STARR
State of Texas Advanced Oil and Gas Resource Recovery

2020–2022 BIENNIUM REPORT

SEPTEMBER 2023

PRINCIPAL INVESTIGATOR
Lorena G. Moscardelli

DIRECTOR
Scott W. Tinker

PROGRAM DIRECTOR
Mark W. Shuster

RESEARCHERS
Lorena G. Moscardelli, William A. Ambrose, Michael Young, Bridget Scanlon, Peter P. Flaig, Mariana I. Olariu, Kelly Hattori, Lucy Ko, Robert G. Loucks, Eric Radjef, Leopoldo Ruiz Maraggi, Nur Schuba, James E. Sivil, Sheng Peng, Tongwei Zhang, Xun Sun, Hongliu Zeng, Osareni C. Ogiesoba, Qilong Fu, Robert Reed, Harold Rogers III, Ian J. Duncan, Robin Dommisse, Jerry Jensen, Angela Hessler, Beverly DeJarnett, and Priyanka Periwal.

ASSISTED BY
Jay P. Kipper, Fritz Palacios, Katherine Garcia, Sarp Karakaya, Mark Blount, Joseph Yeh, Nathan Ivicic, Brandon Williamson, Rudy R. Lucero, Evan O'Donnell, Michael Wang, Jason Suarez, Dena Miller, Melissa Coffman, Poe Chen, Amelia Bridges, Dallas Dunlap, Erin DeConcini, Carlos Garza, Jamie H. Coggin, Kenneth Edwards, Vickie Amidon, Beverly Benham, Jan Braboy, David Chang, Roanne Draker, Jennifer Galaviz, Gwen Hebert, Travis Hobbs, Elyse Vane, Kim LaValley, Jana Robinson, and Jessica Rowling.

BUREAU OF ECONOMIC GEOLOGY

Bureau of Economic Geology
Scott W. Tinker, Director
Jackson School of Geosciences
The University of Texas at Austin

STATE OF TEXAS ADVANCED RESOURCE RECOVERY PROGRAM (STARR)

2020–2022 BIENNIUM REPORT
September 2023

PRINCIPAL INVESTIGATOR
Lorena G. Moscardelli

DIRECTOR, BUREAU OF ECONOMIC GEOLOGY
Scott W. Tinker

PROGRAM DIRECTOR
Mark W. Shuster

RESEARCHERS

Lorena G. Moscardelli, William A. Ambrose, Michael Young, Bridget Scanlon, Peter P. Flaig, Mariana I. Olariu, Kelly Hattori, Lucy Ko, Robert G. Loucks, Eric Radjef, Leopoldo Ruiz Maraggi, Nur Schuba, James E. Sivil, Sheng Peng, Tongwei Zhang, Xun Sun, Hongliu Zeng, Osareni C. Ogiesoba, Qilong Fu, Robert Reed, Harold Rogers III, Ian J. Duncan, Robin Dommisse, Jerry Jensen, Angela Hessler, Beverly DeJarnett, and Priyanka Periwal.

ASSISTED BY

Jay P. Kipper, Fritz Palacios, Katherine Garcia, Sarp Karakaya, Mark Blount, Joseph Yeh, Nathan Ivicic, Brandon Williamson, Rudy R. Lucero, Evan O'Donnell, Michael Wang, Jason Suarez, Dena Miller, Melissa Coffman, Poe Chen, Amelia Bridges, Dallas Dunlap, Erin DeConcini, Carlos Garza, Jamie H. Coggin, Kenneth Edwards, Vickie Amidon, Beverly Benham, Jan Braboy, David Chang, Roanne Draker, Jennifer Galaviz, Gwen Hebert, Travis Hobbs, Elyse Vane, Kim LaValley, Jana Robinson, and Jessica Rowling.

TABLE OF CONTENTS

QAe9780

EXECUTIVE SUMMARY

The mission of the State of Texas Advanced Resource Recovery (STARR) program is to conduct geoscience and engineering research to increase the production and profitability of earth resources, including oil, natural gas, hydrogen, geothermal and minerals, within the State of Texas while encouraging responsible economic development and supporting education and environmental stewardship. As part of this mission, one of our main objectives is to help increase severance tax income for the State of Texas through research projects that promote the drilling of profitable oil and gas wells in the state. Most recently, our team has also initiated research activities to support the development of emerging energy opportunities within the State of Texas, the idea is to be prepared and expand revenue opportunities in the future as these industries evolve and we become more energy independent.

The Bureau of Economic Geology receives funds from the State to conduct research that assists energy operators, particularly small oil and gas operators, in adding new or increasing existing production throughout Texas. Revenue associated with STARR projects must equal or exceed the amount appropriated to the program by the Legislature. This report summarizes accomplishments of the STARR program from September 1, 2020, to August 31, 2022.

Credit to the STARR program for the 2020–2022 biennium, in accordance with methodology approved by the State of Texas Comptroller's office, is approximately $118,416,980 (table 1). ***Relative to total funding of $9.7 million over the current biennium, STARR is revenue positive by a factor of 12.2.***

Table 1. Summary of the field and regional studies that were active during the 2020–2022 biennium

Field Study Name	Years	Condensate (BBL)	Oil Well Head Value ($)	Oil Severance Tax (4.6%)	Gas (MCF)	Gas Well Head Value ($)	Gas Severance Tax (7.5%)	Oil Severance (100 %)	Gas Severance (100%)	Total Oil ($)	Total Gas ($)
Barnett Shale Denton and Wise Counties in conjunction with MSRL and FRAC Rebecca Harrington BKV corporation Lucy Ko, Julia Gale and STARR team project 273	2020-2022	93,175	9,559,248.37	439,725.43	3,878,587.00	26,044,396.93	1,953,329.77	439,725.43	1,953,329.77	439,725.43	1,953,329.77
Caddo Group, Canyon Group, and Tannehill Formation Knox County Clint Walker Daylight Petroleum Bill Ambrose project 209	2018-2020	2,189	136,707.91	6,288.56	-	-	-	6,288.56	-	6,288.56	-
Cisco Group Motley, Floyd, Briscoe, and Hall Counties Dan Earl Duggans Independent Eric Radjef and Bill Ambrose project 252	2020-2022	3,056	299,001.23	13,754.06	-	-	-	13,754.06	-	13,754.06	-
Cisco Group, Canyon Group, and Strawn Group Nolan County Neville Henry Winchester Energy Bill Ambrose and David Smith project 219	2020-2022	16,866	966,152.21	44,443.00	933	4,161.63	312.12	44,443.00	312.12	44,443.00	312.12
Clearfork Formation Crosby, Garza, Lynn, Dickens, Lubbock, and Kent Counties Surge Energy Qilong Fu and Hongliu Zeng project 206	2020-2022	373	29,081.12	1,337.73	-	-	-	1,337.73	-	1,337.73	-
Cleveland Formation and Marmaton Group, (Ochiltree, Lipscomb, and Hemphill Counties): (Tecolote, Inc.): Tucker Hentz and Bill Ambrose project 187	2018-2020	430,405	19,415,352.14	893,106.20	2,698,528	7,475,026.48	560,626.99	893,106.20	560,626.99	893,106.20	560,626.99
Frio Formation San Patricio, Nueces, Bee, and Refugio Counties Jeff Swanson Durango Resources Surge Energy Bill Ambrose project 203	2018-2020	184,222	11,327,778.55	521,077.81	565,014	1,903,676.58	142,775.74	521,077.81	142,775.74	521,077.81	142,775.74
San Andres Seminole Unit Gaines County Amerada Hess Ian Duncan and STARR team project 276	2020-2022	5,641	524,074.22	24,107.41	-	-	-	24,107.41	-	24,107.41	-
Strawn Group Coke and Nolan Counties Affirmed Resources Bill Ambrose project 216	2020-2022	24,073	1,416,695.57	65,168.00	1,598	6,429.13	482.18	65,168.00	482.18	65,168.00	482.18
Strawn Group Fisher County Darrell Mauldin Travcon Energy Peter Flaig and Bill Ambrose project 250	2020-2022	336,600	31,796,452.32	1,462,636.81	688,824	4,458,530.24	334,389.77	1,462,636.81	334,389.77	1,462,636.81	334,389.77
Strawn, Canyon, and Cisco Nolan County Brad Caponigro Bill Ambrose project 200	2018-2020	43,329	2,229,589.80	102,561.13	100,142	310,952.71	23,321.45	102,561.13	23,321.45	102,561.13	23,321.45
Wilcox Group Colorado, Wharton, and Lavaca Counties EOGJinyu Zhang and Bill Ambrose project 218	2018-2020	141,341	9,947,854.77	457,601.32	3,563,891	14,033,328.83	1,052,499.66	457,601.32	1,052,499.66	457,601.32	1,052,499.66
Wilcox Group Dewitt County C. Dave Copeland Copeland Resources, Inc. Iulia Olariu project 174	2018-2020	4,648	211,337.23	9,721.51	123,064	297,430.02	22,307.25	9,721.51	22,307.25	9,721.51	22,307.25
Wilcox Group Zapata County Hilcorp Bill Ambrose project 195	2018-2020	1,200	63,758.82	2,932.91	461,880	1,259,713.26	94,478.49	2,932.91	94,478.49	2,932.91	94,478.49
Yegua Formation Jackson County Patrick McCollough Emerald Bay Exploration Chris Ogeisoba and Bill Ambrose project 205	2018-2020	24,514	1,451,237.43	66,756.92	1,540,779	5,302,522.83	397,689.21	66,756.92	397,689.21	66,756.92	397,689.21
Barnett Shale (Wise County) (in conjunction with MSRL) (Devon): Rob Reed and Bob Loucks project 274	2020-2022	92,866	9,529,030.20	438,335.39	3,813,446	25,600,359.00	1,920,026.93	438,335.39	1,920,026.93	438,335.39	1,920,026.93
Tannehill sandstones (King County): Jack Deans and Trey Cortez (Burnett Oil Company): Chris Ogiesoba (project 275)	2020-2022	3,807	359,850.13	16,193.26	148	824.04	61.80	16,193.26	61.80	16,193.26	61.80
Austin Chalk (Tyler, Jasper, Newton, Sabine, Vernon, Beauregard Co.) (in conjunction with RCRL): Adam Haecker and Chrystiano Mardi (Continental Resources, BPX Energy Inc and RKI Energy Resources): Bob Loucks, Sheng Peng, Kelly Hattori, Priyanka Periwal, Josh Lambert, Christopher Zahm and Lucy Ko (project 277)	2020-2022	55,798	5,939,958.47	267,298.13	550,940	4,367,937.64	327,595.32	267,298.13	327,595.32	267,298.13	327,595.32
Totals		**1,464,103**	**105,203,160.49**	**4,833,045.58**	**17,987,774.00**	**91,065,289.32**	**6,829,896.68**	**4,833,045.58**	**6,829,896.68**	**4,833,045.58**	**6,829,896.68**
								Field Study Revenue ($)		**11,662,942.26**	

Table 1. Summary of the field and regional studies that were active during the 2020–2022 biennium (cont.)

Regional Study Name	Years	Condensate (BBL)	Oil Well Head Value ($)	Oil Severance Tax (4.6%)	Gas (MCF)	Gas Well Head Value ($)	Gas Severance Tax (7.5%)	Oil Severance (25 %)	Gas Severance (25%)	Total Oil ($)	Total Gas ($)
Bell Canyon and Cherry Canyon Loving, Reeves Cos in conjunction with QCL, Ambrose, Covault project 254 (Delaware Mountain Group)	2020-2021	65,888	6,060,464.99	272,720.92	168,262	1,015,177.67	76,138.33	68,180.23	19,034.58	68,180.23	19,034.58
San Andres Fm. Permian Basin 12 counties Bo Ren and Ian Duncan project XXX	2020-2022	5,973,787	546,056,232.25	25,118,586.68	7,322,244	44,206,038.34	3,315,452.88	6,279,646.67	828,863.22	6,279,646.67	828,863.22
Cisco Group Concho, Menard, Coke, Runnels, Tom Green, Nolan, Taylor Schleicher Cos Palacios project 268	2020-2022	1,529	157,828.01	7,260.09	-	-	-	1,815.02	-	1,815.02	-
Lower Strawn Group Jack and Wise counties Andrew Roberts project 269	2020-2022	1,519	130,612.05	5,877.54	10,337	76,176.34	5,713.23	1,469.39	1,428.31	1,469.39	1,428.31
Strawn Formation Jack, Young, Palo Pinto, and Stephens Counties Andy Roberts project xxx	2020-2022	39,792	2,839,913.15	130,636.00	115,212	461,727.50	34,629.56	32,659.00	8,657.39	32,659.00	8,657.39
Strawn Formation Stonewall, Knox, Haskell, Dickens, and King Counties Peter Flaig Kelly Hatori	2020-2022	80,430	6,081,101.14	279,730.65	57,899	241,145.27	18,085.90	69,932.66	4,521.47	69,932.66	4,521.47
Wilcox Group Grimes, Brazos, Montgomery, Burleson, Washington, Milam, Etc Ambrose, Zhang, Olariu, Flaig project xxx	2018-2020	200,759	14,352,843.11	660,230.78	4,128,087	16,634,744.04	1,247,605.80	165,057.70	311,901.45	165,057.70	311,901.45
Cisco and Canyon Groups (Nolan, Howard, Taylor, Runnels, Coke, Tom Green, Concho, Schleicher, Mitchell, Sterling, Irion, and Menard Counties) project 190	2018-2020	50,923	2,497,276.82	114,874.73	380,748	1,058,843.48	79,413.26	28,718.68	19,853.32	28,718.68	19,853.32
Pettet and Sligo (Rusk, Cherokee, Smith, Gregg, Panola, Nacogdoches, and Wood Counties) project 247	2020-2022	4,152	369,868.99	17,013.97	159,540	885,141.82	66,385.64	4,253.49	16,596.41	4,253.49	16,596.41
Strawn Group King, Stonewall, Dickens, Kent Cos Flaig, STARR Team project 264	2020-2022	9,117	919,644.15	41,383.99	-	-	-	10,346.00	-	10,346.00	-
Wolfcamp Formation Reagan and Hockley Counties in conjunction with the TORA Group Bill Ambrose and Brian Casey project 251	2020-2022	2,510,478	230,379,833.38	10,597,472.34	3,800,435	24,508,361.97	1,838,127.15	2,649,368.08	459,531.79	2,649,368.08	459,531.79
Austin Chalk Group (La Salle, Wilson, Gonzales, Dewitt, Fayette, Lee, Burleson, Roberson, Walker, Polk, Tyler, Sabine, Vernon counties) Bob Loucks and Sheng Peng (project 266)	2020-2022	870,591	83,150,143.83	3,741,756.47	2,556,949	15,706,038.86	1,177,952.91	935,439.12	294,488.23	935,439.12	294,488.23
Lower Strawn Gp. (Jack and Wise counties) Andrew Roberts (project 269)	2020-2022	1,519	130,612.05	5,877.54	10,337	76,176.34	5,713.23	1,469.00	1,428.00	1,469.39	1,428.31
Wolfcamp and Eagle Ford (Reagon and Karnes Counties) (in conjunction with MSRL) (project 271) Sheng Peng and Robert Reed	2020-2022	24,847,385	2,492,139,067.16	112,146,258.02	52,493,820	362,841,799.11	27,213,134.93	28,036,564.51	6,803,283.73	28,036,564.51	6,803,283.73
DEAN SANDSTONE: (Reagan, Glasscock, Midland, Irion, Sterling, Howard, Martin, Pecos, Crockett Counties) (Li Liu) (project 154b)	2018-2020	789,599	38,509,785.75	1,732,940.36	1,378,061	3,810,774.01	285,808.05	433,235.09	71,452.01	433,235.09	71,452.01
Serbin Field Taylor Sandstone Formation (Lee, Bastrop, and Fayett Counties) (Project #?) (Riley Exploration Group) Chris Ogiesoba and Bill Ambrose	2020-2022	27	2,898.51	130.43	160	1,188.79	88.16	32.61	22.29	32.61	22.29
Austin Chalk Maverick, LaSalle, Wilson, DeWitt, Fayette, Lee, Polk co's with RCRL MSRL Loucks, Reed, Ko, Zham, Larson project 270	2020-2022	1,947,373	171,850,722.15	7,733,282.50	9,017,917	49,695,739.65	3,727,180.47	1,933,320.62	931,795.12	1,933,320.62	931,795.12
Eagle Ford (Karnes) (Project 282) Sheng Peng	2020-2022	43,780,824	4,123,626,185.36	185,563,178.34	82,880,501	530,073,489.62	39,755,511.72	46,390,794.59	9,938,877.93	46,390,794.59	9,938,877.93
Totals		**81,175,692**	**7,719,255,032.85**	**348,169,211.35**	**164,480,509.00**	**1,051,292,562.81**	**78,846,941.22**	**87,042,302.46**	**19,711,735.25**	**87,042,302.85**	**19,711,735.56**
								Regional Study Revenue ($)		**106,754,038.41**	
								Total Revenue ($)		**118,416,980.67**	

STARR MISSION AND PROGRAM

The STARR mission is to conduct geoscience and engineering research to increase the production and profitability of earth resources, including oil, natural gas, hydrogen, geothermal and minerals, within the State of Texas while encouraging responsible economic development and supporting education and environmental stewardship (fig. 1).

Figure 1. STARR organizational structure. The oil and gas division is our largest with researchers engaging in research and exploration related activities in collaboration with small Texas operators.

Texas leads the nation in oil and gas production from a combination of unconventional shale resources and continued development of conventional resources. The STARR program provides geological and engineering support to smaller operators who have limited staffing so that they can access state of the art tools and expertise to support their efforts to maintain and increase energy production within the state. STARR also engages in research to identify emerging energy opportunities within the State of Texas; this research is strategic for the future of the State, and it includes assessments for hydrogen production and storage, improvement of techniques associated with CO_2 enhanced oil recovery (EOR) for older oil fields, and evaluation of geothermal potential, among others. In addition, STARR personnel and collaborators conduct important research associated with water management and environmental stewardship. The results from STARR are published in journals and Bureau Reports of Investigation and are presented at conferences in Texas and more broadly (see appendixes B and C). As the energy economy grows and evolves, the work of STARR will continue to help shape energy exploration and resource assessment within the great State of Texas.

Energy Division: Oil and Gas

Texas continues to produce more oil and natural gas than any other state (fig. 2). In 2021, Texas produced 1.73 billion barrels of oil and 6.7 trillion cubic feet of gas (Railroad Commission of Texas). No other state, or other region worldwide, has been as heavily explored or drilled for oil and natural gas as Texas. In September 2022, approximately 172,645 active oil wells and 98,878 active gas wells were producing oil and natural gas in the state (Railroad Commission of Texas) (fig 3).

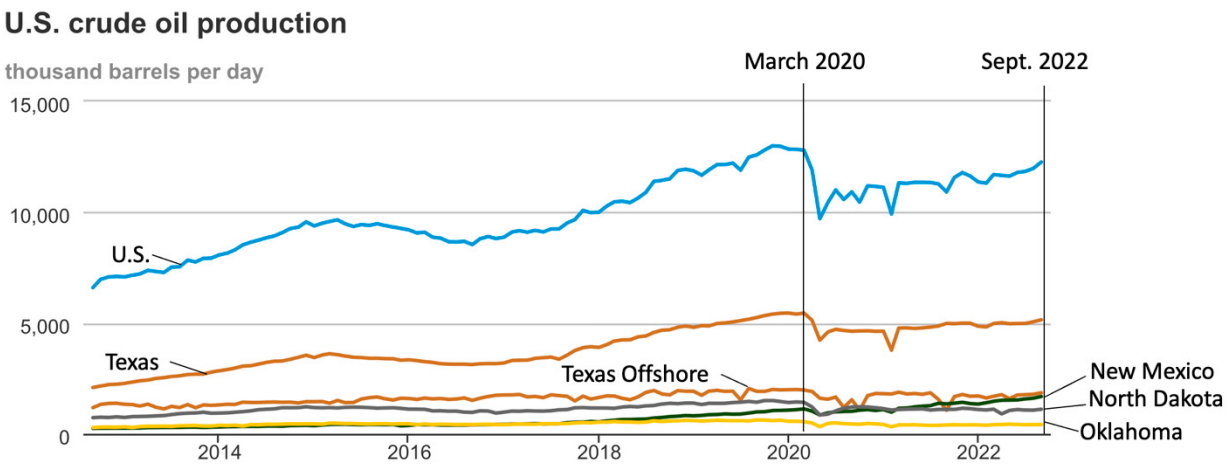


Figure 2. Crude oil production in thousand barrels per day for the United States compared to other key producing states. Source: U.S. Energy Information Administration

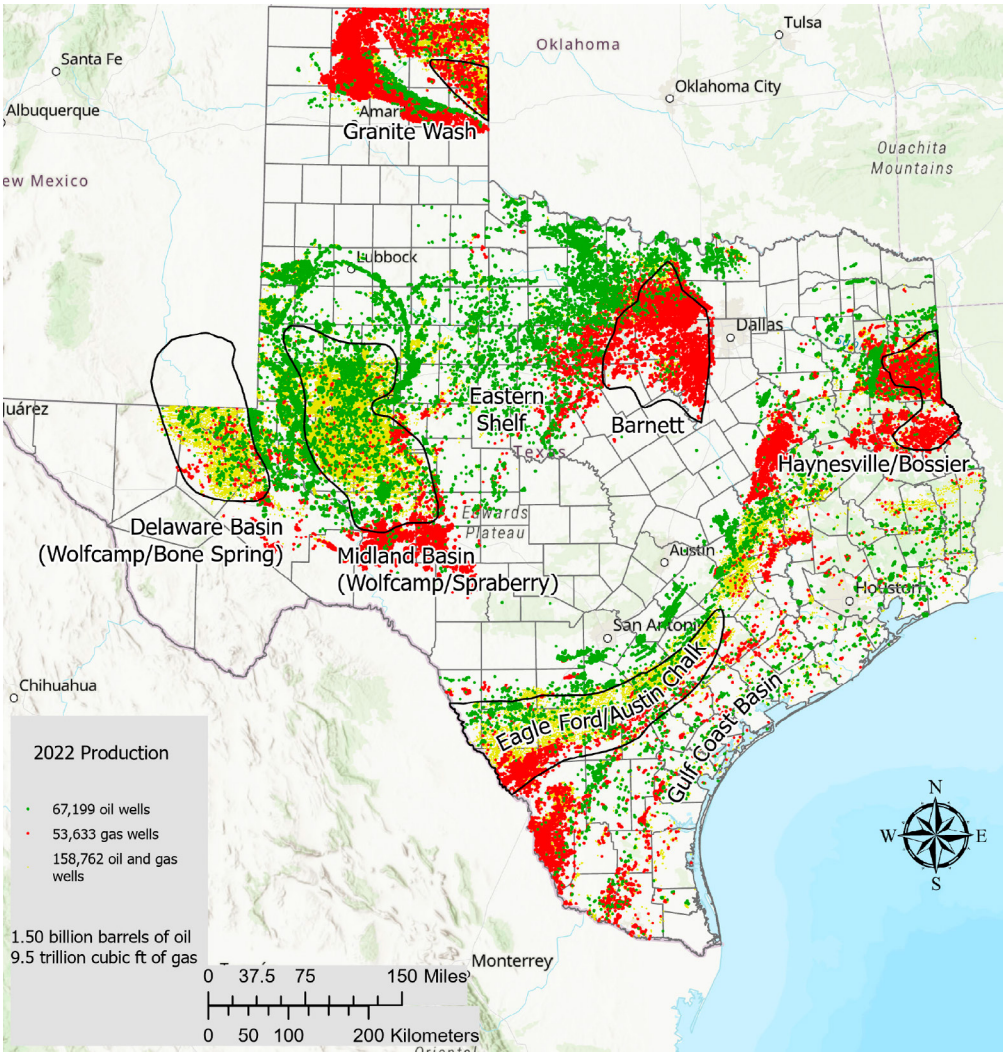


Figure 3. Map with active oil and gas.

Despite decades of heavy exploration and drilling within the state, the data clearly points to the untapped potential of the Texas subsurface with oil and gas production steadily increasing since 2009. The 2020 COVID-19 pandemic caused a decrease in oil and gas production as commodity prices plummeted (fig. 4). However, the decline rate has stabilized and production from the Permian Basin continues to drive growth not just in Texas but across the national landscape (Blackmon, 2022). The STARR program provides geological and engineering support to smaller operators in Texas who have limited staffing and technical resources so that they can access state of the art tools and expertise to increase their oil and gas exploration and production activity. Many oil and gas companies benefit from STARR field and regional studies (see Letters of Cooperation [see appendix A]).

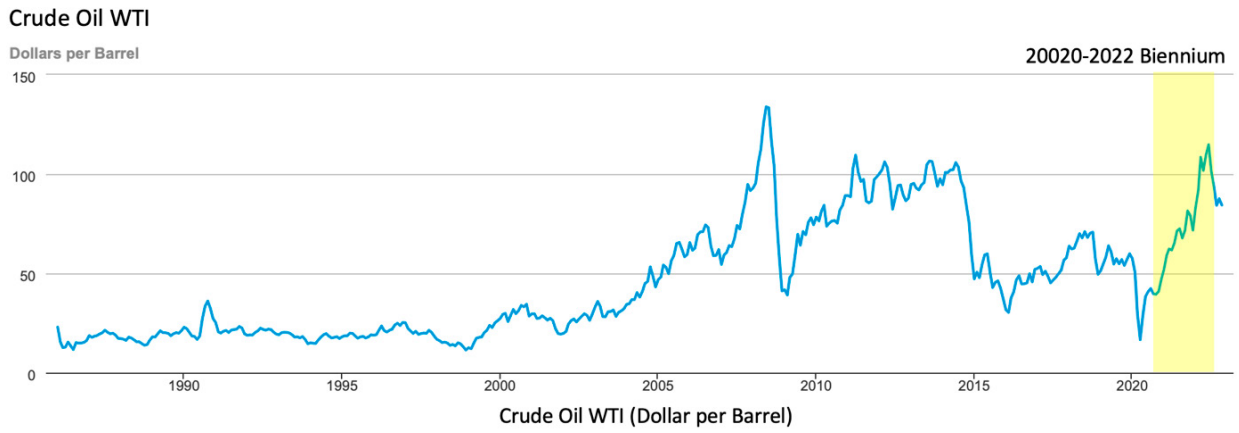


Figure 4. Oil and gas prices during the 2020–2022 biennium.

STARR researchers provide technical support that leads to drilling opportunities for increased production and reserves. The STARR program provides a variety of research products that include core descriptions and interpretations, as well as subsurface lithology and structure maps from wireline-log data (fig. 5). STARR researchers also produce a host of research products from seismic data such as cross sections, inversion analyses, stratal-slice maps, and attribute maps. These research products help oil and gas operators to define new exploration and production targets from infill wells, recompletions, field extensions, redesigned waterfloods, EOR, and exploration wells in sparsely drilled areas outside of existing fields In this biennium, STARR researchers have conducted several field scale and regional studies that include work in the Barnett Shale in the Fort Worth Basin, the Strawn Group in Scurry County, the Tannehill sandstone in the Eastern Shelf, the Cisco oil play in the Palo Duro Basin, the Frio Formation in San Patricio and Aransas counties, and the Cretaceous-volcanic play in The Thrall field in Williamson County.

Figure 5. STARR researchers delivering a core workshop on the Strawn Group for Texas operators in the Oil Information Library of Wichita Falls in 2022.

STARR emphasize technology-transfer and has a multi-faceted technology-transfer approach. During the current 2020–2022 biennium, STARR researchers produced a variety of publications, presentations, and workshops. These are summarized in appendixes B to D.

During the 2020–2022 biennium, STARR researchers gave several presentations and conducted reviews of core, wireline-log, and seismic data for industry partners (fig. 5). A partial list of recent and current STARR partners includes BKV Corporation, Devon, Fasken Oil, Continental Resources, Burnett Oil Company, Carr Resources, Winchester Energy, Travcon Energy, BPX Energy Inc, RKI Energy Resources, P&F Operations, Tony Ortiz Production Services, Jim Levy (independent), Dan Earl Duggans (independent), and Claude Joseph and Nathaniel Mayfield (independents). A comprehensive list of oil and gas operators who have worked with STARR since 1995 is presented in table 2.

Table 2. STARR O&G field studies, 1995 to present

Field	Operator	Period of Project STARR Interaction
Barnett Shale (Denton and Wise Counties)	BKV Corporation	2021–
Strawn Group (Scurry County)	Carr Resources	2020–
San Andres Seminole unit (Gaines County)	Fasken Oil	2020–
Strawn/Tannehill (King County)	Burnett Oil	2019–
Frio Formation, Aransas Pass field (Aransas and Refugio Counties)	Claude Joseph and Nathaniel Mayfield (Independents)	2020–2022
Cisco Group (Motley, Floyd, Briscoe, and Hall Counties)	Dan Earl Duggans (Independent)	2020–2022
Caballos Novaculite, Maravillas Chert, Thistle field (Pecos County)	Jim Levy (Independent)	2020–2022
Serpentine Thrall field (Williamson County)	P&F Operations	2020–2022
Strawn Group (Fisher County)	Travcon Energy	2020–2022
Austin Chalk (Tyler, Jasper, Newton, Sabine, Vernon, Beauregard Counties)	RKI Energy Resources	2020–2022
Austin Chalk (Tyler, Jasper, Newton, Sabine, Vernon, Beauregard Counties)	BPX Energy, Inc.	2020–2022
Austin Chalk (Tyler, Jasper, Newton, Sabine, Vernon, Beauregard Counties)	Continental Resources	2020–2022
Barnett Shale (Wise County)	Devon	2020–2021
Pearsall Formation (Maverick County)	Tony Ortiz Production Services	2020–2022
Hope Sandstone (Concho County)	SCAL, Inc.	2020–2022
Woodbine Group (Polk County)	Pantheon Oil and Gas	2020–2022
Cisco and Strawn Groups (Nolan County)	Winchester Energy Limited	2020–2022
Clearfork formation (Crosby County)	Surge Energy	2020–2022
Strawn Group (Coke/Nolan Counties)	Affirmed Resources	2020–2022
Caddo/Canyon/Tannehill (Knox County)	Daylight Petroleum	2019–2020
Yegua Formation (Jackson County)	Emerald Bay Exploration	2019–2020
Frio Formation (Nueces/San Patricio Counties)	Durango Resources	2019–2020
Wilcox Group (Zapata County)	Hilcorp	2019–2020
Ellenburger Group (Kendall County)	Starcreek Energy	2019–2020
Taylor Group (Williamson County)	Boardman Industries	2019–2020
Cleveland formation (Lipscomb/ County)	Tecolote, Inc.	2019–2020
Strawn Group (Knox County)	Tri-Star Petroleum Company	2018–2020
Woodbine Group (Polk County)	Petrotex	2018–2020
Tannehill formation (Nolan/Taylor/Coke County)	Teal Exploration	2018–2020
Wilcox Group (Dewitt County)	Copeland Resources	2017–2019
Bend Conglomerate (Jack County)	TECCorp International	2017–2019
Wilcox/Reklaw (Duval County)	Stalker Energy	2016–2018
Spraberry Formation (Reagan/Martin Counties)	De la Terra Exploration	2016–2018
Tannehill sandstone (Nolan/Taylor County)	TravCon Geology	2016–2018
Austin Chalk (Jasper County)	Fourhorses LLC	2016–2018
Wilcox/Carrizo (Grimes County)	Prolifico Exploration	2016–2018
Austin Chalk/Eagleford (Fayette County)	Oak Spring Energy	2016–2018
Cleveland formation (Hansford County)	Latigo Producing	2016–2018
Reinecke Horseshoe Atoll (Borden County)	Harmonia, Inc.	2016–2018
Smackover Formation (Rains County)	Dyersdale Energy	2016–2018
San Miguel/Olmos (Maverick County)	Endeavor Natural Gas LP	2016–2018
Ellenburger (Nolan County)	Winchester Energy Limited	2016–2018
Thrall (Williamson County)	Patriot Operating Co.	2016–2018

Table 2. STARR O&G field studies, 1995 to present (cont.)

Field	Operator	Period of Project STARR Interaction
Wolfcamp Formation (Howard County)	Anadarko Petroleum	2016–2018
Serbin (Bastrop/Lee Counties)	Riley Exploration	2015–2017
Nowack/Thrall (Williamson County)	Trinity Brothers	2015–2017
Spraberry/Dean/Wolfcamp (Howard County)	Haimo America, Inc.	2015–2017
Wilcox Group (Lavaca County)	Imagine Resources LLC	2014–2016
Douglas/Tonkawa formations (Lipscomb County)	Jones Energy, Ltd.	2014–2016
Wilcox Group (Bee County)	Formosa Petrochemical	2014–2016
ClearFork/Spraberry/Wolfcamp (Howard, Borden, Scurry Counties)	Harmonia, Inc.	2014–2016
Marble Falls Formation (Jack County)	Atlas Resource Partners	2014–2016
Eaglebine trend (Fayette County)	Devon Resources	2014–2016
Wolfcamp Formation (Howard County)	Excellong	2013–2015
Wilcox Group (Bee, Goliad Counties)	Excellong	2013–2015
Woodbine Group (Kerens, South field)	Five Star Energy	2013–2015
Woodbine Group (East Texas field)	Zone Energy	2013–2015
Pettet Limestone (Anderson County)	Arête Resources	2013–2015
Woodbine Group (AA Wells, Hortense fields)	Apache Corporation	2013–2015
Tonkawa, Douglas formations (Hemphill County)	Chesapeake Energy	2013–2015
Buda Limestone (Dimmit County)	US Enercorp	2013–2015
ClearFork formation (Iatan field)	BASA Resources	2013–2015
Woodbine Group (Tyler County)	BP	2012–2014
Harkey, Swastika, Cline Woodbine/Eagle Ford (Polk County)	BP	2012–2014
Glorieta group (Ward County)	Whiting Resources	2012–2014
Mississippian Lime (Shackelford, Stephens, Throckmorton, Young Counties)	Tracker Resources	2012–2014
Atoka/Cherokee Group (Ochiltree, Lipscomb, Hemphill Counties)	Arête Resources	2012–2014
San Angelo Sandstone (Irion County)	Renda Energy	2012–2014
Pearsall Formation (McMullen, Dimmit County)	Valence, Devon	2012–2014
Cisco limestone (Tom Green County)	AEATX	2012–2014
Woodbine Group (Walker County)	Chesapeake Energy	2012–2014
Woodbine Group (Leon County)	Risco La Sara Operations, Chesapeake Energy	2012–2014
Cleveland/Marmaton/Granite Wash (Hemphill County)	Devon Resources, Arête Resources	2012–2014
Frio Formation (Refugio County)	T-C Oil Company	2012–2014
Austin Chalk (Dimmit County)	Newfield Exploration Company	2011–2013
Ranger Limestone (Eastland County)	Stalker Energy	2011–2013
La Sara field (Frio)	Risco La Sara Operations	2011–2013
Bend Conglomerate (Wise County)	Devon Energy	2011–2013
K-R-S field (Marble Falls Limestone)	Cobra Oil & Gas, Stalker Energy	2011–2013
Double A Wells field (Woodbine)	Vision Resources	2011–2013
Sugar Creek field (Austin Chalk/Woodbine)	BBX Operating	2011–2013
Dismukes field (Dimmit County: Austin Chalk/Eagle Ford Shale)	CML Exploration	2011–2013
Eliasville and Breckinridge fields (Caddo Limestone)	BASA Resources	2011–2013
Lavaca Bay field (Frio)	Neumin Production Co.	2010–2012
Spraberry/Wolfcamp (Midland County)	Pioneer Natural Resources	2010–2012
Haynesville	Petrohawk, Common Resources, BP	2009–2011

Table 2. STARR O&G field studies, 1995 to present (cont.)

Field	Operator	Period of Project STARR Interaction
Alabama Ferry field	Antioch Energy LLC	2009–2011
Lavaca Bay field	Neumin Production Co.	2008–2010
Cleveland/Marmaton/Atoka field	Jones Energy, Ltd.	2008–2010
Sugarkane field	Texas Crude	2006–2008
East Texas field (Moncrief lease)	Danmark Energy	2007–2009
Copano Bay	MPG Petroleum	2007–2009
Mustang Island (Frio)	Sabco Operating Co.	2006–2008
Spur Lake and Broken Bone fields	Gunn Oil Co.	2007–2009
North Newark field (Barnett)	Various operators	2007–2009
East Texas field (Woodbine)	Various operators	2006–2008
Gold River North field (Olmos)	St. Mary's Land and Exploration	2007–2009
Gold River North field (Olmos)	Huber	2006
LaSalle, Calhoun offshore (Frio)	Gulf Energy Exploration	2005–2007
West Bay area study (Alligator Point field; Frio, Miocene)	Gulf Energy Exploration	2005–2007
Carancahua and Matagorda Bay projects (Frio, Miocene)	Brigham Exploration Company	2004–2008
Galveston Bay Shelf area study (Frio)	Santos USA Corp	2004–2006
Yates field EOR (Permian)	Kinder Morgan	2004–2006
Laguna Madre (Frio)	Novus	2004–2005
Northeast Red Fish Bay project (Frio)	Cabot Oil and Gas	2003
Mustang Island offshore (Frio)	Cabot Oil and Gas	2003
Red Fish Bay field (Deep Frio)	Boss Exploration, Cinco	2003–2008
Red Fish Bay field (Middle Frio)	IBC Petroleum, Cinco	2001–2008
Mustang Island 889 field (Frio)	Sabco Oil and Gas	2000–2001
Encinal Channel field (Frio)	Sabco Oil and Gas, Royal Exploration	1999–2000
Corpus Christi NW field (Frio)	Sabco Oil and Gas, Royal Exploration	1998–2000
Corpus Christi East field (Frio)	Sabco Oil and Gas, Royal Exploration	1998–2000
Red Fish Bay field (shallow Frio)	Pi Energy	1996–1997
Umbrella Point field	Panaco, Incorporated	1995–1999
Duval County Ranch field	Killam Oil	1998–1999
Ozona field	Union Pacific Resources, Cross Timbers Oil Co.	1996-1999
Bar Mar field	Hanson Corporation	1997–1998
Lockridge, Waha, and Waha West fields (primary funding by U.S. Department of Energy and Gas Research Institute)	Shell Oil and Mobil Oil (now ExxonMobil)	1996–1998
Geraldine Ford and Ford West fields (primary funding by U.S. Department of Energy)	Conoco, Incorporated	1995–1997
Keystone East field	Bass Enterprises, Hallwood Energy, Pioneer Natural Resources, Vista Resources	1995–1999

Synopsis STARR Energy Projects

Fort Worth Basin Barnett Shale

This project was initiated as a request from the BKV Corporation to gain insights into their newly acquired Barnett Shale asset in the Fort Worth Basin. STARR researchers conducted core descriptions and core analysis of the Barnett Shale in the mid-2000s for the historical operator Devon, our researchers shared these results with BKV geoscientists and engineers as part of a workshop that took place in the BEG's Austin Core Research Center in November of 2021 (fig 6). This activity allowed BKV to accelerate their understanding of their new acreage by gaining valuable insights into the reservoir quality and regional stratigraphy of the Barnett Shale in Denton and Wise counties (fig 7). This highlights the importance of the STARR program as a venue to retain knowledge associated to data sets from oil and gas fields across Texas, allowing us to preserve and share information of assets that often times change hands to new operators.

Figure 6. Dr. Bob Loucks from BEG leading the discussion during the Barnett Shale core workshop for BKV.

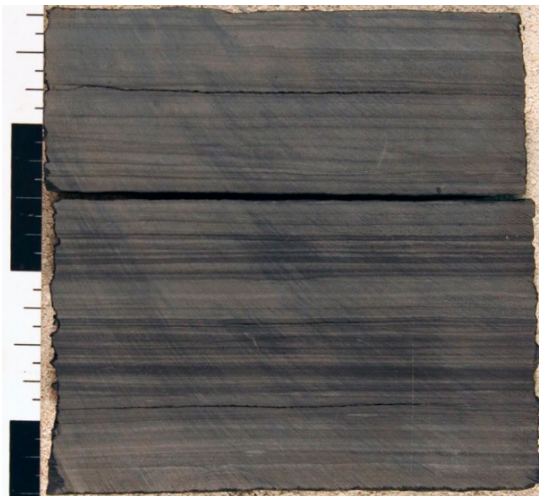


Figure 7. Barnett argillaceous siliceous mudstone showcasing very low-angle ripples (Photograph by Dr. Bob Loucks).

In addition, STARR researchers, in collaboration with BKV personnel, engaged in new work that aimed at increasing our petrophysical understanding of the Barnett Shale. Core samples were selected to perform porosity and permeability measurements using experimental techniques developed by Dr. Sheng Peng in our Unconventional Petrophysics Laboratory (UPL) at BEG. Dr. Peng uses integrated laboratory and multiscale imaging techniques to better understand shale pore systems and associated fluid flow (these techniques are not commercially available). These results were then compared to independent geological observations and interpretations derived from integrated core description, petrography (thin section and SEM), and geochemistry (XRF and HAWK analyses).

Strawn Depositional Model and Oil Analysis

The project started with the revision of depositional models for the Strawn "A" and "C" in Scurry County and core viewing sessions for wells Shell #1 Hoepfl and Gunn #47 Burnett. Increased interest in the Strawn Group for oil and gas exploration triggered the expansion of this STARR project, as a result a full core workshop was hosted in BEG's Core Research Center in Austin in 2021 and an additional workshop was hosted in the Oil Information Library of Wichita Falls in 2022 (fig 8). STARR researchers are currently conducting active research on the topic and upcoming publications are in the pipeline.

Figure 8. STARR researcher Kelly Hattori delivering a talk to the Oil Information Library of Wichita Falls on the petrography of the Strawn Group.

As part of the Carr Resource engagement, STARR researcher Kelly Hattori performed new petrographic analysis of well Shell #1 Hoepfl targeting units "A" and "C" (fig 9). In addition, Dr. Xun Sun and Tongwei Zhang performed geochemical analysis on four samples of produced oils from the Strawn Group provided by Carr Resources. Results indicated that these oils originated from a marine source rock deposited in a slightly reducing environment. Dr. Peter Flaig is also engaging in outcrop studies including exposures in the San Saba Greater Texas Stone Quarry where palynological data has also been collected. The main objective of this overarching research project is to provide a multidisciplinary and comprehensive evaluation of the Strawn Group at a regional scale to help unravel the nature and untapped potential of this petroleum system in West Texas and support operators in their exploration efforts.

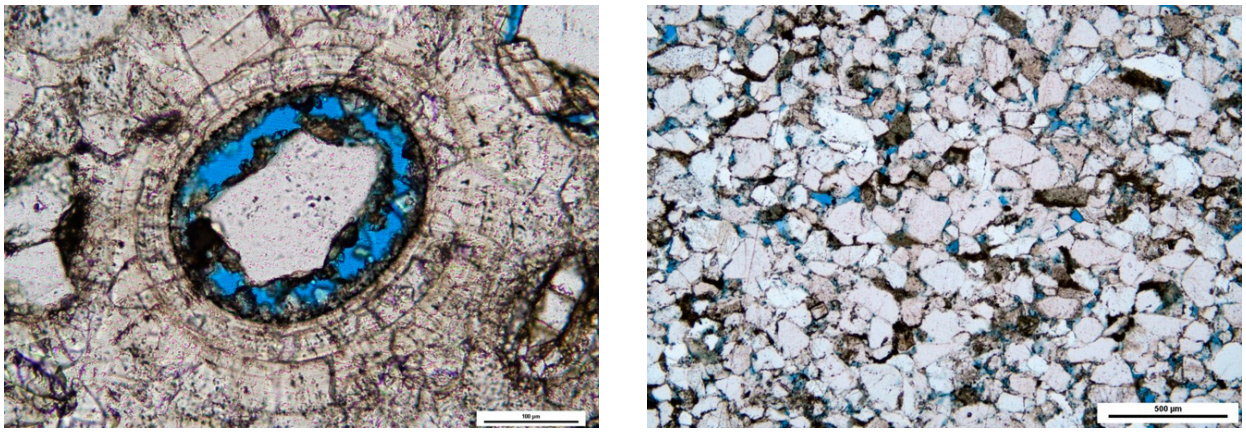


Figure 9. Microphotographs from well Shell #1 Hoepfl. To the left (Strawn "A"), relict oolitic textures can be observed around some detrital quartz grains, pore network is mostly moldic from dissolved oolitic coatings around quartz grains, and dissolved skeletal grains (Depth: 7106'). To the right (Strawn "C"), very fine sandstone with no carbonate cement, majority detrital quartz with some polycrystalline quartz, chert, and feldspar. Pore network mostly interparticle (Depth: 7266'). Microphotographs and interpretation by Kelly Hattori.

Tannehill Sandstone Trends

STARR researcher Dr. Osareni Ogiesoba performed a simultaneous seismic inversion study of the northern part of the Eastern Shelf in King County in collaboration with colleagues from Burnett Oil. The main objective of the seismic inversion exercise was to determine the areal extent of the Tannehill sandstone within the operator's acreage. Dr. Ogiesoba started to approach this problem by investigating if the reported thickness of the Tannehill sandstone could be resolved seismically. The seismic resolution of the operator's dataset is 26 meters per cycle while the thickness of the Tannehill sand as reported in wells is only 8 meters and therefore unresolvable by using simple seismic observations. Dr. Ogiesoba then proceeded to perform a more sophisticated seismic inversion using a prestack simultaneous inversion workflow and introducing pseudo-horizons to constrain the inversion process. This procedure helped Burnett Oil to better understand the capabilities and limitations of their seismic dataset as well as the areal extent of the Tannehill Sandstone. Dr. Ogiesoba showed that the Lower Tannehill Sandstone interval is divided into two zones (Zone A and Zone B) by the Lower Stockwether Limestone (LSW LT) (fig. 10). A component of this work was shared with a broader audience as part of a technical presentation in the 2021 Annual Convention of the Southwestern Section of the American Association of Petroleum Geologists in Dallas.

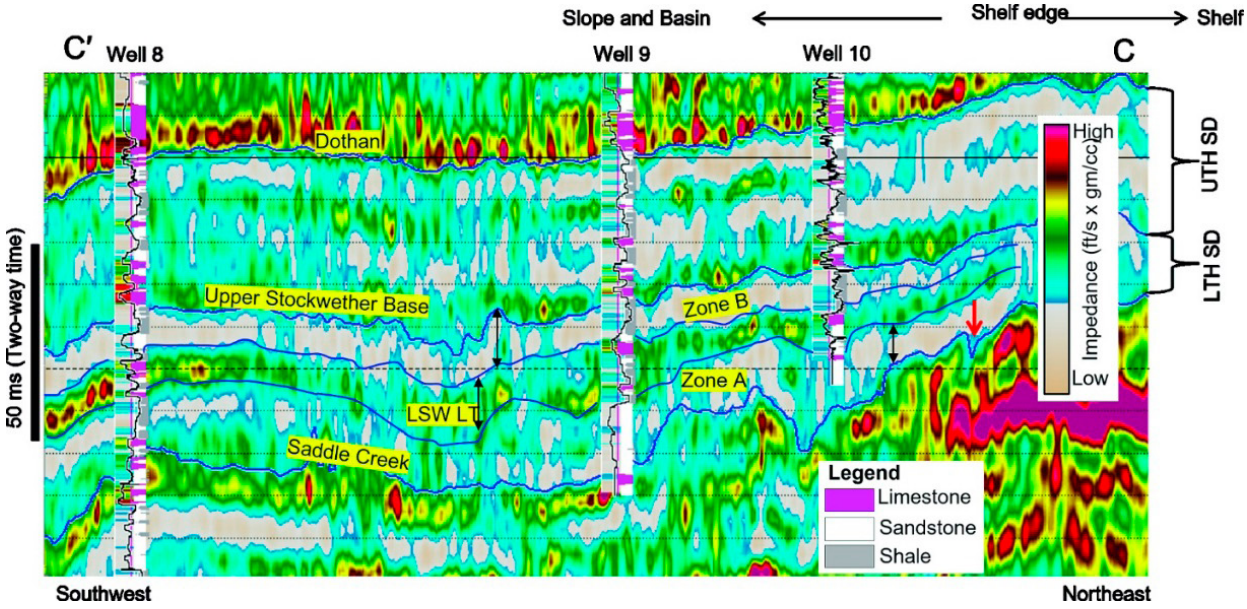


Figure 10. Results of seismic inversion showing cross section C–C′ through the impedance volume going through wells 8, 9, and 10. The line showcases the Lower Tannehill Sandstone Zone A and Zone B. Note the reasonable agreement between inserted impedance color-log and inverted impedance section. Interpreted lithology log is inserted for lithology identification. Black curve is gamma-ray log. Note also, that Zone A interval is mostly sandstone rich, whereas Zone B interval is mostly shale rich, as shown at wells 9 and 10.

Frio reservoir characterization in Aransas Pass field

The Frio Formation has produced oil and gas in Aransas Pass field in San Patricio and Aransas Counties since the late 1930s. Nevertheless, the field has a good potential for additional oil and gas recovery because many reservoirs have been bypassed and completed in limited areas. These reservoirs have a variety of depositional origins—deltaic, barrier-strandplain, and lower-coastal-plain—that record multiple, high-frequency episodes of regression and transgression. Many producing wells in the field occur along sandstone-body pinchouts associated with transitions between facies.

This STARR reservoir characterization study has 5 (five) objectives and is led by STARR researcher Bill Ambrose. They are to (1) divide the Frio Formation into ~40 high-frequency, regressive-transgressive, and mappable depositional units in a growth-faulted, ~15-mi^2 (~40-km^2) area encompassing Aransas Pass field; (2) construct detailed net-sandstone maps of each depositional unit, depicting the sandstone-body geometry (fig. 11); (3) integrate wireline-log responses and stratigraphic cross sections with net-sandstone maps, inferring facies and depositional systems and reconstructing the paleogeography for each depositional unit, (4) interpret depositional controls on sandstone-body reservoir architecture; and (5) relate oil and gas production to facies, depositional systems, and structural position. By dividing the Frio Formation into high-frequency depositional units rather than characterizing amalgamated stratigraphic units, this study resolves sandstone-body geometry and depicts changes in styles of depositional systems and provides a framework for future infield exploration and development by projecting multiple, sandy depositional axes into sparsely drilled areas.

This study demonstrates that a high-resolution stratigraphic framework is effective in resolving sandstone geometry at the reservoir scale, a necessary prelude in understanding the distribution of producing wells and how it relates to facies heterogeneity. In addition, detailed net-sandstone and facies maps within a high-resolution stratigraphic framework can also be useful in delineating areas in the field where there have been few completions, thereby identifying areas for additional infield exploration.

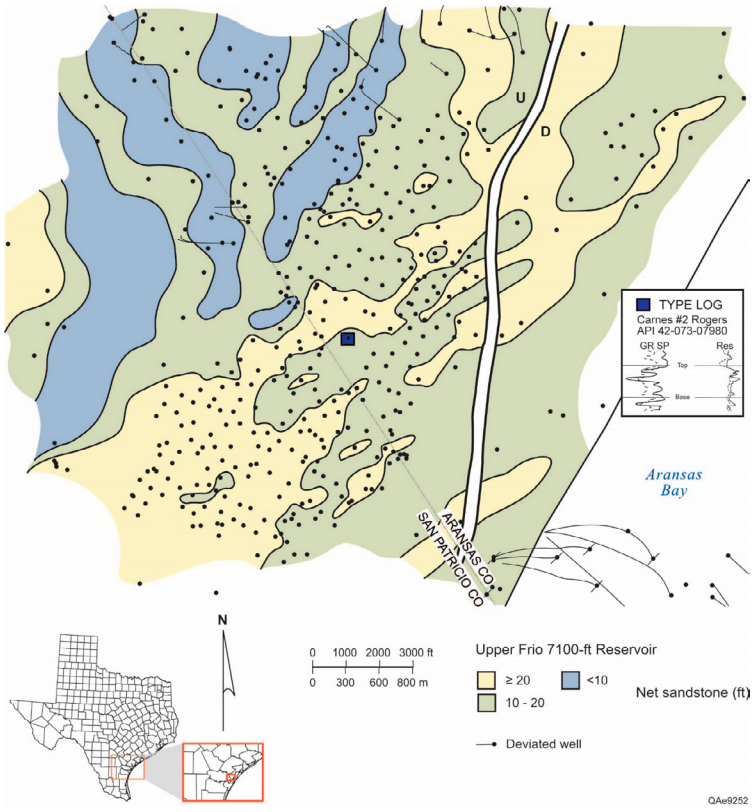


Figure 11. Net-sandstone map of a typical Frio reservoir in Aransas Pass field. Northeast-southeast-trending sandstone bodies, more than 20 ft (>6 m) thick, represent barrier-core and shoreface facies. These shorezone deposits are intersected by a system of narrow, south-trending sandstone bodies in the northern part of the field. These tidal-inlet deposits disrupt the continuity of the shorezone system, potentially segmenting the main reservoir into poorly drained compartments.

Cisco Play Extension

The objective of this project was to evaluate the potential of extending a Cisco oil play from the Wolf Flat field in the Palo Duro Basin. Between October 1987 and July 1994, seven productive wells were drilled within the approximately 640-acre Wolf Flat Field, in Motley County near the Hall County line. The Wolf Flat field has produced approximately 1.6 mm bbls oil and 30 mm bbls water from 7 wells. In the early days of production, water cut was a reasonable 10-20%. It wasn't until about the tenth year of production that water cut increased appreciably. 80-90% of the cumulative oil was produced in the first 10 years or so, before the large increases in water cut occurred. Since the mid-1990s, there has been sporadic, largely unsuccessful, exploration around the Wolf Flat Field.

The plan for this study was to define the reservoir stratigraphy and structural elements of the Cisco play in the area of the Wolf Flat field, and to determine whether the key elements of the play can be reasonably mapped and extended away from known areas of Cisco production (fig. 12). The concept is that the Wolf Flat carbonate trend may extend northwestward, along a paleo-shelf margin trend increasing the exploration potential of this area. Regional observations derived from this work were presented by STARR researcher Eric Radjef at the Southwest Section of the American Association of Petroleum Geologists in Wichita Falls in 2023.

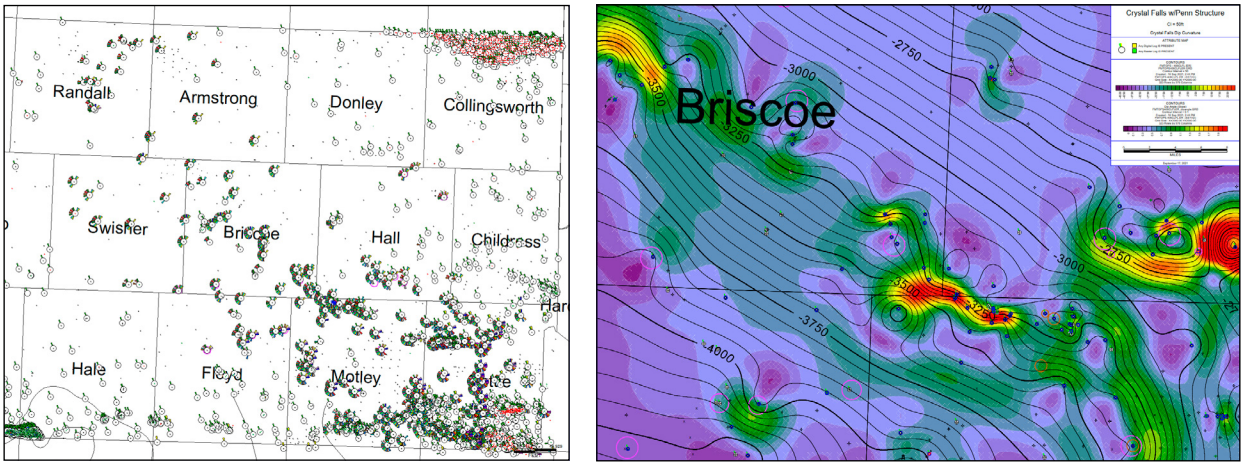


Figure 12. Map to the left showcases the area of interest where more than 400 wells were interpreted, and correlations were generated using 30 key stratigraphic markers. The map to the right showcases the structure and dip magnitude map of the Crystal Falls unit (Lower Permian), this maps was generated using tops from 244 wells (map and interpretations by STARR researcher Eric Radjef).

The Thrall Field – Revisiting the Geology of an Old Friend

The Thrall field is located just six miles east of Taylor in Williamson County. In 1914, Mr. Fritz Fuchs was drilling a well hoping to find water but instead a considerable amount of oil was found at a depth of around 300 ft. In 1915, arrangements were made to drill deeper, and the discovery of the Thrall field was confirmed. Very early, the Bureau of Economic Geology got involved in the study of the field, this involvement has continued over a century while we update our understanding of these fascinating volcanic units as new data and technology becomes available. The Thrall field is part of the Balcones Igneous Province where several small producing fields have been associated with this Cretaceous-volcanic play, these fields include Chapman-Abbott, Hilbig, Dale, and the Elaine field in addition to Thrall.

As part of this study STARR researchers have engaged in detailed core descriptions and advanced microscopic analysis of the popular "serpentine units" that are associated with these fields in the Balcones Igneous Province. Dr. Rob Reed and Dr. Bob Loucks have concluded that the term "serpentine" is inappropriate for these rocks that are in fact mafic volcanic tuffs (fig 13). Dr. Hongliu Zheng has used three-dimensional seismic data from the Elaine field in South Texas to unravel the architecture of these tuff-dominated volcanic complexes that are also related to the carbonates of the Upper Cretaceous Taylor Group (fig 13). In addition, Dr. Xun Sun performed geochemical analysis of produced oils in the Thrall field concluding that these oils are likely a mixture derived from different source rocks; however, migration mechanisms still remain dubious. The Balcones Igneous Province might still be an underexplored province and further work is required to fully understand this fascinating petroleum system.

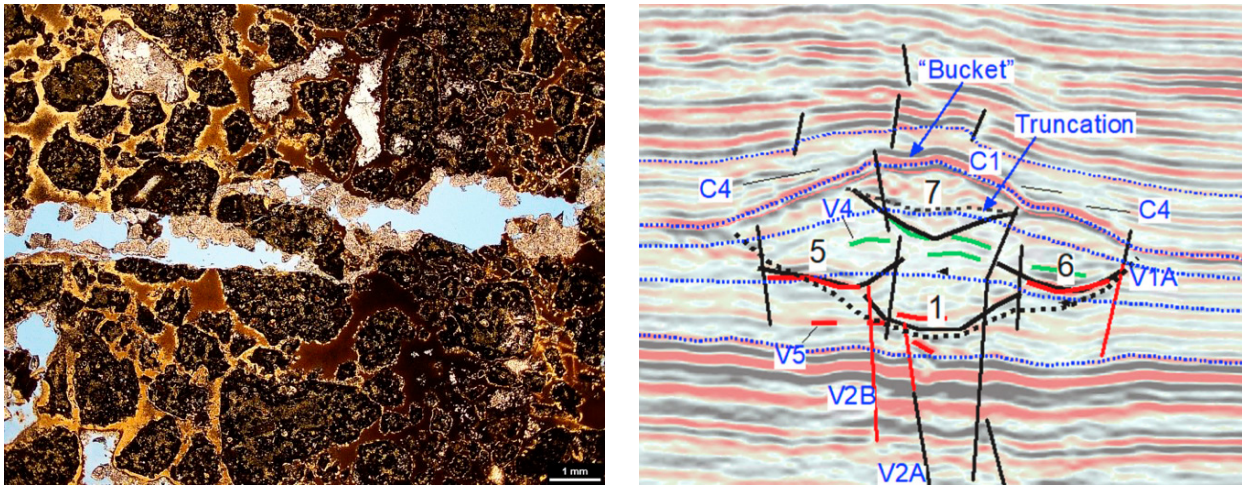


Figure 13. Microphotograph of mafic tuffs from well Sun T.P. Simmons #1-A in Williamson County (1681.4 ft) showcasing macrofractures (left). Interpreted seismic line from the Elaine Field showcasing the geometry of volcanic mounds in the Balcones Igneous Province (right). Figure from Zeng et al. (2023).

Emerging Energy Opportunities in Texas

STARR is engaging in projects with energy companies and partners that are interested in understanding the potential to develop emerging energy opportunities within the State of Texas (table 3). From geothermal opportunities to hydrogen storage and everything in between, Texas is well positioned to continue harnessing its oil and gas potential while extending business opportunities into emerging markets such as hydrogen. STARR is leveraging technical subsurface knowledge and legacy data to help companies screen new opportunities in these areas as we are also incorporating technoeconomic analysis.

Table 3. STARR Energy Transition Partnerships, 2021 to present

Wilcox Group (Gulf Coast) – Geothermal and Hydrogen	Repsol	2021–2022
Wilcox Group (Gulf Coast) – Geothermal	Murphy	2021–2022
Onshore Seismic – Hydrogen and Carbon Sequestration	CGG	2022–2023
Emerging Energy and Resource Opportunities (Permian Basin)	University Lands	2022–

STARR and University Lands

In 2022, the STARR program entered into a partnership with University Lands, which is the fiduciary steward of 2.1 million acres of land across 19 counties in West Texas (fig. 14). University Lands manages surface and mineral interests of this land for the benefit of the Permanent University Fund (PUF). The PUF is a university endowment that benefits more than 20 educational and health institutions across The University of Texas System and Texas A&M University System. University Lands is on track to post its best-ever annual revenue in fiscal year 2022 thanks to favorable oil and gas prices and stabilizing production in the Permian Basin after the 2020 COVID-19 pandemic (Lorin and Chapa, 2022). University Lands has recognized a need to evaluate emerging energy and resource opportunities within their acreage, and a new partnership with STARR has been established to conduct research on a variety of topics including fiscal and environmental impacts.

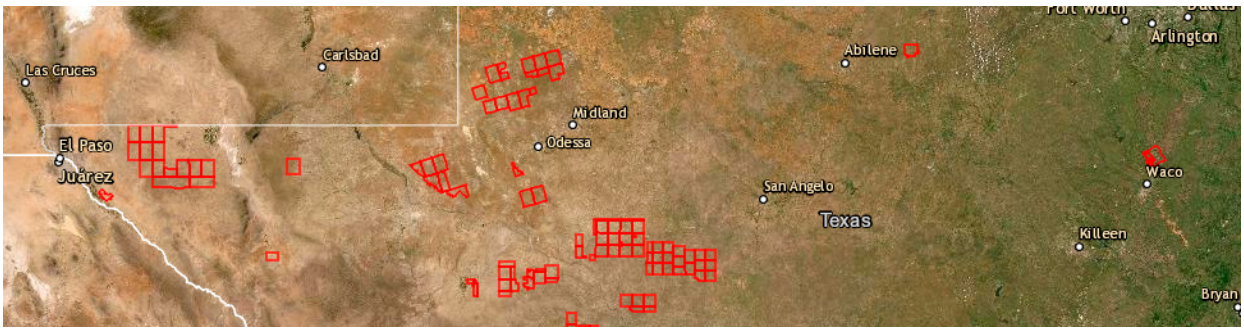


Figure 14. Location of University Lands' acreage.

The STARR–UL partnership will generate a geospatial framework and database that will be incorporated into University Lands' Geographic Information System (GIS) of existing surface and subsurface data, current usages and infrastructure, energy resource and mineral resource potential, and subsurface storage potential. This framework and database would be used to identify and analyze future development opportunities including but not limited to carbon capture and sequestration, hydrogen generation and storage, geothermal, and critical mineral mining.

Geothermal

STARR has also performed work at the request of some energy companies that are exploring options to lower their carbon emissions by using geothermal solutions within Texas. Research results from STARR in the Wilcox Group has proven to be particularly useful for these operators since new well log analysis and seismic interpretations, as well as state of the art biostratigraphic and chemostratigraphic analysis, have helped refine stratigraphic correlations across fault blocks to better understand compartmentalization and "reservoir" distribution.

STARR REVENUE-NEUTRALITY METRICS

STARR Energy

An important goal of the STARR program is to demonstrate revenue neutrality. STARR's revenue neutrality is calculated over a period of two years. Royalties and severance taxes for the State are the basis for revenue-neutrality calculations (table 4). This metrics table was developed in conjunction with the State of Texas Comptroller's office in 2004.

Revenue values summarized in table 1 are derived from total production in areas defined by field and regional studies during the 2020–2022 biennium. Total revenue value is defined as all new production multiplied by the price of oil and gas for a given month and totaled from oil and gas well head value. STARR involvement in regional plays allows the Bureau of Economic Geology to sum up 25% of the severance tax, whereas severance-tax credit for STARR field studies is at a 100% value (table 4). The total revenue in table 1 is the summation of this process for every regional and field study in the current biennium.

Credit to the STARR program for the 2020–2022 biennium, in accordance with methodology approved by the State of Texas Comptroller's office, is approximately $118,416,980 (table 1). Relative to total funding of $9.7 million over the current biennium, STARR is revenue positive by a factor of 12.2.

STARR Land, Water, and Energy Nexus

STARR funds continue to leverage and match external grants in two different programs. For the energy side of the program, the U.S. Department of Energy sponsored the Regional Induced Seismicity Collaborative (RISC) program at $500,000 per biennium to improve communication between the state surveys and regulatory communities. For the water and land side of the program, the Cynthia and George Mitchell Foundation underwrote three studies at ~$465,000 to support the Respect Big Bend initiative to assess potential impacts to land resources from all energy infrastructure, to better communicate water resources at the municipal scale (Boerne, TX) to local stakeholders and decision makers, and to improve how groundwater pumping and availability are impacted by increasing depths to groundwater level. Together, these programs represent a leveraging of approximately 9:1, and they remain vital for maintaining the quality of Texas' resources.

Table 4. STARR revenue-neutrality metrics

Type of STARR recommendation	Expiration period following recommendation (Initial/incremental production must begin before recommendation expires)	Time period for credit following initial production	Royalty credit	Severance tax credit
1. Drilling new infill or step-out well in established field	4 years	2 years	100%	100%
2. Drilling new infill or step-out well in established field with multiple reservoir intervals	4 years	2 years following completion of each additional reservoir interval	100%	100%
3. Recompletion–missed pay well in established field	4 years	2 years	100%	100%
4. Enhanced oil recovery (EOR) field project	4 years	2 years following date selected by STARR within a 5-year period from initial operator action	100% of incremental production	100% of incremental production
5. Exploration well	4 years	2 years	100%	100%
5a. Subsequent development wells following discovery of new field	2 years following initial production from exploration well	2 years	100%	100%
5b. Copycat wells following discovery of new field	2 years following initial production from exploration well	2 years	25%	25%
6. Wells drilled on basis of influence of regional trend studies	4 years starting 6 months after releasing study	2 years	25%	25%

STARR LAND, WATER, AND ENERGY NEXUS

Overview and Goals of the Project

For the last several years, STARR Land/Water (formerly Water/Energy) research by the Bureau in the State of Texas has focused on several specific areas. These areas include whether disposal of wastewater through UIC Class II wells in the Panhandle could induce earthquakes in the region; the communication of regional earthquake activity from the state geological surveys to the regulatory community and public; and improvement in quantifying groundwater availability and affordability, given expected future groundwater conditions. All of these projects touch on the need to better communicate complex topics of Earth sciences to stakeholders and decision makers. Overall, wastewater management remains a significant issue in Texas. Disposal of produced water through UIC wells is still the dominant management option, despite advancements in treatment technologies. Even so, each state in the southern midcontinent of the United States with oil and gas activities is addressing water management issues, many of which involve earthquakes. By synthesizing approaches taken by the state surveys in Texas, Oklahoma, Kansas, New Mexico, and Arizona, data and information is now more easily transferable across jurisdictions. During this biennium, for example, using funding from the RISC, a memoir was developed, led by the Bureau, with contributions from each of the respective state surveys that describes their data and information management approaches, particularly as they relate to communicating findings to their regulatory agencies. RISC continued leading a highly successful webinar series dedicated to understanding induced seismicity for a broad array of stakeholders. STARR leveraged funding from the Cynthia and George Mitchell Foundation (CGMF) to help project future fossil and renewable energy activities in West Texas and the potential impacts of these activities on land use and land health. STARR leveraged funding from the CGMF to better communicate water resource supply and demand for the community of Boerne, TX. The approach, based on the Internet of Water, compiled and harmonized data from over ten different federal, state, and local sources into a single dashboard that allowed the public and decision makers to view their own water resource status. In each of these cases, STARR funding was used to improve how geologic data and information are communicated to the public.

Examples of Results and Findings

Water and Seismicity

The earthquake research program at the Bureau, known as TexNet-CISR, which is dual funded by private operators and the State of Texas, is a national leader in operational seismology. The research program provides vital data to the Railroad Commission of Texas (RRC), operators, and the public, and publishes dozens of papers and bulletins.

Research focused on the Texas Panhandle is linking disposal volumes and intervals to historical and recent earthquake activity (Acevedo and others, 2022). Results showed a correspondence between the rate of events (M≥2.5), which increased from 1.21 to 3.50 events per year, and wastewater injection. Since 2015, as injection rate decreased, so too did the earthquake event rate.

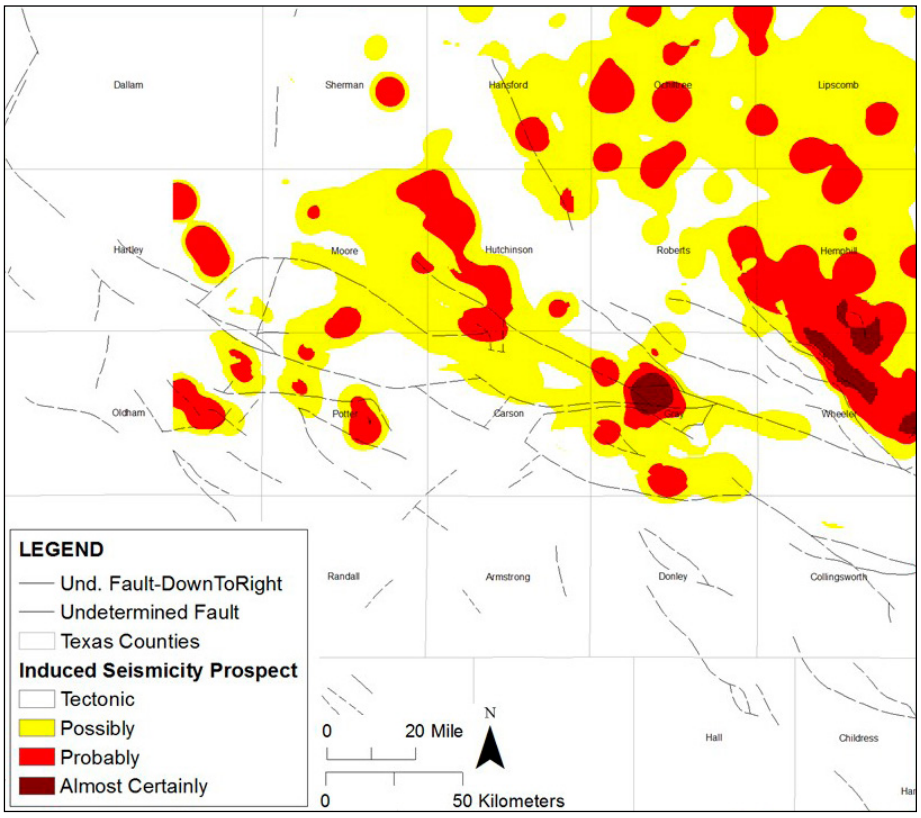


Figure 15. Map showing prospect regions. Dashed lines depict basement-rooted faults with undetermined geometry (Acevedo and others, 2022).

Water Issues Related to Oil and Gas Production in Texas

Our previous analysis of water–energy nexus issues focused on the major plays in the United States. In the past biennium, we expanded our analysis to focus on a case study considering the Permian Basin. We conducted a detailed study of water use for hydraulic fracturing and produced water volumes and assessed potential impacts on groundwater resources in the Permian Basin. We evaluated the time series of saltwater disposal in the Midland and Delaware Basins within the Permian Basin. We published these results in a refereed journal article in 2022 (Scanlon and others, 2022b).

STARR funding provided support to expand on the study we conducted to assess water use in the mining industry in Texas (Reedy and others, 2022). The Texas Water Development Board study focused on quantifying water use for hydraulic fracturing and produced water volumes based on data in 2019; however, we used STARR funding to extend these data through 2021 for hydraulic fracturing and through 2020 for produced water volumes. The spatial and temporal trends in water use for all oil and gas plays in Texas were evaluated and linked to the water sources, particularly the aquifers in the Permian Basin, such as the Ogallala aquifer. These data allow us to compare with the quantitative data reported by the Texas Produced Water Consortium (TPWC, 2022). We used a different database than was used by the consortium that allowed us to assess uncertainties in water quantity estimates, particularly produced water volumes, which provide an additional source of water in the Permian Basin region for other user sectors.

Orphaned Wells in Texas

We used STARR funding to assess the spatiotemporal distribution of abandoned wells in the Permian Basin (fig. 16a). We also mapped the distribution of plugged wells in the state (fig. 16b). We are examining these data sets to get a better understanding of the distribution of orphaned wells and their potential to contaminate overlying aquifers. We have conducted preliminary assessments of data analytic approaches to rank orphaned wells in terms of vulnerability for causing aquifer contamination in the Permian Basin. We were invited to give a presentation at the American Geophysical Union on this topic in December 2022 (Scanlon and others, 2022a).

(a)

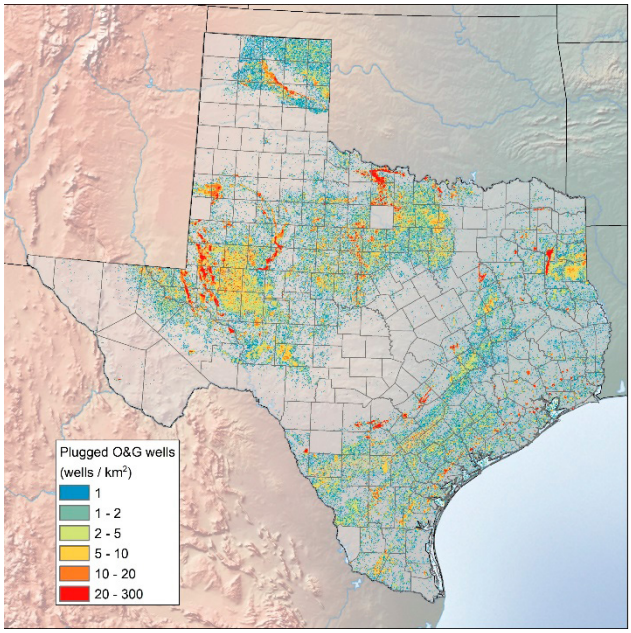


Figure 16a. Current distribution of orphaned wells in Texas. A total of ~8,500 wells are listed in the RRC database.

(b)

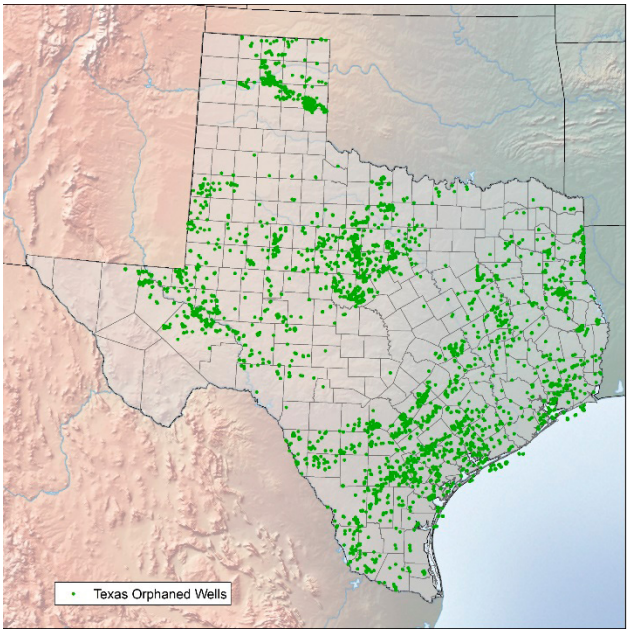


Figure 16b. Distribution of plugged wells in Texas. About 1.1 million wells have been plugged in the state (Scanlon and others, 2022b).

Water, Land, and Energy

Research focus during this biennium was on water resources and its affordability and delivery to Texas citizens. Two projects are examples:

1. We studied when groundwater availability could be constrained by depth to water, potentially exceeding the operational envelope of the well (see image), and when the cost to pump groundwater could exceed the economic value water brings the user. These studies are allowing groundwater users to design wells that are effective and affordable.

2. We studied water resources for the City of Boerne, TX, and designed an Internet-of- Water dashboard to help officials, utilities, and the public to track supply and demand in the community. This is the first municipal-scale program of its kind in the United States. The approach and concepts have been presented to the Governor's office, several state agencies, and non-governmental organizations, with the goal of expanding the program to other, similar-sized communities.

BEG Core and Research Facilities

The BEG core facilities hold a collection of more than 2,000,000 boxes of core and cuttings with rock material from wells drilled throughout Texas, the United States, and the world. Our warehouses and laboratory facilities are state of the art and allow us to properly preserve our vast holdings of multi-million-dollar subsurface data. The vast majority of core and cuttings come via donations from Texas oil and gas operators. These rock holdings allow us to pursue high quality and impactful research that would not be possible without access to these holdings. Managing and operating our facilities are not trivial tasks and we have a dedicated and talented team of technical staff and facility managers who assist researchers in all kinds of projects (fig. 17). Our core and research facilities are true gems and a state resource that will continue to provide valuable data to BEG researchers in the pursue of high quality, impactful, and timely research to benefit energy operators within the great State of Texas and beyond.

Figure 17. BEG core facilities are home to more than 2,000,000 boxes of core and cuttings. In the picture, BEG core facility in Austin Texas with our technical staff (left: Rudy Lucero, and right: Brandon Williamson) and facility manager (center: Nathan Ivicic).

REFERENCES

Acevedo, J. P., Lemons, C. R., Young, M. H., McDaid, G., and Scanlon, B. R., 2022, Analysis of wastewater injection and prospect regions for induced seismicity in the Texas Panhandle, USA: AAPG Bulletin, v. 106, no. 4, p. 670–699, DOI:10.1306/eg.01072120005.

Arciniega-Esparza, S., Hernández-Espriú, A., and Young, M. H., 2022, Implications of unconventional oil and gas development on groundwater resources: Current Opinion in Environmental Science & Health, v. 27, no. 10, article no. 100346, DOI:10.1016/j.coesh.2022.100346.

Blackmon, D., 2022, "Permian Basin drives the U.S. oil industry despite limits on growth": Forbes.com, https://www.forbes.com/sites/davidblackmon/2022/11/19/permian-basin-drives-the-us-oil-industry-despite-limits-on-growth/?ss=energy&sh=11f4f6e8788f (accessed January 24).

Lorin, J., and Chapa, S., 2022, "Harvard's status as wealthiest school faces oil-rich contender in the University of Texas": Bloomberg.com, https://www.bloomberg.com/graphics/2022-harvard-university-of-texas-richest-college-oil-endowments/?leadSource=uverify%20wall (accessed January 24).

Reedy, R. C., and Scanlon, B. R., 2022, Water use by the mining industry of Texas: The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Texas Water Development Board under contract no. 2100012474, 78 p.

Rueda, V., Young, M. H., Faust, K., Rateb, A., and Leibowicz, B. D., 2022, System dynamics modeling in local water management: assessing strategies for the city of Boerne, Texas: Water, v. 14, no. 22, article no. 3682, 19 p., DOI:10.3390/w14223682.

Scanlon, B. R., Reedy, R. C., Nicot, J.-P., and Young, M., 2022a, Plugging orphaned wells in Texas to reduce adverse environmental impacts: AGU Fall Meeting, abstract SY15C-0438.

Scanlon, B. R., Reedy, R. C., and Wolaver, B. D., 2022b, Assessing cumulative water impacts from shale oil and gas production: Permian Basin case study: Science of The Total Environment, v. 811, article no. 152306, 11 p., DOI:10.1016/j.scitotenv.2021.152306.

Thompson, J. C., Kreitler, C. W., and Young, M. H., 2020. Exploring groundwater recoverability in Texas: maximum economically recoverable storage: Texas Water Journal, v. 11, no. 1, p. 152–171.

TPWC, 2022, Beneficial use of produced water in Texas: challenges, opportunities and the path forward: Texas Produced Water Consortium (TWPC), report to the Texas Legislature 2022, 130 p.

APPENDIX A: LETTERS OF COOPERATION

The following selected letters are from partner companies with whom the STARR program has recently collaborated. These letters document the strong interaction between STARR and the oil and gas industry.

1200 17th Street, Suite 2100
Denver, CO
80202
bkvcorp.com

March 31, 2022

Lorena G. Moscardelli, Ph.D.
Research Scientist and Principal Investigator
State of Texas Advanced Resource Recovery (STARR) Program
Bureau of Economic Geology, Jackson School of Geosciences
The University of Texas at Austin
P.O. Box X
University Station
Austin, TX 78713-8924

Dear Dr. Moscardelli:

I would like to acknowledge the recent and already significant contributions that the State of Texas Advanced Resource Recovery (STARR) Program at the Texas Bureau of Economic Geology have made to BKV Corporation's understanding of our Fort Worth Basin Barnett Shale assets in Denton and Wise Counties, Texas.

The Bureau has quickly and effective shared with us the core descriptions and core analysis that they conducted on BKV's asset in the mid-2000s for the historical operator, Devon. We have benefitted from attending a workshop for our team on Nov. 9, 2021. Dr. Moscardelli and her team presented six insightful lectures on their Barnett research followed by the viewing of five cores that Devon had donated to the Bureau that are now under our operatorship. We gained important insights into reservoir quality and regional stratigraphy that will help us better target our restimulation and new drilling efforts.

Additionally, BKV benefitted from attending the STARR fall workshop on the Strawn on October 26, 2021. The Strawn formation is prospective just west of our acreage. Gaining knowledge of this formation helped in improving our regional geologic understanding.

We are in the planning stages of new experimental permeability work with STARR researchers that will aid in the understanding of the petrophysical properties for further development opportunities.

It should be noted that STARR provides a valuable service in retaining institutional memory and data for assets as they change hands to new operators like ourselves. BKV looks forward to a long and fruitful relationship with the STARR program as we develop our gas resources in Texas.

Sincerely,

Rebecca R. Harrington
Principal Geologist BKV Corporation

CARR RESOURCES, INC.
Oil & Gas Exploration and Production

305 S. Broadway, Suite 900
Tyler, Texas 75702
john@carrresources.com
903/597-2336 Fax 597-1898

March 30, 2022

Lorena Moscardelli, Ph.D.
Project Director STARR Program
Bureau of Economic Geology – The University of Texas at Austin
P. O. Box X – University Station
Austin, Texas 78713-8924

Dear Dr. Moscardelli,

I want to formally thank you and the entire team of research scientists that you represent, on behalf of Carr Resources, Inc. for the wonderful work done by your staff to assist Carr Resources, Inc. in our understanding of the stratigraphy, sedimentology and likely oil source for the Strawn reservoir that we are developing in southeastern Scurry County, Texas. The following is a short synopsis of why this work was so important to Carr Resources, Inc. Please feel free to share this with whomever you wish.

Prior to our acquisition of the lease block in Scurry County in late 2019, no one on the Carr staff had ever worked any of the Paleozoic section on the Eastern Shelf or within the Midland Basin. When we made the decision to purchase the lease block I immediately reached out to Bill Ambrose, now semi-retired, for any help he might be able to provide. We quickly identified that the BEG has possession of the cores from both the Strawn "A" and "C" from the Shell #1 Hoepfl within three miles of our lease block. I sent Bill copies of the well logs and he was able to get the core laid out for viewing just before being shut down for the Covid 19 pandemic. When he was allowed in to view the core, he sent me copies of his core logs, which answered some questions and raised others. I viewed the core with Bill last summer and at that time was informed that a Strawn Core Workshop was planned for late October, to coincide with the Geo-Gulf Conference. At the core work shop I learned much about the Strawn through the presentations of many researchers, including Lorena Moscardelli, Peter Flaig, Bill Ambrose, Kelly Hattori, Lucy Ko, Eric Radjef, and Qilong Fu among others. During the core review, I saw core from the Gunn #47 Burnett in King County, which looked nearly identical to the Shell core I had reviewed earlier with Bill. I also discovered that the BEG was in need of more Strawn oil samples to further their understanding of oil sources for the Strawn; samples which we could provide. This prompted Dr. Moscardelli to propose some further joint work.

Last week, I was invited to review the results of the data generated by the team assembled by Dr. Moscardelli to generate, evaluate and prepare the data from both the oil samples and from the thin sections prepared and analyzed from the Shell #1 Hoepfl core. Presentations by Lorena Moscardelli, Peter Flaig, Kelly Hattori, Lucy Ko and Tongwei Zhang developed a regional depositional model and an oil migration framework that has allowed me to greatly refine my own models for the area.

There is no way that I, or anyone on the Carr Resources, Inc. staff has the capability to develop the data that the team of researchers directed by Dr. Moscardelli had assembled

for our company. We have neither the staff and equipment to generate the data, nor do we have the institutional framework of knowledge within which to interpret the data. In addition, the discussion after the presentations provided a sounding board wherein we could all discuss the data and bounce ideas back and forth on applying the data into a more refined depositional model by adding the timing of glacio-eustatic cycles.

I strongly encourage the Bureau of Economic Geology to continue the current model of seeking partnerships with companies to research specific geologic problems. The individual companies acquire data and understanding that they could never self-generate while doing their primary function, which is to find, develop, and produce energy for the Great State of Texas, and the BEG adds to their already prodigious regional knowledge base which makes their insights even more useful for the following research collaborators.

I give my heart-felt thanks to Lorena, Bill, Kelly, Peter, Lucy and Tongwei for all of their work and look forward to many more opportunities to collaborate with them again. A year ago, they were just the authors of papers that I had read; I now am honored to know all of them as friends as well.

Very truly yours

Richard L. Adams

Carr Resources, Inc.

March 26, 2022

Dr. Lorena Moscardelli
Principal Investigator
STARR Program
Bureau of Economic Geology
The University of Texas at Austin

Dr. Moscardelli:

We have recently been the recipients of a research project prepared within the State of Texas Advanced Resource Recovery project [STARR] at the Texas Bureau of Economic Geology. Our project, located in the southern region of the Palo Duro Basin, was conducted and prepared by Eric Radjef, principal geoscience investigator. Eric`s fine work has allowed us to kick-start our exploration program in an under-developed area. Within the project deliverables were numerous exhibits [cross-sections, isopach, structure & trend maps], that reflect an assertive & comprehensive interpretation of a variety of data sources.

This regional study, which includes a narrative, provides us a supported understanding of our exploration targets & trend of interest. Further, it has been helpful to receive follow-on advice and we look forward to further counsel on the project.

We, the principals of a small operating company, are appreciative of the opportunity to be recipients of the STARR Program. As we develop our exploration project, it will be our hope to add to the oil reserves and tax & royalty income of the State of Texas.

Dan Earl Duggan
Principal
Fort Worth
817.565.6400

DX WELLS

FASKEN | OIL AND RANCH

6101 Holiday Hill Road
Midland, Texas 79707-1631
phone (432) 687-1777
fax (432) 687-0669

April 18th, 2022

To: Lorena Moscardelli, Ph.D.
Project Director STARR Program Bureau of Economic Geology
University of Texas at Austin
P. O. Box X - University Station
Austin, Texas 78713-8924

Dear Dr. Moscardelli,

I'm writing to acknowledge Fasken Oil and Ranch's gratitude to STARR, and in particular, to Dr's Ian Duncan and Frank Male for supporting our CO2 injection operations in the Hanford Field in the Central Basin Platform of the Permian Basin of West Texas. Over the past few decades our company has worked on this field and has been disappointed in the production level achieved through injecting CO2 into the ROZ. Dr. Duncan has provided insights and analysis that are greatly assisting our work on the field and our drive to increase oil production.

The STARR staff has provided input into our work that would have been difficult to get from any other source. The BEG adds their significant knowledge base (through its scientists and engineers) to the practical experience of operators like Fasken which provide.

We strongly encourage the State of Texas to continue the STARR Program. We expect that the return on investment will be high.

We look forward to our ongoing work with the Team.

Sincerely yours,

Stonnie Pollock
Exploration Manager
Fasken Oil & Ranch, Ltd.

Mayfield Energy, LLC

3406 Mulberry Creek Drive
Austin, TX 78732
Phone: (512) 632-1450
RRC Operating #: 535975

May 10th, 2022

Re: STARR PROGRAM

Mr. William Ambrose
Project Director, STARR Program
The University of Texas at Austin
Austin, TX 78713-8924

Dear Mr. Ambrose:

I would like to take a moment to personally thank you, and everyone involved in the State of Texas Advanced Resource Recovery (STARR) program at the Texas Bureau of Economic Geology, on behalf of our company, Mayfield Energy, LLC. We have been studying the possibility of developing a depleted Gulf Coast Frio sand for over 5 years, and with the data and help offered from STARR, we have finally made the assessment that this project is indeed viable.

By analyzing hundreds of logs and scout tickets from Aransas and San Patricio Counties that are housed at the Bureau, STARR was able to create professional structure maps of multiple sand zones, as well as correctly moved dozens of well locations that were incorrectly located on IHS. This was integral to the feasibility of our project, and it would not have been possible without the program's resources and dedication to helping small operators and companies like mine.

Again, many thanks. It has truly been an honor getting to know everyone, and working with the amazing staff on hopefully making this dream a reality!

Sincerely Yours,

Nathaniel Mayfield
President, Mayfield Energy, LLC

MURPHY
OIL CORPORATION

Edward C Cazier
Geological advisor

March 1, 2022

Lorena Moscardelli, Ph.D.
Project Director STARR Program
Bureau of Economic Geology - The University of Texas at Austin
P. O. Box X - University Station
Austin, Texas 78713-8924

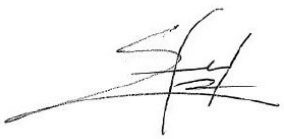
Dear Dr. Moscardelli,

I'm writing to acknowledge Murphy's gratitude to STARR, and in particular, to Mariana Olariu, Ph.D., for supporting and accelerating our work on Wilcox Group sedimentology and stratigraphy in south Texas. Over the past decade, Murphy's onshore Texas subsurface work has focused on unconventional reservoirs, such as the Eagle Ford Shale and Austin Chalk. As a result, our institutional knowledge on onshore conventional reservoirs, such as the Wilcox, has been neglected.

Murphy had a requirement recently to quickly perform an evaluation of the Wilcox Group. This evaluation included establishing a stratigraphic framework and identifying areas of thick sandstone deposition in a number of focus areas in South Texas. Since the Bureau of Economic Geology has performed many studies in these areas, and retains significant institutional knowledge of Texas reservoirs, Murphy was able to rapidly get up to speed on Wilcox sedimentology and stratigraphy. If we had needed to do this work on our own, it would have taken weeks longer and I'm convinced that the result would not have been as good.

I encourage the Bureau of Economic Geology to continue to maintain this institutional knowledge of Texas geology, for the benefit of all companies operating in this state. I thank Mariana Olariu for her rapid and professional collaboration with Murphy and appreciate your support of Mariana's work with us.

Very truly yours,



Edward C Cazier

9805 Katy Freeway, Suite G-200, Houston, Texas 77024
281.675.9000

Fort Worth Geological Society

PO Box 17075, Fort Worth, Texas 76102
genfwgssec@gmail.com

Lorena G. Moscardelli

April 12, 2022

Project Director
STARR Program
Bureau of Economic Geology
The University of Texas at Austin
P. O. Box X
University Station
Austin, Texas 78713-8924

Dear Dr. Moscardelli:

I would like to thank you and acknowledge the contributions made to the oil and gas community of Fort Worth and the entire Southwest Section of the American Association of Petroleum Geologists (SWSAAPG) through research carried out by the State of Texas Advanced Resource Recovery project (STARR) at the Texas Bureau of Economic Geology.

The technical expertise exhibited and presented by the Bureau has contributed to our understanding of several regions of importance to many of the local independent explorationists as well as several operators within our societies. Publications and presentations with clear depictions of reservoir quality and hydrocarbon accumulation trends in these key areas around Texas have been significant resources to our members. We hope that the STARR program will continue to receive funding from the State of Texas so that research of this nature can continue to enrich our understanding of these petroleum systems. Being in such a unique position to disseminate impartial studies is a critical part of scientific non-profit work and programs like the STARR help us achieve our goals each year.

The Bureau's studies, publications and presentations performed by your exemplary staff have provided an education and insight into many recent advances in petroleum exploitation that has been successfully applied by our members. The STARR program continues to help societies like ours relay quality science to our respective communities without hesitation.

Sincerely,

Trey Cortez
Fort Worth Geological Society President

BURNETT OIL CO., INC.
801 Cherry St. Unit 9, Fort Worth, Texas 76102
(817)332-5108

Lorena G. Moscardelli

April 12, 2022

Project Director
STARR Program
Bureau of Economic Geology
The University of Texas at Austin
P. O. Box X
University Station
Austin, Texas 78713-8924

Dear Dr. Moscardelli:

Burnett Oil Co. would like to thank and acknowledge your team for the work they have done to help us understand several target formations in King County, Texas by research carried out through the State of Texas Advanced Resource Recovery project (STARR) at the Texas Bureau of Economic Geology.

Detailed core descriptions with petrology reports and the full-day seminar held at your facilities have greatly added to our understanding of the depositional systems controlling Strawn lime and sandstone reservoirs within our area of interest. Geochemical research by the Bureau has contributed to our current hydrocarbon sourcing and distribution interpretation within this complex stacked petroleum system. Most recently, we have been pleasantly surprised with the steps your team has made using seismic inversion to identify Tannehill sand trends within our acreage. This diligent work being performed by your team on seismic conditioning and inversion is helping us understand the capabilities and limitations of our seismic dataset.

We hope to continue this great partnership in King County and will consider working with you on other assets as they come into our portfolio. As a small independent operator, we value programs like this that help expand our technical understanding of a play by partnerships with expert collaborators for the purpose of efficient exploration and development of mineral interests. We hope that the STARR program will continue to receive funding from the State of Texas.

Sincerely,

Rafael Zelaya
Vice President of Exploration

Burnett Plaza · Suite 1500
801 Cherry Street · Unit #9

Burnett Oil Co., Inc.

Fort Worth, TX 76102-6881
(817) 332-5108

P&F Operations, LLC

Lorena G. Moscardelli, Ph.D. November 5, 2022
Research Scientist and Principal Investigator
State of Texas Advanced Resource Recovery (STARR) Program
Bureau of Economic Geology, Jackson School of Geosciences
The University of Texas
P.O. Box X, University Station
Austin, Tx 78713-8924

Dear Ms. Moscardelli,

We have been supported by the STARR Program for several years in an Enhanced Oil Recovery Program in the Thrall field originally discovered in 1915 by my Grandfather Fritz Fuchs and initially studied by Dr. J.A. Udden in 1916. Dr. William A. Ambrose initially guided our involvement with STARR and assigned resources that provided a broad analysis of the Thrall Field.

We have donated three (3) sets of complete cores taken from the Thrall Field which have provided valuable information to both STARR and our efforts to understand this field. We would like to thank Dr. Ambrose for making this happen. The team has provided several workshops and meetings to discuss results that are extremely valuable in understanding the source of the oil, field structure, core log data and analysis, well log analysis, and field structure.

The information provided by STARR is enabling our efforts to continue to Enhance recovery of oil from this field and guide our Drilling Program. The understanding derived from this project is certainly applicable to restoring oil production from other Tuff and Serpentine mounds found in the area.

We want to thank the STARR team for their support. The research and expertise provided is of tremendous value and not readily available if the STARR Program did not exist. We look forward to continued interaction as this field is developed.

Sincerely,

Gary W. Pankonien
Chief Executive Officer
P&F Operations, LLC

OIL INFORMATION LIBRARY
OF WICHITA FALLS
100 ENERGY CENTER
710 LAMAR STREET
WICHITA FALLS, TEXAS 76301
940-322-4241 oil@wf.net

June 25, 2022

Dr. Lorena G. Moscardelli
Project Director
STARR Program
Bureau of Economic Geology
The University of Texas at Austin
P. O. Box X
University Station
Austin, Texas 78713-8924

Dear Dr. Moscardelli:

On behalf of the Board of Directors of the Oil Information Library of Wichita Falls, I would like to express our appreciation to you and especially to Dr. Peter Flaig along with his associates Kelly Hattori, and Dr. Lucy Ko for their presentation "Mixed Carbonate-Siliciclastic Reservoir Systems of the Strawn Group with a Focus on King and Stonewall Counties, Texas" at our seminar earlier this month. The research carried out by the State of Texas Advanced Resource Recovery project (STARR) at the Bureau of Economic Geology (BEG) on the Strawn formation of the Eastern Shelf is of tremendous value to our members, most of whom are independent geologists or independent operators exploring for and developing conventional prospects in the Strawn and other formations in central and north Texas.

The library and its members have always relied heavily on the publications and presentations of the BEG and we hope that the STARR program will continue to receive the funding necessary to provide these critical services to the oil and gas community. With so much focus on unconventional resources, research in the Strawn and other conventional reservoirs is of great interest to our members. We certainly hope the STARR program will continue to receive funding from the State of Texas to continue work such as that presented at the seminar.

Once again, thank you to you, Peter, Kelly, Lucy, and all the individuals working with the STARR program and the BEG.

Sincerely,

Jerry L. Hickman
Secretary/Treasurer, Oil Information Library of Wichita Falls

APPENDIX B: STARR PUBLICATIONS

One of the main goals of the STARR project is to disseminate results and new concepts developed by the program. During current reporting biennium (September 1, 2020 to August 31, 2022), STARR researchers generated 34 peer reviewed publications, including two Bureau Reports of Investigation.

1. Acevedo, J. P., Lemons, C. R., Young, M. H., McDaid, G., and Scanlon, B. R., 2022, Analysis of wastewater injection and prospect regions for induced seismicity in the Texas panhandle, United States: AAPG Bulletin, v. 106, no. 4, p. 679–699.

2. Ambrose, W. A., Flaig, P., Zhang, J., Olariu, M. I., Denison, C., Demchuk, T., and O'Keefe, J., 2020, The Midway to Carrizo succession in the southeastern Texas Gulf Coast: evolution of a tidally influenced coastline: GCAGS Journal, v. 9, p. 41–75

3. Ambrose, W. A., Tucker, F. H. and Smith, D. C., 2022, Facies variability and geological controls on reservoir heterogeneity in deepwater slope reservoirs in the Pennsylvanian Cisco Group, Lake Trammel South field, Nolan County, Texas: The University of Texas at Austin, Bureau of Economic Geology, Report of Investigations, v. 288, 35 p.

4. Duffy, O. B., Moscardelli, L., Hudec, M., Dooley, T., Peel, F., Apps, G., Shuster, M., and Looff, K., 2022, Potential controls on the origin, nature and distribution of shear zones in salt stocks: salt tectonic insights with a solution mining perspective: Solution Mining Research Institute Spring 2022 Technical Conference, 26 p.

5. Eastwood, R. L., and Smye, K. M., 2022, Effects of overpressure on mechanical properties of unconventional shale reservoirs through novel use of a sonic overpressure indicator: SPE Reservoir Evaluation & Engineering, v. 25, no. 1, p. 52–60.

6. Fu, Q., and Ambrose, W. A., 2020, Lithofacies and diagenetic features of Strawn carbonates in the subsurface of north-central Texas: implications for controls on reservoir quality: GCAGS Journal, v. 9, p. 115–132

7. Fu, Q., Peng, J. and Janson, X., 2022, Reply to comment on "Dynamic climatic changes during the late Pennsylvanian icehouse: new insight from high-resolution geochemical records in the Cline Shale, North America" by Peng, Fu and Janson: Gondwana Research, 109, p.166–167.

8. Hattori, K. E., and Loucks, R. G., 2021, Cyclicity of carbonate shoaling sequences of the Lower Cretaceous Pettet Formation, Rusk County, East Texas: GCAGS Journal, v. 10, p. 31–46.

9. Liu, L., Ambrose, W. A., Lawton, T. F., and Stockli, D. F., 2021, Tectonic controls on the evolution of mixed carbonate-siliciclastic systems: insights from the late Palaeozoic Ouachita-Marathon foreland, United States: Basin Research, v. 33, no. 4, p. 2281–2302.

10. Loucks, R. G., Lambert, J. R., Patty, K., Larson, T. E., Reed, R. M., and Zahm, C. K., 2020, Regional overview and significance of the mineralogy of the Upper Cretaceous Austin Chalk Group, onshore Gulf of Mexico: GCAGS Journal, v. 9, p. 1–16.

11. Loucks, R. G., Larson, T. E., Zheng, C. Y. C., Zahm, C. K., Ko, L. T., Sivil, J. E., Peng, S., Ruppel, S. C., and Ambrose, W. A., 2020, Geologic characterization of the type cored section for the Upper Cretaceous Austin Chalk Group in southern Texas: a combination fractured and unconventional reservoir: AAPG Bulletin, v. 104, no. 10, p. 2209–2245.

12. Loucks, R. G., and Peng, S., 2021, Matrix reservoir quality of the Upper Cretaceous Austin Chalk Group and evaluation of reservoir-quality analysis methods; northern onshore Gulf of Mexico, U.S.A.: Marine and Petroleum Geology, v. 134, no. 105323, 11 p.

13. Loucks, R. G., and Reed, R. M., 2022, Implications for carbonate mass-wasting complexes induced by volcanism from Upper Cretaceous Austin Chalk strata in the Maverick Basin and San Marcos Arch areas of south-central Texas, USA: Sedimentary Geology, v. 432, article no. 106120, 18 p.

14. Loucks, R. G., Reed, R. M., Ko, L. T., Zahm, C. K., and Larson, T. E., 2021, Micropetrographic characterization of a siliciclastic-rich chalk; Upper Cretaceous Austin Chalk Group along the onshore northern Gulf of Mexico, USA: Sedimentary Geology, v. 412, no. 105821, 19 p.

15. Loucks, R. G., Zahm, C. K., Larson, T. E., Zahm, L. C., and Peng, S. [erroneously credited as "Peng Zeng"], 2021, Stratal architecture, lithofacies, environmental setting, depositional processes, and associated geological characteristics of the Upper Cretaceous Austin Chalk in Louisiana: GCAGS Journal, v. 10, p. 47–75.

16. Male, F., and Jensen, J. L., 2022, Three common statistical missteps we make in reservoir characterization: AAPG Bulletin, v. 106, no. 11, p. 2149–2161.

17. Male, F., Jensen, J. L., and Lake, L. W., 2020, Comparison of permeability predictions on cemented sandstones with physics-based and machine learning approaches: Journal of Natural Gas Science and Engineering, v. 77, no. 103244, 12 p.

18. Nicot, J.-P., Darvari, R., Eichhubl, P., Scanlon, B. R., Elliott, B. A., Bryndzia, T. L., Gale, J. F. W., and Fall, A., 2020, Origin of low salinity, high volume produced waters in the Wolfcamp Shale (Permian), Delaware Basin, USA: Applied Geochemistry, v. 122, no. 104771, 18 p.

19. Nicot, J.-P., Smyth, R. C., Darvari, R., and McKinney, S. T., 2022, New hydrogeochemical insights on a West Texas desert spring cluster: Trans-Pecos Balmorhea-area springs: Applied Geochemistry, v. 142, no. 105331, 14 p.

20. Ogiesoba, O. C., and Ambrose, W. A., 2021, A systematic approach to identifying hydrocarbon sweet spots using integrated seismic multiattribute, wireline-log, and core analyses: case study from the Upper Cretaceous Taylor Serbin field, southeast Texas: The University of Texas at Austin, Bureau of Economic Geology, Report of Investigations, v. 287, 76 p.

21. Ogiesoba, O. C., and Zeng, H., 2022, Identification of sandstone-rich zones in upper bathyal, deep water environment on south Texas Gulf Coast: Interpretation, v. 10, no. 2, p. T265–T278.

22. Peng, J., 2021, Sedimentology of the Upper Pennsylvanian organic- rich Cline Shale, Midland Basin: from gravity flows to pelagic suspension fallout: Sedimentology, v. 68, no. 2, p. 805–833.

23. Peng, J., Fu, Q., and Janson, X., 2022, Dynamic climatic changes during the Late Pennsylvanian icehouse: new insight from high-resolution geochemical records in the Cline Shale, North America: Gondwana Research, v. 106, p. 247–258.

24. Peng, J., Fu, Q., Larson, T. E. and Janson, X., 2021, Trace-elemental and petrographic constraints on the severity of hydrographic restriction in the silled Midland Basin during the late Paleozoic ice age: GSA Bulletin, v. 133, no. 1-2, p. 57–73.

25. Peng, J., and Larson, T. E., 2022, A novel integrated approach for chemofacies characterization of organic-rich mudrocks: AAPG Bulletin, v. 106, no. 2, p. 437–460.

26. Peng, J., Milliken, K. L., and Fu, Q., 2020, Quartz types in the Upper Pennsylvanian organic-rich Cline Shale (Wolfcamp D), Midland Basin, Texas: implications for silica diagenesis, porosity evolution and rock mechanical properties: Sedimentology, v. 67, no. 4, p. 2040–2064.

27. Peng, J., Milliken, K., Fu, Q., Janson, X., and Hamlin, H. S., 2020, Grain assemblages and diagenesis in organic-rich mudrocks, Upper Pennsylvanian Cline shale (Wolfcamp D), Midland Basin, Texas: AAPG Bulletin, v. 104, no. 7, p. 1593–1624.

28. Peng, S., 2020, Gas-water relative permeability of unconventional reservoir rocks: hysteresis and influence on production after shut-in: Journal of Natural Gas Science and Engineering, v. 82, no. 103511, 11 p.

29. Peng, S., 2021, Advanced understanding of gas flow and the Klinkenberg effect in nanoporous rocks: Journal of Petroleum Science and Engineering, v. 206, no. 109047, 14 p.

30. Peng, S., Shevchenko, P., Periwal, P., and Reed, R. M., 2021, Water-oil displacement in shale: new insights from a comparative study integrating imbibition tests and multiscale imaging: Society of Petroleum Engineers Journal, v. 26, no. 5, paper no. SPE-205515-PA, p. 3285–3299.

31. Reed, R. M., Loucks, R. G., and Ko, L. T., 2020, Scanning electron microscope petrographic differentiation among different types of pores associated with organic matter in mudrocks: GCAGS Journal, v. 9, p. 17–27.

32. Reedy, R. C., and B. R. Scanlon, 2022, Water use by the mining industry of Texas, The University of Texas at Austin, Bureau of Economic Geology, final report prepared for the Texas Water Development Board under contract no. 2100012474, 78 p.

33. Ren, B., and Duncan, I. J., 2021, Maximizing oil production from water alternating gas (CO2) injection into residual oil zones: the impact of oil saturation and heterogeneity: Energy, v. 222, no. 119915, 13 p.

34. Ren B, Jensen J. L., Lake L. W., Duncan, I. J., and Male, F., 2022, Analysis of vertical permeability and its influence on CO2 enhanced oil recovery and storage in a carbonate reservoir: Society of Petroleum Engineers Reservoir Evaluation & Engineering, v. 25, no. 3, p. 414–432.

35. Ren, B., Male, F., Duncan, I. J., 2022, Economic analysis of CCUS: accelerated development for CO2 EOR and storage in residual oil zones under the context of 45Q tax credit: Applied Energy, v. 321, no. 119393, 11 p.

36. Roberts, A. K., Ambrose, W. A., Flaig, P. P., Steel, R. J., and Olariu, C., 2022, Controls on facies variability and distribution during the Pennsylvanian glacial period from the lower Strawn Group, Fort Worth basin, Texas: AAPG Bulletin, v. 106, no. 8, p. 1679–1702.

37. Scanlon, B. R., Reedy, R. C., and Wolaver, B. D., 2022, Assessing cumulative water impacts from shale oil and gas production: Permian Basin case study: Science of The Total Environment, v. 811, no. 152306, 11 p.

38. Shuster, M. W., Zahm, C. K., and Hennings, P. H., 2021, Oil and gas in fractured crystalline igneous and metamorphic rocks: global overview and examples from Texas, in Callahan, O. A., and Eichhubl, P., eds., The geologic basement of Texas: a volume in honor of Peter T. Flawn: Austin, Tex., The University of Texas at Austin, Bureau of Economic Geology, Report of Investigations, v. 286, 68 p.

39. Soto-Kerans, P., Loucks, R. G., and Kerans, C., 2021, Deeper-water deposition in intrashelf basins: example from the Lower Cretaceous (Albian) upper Glen Rose Formation in the Houston trough, eastern Texas: AAPG Bulletin, v. 105, no. 7, p. 1405–1434.

40. Zeng, H., He, Y., and Zeng, L., 2021, Impact of sedimentary facies on machine learning of acoustic impedance from seismic data: lessons from a geologically realistic 3D model: Interpretation, v. 9, no. 3, p. 1009–1024.

41. Zhang, J., Sylvester, Z., and Covault, J., 2020, How do basin margins record long-term tectonic and climatic changes?: Geology, v. 48, no. 9, p. 893–897.

APPENDIX C: STARR PRESENTATIONS

One of the main goals of the STARR program is to disseminate results and new concepts in oil and gas research. During current reporting biennium (September 1, 2020 to August 31, 2022), STARR researchers gave a variety of presentations to oil and gas operators, as well as to the broader energy industry within the State of Texas; this is a vital outreach activity impacting new oil and gas production in Texas, as well as the development of new energy sources.

1. Ambrose, W., and Hentz, T. F., Geologic controls on stratal architecture and regional sediment distribution in the Cisco Group, Eastern Shelf of the Permian Basin: presented at Geological Society of America South-Central Section, Fort Worth, Texas, March 9–10, 2020.

2. Ambrose, W., and Hentz, T. F., Unresolved issues in integrating Pennsylvanian stratigraphy, depositional systems, and tectonics in the Eastern Shelf of the Permian Basin: presented at Geological Society of America South-Central Section, Fort Worth, Texas, March 9–10, 2020.

3. Dommisse, R., Advanced structural and stratigraphic modeling techniques in shale and tight oil basin reservoir studies: presented to GeoGulf 2021, Austin, Texas, October 29, 2021.

4. Dommisse, R., Geomodeling and Data Analytics: presented to URTeC 2022 Conference, Houston, Texas, June 20, 2022.

5. Dommisse, R., Duncan, I., and Ren, B., Geology and reservoir properties of the residual oil zone (ROZ) of the San Andres Seminole unit, West Texas: presented to AAPG, presented at SWS AAPG Conference, Houston, Texas, June 23, 2021.

6. Duffy, O., Moscardelli, L., Hudec, M., Dooley, T., Peel, F., Apps, G., and Shuster, M., Potential controls on the origin, nature, and distribution of shear zones in salt stocks: salt tectonic insights with a solution mining perspective: presented at Solution Mining Research Institute Spring 2022 Technical Conference, Rapid City, South Dakota, May 4–5, 2022

7. Duffy, O., Moscardelli, L., Rogers, H., Lin, N., Ren, B., Hudec, M., and Shuster, M., H2 storage potential in Texas salt: early insights: presented to GeoGul2021, Austin, Texas, October 28, 2021.

8. Duncan, I., Analysis of vertical permeability and its influence on CO2 EOR and storage in a carbonate reservoir: presented at 2021 Society of Petroleum Engineers Annual Technical Conference and Exhibition (ATCE), Dubai, United Arab Emirates, September 21–23, 2021 (online).

9. Duncan, I., Fracking and refracking: presented to the 2022 East Texas Geological Society Prospect and Tech Expo, Tyler, Texas, March 29, 2022.

10. Flaig, P., Examples of depositional systems of the Strawn Group in the Fort Worth Basin and Eastern Shelf of the Permian Basin: presented to the 2022 East Texas Geological Society Prospect and Tech Expo, Tyler, Texas, March 29, 2022 (online).

11. Flaig, P., Ambrose, W., and Hasiotis, S., The relationship of coastal-shelfal tidal clastic systems to ramp carbonates in the upper Strawn revealed from core and wireline logs in Stonewall and King counties, Permian Basin, Texas: presented at Geological Society of America South-Central Section, Fort Worth, Texas, March 9–10.

12. Fu, Q., and Ambrose, W., Lithofacies and diagenetic features of Strawn carbonates and Tannehill siliciclastics in King county, Texas: implications for reservoir quality: presented at Geological Society of America South-Central Section, Fort Worth, Texas, March 9–10.

13. Hattori, K., Halokinetic influence on carbonate depositional environments: an example from the Fairway Field, East Texas Basin: presented to the Austin Geological Society, October 5, 2020.

14. Hattori, K., A new sequence stratigraphic framework for the Early Cretaceous Pettet Formation of East Texas and investigation of controls on facies deposition: presented to the East Texas Geological Society, November 18, 2020.

15. Hattori, K., Facies and sequence stratigraphy of the Early Cretaceous Pettet Formation, Rusk County, East Texas: presented to the 2021 AAPG Southwest Section and Fort Worth Geological Society, Fort Worth, Texas, June 29, 2021.

16. Hattori, K., Paleoecology of a mid-Cretaceous patch reef: fossil assemblages yield evidence of environmental change through time: presented at GSA Connects 2021, October 12, 2021.

17. Hattori, K., and Loucks, R., Regional and local controls on ooid shoal development in the Lower Cretaceous Pettet Formation, East Texas, USA, and effect on reservoir distribution: presented at AAPG IMAGE 2021, September 28, 2021.

18. Hattori, K., and Loucks, R., Cyclicity of carbonate shoaling sequences of the Lower Cretaceous Pettet Formation, Rusk County, East Texas: presented at GeoGulf 2021, October 29, 2021.

19. Hattori, K., and Loucks, R., Evaluating the overprint of local-scale controls on eustatically-driven sequence stratigraphic frameworks: an example from the Early Cretaceous Pettet Formation, East Texas, USA: presented at Mountjoy Carbonate Research Conference III, August 18, 2022.

20. Karakaya, S., Ogiesoba, O., and Olariu, C., Lateral lithology heterogeneity due to autogenic processes in mixed carbonate and siliciclastic deposits of Cisco Group, the Eastern Shelf of the Permian Basin, King County, north-central Texas, poster presentation: presented at IMAGE 2022, Houston, Texas, August 30, 2022.

21. Karakaya, S., Ogiesoba, O., and Olariu, C., Seismic expressions of lower Wolfcampian Tannehill Channel Systems in King County on the Eastern Shelf of the Midland Basin, Texas, oral presentation: presented at IMAGE 2021, Denver, Colorado, September 29, 2021.

22. Loucks, R. G., and Reed, R. M., 2021, Gravity-flow deposits in the Upper Cretaceous Austin Chalk B unit in South and Central Texas and their relationship to contemporaneous volcanism: presented to GeoGulf, Austin, Texas, October 28, 2021.

23. Male, F., Rysak, B., and Dommisse, R., Statistical analysis of fractures from the Hydraulic Fracture Test Site 1: presented to the SPE/AAPG/SEG Unconventional Resources Technology Conference, Houston, Texas, USA, July 2021.

24. Male, F., and Zahm, C., Regional productivity in the Austin Chalk with emphasis on fault zone production in the Karnes Trough area: presented to GeoGulf 2021, Austin, Texas, October 29, 2021.

25. Moscardelli, L., State of Texas Advanced Resource Recovery (STARR) program and its role supporting knowledge sharing and creation in the Permian Basin, Eastern Shelf and Fort Worth Basin: presented to the 2021 AAPG Southwest Section and Fort Worth Geological Society, Fort Worth, Texas, June 29, 2021.

26. Moscardelli, L., State of Texas Advanced Resource Recovery Program–overview and future directions: presented to the 2022 East Texas Geological Society Prospect and Tech Expo, Tyler, Texas, March 29, 2022 (online).

27. Moscardelli, L., Energy and the energy transition: presented to GeoFORCE 12th Grade Academy, Austin, Texas, August 18, 2022.

28. Moscardelli, L., Mora, C., and Kahn, A., Creating a stronger workforce through diversity, equity, and inclusion (DE&I): panel discussion at GeoGulf 2021, Austin, Texas, October 28, 2021.

29. Mosser, L., Ghon, G., and Baechle, G., Interpretation of deep neural networks for carbonate thin section classification: presented to Second International Meeting for Applied Geoscience & Energy, Aug 29, 2022.

30. Ogiesoba, O., Simultaneous seismic inversion study of the northern part of the eastern shelf, King County, Central Texas: presented to the 2021 AAPG Southwest Section and Fort Worth Geological Society, Fort Worth, Texas, June 29, 2021.

31. Ogiesoba, O., A Systematic approach to identifying hydrocarbon sweet spots using integrated seismic multiattributes, wireline-log, and core analysis: case study from the Upper Cretaceous Taylor Serbin field, southeast Texas: presented to Austin Geological Society, presented at Austin, Bureau of Economic Geology, The University of Texas at Austin, April 4, 2022.

32. Palacios, F., An updated Eastern Shelf-Midland Basin stratigraphic framework across the southern Greater Permian Basin: implications for the distribution of Virgilian and Wolfcampian reservoirs: presented to the 2021 AAPG Southwest Section and Fort Worth Geological Society, Fort Worth, Texas, June 29, 2021.

33. Peng, J., Quartz types in the Upper Pennsylvanian organic-rich Cline Shale (Wolfcamp D), Midland Basin, Texas: presented to the 2021 AAPG Southwest Section and Fort Worth Geological Society, Fort Worth, Texas, June 29, 2021.

34. Peng, S., Gas-water relative permeability of unconventional reservoir rocks: hysteresis and influence on production after shut-in: presented at URTeC 2020 (virtual).

35. Peng, S., Shevchenko, P., Periwal, P., and others, Water-oil displacement in shale: new insights from a comparative study integrating imbibition tests and multiscale imaging: presented at URTeC 2021 (virtual).

36. Reed, R., Variability of quartz types in the Upper Mississippian Barnett shale, Fort Worth Basin, Wise County, Texas: implications for rock brittleness: presented to the 2021 AAPG Southwest Section and Fort Worth Geological Society, Fort Worth, Texas, June 29, 2021.

37. Reed, R. M., and Loucks, R. G., Complex roles for calcite in organic-rich mudrocks: using micropetrography to understand grains, fossils, and cements: presented to the 2021 International Meeting for Applied Geoscience & Energy, Denver, Colorado, September 29, 2021.

38. Reed, R. M., and Loucks, R. G., Complex roles for calcite in organic-rich mudrocks: using micropetrography to understand grains, fossils, and cements: presented to the 2021 Geological Society of America Annual Meeting, Portland, Oregon, October 12, 2021.

39. Reed, R. M., Loucks, R. G., and Ko, T. L., Differentiation among different types of pores associated with organic matter in mudrocks using scanning electron microscope petrography: presented to the 2022 Geological Society of America Annual Meeting, October 29, 2022 (online).

40. Reed, R. M., Loucks, R. G., and Periwal, P., Preliminary results of micropetrographic investigations of enigmatic volcanic ash material in the Upper Cretaceous Austin Chalk of Central and South Texas: presented to GeoGulf 2021, Austin, Texas, October 28, 2021.

41. Roberts, A., Controls on facies variability and distribution during the Pennsylvanian glacial period from the lower Strawn Group, Fort Worth Basin, Texas: presented to the 2021 AAPG Southwest Section and Fort Worth Geological Society, Fort Worth, Texas, June 29, 2021.

42. Ruiz Maraggi, L.M. and Moscardelli, L., Modeling hydrogen storage capacities, injection and withdrawal cycles in salt caverns using the GeoH2 salt storage and cycling app: presented to American Association of Petroleum Geologists Hydrogen 2022 Virtual Technical Symposium, December 2, 2022 (online).

43. Savvaidis, A., Lomax, A., and Dommisse, R., Induced seismicity hypocentral depth stability and sensitivity to Vp/Vs in the south Delaware Basin, West Texas: presented to AAPG/SEG IMAGE Conference, Houston, Texas, August 2022.

44. Scanlon, B. R., Produced water as water supply: presented to the 2020 Virtual Texas Groundwater Summit, September 1, 2020.

45. Scanlon, B. R., Assessing impacts of water management related to oil and gas development on water resources: presented to Austin Geological Society, Austin, Texas, January 12, 2021.

46. Scanlon, B. R., Mining water use: presented to Texas Alliance of Groundwater Districts, Austin, Texas, January 26, 2021.

47. Scanlon, B. R., Management of produced water in the Permian Basin: presented to Texas Commission on Environmental Quality, Austin, Texas, February 23, 2021.

48. Scanlon, B. R., Produced water update: presented to Texas Desalination Association, September 15, 2021.

49. Scanlon, B. R., Past and projected produced water volumes in the Permian Basin and related management options: presented to Texas Commission on Environmental Quality, Austin, Texas, May 11, 2022.

50. Scanlon, B. R., Past and projected produced water volumes in the Permian Basin and related management options: presented to North American Onshore Oil and Gas Industry, Houston, Texas, September 27, 2022.

51. Scanlon, B. R., Water issues related to oil and gas production in the Permian Basin: presented to ExxonMobil Master Class, Houston, Texas, November 8, 2022.

52. Schuba, N., Moscardelli, L., Lawton, T., and Gray, G., Significance of paleogeography for cavern development in bedded salts: a case study from New Mexico and West Texas: presented to American Association of Petroleum Geologists Hydrogen 2022 Virtual Technical Symposium, December 2, 2022 (online).

53. Zhang, J., Lithofacies segmentation in cores of Wilcox Group (Gulf of Mexico) and Spraberry Formation (Permian Basin) using U-net based convolutional neural networks: presented to the 2021 AAPG Southwest Section and Fort Worth Geological Society, Fort Worth, Texas, June 29, 2021.

APPENDIX D: STARR WORKSHOPS AND GUIDEBOOKS

STARR researchers have prepared and delivered the following thematic workshops and guidebooks to oil and gas operators during the current reporting biennium (September 1, 2020 to August 31, 2022).

1. Denison, C., and Flaig, P., 2021, Paleocene-Eocene stratigraphy and paleontology of Central Texas: Wilcox Group and Claiborne Group: Bureau of Economic Geology, Jackson School of Geosciences, Field Guide, 27 p.

2. Flaig, P., Hattori, K., Ambrose, W., Fu, Q., Dejarnett, B., Ko, L., Radjef, E., Carr, D., Hasiotis, S., Ogiesoba, C., and Moscardelli, L., 2021, Mixed carbonate-siliciclastic reservoir systems of the Strawn Group: focus–upper Strawn, King and Stonewell Counties, Texas: Bureau of Economic Geology, Jackson School of Geosciences, Core Workshop Guidebook, 94 p.

3. Kerans, C., Hunt, B. B., and Hattori, K. E., 2021, Stratigraphic framework and hydrogeology of the Trinity Aquifer/Cow Creek Formation and tie to Oceanic Anoxic Event 1A, Central Texas: Bureau of Economic Geology and the Gulf Coast Association of Geological Societies and Gulf Coast Section of SEPM, Field Trip Guidebook, 35 p.

4. Fu, Q., Gale, J., Ko, L. T., Loucks, R. G., Moscardelli, L., Reed, R. M., Dommisse, R., Milliken, K., and Rowe, H., 2021, STARR Barnett workshop for BKV: Bureau of Economic Geology, Jackson School of Geosciences, Core Workshop Guidebook.