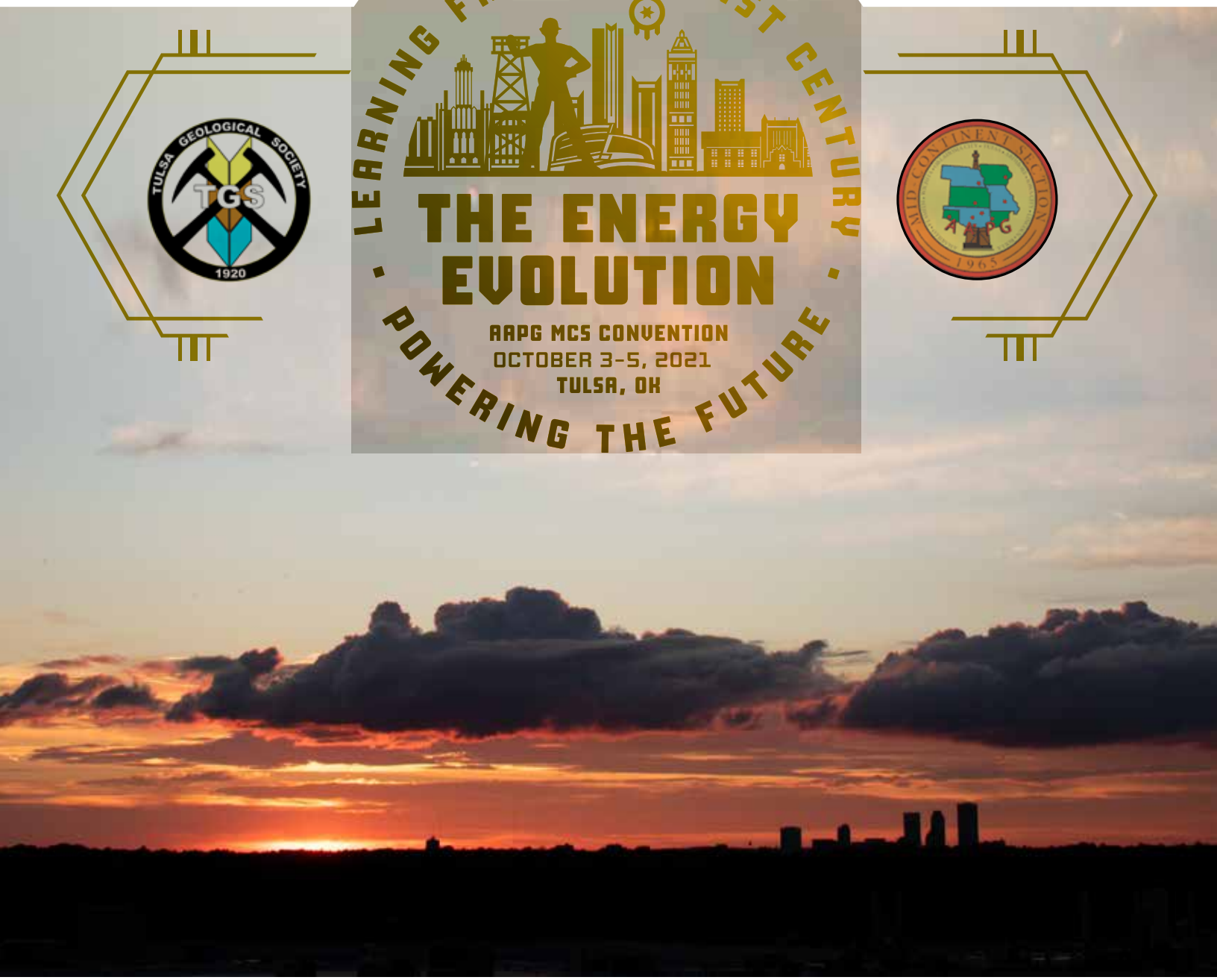
HOSTED BY TULSA GEOLOGICAL SOCIETY

MID-CONTINENT SECTION OF AAPG

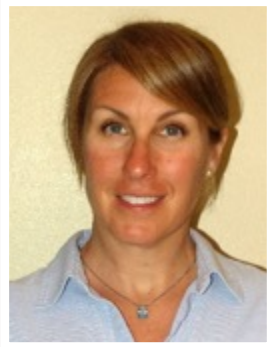


2021 AAPG MID-CONTINENT SECTION CONVENTION

OFFICIAL PROGRAM

TULSA, OKLAHOMA | OCTOBER 3-5, 2021 | HYATT REGENCY DOWNTOWN

Chairman's Welcome



On behalf of the Mid-Continent Section of the AAPG and the Tulsa Geological Society, it is my pleasure to welcome you to the 2021 Mid-Continent Section Convention, "The Energy Evolution- Learning from the Past, Powering the Future", October 3-5th, 2021, at the Hyatt Regency Downtown in Tulsa, Oklahoma. As the Mid-Continent oil and gas industry begins to rebound from an endless past couple of years of challenges, this convention is a chance to reconnect with our friends and colleagues, shake some of the dust off, and embrace new ideas.

The heart of any convention revolves around the technical program, and our geological community has stepped up and knocked it out of the park. We have a diverse array of oral presentations, special sessions, panel discussions, field trips, and short courses planned. The technical program offers us an opportunity for the exchange of new ideas that all of us have craved during the last year. Per the theme of this year's convention, our technical program will focus on learning from the past - better understanding our complex reservoirs and petroleum systems- and integrating this knowledge with the latest technologies to focus on making money in the future. We will also extend our rich knowledge base from the petroleum industry to carbon capture and storage and to other energy sources to power a sustainable future.

Geologists love to interact, and we have many networking opportunities for you to take advantage of, including the Sunday evening ice-breaker, the Monday mini-ice breaker, the Monday All-Convention Luncheon, and the Tuesday DPA Luncheon. We also have networking events planned that highlight Tulsa's rejuvenated downtown, including a brewpub tour of the Pearl District Saturday evening, the post ice-breaker "Rocktoberfest" at Fassler Hall, and an outdoor dinner and a movie Monday evening at Guthrie Green, an urban green space in Tulsa's Brady Arts District.

The exhibit hall will be full of companies showing off the latest technologies and their newest ideas. We invite you to visit the exhibit hall and spend time with the vendors and exhibitors.

What a challenging and interesting past two years we have had! I wish to extend a huge thank you to the Convention Committee, who have done an outstanding job in less-than-ideal circumstances, meeting remotely for much of the planning phases for this convention, and hoping it would be possible to hold as an in-person meeting. Their dedication and many hours of hard work over the last two years have made it possible for this convention to take place. Please thank them if you see them around.

We also welcome you to Tulsa, with its long and storied past as the historical "Oil Capitol of the World"! We are excited to have you join us to learn, share ideas and create new opportunities, see old friends, and meet new ones. It is through sharing of ideas and perhaps challenging a few, that we can apply geoscience to provide power to a world starved for adequate energy. We look forward to seeing you, growing our knowledge base together, and having fun!

Best Regards,

Tara L Benda

General Chair

Sponsors

Gratitude. No word better describes our feelings as we concluded the sponsorship drive for the 2021 AAPG Mid-Continent Section Convention. We all recognize the difficult times we are facing in the oil patch. Yet many companies and individuals have found a way to keep supporting regional technical meetings like this one. So please join with us in expressing a heartfelt thank you to each and every sponsor. At a minimum, stop by each booth, or speak directly to an individual or company representative, and let them know how much you appreciate their support. And if your company can use the services of our sponsors, please give them a chance to earn your business!

Centennial

OSAGE Minerals Council

Lithium

AHS
Advanced Hydrocarbon Stratigraphy
AdvancedHydrocarbon.Com

Gold

Gable Gotwals Counsel

JEV Jericho Energy Ventures

Sage Natural Resources

Geoscience Foundation of Tulsa

Laredo Petroleum, Inc.

Silver

Selman and Associates, Ltd

Impac Exploration Services

Marjo Operating Mid-Continent, LLC.

Casillas Petroleum Corp

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Primary Fuels

Wind River Resources

Wireline Logging Solutions

Equus Energy Partners, LLC

LAWCO Technology Driven

GypsyGlenn Oil Company

Ceja Corporation

Ron and Cheryl Snyder

Continental Resources

Copper

Bluejacket Energy

PQ GeoConsulting

Table of Contents

President's Welcome

Greetings! It is a pleasure to welcome you to Tulsa!

It is a pleasure for The Tulsa Geological Society to again host the Midcontinent Section Meeting of the American Association of Petroleum Geologists.

Founded in 1920, three years after the founding of the AAPG, The TGS is celebrating its 101st year as a technical society. Centennials offer a unique opportunity to reflect on events that truly shaped the world in which we are living today. It is important to look at our origin story as an industry and reflect on the events we, as a collective body of scientists, have been witness to. Centennials also provide an opportunity to contemplate how the future may be shaped.

In 1920, The TGS was founded at a time when demand for oil was increasing, and price was surging. With the industry wide acceptance of the anticlinal theory of hydrocarbon accumulation, survey teams of geologists were deployed out across the Midcontinent prairies and hills. It was the 1920 discovery of the Giant Burbank Field that secured The Osage as the center of the Midcontinent oil business. Tulsa, known to many as The Magic Empire, was established as a wealthy powerhouse in exploration, refining, and banking, with the latter two sustaining the region through the busts.

As the City of Tulsa and its iconic skyline on the prairie grew, so too did the role of the Petroleum Geologists whose discovery thinking allowed the energy industry to move from the prairies to the gulf waters and the wilds afar.

Along with the stories of wealth and success are events that have cast long shadows. This May the City of Tulsa recognized the centennial of the Tulsa Race Massacre, a horrific event that laid ruin to America's Black Wall Street. Today you can walk through Greenwood and see firsthand the thriving business community taking shape. In the sidewalk you can see the bronze plates which honor the businesses that were burned, many of which were never rebuilt.

One hundred years ago, just to Tulsa's northwest, on the Osage Reservation, the 2,229 Osage Allottees began to receive royalty checks of, still today, staggering size from their collective interests in the vast Osage Mineral Estate. With this wealth came a dark time captured very well in the best seller Killers of the Flower Moon.

As our Centennial Sponsors, The Osage Minerals Council represents the Osage Shareholders, descendants of the 2,229 original allottees. We are honored to have the Osage Minerals Council as our Centennial sponsor and support their efforts on the next opening of the mineral resources of The Osage.

As you take in our beautiful downtown, please take time to tour Greenwood. It is a powerful experience that will stay with you. If your schedule allows, register for the Pre-Convention Osage Nation Field Trip with Osage Geologist Bill Lynn. It will most certainly be a memorable experience.

We study the past to understand the present. And by recognizing the past, in full color, we can shape a better future. As Earth energy scientists we have a lot of work ahead and a growing human population depends upon our optimism, ideas, and success. Let's get to it!

Thank you for joining us. We hope you have a fantastic meeting.

Cerca Trova!

Shane Matson
President, The Tulsa Geological Society

Convention Committee

Amy Close
Laredo Petroleum
Technical Program Co-Chair

Tim Phillips
Devon Energy
Technical Program Co-Chair

Johannes Douma
Nadel and Gussman Ventures
Technical Program GST Co-Chair

Daniel Woody
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Oral Sessions CoChair

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Oral Sessions Co-Chair

Sarah Darby
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Website Chair

Ron Haveman
Jericho Energy Ventures
Volunteer Chair

Ellie Roper
Guest/Spouse Hospitality

Ryan Dupree
Alumni Chair

Meeting at a Glance

FRIDAY, OCTOBER 1

Mountain Bike Geo-Tour Bentonville, Arkansas Field Trip (Friday-Sunday)

SATURDAY, OCTOBER 2

Exhibit Contractor Move-In, Tulsa Ballroom	7AM-5PM
Pennsylvanian Deltaics, Skiatook Lake Field Trip	8AM-6PM
Data Analysis/Machine Learning Short Course, Promenade B	8AM-5PM
QGIS for Geoscience Professionals Short Course, Promenade A	8AM-Noon
Registration Open, Ground Floor Foyer	3-6PM
Pearl District Brewery Tour	7PM

SUNDAY, OCTOBER 3

Redbud/Catoosa Penn Road Cut Field Trip	7AM-3PM
Registration Open, Ground Floor Foyer	8AM-6PM
Fundamentals of Carbon Capture, Utilization, and Storage Short Course, Promenade C	8AM-4PM
Geochemistry Short Course, Diplomat Room	8AM-4:30PM
Exhibit Contractor Move-In, Tulsa Ballroom	8AM-4:30PM
Speakers'/Poster Presenters'/Judges' Room Open	1-5PM
Guest/Spouse Hospitality Suite Open	3-5PM
Opening Session/Awards Ceremony	4:30-6PM
Opening Icebreaker in Exhibit Hall	5:30-8PM
Post Icebreaker "Rocktoberfest" at Fassler Hall	7:30-10PM

Meeting at a Glance

MONDAY, OCTOBER 4

Speakers/Poster Presenters Breakfast, Promenade D	7-7:45AM
Judges Breakfast (Monday Session judges), Directors 3	7-7:45AM
Speakers/ Poster Presenters/Judges Room Open, Executive Room	7AM-5PM
Registration Open, Ground Floor Foyer	7AM-6:30PM
Guest/Spouse Hospitality Suite Open, Studio 315	7:30-9:30AM
Exhibit Hall Open	8AM-6PM
Posters/Core/Prospect Exhibit Open, Tulsa/Oklahoma Ballrooms + Foyer	8AM-6PM
Oral Sessions, Promenade A, B, C & Diplomat Room	8-11:30AM
All-Convention Luncheon, Promenade D	11:30AM-1PM
Oral Sessions, Promenade A, B, C & Diplomat Room	1:15-5:05PM
Guest/Spouse Hospitality Suite Open, Studio 315	3-5PM
Panel Discussion: Business Side of the Petroleum Industry, Promenade B	4:30-6:30PM
Mini-breaker, Tulsa & Oklahoma Ballrooms + Foyer	4:30-6PM
OSU Alumni Reception, The Brook, Downtown Tulsa	5:30-8PM
All-Alumni Reception, Promenade D	6-7:30PM
Outdoor Dinner and Movie at Guthrie Green	7-10PM

TUESDAY, OCTOBER 5

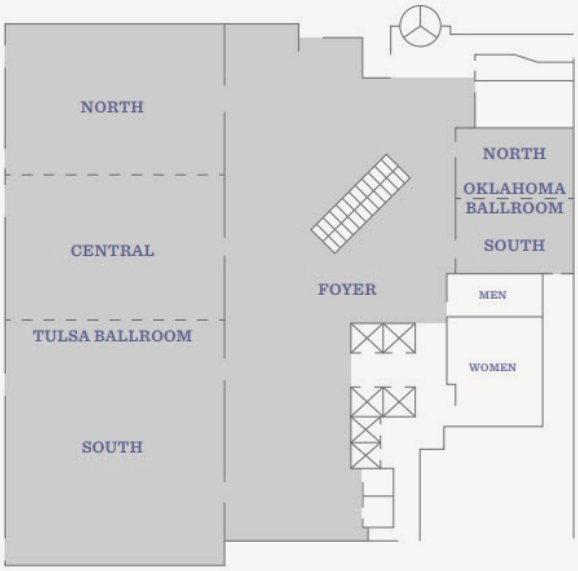
Speakers/Poster Presenters Breakfast, Promenade D	7-7:45AM
Judges Breakfast (Tuesday Session judges), Directors 3	7-7:45AM
Mid-Continent Section Council Meeting, Directors 4 Room	7-9:30AM
Speaker'/ Poster Presenters/Judges Room Open, Executive Room	7AM-5PM
Registration Open, Ground Floor Foyer	7AM-Noon
Guest/Spouse Hospitality Suite Open, Studio 315	7:30-9:30AM
Osage Minerals Council Breakout Session, Diplomat Room	10-11:30AM
Exhibit Hall Open	8AM-1PM
Posters/Core/Prospect Exhibit Open, Tulsa/Oklahoma Ballrooms + Foyer	8AM-1PM
Morning Oral Sessions, Promenade A, B, C & Diplomat Room	8-11:30AM
DPA Luncheon, Promenade D	11:30AM-1PM
Walk-N-Talk Box Lunch with exhibitors	11:30AM-1PM
Afternoon Special Session: Ovintiv's Success in the Anadarko, Promenade A	1:15-4PM

Hyatt Regency Downtown Tulsa

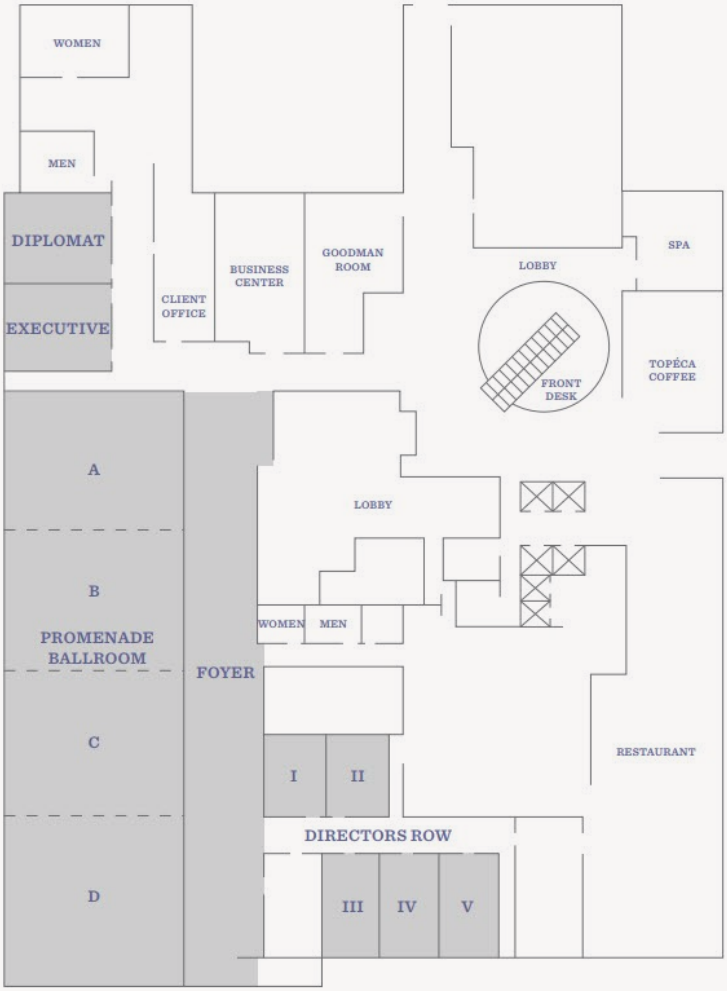
100 E 2ND ST

The Hyatt Regency Tulsa is located in the heart of Oklahoma's vibrant business, entertainment and cultural districts. This downtown hotel overlooks the scenic gardens of the Williams Center Complex and is only eight miles from Tulsa International Airport. Adjoined via skybridge to Williams Towers, the property is adjacent to the famous Tulsa Performing Arts Center and just a few walking blocks from the Cox Convention Center, BOK Center, and more than 50 restaurants and bars.

FIRST FLOOR
CONCOURSE LEVEL



SECOND FLOOR
LOBBY LEVEL



REGISTRATION

Ground Floor Foyer

You may pick up your badge and tickets to optional events in the registration area in the 2nd Street Atrium (ground floor foyer) of the Hyatt or REGISTER AT THE EVENT anytime during the following hours:

Saturday 3:00-6:00 PM
Sunday 8:00 AM-6:00 PM
Monday 7:00 AM-6:30 PM
Tuesday 7:00 AM-12:00 NOON

WIFI

There is complimentary WIFI throughout the Hyatt meeting space and our meeting group code is MCAAPG2021.

EXHIBIT HALL

Tulsa Ballroom & 2nd Street Atrium

Sunday 6:00 PM-8:00 PM
Monday 8:30 AM-6:00 PM
Tuesday 8:30 AM-1:00 PM
Admission by registration badge only

OPENING SESSION AND AWARDS CEREMONY

Sunday, October 3rd 4:30-6pm - Promenade A/B

The Opening Session and Awards Ceremony is sponsored by the Osage Minerals Council, Ceja Corporation, Ron and Cherl Snyder, Blue Jacket Energy and The GypsyGlenn Company.

Please join us as we kick-off the 2021 AAPG Mid-Continent Section Convention with our opening session! After introductory remarks and a welcome to Tulsa from the General Chair, Tara Benda, Tulsa Geological Society President, Shane Matson, and Principal Chief of the Osage Nation, Geoffrey Standing Bear, awards will be presented to distinguished Section members and the poster and oral session winners from the 2019 Meeting in Wichita. Please gather to honor those who have been judged by their peers to have presented exceptional work in advancement of the science of petroleum geology and those who have served the Section with distinction.

2021 AAPG Mid-Continent Section Awards

A. I. Levorsen Memorial Award

The A.I. Levorsen Memorial Award is given in recognition for the "Best Technical Paper" at the AAPG Section meetings with particular emphasis on creative thinking toward new ideas in petroleum exploration.

The A.I. Levorsen Award recipients are **Jenny Meng**, **Yevhen Hollubnyak**, **Jennifer Hollenbach**, and **Franek Hasiuk**, for their presentation: "Evaluating Seal Integrity for CO2 Storage complex at Patterson Field, southwest Kansas" at the 2019 AAPG Mid-Continent Section Meeting in Wichita.

Roger N. Planalp Memorial Award (Best Poster Presentation)

The Roger N. Planalp Memorial Award is given in recognition for the "Best Poster" presentation at the AAPG Mid-Continent Section meeting. The award is in honor of Roger N. Planalp, who passed away in 1986 while serving as President of the Mid-Continent Section.

The Roger N. Planalp Award recipient is **Luke Rijfkogel**, for his poster on "Incorporating seismic attributes, well-logs and computer tomography scan for porosity prediction of a 3D seismic survey, Wellington Field, KS", presented at the 2019 AAPG Mid-Continent Section Meeting in Wichita.

Certificate of Meritorious Service Awards

The Mid-Continent Section Certificate of Meritorious Service Award is given to those individuals who have contributed their time, dedication, and volunteer services to the AAPG Mid-Continent Section.

Doug Davis- Outstanding Leadership as the President of the Mid-Continent Section 2017-19

Toby Eck- Outstanding Leadership as the General Chair of the 2019 AAPG Mid-Continent Section Convention, Wichita, Kansas

General Meeting Info

OPENING ICEBREAKER

Sunday, Oct 3rd, 5:30-8:00PM, Exhibit Hall following the Opening Session/Awards Ceremony

Free entry with your registration. Re-connect with old friends and coworkers and meet new ones and see the exhibitors at the traditional opening icebreaker! Music by the jazz trio Play It Again Scott. After the opening icebreaker, come over to Fassler Hall for refreshments at Rocktoberfest (a ticketed event)! Reserve your tickets online or when you register.

MINI-BREAKER

Monday, Oct 4, 4:30 PM-6:00 PM, Tulsa & Oklahoma Ballrooms, 2nd Street Atrium

Free entry with your registration badge. Grab a drink and head to the Panel Discussion on "The Business Side of the Petroleum Industry" or spend time in the exhibits and posters. Come have a cold one on us before heading over to Dinner and a Movie at Guthrie Green.

SPEAKER AND POSTER PRESENTERS ROOM AND JUDGES ROOM - Executive Room

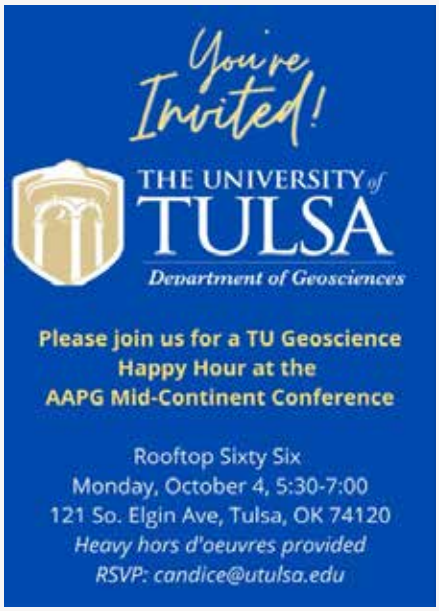
All oral presenters will be required to check in at the Speaker Ready Room to load their presentations any time the day before their talks for morning sessions (if they have not already sent their talk prior to the Convention) and by 7:30am the day of their talks for afternoon session speakers. Please note that all speakers, judges, session chairs and poster presenters will be expected to attend a breakfast on the day of their sessions for last-minute instructions, explanation of the audiovisual equipment, etc., and for judges, to pick up their judging packets.

Practice tables and electrical hook-up for laptops will be available. Poster presenters will likewise find assistance, as well as "emergency" supplies such as scissors, tape and Velcro. The Ready Room will be open:
Sunday 1:00 PM-5:00 PM
Monday 7:00 AM-5:00 PM
Tuesday 7:00 AM-5:00 PM

ALL-ALUMNI RECEPTION

Monday October 4th, 6-7:30pm Promenade D

The AAPG Mid-Continent Section Convention is an opportunity to reconnect with your university.
Tables are provided and a cash bar will be on site.



GUEST/SPOUSE ACTIVITIES

We look forward to welcoming you to the revitalized heart of Tulsa during one of our prettiest times of year. We are making some of the best of Tulsa's activities available as do-it-yourself –- walking tours, suggestions for shopping and additional haunts to explore, including the Gathering Place- voted the best city park by USA Today, the Brady Arts District's museums and restaurants – and we hope you will be eager to find a companion and set off on your own. Some destinations are just a short drive away- including the Gilcrease Museum, Philbrook Museum, and the Tulsa Botanic Gardens. So when you are not relaxing in the hospitality suite, be sure to avail yourself of all there is to do and see in the greater Tulsa area!

GUEST HOSPITALITY SUITE

Registered guests are encouraged to visit the Guest Hospitality Suite in Studio 315 on the 3rd floor of the Hyatt Regency.

Hours of operation:

Sunday, Oct 3	3:00 PM-5:00 PM
Monday, Oct 4	7:30 AM-9:30 AM & 3:00 PM-5:00 PM
Tuesday, Oct 5	7:30 AM-9:30 AM

The hospitality suite is the perfect place to rendezvous with fellow "explorers"! Registered spouses and guests are invited to join us for each day to sample featured local wines, beers, and hors d'oeuvres. Stop in to see old friends, meet new ones, and enjoy a lite bite and drink made by local artisans.

The Guest/Spouse registration fee of $75 includes not only access to the hospitality suite but also admission to Sunday's Icebreaker, the mini-breaker on Monday, and the exhibit hall box lunch on Tuesday. Guests may purchase tickets to any of the special events as well.

OSAGE MINERALS COUNCIL BREAKOUT SESSION - Diplomat Room

Multiple and Diverse Opportunities Throughout the Osage Mineral Estate

Tuesday, October 5 10-11:30am Diplomat Room

Introductory Remarks - Osage Mineral Council Chairman Everett Waller
Randy Lawson, Chairman & CEO LAWCO Energy
Shane Matson, Jericho Energy Ventures
Tracy Evans, President & CEO Perdure Petroleum LLC
Closing Remarks - Susan Forman

Each presentation will last 15 minutes with a 15-minute Q&A after all three presentations.

The Osage Mineral Estate: Rich History – Even Brighter Future if We All Work Together
Randy Lawson, LAWCO Energy

The Osage Mineral Estate has a long and storied oil patch history replete with rags to riches stories that established some of the most successful giant oil names in the industry, such as Warren, Phillips 66, and Conoco. After nearly one billion barrels of oil and a quarter billion cubic feet of natural gas in 120 years of exploration and production, has everything been found? With bypassed, untested, and undrained areas, enhanced recovery, new exploration horizons, leading edge technologies, seismic, and over 300 different combinations of single or multiple completions from approximately 7,000 active "properties", with numerous sands, limestones, and multiple porosity intervals within zones, every horizon is an opportunity! There are more oil and gas and other rare earth elements yet to be discovered and developed and potential for Helium production and possibly thermal energy to explore. Our speakers will give you a sampling of all these opportunities by sharing their current value enhancing projects using the latest in CO2 EOR and adding value by using leading edge technologies and describing the critical importance of a reasonable regulatory environment.

Speaker Bio: Randy Lawson is an entrepreneurial businessman engaged primarily in energy development, real estate development and other angel or venture capital investment businesses. In 1985 he founded the original entity of the Lawco Energy Group (www.lawcoenergy.com) and later organized his real estate companies and other affiliates. The Lawco team is technology driven TM utilizing leading-edge technologies to mitigate risk and increase probability for successfully finding oil and gas. Lawco enjoys a long and proud collaborative mutually beneficial relationship with the Osage Nation and the Osage Minerals Council. Lawco has been conducting operations in Osage County for over fifteen years and studying the geology of the Osage Mineral Estate for over thirty years.

He has prior experience in management with Gulf Oil Corporation (now Chevron) in Houston and New Orleans.
Randy currently serves on the Arvest Bank Benton County Board of Directors, as current Chairman of the Board for Mercy Hospital Northwest Arkansas, Aspen Heights, Northwest Arkansas Council, as Chairman of Economics Arkansas, and serves as an advisor on the Geosciences Advisory Board within the College of Arts and Science and as an executive advisor on the Sam M. Walton College of Business, University of Arkansas.

Randy served as a former Chairman and Vice Chairman of the Arkansas State Board of Education following appointment by former Governor Mike Huckabee for a six-year term.

He formerly was elected and served as a Trustee and Secretary of The NW Arkansas Community College Board of Directors. Randy previously was elected and served on the Bentonville Public Schools Board of Education in Bentonville, AR, for ten years serving as President for two years and in all other officer positions. He is a former Chairman of the Excellerate Foundation Board of Directors and currently or has previously served numerous national, regional, and local civic, professional, or non-profit organizations over the last thirty plus years.

He is a graduate of the University of Arkansas (B.S.B.A with emphasis in Economics and Geology 1981) and was a former Razorback football player under Coach Frank Broyles and Coach Lou Holtz. Randy and his wife, Valorie, have been married for over forty-one years and are members of Cross Church. They have two children and four grandchildren. Son, Aaron, and daughter, Rachel, both work within the family office.

North Burbank Unit – The Next Century
Tracy Evans, Perdure Petroleum LLC
The presentation will include a brief history of the field, current status, and future continued development of Perdure's CO2 EOR operations at the North Burbank Unit in Northwest Osage County.

Tracy Evans is President and Chief Executive Officer of Perdure Petroleum LLC. Tracy held various executive management positions including President and Chief Operating Officer with Denbury Resources (NYSE: DEN) one of the largest CO2 EOR recovery focused companies in the United States. Multiple large-scale CO2 pipelines and sixteen CO2 projects were either expanded or initiated during his tenure at Denbury. Earlier in his career he held management, technical and operating positions with Matador Petroleum and Enserch Exploration in various operating areas within the US. He is a professional engineer, with a BS in petroleum engineering from the University of Oklahoma and an MBA from the University of Texas at Dallas.

Helium Potential of the Osage Uplift: Observations from Drilling and Production Testing of the Wah Zha Zhi #1
Shane Matson*, Jericho Energy Ventures
Helium potential of the Cherokee Platform was first identified in 1921 in USGS Professional Paper 121, Helium-Bearing Natural Gas. The Pearson Switch Field in Osage County, Oklahoma produced ~1% helium from a 1200' deep Pennsylvanian sand.

As the USGS, through the EarthMRI project, seeks to identify strategic Rare Earth Elements and mineral resources critical to energy security, the non-hydrocarbon resources of the shallow Mid-Continent play a critical role.
While continued mismanagement and regulatory attack by the Bureau of Indian Affairs Osage Agency have dramatically reduced production and drilling of new wells, Osage County provides a terrain of lightly drilled and unleased lands with the advantage of common mineral ownership of the Osage Mineral Estate.

In 2012 Spyglass Energy Group drilled the Wah Zha Zha #1-Deep on their Pearsonia Concession in NW Osage County. This historic well production tested low volumes of gas from 4,000' of open hole granitic basement. The gas was low BTU with high (>10%) helium concentration. An effort to determine completion methods is warranted. Industry can look to George Mitchell's effort on the Barnett Shale of the Fort Worth Basin for inspiration.

Shane Matson grew up in Tulsa, Oklahoma and learned to drive on the lease roads of the Glenn Pool oil field. After completing his geological studies at the University of Arkansas, Matson returned to Tulsa where he has spent much of the past eighteen years working as a prospecting geoscientist and operator, focused on reservoirs of the Midcontinent. Additionally Matson works at Director of New Earth Ventures for Jericho Energy, a blended energy company with oil and gas operations and a growing hydrogen-focused energy business. His subsurface interests range widely from 3D Seismic Characterization of Pennsylvanian sandstones and Mississippian cherts to Pre-Cambrian extrusives as low temperature geothermal opportunities. He enjoys getting lost in old well data and when his head is not buried in the sand he can be found in the Ozarks of northwest Arkansas with his family where he enjoys sunrises with dark coffee, riding bikes, hiking, and canoeing the Kings River.

Matson is currently serving as the 101st President of The Tulsa Geological Society
He is an honorary member of the External Advisory Board, Department of Geosciences, University of Arkansas

Tulsa Time

From Indian Territory to oil boomtown, Tulsa has experienced many changes over the generations. Inhabited for thousands of years by Native American tribes, including the Osage, "Children of the Middle Waters", Tulsa is deeply rooted in Native American heritage, oil, arts and culture. Today the city is experiencing a renaissance of its iconic downtown, and as a participant in the 2021 AAPG Mid-Continent Section Convention, you will find yourself in the middle of this latest change in our cityscape and this amazing new vibe.

From the museums and galleries of the Tulsa Arts District, to the rich history and culture of the Greenwood District, to the stunning architecture of the Deco District, to the fun Blue Dome District and the funky East Village, there is plenty to do and see in Tulsa- and much within a few blocks of the Hyatt!

Designed as a vibrant and inclusive space, the Gathering Place blends nature with an urban setting. Since opening in 2018 and named USA Today's Best New Attraction, Gathering Place has provided Tulsans and visitors alike with space to play, relax and gather along the river.

Nestled on 25-acres of pristine gardens in the heart of midtown Tulsa, Philbrook Museum of Art offers world-class art in a villa that transports visitors to the Italian countryside.

An all-season oasis blooming in the Osage Hills just eight miles northwest of Tulsa, each spring the Garden celebrates Tulsa Botanic Blooms with over 100,000 tulips, hyacinths, daffodils and other spring flowers. The Lakeside Promenade gracefully encompasses a seven-acre lake, and the Cross Timbers Trail provides a 1.5 mile hike through the native prairie and forest.

Networking Events

PEARL DISTRICT BREWERY TOUR

Saturday, October 2nd, 7PM
Pearl District

Cost: $50/person, includes transportation with beer guide
Limited to 40 participants

Get a taste of Tulsa's renowned breweries with a Pearl District Brewery Tour. Registration gets you a seat on the brew bus, in-season flight samples at each location, and behind-the-scenes view of Tulsa's growing brewing community. You'll also have a beer guide going along with you to tell you about the breweries, help you pick beers and tell you lame jokes.

POST ICEBREAKER "ROCKTOBERFEST" at FASSLER HALL

Sponsored by Wind River Energy, Selman and Associates, and Olifant Energy II

Sunday, October 3rd, 7:30-10PM
Fassler Hall, 304 S Elgin, Blue Dome District

Cost: $45/person, includes buffet and open bar.
LIMITED! Only 200 tickets available!

Come celebrate "Rocktoberfest" with your geo-buddies after the traditional Sunday icebreaker at this authentic German beer hall, located only four blocks from the Hyatt!

OUTDOOR DINNER AND MOVIE AT GUTHRIE GREEN

Sponsored by Impac Exploration Services

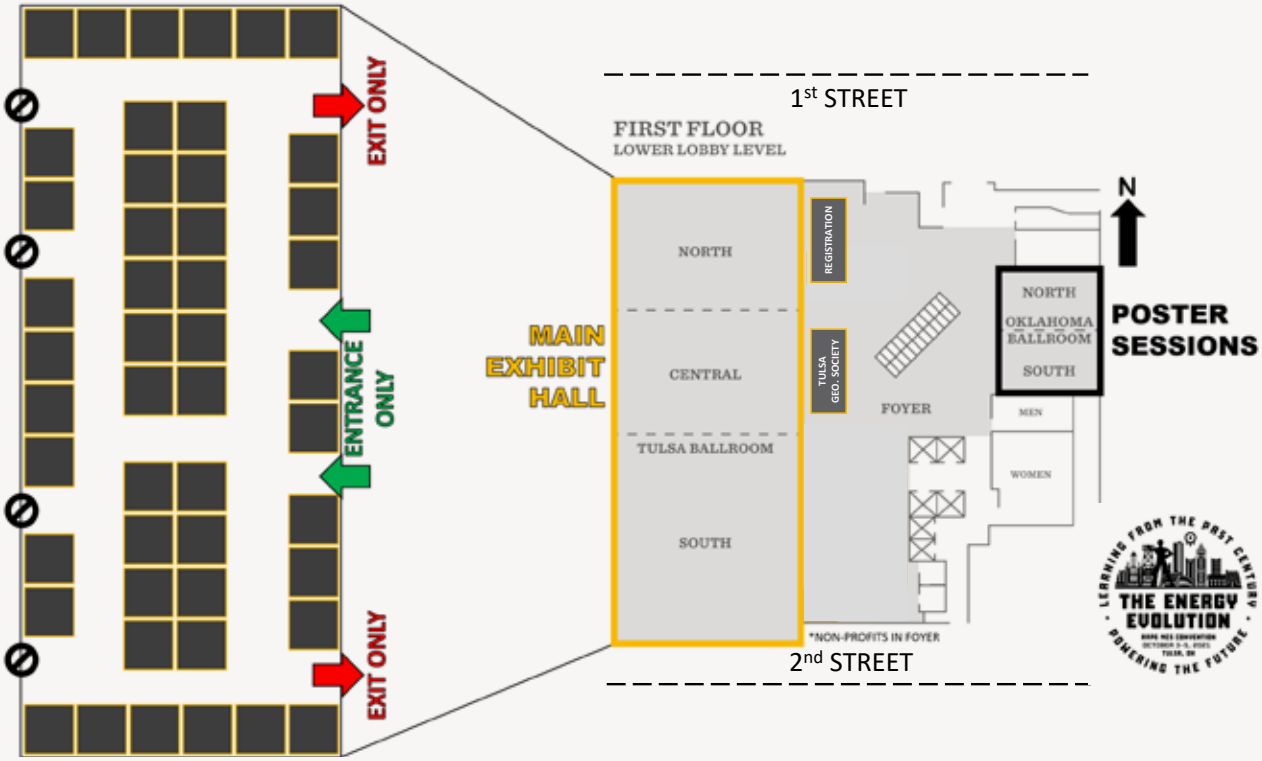
Monday, October 4th, 7PM
Guthrie Green

Cost: $25/person, includes meal/drink ticket

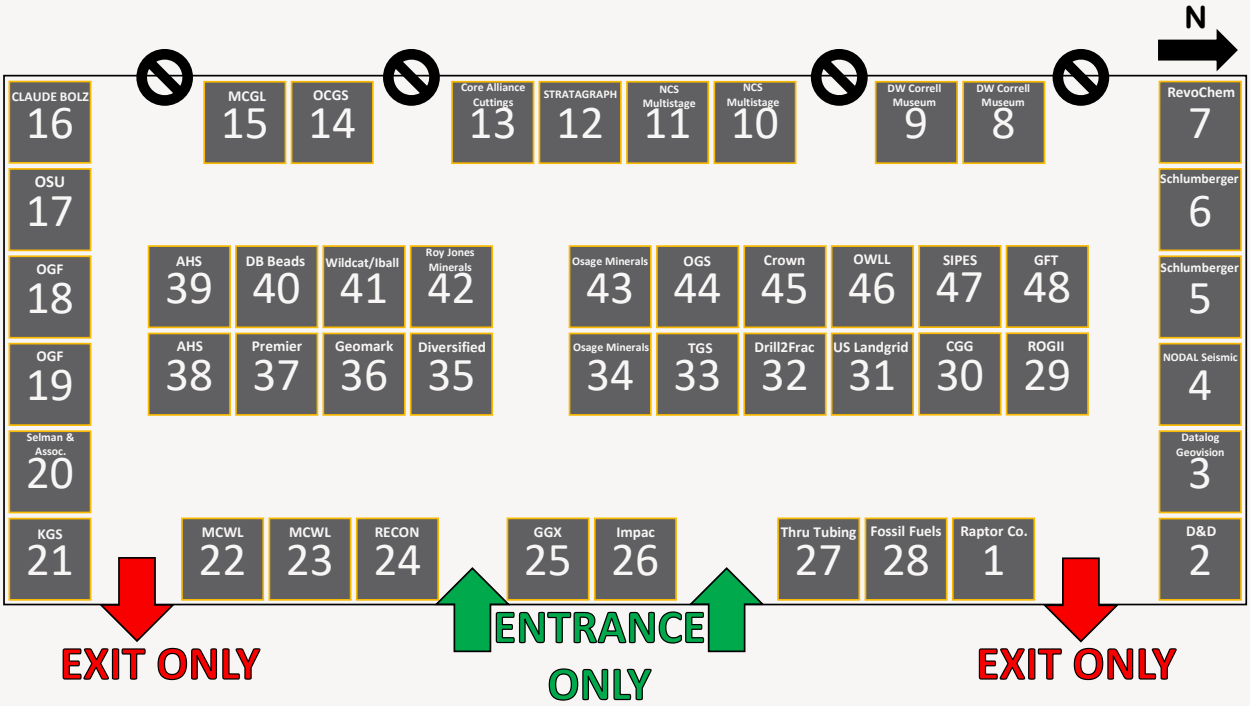
Guthrie Green Movie Night, Enjoy the evening outdoors in Tulsa's new and award-winning urban green space in the heart of the Brady Arts District – museums, merchants, food trucks, beverages, and a screening of ***There Will Be Blood***.

EXHIBITOR FLOOR PLAN

EXHIBIT HALL LAYOUT



MAIN EXHIBIT HALL FLOORPLAN



Exhibitor Directory

BOOTH 1	Raptor Consulting	Patrick Jordan	raptorconsulting.com
BOOTH 2	Desk and Derrick Club of Tulsa	Jill Klein	tulsadandd.net
BOOTH 3	DataLog/GeoVision	Ryan Nostrud	dataloggs.com
BOOTH 4	NodalSeismic, LLC	Bill Erickson	nodalseismic.com
BOOTHS 5/6	Schlumberger	Ana Flores	slb.com
BOOTH 7	RevoChem	Bob Aylsworth	revochem.com
BOOTHS 8/9	DW Correll Museum	Eric Hamshar	cityofcatoosa.org/163/DW-Correll-Museum
BOOTHS 10/11	NCS Multistage, LLC	Gigi Rodriguez	ncsmultistage.com
BOOTHS 12/13	Stratagraph, Inc and Core Spec Alliance	Wayne Cook	stratagraph.com corealliances.com
BOOTH 14	Oklahoma City Geological Society	Dick Howell	ocgs.org
BOOTH 15	Mid-Continent Geological Library	Michelle Hone	mcglibrary.org
BOOTH 16	Elsing Museum	Claude Bolze	
BOOTH 17	Oklahoma State University	Sandy Earls	geology.okstate.edu
BOOTHS 18/19	Oklahoma Geological Foundation	Terry Hollrah	oklahomageologicalfoundation.org
BOOTH 20	Selman & Associates Ltd.	Michelle Walton	selmanlog.com
BOOTH 21	Kansas Geological Society	Wesley Hansen	kgslibrary.com
BOOTHS 22/23	MCWL/Paladin Geological	Emily Pryor/Chris Babb	mcwlinc.com
BOOTH 24	Recon Petrotechnologies	Andrew Nguyen	reconpetro.com
BOOTH 25	GVERSE GeoGraphix	Cristina Viteri	gverse.com
BOOTH 26	Impac Exploration Services	Chris Craighead	impacxs.com
BOOTH 27	Thru Tubing Solutions	Charley Mathis Leigha Horner	thrutubing.com
BOOTH 28	Knight Energy Services	Matthew Hill	ke.services
BOOTH 29	ROGII Inc	Kamilla Niz	rogii.com
BOOTH 30	CGG	Evelyne Ottesen	cgg.com

Exhibitor Directory

BOOTH 31	Drill2Frac	Meg Dodge	drill2frac.com
BOOTH 32	US Landgrid	Anothy Ford	uslandgrid.com
BOOTH 33	TGS	Danielle Landry	tgs.com
BOOTHS 34/43	Osage Mineral Council	Susan Forman	data-osageminerals.hub.arcgis.com
BOOTH 35	Diversified Well Logging	Tracy Walker	dwl-usa.com
BOOTH 36	GeoMark Research	Britney Hughes	geomarkresearch.com
BOOTH 37	Premier Oilfield Group	Justin Vandenbrink Bradi Cruz	pofg.com
BOOTHS 38/39	Advanced Hydrocarbon Stratigraphy	Mike Smith	advancedhydrocarbon.com
BOOTH 40	DB Beads	Betty Hollrah	dbbeading.com
BOOTH 41	Wildcat Well Logging	Seth Stacey	wildcatwelllogging.com
BOOTH 42	The Mineral Pocket	Roy Jones	
BOOTH 44	Oklahoma Geological Survey	Molly Yunker	ou.edu/ogs
BOOTH 45	Crown GeoChemistry, Inc	Bruce Warren/Dee Hall	crowngeochemistry.com
BOOTH 46	Oklahoma Well Log Library	Bob Von Rhee	okwll.net
BOOTH 47	SIPES	Gregg Alletag	sipes.org
BOOTH 48	Geoscience Foundation of Tulsa	Kristie Ferguson	geosciencefoundationoftulsa.com
BOOTH 52	Tulsa Geological Society	Shane Matson	tulsageology.org
BOOTH 60	Fort Hays State University, Geosciences	Henry Agbogun	fhsu.edu/geo
BOOTH 61	University of Tulsa Collins College of Business	Buford Pollett	business.utulsa.edu
BOOTH 63	University of Tulsa Geology	Jingyi Chen	engineering.utulsa.edu/geosciences

OSAGE
Minerals Council

813 Grandview Avenue — Pawhuska, OK 74056 — 918.287.5447

On behalf of the Osage Minerals Council, welcome to the AAPG Summit. We wish everyone safe and enjoyable event.

In memory of OMC Chairman Andrew Yates, front-right, 10/6/60-2/16/21.

We are excited for the opportunity to share our Osage Reservation with you and hope your experience learning about the Osage Reservation and Mineral Estate is the highlight of the conference.

ADVANCED HYDROCARBON STRATIGRAPHY (AHS)

Untapped Value from Well Cuttings

for Pay identification and Reservoir characterization

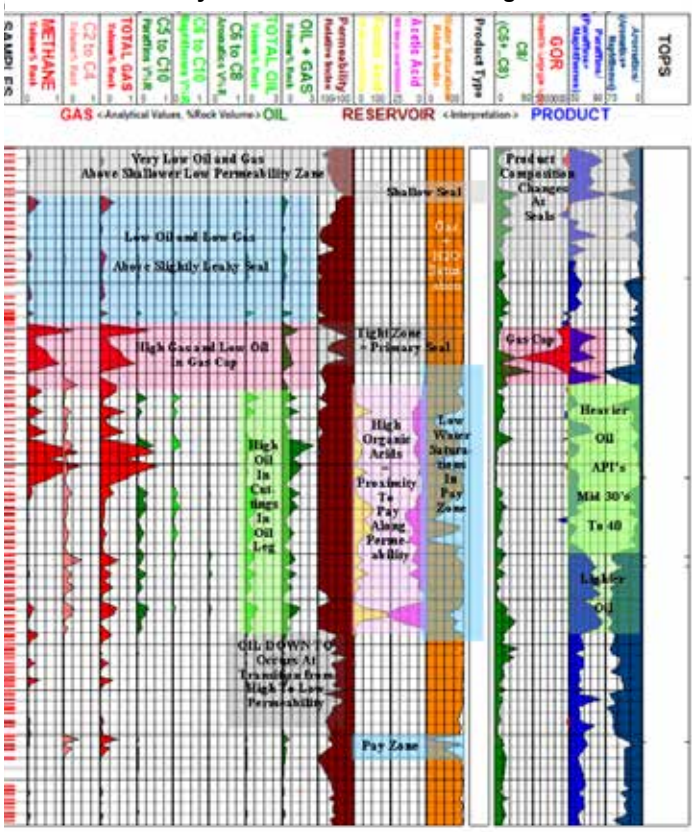
RVStrat^{sm}- Rock Volatiles Stratigraphy

AHS technology provides **advanced volatiles well logs and innovative interpretation** from mass spectrometer analysis of **well cuttings, drilling muds and core samples**. Unconventional (pilots and laterals) and vertical conventional wells (old and new) can be analyzed; samples from oil based muds and PDC drilling bits can be analyzed and interpreted.

AHS has developed an independent predictive analysis and interpretation for:

- **Pay identification & HCcharacterization (C_1-C_{10}):**
  - Pay zones, proximity to Pay
  - Water contacts, fresh H_2O
  - HC migration history
  - Estimated ultimate recovery (EUR)
  - API predictions (oil vs gas)
- **Rock properties prediction:**
  - Properties logging:
    - Perm (k) estimates
    - Mechanical strength
  - Reservoir compartmentalization:
    - Fault identification
    - Fracture recognition
    - Seal(s) detection
- **Report development & consultation:**
  - Volatile well logs:
    - HC's and rock properties interpretation
  - Operational recommendations within Ops time constraints:
    - Pay and missed pay identification
    - Landing zones identification
    - Proximity to pay indicators
    - **Completion recommendations: Subsurface stage by stage performance**
  - Mapping: HC and rock properties

Pay and Reservoir Volatiles Log



Sampling intervals of 10' to 30' are collected, analyzed and characterized for HC pay, proximity to pay, non-pay and rock properties to provide a comprehensive report and operational recommendations

Advance **H**ydrocarbon **S**tratigraphy's low cost innovative patented technology is being utilized for production and exploration wells, conventional, unconventional and hybrid reservoirs in US domestic and international basins.

Contact **AHS** for your **hydrocarbon characterization, rock property** predictions and expert **consultation**.

Come See Us In Booth 38/39

at AAPG MidCon in Tulsa

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2931 West 21st Street
Tulsa, OK 74107 USA
918-583-2474

Michael P Smith, PhD
President
Michael@AdvancedHydrocarbon.Com

Technical Program

Our Technical Program offers us the chance to reconnect with our friends and colleagues, and engage in an exchange of new ideas that all of us have craved for the last year. Per the theme of this year's convention, our technical program will focus on learning from the past - better understanding our complex reservoirs and petroleum systems and integrating this knowledge with the latest technologies - to focus on making money in the future.

We have a diverse roster of short courses, with focus on new technologies, like QGIS, Data Analytics and Machine Learning, and Carbon Capture, Utilization, and Storage. Our field trips highlight the geology of NE Oklahoma and NW Arkansas and offer fun adventures like mountain biking and boating.

The first day of the Technical Program will provide the opportunity to embrace stratigraphic, sedimentologic and structural/tectonic challenges in the Mid-Continent, along with gaining a better perspective on induced seismicity and, in honor of the 100th year of the Tulsa Geological Society, we will review some of the giant historical fields of the Mid-Continent. Lessons from conventional and unconventional plays, seismic imaging and reservoir characterization, and the utilization of data analytics, machine learning, and GIS will be presented. A special session on climate change and the energy transition will address how it affects our industry and governmental policy and the future energy mix in the US. We will also have a chance to listen to AAPG president Gretchen Gillis present plans for the future of AAPG. The first day will finish off with a very interesting panel discussion on the business side of the petroleum industry… a chance to see where the smart money is going!

Our second day digs deeply into the Anadarko Basin, with a session on the Anadarko as a Super Basin, and wrestles with the geochemistry and basin modeling that underpin our most important plays. The session on energy minerals and alternative energy sources addresses the ongoing energy transition/evolution. Tuesday afternoon is highlighted by an exciting special session presented by Ovintiv geoscientists, discussing Ovintiv's conceptual and philosophical approach that they have employed in their successful efforts in the STACK/SCOOP play.

The poster sessions will cover a broad spectrum of interesting topics from Helium potential in Osage County to EOR with CO2 and seismic inversion for optimal storage of CO2 to how fossil fuels fit into Earth's carbon cycle and recovery of heavy metals from produced water with dolomite filtration.

Join us in embracing these impressive technical insights, challenge old concepts, and develop new ideas and analogs as we experience a renewed opportunity to reconnect with geoscience and our fellow geoscientists!

Geological and Mountain Bike Tour of the OZ Trails in Northwest Arkansas

DATES: Friday, Oct 1st – Sunday, Oct 3rd
INSTRUCTORS: Joel Donahue, Ryan Dupree, and Shane Matson
COST: $350/person *(2 nights/Double Occupancy/Lodging Included)*
COURSE LIMIT: 30 participants

Course Description: This field trip will take advantage of the magnificent Ozark Outcrop Belt of the Springfield Plateau. In recent years, the region has seen massive investment in mountain biking infrastructure in Northwest Arkansas. New access to outcrops has been developed throughout the region allowing for a fresh look into Paleozoic depositional systems, from the Pennsylvanian into the Ordovician.

Participants meet in Bentonville, Arkansas on Friday October 1 for a happy hour sponsored by Bentonville-based Lawco Energy, at the historic Fred's Hickory Inn. Following happy hour we will adjourn to the Town Square for dinner-on-your-own and to take in an evening of festivities and local bluegrass music.

Saturday morning riders will meet at 7:00 a.m. for a light breakfast and depart from the Hotel 21C on bikes for a guided morning ride on the All-American Trail System. We will make our way towards a picnic lunch provided by Airship Coffee at the incredible Coler Mountain Mountain Bike Preserve. The day will finish on two-wheels at 21C for a happy hour. We will once again adjourn for a dinner-on-your-own and more town festivities. Sunday morning, we will depart in shuttle vans to Hobbs State Park-Conservation Area on Beaver Lake to ride the eight-mile Karst Loop, part of the Epic Trail System of Arkansas. We will return to the hotel by 1 p.m. so participants can travel to Tulsa in time for the Opening Session for the 2021 AAPG Mid-Continent Meeting.

As the trip coincides with both the Downtown Bentonville First Friday block party as well as the nationally recognized Fresh Grass Festival (separate tickets online) the experience is sure to be as epic off the bike as it will be on two wheels and at the outcrop. This trip provides a unique opportunity to witness the emerging cultural center of the midcontinent alongside the geologic beauty of the natural state.

Participants are welcome to bring their own equipment. For those needing mountain bikes or wanting to try the latest and greatest, we have partnered with The Gear Head Experience Center and reserved full-suspension Specialized Mountain bikes. A selection of electric mountain bikes is available.

Logistics: Participants will meet Friday afternoon in Bentonville, AR at Hotel 21C. Transportation to and from Tulsa is not provided but can be arranged. Flights into XNA, Northwest Arkansas National Airport, are reasonably priced and convenient for those travelling from out of state.

Depositional Complexities of Upper Pennsylvanian Fluvial-Dominated Deltaic Deposits, Skiatook Lake, Oklahoma

DATES: Saturday, Oct 2nd
COST: $165/person

INSTRUCTOR: Dr Lee Krystinik, Equus Energy Partners
COURSE LIMIT: 35 participants

Course Description: This field trip documents the remarkable diversity of reservoir and seal deposits of the Upper Pennsylvanian (late Missourian to early Virgilian) river-dominated deltaic and interdeltaic deposits exposed around Skiatook Lake, northwest of Tulsa, OK. The group will spend most of the day cruising on pontoon boats to examine a series of excellent coastal exposures ranging from marine shale to pro-deltaic event beds and delta-front turbidites to massive, amalgamated distributary-mouth-bar deposits, distributary channels deformed by dewatering and a sub-lacustrine gas seep coming out of these sands. The trip will finish with beers and a social hour overlooking the lake.

Logistics: Rental vans depart from the Hyatt hotel at 8:00 AM and return the participants to the hotel by 6:00 PM. Lunch, snacks, and drinks will be provided during the trip along with a selection of beers at the end of the trip.

Instructor Bio: Lee F. Krystinik specializes in applied sedimentary and stratigraphic analysis to predict clastic reservoirs and has a Ph.D. in geology from Princeton University. Krystinik has held positions as Manager of Geology at Union Pacific Resources, Global Chief Geologist for ConocoPhillips, Co-founder of Fossil Creek Resources and is now a founding Partner in Equus Energy Partners, an exploration partnership that uses new technologies in the search for overlooked targets.

His areas of interest include syn-tectonic sedimentation and other controls on basin-fill architecture, integrated play assessment, and cost-effective implementation of new concepts and technology. Dr. Krystinik has been an AAPG Distinguished Lecturer in North and South America and he is a past President of both SEPM and AAPG.

Osage Nation Field Trip

DATES: Saturday, Oct 2nd
INSTRUCTORS: Bill Lynn
COST: $135/person
COURSE LIMIT: 22 participants

Logistics: The bus will leave Hyatt Regency Downtown Tulsa Hotel Saturday morning at 8:00AM. Lunch, snacks and drinks will be provided with a traditional Osage dinner at noon. The bus will return to hotel by 6:00 PM.

Description: Experience a day with our Centennial Sponsors, the unique Wazhahe Nikashe, the Osage people on their own reservation. This field trip will explore Osage geology, stratigraphy, production/company history, culture and even include some language learning. The first stop will be at the first giant, the Avant Pool and the Candy Creek Rock Crusher for a hands on look at the Avant limestone. The Avant is a conspicuous limestone located in the lower valley of Candy Creek in the Southeast Osage woodland area. The Avant has been described as marine phylloidal algal mound. This Ochelata Group Member of the MIssourian Series age limestone marks the end of the lower and the beginning of the Upper Pennsylvanian System. Then it's off to the Northwest to Pawhuska for stops at the Osage Museum and Immaculate Conception Catholic Church's Osage window, the only one like it in the world. The guests will then get to experience the importance of traditional Osage dinner at Wakon Iron Hall. After the meal, the group will get to a hands on feel of a natural oil seep from the Revard sandstone. After that, West through the open, rolling Osage Prairie to another giant, the fabulous Burbank Pool, for a tour through EOR operations on what was once called the largest water flood in North America, the North Burbank Unit. Finally, a beer stop back in downtown Pawhuska on the way back through to the Tulsa.

Instructor Bio: William R Lynn is a member of the Osage Tribe and is now working as the Geologist for the Osage Minerals Council. He has a BS in Geology from Oklahoma State University and has worked for his Father, J Roger Lynn and helped found Osage Oil Scouts. He spent 26 years working for Lamamco Drilling Company SM Oil & Gas LLC in five states but has always called Pawhuska his home. He's a member of TGS and AAPG.

Sedimentology, Sequence Stratigraphy and Paleontology of a Pennsylvanian Transgressive Sequence, Catoosa, Oklahoma & Geology of Redbud Nature Preserve

DATES: Sunday, Oct 3rd
COST: $110/person

INSTRUCTORS: John McLeod, Doug Jordan, Whitney Landress
COURSE LIMIT: 30 participants

Course Description: A large roadcut in near Catoosa, Oklahoma exhibits a classic deepening transgressive sequence of Cherokee Platform shallow to deep water shelf facies. The basal silty units of the Labette formation, finely laminated and dramatically deformed, grade upward into a coarser reservoir sandstone (Peru Sand) and algal limestone before culminating is black source rock shale with phosphatic nodules. The overlying massive Oologah Limestone is the major commercial source of limestone for Tulsa and is quarried extensively just west of this cut. Each facies in this sequence contains a diagnostic assemblage of plant, trace or shelly fossils.

Geology of Redbud Nature Preserve

Due to the underlying rocks, and the way water flows over, around, and through them, there are a great variety of habitats in a very small area. The one-mile trail wanders through places that resemble the flat, dry, sunny upland prairies and forests of central Oklahoma's Cross Timbers. It also climbs through a shady, damp, steep-sided valley that would be at home in the Ozark Mountains. Tarantulas and cactus live less than half a mile from salamanders and ferns! Those are only the two most extreme examples. It's like a patchwork quilt of many small ecological zones, with different amounts of sunlight, water, soil, and wind in each one.

Logistics: Rental vans depart from the Hyatt hotel at 7:00 AM and returns the participants to the hotel by 3:00 PM. Trip will begin at the roadcut near Catoosa, pick up lunch at Subway, then head to Redbud Nature Preserve to have lunch and do the second part of the trip. Lunch, snacks, and drinks will be provided.

Instructor Bios: John McLeod is an independent geologist and geochemist and founder of Source Rocks International based in Tulsa, Oklahoma. He previously held petroleum geoscience positions with Mobil Oil, Oryx Energy, EOG Resources, Chesapeake Energy and SM Energy. His principal interests are exploration and petroleum systems analysis, source rock geochemistry, paleontology and field geology in exotic locations. Since late 2019, he developed an interest in adapting open-source QGIS and public data to the mapping and analysis needs of petroleum geoscientists. His current research interests include characterization of the Carboniferous petroleum systems of the Cherokee Platform and the genesis of black shale/phosphate nodule source rocks.

Doug Jordan is a consulting sedimentologist at the company he founded, Applied Sedimentology LLC in Edmond, Oklahoma. Over 42 years, he has held petroleum geoscience positions with Cities Service, Reservoir's, ARCO International, Oryx Energy, EOG, and Chesapeake Energy in Tulsa, Houston, Plano, Caracas, and Oklahoma City. Since early 2021, he has consulted with a major firm in Oklahoma City, working projects in the Gulf Coast (onshore), Rockies, and Appalachian Basin where he has integrated sedimentology, sequence stratigraphy, and petrophysics in characterizing tight oil and gas clastic and carbonate reservoir rocks. His principal interests include detailed facies analysis and mapping of sedimentary rocks in core and outcrop. He has recommended the drilling of over 100 vertical and horizontal wells throughout the world and has published over 60 peer-reviewed papers and abstracts.

QGIS (Free Software) for Geoscience Professionals

DATE: Saturday, Oct 2nd, 8AM-Noon
COST: $80/Professional, $20/Student
INSTRUCTOR: John McLeod
ROOM: Promenade A

Course Description: QGIS is the leading open-source Geographic Information System (GIS) that stores and analyzes geographically referenced data in a relational database and displays it as a stack of viewable map layers. QGIS offers users a good alternative to perform key geoscience analysis and mapping functions of commercial programs at no cost for the software. In this course, we will learn to

- Use the QGIS program, its extensions and many plugins*
- Interpolate, grid, and contour geoscience data*
- Obtain free and real-time geoscience data
- Query and filter data
- Georeference and digitize legacy maps
- Link map features to external data, websites, or handler applications

Enrollees should have some previous experience using mapping software. The course will be taught as a series of lectures, demonstrations, and class exercises. Enrollees should bring their own laptop computers loaded with the QGIS program and class data files that will be made available for download prior to the course.
*The most important skills to be learned in this introductory course

Instructor Bio: John McLeod is an independent geologist and geochemist and founder of Source Rocks International based in Tulsa, Oklahoma. He previously held petroleum geoscience positions with Mobil Oil, Oryx Energy, EOG Resources, Chesapeake Energy and SM Energy. His principal interests are exploration and petroleum systems analysis, source rock geochemistry, paleontology and field geology in exotic locations. Since late 2019, he developed an interest in adapting open-source QGIS and public data to the mapping and analysis needs of petroleum geoscientists. His current research interests include characterization of the Carboniferous petroleum systems of the Cherokee Platform and the genesis of black shale/phosphate nodule source rocks.

Geosteering Fundamentals (Cancelled)

DATE: Saturday, Oct 2nd, 1-5PM
COST: $80/Professional, $20/Student
INSTRUCTORS: Jackie Palmer, Drew Thomas & Dylan Miner
ROOM: Promenade A

Course Description: This course is designed for professionals who have an introductory understanding of geosteering and the drilling process. The course will instruct students throughout the vertical, curve, and lateral portions of a well - focusing on traditional Gamma Ray data manipulation to compare to vertical type logs. Students will also examine geosteering best practices and interpret alternate datasets. ROGII is providing the software package so students will also receive an introduction to StarSteer software.

Class Requirements: Students **MUST** bring their own windows laptop to use StarSteer in class. A mouse is also HIGHLY RECOMMENDED.

Introduction to Data Analysis and Machine Learning Leveraging Python

DATE: Saturday, Oct 2nd, 8AM-5PM
COST: $135/Professional, $35/Student
INSTRUCTORS: David Bentham and Eric Smith
ROOM: Promenade B

Course Description: This an introductory course to Data Analysis and Machine Learning leveraging Python that will cover the basics from understanding what Python is and what an API is, to data acquisition and visualizations, finally finishing up with exploratory data analysis and basic machine learning. We will use real world data solving real world problems leaving participants with a function workflow to use beyond the classroom.

Instructor Bios: David Benham is a Senior Data Scientist with Laredo Petroleum. His expertise lies in unlocking the power of data to accelerate Laredo's digital transformation. Prior to joining Laredo, David spent 10 years in the energy section and 2 years in the manufacturing sector leading data science initiatives that solved for various business challenges in the well planning, performance, and production domains.
Eric Smith is a Senior IT and Data Engineer at Laredo Petroleum.

Geochemistry as the most useful tools for evaluating and developing conventional and unconventional plays (petroleum systems analysis to production allocation)

DATE: Sunday, Oct 3rd, 8AM-4:30PM
COST: $135/Professional, $35/Student
INSTRUCTOR: Dr Wahid Rahman
ROOM: Diplomat Room

Course Description: Geochemistry is the most useful tool for evaluating and developing conventional and unconventional plays (petroleum systems analysis to production allocation)

- The Geochemistry course will provide introduction and evolution of conventional and unconventional petroleum systems. The intent is to cover most of the geochemical methods: total organic carbon (TOC), organic facies (kerogen/macerals types), vitrinite reflectance/thermal maturity (Ro) and its equivalent (VRoE) from bitumen, pyrolysis data (hydrogen index, Tmax,) and produced oil and gas.
- Geochemistry to understand Level of Organic Maturation (LOM), prediction of hydrocarbon phase, API gravity, gas-to-oil ratio (GOR), condensate-to-gas ratio (CGR), production allocation and identifying Drainage volume (DRV)
- Geochemist data to analyze and understand petroleum systems from molecular scale to basin scale through basin modeling.
- Course will also cover oil to oil and oil to source rock correlations through Source Rock (e.g. TOC, SRA, Rock-Eval) and produced hydrocarbon (oil and gas) though geochemistry data (GC, GCMS, GC-IRMS).
- There will be examples from different US onshore unconventional resource plays and conventional plays from published data. Course attendees will be able to learn the fundamentals and application of geochemistry to exploration, development and production of oil and gas in both conventional and unconventional plays.

Instructor Bio: Dr. Wahid Rahman is currently working as a Petroleum Geochemist/Director at Geoscience and Petroleum Research Inc, Houston, Texas, USA. Dr. Rahman has previously worked as Chief Geochemist at Paladin Geological Services,

Geological Adviser at Ossidiana Energy, Staff Geochemist at Pioneer Natural Resources, and as Sr Geochemist at Devon Energy. Dr Rahman has 19+ years of industry, academic, and research experience in the field of geochemistry, basin modeling, environmental geochemistry and geology; has worked most of the North American onshore unconventional and conventional petroleum plays/basins. Dr Rahman's research interest include organic geochemistry, basin modeling, environmental geochemistry, Isotope geochemistry, surface geochemistry, conventional and unconventional resource play evaluation, HC migration pathway analysis, thermal maturity of organic matter (OM) and hydrocarbons (oil and gas), relationship between OM maturity versus Gas Oil Ratio (GOR), pressure gradient, kerogen/OM density, formation water geochemistry to figure out reservoir continuity, water resistivity (Rw), water saturation (Sw), inorganic geochemistry, well completion geochemistry, stable isotope geochemistry, production allocation and reservoir geochemistry. Wahid has over 35 conference presentations, papers, and peer- reviewed journals (with more than 600 citations) in the field of geochemistry, environmental geochemistry, and geology. He received his Ph.D. in Organic Geochemistry from Southern Illinois University, Carbondale, IL; M.S. in Geology from Auburn University, Auburn, AL; M.S. and B.S. in Geology from University of Dhaka, Dhaka, Bangladesh.

Fundamentals of Carbon Capture, Utilization, and Storage

DATE: Sunday, Oct 3rd, 9AM-4PM
INSTRUCTORS: Dr Camelia Knapp, Dr Jack Pashin, Dr Eugene Holubnyak, Sallie Greenberg, and Richard Esposito
COST: $135/Professional, $35/Student ROOM: Promenade C

Instructor Bios:
Camelia Knap: With my original training in Geophysical Engineering in my home country of Romania, and work experience with the oil & gas industry and crustal-scale seismic research prior to my doctoral program at Cornell University, my background and research interests have broadened through training and academic employment at Cornell University and the University of South Carolina. I have engaged in collaborative and interdisciplinary research with other faculty throughout my research career, being the recipient of valuable mentoring in my earlier years, and attempting to provide the same for junior faculty in later years. My research portfolio includes (1) application of active source seismology to the structure, composition, and physical properties of the Earth crust and upper mantle, (2) environmental research as it relates to high-resolution imaging of the shallow subsurface for issues related to natural or manmade hazards and hydrogeology, (3) study of marine gas hydrates seen as future energy resources and potential global climate change triggers, (4) geophysical characterization to assess geologic reservoirs for CO2 storage, and (5) seabed geological and geophysical characterization for wind energy development.

Jack Pashin joined the faculty of the Boone Pickens School of Geology at Oklahoma State University in January 2013 as the Devon Energy Chair of Basin Research. He received a B.S. degree in geology from Bradley University in 1982, and M.S. and Ph.D. degrees in geology from the University of Kentucky in 1985 and 1990, respectively. Prior to joining OSU, Dr. Pashin served as Associate Director of the Geological Survey of Alabama, where he led the Energy Program. He joined the Geological Survey of Alabama in 1988 and led numerous research projects on coalbed methane, shale gas, onshore and offshore conventional reservoirs, and geologic carbon sinks. Dr. Pashin is strongly committed to geological education, has served on graduate committees at eight U.S. and Australian universities, and is involved in a range of educational outreach initiatives. He has published extensively on a variety of topics in sedimentary geology, structural geology, and reservoir geology and has won many awards for his research. He has served as an AAPG Haas-Pratt Distinguished Lecturer and is active in several geological societies and committees. Jack is an honorary member of the Energy Minerals Division

(EMD) of AAPG, is an AAPG Charles Taylor Fellow, has been elected to GSA Fellowship, and has served as Chair of the GSA Coal Geology Division. He has chaired the AAPG-EMD Coal and Coalbed Methane Committees, the Antoinette Lierman Medlin Scholarship Committee of the GSA Coal Geology Division, and was co-leader of the technical working group of the IOGCC Task Force on Offshore Geological Carbon Sequestration. He is an Associate Editor of the AAPG Bulletin and serves on the Editorial Board of the International Journal of Coal Geology.

Eugene Holubnyak is a Petroleum Engineer at Kansas Geological Survey (KGS) and has over 14 years of experience in applied geoscience and energy-related research. Eugene has worked for five years at Plains CO2 Reduction (PCOR) Partnership before transitioning to KGS in 2012. He managed several research and field scale projects funded by Department of Energy including Wellington Field CO2 EOR and storage pilot (DE-FE0006821) and participated in numerous DOE funded projects as a Co-PI.

Currently, Mr. Holubnyak is serving as a Joint-PI for CarbonSAFE Phase II Integrated Mid-Continent Stacked Carbon Storage Hub project (DE-FE0031623), leading KS CCUS Task Force, and representing KGS at the Regional Carbon Capture Deployment Initiative.

Eugene is specializing in reservoir modeling, simulations, and fluid geochemistry applied to oil & gas reservoirs and waste fluid injection. Mr. Holubnyak is very familiar with UIC program, including hands on experience with UIC Class VI well permitting and preparing projects to qualify for 45Q credits.
Eugene is also interested in space exploration and developments in Advanced Life Support Systems for space settlements. He is continuing research and publication activities in this area.

Sallie Greenberg: Earth Scientist, Educator, and Evaluator with 30 years applied research experience in geology and social science addressing energy and environmental challenges associated with fossil fuel resources. Specializing in strategic visioning for natural resource organizations, carbon storage project evaluation, leading scientists, science communication, stakeholder engagement, and program evaluation with extensive experience in preparing proposals; project, data, and personnel management; international research program and project development, and strategic planning.

Richard Esposito: Experienced R&D program manager with a demonstrated history of working in the electrical utility industry. Skilled in area of carbon capture, utilization, and storage (CCUS), bulk energy storage, geothermal power, and associated environmental permitting and regulations. Strong educational background in both engineering and geology with a PhD in engineering from University of Alabama at Birmingham and a B.S. and M.S. in geology from Auburn University.

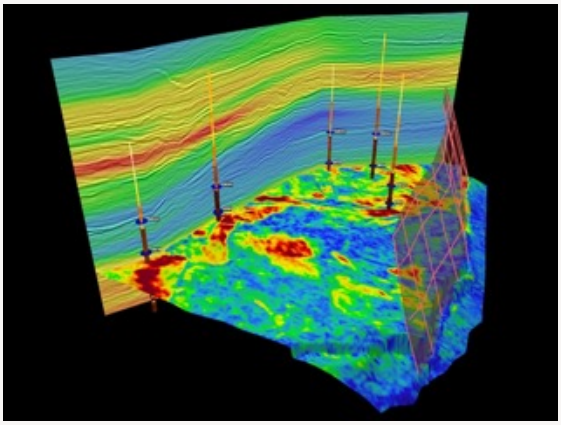
Seismic Interpretation Bootcamp Using OpenDtect (Free) Software

DATE: Sunday, Oct 3rd, 8AM-4PM
COST: $135/Professional, $35/Student
INSTRUCTOR: Dr Lanre Aboaba
ROOM: Directors 3

Course Description: This course will add value for petrotechnical professionals and support staff by providing a practical knowledge and a working understanding of the techniques and concepts used in the seismic interpretation process. This course provides a thorough introduction to all aspects of seismic data, from the fundamentals of the seismic method to mapping and the use of seismic attributes.

Topics include:

1. Basic interaction
   a. Tree, scene, elements
      i. Cursor modes, display inline, crossline, time slice
      ii. Navigation: jumping, stepping, interactive, random line
   b. Standard views, perspective
      i. Z-scale, color bars and clipping
   c. Pre-load data, save and restore session
2. Seismic interpretation
   a. Horizon interpretation
      i. Seeds and 3D auto track
      ii. 2D auto track, line stepping, 3D infill tracking
   b. Fault interpretation
      i. Fault planes and sticks
   c. Basic depth conversion
3. Attributes
   a. Instantaneous attributes
   b. Windowed energy
   c. Variance (aka coherence, similarity)
      i. Parameter testing
   d. Spectral decomposition
4. Bright spots and geobodies (as time permits)



Instructor: Dr. 'Lanre Aboaba received a B.Tech. in applied geophysics form the Federal University of Technology, Akure, Nigeria, an M.S in geophysics from the university of Oklahoma, and a Ph.D. in geosciences from the University of Arkansas. He has worked with Degeconek and BP. His research interests include qualitative/quantitative seismic interpretation, reservoir characterization, and rock physics. He is a member of the SEG, AAPG, NABG and TGS

Luncheons

ALL-CONVENTION LUNCHEON

Monday, October 4th 11:30am-1pm Promenade D
Cost: $45/person
Keynote Speaker: Dr Scott Tinker, Bureau of Economic Geology
Title: The Coming Energy Decade and the Role for Geoscientists

Dr Scott Tinker works to bring industry, government, academia, and nongovernmental organizations together to address major societal challenges in energy, the environment, and the economy.

Dr Tinker is Director of the 250-person Bureau of Economic Geology, the State Geologist of Texas, and a professor holding the Edwin Allday Endowed Chair in the Jackson School of Geosciences at UT-Austin.With Director Harry Lynch, Tinker coproduced and is featured in the award-winning energy documentary film Switch, which has been screened in over 50 countries to more than 15 million viewers and is used on thousands of K-through-12 and college campuses. Dr Tinker formed the nonprofit Switch Energy Alliance in 2016 and has completed two new films: Switch On, a feature length documentary addressing global energy poverty, and Energy Makes our World, a five-minute, Hollywood-quality film made for global museums and giant screens. Tinker is the voice of EarthDate, a two-minute weekly program that focuses on remarkable stories of Earth. EarthDate is produced by the Bureau of Economic Geology and is featured on over 400 NPR and public radio stations in all 50 United States.

Dr Tinker has served as president of several associations, including the American Geosciences Institute (AGI), the Association of American State Geologists (AASG), the American Association of Petroleum Geologists (AAPG), and the Gulf Coast Association of Geological Societies (GCAGS). Dr Tinker is an AGI Campbell Medalist, AAPG Halbouty Medalist, GCAGS Boyd Medalist, and a Geological Society of America Fellow. In his visits to some 65 countries, he has given over 850 keynote and invited lectures.

AAPG DIVISION OF PROFESSIONAL AFFAIRS LUNCHEON

Tuesday, October 5th 11:30am-1pm Promenade D
Cost: $45/person
Keynote Speaker: Tom Loughrey, Friezo Loughrey Oil Well Partners (FLOW)
Title: Why Oil & Gas Data is Not Your Friend

Tom Loughrey, co-founder and president of Friezo Loughrey Oil Well Partners (FLOW), has nearly 20 years investing across the oil & gas capital structure at hedge funds: Argent Fund Group, Raven Rock Capital, and Silverback Asset Management.

Tom's search for speed and accuracy led him to design and develop FLOW's unbiased valuation tools.
Tom started his career in energy investment banking at Salomon Brothers and Credit Suisse after graduation from Dartmouth. Tom received his MBA as a Tiger Fellow from the University of North Carolina.

Oral Technical Sessions

MONDAY MORNING, OCTOBER 4TH 8:00-11:30AM

Session: Sedimentology, Stratigraphy, and Reservoir Characterization of the Mid-Continent - Promenade A

8:00am Opening remarks Session Chairs: Dr Sal Mazzulo, Dr Mac McGilvery, Dr Jim Puckette

8:05am Faulting influenced valleys, Red Fork and Skinner intervals, north-central Oklahoma (Jim Puckette*, Kevin Toth)

8:35am Multiscale reservoir characterization of Mississippian strata using seismic-constrained reservoir characterization and modeling, STACK play, Anadarko Basin, Oklahoma (Matthew J Pranter*, Jerson Tellez, Michael Miller, Chris McLain)

9:05am Evidence of Lower Morrowan Incised Valleys, Southern Oklahoma (Clay Fitzgerald*, Jim Puckette)

9:35am Morning break

10:00am The tectono-stratigraphy and basin fill architecture of the Atoka-Desmoinesian succession, Arkansas Arkoma Basin (Mac McGilvery*)

10:30am New Interpretations of the Stratigraphy and Sedimentology of Siluro-Devonian Rocks in Exposures Along the Western Margin of the Illinois Basin (Brian Wilhite*, S.J. Mazzullo)

11:00am The Unrealized Unconventional Shale Play of the Eastern Mid-Continent: the New Albany Shale, Illinois Basin (Brian Wilhite*)

Session: Induced Seismicity in the Mid-Continent - Promenade B

8:00am Opening remarks Session Chairs: Dr Brett Carpenter, Scott Singleton

8:05am The Fractures of Oklahoma's Basement: Geometry, Alteration, and Associated Sedimentary Sequence Deformation (Brett Carpenter*, Paul Gilbert, Matt Hamilton, Candace Johnston, Folarin Kolawole, Max Firkins, Brittany Stroud)

8:35am INDUCED SEISMICITY: Trigger - Pressure versus Geochemistry PART 1 The Legacy Contribution of the Rangely Seismicity Experiment (Gary Rowell*)

9:05am INDUCED SEISMICITY: Trigger - Pressure versus Geochemistry? PART 2 Application of Geochemistry to The Mid-Continent (Gary Rowell*)

9:35am Morning Break

10:00am Improving Regional Earthquake Focal Depth Location in Oklahoma (Paul Ogwari*, Jacob I. Walter, Andrew Thiel, Fernando Ferrer, Isaac Woelfel)

10:30am Basement structural architecture suggestive of multiple structural regimes, Pawnee Co., NE Oklahoma (Scott Singleton*, Shane Matson)

11:00am PP and PS anisotropy and the estimation of stress state, Pawnee Co., NE Oklahoma (Scott Singleton*)

Session: Structure, Tectonics, Geomechanics and Petrophysics of the Mid-Continent - Promenade C

8:00am Opening remarks Session Chairs: Dr Molly Turko, James Van Alstine

8:05am A Structural Analysis of the Washita Valley Fault: A Smoking Gun to Evolving Pennsylvanian Tectonics? (Molly Turko*)

8:35am Some of the pre-Pennsylvanian Unconformities of Southern Oklahoma (Jerry McCaskill*)

9:05am TECTONIC EPISODES THAT CREATED THE DEPOSITIONAL PATTERNS AND STRUCTURAL TRAPS IN THE NORTHERN MIDCONTINENT (Marv Carlson*)

9:35am Morning Break

10:00am What is the Labette Fault and Why is it On Every Map (Shane Matson*, Ron Haveman, Kevin Crain, Scott Singleton)

10:30am Wellbore Cement Mechanical Enhancement by Addition of Zeolite and Graphene (Cody Massion*, Sai Vamsi Krishna Vissa, Mileva Radonjic)

11:00am Early Development of a Novel Formation Imaging Tool for Cased Hole Wells (Robert Davis*, Richard M. Bateman, D. Ray Ethridge, Andrew P. Jagger, Jonathan G. Kuespert, Marshall S. Levine, Mike Mayfield, and J. Max Weldon)

Session: One Hundred Years of Discovery: Giant Fields of the Mid-Continent and Geological History of the Mid-Continent - Diplomat Room

8:00am	Opening remarks	Session Chairs: Shane Matson, Mike Kuykendall
8:05am	Osage Giants (Bill Lynn*)	
8:35am	Shoulders of a Giant: H.V. Foster, The Indian Territory Illuminating Oil Company and the Opening of The Osage, Seminole and Oklahoma City Fields (Shane Matson*)	
9:05am	Glenn Pool Oil Field - Oklahoma's First Giant (Mike Kuykendall*)	
9:35am	Morning Break	
10:00am	Panhandle-Hugoton Field (Ray Sorensen) Lee Krystinik*	
10:30am	Pre-Drake Petroleum Literature (Ray Sorensen) Lee Krystinik*	
11:00am	A Reflection on The Development of The Paleozoic Lithostratigraphic Nomenclature In Arkansas With A Review Of The Nomenclatorial Standards And Proposal Requirements (Noah Morris*, Walter L. Manger)	

MONDAY AFTERNOON, OCTOBER 4TH 1:10-5:05PM

Session: Sedimentology, Stratigraphy, and Reservoir Characterization of the Mid-Continent - Promenade A

1:10pm	Opening remarks	Session Chairs: Dr Sal Mazzulo, Dr Mac McGilvery, Dr Jim Puckette
1:15pm	The Excello Shale of Northeast Oklahoma Revisited: Not the Kansas Mulky (John McLeod*)	
1:45pm	Diagenetic Controls on Reservoir Quality of the Sycamore Formation, northern Ardmore Basin, Oklahoma (David Duarte*, Benmadi Milad, R. Douglas Elmore, Matthew J. Pranter, and Roger Slatt)	
2:15pm	From rocks to models revisited: using machine learning techniques to link thin-section petrography and 3D facies modeling (David Duarte*, Matthew J. Pranter)	
2:45pm	Afternoon Break	

Session: Advances in Seismic Reservoir Characterization and Imaging - Promenade A

3:00pm	Opening remarks	Session Chairs: Ryan Fairfield, Scott Singleton
3:05pm	Changes in structural style through the Paleozoic, Pawnee Co., NE Oklahoma (Scott Singleton*, Shane Matson, Ron Haveman)	
3:35pm	Seismic Characterization of Shoestring Sands on the Osage Uplift, Northeastern Oklahoma (Shane Matson*, Ron Haveman, Scott Singleton)	
4:05pm	Finding Geology in 3D Seismic Gathers (Mark Falk*, Mike Lovell, Marianne Rauch)	
4:35pm	Correct Reservoir Size Estimation with Depth imaging: more than just a single process (Robert Springman*, Scott Boyer)	

Session: The Next Age of Making a Profit in the Mid-Continent: Unconventional and Conventional Plays - Promenade B

1:10pm	Opening remarks	Session Chairs: Bob Von Rhee, Drew Thomas, Ron Snyder
1:15pm	The Greater Anadarko Basin-Drilling and Production Trends in the First Two Decades of the 21st Century (John Mitchell*)	
1:45pm	The Value of Curiosity: Reimagining the Exploitation of Mature Mid-Continent Conventional Reservoirs to Produce Significant Incremental Reserves (Scott Robinowitz*)	
2:15pm	A Data-Driven Approach to Geology and Spacing Optimization in the Meramec (Evan Macdonald*, Drew Depoe, David Law)	
2:45pm	Afternoon Break	

3:00pm Remarks
3:05pm Advanced Wellsite Geochemistry for Light Hydrocarbon Analysis Unconventional Systems (Andrew Sneddon*, Sheng Wu, Le lu)
3:35pm Geochemical Evaluation of Oil and Gas Samples from the Upper Devonian and Mississippian Reservoirs Southern Anadarko Basin Oklahoma and its Implication for the Woodford Shale Unconventional Play (Michael Abrams, Drew Thomas*)
4:05pm Combining fracture depletion mapping from drilling data with Image logs to better understand fracture driven interactions (Kevin Wutherich*)
4:35pm Impact of Detrital Clay on Reservoir Properties, Distal Marmaton Granite Wash, Roger Mills County, Oklahoma (Autumn Graf*, Jim Puckette)

Session: Energy Evolution: Future of Energy- 21st Century and Beyond: Data Analytics, Machine Learning, and GIS - Diplomat Room

1:10pm Opening remarks Session Chair: Joe Wicker
1:15pm Using an Integrated Geomodel to Assess of the Howard-Glasscock Nose area, Midland Basin (Daniel Woody*, Maria Fernanda Kelley, Tammy Campbell, Joe Wicker, Amy Close, Zach Poland, Craig Andrews)
1:45pm High Resolution Petrophysical Property Distribution Utilizing Multi-Variate Analytics (Joe Wicker*, Zach Polland, Daniel Woody, Tammy Campbell)
2:15pm Implementing an Oil Field Data Repository with ArcGIS Online: Osage County, Oklahoma (Mark Cooper*)

Session: Insights from the Permian Super Basin - Diplomat Room

3:00pm Opening remarks Session Chair: Tim Phillips
3:05pm The West Texas (Permian) Super Basin: prototype and analog (Bill Fairhurst*, Tom Ewing, and Bob Lindsay)
3:35pm Geological Characterization of the 3rd Bone Spring Lime for Development Optimization: A Case Study in the Central Delaware Basin (Tim Phillips*, Zak Ward, John Stachowiak, Sloan Anderson)

Special Session: Climate Change, Practicalities of Energy Evolution, and the Future Energy Mix - Promenade C

1:10pm Opening remarks Session Chair: Lee Krystinik
1:15pm Changing Energy Mix: Paul Meier

Paul Meier works as an independent consultant, having retired from ConocoPhillips in 2008 after 30 years of service, where he was a research fellow, working on projects including S ZorbTM sulfur removal technology, catalytic cracking, heavy oil upgrading and modeling, multi-company research alliances for the DOE hydrogen vehicle and oxygen transport membrane (OTM) research, Fischer-Tropsch catalyst research, heavy metals removal from wastewater, process modeling for fluidized and fixed bed processes, experimental thermodynamics, catalytic hydrogenation, and vapor liquid equilibrium and liquid density studies for shale oil. He then worked as a clean fuels consultant for Sinopec, the China Petroleum and Chemical Corporation and gave lectures at R&D centers around China on topics such as Alternate Energy, Clean Coal Technology, and R&D Management Issues. He has consulted with ConocoPhillips on CO2 capture and sequestration and ADI Analytics (in Houston) on plastics recycling to crude oil and octane models.

Paul has 15 patents and numerous published papers and presentations. At ConocoPhillips, he earned

several corporate awards, and most noteworthy were the SPIRIT award for a project reaching commercial success, a Technology Innovation award, and the Lifetime Achievement Individual award.

Paul received a BS degree in Chemistry from the University of Arkansas, and an MA and a PhD in Physical Chemistry from Rice. He is also a registered professional engineer and is member of several professional societies including the American Chemical Society, the Oklahoma Society of Professional Engineers, the National Society of Professional Engineers, and Sigma Xi.

2:00pm Facts vs Fears: What does the Data Tell Us About Climate Change and the Future of Energy? Lee Krystinik

Lee F. Krystinik specializes in applied sedimentary and stratigraphic analysis to predict clastic reservoirs and has a Ph.D. in geology from Princeton University. Krystinik has held positions as Manager of Geology at Union Pacific Resources, Global Chief Geologist for ConocoPhillips, Co-founder of Fossil Creek Resources and is now a founding Partner in Equus Energy Partners, an exploration partnership that uses new technologies in the search for overlooked targets.

His areas of interest include syn-tectonic sedimentation and other controls on basin-fill architecture, integrated play assessment, and cost-effective implementation of new concepts and technology. Dr. Krystinik has been an AAPG Distinguished Lecturer in North and South America and he is a past President of both SEPM and AAPG.

2:45pm Afternoon Break

3:00pm Climate Change, Misleading Policy Making & The Road Ahead: Dennis Hedke

Dennis Hedke is a Consulting Geophysicist, Principal at Hedke Geoscience Consulting, LLC, based in Wichita, KS. He obtained his B.S. In Geophysics from Kansas State University, and his M.S. in Materials Science from the University of Virginia School of Engineering and Applied Science.

Over the course of his career, he has worked primarily with small to mid-sized Independent Oil and Gas firms, in roles from Staff Geologist/Geophysicist, including position of Geophysical Manager. Additionally, he has held Senior Management positions in a publicly traded company.

He has exploration and development experience in multiple US Basins in the Mid-Continent and Rocky Mountain regions, as well as abroad in the countries of Colombia, South America, and Chad, Africa, Turkey and Azerbaijan.

He was involved in a research project managed by the Kansas Geological Survey, funded by the U.S. Department of Energy, over the course of many years, utilizing both conventional p-wave, as well as Multi-Component seismic, over many significant hydrocarbon accumulations in both clastic and carbonate reservoirs.

He was appointed by the Governor of Kansas to fill a vacancy in the House of Representatives, commencing in January 2011. He was then appointed in December 2012 to be Chairman of the House Energy & Environment Committee, a position he held until he retired at the close of the 2016 Session.

Past-President of the Kansas Geological Society (1998)

Past-President of the Kansas Geological Foundation (2019-20)

Co-Founder and Past-President of the Geophysical Society of Kansas (2008)

Active Member of the AAPG and the SEG

3:45pm "Same as it Never Was: Navigating the Accelerating Change with a Little Help from the AAPG" by Gretchen Gillis, AAPG President

MONDAY, OCTOBER 4TH 4:30-6:30PM

PANEL DISCUSSION - Show Me the Money: The Business Side of the Petroleum Industry - Promenade B

Session Chair: Kristie Ferguson

The last couple of years in the oil and gas business have been volatile, to say the least, even in an industry all too familiar with the boom-and-bust cycles. The 2020 downturn during the COVID pandemic that some called a "black swan" (or cluster-flock) was the most significant downturn experienced by many of the "new guard" in the industry. This panel discussion is set to cover topics from the massive shift of investments, ESG, and how to navigate the future. The panel will also discuss deal structures of the future and how they will differ from those in the past. You won't want to miss this dynamic group of speakers who will cover key financial drivers that will impact us now and in the future!

Speakers

Richard Ball, Director, Detring Energy Advisors

Richard Ball is a Certified Petroleum Geologist who worked both conventional and unconventional reservoirs with Chevron for 10 years, including onshore US, Gulf of Mexico Shelf/Deep Water, and West Africa Shelf. He has served as Treasurer and Secretary on the AAPG Executive Committee and continues to serve as Councilor for the AAPG Division of Professional Affairs. Mr. Ball is a proud graduate of Stephen F. Austin State University and the University of Louisiana at Lafayette, where he earned his B.S. (2005) and M.S. (2007), respectively. Richard joined Detring Energy Advisors at the end of 2016. Since then, he has assisted the company in completing over $2.8B of transactions and launching Petro Divest Advisors, a small-cap advisory firm.

Gavin McQueen, President and COO, Sage Natural Resources

Gavin McQueen is a Petroleum Engineer with experience in production, completions, facilities and reservoir engineering in Texas, Oklahoma, Louisiana, North Dakota and Wyoming. Gavin has led technical teams pursuing asset development, acquisitions and divestitures, and as a corporate planner in development of long-range planning, deterministic and statistical models, process optimization, and financial integration and restructuring. Previous employment was with XTO Energy and Samson Resources. Currently he leads Sage Natural Resources and Sage Power and Reliability Company ("SPARC") as its President and COO. Sage owns and operates over 500 wells in the Ft. Worth Basin and is actively drilling and developing its assets.

Gavin attended Texas A&M University where he received a bachelor's degree in Petroleum Engineering and minor in Geology. Gavin received the Robert L. Whiting Outstanding Student in Petroleum Engineering upon graduation. He is a member of the Society of Petroleum Engineers, Mid-Continent Section.

Dick Stoneburner, Managing Director, Pine Brook Partners

Mr. Stoneburner joined Pine Brook in April 2013 and is a managing director on the energy investment team. Mr. Stoneburner represents Pine Brook as a director of Accelerate Resources Holdings, LLC; Brigham Minerals, LLC; Pursuit Oil & Gas, LLC; Elevation Resources, LLC and Saguaro Resources, LLC.

Mr. Stoneburner has over 42 years of experience in the oil and gas industry. He served as president of the North America Shale Production Division for BHP Billiton Petroleum from 2011 to 2012. From 2009 to 2011, Mr. Stoneburner served as president and chief operating officer of Petrohawk Energy Corporation. He was the company's chief operating officer from 2007 to 2009 and led their exploration activities as vice president and then executive vice president of exploration from 2003 to 2007. Mr. Stoneburner began his career as a geologist in 1977 and held positions at Texas Oil and Gas Corp., Weber Energy Corp., Hugoton Energy Corp. and 3TEC Energy Corp.

Mr. Stoneburner is Non-Executive Chairman for Tamboran Resources and is an advisor to Ayata. He also serves on the advisory council of The Jackson School of Geosciences at the University of Texas at Austin, on the visiting committee of the Bureau of Economic Geology at the University of Texas at Austin and is a board member of Switch Energy Alliance. He is also a former board member for Memorial Assistance Ministries and past President and former board member of the Houston Producers Forum.

Mr. Stoneburner holds a B.S. in Geological Sciences from the University of Texas at Austin, an M.S. in Geological Sciences from Wichita State University, was a member of the American Association of Petroleum Geologist's Distinguished Lecturer Series in 2012-2013 and was awarded the Norman Foster Outstanding Explorer of the Year award by the AAPG in 2016.

Bryan Lemmerman, Chief Financial Officer, Laredo Petroleum
Bryan Lemmerman joined Laredo in June 2020 as Senior Vice President and Chief Financial Officer. Mr. Lemmerman has more than 15 years of experience in the energy exploration and production industry, including an extensive background in strategic planning and business development. He previously spent 10 years with Chesapeake Energy Corporation, serving in financial roles with increasing responsibility, most recently as Vice President – Business Development and Treasurer. Prior to joining Chesapeake, Mr. Lemmerman was a portfolio manager at Highview Capital Management and Ritchie Capital Management, overseeing investments in public and private energy companies. He began his career as a tax consultant with Deloitte & Touche. Mr. Lemmerman holds a Bachelor of Business Administration in Accounting and Master of Science in Accounting from Texas A&M University and a Master of Business Administration from the University of Texas.

TUESDAY MORNING, OCTOBER 5TH 8:00-11:30AM

Session: The Anadarko Super Basin - Promenade A

Session Chairs: Rick Fritz, John Mitchell

8:00am	Opening remarks
8:05am	Key Traits of the Anadarko Super Basin (Rick Fritz*)
8:35am	Woodford Shale Plus of the Anadarko Super Basin (Rick Fritz*, John Mitchell)
9:05am	The Anadarko Super Basin: An Examination of the Pennsylvanian Total Petroleum System (John Mitchell*)
9:35am	Morning Break
10:00am	The Birth and Tectonic Evolution of the Anadarko Super Basin (Molly Turko*)
10:30am	Pressure revisited: Examining the Relationship between Pressures, Migration, and Production in the Anadarko Basin (Jim Puckette*)
11:00am	The Anadarko Basin: A Super Past and Challenging Unconventional Future (Andrew Cullen*)

Session: Geochemistry and Basin Modeling of Mid-Continent Petroleum Systems - Promenade B

Session Chairs: Mike Smith, Wahid Rahman

8:00am	Opening remarks
8:05am	Analyzing Formation Water in Cuttings (Mike Smith*)
8:35am	High Resolution Unconventional Reservoir Modeling of Devonian Strata in the Midcontinent Arkoma Basin Utilizing Rock Volatile Analysis (Jamar Bynum*, Mike Smith, Chris Smith)
9:05am	Volatiles Analysis of Cuttings from Eagle Road Oil's Eisenhower 7-22N-4E Mississippian Lime Lateral in Pawnee County, Oklahoma, to Assist in Developing and Defining a New Oil Play (Chris Smith, Shane Matson, Timothy Smith, Patrick Gordon, Mike Smith*)
9:35am	Morning Break
10:00am	Organic Geochemistry on Assessment of Petroleum Fluid Phase Behavior, Migration Pathways, and Petroleum Systems Analysis: A Case Study from Anadarko Basin, Oklahoma, USA (Wahid Rahman*)
10:30am	Investigation of the Genetic Relationships between Oils in Western Kansas – USA (Henry Agbogun*,

Hendratta Ali)

Session: Energy Evolution: Future of Energy- 21st Century and Beyond: Energy Minerals, Alternate Resources, and Carbon Capture, Utilization, and Storage - Promenade C

8:00am Opening remarks **Session Chairs: Jesse Edmonson, Billy Coffey, Kelsey Putman Hughes**
8:05am The Case for Building Domestic Supply Chains of Critical Minerals (Jesse Edmonson*)
8:35am Structural Geology: An Exploration Tool for Sediment-Hosted Metals (Molly Turko*)
9:05am Solar Solutions for Oklahoma's Oil and Gas Producers (Kelsey Putnam-Hughes*, Drew Thomas, Travis Fultz)
9:35am Morning Break
9:55am Remarks
10:00am Developing a Geothermal Technology Strategy for the Mid-Continent Incorporating the Approaches Used in Other Parts of the U.S. and the World (Susan Nash*)
10:30am Integrated 3D Geology and 3D Gravity Interpretation Identifies Energy, Minerals, Carbon Sequestration, and Hydrologic Systems (Kevin Crain*, Shane Matson)
11:00am Geologic Framework of an Anthropogenic Carbon Capture and Sequestration System at the Kemper County Energy Facility, East-Central Mississippi (Conn Wethington*, Mercy Achang, Jack Pashin, and Stone Urban

TUESDAY AFTERNOON, OCTOBER 5TH 1:15-4PM

Special Session: Success in the Anadarko: Ovintiv's "Never Satisfied" Approach to Petroleum System Learning, Multi-discipline Collaboration, and Operational Efficiency - Promenade A

This special half day session offers an opportunity for the STACK team at Ovintiv to highlight their work in the Anadarko. Ovintiv's collaborative success in the Meramec STACK play is the result of understanding the total petroleum system and significant gains in operational efficiency. Understanding the source, migration, reservoir, and seal is just as critical in an unconventional play as in a conventional play.

1:15pm The Importance of Basin Depositional Understanding to the Petroleum System In the STACK/SCOOP play (A. Leavitt*, K. Xue, J. Sinclair, R. Brito, O. Djordjevic)
1:25pm Core/Petrographic Facies Tied to Log Based Facies across the Meramec and Woodford: Application to Understand Well Performance and Depositional Environment (K. Xue*, R. Brito, C. Cross, C. Guenard, J. Sinclair)
1:55pm Understanding of Fractures and Faults in the Anadarko Basin to Understand/Predict Well Performance and Potential Seismicity Mitigation Planning (O.J. Teran*, S. Maxwell, S. Doss, C. Guenard, M. Martin, J. Sinclair, A. Leavitt)
2:25pm The Use of Permanent and Dip-in Fiber Technology to Understand Cross Well Strain of Hydraulic Stimulations and the Interaction of Natural Fractures in Completion Operations and Parent Well Mitigation (S. Maxwell*, O.J. Teran)
2:45pm Afternoon Break
3:00pm Evaluating the STACK and SCOOP Rock and Petroleum System History: Combined Rock Volatiles and Petrophysics Data of Cored Wells Across the Anadarko Basin (M. Smith*, J. Sinclair*, C. Smith, A. Leavitt)
3:20pm Bringing it All Together for Data Driven Decisions Making (M. Tabatabaei*, J. Sinclair, A. Leavitt)
3:40pm Ovintiv's "Never Satisfied" Approach to Petroleum System Learning, Multi-discipline Collaboration, and Operational Efficiency (Aaron Leavitt*)

POSTER SESSIONS

Poster Hall and Oklahoma Ballroom

Poster Session Chair: Sarah Darby

MONDAY, OCTOBER 4 8:00AM-6:00PM Authors present 9:30-10:30 AM & 2-3PM

Booth 1 Multiscale Characterization of the Caney Shale – A Case Study from Southern Oklahoma (Yulun Wang*, Guofan Luo, Allan Katende, Julie Cains, Mercy Achang, Conn Wethington, Jim Puckette, G. Michael Grammer, Jack Pashin, George E. King, Mileva Radonjic)

Booth 2 Integrated Seismic Analysis: Using Model-Based Inversion to Predict Geologic Reservoir Properties for Carbon Storage (Paiden Pruett*, Camelia C. Knapp)

Booth 3 Conodont Constrained ages of Mississippian Carbonate-Siliciclastic Sequences, STACK Play, Oklahoma (Jim Puckette*, Brandon Stukey, Cory Godwin)

Booth 4 Applications of first-arrivals travel time tomography on improving static errors corrections in 3-D land seismic processing (Cody Totten*, Abdelmoneam Raef)

Booth 5 Joints in the Middle-Pennsylvanian McAlester Formation, Ft Smith, Arkansas (Jacob McLain*, Dave Mayo)

Booth 6 AN INTEGRATED APPROACH FOR SHEAR WAVE VELOCITY ESTIMATION IN GAS SATURATED RESERVOIRS (Joshua Ademilola*, Seyi Obafemi)

Booth 7 Sedimentology, Depositional Environment, and Stratigraphic Hierarchy of Upper Cretaceous Tuscaloosa Marine Shale in Central U.S. Gulf Coast (Wan Yang*, David Borrok, Mehdi Mokhtari, Efren Mendez)

Booth 8 Evaluation of unsupervised machine learning methods for seismic facies classification: Applications on Reservoir Characterization in the Cenozoic Deep-water Strata, Australia (Laura Ortiz Sanguino*, Karelia La Marca, Heather Bedle)

TUESDAY, OCTOBER 5 8:00AM-1:00PM Authors present 9:30-11AM

Booth 1 Petrophysical analysis of Mississippian rock types and reservoir properties within a sequence-stratigraphic framework, eastern Anadarko Basin, Oklahoma, USA (Fnu Suriamin*, Matt Pranter)

Booth 2 Simulation of carbon dioxide injection for enhanced oil recovery from shale reservoir, onshore midcontinent. (Sreejesh Sreedhar*, Camelia C. Knapp, James H. Knapp)

Booth 3 Quantitative Evaluation of CO2 Storage Potential in Atlantic Offshore Lower Cretaceous Strata, Southeastern United States (Dawod Almayahi*, James H. Knapp, Camelia Knapp)

Booth 4 Review of Effective Technological Developments for Existing Oil and Gas Fields and Future New Energy in the Energy Transition (Susan Nash*)

Booth 5 Blended Solar and Natural Gas Solutions for ESG and Risk Management (Susan Nash, AAPG)

Booth 6 Joints in the Middle-Pennsylvanian McAlester Formation, Ft Smith, Arkansas (Jacob McLain*, Dave Mayo)

Booth 7 Fossil Fuel Industries are an Important Component to The Earth's Carbon Cycle of Life (Curtis Faulkner*)

Booth 8 Removal of mixture heavy metals and metalloids from petroleum produced water by dolomite filtration (Khalid Haji Omar*, Javier Vilcaez)

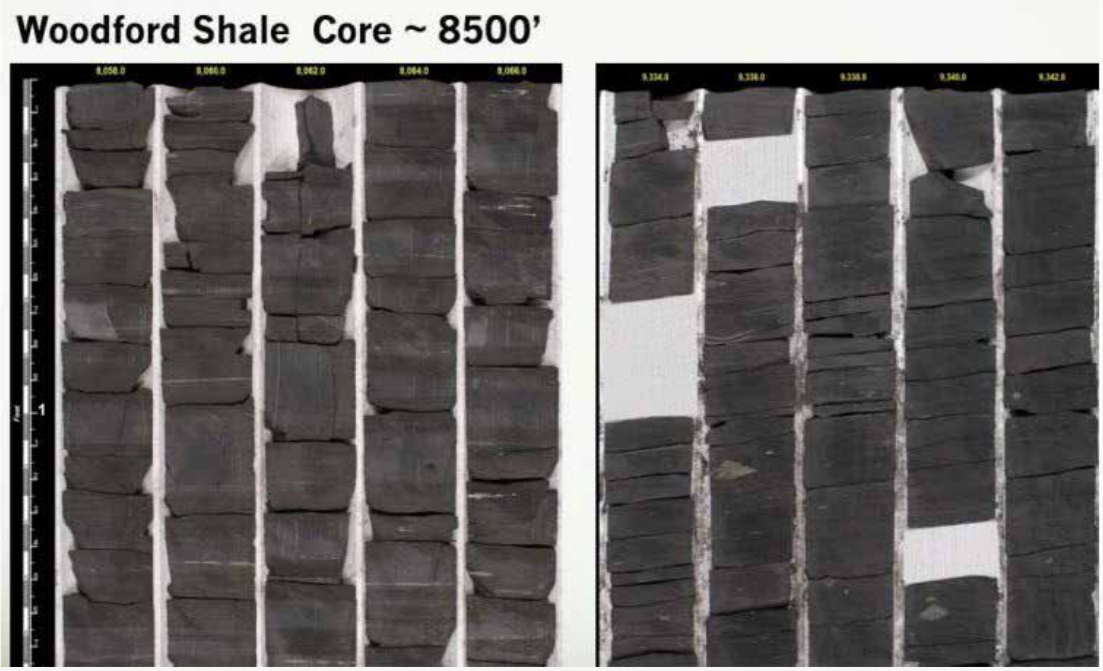
Booth 9 Hiatus Mapping in Texas (Nikola Bjelica*, Lorenzo Colli, Magdalena Ellys Curry, Andrew S. Madof)

Booth 10 The Relationship Between Early Paleozoic Faults on Shallow Permian Aged Strata Using Seismic Attributes in Northwest Ector County, Texas (Jozef Szypulski*)

CORE EXHIBIT

Poster Hall

What is a geology convention without real rock?!? We will also have a core exhibit in the poster hall at the convention. The core provided- 180'- represents a portion of one of the most drilled horizontal targets in Oklahoma, the Devonian Woodford Shale. With TOC averaging 4-6% and maturity ranging from black oil to dry gas, the Woodford is a world class source rock providing a large amount of the hydrocarbons historically produced from Oklahoma. This core specifically comes from the SCOOP (South Central Oklahoma Oil Province) play, which has been drilled horizontally since ~2010 with great success.



Woodford Core photo credit: Ken Wolgemuth

PROSPECT EXPO

MONDAY 8AM-5PM AND TUESDAY 8AM-1PM FOYER

The prospects will be shown in the Downstairs Foyer during the time the Poster Exhibit Hall is open. Come talk to sellers and see some prospects!

MONDAY, OCTOBER 4

Session: Sedimentology, Stratigraphy, and Reservoir Characterization of the Mid-Continent Monday AM/PM

Faulting influenced valleys, Red Fork and Skinner intervals, north-central Oklahoma

Jim Puckette, Kevin Toth, Oklahoma State University*

This study was undertaken to determine the controls of the distribution of valley filling sandstone within the Pennsylvanian (Desmoinesian) Red Fork and Lower Skinner sequences in parts of Noble, Pawnee and Osage counties, Oklahoma. The principal trend of interest exhibits linear distribution patterns for the both the Red Fork and Lower Skinner sandstones that differ from regional sediment dispersal systems and results in the stacking of reservoirs. The sandstone-bearing channels at the focus of this study are highly elongated and narrow (>10 mi long and<1 mi wide) (16 km and 1.6 km), contain thick sandstone bodies (50-200 ft thick) (15-60 m), and are unexpectedly stacked. These observations prompted the hypothesis that accommodation was generated along the same trend across two 4th order high-frequency cycles for a cumulative time span ranging from 0.4-1.0 million years. Mapping using wireline logs and a 3D seismic volume that covers the central part of the study revealed that the distribution of these narrow, channel-filling, "shoestring" sandstones could be delineated using the abundant wireline log control in this mature area. However, if the orientation of these channels was influenced by faulting, these faults were not indicated by missing section on wireline logs or changes in contour gradient on structure and thickness maps constructed using log data. The 3D seismic volume covering part of the study area in Noble and Pawnee counties, including these "shoestring" channels, provided data necessary to delineate fault offsets in the pre-Pennsylvanian section. It is proposed that these faults influenced paleotopography and drainage patterns during Cherokee deposition and that erosion favored the fault-influenced topographic lows, generating valleys that subsequently filled during transgression. Furthermore, Cherokee paleotopography was quite different from pre-Pennsylvanian paleotopography as inferred from interval thickness maps and the distribution of Mississippian Chat. By detecting offset and a potential causative fault at the contact between the Mississippian carbonate section and overlying Pennsylvanian siliciclastics, seismic data provide an additional exploration tool to infer the position of shallower Pennsylvanian "shoestring" sandstone reservoirs.

Multiscale reservoir characterization of Mississippian strata using seismic-constrained reservoir characterization and modeling, STACK play, Anadarko Basin, Oklahoma

Matthew J Pranter, Jerson Tellez, University of Oklahoma, Michael Miller, Pioneer Natural Resources, and Chris McLain, Marathon Oil Company*

Mississippian Meramec reservoirs of the Sooner Trend in the Anadarko (Basin) in Canadian and Kingfisher Counties (STACK) play are comprised of silty limestones, calcareous siltstones, argillaceous calcareous siltstones, argillaceous siltstones, and mudstones. We found that core-defined lithologies are related to petrophysics-based rock types derived from porosity-permeability relationships using a flow-zone indicator approach. We classified lithologies and rock types in non-cored wells using an artificial neural network (ANN) with overall accuracies of 93% and 70%, respectively. Mudstone-rich rock type 1 exhibits high clay and relatively low calcite, whereas calcareous-rich rock type 3 has high calcite and low clay content with rock type 2 falling between rock types 1 and 3. Results of the ANN were applied to a suite of well logs in non-cored wells to generate lithology and rock-type logs. The Meramec consists of seven stratigraphic units characterized as shoaling-upward parasequences. Key faults were interpreted using 3D seismic, seismic attributes, and well data. We used seismic variance to interpret fault-damage zones.

To address the stratigraphic and structural controls on the lithological and petrophysical heterogeneity of the Meramec, we used machine learning and geostatistical methods to develop well-constrained 3D reservoir models of lithology, rock types, and petrophysical properties. The models integrate the stratigraphic and structural framework with data from core, thin sections, core-plug ultrasonic velocity measurements, well logs, 3D seismic, and seismic attributes. We estimated and compared rock brittleness index (BI) using two laboratory-based measurements from core data: mineralogical- and mechanical-derived BI. We used velocity measurements and well logs with an artificial neural network approach to establish relationships among the geomechanical properties and acoustic impedance. We then applied these relationships to generate 3D geomechanical models constrained to seismic volumes.

The data and reservoir models illustrate: 1) a relationship between the stratigraphic hierarchy and associated parasequence and parasequence set stacking and different scales of facies and reservoir variability, 2) structural controls on channelized deposits, 3) an inverse relationship between hydrocarbon production and distance from interpreted fault-damage zones, and 4) the critical role of stratigraphic stacking patterns for horizontal well placement.

Evidence of Lower Morrowan Incised Valleys, Southern Oklahoma

Clay Fitzgerald, Jim Puckette, Oklahoma State University*

Early Pennsylvanian (Morrowan) incised valleys contain reservoirs with a long history of oil and gas production across the southern midcontinent. Literature is rich with papers describing well known oil and gas accumulations in Morrowan rocks from Colorado to Arkansas. Many of these oil and gas fields occur in the Upper Morrow, but reservoirs formed as fill in incised valleys are prevalent in the Lower Morrow as falling sea level exposed the Mississippian shelf generating accommodation that is interpreted to have filled mostly during subsequent transgression. As many as seven high frequency cycles are recognized in the Morrowan and many Lower Morrowan sandstone reservoirs developed immediately above the Pennsylvanian/Mississippian unconformity. These reservoirs have been assigned a variety of local and operational names including Keyes in Cimarron County, Oklahoma to Cromwell in southern Oklahoma and the Arkoma basin. This study focuses on an area of thicker Cromwell sandstone in southern Seminole, western Hughes, and eastern Pontotoc counties, Oklahoma. This area has a long history of oil and gas production from the "Upper Cromwell Sand" but contains thicker sections of "Lower Cromwell Sand" distributed at a high oblique angle to sandstone trends in the upper part of the Cromwell interval. Higher resolution stratigraphic correlations demonstrate that sandstone bodies in the lower Cromwell interval appear to thicken at the expense of the underlying shale called the Springer Shale. Thickness maps of the Springer Shale and overlying Lower Cromwell sandstone clearly demonstrate this relationship and prompted the explanation that the Lower Cromwell sandstone represents an incised valley fill that formed following erosion of the Springer Shale. No cores were available for the Lower Cromwell sandstone, but wireline log data augmented with cores of the marginal marine to marine Upper Cromwell sandstone were used to reconstruct depositional history. It is proposed the Springer Shale was incised during the falling stage and lowstand systems tracts to generate accommodation. Lower Cromwell sand accumulated in valleys mostly during transgression, which culminated with mud deposition during maximum flooding. Abundant sediment supply in the subsequent highstand resulted in a return to sand-rich conditions during Upper Cromwell time.

The tectono-stratigraphy and basin fill architecture of the Atoka-Desmoinesian succession, Arkansas Arkoma Basin

Mac McGilvery, University of Arkansas*

The Atoka Formation in the Arkansas Arkoma Basin provides an excellent example of the interaction of eustacy, subsidence, and sediment supply on the stratigraphic architecture and internal depositional systems of the succession. The Lower Atoka records high frequency cyclicity that took place on the Northern Arkansas Structural Platform that predated the Arkoma foreland basin. The platform was very low relief and tectonically stable. Glacio-eustatic changes in sea level resulted in rapid and long-distance shifts of the paleo shoreline on the order of 60 to 100 miles. The lower Atoka is characterized by thin, repetitive shore zone/deltaic and shelf deposits. The Middle Atoka records the onset of rapid tectonic subsidence and the transition to large scale shelf to basin systems. The proximal shore zone/deltaic successions are thicker and exhibit a lower frequency of cyclicity. These marginal marine systems fed large scale slope and basin systems that included, delta-fed slope aprons, Lower slope fan systems, and large scale, aggradational basin floor complexes. These basin floor complexes are comparable in thickness and scale to that of the Jackfork Fm. of the Ouachita Mountains as well as the Paleogene and Miocene systems in the deepwater Gulf of Mexico Basin. The Upper Atoka and Desmoinesian succession records the transition to sediment supply as the dominant factor in stratigraphic cyclicity as tectonic subsidence begins to diminish ahead of the final collision of Gondwana with Laurasia during the formation of the super continent Pangea. The basin fill history of the Arkoma Basin shares some similarity with other foreland basins around the world such as the Eocene fill of Spitsbergen Svalbard, The Cretaceous fill of the Coleville Basin North Slope Alaska, and the Permian fill of the Karoo Basin. These are all exciting and unique places to study geology but be reminded our Midcontinent geology is just as cool and much more accessible. A series of updated log cross sections will be presented to illustrate the three-fold tectonostratigraphic subdivision of the Atoka as well as the systematic change in log motif from shelf to basin. The similarities to the other foreland basins previous mentioned will be illustrated.

New Interpretations of the Stratigraphy and Sedimentology of Siluro-Devonian Rocks in Exposures Along the Western Margin of the Illinois Basin

Brian Wilhite, Woolsey Petroleum, S.J. Mazzullo, Wichita State University*

Petroleum reservoirs in the Silurian and Devonian (S-D) in the Illinois Basin have produced more than 350 MMBO, primarily from presumed Silurian "pinnacle reefs" and draping Middle Devonian carbonate rocks and sandstones. These rocks are exposed along the western margin of the basin, and their study allows critical evaluation of long-held interpretations of their stratigraphy

and depositional environments, and comparison to numerous cores of correlative subsurface reservoirs. The exposures include a vertical section from the Silurian St. Clair Limestone to basal strata of the Upper Devonian New Albany Shale Group. Our outcrop and subsurface studies suggest that the Silurian (Wenlockian) St. Clair and overlying argillaceous and typically reddish/greenish Moccasin Springs (Ludlovian to basal Pridolian) limestones are lime mud-dominated and of very shallow-water origin. Although the latter formation, which is markedly erosionally-truncated, has long been considered the unit in which pinnacle reefs developed, no such reefs have been identified in outcrops or in the subsurface. Rather, we show that recurrent reef and bank-facies packages are present in surface exposures, and in the subsurface, in the Silurian-Lower Devonian (Pridholian to Siegenian), Bailey Limestone. This formation is regionally progradational and deepens into the subsurface. Rather than being a separate lithologic unit overlying the Bailey, the Grassy Knob Chert actually is a surficial weathered section and it is not present in the subsurface. The superjacent Little Saline Limestone (Missouri)-Backbone Limestone (Illinois) and its deepwater equivalent, the Clear Creek (all Emsian), unconformably overlies the Bailey and marks the uppermost Lower Devonian of the Tippecanoe II Supersequence in the basin. Sandstones in the basal part of the erosionally-truncated Middle Devonian (Eifelian) Grand Tower Limestone represent nearshore marine to perhaps tidal channel deposits. In contrast, sandstones in basal beds of the overlying Middle Devonian (Givetian) St. Laurent Limestone (Missouri) include nearshore-marine and thick eolian dunes. Abundant sand grains in the very arenaceous, mud-dominated limestones at the top of the formation likely are wind-derived. These Middle Devonian rocks have many internal disconformities and pass regionally down-dip to shallow-water and moderate-depth lime muds and shales of the Lingle Formation (upper Eifelian to Givetian) in Illinois and Missouri.

The Unrealized Unconventional Shale Play of the Eastern Mid-Continent: the New Albany Shale, Illinois Basin

Brian Wilhite, Woolsey Petroleum*

The Upper Devonian New Albany Shale (NAS) is the primary source rock for the 4.3 billion barrels of oil produced from conventional reservoirs in the Illinois Basin. Once thought to be thermally immature and not a valid unconventional target, recent study suggests that the Grassy Creek (GC) Formation of the NAS indeed is a mature source rock. Eleven wells (1 horizontal) were drilled across the basin; in 9 of them the entire NAS section was cored for reservoir and prospectivity evaluation. The GC comprises the upper half of the NAS Group and is as much as 150'+ thick. The shales have TOC concentrations as high as 11% and average of 6.5%. Vitrinite is rare, and when present has suppressed Ro values (0.7+). Other proxy indicators for maturity, i.e. Tmax, average 445 (max. 448), and CAI values are 2.5-3.0. Both parameters indicate higher maturity than Ro suggests, putting the GC in the wet gas window. Petrophysically the GC compares well with plays elsewhere, such as the Utica/Point Pleasant, Duvernay and the Woodford. Pore types include organo, desiccation, interparticle and fracture porosity, and average 5% to as high as 7+%. Permeability averages 50 nD but is as much as 170+ nD. Poisson's Ratio and Static Young's Modulus illustrate the rocks to be brittle, and XRF analysis suggests biogenic silica to be the contributing factor to the brittleness as there is no chert. Effective hydrocarbon porosity is in excess of 70% and calculates to 25 MMSTBO/640 acres. Geochemical and petrophysical properties increase in quality toward the interior of the modern-day basin center. Vertical wells had shows of both gas and live oil upon completion, and some wells had sustained albeit non-economic, short-lived production. Produced gas is very rich at 1,500 BTU, and oil from the shale is light green with a gravity of 44o. Gas chromatograph analysis of the oil shows prominent light ends, and matched the rock extracts, which suggest that produced oil is sourced in-situ. One horizontal well was drilled updip from the basin center, on the eastern-shelf in Indiana and, although only 47% of the lateral was completed, it had a daily maximum production of 400 MCF & 45 BO. Based on geochemical and petrophysical properties, and production in an updip, less mature part of the basin, the NAS (i.e., the Grassy Creek) is a valid unconventional target.

The Excello Shale of Northeast Oklahoma Revisited: Not the Kansas Mulky

John McLeod, Source Rocks International*

The Pennsylvanian (Desmoinesian) Excello shale (Cabiness Group, Senora Formation) is a world-class black phosphatic petroleum source rock deposited in a restricted shelf environment that spanned portions of the Cherokee Platform in northeast Oklahoma and southeast Kansas, the Forest City Basin in eastern Kansas and western Missouri, and the Illinois Basin. From 1994 through 2009, more than 400 wells were completed in the formation in an area north of Tulsa to exploit a broad shallow natural gas resource. At the time of their development, these wells were described as Mulky producers, named for a prominent Pennsylvanian coal that was extensively mined in southeast Kansas. In the mining district, Excello shale overlies Mulky coal with little stratigraphic separation. In Oklahoma, however, the Mulky coal is thin or absent, and the Excello is underlain by the Breezy Hill limestone. This misnaming of Excello completions as Mulky was ubiquitous and undoubtedly driven by favorable tax treatment at the time for designated coalbed

methane (CBM) wells. As a tight shallow gas resource from an organic-rich marine source rock, the Excello play is best explained as likely biogenic methane derived from near surface bacterial degradation of abundant kerogen. The Excello, in contrast to some other phosphatic black shale, has favorable reservoir characteristics – brittleness and matrix porosity - that facilitate gas production. Like the many other stacked black phosphatic Pennsylvanian shales in the region, the Excello is also noteworthy for its uranium and rare earth content which are of current interest.

Diagenetic Controls on Reservoir Quality of the Sycamore Formation, northern Ardmore Basin, Oklahoma

David Duarte*, Benmadi Milad, R. Douglas Elmore, Matthew J. Pranter, and Roger Slatt, University of Oklahoma

Diagenetic processes and products can significantly impact formation reservoir quality. It is important to understand diagenesis of tight reservoirs, such as the Sycamore Formation, to adequately predict the spatial variability of reservoir quality. This study evaluates and explains the impact of diagenesis on reservoir quality of the Sycamore Formation and identifies intrinsic geological factors that control diagenesis. Using 6 cored wells (287 m; 942 ft), we combined petrographic analysis (N=92 samples), scanning electron microscopy (N=10 samples), as wells as X-ray fluorescence (XRF; 0.3-m [1-ft] resolution), X-ray diffraction (XRD; N=48 samples), porosity, and permeability data (N=92 samples) to evaluate the Sycamore Formation. The Sycamore Formation is a mixed carbonate-siliciclastic system interpreted, in part, as gravity-flow deposits. In the Sho-Vel-Tum field in the Ardmore Basin, the Sycamore Formation overlies the Woodford Shale and underlies the Caney Shale. We identified four facies: massive calcite-cemented siltstones, massive calcareous siltstones, bioturbated mudstone, and argillaceous mudstones. We found that calcite cement controls reservoir quality, especially porosity in massive siltstones. Calcite cement decreases permeability during early diagenesis and controls the flow of later diagenetic fluids responsible for dissolution porosity. Additionally, two factors drive diagenesis of the Sycamore Formation. First, the spatial distribution of carbonate and siliciclastic material controls the distribution of micrite that eventually is replaced by calcite cement. Second, a change from a carbonate-dominated system to a more mixed system through time controls the distribution of calcite cement. Based on our observations is possible to predict the reservoir quality of the Sycamore Formation at Sho-Vel-Tum field. Identifying the geological controls on diagenesis and defining the influence of diagenesis on reservoir quality in tight formations is important to adequately predict and model its spatial variability.

From rocks to models revisited: using machine learning techniques to link thin-section petrography and 3D facies modeling

David Duarte, Matthew J. Pranter, University of Oklahoma*

Cores provide valuable information on the geological attributes of subsurface formations. From core observations and petrographic analysis of thin sections it is possible to define rocks with similar mineral composition, lithologies, and pore types (i.e., facies). Facies logs illustrate the stratigraphy of reservoirs and are often used to constrain 3-D rock-type models. However, core data are commonly scarce, thus, alternative data, such as well logs, with a different vertical resolution and volume support are more commonly used to characterize the beforementioned attributes. Given the differences in resolution between thin sections and well logs, novel Machine Learning (ML) techniques are useful to relate these data types and to classify facies at an appropriate vertical resolution to characterize subtle changes in rock properties. We present a workflow that relates facies and elemental composition with well logs using two ML steps to link thin-section data with 3D facies models. To define facies, we use 1000 ft of core from 6 wells and 96 thin sections from the Sycamore Fm. in the Ardmore Basin. Elemental composition (1-ft resolution) was measured with a portable X-ray fluorescence analyzer (HHXRF). Two ML steps were implemented: 1) a semi-supervised self-training model to generate facies logs for cored wells based on thin-section-defined facies and HHXFR data, followed by 2) a supervised model to classify facies in non-cored wells based on facies logs (from step 1) and triple-combo logs. Constrained 3D facies models are generated using sequential-indicator simulation.

We defined 3 facies: calcareous siltstones, calcite-cemented siltstones, and claystones. The self-training method is an iterative process that uses thin-section-defined facies to create pseudo-labels based on the probability (> 80%) of being correctly predicted. The final model, when none of the pseudo-labels achieved the probability threshold, achieved 91% accuracy. For the supervised step, we optimized a Random Forest model to predict facies in all non-cored wells using all combinations of well logs and selected hyperparameters. For this, we used grid search and 5-K cross-validation techniques. The 3D facies models were useful to explore the stratigraphic variability of facies and reservoir quality. The ML steps provide a useful methodology to upscale information when using a rock-based approach to fill the resolution gap between data types.

MONDAY AM/PM

Session: Induced Seismicity & Advances in Seismic Reservoir Characterization and Imaging

The Fractures of Oklahoma's Basement: Geometry, Alteration, and Associated Sedimentary Sequence Deformation

Brett Carpenter, Paul Gilbert, Matt Hamilton, Candace Johnston, Folarin Kolawole, Max Firkins, Brittany Stroud, University of Oklahoma*

The dramatic increase of widespread seismicity in Oklahoma from 2009-2016 has been attributed to the reactivation of pre-existing, critically-stressed, and seismically unstable faults due to decades of wastewater injection. The vast majority of the noted earthquakes occurred in the Precambrian igneous terranes that underlie much of Oklahoma, whereas the majority of injection, during that time period, occurred in shallower sedimentary sequences. Two conditions required for pore-fluid pressure driven fault reactivation are the nature, distribution, & geometry of basement-hosted faults, and pathways for downward fluid pressure migration. In this study, we mainly focus on pathways for fluid pressure migration by characterizing fractures and faults in crystalline basement material from the core to the regional scale. However, in addition, we present information on recently characterized fractures in Permian sedimentary rocks. We document fracture spacing, orientation, and alteration in core samples and outcrops from northern and southern Oklahoma. At the regional scale, we document the orientation and upward continuation of seismically visible fractures (faults) in north-central Oklahoma via analyses of 3D seismic data. Our multidisciplinary analyses show: 1) the presence of pervasive vertical fractures in basement core from near the sediment-basement interface; 2) that many fractures, observed in both core and outcrop, are mineralized or otherwise altered, 3) that an outcrop scale strike-slip fault is characterized by densely-spaced parallel slip zones within a broader 260m-wide damage zone, and 4) that on the regional scale, Oklahoma's buried igneous basement is riddled with pre-existing faults, many of which penetrate into the overlying sedimentary sequences, including the Arbuckle and Simpson groups. Our results document both fracture- and fault-related pathways for fluid pressure migration into the basement from the Arbuckle Group.

INDUCED SEISMICITY: Trigger - Pressure versus Geochemistry PART 1 The Legacy Contribution of the Rangely Seismicity Experiment

Gary Rowell, Independent*

The dominant theory of injection induced earthquakes is based on injection fluid increasing pore pressure, reducing effective stresses, creating failure at seismogenic depths. The pore pressure theory was extended from the laboratory-based Coulomb's Law of Failure for civil engineering projects and applied to geologic conditions by Hubbert and Rubey in 1959. The theory was adapted by James Evans in 1966 to explain the cause and effect of the Rocky Mountain Arsenal disposal well and the Denver area seismicity. In June 1969, following ten years of peer review, Hubbert and Rubey retracted their support for most of the geologic relevancy of Coulombs Law, stating; "Regarding the Coulombs law of frictional sliding in rock deformation, it seems to us now that the accumulated data obtained by triaxial testing is sufficient to establish that this simple law in fact does not hold under conditions of extreme stress". The Rangley Oil field was discovered in 1933 and had produced about 400 million barrels of oil, including twelve years of secondary production, prior to earthquake testing. An Experiment in Earthquake Control at Rangely, Colorado, is one of the anchor studies that solidified the pore pressure interpretation of induced seismicity. The earthquake experiments were conducted between October 1969 and May 1974 and were deemed so conclusive that in 1976, researchers declared; "The experiment at Rangely has confirmed the hypothesis that earthquakes may be triggered by increase of fluid pressure and has shown that the effect is well accounted for by the Hubbert-Rubey principle of effective stress." (Raleigh et al) and "The cessation of seismic activity within 1 day of the initiation of backflowing the experimental wells in May 1973 established the correlation between fluid pressure and earthquakes beyond reasonable doubt." However, subsequent tertiary operations revealed dysfunctional hydrodynamic characteristics within the reservoir; "The contribution of fracture permeability at Rangely is just now being appreciated, not as a benefit, but as a hindrance; fractures appear to act as carbon dioxide "thieves", decreasing the effectiveness of the current carbon dioxide flood." (Bowker,1989). This presentation will review the Rangely experiment with a broader review of the field's operational history and offer an alternative geochemical contributor to that experiment; and induced seismicity in general.

INDUCED SEISMICITY: Trigger - Pressure versus Geochemistry? PART 2 Application of Geochemistry to The Mid-Continent

Gary Rowell, Independent*

Part 1 of this presentation reviewed the challenges associated with injection pressure as a trigger of induced earthquakes and covered some generalities of geochemical triggers. The Rangely Oil Field experiment was used as an example of adapting a geochemical

trigger versus the legacy pressure assumptions. Part 2 reviews additional geochemical trigger conditions that may be associated with the high- volume disposal in the sub-pressured seismogenic conditions of the Mid-Continent. Despite decades, and billions of barrels of fluid disposal, the Mid-Continent's Arbuckle/basement system remains a predominately sub-pressured system. Research of the Mississippian waste-water disposal and associated seismic activity in the Kansas-Oklahoma area has suggested that 99% of modeled injection pressure at seismogenic depths increased less than 3000 Pa (0.435 psi) per month. Are these low-pressure changes relevant at sub-pressured seismogenic depths? For geochemical triggers to be relevant, the receiving zone(s) must allow for fluid circulation. The Arbuckle/basement's high volume fluid disposal operations appear to attest to this capability. The fluid circulation is a result of the expansion of the original Proterozoic fracture system by the progressive tectonics associated with the Acadian, Wichitan and Arbuckle orogenies. These tectonic adjustments enhanced or added fractures which increased fluid storage, allowed fluid dispersion, and provided dissipation of paleo-pressures; creating the current vacuum conditions associated with disposal depths. Further, studies by the Society of Petroleum Engineers associated with hydraulic fracturing, and research associated with the Rocky Mountain Arsenal disposal well, have shown that fluid injection can reduce the temperature of the injected intervals for months or years. Temperature affects all chemical activity. The potential geochemical trigger for the recent Mid-Continent seismicity is a combination of the increase in solubility of carbonate mineralization of the fault zones caused by cooling of the flow pathways by high fluid volumes and the ionic interaction between the elevated sodium chloride of the Mississippian wastewaters. The subsequent slip weakening was possibly complemented by mobilizing the authigenic clays released during the associated dissolution. These interactions weakened the susceptible fault zones, allowing failure under existing ambient stress conditions.

Improving Regional Earthquake Focal Depth Location in Oklahoma

Paul Ogwari, Jacob I. Walter, Andrew Thiel, Fernando Ferrer, Isaac Woelfel, Oklahoma Geological Survey*

Earthquake activity in Oklahoma occurs in multiple geologic provinces characterized by dipping formations and stratigraphic layers of varying thickness. The earthquakes in the region have traditionally been located using a 1D velocity model applied to both the regional seismic network and local arrays. The regional 1D velocity model, that has the top of the relatively higher velocity Precambrian basement at 1.5 km depth, provides high precision earthquake epicentral locations with relatively higher focal depth uncertainties especially within the Anadarko basin, in western Oklahoma, where the top of the basement deepens up to 10 km. Within the Anadarko basin, an upward focal depth shift of 3km can place numerous current earthquake depths into the sedimentary layers thereby significantly altering the interpretation of the earthquakes' source analysis. We address the depth uncertainty by relocating the earthquakes using modified 1D velocity models on close epicentral-distance subnetworks and, later, apply the results to constrain a 3D velocity model that reflects the varying stratigraphy of the region. The velocity model layering corresponds to the geologic deposition and the velocity of the structures atop the basement is constrained using sonic logs from wells near the 2010 Mw4.1 Lincoln County earthquake sequence. We intend to further test and evaluate whether the final 3D velocity model would be suitable for routine regional earthquake location for ANSS catalog products.

Basement structural architecture suggestive of multiple structural regimes, Pawnee Co., NE Oklahoma

Scott Singleton, Independent Reservoir Geophysicist, Shane Matson, Jericho Energy Ventures*

Currently a subject of great concern in the industry is to determine the causal mechanism for a fairly large number of earthquake events in Oklahoma, the vast majority of which are deep within the basement on the Cherokee Platform and, except for a few notable examples, of small magnitude. To do so requires a good understanding of the basement structural architecture, including any reactivation in the more recent geologic past that may have impacted the sedimentary overburden. This is because one of the possible mechanisms for basement slip events is fluid injection in the Arbuckle reaching permeable fault zones and traveling down those zones.

A 150 sq. mi. seismic data set used for this mapping extended to 4 seconds (about 30,000'). Within this portion of the basement the primary feature is a horizontal to gently westward dipping hard interface at about 20,000' to 22,000'. A number of westward-dipping fault tails intersect with this surface as they become horizontal, thus leading to the conclusion that this layer is a deep-rooted decollement whose source faults originate at some distance to the east. In the western third of the survey this deep decollement is broken up into a number of fragments that lie between 20,000' and 25,000'. Coincident with this is a subtle change in seismic character to more of a transparent background reflectivity. Comparing this basement description to Denison's (1981) basement geologic map, it is apparent that the decollement surface is within his Washington Volcanic Group of extrusive rhyolites and metarhyolites whereas the western third is within the Central Oklahoma Granite Group which he calls a granitic batholith.

Above this surface are a number of vertical faults near the top of the basement whose dips decrease substantially at 12,000' to 15,000'. Some of these faults are mappable onto the eroded basement surface and sometimes into the overlying Arbuckle Formation or shallower, indicating reactivation in the early Paleozoic. In particular, the NE-SW trending Watchorn shear fault zone was reactivated and has movement into the Mississippi Lime and Marmaton. In addition, a few mostly E-W trending faults extending off of the Watchorn were also reactivated in the early Paleozoic and show as much movement as the Watchorn. But these few faults are the exception. Most vertical faults in the upper basement zone were not reactivated in the Paleozoic and are completely or mostly invisible on the eroded basement surface.

PP and PS anisotropy and the estimation of stress state, Pawnee Co., NE Oklahoma

Scott Singleton, Independent Reservoir Geophysicist*

Both compressional waves (PP) and converted shear waves (PS) are sensitive to rock anisotropy which causes both amplitude (dynamic) and velocity (kinematic) variations in seismic data. Processing of full azimuth PP and PS data is designed to remove these effects so that the stack image is free of distortion. A byproduct of this effort is a quantification of the magnitudes and directions of anisotropy which we can use in our analysis. Anisotropy in both data types is caused by fractures which, if only a single set is present, is usually indicative of the minimum horizontal stress direction. PP data can be confused by multiple non-parallel sets of fractures, which require additional techniques to correctly determine fracture state and thus stress state. PS data is primarily influenced by stress-aligned microcracks and thus is a good indicator of stress direction and magnitude although PS data is more difficult to process.

A 150 sq. mi. 3-C seismic data set in Pawnee County was used to estimate fracture content and horizontal stress. The PP data was more successful identifying fractures and clearly indicated that the Pennsylvanian section has a different fracture regime than the Ordovician/Mississippian, which included the last pulse of tectonism in this area. In this lower Paleozoic section, the reactivated Watchorn Fault is clearly not associated with heavy fracturing and presumably also stress. Most fracture zones are along prominent E-W laterals extending away from the Watchorn. These lateral faults were reactivated along with the Watchorn in the early Paleozoic. The PS data proved not to be sensitive to fracture systems. Instead it was an indicator of stress magnitude, which in itself was very useful. It showed that the same E-W laterals extending off the Watchorn are indeed stressed. However, in addition to those known stress points, two other areas turned up as stressed: The northern Watchorn Fault showed stress along its trace as well as throughout the northern part of the survey which is immediately south of the 2016 magnitude 5.8 Pawnee event. The second area of stress is along a NE-SW trending line in the eastern part of the survey that shows short E-W trending Reidel shear features on the seismic attributes in the Pennsylvanian but no fault scars of any age down through the basement.

Changes in structural style through the Paleozoic, Pawnee Co., NE Oklahoma

Scott Singleton, Independent Reservoir Geophysicist, Shane Matson, Ron Haveman, Jericho Energy Ventures*

Pawnee County lies on the Cherokee Platform/Osage Uplift. Located between the Nemaha Uplift to the west and the Ozark Uplift to the east, this tectonic province has undergone multiple stages of tectonic activation and reactivation. The Precambrian basement rocks in northeast Oklahoma preserve a complex structural fabric resulting from a long tectonic history which includes assembling of the craton and megashears, tensional rifting of the Mid-Continent, and Mississippian-Pennsylvanian compressional tectonics associated with Pangea tectonics which continued episodically through the Permian. This fabric has been detailed in another paper at this conference. Reactivation of a subset of these faults occurred during the Ouachita Orogeny in the Paleozoic. This paper reviews the fabric of these reactivated faults within the Paleozoic sedimentary section.

A 150 sq. mi. seismic data set in Pawnee County was used for this mapping. The main fault in this data set is the Watchorn Fault, a regional NE-SW left-lateral shear fault. Named for the Watchorn Field, this fault originated in the Precambrian and was reactivated in the Paleozoic. All other reactivated faults extend roughly east-west away from the Watchorn, although it should be noted that the shallow basement includes a variety of other fault orientations and styles that were not reactivated in the Paleozoic. The Watchorn shows a scarp from the eroded basement surface up through the top of the Mississippi Lime and there is evidence it extends to the top of the Pennsylvanian Marmaton (Des Moinesian). By Layton time (Missourian) the Watchorn is only dimly visible but left-lateral Riedel shear features can now be seen through geometric attribute rendering, indicating continued stress along the trace of the scarp.

There are four E-W faults extending away from the Watchorn that were reactivated in the Paleozoic. Two are on the west side of the survey and the tails of these two faults intersect in the basement, thus mimicking a graben structure even though no graben

is visible. Neither of these faults intersect the Watchorn but end at some distance away. The remaining two reactivated E-W faults occur in the southeast of the survey. One of these faults gets close to the Watchorn but deviates to the south, thus not intersecting it. These faults mostly disappear by Marmaton time. The faults to the east of the Watchorn are replaced upwards in the Pennsylvanian section with right-lateral Riedel shear features.

Seismic Characterization of Shoestring Sands on the Osage Uplift, Northeastern Oklahoma

Shane Matson, Ron Haveman, Jericho Energy Ventures, Scott Singleton, Independent Reservoir Geophysicist*

Pennsylvanian deposits in the Midcontinent region known as Shoestring Sands have been an exploration objective for a century. Generally Striking northeast-southwest, these deposits are easily recognized on many regional maps showing surface hole location of completed wells, with the most famous being the Ceres Field in Noble County, OK.

Utilizing OpendTect, utilizing 3D seismic interpretations and calculating geometric attributes available with the free OpendTect seismic interpretation software we present methodology to better image these deposits and sharpen edges. With thousands of square miles of 3D acquired in the past decade this methodology allows for fast high grading of vertical prospects and discrete targeting using horizontal drilling and exploitation.

Finding Geology in 3D Seismic Gathers

Mark Falk, Mike Lovell, Integrated Subsurface Technology, Marianne Rauch, TGS

Reservoir characterization is improved using detailed integration of digital log data and 3D seismic data. Specifically, 3D seismic pre-stack gathers contain significant information about lithology, rock properties and fluid content. Our challenge is to integrate log scale geologic information with seismic scale measurement of the same geology. Gulf Coast geoscientists have actively been using integrated seismic gathers and well logs in AVO and inversion analysis for decades. Rocks of the mid-continent have often lead us to discount or dismiss completely the analytical capabilities of on-shore seismic gathers. We present here examples of the power of digital log analysis, log cross plots and integration with seismic pre-stack gathers in Oklahoma.

TGS is an industry leader in licensing geologic data. TGS holds a unique capability to provide a fully integrated package of digital well log data and 3D seismic data. Often, operators, engineers and geologists review only the poststack seismic volumes in their efforts to assess risk reduction in exploration and field development. Generally, seismic data is often thought to provide only structural information as a driver for keeping horizontal wells “in zone”.

WE present here a more robust value in the 3D seismic data. Fully integrated geologic description of lithology, rock characteristics, rock mechanics, and fluid content are important outputs from the TGS integration of digital well logs and pre-stack seismic gathers. We emphasize the value of well log cross plots in the seismic realm: what are the key drivers of lithology and reservoir geomechanics which are expressed in the seismic response from P wave source and receiver 3D data? How does 3D AVO and inversion expand our understanding of reservoir performance?

Correct Reservoir Size Estimation with Depth imaging: more than just a single process

Robert Springman, Scott Boye, AFFILIATION*

The utilization of non-seismic data in the structural imaging arena has been shifting its importance from an afterthought to an essentially a priori ingredient. The necessity to image complex subsurface structures that are at the right depth, correct geographical location and correct geometry and topology has become paramount for a successful business model that guides drilling, geosteering, completion, fracking and re-fracking, as well as production and EUR estimations. This article can be thought of as an update and continuation on our 2013 First Break publication (Stein et al 2013) that introduced the concept of TrueDepth. The key to being able to produce a high-quality image begins with the attention to detail in the pre-processing stages of any project. Employing the right process in the correct manner is a key step to producing the inputs required for the high-end processes that are shown in this presentation. Particularly important has been the development of a new workflow that increases the efficiency and robustness of the techniques. The new workflow incorporates several new pieces of technology making the resulting images more accurate. Some key examples are demonstrated that will help to produce the high-quality input that is key to the entire process. We will finish the article

by demonstrating the value of the new workflow and technologies by applying them to a real case history.

MONDAY MORNING

Session: Structure, Tectonics, Geomechanics and Petrophysics of the Mid-Continent

A Structural Analysis of the Washita Valley Fault: A Smoking Gun to Evolving Pennsylvanian Tectonics?

Molly Turko, Applied Stratigraphix and Turko Tectonics*

It is proposed that the Washita Valley Fault in the southeast Anadarko Basin originated when Precambrian-Cambrian pre-existing rift-related faults became reactivated as a rotational stress field reached a favorable orientation for strike-slip displacement. During the Early to Middle Pennsylvanian, contractional deformation dominated as a Precambrian-Cambrian failed rift underwent structural inversion along a northeast directed stress field. Structures that developed in the basin consisted primarily of thin-skinned fold-thrust structures resulting from slip along two main detachment levels. By the Late Pennsylvanian, stress rotated towards the east-northeast causing left-lateral strike-slip displacement along east-west oriented structures. During this time the Washita Valley Fault originated from an east-west oriented pre-existing basement fault. The Washita Valley Fault formed as a near-vertical segment cutting through the earlier fold-thrust structures. Movement was accompanied by oblique normal slip allowing grabens to develop that were subsequently filled with Virgilian age sediment. A left-step of the Washita Valley Fault allowed for a significant graben to develop near the east end of the study area resulting in a thick Virgilian age growth section validating the timing of fault movement. The Wichita Mountain Fault also underwent a component left-lateral strike-slip displacement during the Late Pennsylvanian highlighting its continuous movement and deformation history in a rotating stress field. While much of the published literature on the Washita Valley Fault is limited to the Arbuckle Uplift, this study documents its subsurface architecture, timing, and structural history in the southeast Anadarko Basin using a modern 3D seismic dataset in relation to evolving Pennsylvanian tectonics.

Some of the pre-Pennsylvanian Unconformities of Southern Oklahoma

Jerry McCaskill, McEnco, Inc*

Although overshadowed by the huge Pennsylvanian angular unconformities associated with the Arbuckle and Wichita orogenies, the unconformities in the pre-Pennsylvanian section help define the structural and stratigraphic history of the Southern Oklahoma Fold Belt as well as impacting energy resource development. These unconformable relationships were worked out by some of the earliest surface and subsurface explorers, but several of them seem to have been forgotten over time, not because they were dis-proven, but because they are not obvious. This paper and poster will use open hole logs cross sections and maps to document several of these unconformable relationships that were worked out before advent of electrical wireline logging. Due to the lack of biostratigraphic control in most of the area, these unconformities will be defined by formation names based on lithology and log character instead of extrapolated zones and ages as much as possible. Some of the unconformities addressed include the following: Pre-Sycamore Formation/Mayes Formation, Pre-Woodford Formation/Mannsville Formation, Pre-Welling Formation (Fernvale), Pre-Viola Springs Formation (Viola), Pre-Timbered Hills Group. Most of the unconformities to be addressed involve gentle long wave-length structures relative to the Pennsylvanian unconformities and as such often require cross sections covering counties instead of townships to properly illustrate. Strike-slip offset across some of the major faults has been documented by several workers in Southern Oklahoma based of the differing stratigraphy across the faults caused by these unconformities. The formations immediately under these unconformities often had porosity enhancement and dissolution along fracture surfaces during the erosional periods, resulting in better reservoirs. There are a few other well documented unconformities such as the pre-Frisco Fm. and pre- or inter- West Spring Creek Fm. that will not be shown on the cross sections and will be mentioned only briefly. Within the Delaware Creek and Goddard Formations there are a number of short wave-length changes and probably a number of unconformities and erosional events that have not been deciphered and will not be covered in this study. Biostratigraphic gaps that cannot be shown with logs will also not be presented such as the boundary between the Haragan Fm. and Henryhouse Fm.

What is the Labette Fault and Why is it On Every Map

Shane Matson, Ron Haveman, Kevin Crain, Scott Singleton*

The Labette Fault, proposed in 1981 by Roger Denison in Oklahoma Geological Survey (OGS) Circular 84, the seminal Basement Rocks of Northeast Oklahoma, warrants a deeper look. In the author's own words "There is no evidence that the fault was active in Paleozoic time." This proposed fault, along which no motion has occurred in the last 540,000,000 years, spent over three decades quietly

ignored by the geoscience community. In 2013, with the well documented increase in seismicity, the OGS began a meaningful effort to better understand the tectonic architecture of the Midcontinent region. A major component of this effort was the vectorization and geospatial referencing of faults published in academic publications. The scientists behind this effort are to be commended. The importance of the OGS publications OF3 Preliminary Fault Map of Oklahoma, OF4 Preliminary Oklahoma Optimal Fault Orientations, are evidenced by the utilization of maps created by government agencies, academic researchers, and industry geologists. The maps and supporting database provide insight into the tectonic history of Oklahoma and are an important part of our scientific efforts moving forward.

Lacking in the published maps are any indication of relative and magnitude motion or timing of slip. For the unfamiliar, it would be easy to assume equal weight prescribed to each fault. The faults after all were published by a well-recognized organization deeply regarding technical work. But not all interpreted faults are created equal. A fault documented using well logs illustrating repeated or missing section, 3D seismic or geological mapping of the surface mapping has different weight versus a proposed fault based upon thin well control, no seismic or potential field geophysical data. Standing alone the relative quantification of a fault's existence is not much of an issue. In the case of the Labette Fault this is not the case. Following the September 3, 2016, earthquake in Pawnee County, OK, exceptional weight was given to Denison's Labette Fault. The Oklahoma Corporation Commission (OCC) used the strike of the Labette Fault to base decisions of which saltwater disposal wells to shut in. The OCC did so without consulting the origin story of the proposed fault, thus making decisions without any scientific merit. The resulting economic impact to companies who operated saltwater disposal wells within an Area of Interest defined by the OCC was significant. The economic impact on exploitation of the Osage Mineral Estate continues to be significant and harms the Shareholders of the Osage Minerals Estate. The cessation of disposing of produced water has significant impact for companies, their employees, communities, and the State of Oklahoma. The subject of future of produced brine disposal needs to be directly addressed. With an understanding that the remaining resources of size in the State of Oklahoma are likely to be found in reservoirs with large transition zones or tight reservoirs which require stimulation using high volume freshwater fracture treatments where flowback water must be either treated or disposed safely into subsurface reservoirs, the regulatory future of produced brine disposal will determine the future of oil and gas production in the State of Oklahoma.

In a review of papers published in peer reviewed journals no meaningful reference or paper has been published looking backward into historical operations where saltwater disposal was critical to primary production. Notably missing from published literature seeking cause for seismicity are the Pawnee Masham and Gray Horse Fields. Both fields are very large dewatering operations of massive Red Fork deposits with high water saturations on the Osage Uplift. Each field required multiple large diameter disposal wells drilled to the base of the Arbuckle or top of basement. The wells were permitted through the OCC for >30,000 barrels of water per day. Curiously both fields are within 10 miles of the proposed Labette Fault. No seismicity was recorded during field development that involved an estimated volume of produced water in excess of 100,000 barrels of water per day for years. No seismicity was recorded during these operations, despite being proximal to the proposed Labette Fault.

The authors here present data supporting the removal of the Labette Fault from the OGS database. We also encourage the State of Oklahoma to provide funding for potential field data acquisition and analysis to better constrain the basement faults across Oklahoma. We encourage our peers in industry, academics and regulatory agencies to take a deeper look into the history of high volume disposal of produced brines before the recent onset of seismicity.

Tectonic Episodes That Created The Depositional Patterns And Structural Traps In The Northern Midcontinent

Marv Carlson, Rock Resources*

The tectonic framework of the northern Mid-Continent consisted of three major episodes: the Precambrian emplacement of the basement constructing this portion of the North American continent from 1.8 to 1.4 BYA, the structural pattern emplaced during earliest Pennsylvanian time, and the Cretaceous/Tertiary Episode all of which have resulted in the deposition and structures we decipher today. The Precambrian Episode was important in that it not only created the southern growth of North America, it also embedded suture zones in the crystalline basement rocks that remained structurally weak zones that were susceptible to later stresses. During much of Pre-Pennsylvanian Paleozoic time, deposition was largely shelf carbonates with minor episodes of broad uplift and erosion. There is a general pattern of facies changes from carbonate northward to shale, particularly in the Upper Ordovician and later in the Upper Devonian. The Early Pennsylvanian Episode was the result of orogenic activity along the then southern edge of the Continent (Ouachita Suture) that created stress across much of the Mid-Continent and resulting structures. The defining structures in the area resulting from this orogenic activity are the sister features – the Nemaha Uplift and the Ancestral

Rocky Mountains. Both of these tectonic features resulted in granitic highs, bounded on the east by major faults, and creating adjacent basins. It has been suggested that the bounding faults for both uplifts are reverse faults with underthrusting of older Paleozoic sediments some of which contain productive traps. Within the area bounded by the two major structural uplifts are a number of minor structures that affected both sedimentation and tectonics resulting in productive oil fields. Many of these fields are structural traps, others are stratigraphic traps derived from depositional factors. Petroleum accumulation was mainly sourced from the tsunami migration northward from the Woodford Shale. Secondary source was on-site generation and accumulation, particularly in Pennsylvanian sediment. Other major accumulation of both oil and gas occurred In the Permian and Cretaceous time in the Hugoton and Denver Basins. The majority of fields in the northern Midcontinent area are in stratigraphic and structural traps particularly in the Lansing-Kansas interval.

Wellbore Cement Mechanical Enhancement by Addition of Zeolite and Graphene

Cody Massion, Sai Vamsi Krishna Vissa, Mileva Radonjic, Oklahoma State University*

Wellbore cement is a man-made hydraulic material that has properties similar to the formation rock. It serves several purposes like providing mechanical support, zonal isolation, maintaining well performance, and finally acting as a long-term capping or sealing the wellbore when it is abandoned. Given the brittle nature of cement, it is subject to mechanical failure at downhole conditions of High Temperature and High Pressure (HTHP). Several additives had been studied as additives to cement in order to improve the strength and petrophysical properties. Two such materials that have seen recent advances are carbon-based materials like Graphene as well as naturally occurring minerals like Zeolites. One zeolite that had been commercially used in a lightweight geothermal cement, ferrierite had piqued our interest given its self-healing capabilities. The underlying mechanism for how ferrierite performs within cement is explored in this work. On the other hand, graphene is a relatively new material that is composed of single atom layer thick platelets of carbon that has shown mechanical properties of both high strength and ductility. Recent studies have shown that these material properties can translate to cementitious material with as little as less than 1% by weight of cement (woc). This study examines the addition of both graphene (0, 0.008, 0.016, and 0.05% woc) and ferrierite (0, 5, 15, and 30% woc) in different percentages to a 16.4ppg Class-H wellbore cement slurry design and what effect is seen in the overall mechanical properties. The cement cores are hydrated and tested at conditions simulating offshore wellbore conditions in the Gulf of Mexico, for the nature of this project. Shear strength is tested in a temperature-controlled Hoek-type triaxial compression cell which simulates the in-situ HTHP conditions of the formation. To capture the microstructure evidence for mechanisms, microscopy tools such as Scanning Electron Microscopy (SEM), Energy Dispersive Spectroscopy (EDS), and Raman microscope are used at the microscale and Computed Tomography (CT) imaging of macroscale. Preliminary results indicate that under HTHP testing conditions, the addition of these two materials have the potential to enhance cement-like materials could have a great impact in a range of applications in need of wellbore construction, such as oil and gas, unconventional drilling, carbon storage, HTHP wells, geothermal exploration, nuclear storage, and ultimate abandonment.

Early Development of a Novel Formation Imaging Tool for Cased Hole Wells

Robert Davis, Richard M. Bateman, D. Ray Ethridge, Andrew P. Jagger, Jonathan G. Kuespert, Marshall S. Levine, Mike Mayfield, and J. Max Weldon, Rock Visualization Technology*

Recent advances in logging tool design and construction have led to the opening of a new window through which formation imaging may be achieved in cased holes. Image logs so obtained allow detection of the orientation and dip of beds penetrated by a cased well. Applications of this novel technology include fault and fracture detection and fill a wide gap in the interpreter's arsenal. It is now possible for the first time in new, or old, cased wells (where few or no open hole logs are available) a 360º view and compute the equivalent of an open hole dipmeter. The history of the original concepts for this novel technology, and its implementation on a shoe-string budget, chronicles the inventiveness of a small team of industry "old hands" working in concert using "sealing wax and string" to perfect a practical working tool that opens new insights to geological interpretation made from the inside of cased wellbores. Examples of early versions of the tool and the recordings made are coupled with formation images and their interpretation for key geological pointers obtained in Mid-Continent wells. Future applications of the technology are discussed including guidance in water-flooding design, assistance in frac stage design and risk avoidance in step-out well drilling.

This novel formation imaging tool relies on natural gamma radiation emanating from the radioactive decay of the atoms of uranium, thorium and potassium that are the constituent parts of rock formations through which oil and gas wells are drilled. Natural gamma ray logging has been a staple of wireline, MWD (measurement while drilling) and LWD (logging while drilling) logging for

many decades. However, standard gamma ray logs are non-directional. Where logging tools have a single gamma ray detector the recording at any given depth in the well is the summation of all the decay events occurring through a 360º arc surrounding the axis of the tool. The current novel tool design, described here, uses multiple gamma ray detectors which are individually screened and oriented so that they only respond to incident gamma radiation arriving from a fixed and limited fraction of the 360º arc. Screening is achieved by the use of precision machined collimators made from ultra-high density materials. This "focusing" method dictates that not all the detectors used in this multi-detector device can be co-planar in the tool. Consequently, subs-sets of coplanar detector sets are arrayed along the length of the tool. The recordings from such arc- and depth-limited directional gamma rays are gathered and, via memorization, combined to provide a coherent record of the 360º directional formation gamma ray activity at each depth in the well. The detectors, focusing screens, photomultipliers and electronics are mounted in a pressure housing that is 3.5" in diameter, allowing access to the majority of cased wells once any completion tubing string has been removed from a candidate well. In order to maximize gamma ray count rates and minimize the effects of the statistical nature of the natural radioactive decay processes, logs are run at a slower than normal logging speed. Key to the utility of a 360º gamma ray log is the orientation of the recorded traces with respect to geographic references (e.g. North & vertical). The tool is combined with a standard gyroscope to determine "position in space".

MONDAY MORNING

Session: One Hundred Years of Discovery: Giant Fields of the Mid-Continent and Geological History of the Mid-Continent

Osage Giants

Bill Lynn, Osage Minerals Council*

Osage Indians are unique Peoples. An Osage person laid his blanket on a creek and gave a trader a bottle of Donile, or rainbow in Osage. Another Osage person broke off some prairie grass, stuck it in a crack in the ground, lit it and it never went out. This occurred prior to The Indian Territory Illuminating Oil Company and petroleum development on the Osage Reservation in the 1890's. The Avant and the Burbank are two early giant oil fields discovered on the Osage Indian Reservation in Oklahoma. These prolific producers, located on opposite sides of the County on the Osage Mineral Estate, continue today. The Avant Pool, discovered in 1904, on the eastern edge of the reservation has produced over 109MBO from the Bartlesville sandstone from around 1700 feet. Standard Oil laid a pipeline and Wolverine, Skelly and Cities Service had huge success through the early years in the Avant. The Avant has gone through gas injection, waterflood, Coal bed methane and a sort of enhanced oil recovery has taken place since using short horizontal laterals and water injection. May of 1920, was the roaring start of the Burbank Pool in western Osage where E W Marland first found the Burbank sandstone. The wells in the area were flowing violently from the pay zone at about 2900 feet. Oil production in the state peaked in 1927 at just under 300 million barrels because of the drilling activity. The Burbank has turned promising oil companies such as Phillips and Sinclair and Skelly into successes. The Burbank continues to produce large volumes of secondary and tertiary oil. Hydrocarbons continue to come out of the Osage rocks naturally and the Osage Nation continues to flourish today.

Shoulders of a Giant: H.V. Foster, The Indian Territory Illuminating Oil Company and the Opening of The Osage, Seminole and Oklahoma City Fields

Shane Matson, Jericho Energy Ventures*

The modern oil era of the Midcontinent Oil Fields began with the opening of the Osage Indian Reservation, now Osage County, OK in 1917. From 1895 to 1916 the entirety of the oil and gas rights to the Osage Reservation, ~1,500,000 acres, was held by the Foster family, long recognized as The Foster Lease. The Foster Lease was developed by two generations of the Foster family through ownership of the Indian Territory Illuminating Oil Company (ITIO). With the foresight of Osage leadership to allot an equal share of the Osage Mineral Estate to each of the 2,229 Osage Allottees, ITIO opened up The Great Osage oil fields through drilling and farming out of large blocks to competitors. Following the termination of The Foster Lease, ITIO opened the giant Seminole and the Oklahoma City Field. This paper looks at the rich history of the esteemed Indian Territory Illuminating Oil Company and the company's important place in the history of Oklahoma.

Glenn Pool Oil Field - Oklahoma's First Giant

Mike Kuykendall, Solid Rock Resources, LLC*

The Glenn Pool Oil Field was discovered sixteen miles south of Tulsa on the Ida Glenn lease by wildcatters Robert Galbreath and Frank Chesley in November 1905, in what was then Indian Territory. Even though the first commercial oil well in the territory, the Nellie Johnston No. 1, was discovered in 1897 approximately 60 miles north near the townsite of Bartlesville, the Glenn Pool Field's rapid development soon made it Oklahoma's first giant oil field and quickly made Tulsa the "Oil Capital of the World" and Oklahoma the nation's biggest oil producer at the time—the Oklahoma oil boom was on! The Glenn Pool oil accumulation (43 sq mi) is the result of migration of hydrocarbons into a shallow (1,500 tvdft) combination / stratigraphic trap consisting of the eastward updip pinch-out of thick (100 – 200 ft), porous (16-24%) and permeable (50 – 200 md), multistoried, alluvial-deltaic / valley-fill sandstones (Middle Pennsylvanian [Cherokee] Bartlesville ["Glenn"] Sandstone) into laterally- and top-sealing siltstones and shales. Reservoir heterogeneity and lateral continuity of various sandstone lithofacies among closely spaced wells can be quite complex resulting in widely varying directional permeability. Early initial production rates from wells completed open-hole using cable tool rigs ranged from 75 – 500 BOPD, up to 4,000 BOPD. In 1907 production was 20 MMBO with a peak of 117,000 BOPD occurring in June 1907--- by 1911 Glenn Pool had produced 92 MMBO and on its way to becoming a giant field. Field-wide reserves averaged 10,000 BO/ac with some areas yielding over 40,000 BO/ac. Current cumulative oil production is estimated to be over 340 MMbbl with most of the field having undergone secondary waterflooding and limited utilization of tertiary recovery methods. A lot has changed in Tulsa and in Oklahoma's oil & gas industry since Glenn Pool's discovery, but it's historical significance, long-lived world-class production, and intriguing reservoir geology have remained the same for over 100 years.

Panhandle-Hugoton Field

Ray Sorensen, Independent (Lee Krystinik)*

Panhandle-Hugoton is the Midcontinent's largest oil and gas field, covering 9500 square miles and with an EUR of 70 TCF and 1.4 BBO. The Panhandle Field, draped over the Amarillo uplift in Texas, contains a 100-foot oil rim on the northern margin and produces high BTU gas. It was discovered on a surface structure in 1918 and the oil rim in 1921. Dry gas discoveries from 1922 to 1927 in SW Kansas (Hugoton) and the Oklahoma Panhandle (Guymon Hugoton) were recognized as part of the same accumulation due to extremely low reservoir pressure relative to burial depth. Lower Permian Wolfcamp carbonates are the primary reservoirs, although older strata are locally productive on structure. The Permian Brown Dolomite in the Panhandle Field is probably the highest quality reservoir in the Midcontinent, capable (using wellhead compression) of commercial gas production rates at reservoir pressures below atmospheric and without reservoir stimulation. Numerous tests have demonstrated that intensely fractured igneous basement has the same hydrocarbon column for approximately 1000 square miles in the Amarillo uplift. Although historical well production intervals were usually limited to overlying strata, the basement rocks contain more than 1BBO within the oil column interval and may have contributed 1-5 TCF to historical gas production through fracture communication. Hydrocarbon accumulation began as soon as the overlying Permian evaporite top seal was deposited, with migration from multiple source rocks in the adjacent Anadarko Basin. The original accumulation was on drape structures over the Amarillo Uplift, extending eastward over the present-day Wichita Mountains. Late Tertiary-Quaternary regional erosion of the top seal in eastern Kansas and southern Oklahoma exposed the regional Permian aquifer to much lower surface elevations, the reservoir pressure plummeted, and the gas cap expanded rapidly. Northward gas expansion in Oklahoma and Kansas was trapped stratigraphically by pinch-out of Permian reservoir facies to the west and eastward tilting from the Laramide orogeny. The enormous production capacity supported development of the interstate gas pipeline system, accompanied by extensive governmental regulation of production allowables and gas prices. Panhandle-Hugoton gas has elevated helium content derived from deep basement faults and was the primary source for creation of the Federal Helium Reserve in 1925.

Pre-Drake Petroleum Literature

Ray Sorensen, Independent, (Lee Krystinik)*

The Pennsylvania Drake Well initiated rapid commercial growth in the petroleum industry, but by 1859 oil and gas knowledge was already significant from at least 2000 published accounts. Coal gas manufacturing for municipal lighting was a mature industry, and asphaltic deposits were used for paving and construction. Laboratory methods were evolving to assess the composition and applications for numerous hydrocarbon types. Scientific appraisal of petroleum occurrences became common with governmental geological surveys and the growth of the geological profession in the early-mid 1800s.Oil and gas had been known from antiquity at seeps and in wells. There were large commercial developments, notably at Baku and Burmah, as well as exploitation at numerous locations in Europe, the Middle East, Asia, and elsewhere. North American pre-Drake published accounts of oil and gas occurrences

were available in what would become 31 states and 5 Canadian Provinces, including most of the Midcontinent region.
Local use and commercial marketing of seep oil for human and veterinary medicine was widespread. Applications were both for external use and oral consumption as a treatment for digestive disorders. Barbadoes green tar, known since the 17th century, was recognized as the generic standard for the medical industry by the 19th century. Medicinal spas were developed near many seeps, including one on the southern margin of the Arbuckle Mountains.
Prior to discovery of nuclear decay, subsurface burning of oil and gas was considered a likely source of heat for volcanic activity. This concept was supported by seeps initiated by volcanic and earthquake activity in well-known locations such as Mt. Vesuvius, and a similar visual appearance of mud volcanoes associated with hydrocarbons. Surface fires became the focus of religious study such as Zoroastrianism and the fire temples at Baku. They were even used in fictional accounts (e. g. Paradise Lost, Faust, Frankenstein) as evidence for the pathways whereby Satan's followers reached the surface of the Earth.
Following the Drake Well discovery, early exploratory success was very limited at most of the previously described locations. The majority of early observations involved hydrocarbons found near outcrops of a potential source rock or reservoir and were more effective at defining the margin of a potentially productive basin than the location for a prospective exploratory well.

A Reflection on The Development of The Paleozoic Lithostratigraphic Nomenclature In Arkansas With A Review Of The Nomenclatorial Standards And Proposal Requirements

Noah Morris, Walter L. Manger, University of Arkansas*

The geology of Arkansas has been documented and described for over 160 years, and over the course of that time, as geological understanding improved, several changes have been made to the stratigraphic nomenclature. Many names have been proposed; some were abandoned, and some are still in use. In sum, over 200 lithostratigraphic names have been proposed for the Paleozoic strata of Arkansas. Nearly 80 of those names are currently recognized by the USGS and/or the Arkansas Geological Survey. Many were introduced during two major time intervals: circa 1890 to 1910, and circa 1945 to 1970. Key moments in the standardization of the nomenclature was provided by the publication of the geological map of the state of Arkansas in 1929 and 1976. Many names were also influenced by the development of what would become the North American Stratigraphic Code, which coincided with the abandonment and replacement of some stratigraphic names. The USGS GeoLex database strives to maintain a repository of nomenclatorial lexicon and related information, but many names are incomplete or missing. In response, a new catalog of Paleozoic nomenclature was produced for names that have been applied to surficial beds within Arkansas, with age, type section locations, original publications, etymology, and other related information. The North American Stratigraphic Code and the International Stratigraphic Guide describes the proper usage of stratigraphic terminology, such as type sections and rank, and have played a major role in standardizing nomenclature. However, even with these standards, stratigraphic terminology is not without conflict, as some names may be recognized by either the USGS or the Arkansas Geological Survey, but not necessarily both. Names that do not meet the criteria set forth in the Code and the Guide may be used informally, but usage between geological agencies may vary. For unresolved stratigraphic problems that may require further revision of the current nomenclature, the Code and the Guide outline the procedure in detail, including proper publication mediums and usage. Adherence to these procedures is necessary in order to clearly establish the need for revision and the reason for accepting the proposed solution.

MONDAY AFTERNOON

Session: The Next Age of Making a Profit in the Mid-Continent: Unconventional and Conventional Plays The Greater

Anadarko Basin-Drilling and Production Trends in the First Two Decades of the 21st Century

John Mitchell, Rutherford Exploration*

The Greater Anadarko Basin located in portions of Oklahoma, the Texas Panhandle, Kansas and Colorado has been a prolific petroleum producing basin since 1915. The basin has a minimum cumulative production of 13 billion barrels of oil and 186 trillion cubic feet of natural gas from Paleozoic reservoirs from Pre-Cambrian to Permian ages. Over the first two decades of the 21st century the transition from vertical to horizontal drilling and production had a major impact on the petroleum industry in the basin. During this time period annual basin oil production increased from 77 MMBO to 212 MMBO while natural gas production increased from 2,243 BCFG to 2,806 BCFG. The impact of horizontal drilling and production technology after 2007 along with the great increase in the relative value of oil prices to natural gas prices led the industry to focus on using horizontal drilling to extract liquid hydrocarbons

from unconventional reservoirs. This talk will first illustrate the geological age distribution of historic Anadarko Basin petroleum production. The presentation will then look at the relations of oil and gas prices from 2000 to 2020 to annual vertical and horizontal drilling and production figures. The talk will conclude with a review of the significant horizontal drilling and production plays in the basin. These plays will be described by geographic extents, primary reservoirs, depths, trap types, petroleum sources and relative production outcomes.

The Value of Curiosity: Reimagining the Exploitation of Mature Mid-Continent Conventional Reservoirs to Produce Significant Incremental Reserves

Scott Robinowitz, Grand Directions*

With development dating from the early 1900s, mid-continent conventional reservoirs have a long history of oil and gas production. Drilling and development programs typically did not consider ultimate recovery or best reservoir management practices to guide field development. Secondary recovery was applied across the region with varying degrees of success. Hydrocarbon price cycles and the misapplication of technology resulted in poor reserve recovery. Grand Directions (Grand) has applied perspective and curiosity to pivot away from the exploitation and secondary recovery strategies historically applied. Grand has utilized short radius horizontal drilling and innovative secondary recovery approaches to "re-plumb" the reservoir. This re-plumbing minimizes water coning, uses gravity segregation to assist in secondary recovery efficiency, manages relative permeability challenges, and places horizontal laterals in the reservoir to enhance sweep efficiency and to recover hydrocarbon historically stranded by compartmentalization. Grand reversed natural decline and/or reactivated fields originally discovered in the early 1900s. These fields were abandoned by other operators considering the projects uneconomic and plugging liabilities. Grand has produced in excess of 2,000,000 barrels from these mature reservoirs and operates these fields consistently at a profit. This paper presents how Grand recovered significant incremental reserves by applying curiosity to aging reservoirs. Curiosity helped Grand solve many of the problems operating engineers and geologists faced since the 1930s. Two fields will be presented in this paper, the Bird Creek Unit located in Tulsa County, OK and the North Avant Unit located in Osage County, OK.

A Data-Driven Approach to Geology and Spacing Optimization in the Meramec

Evan Macdonald, Drew Depoe, David Law, Enverus*

Activity levels in the SCOOPISTACK tapered significantly from the ~110 active rigs in the latter half of 2018 to only ~15 rigs in 1H21. However, we have seen multiple operators accelerate their development programs in response to the recent rally in commodity prices, leading to a rig count of ~28 in September 2021. The most targeted interval in the SCOOPISTACK has consistently been the Meramec, representing approximately half of both active rigs and total TILs since 2015. The Meramec is a complex formation composed of multiple parasequences, or packages, with varying petrophysical properties and features a high degree of facies changes both vertically and laterally, as well as significant changes in depth and hydrocarbon mix. This geological heterogeneity has been a stumbling block for operators who have struggled with downspacing and parent/child interference, resulting in inconsistent oil productivity and greater than expected degradation when pivoting to full-field development. As activity ramps up in a regime where investors favor returns over production growth, there needs to be a better understanding of the asset fundamentals to maximize capital efficiency. Taking a data-driven approach helps us understand the geology of the play and how it affects optimal completion designs and spacing, along with its implications for the quality and quantity of remaining inventory.

We leveraged our large database of well logs and geological maps, historical production and spacing and completion parameters to perform a random forest regression that derived the key variables that drive recoveries in the Meramec. We then applied a K-means clustering algorithm to break the play into 4 distinct focus areas based on similarity of the most impactful geological factors. This process allows us to normalize for geology when assessing the correlation between horizontal spacing and oil productivity. We then evaluated section-level NPVs as a function of horizontal spacing and determine optimal designs for each of the clusters as a function of well costs and the price deck.

With the continued delineation of the STACK, we now have more data to help shape our view on the play. By taking these large and complex data sets and a multidisciplinary approach, we are able to differentiate regions of the play by the underlying asset quality, quantify operator exposure to these areas and model localized optimal development programs. This study of the STACK shows how key geological drivers can be determined using multivariate analyses and how to translate this analysis into actionable insight.

Advanced Wellsite Geochemistry for Light Hydrocarbon Analysis Unconventional Systems

Andrew Sneddon, Sheng Wu, Le Iu, MCWL Paladin Geological*

As the oil industry emerges deeper into the unconventional drilling and production of oil and gas reservoirs, more advance techniques have been developed to better model unconventional resources with respects to their different fluid properties, transport mediums and nano-porosity development, understanding and ultimately, a competent, reliable method for identifying the highest producing zones. MCWL Paladin Geological has developed an unprecedented method utilizing onsite organic geochemical analytics (TOA, Tight Oil Analysis) to determine the key factors (light hydrocarbons, saturations, location of mobile hydrocarbon storage zones and accessibility and horizontal delineation of exposure to mobile hydrocarbons. This tool focuses on the detection and quantification of hydrocarbons<C18 via wellsite pyrolysis methodologies, which comprise of the predominate hydrocarbon chains in produced oil for unconventional production. The tool supplies operators with a zone-by-zone characterization of sweet spot targets during drilling of unconventional reservoirs. Our projects have helped various operators identify vertical target zones, lateral delineation of high production zones and assess and evaluate multi-stacked pay zones. This presentation will give the audience an in-depth view of how this analysis has delivered critical information during drilling in a variety of different basins and reservoir types. In addition, this presentation will give the audience a glimpse into the future of wellsite analytical developments which will directly impact the success and understanding of Unconventional petroleum systems.

Geochemical Evaluation of Oil and Gas Samples from the Upper Devonian and Mississippian Reservoirs Southern Anadarko Basin Oklahoma and its Implication for the Woodford Shale Unconventional Play

Michael Abrams, Imperial College London, Drew Thomas, Rimrock Resources*

The Woodford Shale, Sycamore, and Goddard formations have become important liquid rich unconventional resource play targets. Most petroleum experts believe the mature Woodford Shale is responsible for much of the southern Anadarko conventional and unconventional petroleum production with notable exceptions. This talk will focus on well head oil and gas samples from the South-Central Oklahoma Oil Province (SCOOP) Woodford Shale and younger Mississippian reservoirs with the intent of characterizing the SCOOP unconventional resource play using produced petroleum. Discrepancies between produced fluid and gas geochemistry, rock maturity, and production characteristics presents an interesting conundrum. The produced condensates contain lower boiling point compounds (C6-C8) that indicate a high maturity product from the Woodford Shale source, whereas the high molecular weight fraction (C15+ biomarkers) suggests a middle mature product from the Woodford Shale source. The produced gas chemistry suggests a low to middle mature product using published gas plots. Production Gas Oil Ratio and well head fluid gravities are typical of a gas-condensate. There is no simple unified petroleum system process to explain all these observations. There could be a combination of factors resulting in this conundrum such as mixing of multiple charges from both local and off-structure sources, phase separation as a result of production, or well head sampling/storage issues. At present it may be difficult to fully explain the current results, however we do believe the geochemistry and production results demonstrate a significant off-structure contribution. A simple petroleum systems model based on source rock organic matter type and maturity does not always correctly predict production or ultimate recovery.

Combining fracture depletion mapping from drilling data with Image logs to better understand fracture driven interactions

Kevin Wutherich, Drill2Frac*

It is well known that pre-existing fractures and depletion play an integral role in the completion and production of infill wells. However, it is often left to speculation as to where and how these depleted fractures are distributed along the wellbore. This paper will discuss a case study in which two complimentary technologies were used to better understand this problem. Based on this, insights will be gained on how to better interpret image logs, and will help to validate the process of using drilling data to identify depletion.

This case study will focus on an infill shale well drilled between offset producers. Depletion mapping was performed on this infill well by using the raw drilling data, acquired at the surface, to retroactively identify areas of pressure depletion and their approximate magnitude. As part of a separate project on this same well, an imaging tool was deployed to identify fractures present. By combining these two complimentary measurements, a better understanding of fracture propagation and drainage is obtained. Through this analysis, it was shown that analysis of drilling data can identify areas of localized depletion. In addition, it was seen that fractures around areas of depletion did have a specific signature which may help further understand the production mechanism of fracture flow.

Impact of Detrital Clay on Reservoir Properties, Distal Marmaton Granite Wash, Roger Mills County, Oklahoma

Autumn Graf, Jim Puckette, Oklahoma State University*

The Marmaton Granite Wash tight gas sandstone play forms a 160-mile long and 30-mile wide fairway across western Oklahoma and the Texas Panhandle. Despite being developed for many years using vertical wells with varying degrees of success, recent advancements in both hydraulic fracturing and horizontal drilling led to the play's resurgence. The Marmaton wash consists of a series of stacked and repetitive sandstone and shale beds resulting in an interval with varying lithology and a variety of depositional patterns. As a result, the Marmaton wash is geologically complex and successful operations require an understanding of the lateral and vertical geologic variability from one interval to the next. To assess productivity, the relationship between depositional facies and reservoir properties was examined. This assessment included determining pore types and abundance, fracture type, orientation, and density as well as mechanical properties of these lithologies that make up the Marmaton wash. The objective was to develop a greater understanding of tight gas sandstone reservoirs in the Marmaton wash and improve targeting locations in the Granite Wash as a whole and similar reservoirs. This study focuses on a cored Marmaton Granite Wash interval from the Laredo Petroleum Inc., Kicking Bird No. 1-20 well in Roger Mills County, Oklahoma that was drilled in 2009. The core was described, correlated to wireline logs, and sampled for thin section analysis and scanning electron microscopy (SEM). Rebound hardness testing was conducted in order to link mechanical properties to the frequency of fracturing and depositional facies. Thin section and SEM images were used to establish detrital composition, quantify porosity, and establish controls on reservoir quality. Eight depositional facies were identified in the interbedded sandstone- and shale-dominated interval. Textural relationships, facies stacking patterns and mineralogy all support the interpretation of a distal submarine fan depositional environment. No porosity was evident in thin section, but SEM images show isolated intergranular pores in the 5 μm - 10 μm range. Mineralogy indicates that sediments were eroded from the Amarillo-Wichita Uplift and deposited in a submarine fan environment as detrital clay-matrix-rich sand with low intergranular porosity. The abundant clay protected grains from dissolution preventing generation of secondary porosity essential to reservoir development in the deep basin.

MONDAY AFTERNOON

Special Session: Climate Change, Practicalities of Energy Evolution, and the Future Energy Mix

Changing Energy Mix

Paul Meier, Independent Consultant*

The energy mix is changing, and renewable energy is growing in importance. If you were born before 1989, you lived in a US where there was no electricity generated from either wind or solar power and very little from geothermal and biomass. Now, after years of growth, the combined generation from wind and solar surpassed hydroelectricity in 2017. Fourteen states now generate more than 10% of their electricity from wind and three generate more than 30%. Coal, which was responsible for 53% of the US electricity generation in 1998 is now only 28%, as natural gas has taken the leadership role, surpassing coal in 2015 as the primary energy for producing electricity. Similarly, the world did not see any electricity generation from wind until 1985 and none from solar until 1989. Now solar plus wind generate 7% of the worldwide electricity. The worldwide demand for all energy types is also increasing rapidly, as energy usage has increased 84% over the last twenty years.

In the transportation sector, bioethanol, produced from corn grain, has grown to 10% of the US gasoline market. Also, biodiesel makes up 3% of the US diesel market. Battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs), virtually non-existent before 2010, now total 2 million and auto manufacturers are committing billions of dollars in research money towards further development.

This presentation uses information from a book, "The Changing Energy Mix," to examine emerging trends in the power and transportation industries for twelve different energy types. Twelve common criteria are used to examine these trends and make quantitative comparisons. These criteria include proven reserves, the levelized cost for each energy type, energy efficiencies and balances, environmental issues, and the energy footprint. Proven reserves are also projected for each renewable energy type.

Facts vs Fears and Sensible Options: What does the Data Tell Us About Climate Change and the Future of Energy?

Lee Krystinik, Equus Energy Partners

The news is full of unprecedented catastrophic events, and talking heads telling us "the Earth on fire", but what actual data underpins the reported "climatic chaos and mass destruction of the global ecosystem"?

Global temperature has been warming since the Little Ice Age. Anthropogenic CO2 has likely contributed to this warming, though the magnitude of this contribution is open to discussion. The facts are that hurricanes, tornadoes, floods, droughts, and fires have not statistically increased in frequency or strength over the last century. Yet the IPCC has declared a Code Red. What underpins these dire predictions? We will examine adjustments made to raw temperature data, an algorithm that makes random noise into a hockey stick, and the sensitivity to CO2 via the water-vapor feedback loop in the IPCC models. The issues of rate, magnitude and severity quickly become

Nonetheless, the ESG train has left the station.. Global policy is driving massive investment in alternative energy, but the task is immense. Starting in 2020, to get to global net zero by 2050, the world would have to build an $8 billion nuclear plant every day of every year for 30 years – we are already behind by 474 plants or $3.8 Trillion along the way to $87 Trillion. Assuming the US successfully accomplishes net zero by 2050, the IPCC maximum sensitivity model for CO2 vs. global temperature yields a 0.14o C global temperature reduction in the year 2100. This gain is miniscule for the cost involved.

So, what sensible options exist? Replace coal with natural gas while investing heavily in research to increase energy efficiency and create better, cheaper alternative energy and especially storage technologies that can out-compete fossil fuels without 20X the subsidies per alternative BTU produced. Build 4th generation nuclear power facilities, presently the cleanest and least environmentally invasive option. Make fusion the next "Moon Shot". Build for resiliency in infrastructure that allows for climate change. AND, keep finding the oil and gas that the world will need for energy over many decades to come.

Climate Change, Misleading Policy Making & The Road Ahead

Dennis Hedke, Hedke Geoscience Consulting*

As geoscientists we recognize that the earth and its climate have been undergoing constant change since the earth was formed. Record keeping of processes that relate to earth's climate has been accomplished only a limited fraction of that time; nonetheless, we do have multiple proxies from which inferences can be made in the attempt to increase our awareness of these processes. The ongoing global debate as to what is relevant to the potential impacts mankind has placed on Earth's climate is anything but fully resolved, and some would claim that a climate crisis exists at the present moment, and that drastic changes need to be made in order to avert long term damage to the planet. Multiple types of data are available that shed light on whether such a crisis exists, and policy-makers are under pressure to attempt to make the best decisions possible in order to protect the planet, its inhabitants, its vast systems, and all that it entails. This presentation will attempt to demonstrate that not only do we not face anything approaching a crisis, but that earth's systems, based on highly credible evidence, are anything but in peril. As geoscientists, who purportedly have an increased sense of earth history, we have great responsibility to do a much better job of educating the general public about the system parameters that we have observed in 'recent' history, and what we would recommend to policy-makers. For example, what do we know about glaciation, sea level, tectonics, the fossil record, species extinctions, and so forth, that can add appropriate evidence to the global debate that relates to climate science? We, as geoscientists and engineers have been justifiably focused on resource extraction, processing, and delivery of energy to a growing global population, the majority of which does not have reliable electric power at all, much less affordable power to heat and cool their homes, and keep computers running at design efficiency. I submit it is high time we, in this very specially equipped profession, do everything possible to properly educate our citizens, as to what the empirical data shows us, as compared to very ineffective models, which have fostered deeply misleading policies that can, if not properly rerouted, lead to catastrophic economic and societal damage. The facts should not allow these policies to advance, rather to be significantly modified, in favor of what the real data unequivocally demonstrates, if only we will acknowledge it.

MONDAY AFTERNOON

Session: Energy Evolution: Future of Energy- 21st Century and Beyond: Data Analytics, Machine Learning, and GIS

Using an Integrated Geomodel to Assess of the Howard-Glasscock Nose area, Midland Basin

Daniel Woody, Maria Fernanda Kelley, Tammy Campbell, Joe Wicker, Amy Close, Zach Poland, Craig Andrews, Laredo Petroleum*

Laredo Petroleum's acreage position within Glasscock and Reagan Counties, Texas, allows a unique view of the development of the Howard-Glasscock Nose along the eastern margin of the Midland Basin. An internal sequence stratigraphic-based framework was developed for the Late Pennsylvanian through Early Leonardian-aged section. Major units include Cline, Canyon, lower, middle and upper Wolfcamp and Spraberry, which approximate composite sequence sets. Four to five subunits comprise each major unit with

boundaries equating to systems tracts. HST and TST are the most commonly preserved components for the Wolfcamp section. HST sets are most common in both the Wolfcamp and Spraberry in the Howard-Glasscock Nose area.
A regional-scale multidisciplinary geomodel has been developed via the integration of well and seismic data over LPI's Glasscock/Reagan county acreage position. Integration of well log, core and seismic data allows for the assessment of a variety of development parameters. The current geomodel exhibits 3-dimensional propagation of well log properties tied to seismic attributes on a scale directly commensurate with landing targets. The integration of well log and seismic data has also allowed some key insights into depositional processes that affected the area, such as highlighting fairways of debris flows and related lithologic variations that are important production drivers.
The integrated model results give insight into the development of both the unconventional reservoirs and their relationship to the edge of a carbonate platform margin. As such, the geomodel has been extensively used by the G & G team for field development and near field exploration decisions.

High Resolution Petrophysical Property Distribution Utilizing Multi-Variate Analytics
Joe Wicker, Zach Polland, Daniel Woody, Tammy Campbell, Laredo Petroleum*
Incorporating and interpolating sparse well data across large areas has proven to be an ongoing challenge in developing geocellular models for unconventional plays. Proprietary workflows have been developed to leverage high-resolution petrophysical information, typically only available in key wells, across a much larger and lower-resolution set of wells. Multivariate analytical methods using standard log suites are applied to predict lithologies, facies, saturations, and mechanical properties. This provides an enhanced source of geomodel well data inputs. Predictive petrophysical models are trained on high data density wells and then applied to standard log-suite data sets. Modeled petrophysical results are generated considerably faster versus traditional petrophysical analysis, decreasing geomodel development cycle times. Modeled results are vetted against blind petrophysical well logs to quantify errors of geomodel properties. While this method will never replace standard petrophysical analysis, it does integrate robust data to improve geomodel quality that would not otherwise be incorporated.

Implementing an Oil Field Data Repository with ArcGIS Online: Osage County, Oklahoma
Mark Cooper, Buffalo Data Services*
In 2017, Osageminerals.org was launched as a map-based pilot program for making oil and gas industry data in Osage County, Oklahoma available to the public free of charge. Since launching, the Osage Minerals Council (OMC) continues to acquire significant quantities of data to be hosted on the site, requiring compute capabilities that would challenge the financial feasibility of continuing to host the site on its original Amazon Web Services (AWS) EC2 reserved instance. When the OMC expressed interest in having GIS capabilities for fieldwork and the need for non-GIS professionals to conduct basic GIS analysis and map creation tasks, ArcGIS Online emerged as the leading solution. The content of the Osageminerals.org pilot site was migrated from AWS to ArcGIS Online, resulting in a more robust, scalable, highly documented, user-friendly environment that is cost-effective and provides a basis for easily implementing GIS-based projects in the future.

MONDAY AFTERNOON

Session: Insights from the Permian Super Basin

The West Texas (Permian) Super Basin: prototype and analog
Bill Fairhurst, Riverford Exploration, LLC, Tom Ewing, Riverford Exploration, LLC, and Bob Lindsay, Lindsay Consulting*
The West Texas Basin, a prototype Super Basin, has produced 63 BBOE. Reserves are twice historical production. The basin has been the driver of production growth in the United States and is an excellent analog for other basins. The basin is built on varied Proterozoic crust. After Cambrian rifting, regional subsidence began in the Ordovician continuing into the Mississippian forming the Tobosa Basin. Tobosa Basin subsidence terminated during Mississippian. That tectonic and structural development, controlled by basement terrains, earlier tectonic and structure were reactivated by the Ancestral Rocky Mountains (ARM) and Marathon/Ouachita orogeny. Periodic subsidence during the Mesozoic caused deformation and Cenozoic uplift tilted the basin to the east. Each of these

events has a significant influence on the petroleum systems. The basin has multiple petroleum systems. During early Paleozoic Tobosa Basin, Simpson Group and Woodford source rocks were deposited. During the transitional basin development, Barnett source rocks were deposited, and during Permian Basin subsidence, the Wolfcamp and middle Permian source rocks were deposited. Mesozoic intervals provided sufficient burial depths for increased extent of thermal effect for maturation and migration. Leonardian and Guadalupian reservoirs have produced 71% of the hydrocarbons from conventional reservoirs. These are most abundant on the shelf-crest, lower shelf to upper slope break, where reservoir development was maximized and became the focus for migration from the deeper Delaware and Midland Basin and shallower, more-proximal shelf and platform source rock systems. Unconventional resource reservoir oil production in the West Texas Super Basin accounted for just under 90% of total basin production at the close of the last decade. Since then, production has declined due to lower rates of investment driven by lower product prices.

Geological Characterization of the 3rd Bone Spring Lime for Development Optimization: A Case Study in the Central Delaware Basin

Tim Phillips, Zak Ward, John Stachowiak, Sloan Anderson, Devon Energy*

The Delaware Basin is deep into the development phase of numerous Leonardian and Wolfcampian targets and optimizing the development of these stacked reservoirs is a primary focus for all operators in the basin. The maturity of our understanding varies across these targets, which makes planning optimal development a challenge given the variable geologic properties and economic profiles present within a single section. Oil price, target selection, frac volume/style, frac sequence, visit timing, stack/stagger layout, frac barriers, pressure, stimulated rock volume, etc., all play into variables or questions that need to be addressed to best achieve an optimal development pattern. The modern-day development geologist needs to be well versed in all of these variables, and vertical pilot wells are a valuable tool in constraining them to limit risk and optimize economics.

An optimally placed pilot well equipped with pressure gauges and fiberoptic strain monitoring in addition to whole core analysis and time lapse geochemistry forms the basis of a downhole laboratory. These downhole labs can quickly inform target selection and the degree of interconnectedness between various targets. They also serve as a hub for collaboration between different geology and engineering disciplines across the organization. One such example we will outline is a recent pilot project in Loving County, Texas focused on the 3rd Bone Spring Limestone.

The 3rd Bone Spring Limestone was previously overlooked and overshadowed by the Wolfcamp in this area of the Delaware Basin. It was thought to have less source potential, lower porosity, and more carbonates that might limit storage and SRV. Older vintage horizontal tests by offset operators were not competitive with Wolfcamp economics, however in 2018 promising results began cropping up. Historical WPX moved quickly to test the 3rd Bone Spring Limestone in the Stateline area and design a pilot project in 2019 that proved to accelerate the play to development within a year. Utilizing improved knowledge of the optimal targets and drainage areas, the latest 3rd Bone Spring Limestone wells have not only matched Wolfcamp producers in the area, but many exceeded, from a Type Curve, ROR and EUR basis. The outcome of the study gave a firm understanding of what spacing and targets are ideal in the area, and the resulting inventory rivals that of the Wolfcamp A.

TUESDAY MORNING, OCTOBER 5

The Anadarko Super Basin

Key Traits of the Anadarko Super Basin

Richard Fritz, Fritz Energy Partners*

More than fifty basins worldwide are identified as “Super Basins,” defined as a basin with cumulative production of at least 5 BBOE, and with future production potential of more than 5 BBOE. By this definition, the Anadarko Basin is a Super Basin; cumulative production is close to 50 BBOE and unconventional reservoirs have the potential to produce another 50 BBOE. At least ten characteristics justify classification of the Anadarko Basin as “super”—eight key geologic elements and two technical-surface characteristics. First, the most important characteristic of a Super Basin is its source rocks. The Woodford Shale is the dominant source rock in the Anadarko Basin. It has generated and expelled more than 300 BBOE. Second, the basin was initiated by a failed rift in Late Precambrian to Middle Cambrian time. Third, the basin was filled with 40,000 feet of Paleozoic strata and multiple reservoirs. Fourth, due to the absence of significant structural inversion in the basin proper, source rocks and migrated oil and gas are mostly mature and relatively predictable to depth of generation. Fifth, a critically important attribute is the left-lateral, north-south basement strike-slip fault system. Sixth, these faults and related fractures along with unconformities and

laterally continuous reservoirs provide abundant migration pathways to good regional and local seals. Consequently, the number of accumulations of petroleum is very large and the styles of traps are numerous and varied. Seventh, among the attributes that make the basin productive, are numerous cells of over-pressured strata, and eighth, an overall paragenetic history that resulted in the development of porous reservoirs. The ninth and tenth features are technological advances and surface conditions, respectively. As a result, the Anadarko Basin has a history of significant conventional oil and gas production and a bright promise of significant non-conventional production.

The Woodford Shale Plus of the Anadarko Super Basin

Richard Fritz, Fritz Energy Partners and John Mitchell, Rutherford Exploration*

One of the most important characteristics of Super Basins is excellent source rock. Most Super Basins have three common attributes regarding source rocks: (1) high volume (>100 ft thick) of organic-rich zones distributed throughout the sedimentary section, (2) high TOC values (>10% TOC), and 3) optimal burial history and temperature profiles—not too hot, not too cold. The Woodford Shale within the Devonian TPS is one of the most prolific source rocks in North America. It covers a large portion of the Midcontinent. The Woodford is thickest in the Anadarko basin (>500 ft). Once adequate levels of thermal stress were reached on burial, the thickness of the Woodford and high total-organic-carbon percentages (>10% TOC) enabled the generation of abundant petroleum. Based on recent hydrous pyrolysis kinetics estimates of oil and gas expulsion from the Woodford Shale may be close to 307 BBOE. This evidence means that a tremendous volume of petroleum was expelled during a period of 40 million years, across Pennsylvanian to Early Permian time; however, it is estimated that the efficiency of expulsion was 27 to 50%. Consequently, large volumes of hydrocarbons remain in the rich Woodford Shale. As a result, operators continue to exploit the Woodford Shale for oil and gas in new resource plays.

Source rocks in the Ordovician are composed dominantly of oil-prone Type II shales. Pennsylvanian source rocks are dominantly gas-prone Type II-III shales. Pennsylvanian source rocks are responsible for much of the shallower production in the Texas and Oklahoma panhandles.

The Anadarko Super Basin: An Examination of the Pennsylvanian Total Petroleum System

John Mitchell, Rutherford Exploration*

The Greater Anadarko Basin, located in portions of Oklahoma, the Texas Panhandle, Kansas and Colorado, has been a prolific petroleum producing basin since 1915. The basin has a cumulative production of 13+ billion barrels of oil and 186+ trillion cubic feet of natural gas from reservoirs of Precambrian to Permian ages. The definition of a petroleum super basin requires that the basin has produced more than 5 billion barrels of oil equivalent historic production. The Anadarko Basin cumulative production more than meets this criteria. This production has come from over 300,000 producing wells at depths ranging from less than 1,000 feet (305 m) to 25,000 feet (7,260 m). The presentation reviews the petroleum system present in late Mississippian through early Permian strata described herein as the Pennsylvanian Total Petroleum System. Chesterian (Upper Mississippian) thru Wolfcampian (Lower Permian) ages have produced more than 6.3 billion barrels of oil (48% of basin total) and 147 trillion cubic feet of gas (79% of basin total). The dominance in percentage of total basin gas production versus that from older, pre-Chesterian reservoirs is explained primarily by kerogen type and thermal maturity of the petroleum source rocks of Upper Mississippian through Pennsylvanian age. Key factors in both local and regional distribution of oil and gas in the studied intervals includes presence, quality and thermal maturity of source rock intervals as well as migration pathways, reservoir lithologies and trapping mechanisms. Regional isopach and production maps of major stratigraphic intervals along with identification of various source rocks and migration pathways will be discussed.

The Birth and Tectonic Evolution of the Anadarko Super Basin

Molly Turko, Applied Stratigraphix and Turko Tectonics*

The tectonic evolution of the Anadarko Basin began in the Precambrian during the breakup of Gondwana when one arm of a failed rift tore through southern Oklahoma as a large igneous province was emplaced. This event was followed by thermal post-rift subsidence as the Great American Carbonate Bank covered North America, resulting in thick carbonate deposition into the failed rift. During the Pennsylvanian Orogeny, intra-plate tectonics inverted the failed rift creating the Wichita Uplift and associated Anadarko foreland basin. A detailed study on structures in the Anadarko Basin and Wichita Uplift records the tectonic evolution of southern Oklahoma which included a rotation in regional stresses during the Late Pennsylvanian. This insight helps to understand the structural styles that developed in the basin and on the Anadarko Shelf with implications to timing of trap and hydrocarbon migration. The

deep Anadarko Basin consists of thin-skin deformation along two regional detachments that can be linked back to the thick-skin frontal faults of the Wichita Uplift. Several of these structures were cut by late-stage strike-slip deformation leading to additional structural complexity. Structures on the Anadarko Shelf occur at a smaller scale, yet still have a significant impact on operations and production by acting as fluid conduits (leaky faults and fractures resulting in mud loss and well connectivity), or by acting as barriers (fault seals and reservoir compartmentalization). These structures include subtle Pennsylvanian-age strike-slip faults, fracture corridors, and reactivated basement faults. By understanding these structures, we can do a better job at predicting the impact on a play, such as identifying sweet spots or preparing for operational risks, but it all starts by looking at the system from the basement up and by knowing the structural origin of the basin.

Pressure revisited: examining the relationship between pressures, migration and production in the Anadarko Basin

Jim Puckette, Oklahoma State University*

Pressure data acquired from drill stem tests, bottom-hole pressure measurements during completion and calculated from wellhead shut in pressures were used to construct the pressure architecture of the Anadarko basin, which has a tiered pressure system consisting of shallow normally pressured reservoirs, an overpressured interval called the mega-compartment complex (MCC) and deep normally pressured reservoirs. The onset of overpressure coincides with the transition from dark oil to gas-condensate reservoirs and decreasing water production. As a result, the MCC behaves like a basin-centered gas accumulation. Normally pressured reservoirs above the MCC, and in adjacent tectonic provinces can contain abundant brine that must be disposed. Deep, normally pressured reservoirs below the MCC in the Hunton, Simpson and Arbuckle-Timbered Hills groups also contain producible water that must be disposed.

Overpressured reservoirs in the Anadarko Basin, like many basins with similar geothermal gradients and tectonic histories, are typically encountered approximately 3 km (10,000 feet) below surface. Exceptions include the Watonga-Chickasha trend, where compartmentalized and overpressured Morrowan reservoirs were uplifted to their present depth approximately 8,000 feet below surface. The top of overpressure is independent of stratigraphy. In Custer and Beckham counties, overpressuring is encountered in Missourian-Virgilian granite wash reservoirs, whereas the top of overpressure occurs in the Desmoinesian in northern Roger Mills and Ellis counties. Porosity in sandstone in the MCC is almost entirely secondary, formed by dissolution of metastable constituents within a rigid rock framework and occurred in conjunction with oil generation. Though isolated areas of overpressure occur in the Hunton Group, the Hunton, Simpson and Arbuckle-Timbered Hills groups are near-normally pressured. Deep normal pressure is linked to the widespread distribution of these units, pervasive pore networks and their connectivity to the surface. This connectivity allowed them to disperse pressure and serve as conduits for migrating oil and gas expelled from the deeper subsiding basin. Normally pressured reservoirs below the MCC contain water and as a result usually require four-way closure to produce. In contrast, most overpressured reservoirs in the MCC produce gas, liquids and minimal water independently of structural position and only require adequate secondary porosity to be economic.

The Anadarko Basin—A Super Past and Challenging Unconventional Future

Andrew Cullen,*

With a cumulative production of more than 50 BBOE over the last 120 years the Anadarko Basin exceeds Super Basin criterion #1 ten times over. The delivery of those volumes has been remarkably consistent, adding Super Basin cumulative production nearly every decade. At the start of the 21 Century the basin appeared to on the downside of the creaming curve when new technology, hydraulic fracturing of horizontal wells, unlocked production from low permeability reservoirs. Since 2010 more than 16,000 horizontal wells have been completed in Oklahoma as the unconventional oil and liquids-rich gas windows in the principal horizontal plays were largely drilled up leaving vast gas for future development. The Anadarko Basin's continued status as a Super Basin rests on meeting criterion #2, a future production potential of more than 5 BBOE. This talk reviews basin's principal reservoir-source rock systems (Ordovician-Silurian, Devonian-Mississippian, and Pennsylvanian) to address the following questions: 1) Is there an additional 5 BBOE future production? 2) If so, where will this production come from? 3) What are the conditions necessary to achieve an additional 5 BBOE future production. Assuming no stepwise change in technology and considering the ongoing shifts in global macroeconomic trends in energy and capital continuing to achieve super basin status over the next decade will be challenging.

The most likely scenario suggests a schism in operators and activity. The deep dry gas plays, which are better suited to long-term LNG players looking to diversify and hedge on supply risk, require not only higher a gas price, but also expanded egress capacity to LNG export terminals. Regardless of whether these requirements are realized, the shallower liquids-rich plays offer a solid future for those independents with well-honed subsurface skills, good land departments, and excellence in operations.

TUESDAY MORNING

Session: Geochemistry and Basin Modeling of Mid-Continent Petroleum Systems

Analyzing Formation Water in Cuttings

Michael P. Smith, PhD, Advanced Hydrocarbon Stratigraphy, Inc

We report on our work in identifying pay zones and oil versus water wettability from cuttings using our unique rock volatiles Cryo Trap Mass Spectrometry system.

Of the 3 dominant fluids in sedimentary basins, oil, gas, and water, water in cuttings has the best possibility of revealing its relative saturation along a borehole. Oil and gas are mostly lost from cuttings during drilling, transport to the surface, handling, and storage. In part this is because of the nearly 1000-fold expansion of the C1 to C4 compounds as they transform from liquid to gas. The density of water, however, is greater at the surface than at depth. Water in tight spaces in rocks slightly shrinks as cuttings are brought to the surface. We have spent much time and effort over many years developing the technology required to read and decipher the formation water story from cuttings.

Our unique Cryo Trap Mass Spectrometry system gently extracts and quantitatively analyzes trace amounts of present-day oil, gas, formation water, and other volatile compounds in drill cuttings and other rock samples (patents granted and pending). We analyze old and new, PDC or Rock Bit, OBM or WBM, and even air-drilled cuttings. Cuttings are either hermetically sealed at the well or lab loaded.

For each depth we analyze 2 aliquots of gas from 400 microliters of cuttings at two pressures, 20 (Aliquot 1) and 2 (Aliquot 2) millibars. Most volatiles freeze onto the liquid nitrogen traps during 7.5-minutes for each aliquot. These volatiles evolve sequentially, in boiling point order, into a mass spectrometer by warming the liquid nitrogen trap. The most volatile gases, i.e., helium, methane, nitrogen, oxygen, and argon, do not freeze onto the liquid nitrogen trap, and are analyzed by bursting a small amount into the mass spectrometer.

In PDC bit cuttings 2 millibar water represents formation water. Water extracted at 2 millibars is released from pores having pore throat diameters between 4 and 1.5 nanometers, less than 20 water molecules across. The 2 millibar, Aliquot 2, water data corresponds well with wireline logs.

Low Aliquot 2 cuttings water data identifies pay zones from PDC bit wells. This determination is independent of salinity, or of conductive minerals or clay bound water, and as such can locate low visibility pays, and pays in wells that are not logged.

High Aliquot 1 to Aliquot 2 water ratios indicates oil wetting behavior. Low Aliquot 1 to Aliquot 2 water indicates water wetting rocks. Oil wetting rocks expel water more readily than do water wetting rocks.

Also, oil versus water wettability is determined comparing cuttings oil from sealed-at-well versus lab-loaded cuttings. For a given depth, oil wetting rocks release more oil from the lab loaded cuttings than from sealed-at-well cuttings. Oil wetting rocks hold onto oil more strongly than water wetting rocks. Water wetting rocks expel much more oil from the sealed-at-well cuttings than from the lab loaded samples.

High Resolution Unconventional Reservoir Modeling of Devonian Strata in the Midcontinent Arkoma Basin Utilizing Rock Volatile Analysis

Jamar Bynum, Baker Hughes, Mike Smith and Chris Smith, Advanced Hydrocarbon Stratigraphy*

Devonian aged strata have been exploited for hydrocarbon production for over a century starting with the first American oil well that was drilled in Pennsylvania, Drake Well #1, and progressed across multiple North American Basins continuously through the modern unconventional era. Technologic advancements in unconventional development have increased the production potential of Devonian strata to include not only the higher reservoir quality sandstone and carbonate lithologies, but also the organic-rich mudstone source rocks. However, with advancements in exploration and drilling came complex production efficiency issues requiring interdisciplinary collaboration between geologists and petroleum engineers. One of the important aspects for understanding these types of reservoirs is integrating the subsurface geology with the geochemistry of both past and present reservoir fluids. This projects approach provides insights into the relationship between the geology and geochemistry across a Midcontinent Arkoma field targeting Devonian strata. Construction of a 3D model, focused on the rock volatile analysis, delineates the distribution of these reservoir properties to understand the key drivers behind reservoir quality, fluid migration, and production. Rock volatile analysis performed on cuttings collected during drilling captures multiple unique geochemical signatures. The 3D model is focused on six key attributes including: total oil volume, total gas volume, acetic acid, toluene to benzene ratios, mechanical strength, and permeability. Mapping these attributes across the structurally complex field identified where open faults are migrating reservoir

fluids and charging juxtaposed fault blocks with hydrocarbons. While proximity to pay and permeability indicators designate which fault blocks contain the highest production potential. This integrative modeling approach has implications for real time drilling decisions, target evaluation, completion strategies, and economic analysis.

Volatiles Analysis of Cuttings from Eagle Road Oil's Eisenhower 7-22N-4E Mississippian Lime Lateral in Pawnee County, Oklahoma, to Assist in Developing and Defining a New Oil Play

Christopher Smith, Timothy Smith, Patrick Gordon, and Michael Smith, Advanced Hydrocarbon Stratigraphy and Shane Matson, Jericho Energy Ventures*

Rock Volatiles Stratigraphy (RVS), invented and developed by Advanced hydrocarbon Stratigraphy and available through Baker Hughes as Volatiles Analysis Service, was run on the Eisenhower 7-22N-4E #1H, a horizontal well drilled by Eagle Road Oil in Pawnee County, SEC 18 T22N R4E. The well was drilled in December 2020 as part of a project to determine if there was a viable oil play in a grainstone deposit in the Mississippian Limestone. The grainstone has been penetrated multiple times with vertical wells, all dry. In 2013 Highmount Operating drilled the Nix 12-2H, SEC 12 T22N R3E targeting the grainstone. The lateral toe, approximately 1000'. The well had an initial potential of 152 BO, 67 MCF, 369 BW. To date the well has a cumulative production in excess of 130,000 BO, making the well one of the most productive horizontal wells in Oklahoma on a per/completed foot basis. The Eisenhower was landed in this low gamma ray (clean) carbonate grain stone formation which was confirmed by the MWD gamma ray. Approximately 2800 ft of the lateral borehole was in the clean carbonate grain stone before exiting the grain stone and entering an increased gamma ray/dirty carbonate lithology for the remaining approximately 1400 ft of the toe of the lateral.

Samples of cuttings for RVS were collected at 75 discrete depths from approximately 4600 ft MD to TD across the lateral to be run as lab loaded samples. Additionally, from 7800 ft MD to TD hermetically sealed at well site samples were collected for RVS at 100 ft intervals. The entire length of the lateral was noted to contain notable shows of liquid hydrocarbons in the RVS data. The RVS analysis of the lab loaded sample type revealed the presence of depressed water volumes across most of the carbonate grainstone and in several positions in the dirty carbonate in the toe of the well. Examining the distribution of benzene, toluene, ethylbenzene, and xylenes (BTEX), most of the grain stone and several the positions in the dirty carbonate contained a hydrocarbon composition like that which would be expected for oil, further suggesting that the observed low water volumes were due to the presence of oil. From approximately 6100-6500 ft MD a high gamma ray lithology mixed carbonate and shale was encountered. The water volume responses for this section of the well are higher while the BTEX composition is not necessarily suggestive of oil. However, in the lab loaded samples this section contained 10-100 times the volume of liquid hydrocarbons as observed in the clean grain stone; tighter rocks typically better retain their liquid hydrocarbons during production and unsealed storage at surface under STP conditions. Furthermore, the distribution of the detected liquids in these cuttings samples was significantly shifted in favor of smaller molecules. Together these results suggest that there must be significant energy/pressure in the system to force so much oil into such a tight rock that apparent molecular sieving occurred which bodes well for the size of a potential hydrocarbon accumulation. Across the length of the well, the composition of the lab loaded samples suggest the resource in the grainstone is of better quality (likely lighter API) than in the dirty carbonate section of the lateral. This is typically evaluated in RVS data by the percentage of paraffins (alkanes) versus paraffins + naphthenes (cycloalkanes) (P/P+N); in this case the clean grainstone on average had a higher P/P+N than the dirty carbonate section. The section of the well that contained sealed at well samples contained a few samples from the grain stone through the transition to the dirty carbonate to TD; this sample type is more useful for evaluating the composition of the resource and revealed a similar trend, on average the grain stone had a P/P+N value of 61% compared to an average value of 65%. Based on the compositional HC data the API of the gasoline range fraction of the resource can be directly calculated; again, the average API gravity values were 65˚ vs 62˚. The difference in the quality of the oil in both sections is likely attributable to biological activity in the dirty carbonate. Both the lab loaded and sealed at well samples show higher acetic acid, a biological byproduct, in the dirty carbonate section than in the adjacent the clean grain stone. The dirty carbonate section has been penetrated by other wells, both vertically and horizontally, but has previously had poor production performance despite the likely presence of oil. The RVS data appears to confirm the presence of oil and lower water saturations but suggests that the poor productivity issues are related to the failure to design and implement a lithology appropriate stimulation. By comparing the volume of oil extracted from the sealed at well samples to the lab loaded samples at the same depth a movability index can be generated. Comparing the few sealed at well samples in the carbonate grain stone to those in the dirty carbonate where the BTEX signature suggest oil to be present it appears that the resource in the grain stone is twice to possibly as much as six times more movable than the resource in the dirty carbonate section.

Organic Geochemistry on Assessment of Petroleum Fluid Phase Behavior, Migration Pathways, and Petroleum Systems Analysis: A Case Study from Anadarko Basin, Oklahoma, USA

Wahid Rahman, PhD, Geoscience and Petroleum Research Corporation

It is hypothesized that oil and gas migrate in an up-dip direction, but the extent of hydrocarbon migration has not been very well documented in many petroleum basins around the world. This study provides some new insights and an overview from US unconventional perspectives through reservoir geochemistry to forecast the extent of self-sourced petroleum, its migration, areal extent, hydrocarbon phase behavior and key reservoir engineering properties evaluations for reservoir geochemistry-based exploration, which leads to proper field development and economic production of oil and gas. Source rock maturity, carbon isotopes, produced oil and gas chemistry, and biomarker ratios were all analyzed and compared to better understand migration and self-sourcing in the study area. In the paper, major emphasis is given to the Woodford Shale, Anadarko Basin, Oklahoma, USA, which is one of the most prolific unconventional petroleum source rocks/reservoirs in the United States. Within the study area, the petroleum produced from this reservoir is self-sourced with a significant component having migrated in from deeper in the basin.

This geochemical work was performed on well cuttings, cores and oils extracted from source rocks; as well as produced oils and gases from the target reservoirs. Sampled Woodford organic-rich shales contain very little vitrinite; however, they contain abundant solid bitumen. Thermal maturity data from solid bitumen were converted to a vitrinite reflectance equivalent (Jacob, 1989) and compared with pyrolysis data (e.g. Tmax and Hydrogen Index). Both methods were found to be in excellent agreement. Source rock maturities vary across the area of study from early oil (~0.70 % Ro) to gas windows (~>1.35 % Ro) and approximately follow the present-day structural depth of the Woodford source rock.

Produced oil and gas geochemistry data (molecular fingerprints, isoprenoid distributions, saturate and aromatic carbon isotopes, biomarker ratios and gas carbon isotopes) from several wells suggest a common Woodford source; however, the oil maturities (e.g. Ro equivalent from biomarkers) are significantly higher than the Woodford source rock in many locations. Furthermore, the predicted GOR (gas-to-oil ratio) values from the same oil chemistry data are well matched with the produced GOR and estimated GOR from the recombined fluid samples. These findings support the interpretation (Rahman, 2019 at DGS; Peryum et al., 2018; Peryum et al., 2017; Rahman et al., 2017a; 2017b) that production from several Woodford wells includes migrated hydrocarbons from a deeper source. This study highlights many important ways in which geochemistry can be used to better evaluate unconventional reservoirs: 1) by identifying the existence and extent of hydrocarbon migration, 2) by predicting and understanding the quality and type of petroleum fluids stored in tight, unconventional source rocks, and 3) by explaining high GOR anomalies as the result of multiple charging episodes in certain areas in tight reservoirs (e.g. Meramec). The approaches described in this paper can be utilized to predict, understand, and more accurately classify unconventional reservoirs all over the world.

An Alternative Hypothesis for the Origin of Woodford-sourced Oil, Cherokee Platform of NE Oklahoma

John McLeod, Source Rocks International

The Cherokee Platform is a large west-dipping monoclinal geologic province that spans northeast Oklahoma and southeast Kansas. It is constrained by the structural provinces of the Nemaha Ridge, Ozark Uplift, Arkoma Basin, Arbuckle Uplift, and the Anadarko Basin. The Platform is noteworthy for the dominance of shallow stratigraphically trapped sweet oil and associated gas production from conventional Pennsylvanian Desmoinesian siliciclastic reservoirs. The early discovery of several shallow fields was instrumental in Tulsa's reign as the "Oil Capital of the World" until the 1940s. Much development was done before modern drilling and completion, well logging, sequence stratigraphy and petroleum system analysis. In later consideration of the plays, shallow mature Pennsylvanian oil was attributed to mature underlying Woodford source rock in the Arkoma basin and deepest Cherokee Platform that migrated north into the Platform. There is some oil-tracer geochemical evidence for a Woodford source of Pennsylvanian-hosted oils, but there are also geological difficulties with an Arkoma-Deep Cherokee trajectory. Expelled and migrating Woodford hydrocarbons would have to penetrate a thick argillaceous Atokan and Lower Desmoinesian interval as well as the more brittle Mississippian. In the Anadarko Basin, the brittle Lime is a proven conduit for Woodford migration and is itself a widespread reservoir. In the contiguous Arkoma fetch, however, a comparable Miss Lime play has not been established. In addition, the current west-dipping structure of the Platform, extending eastward from the Anadarko Basin, is not an efficient migration path for north-migrating hydrocarbons from the southern depocenter. An alternative to an Arkoma-Cherokee Woodford origin for at least part of the Oklahoma shallow Platform is present in the Osage County thermal anomaly. In contrast to Arkoma burial heating, the Osage anomaly is cut by basement faults that could have provided a conduit for thermal alteration of source rocks and the migration of hydrocarbon fluids. In part of the anomaly, mature Woodford source rock directly contacts overlying Desmoinesian siliclastic reservoirs. In addition, numerous cyclothems containing

world-class phosphorite source rock– the core shales of "lost" Pennsylvanian petroleum systems - are present throughout the thermal anomaly that likely have contributed to Cherokee Platform hydrocarbon accumulations.

Investigation of the Genetic Relationships between Oils in Western Kansas – USA

Henry Agbogun, Hendratta Ali, Ft Hays State University*

Oil has been produced in the State of Kansas since the 1860s, but the associated regional petroleum systems are still poorly understood. Sufficiently thick and thermally matured source rocks capable of generating petroleum have not been identified locally in the region. The source(s) of the oils being produced is still uncertain and debatable. This work investigates the genetic relationship between oil produced from various hydrocarbon bearing interval from different fields in Western Kansas. Findings should provide insight into the possible origin and sources that generated and supplied the oils into the reservoir units, as well as enable the geochemical characterization of the oil samples. Twelves oil samples produced from three different stratigraphic intervals (Cambrian/Ordovician, Mississippian and Pennsylvanian) from ten counties in Western Kansas were collected and analyzed using laboratory gas chromatography (GC) equipment. Data obtained include the pristane/phytane (Pr/Ph) ratio, proportion of different hydrocarbon fractions, and API gravity to compare and characterize the petroleum samples. Statistical analyses were performed to investigate relationships between the measured parameters of the samples. The measured Pr/Ph ratio ranged from 0.8 to 1.1, while the Pr/n-C17 to Ph/n-C18 ratio ranged from 0.4 to 0.9. These ratios suggest algal organic matter and deposition under marine/reducing conditions for all the samples. The n-C13 to n-C40 carbons components in the samples ranged from 89 % to 92 %, with API gravity ranging from 29 to 36 indicating a predominance of heavy condensates in the samples. Principal components analysis of the various measurements indicates one factor accounting for 92 % variation in the dataset. Considering similarities in measured parameters, and preliminary results of statistical analysis, it appears that all the analyzed oils originate from the same source rock.

TUESDAY MORNING

Session: Energy Evolution: Future of Energy- 21st Century and Beyond: Energy Minerals, Alternate Resources, and Carbon Capture, Utilization, and Storage

The Case for Building Domestic Supply Chains of Critical Minerals

Jesse Edmonson, US Critical Minerals*

The necessary supply chains to support 21st century technology require a tremendous amount of new mining for raw minerals and metals, as well as the advanced processing of these minerals to be technology-ready. Both of the steps have an obvious environmental footprint, yet they are both essential to support the clean energy transition and strategic aerospace and defense technologies. Top business leaders, investors, and policy makers are becoming increasingly focused on the vulnerabilities embedded within these supply chains and the potential for material scarcity bottlenecks that could have massive implications the economy and both energy and national security. This talk will provide a general overview of the critical minerals industry and discuss the complexity and necessity of building domestic supply chains with a focus on battery-materials.

Structural Geology: An Exploration Tool for Sediment-Hosted Metals

Molly Turko, Applied Stratigraphix and Turko Tectonics*

The role of structural geology in sediment-hosted metal exploration has been widely overlooked. Recent field work on Uranium, Vanadium and Copper-bearing Triassic-Jurassic aged strata of the Colorado Plateau suggests that up to 80% of mineral occurrence is along fracture and fault networks. Sediment-hosted copper deposits at the Cashin mine in southwest Colorado favor fault and fracture networks over a permeable eolian sandstone matrix. Residual hydrocarbons, bitumen, were preserved in these networks and acted as the reductant for copper mineralization. A lack of widespread bitumen in the matrix resulted in uneven distributions of the deposit. Identifying areas of enhanced fracturing and faulting will lead to better targeting and development of these types of deposits. Technological advances over the past 40 years in structural geology topics have increased our understanding in fracture mechanics, mechanical stratigraphy, and the relationships between fault geometries and strain. These concepts have allowed us to better predict spatial trends in areas of enhanced fracturing and faulting, which could be "sweet spots" for a deposit. In this presentation we will discuss observations from recent field work at the Cashin mine and present the concepts and workflows to identify areas of enhanced fracturing and faulting. Additionally, we will also show the impact of fracturing and faulting on Uranium and Vanadium deposits, so that this topic is not only limited to a single field area, but to sediment-hosted metals worldwide.

Solar Solutions for Oklahoma's Oil and Gas Producers

Kelsey Putman-Hughes, Drew Thomas, Travis Fultz, Wind River Resources*

Oklahoma is uniquely positioned both geologically and geographically to possess a wealth of naturally occurring in-state energy generating resources in the form of hydrocarbon, wind, geothermal, and solar energy production. According to the U.S. Energy Information Administration (EIA) report on national energy production and consumption for 2020, Oklahoma ranked 4th highest in crude oil and natural gas production, 8th for wind energy resource potential, and 6th for solar energy resource potential. As much as two-fifths of Oklahoma's electricity was generated from renewable sources in 2020, with solar energy representing less than 0.3% of that renewable contribution. While ranked in the top 10 in the nation for solar energy potential, Oklahoma ranked 49th in solar project development. Underutilization of Oklahoma's solar resource represents missed cost savings and a diversified revenue stream for oil and gas operators, a loss of surface use leasing dollars for landowners, and an opportunity for rural Oklahomans to receive low-cost energy. Applying an energy agnostic model explored in Alberta in 2020, Oklahoma's oil and gas operators (as well as the federal and state governments) have the opportunity to save on plug and abandon costs of un-economic wells by installing solar panels on the existing well pads of the no longer productive wells. This model focuses heavily on utilizing existing oil and gas infrastructure as a means of cost savings during the well site remediation process, as well as a lowered environmental impact on the land by using previously impacted property for the new solar array. In this process the wells are P&A'd as per standard regulations, yet the well pad, roads, and any useful electrical lines would remain to act as the infrastructure to accommodate the installation of ground mounted solar panels. These ground mounted solar panel arrays may be raised to a sufficient height to allow for the free travel of cattle on ranch property and arranged to enable any existing oil and gas production. This model encourages oil and gas operators to view their uneconomic wells and their associated infrastructure as an asset rather than a burden to remediate.

Developing a Geothermal Technology Strategy for the Mid-Continent Incorporating the Approaches Used in Other Parts of the U.S. and the World

Susan Nash, AAPG*

The goal of this paper is to recommend a methodology for developing a geothermal technology strategy for the Mid-Continent that incorporates the approaches used in geothermal energy exploration and development in other parts of the U.S. and the world. Beginning with identifying the long-term operational and financial objectives, the paper develops a decision tree that incorporates geological, technological, and economic factors. Specifically, the paper incorporates the geothermal energy studies published by governmental, commercial, and academic organizations in Europe, Southeast Asia, and North America. It identifies the studies and describes the methods, data, and findings for each one. It also discusses the approaches used in sedimentary basins as opposed to igneous or metamorphic geothermal regimes. A list of categories including geothermal gradient, water resources, induced seismicity risk, and infrastructure is presented. After analyzing the existing studies, a generic methodology is described which includes an overview of the types of data, the format and structure of the data, the sources of data, and the basic analytical approaches used to develop a set of criteria for classifying and ranking geothermal resources. The technical impediments are identified, along with potential solutions. After that, economic impediments are identified, with potential solutions. The paper continues with a checklist of necessary data, geological conditions, technological capability, and commercial conditions in order to identify and rank prospective geothermal prospects or potential partnership opportunities.

Integrated 3D Geology and 3D Gravity Interpretation Identifies Energy, Minerals, Carbon Sequestration, and Hydrologic Systems

Kevin Crain, cGP, Shane Matson, Jericho Energy Ventures*

Identifying and delineating alternative energy resources, minerals, hydrologic systems, and carbon sequestration reservoirs requires a new exploration viewpoint using integrated geology interpretations and potential field data. Then monitoring the dynamic systems of carbon sequestration reservoirs and hydrologic systems requires rapidly updating the geologic model and acquiring new 4D airborne geophysical data.

An initial mid-continent large-scale gravity interpretation integrating a regional 3D geology model and legacy sparse land gravity data recovered high-density anomalies in the basement. In Oklahoma, these high-density anomalies correlate well to published Woodford shale vitrinite reflectance thermal maturity data. The correlation with the thermal maturity data indicates these high-density igneous intrusions have had a higher geothermal gradient than the regional thermal gradient.

Multiple high-density anomalies are evident in the "Tri-State" area from Osage county and SE Kansas, SW Missouri, NE Oklahoma, and NW Arkansas. Within the Tri-State area, economic mineralization was emplaced by hydrothermal fluids from the high-density intrusions within the basement. But with the current state of the low-resolution legacy gravity data, it is impossible to resolve

detailed information on these blind resources. Resolving detailed location and extent of potential targets within such a large area as Osage county and the Tri-State region requires acquiring new 3D gravity data and updated 3D geology interpretations.
At the current survey cost, 2.5 million dollars-US acquires approximately twenty-six thousand line kilometers. Twenty-six thousand line kilometers cover Osage County's area with airborne gravity gradiometry with better quality and higher resolution than the legacy surface gravity data. And 9.5 million dollar-US will cover from Osage County and SE Kansas to SW Missouri and NW Arkansas.
The inversion of new 3D geology interpretations and the 3D gravity data will recover new unknown targets of geologic interest in minerals, energy, hydrology, and environmental remediation.

Geologic Framework of an Anthropogenic Carbon Capture and Sequestration Complex at Plant Ratcliffe, East-Central Mississippi
Conn Wethington, Jack Pashin, Jamar Bynum, Mercy Achang, and Stone Urban, Oklahoma State University*
The Paluxy Formation and Tuscaloosa Group in the eastern Gulf of Mexico Basin constitute a widespread succession of sandstone and shale that presents a multi-gigatonne storage opportunity for anthropogenic CO2. Geologic characterization of these strata at the Kemper County Energy Facility in east-central Mississippi as part of the U.S. Department of Energy's CarbonSAFE program focuses on delineating the stratigraphic framework with an emphasis on reservoir and seal analysis. Core studies in conjunction with petrophysical well-log analyses from six exploration wells have yielded a high-resolution stratigraphic characterization of the targeted CO2 storage reservoirs, baffles, barriers, and seals. The porosity of Cretaceous sandstone averages 30 percent, and permeability is locally as high as 16,000 mD. Sealing strata and barriers to flow include mudstone units in the Washita-Fredericksburg interval, Tuscaloosa Group, Selma Group, and the Porters Creek Clay.
SEM coupled with EDS analysis is widely used to characterize shale as a petroleum source rock and reservoir rock, but little work has been published evaluating mudstones as confining layers in CO2 storage complexes. SEM and EDS are being used to characterize microfabric, mineralogy, and pore systems within mudrocks at the Kemper County Energy Facility. Characterization has two-fold importance: (1) to characterize free and adsorbed storage potential and (2) to characterize potential migration of CO2 molecules into mudstone baffling layers and seals by capillary processes and diffusion, which can ultimately result in leakage from the primary injection targets.
Mudstone in the Tuscaloosa Group supports free storage in interparticle pores as well as adsorption on organic matter and smectitic clay surfaces. Mudstone in the Paluxy Formation and Washita-Fredericksburg interval lacks significant organic matter, so most adsorption is on clay. High water saturation in the Cretaceous mudstone units helps keep capillary entry pressure high, and mudrock permeability is on the order of 1 nD. Entry of supercritical CO2 into the mudrock units greatly reduces water saturation, and drying ultimately raises permeability by an order of magnitude. These low permeability values indicate that the mudrock units are effective baffles, barriers, and seals and slow permeation of the mudrock pore systems makes significant migration of injected CO2 out of the storage complex unlikely.

TUESDAY AFTERNOON

Special Session: Success in the Anadarko: Ovintiv's "Never Satisfied" Approach to Petroleum System Learning, Multi-discipline Collaboration, and Operational Efficiency

Ovintiv's collaborative success in the Meramec STACK play is the result of understanding the total petroleum system and significant gains in operational efficiency. Understanding the source, migration, reservoir, and seal is just as critical in an unconventional play as in a conventional play. The work done by Newfield prior to the merger with Encana/Ovintiv is founded on an intimate understanding of the rocks and the fluids within the Eastern Anadarko Basin. Tying core measurements to the logs, understanding differences in measurement techniques, identifying structural fabrics, understanding depositional fabrics, and diving into the physical characteristics in macro and micro scale have led to an integrated story and ultimate optimization of well placement, stacking, and spacing. The key to success is attributed to not only internal collaboration, but also learning from other operators and subject matter expert service providers to continue pushing on our overall understanding and a constant drive to learn and improve. Today's session will cover some examples of our geologic and reservoir work in a petroleum system framework to make better development decisions. These examples include depositional understanding, rock lithologic facies to understand reservoir performance and drilling targets, integrating learnings from new technology and subject matter experts, and utilizing data analytics

tools to normalize well performance and identify key performance drivers. Additional examples of our work include integration of fracture and faulting in hydrocarbon migration, completion dynamics/SRV and impacts to productivity as well as induced seismicity. Fiber optic monitoring of cross-well strain has been an important part in our understanding of how these faults and fractures react to completions.

The Importance of Basin Depositional Understanding to the Petroleum System In the STACK/SCOOP play

A. Leavitt, K. Xue, J. Sinclair, R. Brito, O. Djordjevic, Ovintiv*

Core/Petrographic Facies Tied to Log Based Facies across the Meramec and Woodford: Application to Understand Well Performance and Depositional Environment

K. Xue, R. Brito, C. Cross, C. Guenard, J. Sinclair, Ovintiv*

A key piece of work completed by the Ovintiv Anadarko team was a facies model for the Meramec, Osage, and Woodford formations for eastern Anadarko basin. This model integrates the rock data from cores and outcrops with well logs. We defined the facies from our core, thin sections, TOC, XRF, and XRD data. In parallel, we generated an electrofacies framework using hierarchical cluster analysis with log data and correlated them to our rock facies. This iterative process allowed us to unify and refine one consistent model from the depositional and reservoir quality perspective by honoring the rock data. Our Woodford, Meramec/Osage facies models comprise seven and eight facies, respectively. Each facies have distinct properties and rock fabrics. After rock-log-facies validation, we generated a 3D facies model across the basin. This model strongly supports our current sequence stratigraphic framework allowing us to assess the lateral and vertical distribution of reservoir quality, drilling execution, and well performance in the Anadarko.

Understanding of Fractures and Faults in the Anadarko Basin to Understand/Predict Well Performance and Potential Seismicity Mitigation Planning

O.J. Teran, S. Maxwell, S. Doss, C. Guenard, M. Martin, J. Sinclair, A. Leavitt, Ovintiv*

The structural analysis of the basement rooted faults throughout STACK and the importance of a structural framework has helped in the understanding of seismicity risks and characterizing well performance. The structural framework was built using core measurements, FMI data and seismic interpretations from the basement through the STACK reservoirs. We used our microseismic catalogues throughout the STACK to not only ground-truth the basement fault picks from seismic but also as kinematic indicators for basement fault slip. The changes in basement fault orientations produced changes in types of secondary structures mapped in the overlying sediments from microseismic data. Our analysis suggests that the majority of post-Mississippian slip on these faults can be explained by single transpressional-type stress field with a SHmax azimuth of NE-SW. Using this information, we can start to get predictive on the type of secondary structures and the extent of the fault zones that may be encountered during drilling and completions as well as how they impact reservoir performance.

The Use of Permanent and Dip-in Fiber Technology to Understand Cross Well Strain of Hydraulic Stimulations and the Interaction of Natural Fractures in Completion Operations and Parent Well Mitigation

(S. Maxwell, O.J. Teran, Ovintiv*

Fiber optic cables have been installed both permanently behind casing and via wireline for temporary monitoring campaigns. Distributed temperature (DTS), acoustics (DAS), slow strain (DSS) and DAS microseismic data have been monitoring primarily focused on hydraulic fracture growth. Integration of cross-well strain and microseismic has proven effective to understand changes with completion design and interaction with pre-existing structures, during both completions and parent well injections for pressure maintenance.

Evaluating the STACK and SCOOP Rock and Petroleum System History: Combined Rock Volatiles and Petrophysics Data of Cored Wells Across the Anadarko Basin

M. Smith, C. Smith, Advanced Hydrocarbon Stratigraphy, J. Sinclair*, A. Leavitt, Ovintiv*

Ovintiv, preceded by Newfield, pioneered exploration and production of the STACK. From 2011-2016, 9 wells were cored from the Meramec through the Woodford in the Anadarko Basin to facilitate scientific study of this world class resource. Petrophysical evaluations combined with core data and recent Rock Volatiles Stratigraphy (RVS) analyses have greatly increased understanding of the STACK and SCOOP petroleum system.

Integrating this new technology with our petroleum system understanding allowed additional insight and learnings around assessing reservoir quality, HC saturations, and nature and timing of Woodford oil migration relative to the timing of induration of Meramec silt-sized calcarenite.

Bringing it All Together for Data Driven Decisions Making

M. Tabatabaei, J. Sinclair, A. Leavitt, Ovintiv*

Like many unconventional plays of other basins, the Anadarko basin Meramec/Woodford play does not have a single factor driving higher well productivity. However, the complexity of the interaction of the hydrocarbons through geologic time and the uncertainly of how our drilling and completions interact with existing structural fabrics make it important to have the right tools to analyze these complex interactions. Data analytics has given us the ability to integrate our learnings from geologic mapping, petrophysics, geochemistry, facies modeling, fault and fracture characterization and physical observations during completions to reconstruct how these factors interact with our completions to deliver best in class well performance and cost. This data analytics approach is used as one of multiple ways to evaluate each DSU to determine the best spacing and stacking. The ability to use this tool to normalize completions, geology, and fluid characteristics along with our economic analysis give us confidence in our ability to deliver the most economic result in each of our cubes.

Ovintiv's "Never Satisfied" Approach to Petroleum System Learning, Multi-discipline Collaboration, and Operational Efficiency

Aaron Leavitt, Ovintiv*

MONDAY, OCTOBER 4

Multiscale Characterization of the Caney Shale – A Case Study from Southern Oklahoma

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In this study, an integrated, multiscale workflow is applied to limited core data to characterize macro- and micro-scale rock properties of the Caney Shale in southern Oklahoma. To understand rock type, mineralogy, pore structures, and elasticity, we utilized multiple types of data, including core sample, thin section, x-ray diffraction (XRD), scanning electron microscopy/energy dispersive x-ray spectroscopy (SEM/EDS), rebound hardness, and indentation hardness. Low vacuum focused ion beam (FIB) SEM is further utilized for 3D characterization. Based on limited samples from one Caney core, mudstone, calcareous siltstone, and silty carbonate are identified and likely represent a spectrum of environments on a ramp system. From a 3D perspective, the spatial distribution and geometry of these rock types are likely highly variable, directly affecting reservoir properties and production design. In addition, these rock types show distinctive pore structures, implying the impact of rock types on petrophysical properties. Silty carbonate contains mostly interparticle pores, whereas the calcareous siltstones and silty mudstones contain a combination of organic matter pores and interparticle pores. In addition, these rock types tend to show distinctive mineralogical compositions. In an order of mudstone, calcareous siltstone, and silty carbonate, clay content decreases, whereas carbonate content increases. In the same order as the facies transitions, rebound hardness and Young's modulus show an increasing trend, implying a direct control of mineralogy on rock mechanical properties and the importance of considering the vertical stacking of facies in production design. As a result of rock-fluid interactions, scaling reactions are possible during completion and production, and could ultimately impact permeability and production rates. Overall, the proposed multiscale approach is important for an integrated characterization of shale reservoirs where engineered fractures are expected to provide permeability at reservoir scale. Ultimately, an optimized, integrated geological characterization of the Caney Shale that is well aligned with the engineering designs in drilling, completion and production will lead to optimal production while providing safe and environmentally responsible operations.

Integrated Seismic Analysis: Using Model-Based Inversion to Predict Geologic Reservoir Properties for Carbon Storage

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Carbon dioxide (CO2) has long been used as a tool for enhanced oil or gas recovery (EOR/ EGR) for conventional plays but has yet to be employed for unconventional reservoirs. The injection of CO2 into unconventional reservoirs could serve as way for EOR/ EGR and for carbon sequestering. The Anadarko Basin is a Paleozoic, mid-continental basin with more than 30,000 feet of sediment infill that shows promise for carbon storage. Porosity and permeability are critical factors in carbon storage and enhanced hydrocarbon recovery methods for unconventional plays. This study implements a model-based seismic inversion workflow to extract porosity distributions from three-dimensional seismic data acquired in the Anadarko Basin. Core porosity and permeability measurements allow for a permeability volume to be extracted from the resultant porosity volume. Focusing on the Cleveland and Skinner formations, the acoustic impedance, porosity, and permeability volumes are analyzed to assess two important factors of EGR and carbon sequestering methods. Furthermore, we will determine whether these formations are potential intervals of interest and make estimates of the CO2 storage capacity in the study area based on the Department of Energy standards. A strong correlation of porosity distribution volumes will allow us to validate the methods as a porosity extraction tool for further integration into seismic data analysis workflows at other potential carbon storage sites.

Conodont Constrained ages of Mississippian Carbonate-Siliciclastic Sequences, STACK Play, Oklahoma

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The objective of this study was to provide biostratigraphically constrained ages for the Mississippian section within the STACK play of the Anadarko Basin. Conodonts recovered from the Pan American, Barnes D-2 core from Major County were used to confirm the age of Mississippian mixed carbonate-siliciclastic sequences, which have enjoyed a number of informal names and ages since first developed for oil and gas production. Conodonts recovered from the Pan American, Barnes D-2 core were compared to those from intensely studied outcrops of Meramecian and Chesterian strata in northeastern Oklahoma that contain siltstones and carbonates similar to those observed in STACK rocks. Results show that the four principal conodont biozones in the Meramecian through middle Chesterian outcrop sections were recognized in conodonts recovered from the Barnes D-2 core some 205 miles (330 km) west of the

outcrop, thus providing a mechanism for constraining the ages of the sampled Mississippian section in the study area. A sequence stratigraphic framework based on depositional facies and vertical stacking patterns within the Barnes D-2 core was correlated with the principal biozones and electrofacies from wireline logs. The contact between the Meramecian and Chesterian ages was identified honoring biostratigraphic constraints. The Osagean and Meramecian boundary, however, could not be resolved due to limited conodont recovery. Osagean rocks may be present in the Barnes D-2 core, in the approximately 200 feet (61 m) of Mississippian carbonate section below the first identified Meramecian biozone. Using core-calibrated stratigraphic surfaces, including radiogenic intervals on the gamma-ray curve, wireline logs were correlated to identify clinoform geometry. Thirty (30) wireline logs were selected to construct a cross section that shows Mississippian stratigraphic architecture subparallel to paleodip. This cross section begins in Major County with the Pan American, Barnes D-2 well in Section 23, T.22N., R.16W., and terminates with the Pan American, Effie B. York well in Section 13, T.18N., R.09W., northwestern Kingfisher County. Based on this correlation, most of the Mississippian section in the Starr-Lacey field area, western Kingfisher County and eastern Blaine County, is lower Chesterian and Meramecian.

Applications of first-arrivals travel time tomography on improving static errors corrections in 3-D land seismic processing

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Seismic datasets play an important role in petroleum exploration in the mid- continent. The role of processing these surveys cannot be underestimated, as it is foundational to the creation of useable seismic data. It is imperative that processing is done properly, as inaccurate data can cause a multitude of problems, from simply unusable data to dry holes drilled due to incorrect placement of seismic reflectors in the subsurface. The proposed research focuses primarily on problems with processing, as well as interpreting, the seismic. Specifically, this project investigates the impact of remaining static errors on the fidelity of the geometrical structural seismic attributes and evaluates the impact on seismic resolution. As this study shows, inaccurate processing of the seismic can have a great impact on the overall success of exploratory drilling. Land data in the Midcontinent presents unique challenges that must be resolved. Among the most prominent are challenges posed by differentially weathered carbonates and anhydrites in the near-surface to correctly modeling and improving statics in the seismic, affecting the overall quality of the processed seismic. When unresolved, these issues have a large negative effect on the image of the subsurface. This project developed a processing workflow specific to the challenges of seismic datasets in Kansas. An iterative process was used and the processing was highly tailored to deal with the specific rock formations seen in Kansas. These formations are primarily composed of carbonates and evaporites, and so greatly affect the static solutions needed. The complete processing workflow was applied to the dataset, producing an optimized post-stack volume through the assessment of static errors corrections on the quality of stacking velocity. Mapped first arrival travel-times were used as the input for travel-time tomographic inversion, creating a velocity model of the near surface. Applying this to the original dataset improves the quality of the seismic cube and removes the obvious topographic imprint present in the original post-stack interpretation. An additional benefit of this workflow was a greatly increased signal-to-noise ratio and significantly improved seismic resolution. Interpretation of this reprocessed dataset more closely corresponds to well data in the area, giving a high level of confidence in the accuracy of the reprocessing workflow.

An Integrated Approach For Shear Wave Velocity Estimation In Gas Saturated Reservoirs

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Shear wave (S-wave) velocity estimation from the Castagna' equation is often inadequate in gas saturated reservoirs. As a result, Fluid Replacement Modeling (FRM) was integrated with a water saturation (Sw) value from each gas-saturated reservoir in "Joshzoic Field", Niger Delta in order to properly evaluate the S-wave velocity for a gas sand since the log signature indicate that the study interval is gas-filled. Wireline log signatures were employed to identify hydrocarbon bearing reservoirs and compute Sw values. FRM and rock physics crossplots were carried out. The neutron and density log signature of the three reservoirs (Sand A, Sand B and Sand C) analyzed in this study show that the reservoirs are gas-bearing. However, the poisson ratio of the three sands calculated from S-wave derived from the Castagna's equation ranges from 0.3 – 0.33 which indicate that the reservoirs are water-bearing. In contrast, rock physics crossplots after FRM with Sw value of each reservoir show anomalous zone that plotted away from the background wet trend. The three gas-filled reservoirs are characterized by high value of P-impedance and Mu-Rho with low value of Vp/Vs ratio, poisson ratio and Lambda-Rho; suggesting that the reservoirs are saturated with gas which corresponds with neutron and density log signature. Hence, this study has been able to show the inadequacy of the Castagna's equation in the evaluation of S-wave velocity in the Field of study, and a novel method has been developed for the determination of S-wave velocity in the Field of study.

Sedimentology, Depositional Environment, and Stratigraphic Hierarchy of Upper Cretaceous Tuscaloosa Marine Shale in Central U.S. Gulf Coast

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Lithology, sedimentary structures, and stratigraphic stacking patterns of Upper Cretaceous Tuscaloosa Marine Shale (TMS) observed in 3 cores in SW Mississippi and Louisiana are used to assess the stratigraphic hierarchy and heterogeneity. The shale was deposited on the outer continental shelf of GOM during late and maximum marine transgression. The cores are 73, 66, and 54 m thick and 10s of km apart. 5 well-laminated lithofacies are clay – f-silt and m-silt mudrocks, m-c siltstone, and vf-f and gravelly f-m sandstones. Laminae are 0.1 mm-10 cm thick, mostly 0.5-3 mm. 5 orders of stratigraphic hierarchy include lamina, lamina set (LS), bed (B), parasequence (PS), and parasequence set. 5 types of LS are 0.5-30 cm thick and include: LS1 – wave-enhanced sediment gravity flow deposits, LS2 – tempestite, LS3 – turbidite, LS4 – current deposits, LS5 – pelagic clay-f-silt mudrocks. LS1-LS3 consist of light gray, massive, normal graded, or cross-laminated m siltstone to sandstone and common gravelly lags with erosional bases. LS4 is gray, parallel-laminated m siltstone to sandstone with flat sharp bases. LS5 is dark gray and parallel laminated with sharp or gradational bases. LS1-LS4 are interpreted as sediment gravity tractional flow deposits; LS5 as suspensional pelagic deposits. LS stacks into 3 types of beds, 1-30 cm thick: B1 consists mainly of light gray LS1-LS4 with<30% of LS5; B2 of dark gray interlaminated LS1-LS5 with 30-60% of LS5; B3 of dark gray LS5 with<40% LS4. Beds stack to form bipartite or tripartite upward-fining or coarsening, 10-100 cm-thick PS. The former dominates, indicating upward-decreasing current energy and current deposition. Finally, stacking of PS defines PS sets that are grouped into transgressive systems tract. An overall upward-fining trend reflects upward deepening related to late and maximum transgression. The hierarchical stratigraphic framework provides a context for detailed reservoir characterization using specific attributes and stratigraphic correlation. TMS deposited in the north contains thicker and coarser tempestites, skeletal lags, and macrofossil debris and more intense bioturbation than that deposited in the lowstand incised valley in the south. The northern site is outside of the valley in a more up-dip location and closer to clastic sources. Sea-level change and shelf topography are the main controls on stratigraphic variability.

Evaluation of unsupervised machine learning methods for seismic facies classification: Applications on Reservoir Characterization in the Cenozoic Deep-water Strata, Australia

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The constant increase in seismic information resolution and size of the surveys has hindered seismic facies' interpretation using conventional methods, which is a critical step in reservoir assessment. The development of unsupervised seismic facies classification algorithms such as K means, self-organizing maps (SOM) and generative topographic maps (GTM) has successfully addressed this problem by clustering features that after careful inspection can be geologically explained. In this research study, we provide a workflow that improves the efficiency in delineating architectural elements and features of interest for reservoir characterization as well as point out the major aspects to be considered before applying unsupervised machine learning methods. We explored the mentioned methods by applying them into a 3D seismic survey in North Carnarvon Basin, Australia in two scenarios: 1) a generalized differentiation of the architectural elements in the deep water setting and 2) detailed mapping of the mass transport deposit (MTD) components in a complex MTD example. As most previous work in application of unsupervised techniques in 3D seismic are oriented to choosing meaningful input data (attributes), we focus on comparing algorithm's efficiency by using a unique suite of attributes, that proved to be efficient in discriminating the features of interest. These attributes are quantitative measurements of a seismic characteristic of interest (instantaneous, spectral, and geometric) employed as proxies of geological properties such as lithology, bed thickness and structures. Results showed that overall, GTM and SOM better depict the features of interest for interpretation. We found that all the methods have benefits and drawbacks that need to be considered while choosing the appropriate algorithm depending on the detail of the expected result. Therefore, we illustrate considerations to be taken in each scenario.

TUESDAY, OCTOBER 5

Petrophysical analysis of Mississippian rock types and reservoir properties within a sequence-stratigraphic framework, eastern Anadarko Basin, Oklahoma, USA

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Knowledge of mineral volumes are crucial in the Mississippian strata as they are primary control on porosity and permeability. A matrix algebra inversion method used to calculate the mineral volume has relatively good predictive accuracy for carbonate (R2 = 0.73), quartz (R2 = 0.66), and clay (R2 = 0.76) minerals. Based on the calculated mineral volumes and effective porosity, the Mississippian strata are classified into 3 rock types. Rock type 1 is characterized by relatively moderate clay (22% - 39%), quartz (26% - 43%), and carbonate (25% - 47%) contents and lower effective porosity (<2%). Rock type 2 has relatively higher quartz (43% - 48%), moderate carbonate (20% - 45%) and clay (6% - 18%) contents and higher effective porosity (4% - 7%). Rock type 3 has relatively higher percentage of carbonates (61% - 85%), lower clay (<11%) and quartz (8% - 30%) contents and moderate effective porosity (2% - 4%). In terms of reservoir quality, rock type 1 is the worst reservoir rock and rock type 2 is the best reservoir rocks with high storage capacity and brittleness. Mississippian strata of the Anadarko Basin in Kingfisher and Canadian counties consist of 1 low-order stratigraphic unit with overall upward-deepening profile. The intermediate order correlates to multiple depositional episodes consisting of lowstand-, transgressive-, and highstand systems tract. Clay-rich rock type 1 typically increases during late highstand systems tract and lowstand system tract and quartz-rich rock type 2 typically increases during transgressive systems tract and early highstand systems tract. Higher order cycle exhibits an ideal upward-shallowing succession within parasequences that consists of bioturbated siltstone, laminated-siltstone, structureless siltstone, and cross-laminated siltstone. Proximally, individual cycles are often capped by skeletal wackestone-packstone. A sequence boundary is characterized by a subaerial exposure with brecciated chert or an erosional surface; and glauconitic siltstone-sandstone is typically present atop of this boundary. The threefold (low, intermediate, and high) stratigraphic orders combined with a dip-oriented 3D model indicate that the reservoir sweet spots containing higher percentage of quartz-rich rock type 2 occur during deepening in the transgressive and highstand systems tract (parasequence Miss 9 to Miss 12).

Simulation of carbon dioxide injection for enhanced oil recovery from shale reservoir, onshore midcontinent.

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Unconventional oil resources are exploited with advancements in technologies like horizontal drilling and hydraulic fracturing. Even though they cover a large area, production from these reservoirs decline rapidly due to the complex nature of the formations. Consequently, the low recovery factor leaves substantial amounts of oil unrecovered. Carbon dioxide (CO2) injection has the potential to be used in unconventional shale reservoirs to increase oil recovery. Each formation has unique characteristics that the oil recovery process, parameters and the outcomes vary with formation. The present study focuses on the Late Devonian-Early Mississippian age Woodford shale, onshore midcontinent. Non-expelled hydrocarbons of this marine black shale is one of the successful resource plays in the midcontinent. The United States Geological Survey (USGS) oil and gas assessment of the Anadarko province shows that the Woodford shale holds undiscovered oil resource of 393 million barrels of oil (MMbo). The enhanced oil recovery using CO2 injection could help in extracting significant amount of the oil resources from the Woodford shale. Reservoir models are essential for understanding the recovery processes. The integrated reservoir models built from interpretation of seismic data and well logs are used for simulation studies of injecting carbon dioxide for enhanced recovery. Reservoir simulation scenarios give insight into effectiveness of using CO2 for enhanced oil recovery from shale reservoirs. This helps to understand the reservoir performance during the EOR process, forecast well production and recovery rate, and finally to optimize the oil recovery process. The study may open up the possibilities and extensive use of CO2 for increasing hydrocarbon production from shale.

Quantitative Evaluation of CO2 Storage Potential in Atlantic Offshore Lower Cretaceous Strata, Southeastern United States

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We present the first comprehensive, quantitative assessment of CO2 storage potential for Lower Cretaceous strata on the outer continental shelf of the South Atlantic Planning Areas, including the Southeast Georgia Embayment and the Blake Plateau. A detailed interpretation of legacy industry 2D seismic reflection profiles and existing well data that we used to create structure and thickness maps for the potential reservoirs and seals of the Lower Cretaceous strata. We identified and assessed three target reservoirs for CO2 geological storage. The CO2 storage capacity of these reservoirs has theoretically calculated based on the DOE-NETL equation. The USDOE equation mathematically expressed: CO2= .h. . . . (USDOE equation).Where GCO2 is the total mass of CO2 in Gaga Ton (Gt), A is target area (in square meter), h is Gross strata thickness (in meter), is percentage of effective porosity, is CO2 density (in kilogram per cubic meter), and E is the percentage of factor efficiency. The large-scale CO2 storage capacity for the Lower Cretaceous reservoirs estimated in Gt. Using the Monte Carlo method for saline formation, dolomite efficiency factors (E) at the formation scale of P10, P50,

and P90 are 2.0%, 2.7%, and 3.6%, respectively. We calculated the CO2 storage potential within the Lower Cretaceous based on the net thickness of the porous and permeable layers. The average porosities of the upper, middle, and lower reservoirs are 27.4%, 28.1%, and 28.7%, respectively. The calculated storage capacity is 3.66 Gt, 65, and 498 Gt that could be securely stored in the Lower Cretaceous reservoirs as a total of CO2 at P90, P50, and P10 respectively.

Review of Effective Technological Developments for Existing Oil and Gas Fields and Future New Energy in the Energy Transition

Susan Nash, AAPG*

This paper provides a detailed evaluation of new technologies deployed in existing oil and gas fields to improve efficiency through automation and a better understanding of the reservoir, detect and eliminate fugitive gas emissions, manage water, streamline supply chains, avoid induced seismicity, and reduce the carbon footprint. In addition, the paper provides an evaluation of new technologies that being successfully adopted in new operations in the energy transition. They include geothermal energy, carbon capture, utilization and storage (CCUS), hybrid integrated energy (solar / geothermal, for example), advances with critical minerals and battery technology. In addition to a review of the technologies, the paper also includes a discussion of the pace of transition, priorities, and the type of blended solutions that are being implemented and also encouraged through large government programs. Finally, all technological implementations are evaluated from within a framework of earth energy and the process of privileging electricity from carbon-free sources, and the fact that the global demand for energy continues to climb, particularly in a COVID and post-COVID world, while the supply of permissible energy. The result is energy that is more expensive than before, so that there is likely to be both cost-push and demand-pull inflation in energy. The cost of energy will be reflected in virtually all sectors of the economy, which will result in a challenging struggle to keep inflationary pressures within non-destructive ranges. Geoscientists and other professionals who continue to develop or deploy technology that makes more earth energy supply available at a lower cost while preserving the environment will be increasingly sought after, and their knowledge will be strategically applied to help companies evolve and grow within new paradigms and parameters of industry and infrastructure.

Blended Solar and Natural Gas Solutions for ESG and Risk Management

Susan Nash, AAPG*

This presentation provides specific solutions for blended solar and natural gas solutions that satisfy environmental, social and governance requirements as well as helping manage the risks associated with a highly volatile price, supply, demand, and regulatory environment. The presentation begins with an overview of the kinds of solar and natural gas energy solutions that are most economical in the Mid-Continent and it details how the energy is used to generate electricity and enter the grid. The second section provides an overview of the state of the art when it comes to solar microsites and boutique applications, which are determined by the specific use of the generated electricity and the proximity to substations and the electrical grid. Examples of the blended use of mobile solar trailers and natural gas are analyzed, and the projected future use of micro-site solar installations, boutique solar, and hybrid natural gas and solar solutions are examined, explained, and critiqued. Finally, a recommended hybrid approach is detailed, along with a description of ideal use cases, risks, and rewards, given three global economy scenarios.

Joints in the Middle-Pennsylvanian McAlester Formation, Ft Smith, Arkansas

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Understanding joints and joint systems in shallow crustal rocks is an essential part of many types of geologic investigation. Joints conduct the flow of subsurface fluids and serve as potential zones of weakness, and are thus of interest to hydrogeologists, petroleum engineers, and civil engineers. Joints are also of interest to structural geologists as indicators of the types and orientations of stress during previous deformational events. Preliminary field work in sandstones of the Middle Pennsylvanian McAlester Formation in the vicinity of Fort Smith, Arkansas has revealed a widespread joint system comprising both systematic and non-systematic joint sets. Data was collected at five isolated outcrops of thinly bedded sandstone spread over an area of about 16 km2. At the time of this writing, the data set contains 141 systematic joints and 39 cross-joints. For each of the five outcrops, joint azimuths were measured and plotted on two rose diagrams – one for systematic joints and the other for non-systematic joints. The systematic joint set has a markedly uniform mean azimuth of 345° ± 1° and spacing ranging from about 0.25 to 1.5 meters. Cross-joints are less abundant and less regularly oriented, with mean azimuth of 262° ± 8°. The systematic joints are interpreted as mode I tensile joints oriented vertically and approximately parallel to NNW-directed compression associated with the Ouachita Orogeny about 300 million years ago. At that time, as evidenced by the orientations of fold axes associated with the orogeny, the maximum

principal stress (1) in the region was oriented slightly west of due north, the least principal stress (3) was oriented just south of due west, and the intermediate principal stress (2) was near-vertical. The systematic joints formed parallel to the vertical 1- 2 plane, concurrent with and roughly perpendicular to the east-west oriented fold axes that characterize the late Paleozoic sedimentary rocks of the Arkansas River Valley. We hypothesize that future mapping will reveal similar relationships of joints and fold axes in brittle sandstone members throughout the region.

Fossil Fuel Industries are an Important Component to The Earth's Carbon Cycle of Life

Curtis Faulkner, Hogback Exploration*

Over the past several decades, both the petroleum and the coal industries have lost its momentum as the safest and lowest cost sources of energy. Instead, these industries have unfairly gained the reputation as high carbon polluters, bad for the environment industries with giant carbon footprints. Even people within these industries are starting to believe these thoughts of "Bad for the Earth" attitudes. Heated debates and hypotheses spark geologic and environmental thoughts about "bad-carbon" and many have jumped on the bandwagon. However, basic fundamental concepts of the Rock Cycle and the Carbon Cycle have been ignored in these "Bad Carbon" teachings. Life on Earth is carbon-based; without carbon, we would not be. Carbon on the Earth is in limited supply and there is no new carbon being created for Earth's carbon-base life. Except for the trace carbon dust that falls from outer space, the Earth is a closed carbon system. So, we as inhabitants of Earth are part of the great carbon cycle; we are all just recycled carbon star dust! When carbon life-forms get buried, they are removed from biologic use and are converted to form coal and hydrocarbons, it is no longer available to be recycled to support new life on the planet's surface. In geologic time, surface carbon would be greatly depleted and unavailable to the Web of Life on the surface of the planet and all life would suffer. If it was not for the rock cycle, plate tectonics, and carbon-rock recycling, life on Earth would be much different today in a highly depleted carbon environment. The Petroleum and Coal Industries in effect bring unavailable carbon back to the surface to be re-used to support life at a much faster rate than the geologic processes of plate tectonics. In effect, bringing this carbon back to the surface for consumption feeds and supports life.

Removal of mixture heavy metals and metalloids from petroleum produced water by dolomite filtration

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Previous studies have suggested the possibility of using dolomite filters made of compressed powdered dolomite to remove heavy metals from petroleum produced water (PW) at an economic cost. However, those studies were conducted using a single type of heavy metal or mixture of heavy metals and metalloids at low salinity conditions. The aim of this study is to elucidate the feasibility of using dolomite filtration and guar gum to remove mixture heavy metals and metalloids from PW characterized high salinity. To this aim, we conducted core flooding experiments at different salinity, injection rate, and grain size conditions, as well as reactive transport simulations. Because of the common occurrence of Sr, Ba, and Cd in PW from oil and gas wells in the Arbuckle Group, the focus of this study is on PW containing Sr, Ba, and Cd, and on dolomite collected from the Arbuckle Group. We found that salinity (NaCl) has a significant negative impact on the removal of Sr and Ba, but not on Cd removal from PW. The smallest the ability of heavy metals and metalloids to form chloro-complexes, the highest the attenuating effect of salinity and acidic pH on the sorption of chloro-complexes on dolomite and vice versa. Like chloro-complexes of Sr, Ba, and Cd, guar-gum complexes inhibit Sr, Ba, and Cd sorption reactions on dolomite. Higher degree of complexation reactions of guar gum with Cd than with Sr and Ba is reflected by a greater decrease of Cd sorption than Sr and Ba sorption on dolomite. Sorption reactions of Sr, Ba, and Cd on dolomite are kinetically controlled reactions that are not limited by the availability of pore surface area, but by the retention time of PW in the dolomite filter. An increase of Sr, Ba, and Cd removal by increasing the number (length) of filters suggest that a complete removal of Sr, Ba, and Cd can be obtained by optimizing the relationship between the injection rate and size of the dolomite filter. Our findings have large implications toward the establishment of a new economic treatment method of PW for contaminant heavy metals and metalloids and the elucidation of the fate of contaminant heavy metals and metalloids present in PW disposed into deep dolomite saline aquifers.

Hiatus Mapping in Texas

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It has been proposed that Texas experienced uplift and tilt during the latter part of the Cenozoic based on onlapping strata and truncated sequences. The precise timing, spatial extent, and amplitude of these vertical motions, as well as their dynamic causes, remain poorly constrained. We propose to analyze regional-scale unconformities from geologic maps and regional cross-sections of Texas to compile hiatus maps at spatial scales of many hundreds of kilometers and at temporal scales of geologic epochs. This

will be complemented by the analysis of subsurface geometries and by a quantitative assessment of the role of post-rift thermal subsidence and lithospheric flexure induced by sediment loading. Our analysis will put additional constraints on the timing and amplitude of tilting, refining our knowledge of the tectonic history of Texas. Additionally, we will be able to assess whether changes in dynamic support from the convecting mantle are required to explain these past vertical motions of the Texas lithosphere.

The Relationship Between Early Paleozoic Faults on Shallow Permian Aged Strata Using Seismic Attributes in Northwest Ector County, Texas

Jozef Szypulski, University of Texas Permian Basin*

The Permian Basin is one of the largest oil and gas-producing basins in the world. The development of the Marathon-Ouachita Fold Belt led to subsidence of the Midland and Delaware Basins and the uplift of the Central Basin Platform (CBP). This uplift led to the development of numerous faults found in the CBP that opened migration pathways for oil and gas. The importance of the CBP in the Permian Basin comes from the San Andres formation which has a history of carbonate deposition and diagenesis which makes this formation a well-known reservoir. These productive fields also have a proven history of enhanced oil recovery (EOR) within the residual oil zones (ROZ) through the advancements of enhanced recovery methods and technology. In our study area located on the CBP, we analyzed seismic attributes, such as coherency, and identified three deep-seated faults below the Pennsylvanian unconformity. We analyzed other seismic attributes, such as dip, structural curvature, and aberrancy to study the flexures in the shallower Permian-aged strata. Based on seismic attribute analysis, we found two lineaments in the Permian aged strata that are close in the orientation of the deep-seated normal faults extending into the Holt formation. We also identified one of the lineaments extending vertically into the San Andres formation. These lineaments correspond to the flexures, which can be zones of fractures, that increase secondary porosity in reservoirs that could impact hydrocarbon migration and long-term CO2 storage.

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