BULLETIN

Corpus Christi
Geological Society

and

Coastal Bend
Geophysical Society

November
2020
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Table of Contents

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2020-2021
www.ccgeo.org

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2020-2021

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Visit the geological web site at www.ccgeo.org

CCGS/CBGS JOINT MEETING SCHEDULE 2020-2021

September 2019

S	M	T	W	Th	F	S
		1	2.	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
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Virtual Meeting Sept 16, 2020
At 11:00 am
Honoring Ray Govett

October 2019

S	M	T	W	Th	F	S
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Oct 21 Virtual Meeting at 11:00 am
Presenter Dr. Osareni Ogiesoba from the BEG

November 2019

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29	30					

Nov. 18 Virtual Meeting at llam
Presenter: Andrew Munoz Geophysicist for Ensign Natural Resources. "Unlocking Value from Vintage Seismic Processing-Pre-Stack Conditioning & Inversion in the Eagle Ford Shale"

December 2019

S	M	T	W	Th	F	S
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6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

Dec 1 Virtual Meeting at 11am
Presenter: Dr. Lisa Tauxe Distinguished Professor of Geophysics, Scripps Inst. Of Oceanography, Univ. of Calif. San Diego. "Hunting The Magnetic Field Through Ocean Drilling"

January 2020

S	M	T	W	Th	F	S
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17	18	19	20	21	22	23
24	25	26	27	28	29	30
31						

Jan 20 Virtual Meeting at 11am
Presenter: David M. Abbott, Jr. AIPG Ethics Columnist & Ethics Chairman Emeritus.
"Selected topics in Geoethics"

February 2020

S	M	T	W	Th	F	S
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28						

CCGS/CBGS Joint Meeting Schedule 2020-2021

March 2020

S	M	T	W	Th	F	S
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April 2020

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May 2020

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23	24	25	26	27	28	29
30	31					

Calendar of Meetings and Events Meetings and Events

Calendar of Area Monthly Meetings

Corpus Christi Geological/Geophysical Society………………………………………………… Third Wed.—11:30a.m.
SIPES Corpus Christi Luncheons…………………………………………………………………… Last Tues.—11:30a.m.
South Texas Geological Society Luncheons……………………………………………………… Second Wed—noon San Antonio
San Antonio Geophysical Society Meetings……………………………………………………… Fourth Tuesday
Austin Geological Society…………………………………………………………………………… First Monday
Houston Geological Society Luncheons…………………………………………………………… Last Wednesday
Central Texas Section of Society of Mining, Metalllurgy & Exp…………………………… 2nd Tues every other month in San Antonio

From the President's Desk

Rick Paige

Greetings from the Green Mountain State.

As I write this I am in Vermont on family business, while trying to work in a little foliage peeping. The colors are just starting to pop!

I've also been reacquainted with metamorphic complex terranes –cobbles and boulders of amphibolite gneisses, garnet schists, and quartzites that I seem to constantly trip over!

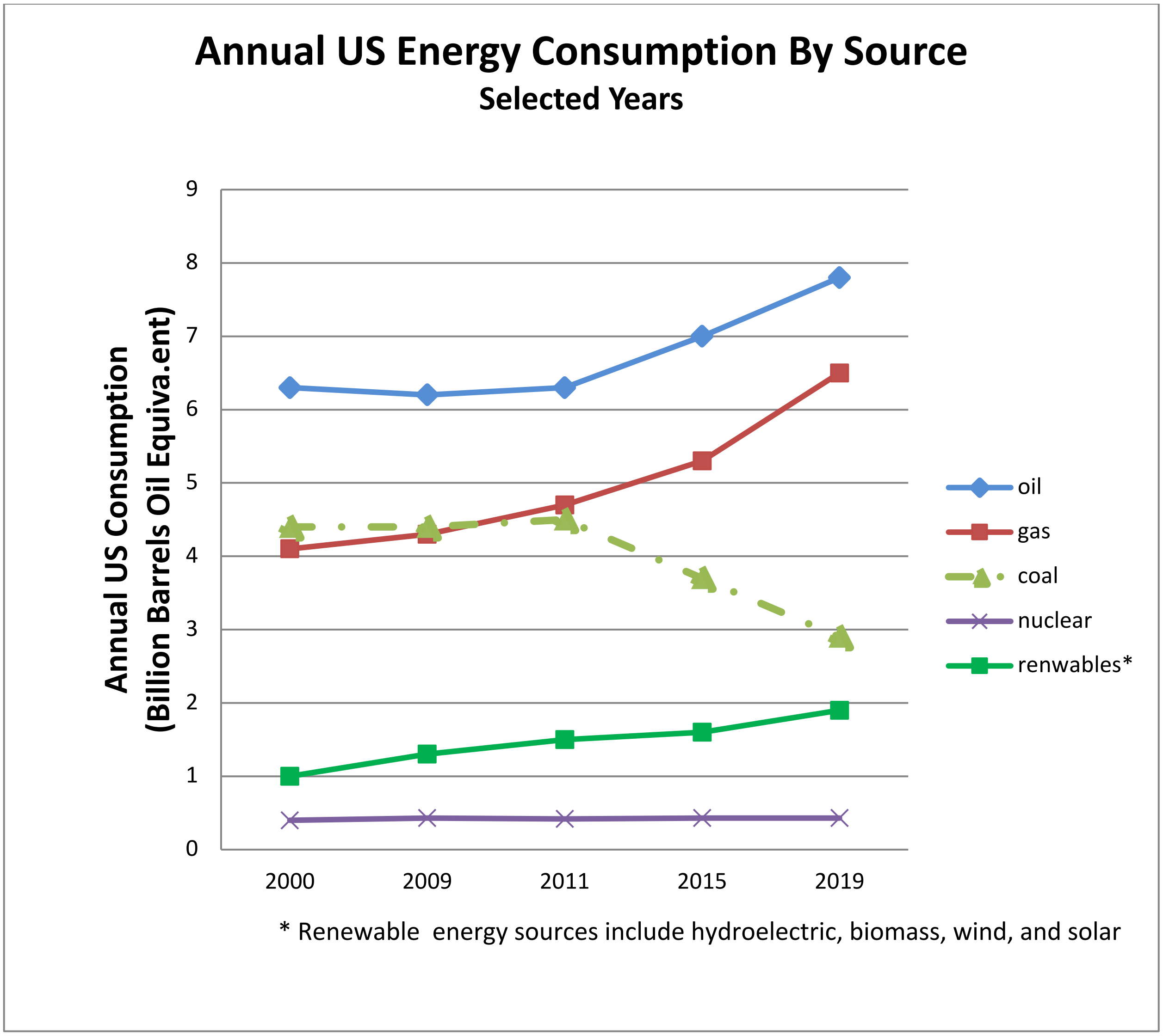
The fact that I can gather data, compose and transmit this letter remotely in our internet connected world highlights just a bit of our 2020 "new normal". By the time you read this we will have presented 2 virtual meetings to membership via Zoom. In September we Zoom broadcast our tribute to Ray Govett receiving the 2020 Distinguished Service Award from the GCAGS. In October, we presented our first technical meeting, featuring Dr. Ogiesoba who spoke to us about diapiric shale and resulting fault patterns. I hope you were able to log in to these presentations without difficulty. If, however, you experienced problems logging in, or with audio/visual aspects, please contact Randy Bissell or me, and we will see if we can resolve the problem for you.

Our next virtual technical meeting is November 18. Andrew Munoz will speak to us about unlocking value from vintage seismic, particularly as it applies to the Eagle Ford. The presentation will start at 11:00 AM with login open at 10:30. Other virtual presentations lined up: in January David Abbott, Jr. will discuss the geoethics of a variety of issues, including hurricane impacts, depletion of natural resources, and the usefulness of geoscientific models, among others. In February Dr. Shusoshuo Han of the UT Institute of Geophysics will speak on full waveform inversion of Cascadia margin data.

We continue to fill out our speaking schedule for the season, and as we have reduced the number of Bulletin publications to 4, please pay attention to email announcements for all upcoming talks. And as I wrote in my last letter, we are establishing our "new normal". Part of that is determining what time of day is best for our virtual meetings. We will open meeting logins ½ hour early, and stay logged on after the presentation to give you a chance to voice your choice. Of course we will continue to aim for the day we can all actually gather together in the same room again!

Energy Reality in America, Revisited

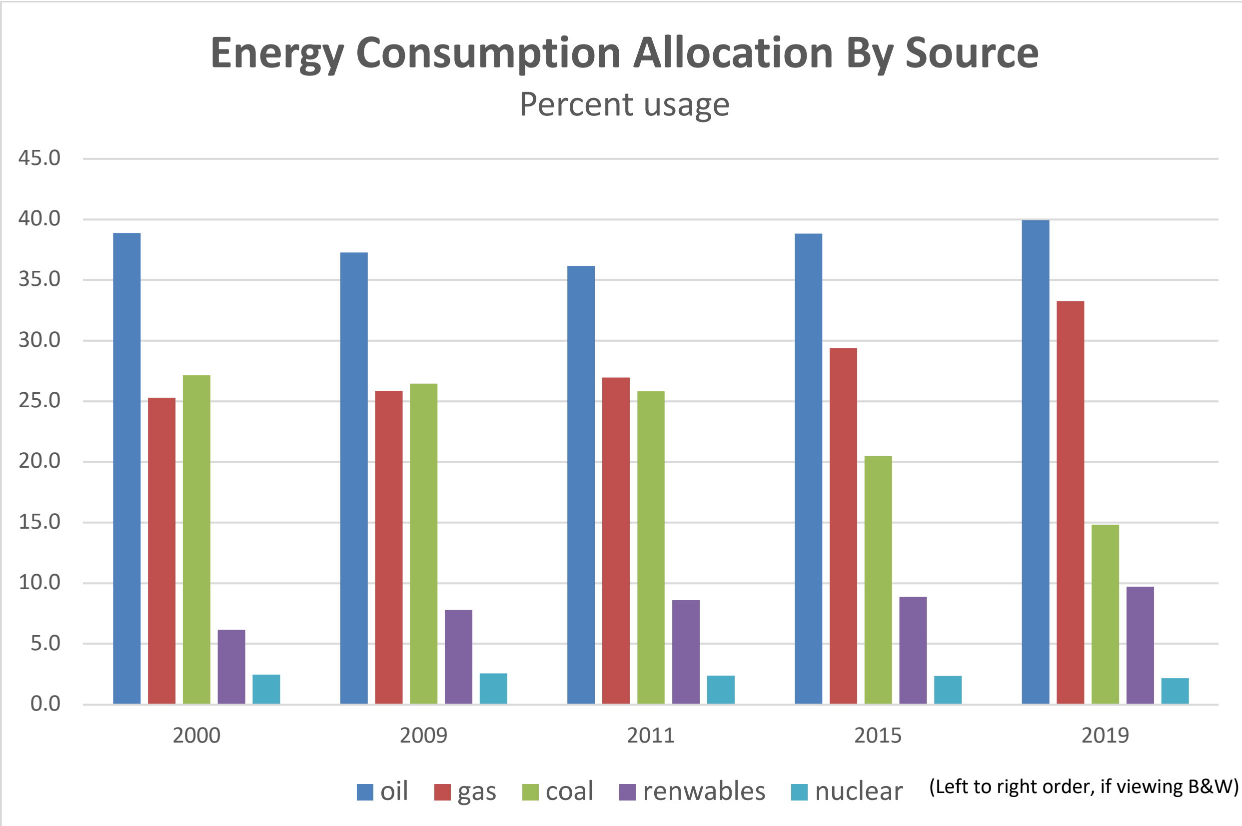
Back in 2010-11, my first term as President, I included in my letters a series of articles on energy capacity by source in America. I started by determining how much each energy type contributes to total U.S. energy consumption. (You can find these President letters at the CCGS website: CCGEO.org/Bulletins/President's Letters.) I thought it would be interesting to see how the numbers compare now, 9 years later. Below is a chart that shows the annual contribution of each major energy type for selected years covering 2000 to 2019[i]. For those energy types that apply, namely oil and gas, the consumption volumes include imports. I have converted all values to Barrels of Oil Equivalent on an energy content (BTU) basis. All data is from the U.S. Energy Information Administration, eia.gov[ii].



(Includes Imported volumes (oil and gas))

In 2000 our total energy consumption was 16.2 Billion BOE. By 2019 that total has increased to 19.5 Billion BOE. You can see that oil and gas consumption has risen, while coal has fallen dramatically. Renewables, which include hydroelectric, biomass, wind and solar, has steadily grown, nearly doubling its output since 2000.

This next chart shows the relative percentage contribution of each type.



Oil has maintained a fairly steady contribution of our energy consumption budget, although the allocation of domestic versus imported volumes has shifted dramatically (not shown here). Meanwhile gas has made a significant increase, gaining 7% share. This has come at the expense of coal, down 12% since 2000. Renewables have also shown a shown a steady increase, but still only represent 10% of total energy consumption.

As we all know, shale oil and gas production over the last 9 years has contributed mightily to the above consumption allocation, reducing oil imports, and domestic coal consumption. While the renewables allocation gain is impressive, the 10% contribution to the total energy consumption budget is not. As I wrote back in 2011, for renewables to become a truly impactful part of the U.S. energy budget a major breakthrough in technology, most probably within electrical energy storage, is necessary. And that storage capacity gain would need to be orders of magnitude over what is possible today. Maybe Elon Musk and his Tesla engineers will discover that breakthrough, but until then, the U.S. will never be powered by entirely green energy. As Scott Tinker, director of the U.T. Bureau of Economic Geology, has pointed out in his documentary series "Switch", over the coming decades we're going to need all of our energy sources.

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[i] The years selected to display were chosen entirely for expediency. Not all data gathering/converting is as easy while traveling as it is from the office! Data from the early years I recovered from my President's letter work back in 2010-11, while the later years I tabulated on the road. Perhaps upon my return I'll construct a master spreadsheet, with embedded conversion formulas, so displaying all the years will be as easy as copying and dropping in the raw data. If I do, I'll submit the results to the Bulletin.

[ii] To find the EIA data: eia.gov, select "Sources and Uses" tab, choose energy type, select "DATA" tab, choose "Summary", finally choose the "overview" spreadsheet.

ZOOM
VIRTUAL MEETING
WEDNESDAY, NOVEMBER 18, 2020

11:00AM

Watch your email, you will receive a notification & invitation a week in advance for the planned upcoming event

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Unlocking Value from Vintage Seismic Processing - Pre-stack Conditioning and Inversion in the Eagle Ford Shale
Presented by: Andrew Munoz

Abstract

Onshore 3D seismic is costly and time-consuming to acquire, and because of the fast cycle times in unconventional resource plays, many operators use previously acquired and processed 3D seismic data. Older datasets often suffer from a host of data quality problems, including statics errors, internal multiples, residual moveout, random noise, attenuation, fold inconsistency, and residual migration artifacts. While data can be improved with full reprocessing, in today's low-price commodity environment, many operators choose to forgo this step to keep costs low and avoid waiting for new data. Pre-stack seismic conditioning offers a quick, cost-effective option to improve seismic data quality and reveal the subtle information necessary for tight-rock delineation. We show that by using a pre-stack conditioning workflow on migrated offset gathers, we can substantially improve a 15-survey merge that has an antiquated processing flow and extract subtle rock property indicators to help horizontal well targeting in the Eagle Ford Shale play.

Presented by: Andrew Munoz

Andrew Munoz is an experienced Geophysicist who has evaluated seismic for multiple unconventional resource plays across the US. He holds a Bachelor's degree from Texas A&M University and a Master's degree from the Colorado School of Mines in geophysics. Andrew specializes in seismic data conditioning, inversion, interpretation, and multivariate statistical analysis for unconventional resource exploration and development. He is currently the Geophysicist for Ensign Natural Resources, a newly formed, private-equity backed operator in the Eagle Ford Shale Play of South Teas.

ZOOM
VIRTUAL MEETING
TUESDAY, DECEMBER 1, 2020

11:00AM

Watch your email, you will receive a notification & invitation a week in advance for the planned upcoming event

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Speaker: Dr. Lisa Tauxe, Distinguished Professor of Geophysics, Scripps Institution of Oceanography, University of California, San Diego
Title of the talk: HUNTING THE MAGNETIC FIELD THROUGH OCEAN DRILLING

Abstract:

Earth's magnetic field has been the target of scientific investigation for over four centuries yet the basic fact that the field switches polarities, though suspected for over a century was not proven until the early sixties. This fact was key to the plate tectonic revolution and part of the rationale to begin drilling the ocean floor with the Deep Sea Drilling Project over fifty years ago. And the study of the Earth's magnetic field has remained an integral part of ocean drilling throughout the history of endeavor.

In addition to flipping polarity, the Earth's magnetic field changes both direction and strength on time scales from decades to millennia. Human observations of field directions provide constraints for field behavior since the age of maritime exploration starting in the fifteenth century but field strength measurements only started in the 19th century, so understanding of the geomagnetic field requires the use of "accidental" records such as sediments and igneous rocks. Because 70% of the surface of the Earth is covered by ocean, marine records are essential to get a global view of history of the Earth's magnetic field and records beyond a few million years require ocean drilling.

The International Ocean Discovery Program maintains cores from fifty years of drilling. Magnetic measurements on these cores continue to provide clues as to the timing and nature of magnetic reversals, attempted reversals (excursions), and the rise and fall in field strength since the Jurassic. Prof. Tauxe will share paleomagnetic results not only from her most recent experience on IODP Expedition 382 to the "Iceberg Alley" in the Scotia Sea but also from previous expeditions since DSDP Leg 73.

Speaker Biography

Dr. Lisa Tauxe is Distinguished Professor of Geophysics at the Scripps Institution of Oceanography, University of California, San Diego. She received her PhD from Columbia University and participated in her first expedition (Leg 73) while a graduate student. She has sailed on a total of five expeditions (Legs 73, 108 and Expeditions 318, 355 and 382).

ZOOM
VIRTUAL MEETING
WEDNESDAY, JANUARY 20, 2021

12:00AM

Watch your email, you will receive a notification & invitation a week in advance for the planned upcoming event

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Selected Topics in Geoethics
Presented by: David M. Abbot, Jr., AIPG-CPG Ethics Columnist and Ethics Chairman Emeritus

Abstract

This presentation will briefly review the development of geoethics and then examine a number of goethical issues including: ethical but upsetting geoscience studies (hurricane impacts, coastal sinking, & rockfall zoning), the sustainability of depleting natural resources, protecting classic outcrops, disclosing uncertainties (be the bookie but not the bettor), the usefulness of geoscience models, and geodiversity and inclusion in the composition of the geoscience profession.

Presenter

Since 1989 I have been writing about geoscience professional ethics issues. My "Professional Ethics & Practices" column in the American Institute of Professional Geologist's magazine, The Professional Geologist, began in 1995 and as of January 2021, 176 columns have been published. I've given short courses on professional ethics around the US for many years. I've written 65 ethics related articles for AIPG, AAPG, the EFG, AusIMM, SEG, and other international groups over the years. I was appointed AAPG's Distinguished Lecturer for Ethics in 2018-19.

CBGS President's Letter

CBGS Board 2019-2020

President- Dr. Subbarao Yelisetti
Vice President- Dr. Mohammed Ahmed
Secretary/ Treasurer-Charles Benson
TAMUK student representative- Monica Estrada
TAMUCC student representative- Ryan Turner

CBGS Scholarships

The Coastal Bend Geophysical Society (CBGS) has donated $10,000 to the Department of Physics and Geosciences, Texas A&M University-Kingsville in support of the multidisciplinary Petrophysics Graduate Program that has been requested. These funds will be used as scholarships in attracting quality graduate students.

The board awarded three scholarships of $2,000 each to undergraduate geophysics majors from Texas A&M University-College Station, University of Houston and Texas A&M University-Kingsville. We will be awarding the scholarships again this year.

Scholarship Requirements

Criteria for awarding the Scholarship from Coastal Bend Geophysical Society of Corpus Christi, Texas:

1. Scholarships are open to undergraduate or graduate students.
2. Must have declared major in Geophysics, or Geology with a concentration in Geophysics or Petrophysics.
3. Preference is given to students attending Coastal Bend schools (TAMU-K, TAMU-CC and Del Mar College), then to Coastal Bend natives attending other universities.
4. Must have a GPA of at least 3.0 and be in good standing with the school.
5. Must make effort to attend a Coastal Bend Geophysical Society Meeting in Corpus Christi Texas after being awarded a scholarship to be recognized by the society.

News

- At the time of writing this report, the U.S. crude futures have gained 117% over the past five months to around $41 a barrel, as reported by Scott DiSavino on reuters.com.
- According to Simmons Energy, the U.S. rig count would fall from an annual average of 943 in 2019 to 431 in 2020 and 326 in 2021 before rising to 583 in 2022.
- According to data from Baker Hughes, the U.S. oil and gas rig count rose to 269 in the week of Oct. 9th.

CBGS Business

CBGS currently has 43 active members, 4 honorary members, and 40 student members. Raised $1,450 towards student scholarships through membership revenue.

CBGS workshops/talks

CBGS organized **2020 SEG Distinguished Lecture** entitled "*Automating seismic data analysis and interpretation*" by Sergey Fomel on February, 11th, 2020, from 11:30 am -12:30 pm. Sergey's biography and abstract can be found at https://seg.org/Education/Lectures/Distinguished-Lectures/2020-DL-Fomel

CBGS has also hosted another lecture entitled *"Spectral Extrapolation and Acoustic Inversion for the Characterization of An Ultra-thin Reservoir"* by Charles Puryear on March 4th, 12-1 pm.

CBGS is looking forward to offer workshops/talks in the future. Topic/speaker suggestions are welcome. Email your suggestions to Subbarao.Yelisetti@tamuk.edu

New Degree Tracks at TAMUK and Graduate Scholarships

- Texas A&M University-Kingsville (TAMUK) started its first cohort of MS Petrophysics program in Fall 2018. If you are interested in joining this program in Spring 2021, please contact the graduate coordinator for MS in Petrophysics, Dr. Subbarao Yelisetti at Subbarao.Yelisetti@tamuk.edu.
- The Department of Physics and Geosciences at TAMUK is offering competitive scholarships for MS Petrophysics students. For additional details about the program and scholarships, please visit the website: https://www.tamuk.edu/artsci/departments/phge/phys/academics/gp.html
- **BS degree in Geophysics, Minor in Geophysics and Certification in Geophysics** offered at Texas A&M University-Kingsville since Fall 2017. Interested students can contact Dr. Subbarao Yelisetti (Subbarao.Yelisetti@tamuk.edu) for additional information.

Education/Events

-SEG

SEG 2020 annual meeting will be held in Houston, TX from Oct 11-16th. See https://seg.org/AM/2020/ for additional details.

See https://seg.org/Education/Lectures/Distinguished-Lectures for information about upcoming SEG distinguished lecture in Houston and other locations.

See https://seg.org/Education/Lectures/Honorary-Lectures for SEG honorary lecture locations in Texas.

-AGU

2020 Fall AGU annual meeting will be held in San Francisco, CA from December 1-17th, 2020. https://www.agu.org/Fall-Meeting

Monthly Saying

"This was our town (Calgary), 'til the oilmen took over. Now they run the Ranchmen's Club and even the Calgary Stampede" - Cattleman George Anderson in 1984 National Geographic article.

Monthly Summary

Texas Oil and Gas Info	Current Month	Last Month	Difference	
Texas Production	**MMBO/BCF**	**MMBO/BCF**	**MMBO/BCF**	
Oil	125.4	121.2	4.2	June
Condensate	19.2	19.5	-0.3	June
Gas	794.5	792.4	2.1	June
	Current Month	**Yr to date - 2020**	**Yr to date - 2019**	
Texas Drilling Permits	437	5022	9169	September
Oil wells	112	1248	2461	September
Gas wells	41	315	680	September
Oil and Gas wells	252	3157	5317	September
Other	20	86	96	September
Total Completions	1559	16913	13384	September
Oil Completions	1288	13247	10518	September
Gas Completions	271	3666	2866	September
New Field Discoveries	0	4	41	September
Other	436	5709	4956	September

Subbarao Yelisetti
President, CBGS

Byron F Dyer Obituary

March 3, 1931 - April 18, 2020 (89 years old)

With heavy hearts, we announce the death of Byron F Dyer (Houston, Texas), born in Dallas, Texas, who passed away on April 18, 2020 at the age of 89. Family and friends are welcome to leave their condolences on this memorial page and share them with the family.

He was predeceased by : his parents, Byron Fred Dyer and Hallie Epperson Dyer; and his children, Stephanie Leigh Dyer and Jeffrey Lane Dyer. He is survived by : his wife Constance Mayes Dyer; his children, Kelly Elaine Gabrisch (Mark) and John Steven Dyer (Christina Gill Dyer); and his grandchildren, Blaine Kelsey Gabrisch, Sheridan Leigh Gabrisch, Grayson Michelle Gabrisch, Mackenzie Leighanne Dyer, Byron Lane Dyer, Madison Elizabeth Dyer (Children Of Jeffrey), Harrison Mayes Dyer and Georgia Grace Dyer.

In lieu of customary remembrances, memorial contributions may be directed toward Houston Methodist Hospital Foundation - Attn.

Byron was a longstanding member of the CCGS.

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GEOGULF2020
LAFAYETTE

Log-Based Facies Analysis and Stratigraphy of the Wilcox Group, Central Texas

Thomas E. Ewing

Frontera Exploration Consultants, San Antonio, Texas

ABSTRACT

Log-based facies mapping yields insights into the complex Wilcox Group stratigraphy of Central Texas (Bastrop-Lee-Burleson-Brazos) and its important groundwater and coal resources. On raster logs (primarily those with gamma-ray profiles), one can identify and aggregate thick channels (big rivers or amalgamated channels, over 100 ft [30 m] thick), other channels (20–100 ft [6–30 m] thick), generally thin and laminated coarsening-upward (CU) sandy units , and coals or coaly intervals. Color-based displays on sections clearly delineate the complexities of Wilcox sedimentation, and allow more reliable correlation.

The Hooper Formation (oldest, overlying Midway mudstone) consists of CU units and a few channels in its lower half and a mix of channels (some thick) and floodplain units (coals, thin sands, and some CU units) in its upper half. The unit is inferred to record deltaic and shoreline progradation followed by delta-plain conditions.

The overlying Simsboro Formation is a complex of sand-rich, dominantly channel deposits (both thick and thin) but also contains floodplain deposits (mud, thin sandstones and occasional CU units) and coals. At least three channel levels can be found in many wells; this has led to inaccurate correlations in past studies. The unit is inferred to record major fluvial aggradation but does not record a single episode of valley incision.

The overlying Calvert Bluff Formation consists of coal-rich floodplain units having channels in its lower section and a thick upper section dominated by thin CU units interspersed with channels (some thick) and some sporadic coals. This upper unit strongly suggests repetitive progradation into shallow standing water in either a lacustrine, floodplain or lagoonal setting.

The top unit, the Carrizo Formation, is a complex of sand-rich channel deposits, but few are thick or amalgamated. Some interspersed floodplain

Ewing, T. E., 2020, Log-based facies analysis and stratigraphy of the Wilcox Group, Central Texas: GeoGulf Transactions, v. 70, p. 107–121.

and CU deposits are found, but they lack coal. The unit represents a return to a sand-rich fluvial environment, but one lacking major river systems.

Net channel sand and percent channel sand maps characterize the principal targets for groundwater resources in each unit (CU units and other thin sands are volumetrically insignificant). They show generally consistent but complex patterns with individual channels rarely wider than a mile (1.6 km). Downdip penetration of fresh water probably depends on the degree of amalgamation of channels in each unit, a function of sand percentage and channel thickness. Flow across faults depends on individual occurrences of thick channels, and leakage along or across faults in the sand-rich Simsboro unit.

INTRODUCTION

The Wilcox Group and Carrizo Sand in east-central Texas (Fig. 1) have been studied for many years. Significant lignite resources and active mining of lignite and clay drove research

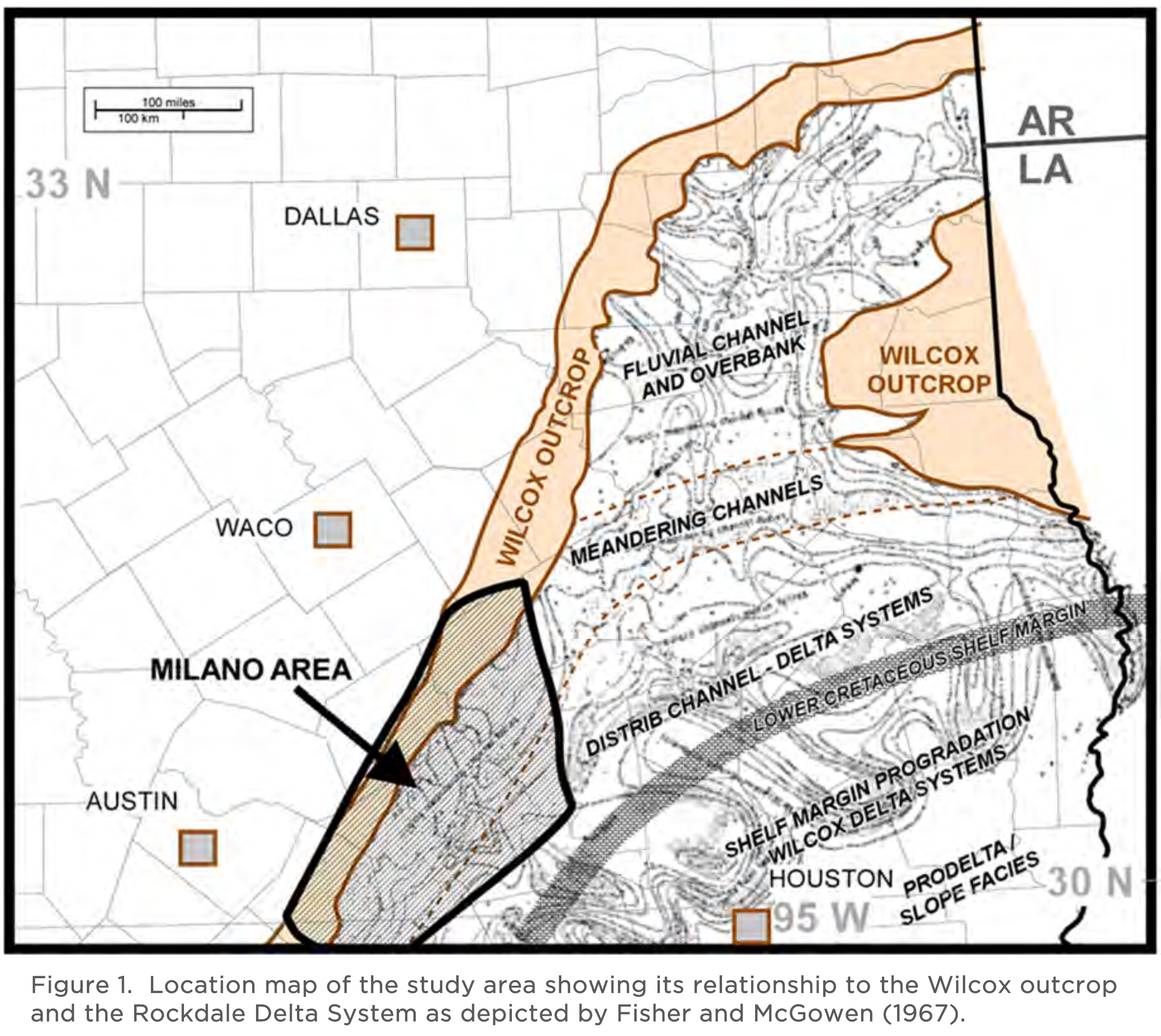
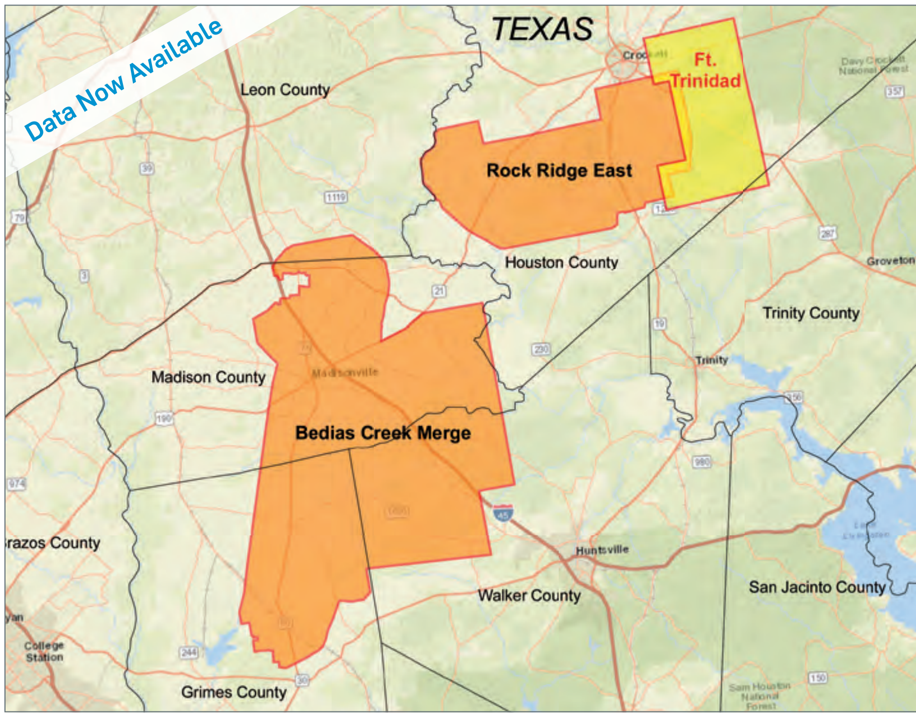


Figure 1. Location map of the study area showing its relationship to the Wilcox outcrop and the Rockdale Delta System as depicted by Fisher and McGowen (1967).

YOU'VE ARRIVED

New Ft. Trinidad 3D Survey
Houston and Trinity Counties, TX



CGG continues to expand its East Texas footprint with high-quality 3D projects while illuminating the stacked pay formations.

Data is already available from our Bedias Creek Merge and Rock Ridge East projects. Orthorhombic PSTM from our newest project Ft. Trinidad is also now available.

The right data, in the right place, at the right time

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from the 1920s to the 1970s, including mapping of the subsurface for lignite resources and in situ mining potential (Ayers and Lewis, 1985). More recently, the large groundwater resources present in the Simsboro and Carrizo sands have attracted statewide attention; groundwater modeling efforts have been significant and are ongoing. Nonetheless, significant geological questions remain regarding stratigraphic correlation and identification of connected sand-rich channel systems, the effects of faulting on these channel connections, the distribution of fresh water, and the depositional environments responsible for the various Wilcox formations.

Stratigraphic Overview and Surface-Based Geology

The stratigraphic nomenclature presently used in this area has evolved through time from the original division by Plummer (1932); the current general usage is shown on Figure 2, which is consistent with regional mapping of surface geology (Barnes, 1970, 1974).

The lowest unit in the Cenozoic is the Midway Formation (or Group), consisting of 600–800 ft (180–240 m) of marine shale and mudstone. Its upper contact is gradational over 200 ft with the Hooper Formation, the lowermost formation in the Wilcox Group. Its type area is at "Hooper Bend" or Wilbarger Bend, the present location of McKinney Roughs Park in western Bastrop

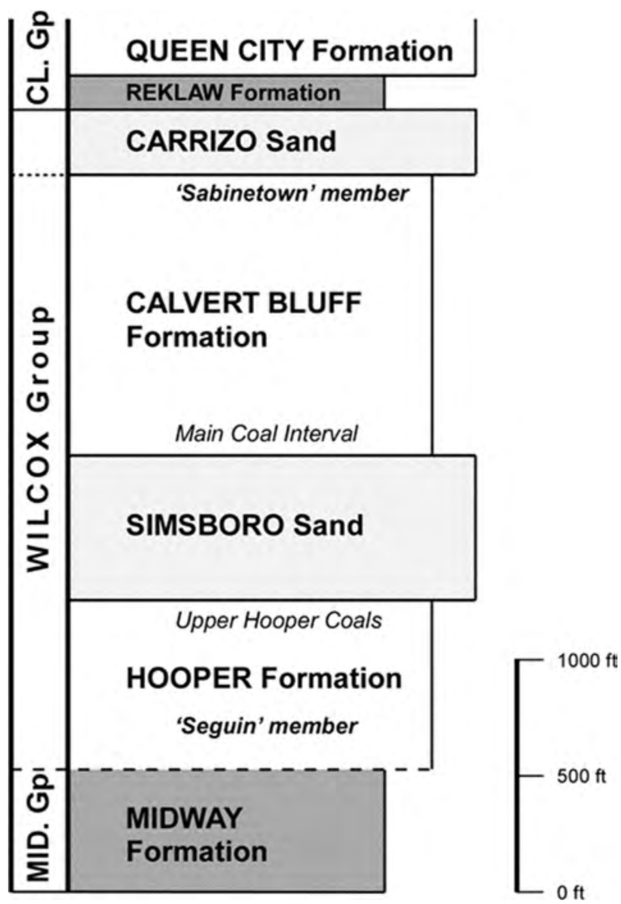

Figure 2. Stratigraphic chart, showing the names as used in this work. Formations are scaled to their thickness in southwestern Burleson County. CL. Gp = Claiborne Group.

County; the formation was proposed in an abstract by Stenzel (1951) and later by Sharp (1966) to replace the "Butler clay member" of Plummer (1932; see discussion in Fisher [1961] and Houston Geological Society [1968]). The lower Hooper consists of marine to marginal-marine sand and mudstone containing some oyster beds, and passes upward into fluvial and alluvial sands and mudstones containing significant lignite. The lower marine to brackish Hooper was originally called the "Seguin Formation" by Plummer (1932); members were described but most authors now include the section as a member of the Hooper (see, however, Yancey et al. [2013]). In this study, the thickness of Hooper is estimated to be 600 ft (180 m) thick near the outcrop, increasing to 1100 ft (330 m) in the downdip area.

The middle part of the Wilcox consists of thick sandstones that usually contain fresh water in most of the study area, as well as intervening mudstone and lignite; this unit is called the Simsboro Formation (or Simsboro Sand; the Simsboro member of Plummer [1932]), after a type locality in western Freestone County, northeast of the study area. Simsboro outcrops have been described in detail by Bammel (1979). In this study, the Simsboro is estimated to be about 600 ft (180 m) thick near the outcrop, increasing only slightly to 700 ft (210 m) in the downdip area.

A major coal and clay interval (including the clay beds at Butler) lies on top of the Simsboro sands and forms the base of the Calvert Bluff Formation (the Calvert Bluff member of Plummer, 1932), which has a type section along the Brazos River in northwestern Robertson County, which is within the study area. The main body of the Calvert Bluff consists of interbedded sandstones and mudstones and some lignite throughout. The top of the unit records more marine influence; this was termed the Sabinetown Formation by Plummer (the Sabinetown transgression of Yancey et al. [2013]). Tidal and marine influences are reported in this unit by Demchuk et al. (2019), who relate the influences to the Paleocene-Eocene thermal maximum (PETM). This interval is not consistently identifiable in well logs in the study area, though there are commonly thin marine or lagoonal mudstones that form an informal "Sabinetown member." In this study, the Calvert Bluff is estimated to be 900 ft thick (270 m) near the outcrop, increasing to 1850 ft (560 m) in the downdip area.

The uppermost sand-bearing unit in this study is the Carrizo Sand (or Carrizo Formation), named from exposures near Carrizo Springs in South Texas where the unit is thick. Here it is a much thinner but still sand-rich unit. Originally this unit has been considered the base of the Claiborne Group and separated from the Wilcox Group by an unconformity, but regional study has shown that the Carrizo is the updip fluvial equivalent of downdip Upper Wilcox delta and shoreline systems. Above the Carrizo is a thin unit (100–300 ft thick) of mudstones and sandstones deposited during a major marine transgression, called the Reklaw Formation (type area in Cherokee County, northeast of the study area), which separates the Carrizo from the overlying Queen City sand-rich section. In this study, the Carrizo is estimated to be about 250 ft (80 m) thick near the outcrop, increasing to 700 ft (210 m) in the downdip area.

Previous Subsurface and Integrative Work

Integration of the surface observations into subsurface geology and regional correlations began in earnest within the oil and gas industry in the 1950s. Fisher and McGowen (1967) published a landmark synthesis of the Wilcox Group across Texas using numerous well logs and the then-emerging techniques of depositional system analysis to outline a Rockdale Delta System, which occupies East and Central Texas. Their key map was used as the background on Figure 1. For this work they did not separate the constituent formations of the Wilcox Group: rather, all strata beneath the Carrizo and above the Midway were treated as one unit. The study area was interpreted to lie in a belt of meandering fluvial facies tracts landward of the main delta systems that prograded southeastward past the Cretaceous shelf margin.

Following on the work of Kaiser et al. (1980), Ayers and Lewis (1985) conducted the most thorough published study of the differentiated Wilcox units in the study area (and to the northeast). Using a substantial database of wells (509 wells in the Bastrop-Robertson area of the present study), they mapped sandstone channel systems and lignite resources in the Hooper, Simsboro, and Calvert Bluff units. They interpreted the Simsboro Sand as bed-load fluvial channels

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of major rivers that fed the main shelf-margin deltas to the southeast. They suggested that the main lignites overlying this sand formed in extensive mires fed by springs of fresh water from the underlying sand.

More recent regional work provides additional context for the Central Texas section. Xue and Galloway (1993, 1995) provide regional sections correlated with high-resolution sequence stratigraphy. They clearly differentiate on a regional basis (as Hargis [1985, 2009] recognized in south-central Texas) three major units within the Wilcox: the major shelf-margin deltaic progradation of the Lower Wilcox; a series of Middle Wilcox transgressive events beginning with the Tilden shale (or Big shale) and concluding with the transgressive Yoakum shale, with intervening but limited on-shelf delta development; and finally Upper Wilcox deltaic progradation fed by the fluvial sands of the Carrizo Formation. In the study area, the Calvert Bluff Formation is inferred to represent the Middle Wilcox, which overlies the sand-rich shoreline to fluvial sequence of the Hooper and Simsboro. However, detailed log correlation from more marine and deltaic sections into the present area that would demonstrate this correlation remains to be accomplished.

The present work began in support of groundwater modeling efforts for the Simsboro Sand in the study area, with the intention of including geologically realistic constraints on sand distribution and on the effects of faulting along the Milano Fault Zone that transects the area (Ewing and Young, 2018). For that work, we used a much larger well database than Ayers and Lewis (1985), correlated the stratigraphic units, mapped the thickness of the Simsboro unit, and compared it to fault throws on the main faults. However, in conducting that work, I realized that our picking of the Simsboro (especially its base) was inconsistent and was often guided by the base of fresh water in thick sandstones. Previous studies and available database picks also showed major inconsistencies in correlations. I also realized that the Simsboro contained more than just sand, but also significant mudstone and coal units that separated multiple thick sand bodies. A realistic interpretation of the effects of faulting on transmissivity and effective modeling of this aquifer complex would have to take this variability into account.

To understand the complexity of sand distribution and facies development in the area, a fairly straightforward log-based method was developed to differentiate thick channel sands (major rivers or amalgamated bodies), thinner channels, coarsening upward sand/shale units (CU units), and lignites (coals by log interpretation). These color-coded interpretations allowed more confidence in regional interpretations. The net channel sandstone (thick or thin) and percent channel sandstone were identified for each major unit and mapped (CU units and other thin sands are probably not volumetrically significant for major groundwater development), along with coal thickness and distribution.

METHOD OF FACIES ANALYSIS

The workflow began with a comprehensive set of well logs (8394 wells) loaded into a Petra database. This was the same database used in Ewing and Young (2018). A total of 1124 wells with raster images that cover the Simsboro interval were used; of these, 565 wells had usable gamma-ray (GR) logs and were selected for facies analysis.

Correlations were made and evaluated across the data set. Good marine markers were found in the Reklaw (maximum flooding surface, lowest resistivity shale), and at several points within the Midway, notably at the Top Cretaceous (with a characteristic high-GR peak). The Carrizo unit was confidently identified below the Reklaw by high percentage of channel sandstones and fresh-water content. The Top Simsboro and the overlying main coal zone were highly correlative and seem to represent a consistent pick across the area (although there are local areas where the uppermost Simsboro is not a channel sandstone). The base of Simsboro was provisionally defined in 2018 but was entirely revised after facies picking. The base of Hooper is gradational and was not picked for this study.

Each well was examined in detail and facies were picked as pay intervals through the Wilcox section. Coals (lignites) were picked using the characteristic signature of low GR, high resistivity, and little or no spontaneous potential (SP) versus adjacent shales. Thick channel sandstones (over 100 ft 30 m] thick) were then picked and colored magenta; these represent either large rivers or amalgamations of channels. Thin shale breaks were included within a single channel sandstone, but if over approximately 30 ft (10 m) in thickness they were considered as separating channel sand bodies. Thinner channels (20–100 ft [6–30 m] thick) were then picked (in orange), using blocky to fining-upward character on GR and other logs. Coarsening-upward sandstone-containing intervals (CU units) were picked (in green) by examination of GR and resistivity character of the units; these intervals contained laminated sandstone and shale and only rarely thicker sandstone bodies. Some CU units might represent increase in organic content upward, especially in association with coal seams. Finally, other thin sands with unidentifiable signatures were colored yellow. The result was a colored section that reflected log patterns in a way that was easily visible and could be visually correlated across log sections (e.g., Fig. 3). This workflow is easily accomplished on most wells that have GR profiles, especially where sandstones other than the main Simsboro and Carrizo aquifers contain saline water. It minimizes the eye's being led by resistive zones bearing fresh water and more closely approximates depositional environments. However, facies picking is less reliable when the thinner sandstones (thin channels, CU units, and other sandstones) contain fresh water, which suppresses SP and makes all non-mudstone units highly resistive. A few logs without GR profiles were interpreted, but the quality of facies picking on such logs is generally not satisfactory.

Once facies picking is complete, regional sections can be hung and interpreted with facility (Figures 4 and 5 give a dip and a strike line, respectively), either as structural sections (datum sea level), or flattened on Top Simsboro or other horizons. Based on these sections, the internal complexity of the Simsboro can be examined and correlation of an approximate base of the Simsboro interval can be attempted in all wells in the database. Maps of sand thickness and percentage and coal percentage can then be prepared. Results and observations from this work will be presented unit-by-unit in the remainder of this paper. These sections and net channel-sand maps can then be used as input for water-resource modeling in the study area.

RESULTS: REVISIONS AND INSIGHTS TO WILCOX STRATIGRAPHY

Two key sections show the overall stratigraphy; a dip section along the southwest boundary of Burleson County (Fig. 4) and a strike section along the northwestern side of the same county (Fig. 5). In general, a lower "green" zone of CU units gives way upward to a mix of channel sandstones and coals; then to the Simsboro interval (magenta and orange) containing multiple thick sandstone bodies; then to a thick Calvert Bluff (green) interval containing occasional channel sandstones; finally at the top the channel-rich Carrizo sandstone interval (red and orange).

Hooper Formation

CU units (green) are ubiquitous in the lower Hooper section, grading upward from the Midway marine shales. These sandy zones are marine and marginal-marine in character; the thicker CU units reach 100 ft (30 m) in thickness although many are thinner. Thicker units may have channel sandstones (orange) at their top. The lower Hooper marks the progradation of deltas and shorelines into the area; some of the Midway represents prodelta deposits. This is the section that can be termed the "Seguin member," although its upper and lower boundaries are indefinite.

The upper portion of the Hooper contains thin channels, coals, and mudstone; some thick channels are present (although not on the lines shown). Coals seem to increase in abundance upward. When mapped (Fig. 6), coals show an irregular pattern, generally thickening downdip but overall show a thickness of 20 ft (6 m) or less in a number of seams. Channel sands are extensively distributed; major fluvial inputs are in south-central Milam and western Bastrop counties. Channels occupy some 20–40% of the formation. Some channels contain fresh water in updip wells.

Simsboro Formation

The Simsboro zone of thick sandstones is revealed by facies picking to be internally complex. Several thick sandstones (over 100 ft [30 m], some to 400 ft [120 m]) occur, often three in one wellbore, with intervening mudstone, coal, and thin sandstone beds. There are wells, however, where just one massive sandstone is present. As mentioned, the top surface is easily correlative; to understand the base of the unit, I have mapped a "lower Simsboro" sandstone, but this is undoubtedly a composite of numerous channels and is occasionally not developed. The

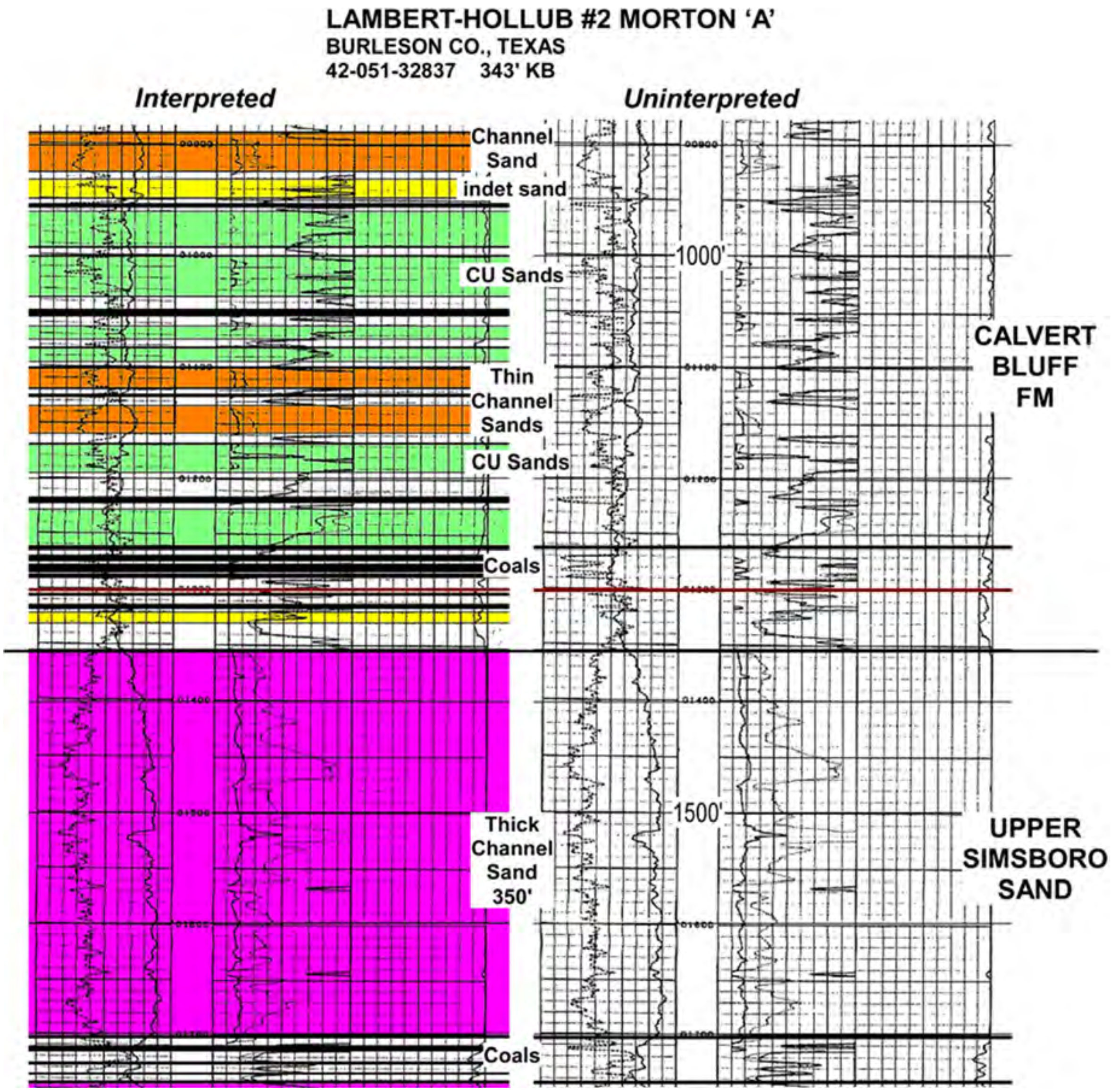

Figure 3. Log of well 32837 in Burleson County, showing typical examples of thick channels in magenta (amalgamated or big river); regular channels in orange; coarsening-upward (CU) units in green; and coals (in black). Uninterpreted on right; interpreted on left.

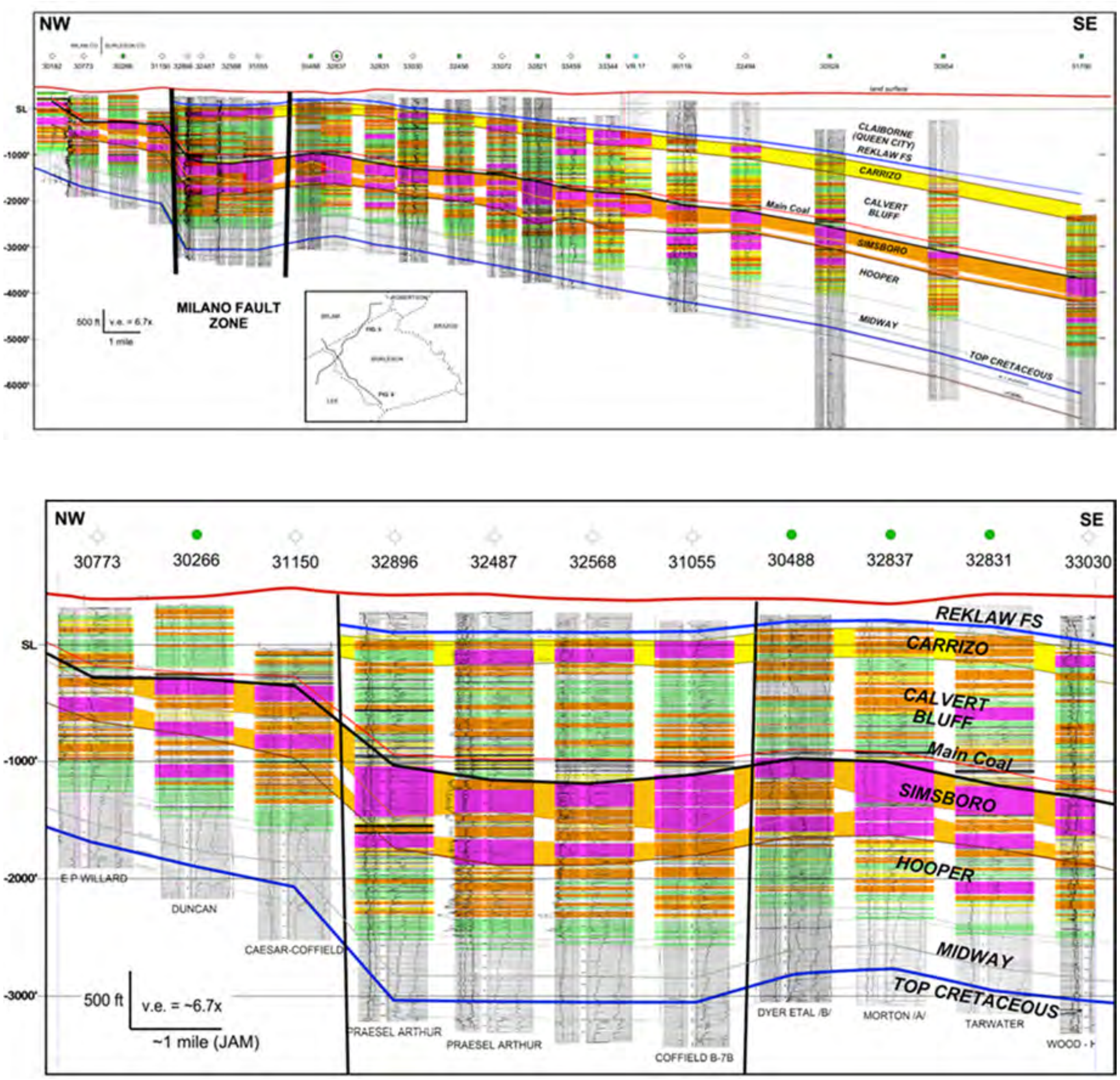

Figure 4. (A) Dip cross-section, southwest Burleson County, on structural datum; wells spaced to a vertical exaggeration of 6.7x. (B) Same section; close-up of (A) across the Milano Fault Zone; presented as "jam section" for clarity.

base of this lower Simsboro is estimated to be the Simsboro-Hooper interval boundary. Figure 5B clearly shows the complexity of this section. Traditional picking of base Simsboro tends to follow the local base of thick sands containing fresh water; so the pick jumps sands in very many places, sometimes well down into the Hooper and at other places up to the upper Simsboro. As in other Wilcox units, individual thick channel sandstones do not correlate well to well in a strike direction, even in closely-spaced oil wells. In most areas, the unit contains 70–90% channel sandstone (Fig. 7), but local areas of low percent sand occur, as in southwestern Bastrop Coun-

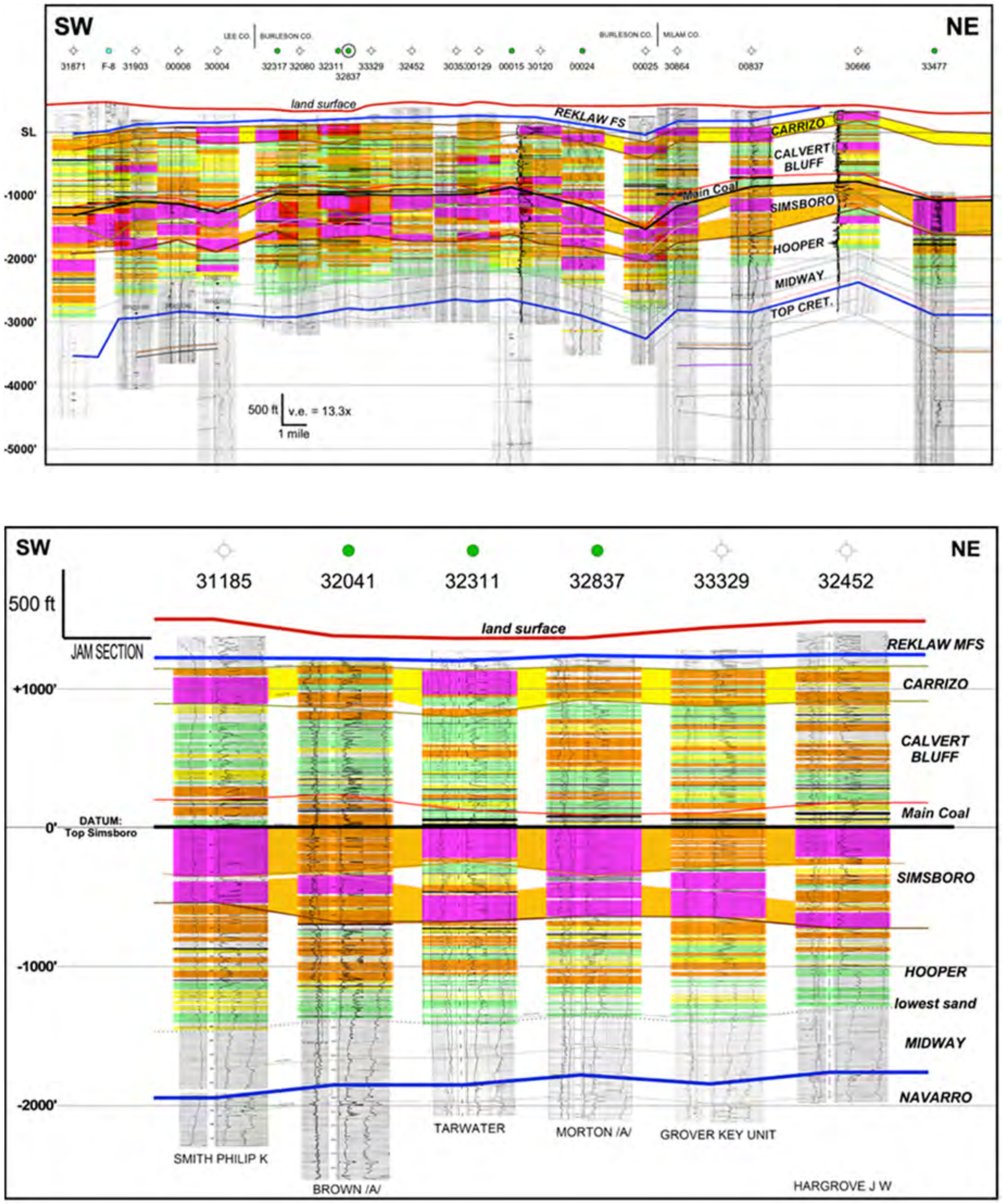

Figure 5. (A) Strike cross section, northwest Burleson County, on structural datum, vertical exaggeration 13.3x; location shown on Figure 4A. (B) Same section, southwestern portion, flattened on top Simsboro; presented as "jam section," showing complexity of Wilcox stratigraphic succession.

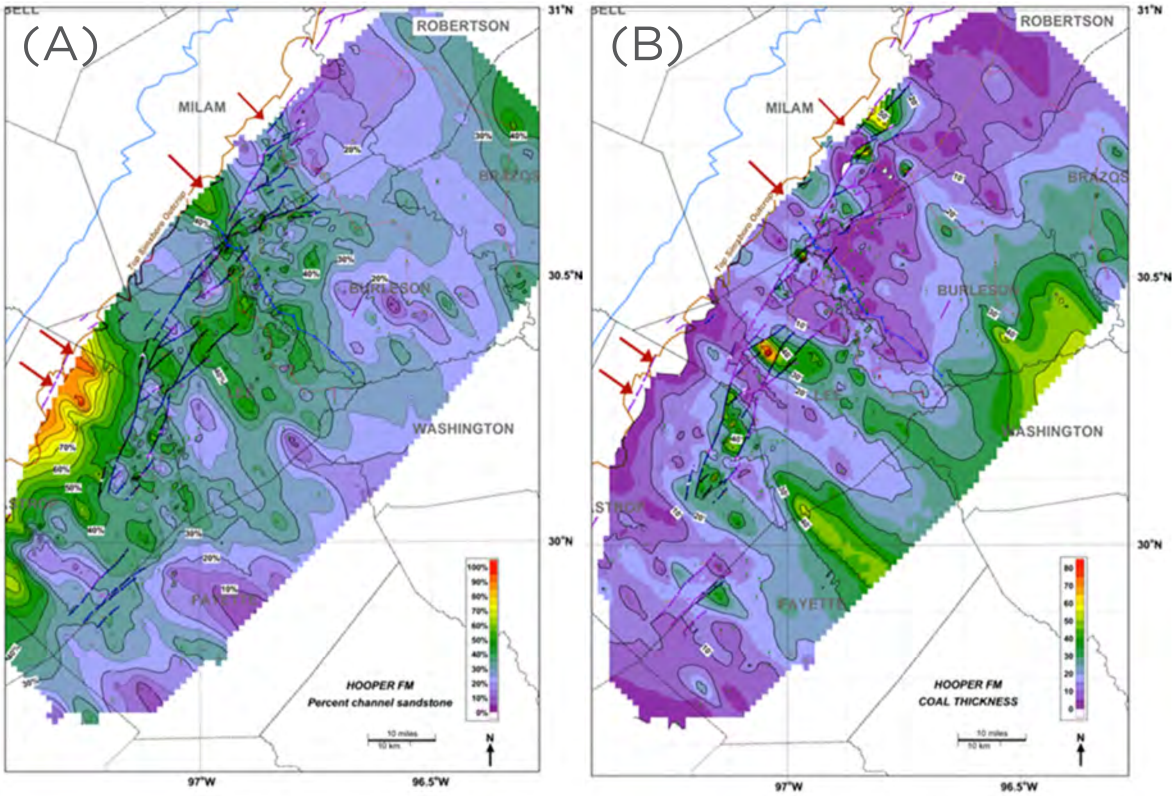

Figure 6. (A) Percent channel sandstone, Hooper interval; (B) and net coal thickness, Hooper interval. Note: All sandstone and coal maps are contoured with a mile northwest-southeast azimuth filter.

ty, northeastern Bastrop County continuing southeast into Fayette County, and small patches in Burleson and Milam counties.

I interpret the Simsboro as including not one but several erosional disconformities on a relatively proximal part of the fluvial floodplain where channels of large bedload-dominated rivers are amalgamating. Interchannel environments are preserved, sometimes in quantity. Connectivity of sand bodies is high, resulting in extensive occurrence of fresh water downdip. Because of the repetitive erosion, this unit probably represents much of Lower Wilcox time.

Calvert Bluff Formation

The base of the Calvert Bluff is occupied by mudstone, thick lignites, and some channel sandstones in most areas. This is the principal lignite seam at Sandow and Three Oaks mines in western Lee County; the mudstones are mined for structural clay at Butler in northern Bastrop County (Mace and Williams, 2004). Coal thickness is usually 20–40 ft (6–12 m), and can be thicker (Fig. 8B).

Above this lower zone, the Calvert Bluff is dominated by numerous thin CU units, usually 10–30 ft (3–9 m) thick, stacked on each other with occasional interspersed thin channel sandstones and rarely by thick channel sandstones. Some coals are present in the intervening mudstones,

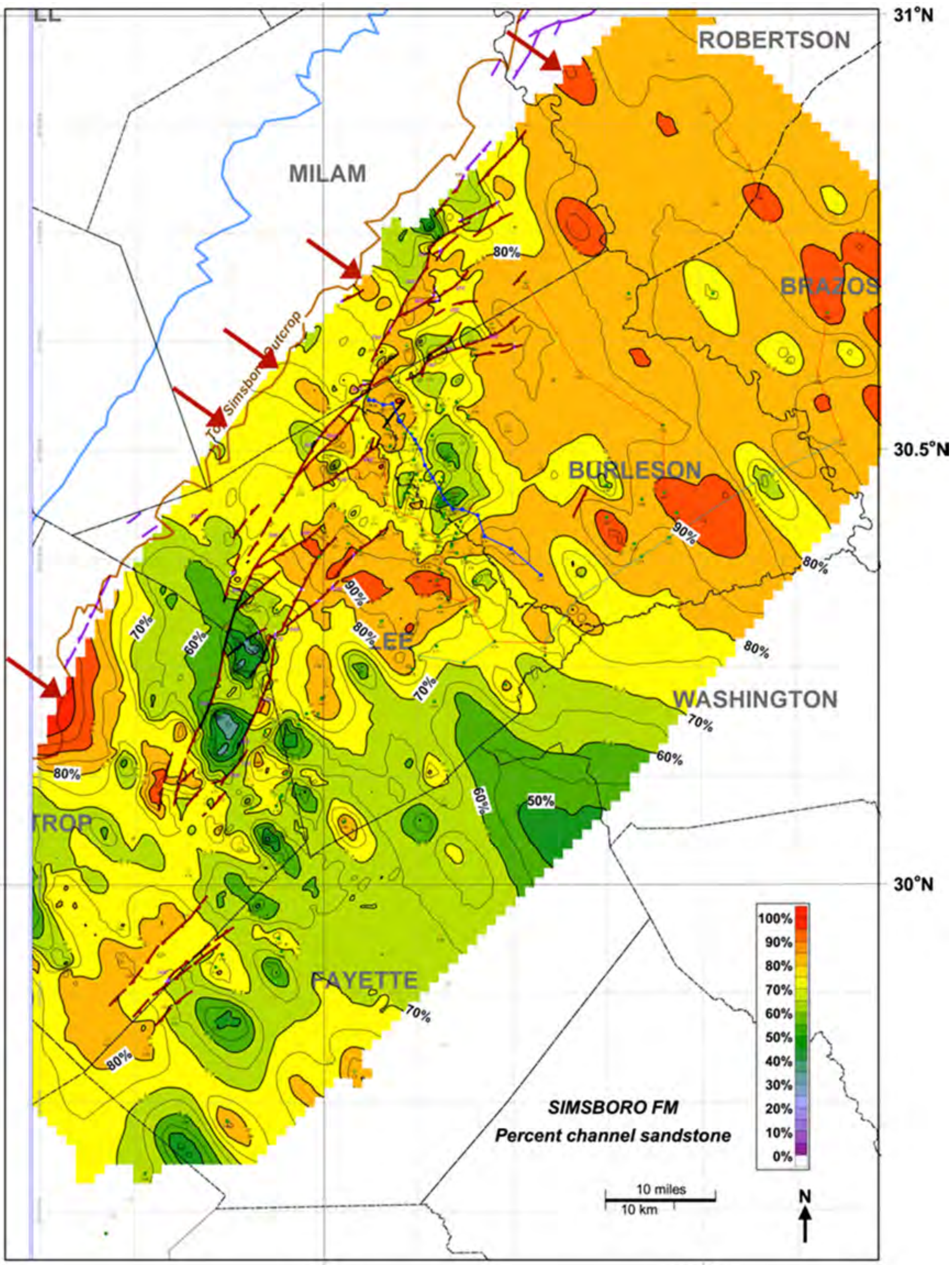

Figure 7. Percent channel sandstone, Simsboro interval. Note: the same color bar is used in all channel percent images.

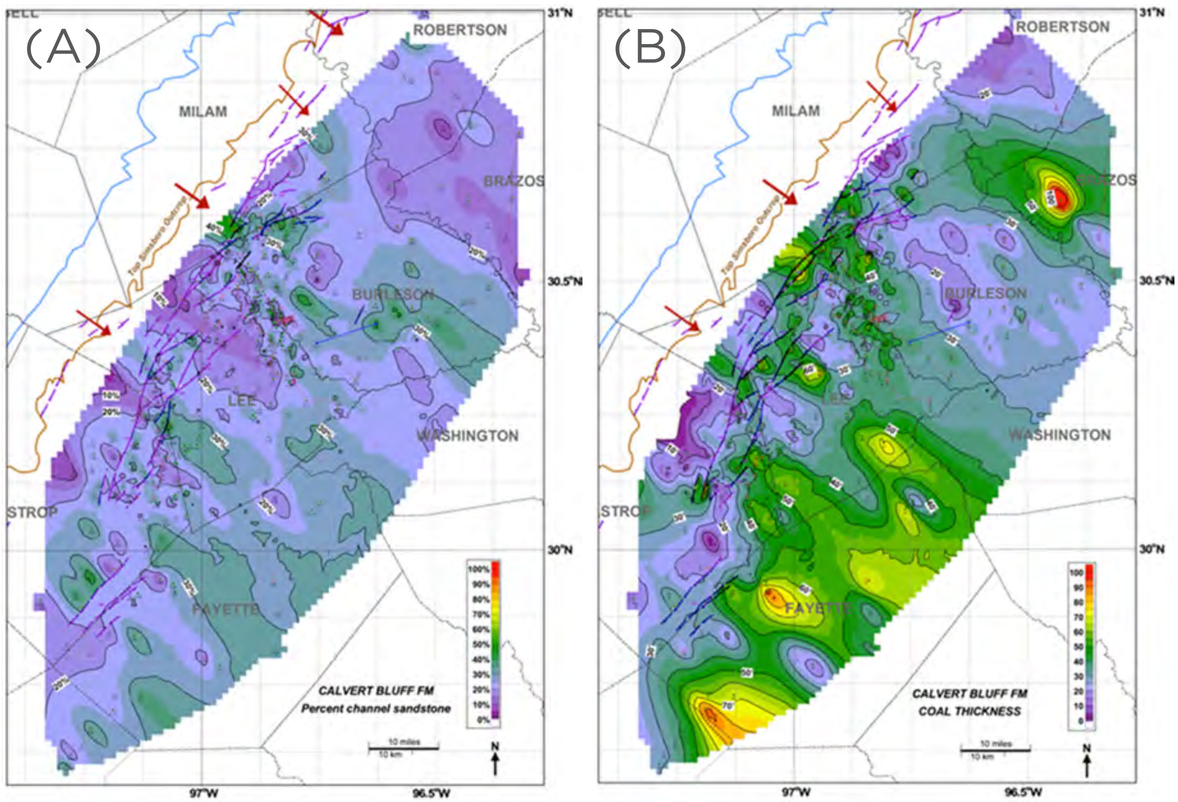

Figure 8. (A) Percent channel sandstone, Calvert Bluff interval. (B) Net coal thickness, Calvert Bluff interval.

but they become less frequent in the shallower parts of the unit. The channel systems are most pronounced in southern Milam County and downdip, but some are present in other areas as well (Fig. 8A). They may contain fresh water in updip (near outcrop) areas.

The abundance of thin CU units and thin channel sandstones gives this formation its distinctive character. This seems to represent a time where shallow freshwater lakes or possibly lagoons existed over much of the floodplain, and repetitive crevasse splay events brought prograding coarser sediment into the system in a series of "microdeltas." Occasional fluvial channels cut through the wet floodplain.

In many wells, there is a concentration of CU units and mudstones at the top of the Calvert Bluff. This may represent the Sabinetown transgression of Yancey et al. (2013). It would be of interest to determine the degree of marine influence throughout the Calvert Bluff sequence.

Carrizo Sand

The Carrizo Sand forms a thin but persistent cap on the Wilcox succession. It contains 65–75% channel sandstone near the outcrop (Fig. 9), with sandstone generally becoming less abundant downdip. The unit is mostly composed of thinner channel sandstones (less than 100 ft [30 m]); few thick channels or amalgamated channels are present. The unit seems to be a stacking of thinner channel sandstones; some CU units are even present within the unit, as well as mudstones. Lignites, however, are absent in all wells.

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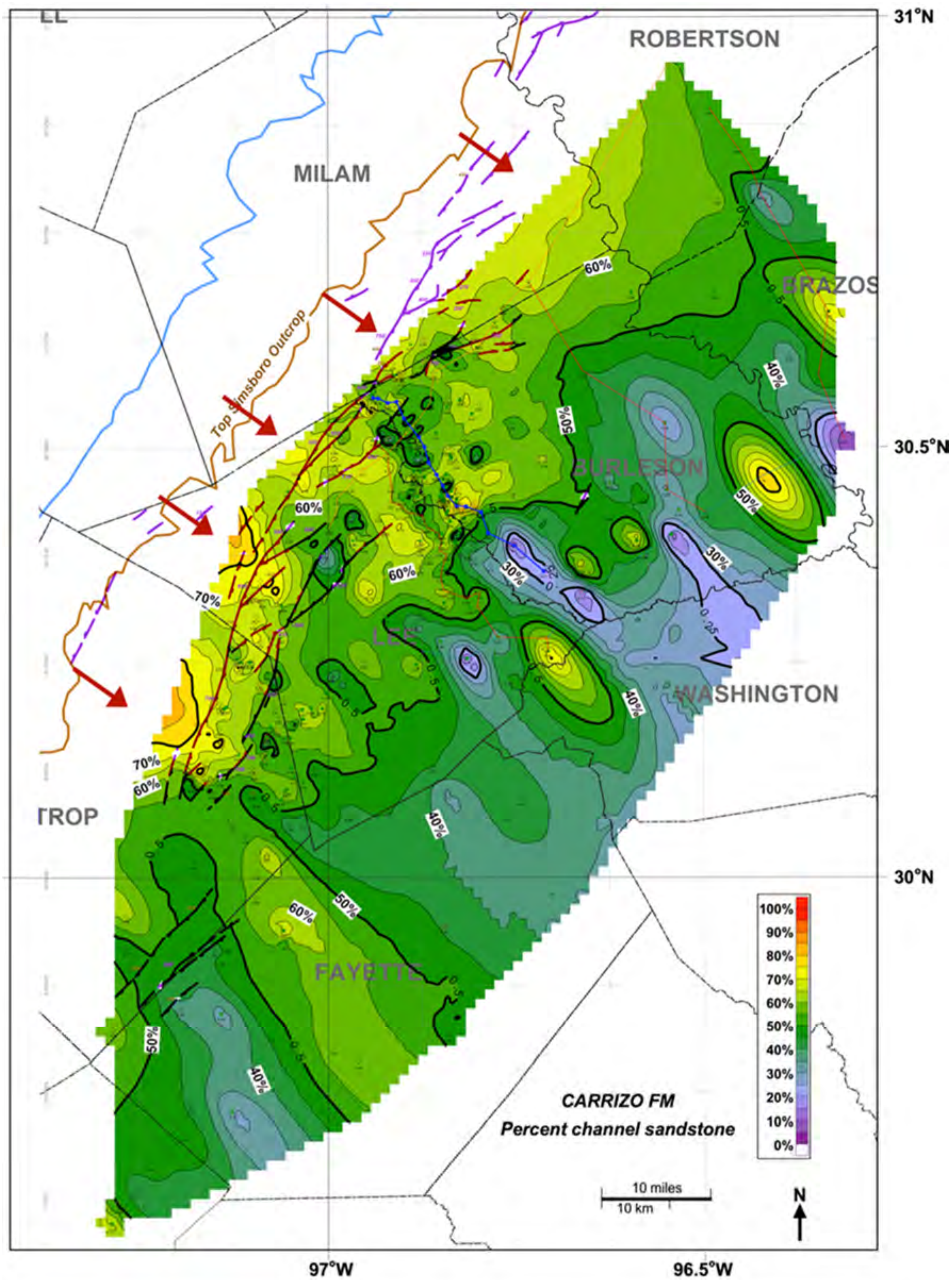

Figure 9. Percent channel sandstone, Carrizo interval.

The Carrizo indicates a regional sand-rich alluvial system but without the presence of big rivers. Connectivity of sand bodies is high, leading to extensive occurrence of fresh water downdip.

CONCLUSIONS

Using a comprehensive data set and carefully picking facies data derived from log patterns has led to a refined understanding of internal Wilcox stratigraphy in the central Texas area. In particular:

- The Simsboro Formation consists of multiple fluvial channels with intervening interchannel floodplain deposits; however, channels locally amalgamate and are well connected, giving the coherent aquifer that we observe.
- The Calvert Bluff is dominantly composed of CU units that indicate progradation into shallow standing water, either freshwater lakes or lagoonal environments. This is consistent with less active progradation and overall backstepping of depositional environments in the Middle Wilcox (Xue and Galloway, 1995).
- The Carrizo Formation is rich in channel sands, but few thick channels do occur, indicating that this area experienced only minor fluvial inputs.
- Coal abundance and thickness reach a peak at basal Calvert Bluff, perhaps related to the underlying sands but also related to the top of Lower Wilcox transgression and stillstand. Coals decline upsection but also down in the Hooper, due either to depositional environment changes or changes in climate.

It would be most useful to have more direct information on the facies represented in these rocks. In particular, core or image log information might help to prove or disprove the facies assignments. The degree of marine and lacustrine influence in the Calvert Bluff should be addressable by paleontology and possibly geochemistry.

The stratigraphy of this area needs to be connected to the regional sections more effectively, in particular tracing the major marine shales of Hargis (1985, 2009) and Xue and Galloway (1993, 1995) into Fayette County and the present correlation grid.

ACKNOWLEDGMENTS

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Corpus Christi Geological Society Papers available for purchase at the Texas Bureau of Economic Geology

Note: Publication codes are hyperlinked to their online listing in The Bureau Store (http://begstore.beg.utexas.edu/store/).

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CCGS 002S $15.00

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http://www.ngdc.noaa.gov/seg/topo/globegal.shtml More great maps to share with kids and students.

www.ccgeo.org Don't forget we have our own we page.

http://terra.nasa.gov/gallery/ Great satellite images of Earth.

www.ermaper.com They have a great free downloadable viewer for TIFF and other graphic files called ER Viewer.

http://terrasrver.com Go here to download free aerial photo images that can be plotted under your digital land and well data. Images down to 1 meter resolution, searchable by Lat Long coordinate. Useful for resolving well location questions.

TYPE LOGS OF SOUTH TEXAS FIELDS by Corpus Christi Geological Society

NEW (2019)TYPE LOGS IN RED; **lost now found**

ARANSAS COUNTY
Aransas Pass/McCampbell Deep
Bartell Pass
Blackjack
Burgentine Lake
Copano Bay, South
Estes Cove
Fulton Beach
Goose Island
Half Moon Reef
Nine Mile Point
Rockport, West
St. Charles
Tally Island
Tract 831-G.O.M. (offshore)
Virginia

BEE COUNTY
Caesar
Mosca
Nomanna
Orangedale(2)
Ray-Wilcox
San Domingo
Tulsita Wilcox
Strauch_Wilcox

BROOKS COUNTY
Ann Mag
Boedecker
Cage Ranch
Encintas
ERF
Gyp Hill
Gyp Hill West
Loma Blanca
Mariposa
Mills Bennett
Pita
Tio Ayola
Tres Encinos

CALHOUN COUNTY
Appling
Coloma Creek, North
Heyser
Lavaca Bay
Long Mott
Magnolia Beach
Mosquito Point
Olivia
Panther Reef
Powderhorn
Seadrift, N.W.
Steamboat Pass
Webb Point
S.E. Zoller

CAMERON COUNTY
Holly Beach
Luttes
San Martin (2)
Three Islands, East
Vista Del Mar

COLORADO COUNTY
E. Ramsey
Graceland N. Fault Blk
Graceland S. Fault Blk

DEWITT COUNTY
Anna Barre
Cook
Nordheim
Smith Creek
Warmsley
Yorktown, South

DUVAL COUNTY
DCR-49
Four Seasons
Good Friday
Hagist Ranch
Herbst
Loma Novia
Petrox
Seven Sisters
Seventy Six, South
Starr Bright, West

GOLIAD COUNTY
Berclair
North Blanconia
Bombs
Boyce
Cabeza Creek, South
Goliad, West
St Armo
Terrell Point

HIDALGO COUNTY
Alamo/Donna
Donna
Edinburg, West
Flores-Jeffress
Foy
Hidalgo
LA Blanca
McAllen& Pharr
McAllen Ranch
Mercedes
Monte Christo, North
Penitas
San Fordyce
San Carlos
San Salvador
S. Santallana
Shary
Tabasco
Weslaco, North
Weslaco, South

JACKSON COUNTY
Carancahua Creek
Francitas
Ganado & Ganado Deep
LaWard, North
Little Kentucky
Maurbro
StewartSwan Lake
Swan Lake, East
Texana, North
West Ranch

JIM HOGG COUNTY
Chaparosa
Thompsonville,N.E.

JIM WELLS COUNTY
Freebom
Hoelsher
Palito Blanco
Wade City

KARNES COUNTY
Burnell
Coy City
Person
Runge

KENEDY COUNTY
Candelaria
Julian
Julian, North
Laguna Madre
Rita
Stillman

KLEBERG COUNTY
Alazan
Alazan, North
Big Caesar
Borregos
Chevron (offshore)
Laguna Larga
Seeligson
Sprint (offshore)

LA SALLE COUNTY
Pearsall
HAWKVILLE:EAGLEFORD

LAVACA COUNTY
Halletsville
Hope
Southwest Speaks
Southwest Speaks Deep

LIVE OAK COUNTY
Atkinson
Braslau
Chapa
Clayton
Dunn
Harris
Houdman
Kittie West-Salt Creek
Lucille
Sierra Vista
Tom Lyne
White Creek
White Creek, East

MATAGORDA COUNTY
Collegeport

MCMULLEN COUNTY
Arnold-Weldon
Brazil
Devil's Waterhole
Hostetter
Hostetter, North

NUECES COUNTY
Agua Dulce (3)
Arnold-David
Arnold-David, North
Baldwin Deep
Calallen
Chapman Ranch
Corpus Christi, N.W.
Corpus Christi West C.C.
Encinal Channel
Flour Bluff/Flour Bluff, East
GOM St 9045(offshore)
Indian Point
Mustang Island
Mustang Island, West
Mustang Island St.
889S(offshore)
Nueces Bay/Nueces Bay
West
Perro Rojo
Pita Island
Ramada
Redfish Bay
Riverside
Riverside, South
Saxet
Shield
Stedman Island
Turkey Creek

REFUGIO COUNTY
Bonnieview/Packery Flats
Greta
La Rosa
Lake Pasture
Refugio, New
Tom O'Connor

SAN PATRICIO COUNTY
Angelita East
Commonwealth
Encino
Enos Cooper
Geronimo
Harvey
Hiberia
Hodges
Mathis, East
McCampbell Deep/Aransas Pass
Midway
Midway, North
Odem
Plymouth
Portilla (2)
Taft
Taft, East
White Point, East

STARR COUNTY
El Tanque
Garcia
Hinde
La Reforma, S.W.
Lyda
Ricaby
Rincon
Rincon, North
Ross
San Roman
Sun
Yturria

VICTORIA COUNTY
Helen Gohike, S.W.
Keeran, North
Marcado Creek
McFaddin
Meyersville
Placedo

WEBB COUNTY
Aquilares/Glen Martin
Big Cowboy
Bruni, S.E.
Cabezon
Carr Lobo
Davis
Hirsch
Juanita
Las Tiendas
Nicholson
O'Hem
Olmitos
Tom Walsh

WHARTON COUNTY
Black Owl

WILLACY COUNTY
Chile Vieja
La Sal Vieja
Paso Real
Tenerias
Willamar

ZAPATA COUNTY
Benavides
Davis, South
Jennings/Jennings, West
Lopeno
M&F
Pok-A-Dot

ZAVALA COUNTY
El Bano

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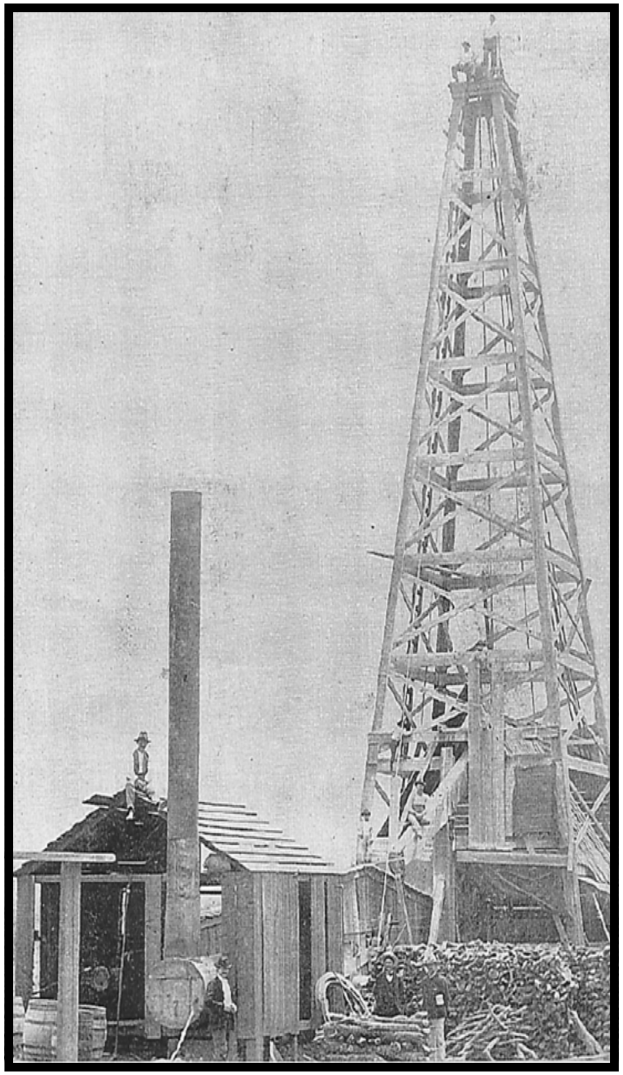

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