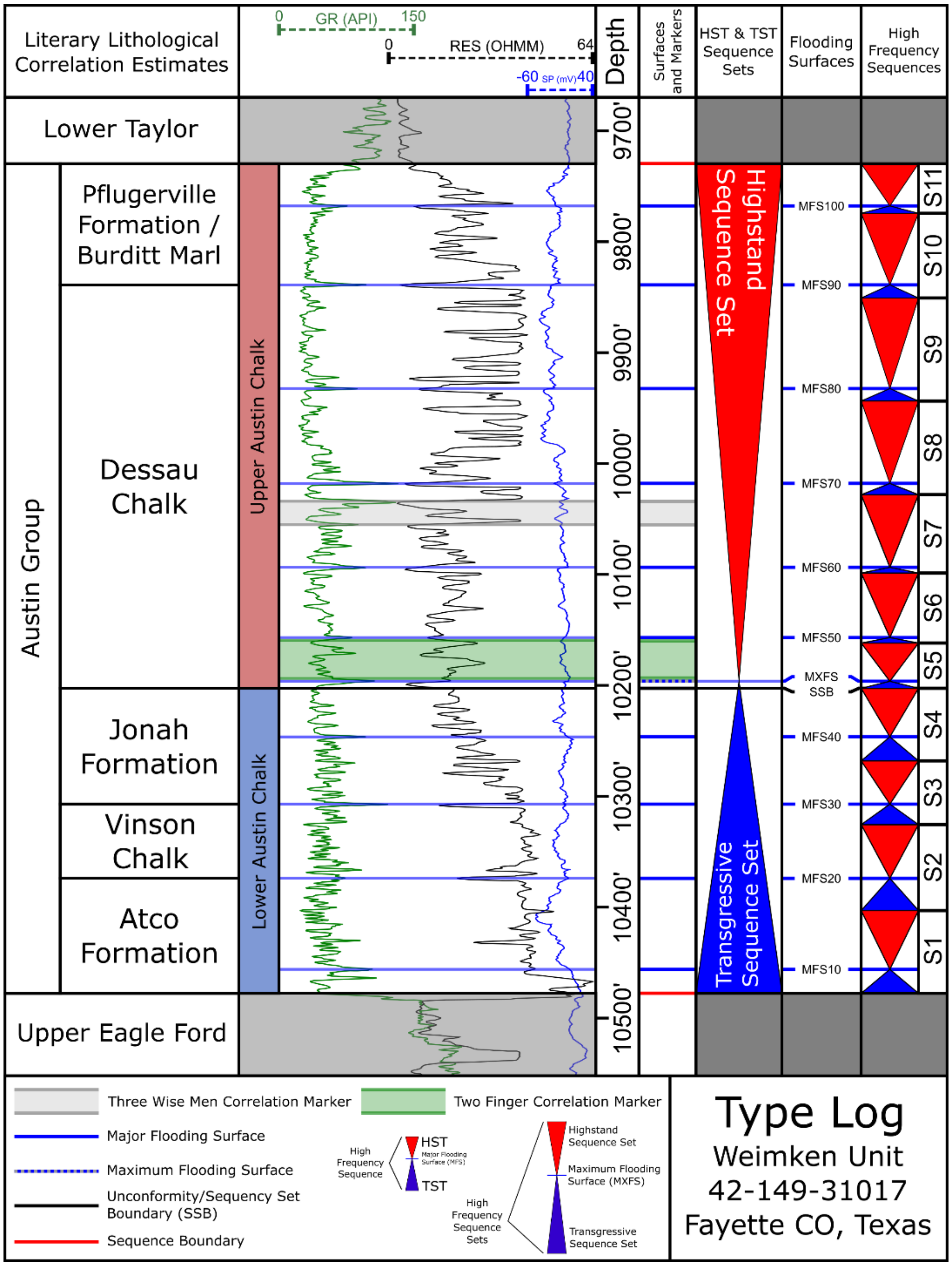


Figure 4 Type Log Cities Services Co. – Ivy B #1 well log highlighting unit correlations, identified surfaces, markers, and sequences. Three columns on the right identify the sequence sets and sequences as interpreted through correlation of interpreted maximum flooding surfaces (MFS) above and below the Sequence Set Boundary (SSB). The center column includes the Gamma Ray (GR - green), Resistivity (RES - black), and Spontaneous Potential (SP – blue) wireline logs. The bell-shaped and funnel-shaped patterns associated with the sequences and sequence sets can be observed between flooding surfaces. Also highlighted are the two major GR and SP correlation units (gray and green).

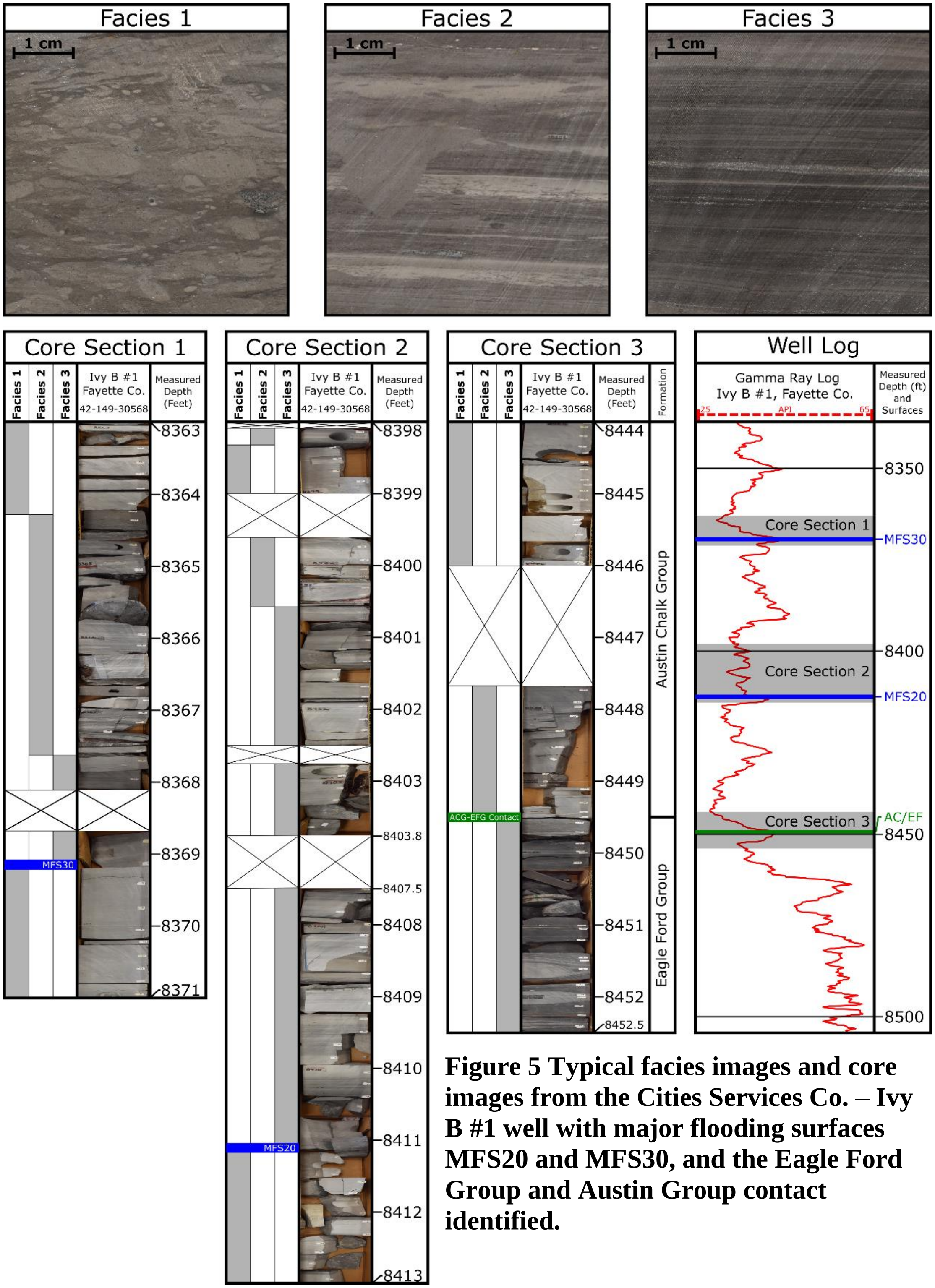


Figure 5 Typical facies images and core images from the Cities Services Co. – Ivy B #1 well with major flooding surfaces MFS20 and MFS30, and the Eagle Ford Group and Austin Group contact identified.

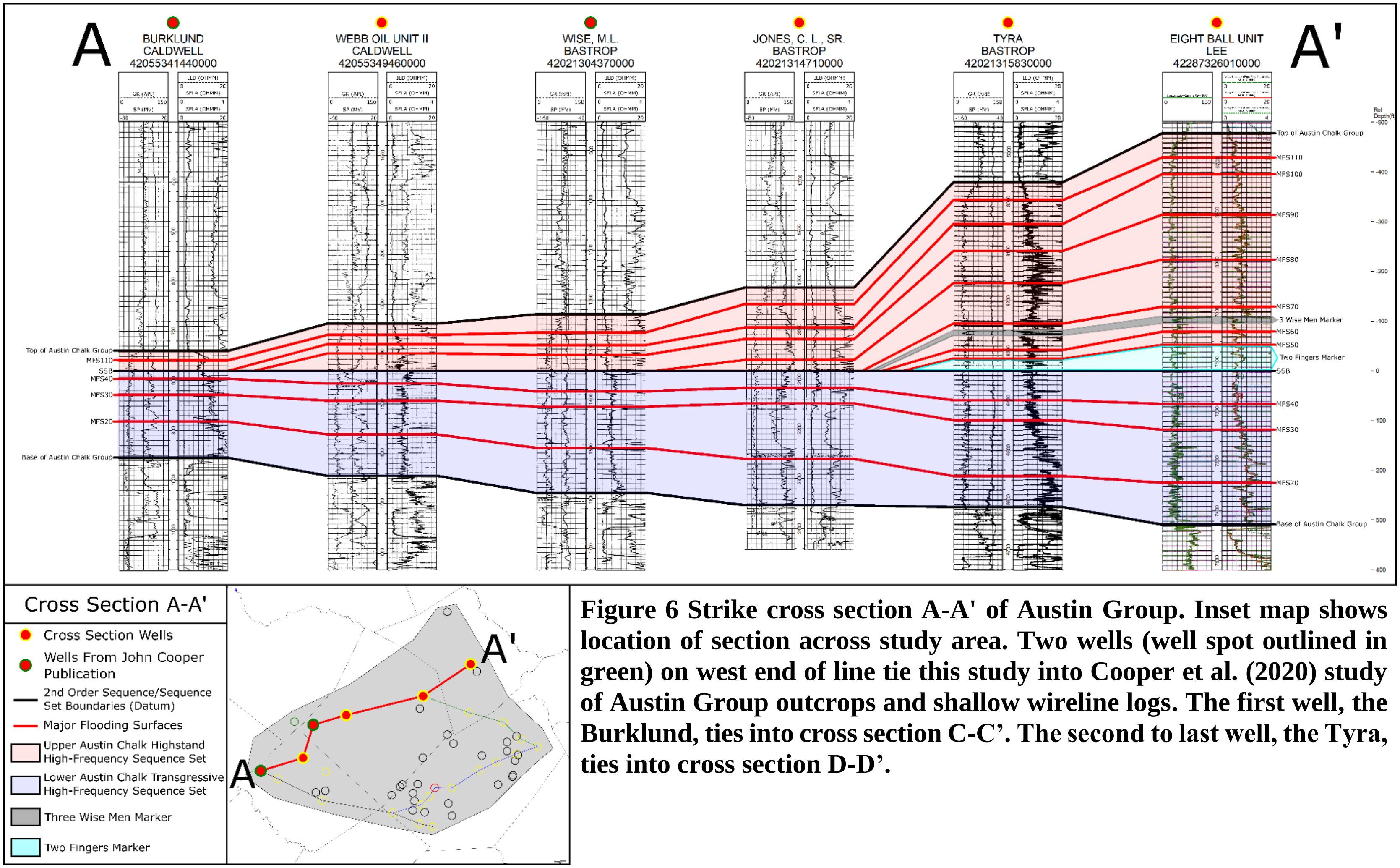


Figure 6 Strike cross section A-A' of Austin Group. Inset map shows location of section across study area. Two wells (well spot outlined in green) on west end of line tie this study into Cooper et al. (2020) study of Austin Group outcrops and shallow wireline logs. The first well, the Burklund, ties into cross section C-C'. The second to last well, the Tyra, ties into cross section D-D'.

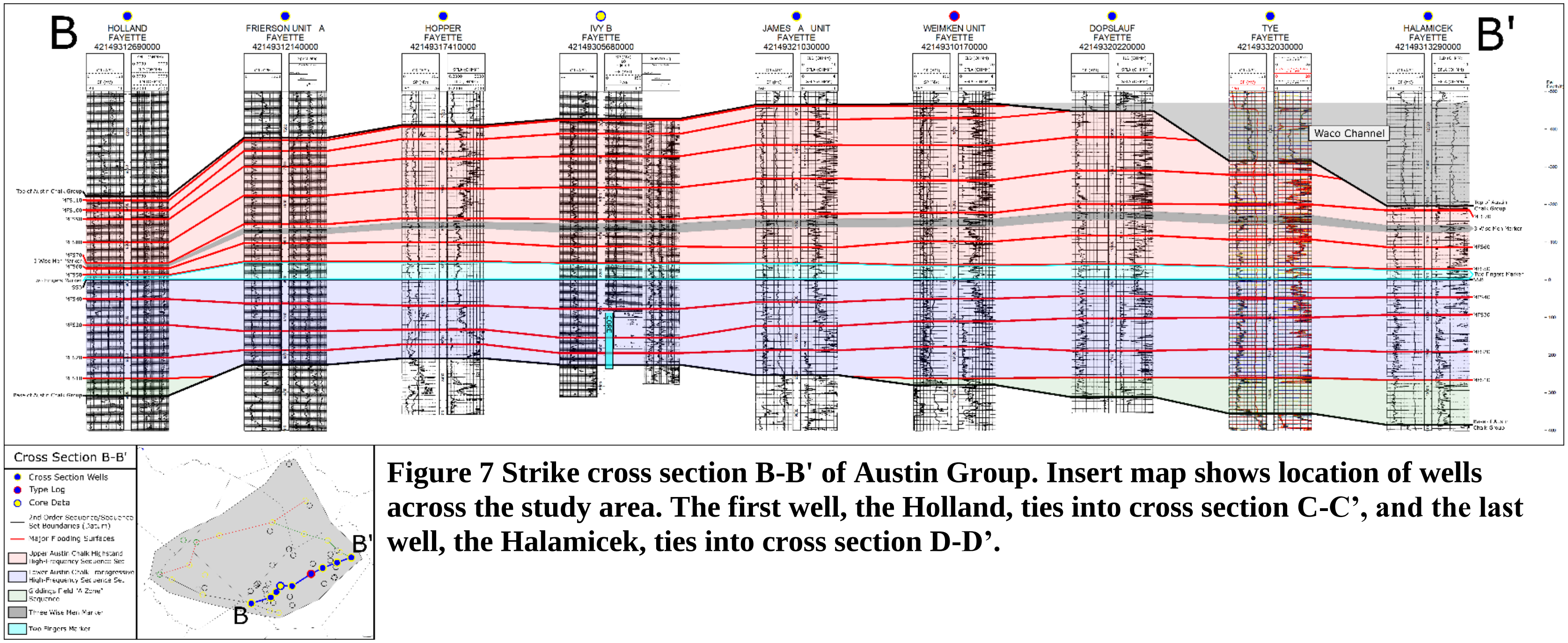
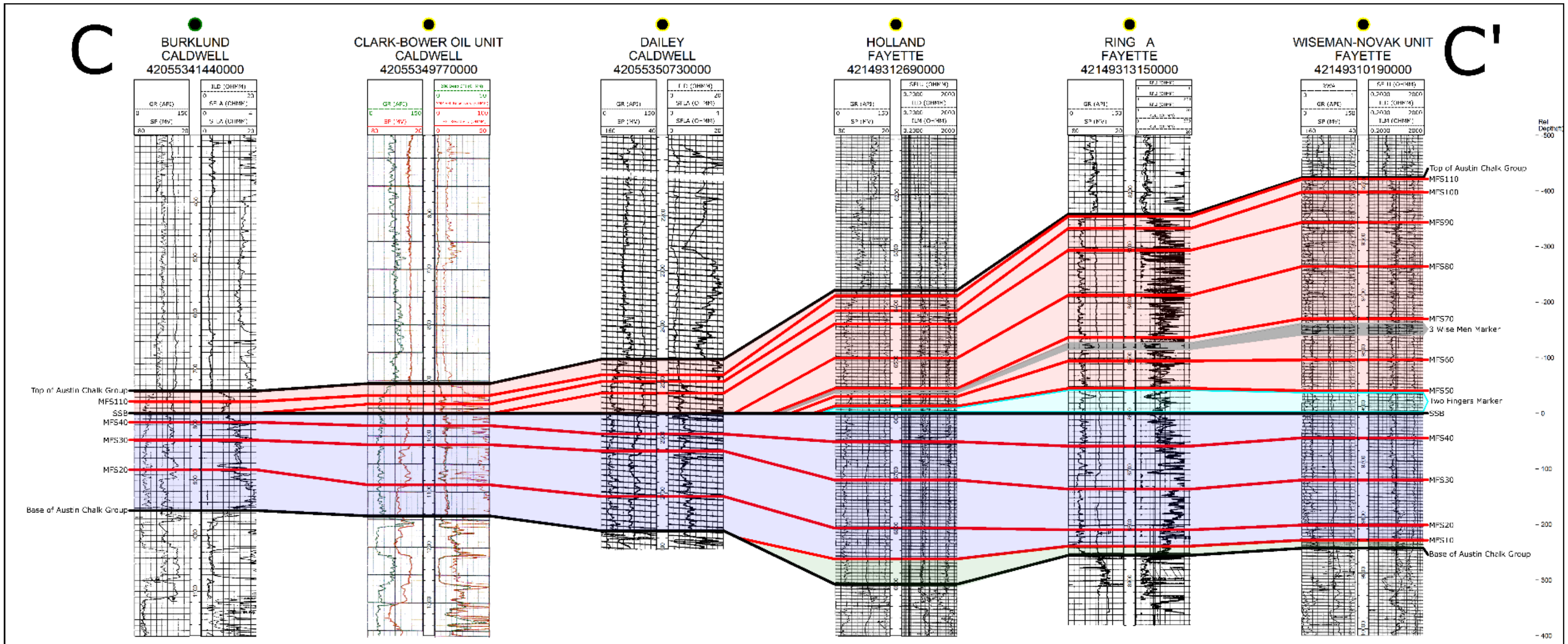


Figure 7 Strike cross section B-B' of Austin Group. Insert map shows location of wells across the study area. The first well, the Holland, ties into cross section C-C’, and the last well, the Halamicek, ties into cross section D-D’.



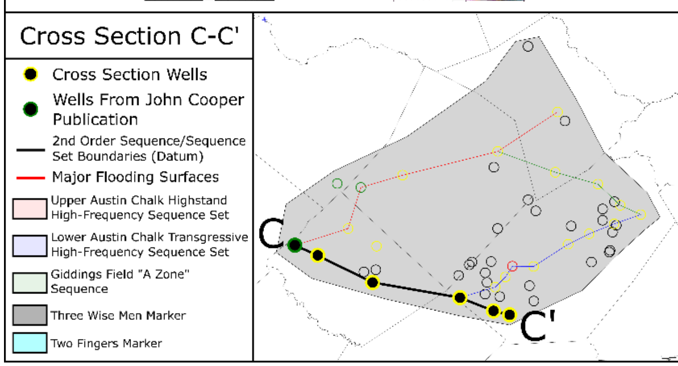


Figure 8 Dip cross sections C-C' of Austin Group. Inset map shows the location of the wells across the study area. The most northwesterly well, the Burklund, ties into Cooper et al. (2020) study of Austin Group outcrops and shallow wireline logs, and also ties into cross section A-A'. The third from last well, the Holland, ties into cross section B-B'.

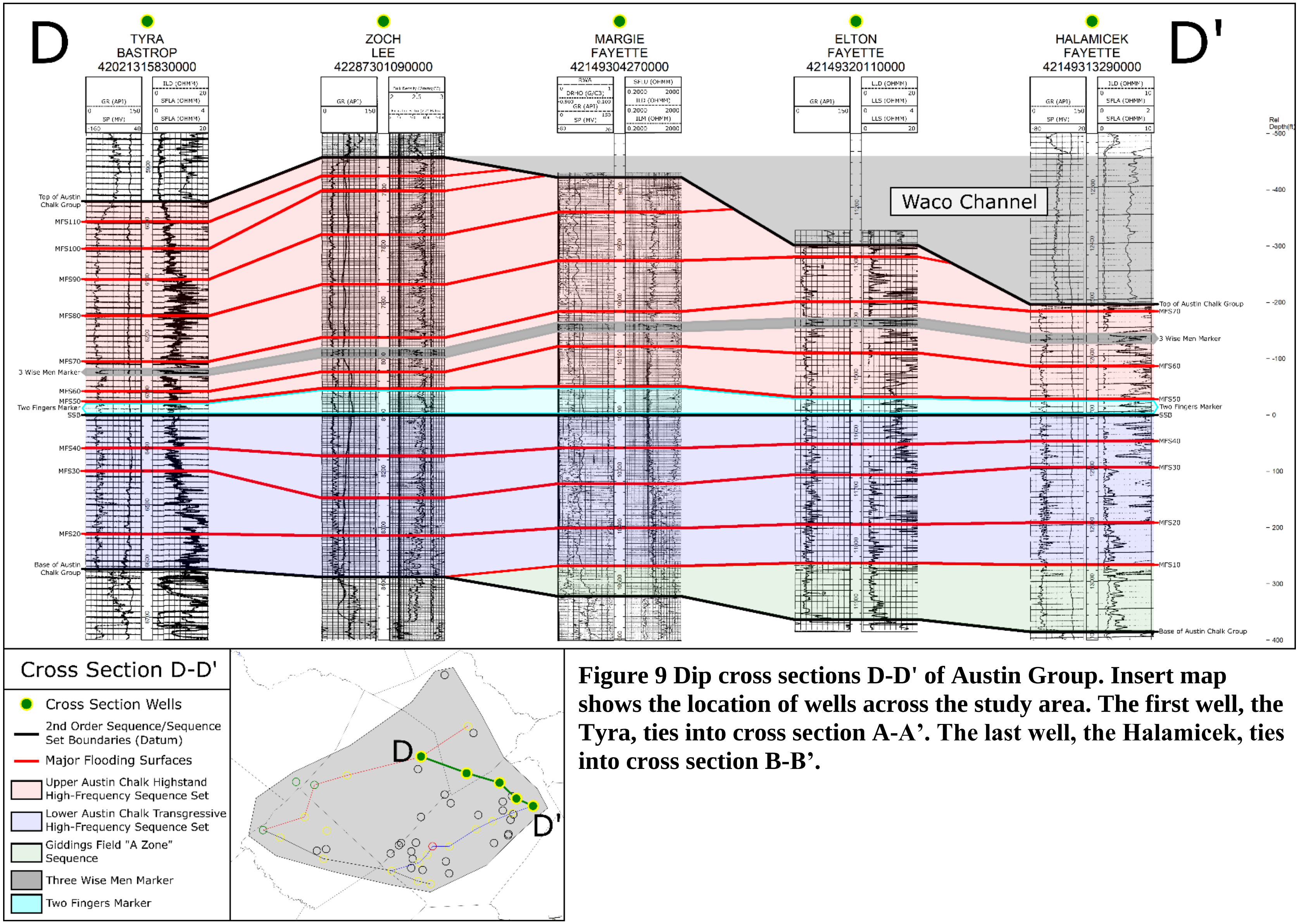


Figure 9 Dip cross sections D-D' of Austin Group. Insert map shows the location of wells across the study area. The first well, the Tyra, ties into cross section A-A'. The last well, the Halamicek, ties into cross section B-B'.

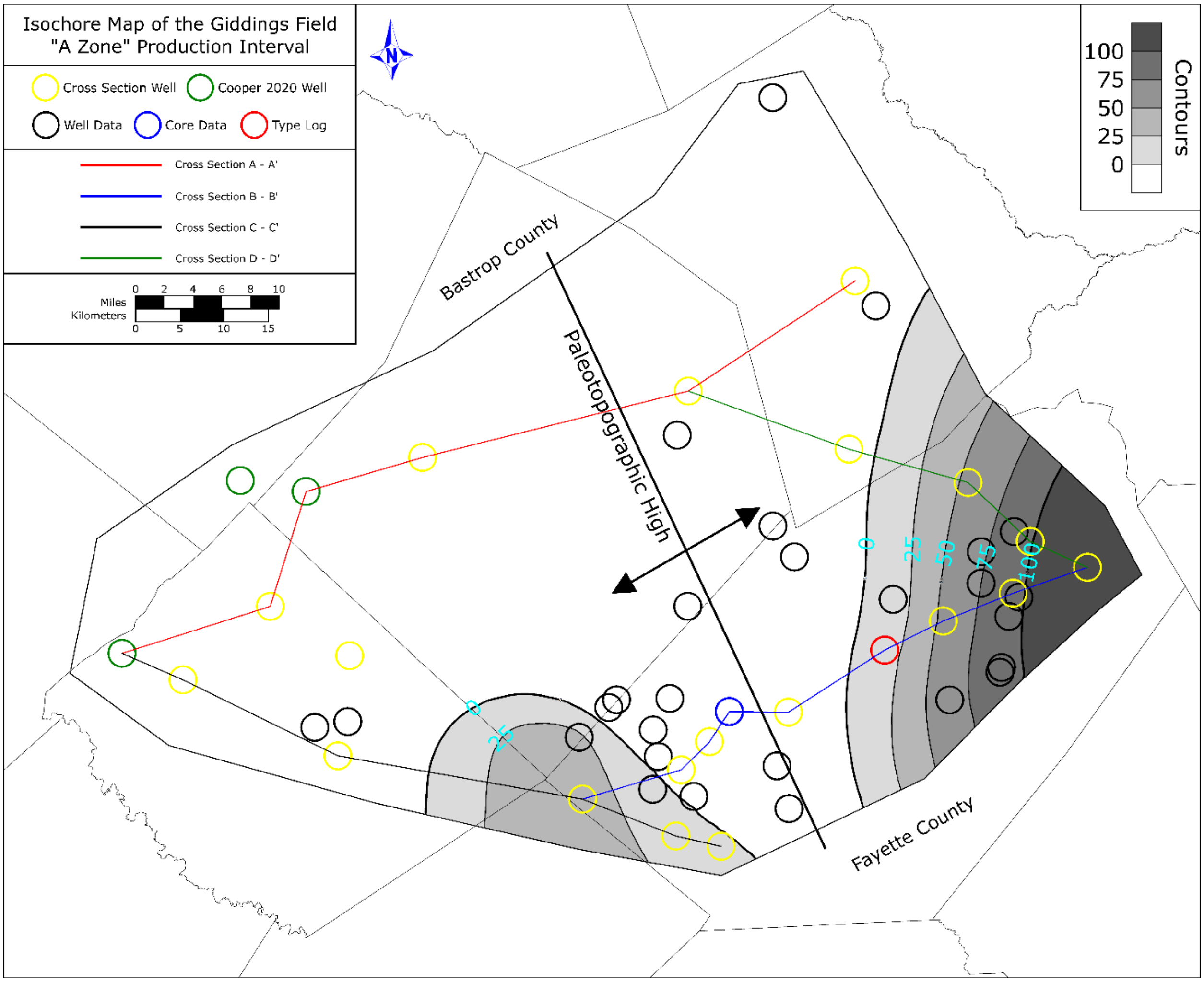


Figure 10 Isochore of Giddings Field "A Zone". Isolated thicks indicate a likely N-S oriented paleotopographic feature.

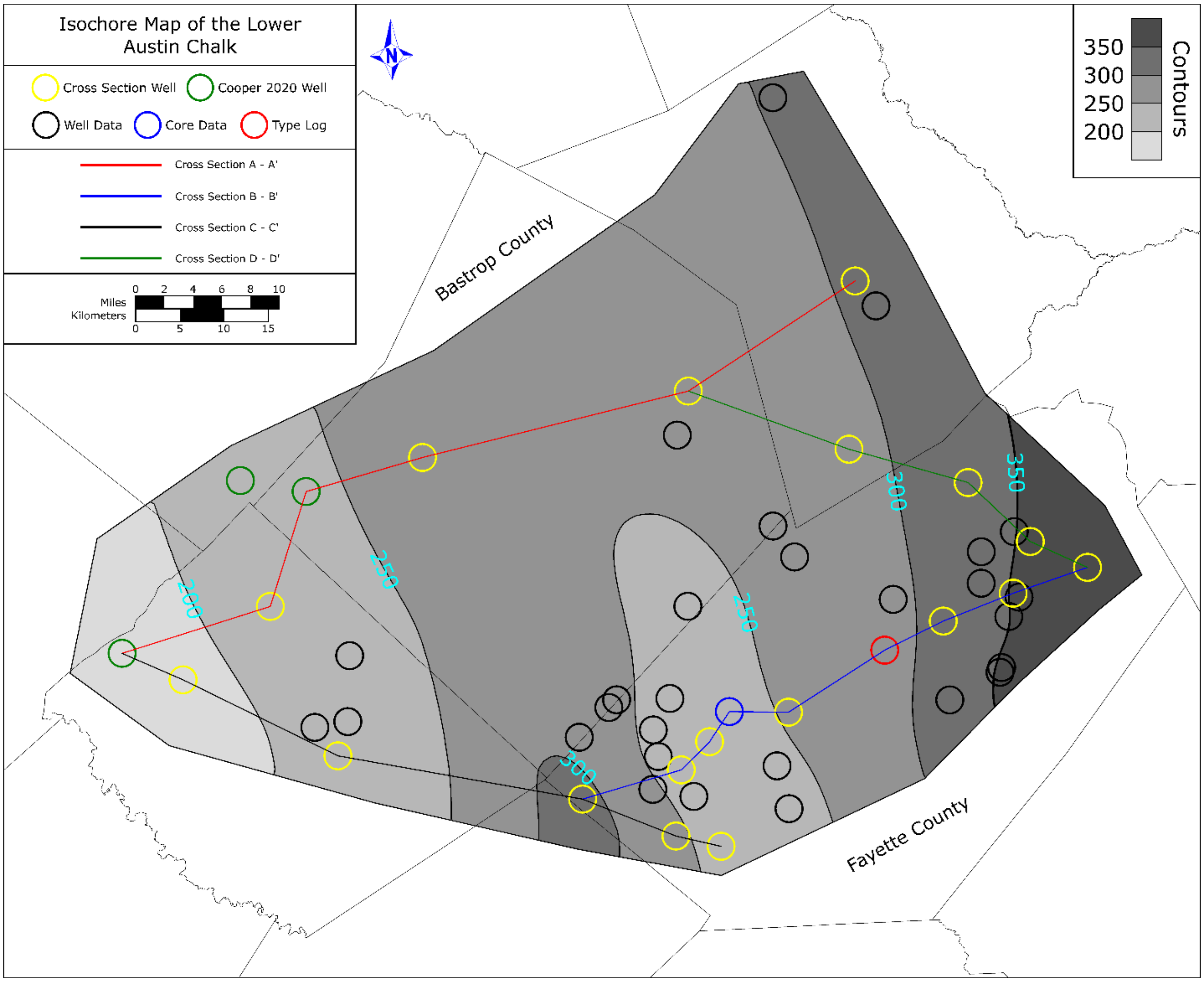


Figure 11 Isochore of Lower Austin Chalk. Thinning of LAC along approximate N-S line (see Figure 10) and minor thickening to the southwest and northwest indicate the paleotopographic high may have persisted throughout the LAC deposition.

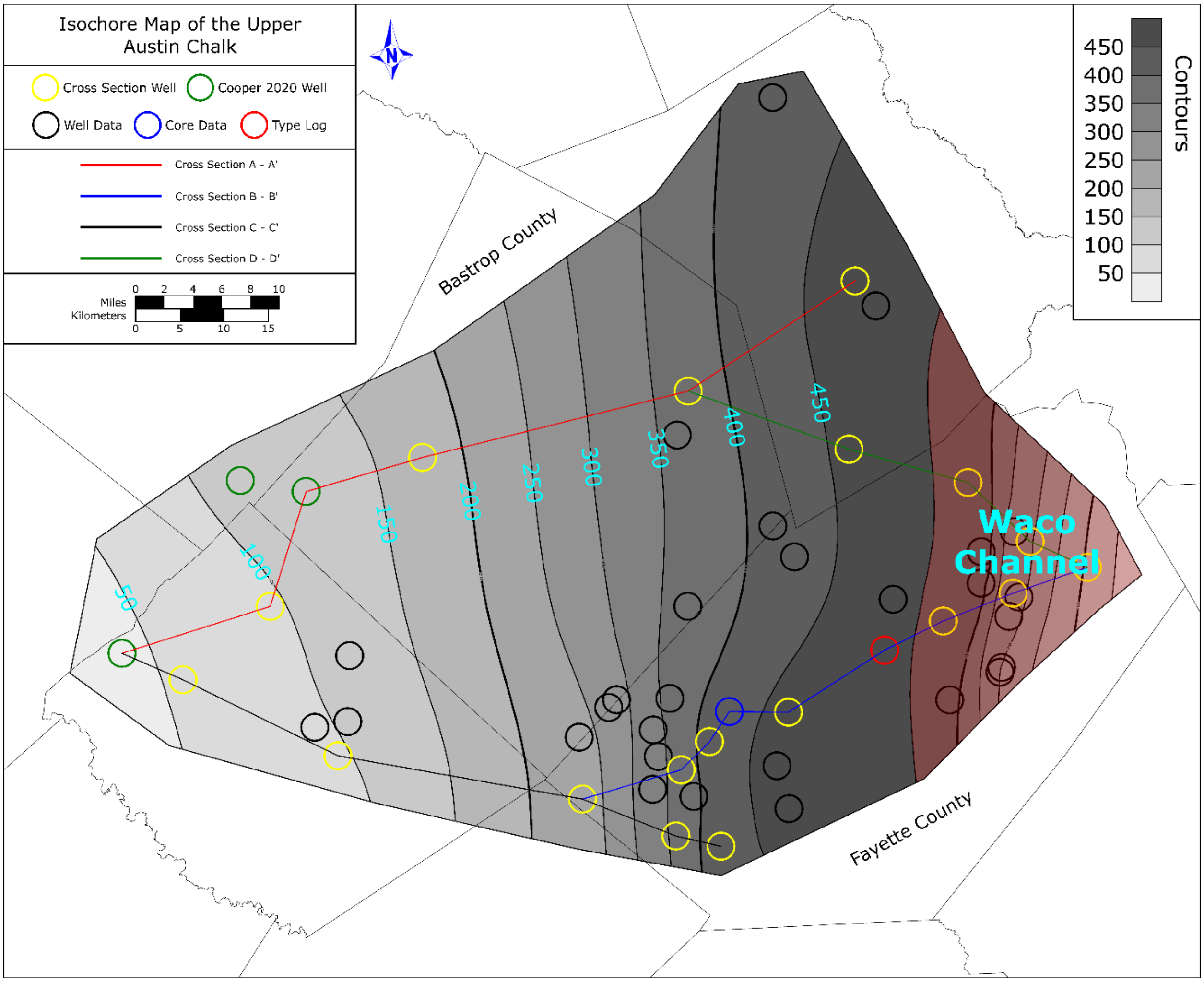


Figure 12 Isochore of Upper Austin Chalk. Thinning of the UAC to the east records erosion and truncation of the UAC during development of the Waco Channel.

APPENDIX

List of Applied Wells

API	Well Name	Well Number	Operator	State	County
42021303400000	PSENCIK, L UNIT	1	LAMMERTS ROBERT P	TX	BASTROP
42149304270000	MARGIE	1	AMMEX PETRO	TX	FAYETTE
42149304760000	MINYARD UNIT	1	MINYARD, A E & LILLIE BELLE	TX	FAYETTE
42149306520000	MULDOON-KREICH UNIT	2	ATLAS ENERGY LP	TX	FAYETTE
42149307600000	GOLDEN HARVEST	1	COFFMAN, THOMAS D INC	TX	FAYETTE
42149310170000	WEIMKEN UNIT	1	LEEXUS OIL LLC	TX	FAYETTE
42149310190000	WISEMAN-NOVAK UNIT	1	ENERGY RESERVES GROUP	TX	FAYETTE
42149310600000	CISTERN	2	INTERCONTINENTAL DRILLING CO.	TX	FAYETTE
42149311370000	FLORUS	1B	F C D OIL CORP	TX	FAYETTE
42149312140000	FRIERSON UNIT A	2	T D C EXPLORATION	TX	FAYETTE
42149312500000	MELLARD, BOBBY UNIT	1	CHAMPLIN EXPLORATION INC	TX	FAYETTE
42149312690000	HOLLAND	1	BURNS R L	TX	FAYETTE
42149313150000	RING A	1	RANDOLPH COMPANY, THE	TX	FAYETTE
42149313250000	SALMANSON	1	SANTA FE ENERGY COMPANY	TX	FAYETTE
42149313290000	HALAMICEK	1	DALECO RESOURCES	TX	FAYETTE
42021303440000	VINKLAREK, A.D.	1	PLAINS PETRO OPERATING CO	TX	BASTROP
42287301090000	ZOCH	2 C	UNITED OIL & MINERALS INC.	TX	LEE
42287307750000	MEDACK	1	RETAMCO OPERATING INC	TX	LEE
42287325830000	CONRAD HART	1	HILCORP ENERGY	TX	LEE
42287326010000	EIGHT BALL UNIT	1	ARMOR LONESTAR, LLC	TX	LEE
42149317080000	MILTON	1	PATTERSON PETROLEUM LP	TX	FAYETTE
42149317400000	GIGI	1	SHA-JAM OPERATING CORP.	TX	FAYETTE
42149317410000	HOPPER	2	SOLANO GAS PROCESSING	TX	FAYETTE
42149318510000	BEBE	1	B B L OIL & GAS CO	TX	FAYETTE

42149319490000	PHILIPPIANS	1	CONOCOPHILLIPS	TX	FAYETTE
42149320110000	ELTON	1	PATTERSON PETROLEUM LP	TX	FAYETTE
42149320220000	DOPSLAUF	1	PATTERSON PETROLEUM LP	TX	FAYETTE
42149320900000	TSCHEIDEL	1	FENN BILL INC	TX	FAYETTE
42149321030000	JAMES A UNIT	2	UNITED OIL & MINERALS INC.	TX	FAYETTE
42149321920000	BAIN	1	UNITED OIL & MINERALS INC.	TX	FAYETTE
42149322730000	MARJORIE	1	YOUNG, JOHN H., INC.	TX	FAYETTE
42149323010000	ALLISON	1	YOUNG, JOHN H., INC.	TX	FAYETTE
42149323530000	BAUMBACH	1	LOWER COLORADO RIVER AUTHORITY	TX	FAYETTE
42149324100000	CROWLEY	1	GEMINI EXPL INC	TX	FAYETTE
42149332030000	TYE	1	YOUNG, JOHN H., INC.	TX	FAYETTE
42021302780000	PESL, CYRIL M.	1	HUGHEY W. R. OPERATING CO.	TX	BASTROP
42021303510000	PIETSCH, M.E.	1	ENERGETICS INC	TX	BASTROP
42021304030000	KLEIMANN	1	SUBURBAN PROPANE EXPL CO, INC.	TX	BASTROP
42021314710000	JONES, C. L., SR.	4	L.O. OIL & GAS, LLC	TX	BASTROP
42021315830000	TYRA	2	CREATIVE OIL & GAS OPERATING,LLC	TX	BASTROP
42021315860000	WEBB, DORIS	1	GEOSOUTHERN ENERGY CORPORATION	TX	BASTROP
42149305680000	IVY B	1	SAGE ENERGY COMPANY	TX	FAYETTE
42453303640000	GEST	1	MAGNA OIL & GAS CORPORATION	TX	TRAVIS
42055341440000	BURKLUND	1	VISTA ENERGY CORP.	TX	CALDWELL
42021304370000	WISE, M.L.	2	CHALFONT OPERATING COMPANY	TX	BASTROP
42055350730000	DAILEY	1	B & S OPERATING CO.	TX	CALDWELL
42055349770000	CLARK-BOWER OIL UNIT	6	BENCHMARK TEXAS PETROLEUM, LLC.	TX	CALDWELL
42055349730000	RODENBERG -A-	2	LEFT BEHIND RECOVERY, LLC	TX	CALDWELL
42055349460000	WEBB OIL UNIT II	2R	BENCHMARK TEXAS PETROLEUM, LLC.	TX	CALDWELL
42055347010000	KELLEY, GARLAND	2	LULOC OIL CO	TX	CALDWELL
42055340420000	MIEARS, A. J.	7D	YNEW CORPORATION	TX	CALDWELL