51st Annual Meeting of the Eastern Section American Association of Petroleum Geologists (ESAAPG)

Energy For All

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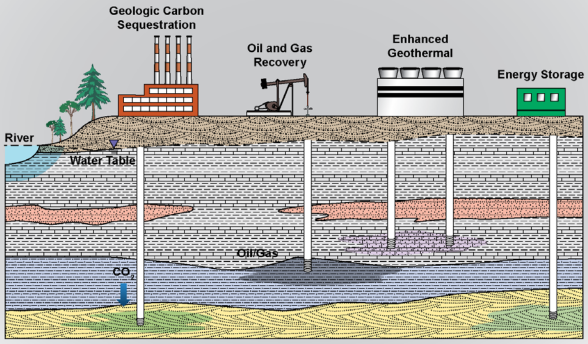

ILLINOIS GEOLOGICAL SOCIETY 1937

ESAAPG - October 2022

October 24–26, 2022

Champaign, Illinois, USA

I Hotel and Conference Center

AAPG Eastern Section

ILLINOIS GEOLOGICAL SOCIETY 1937

Hosted by: Illinois State Geological Survey
Illinois Geological Society

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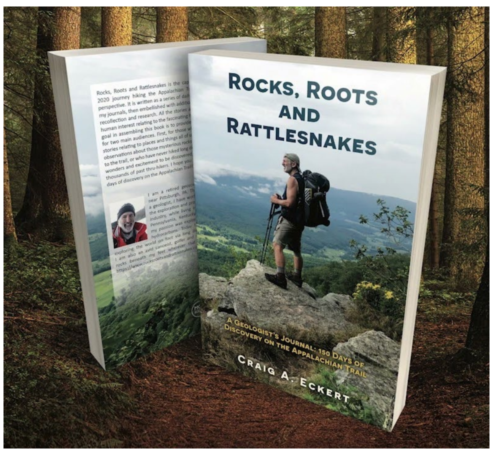

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Contents

Welcome

Welcome,

The Illinois Geological Society and the Illinois State Geological Survey are honored to welcome you to Champaign, the University of Illinois Campus, and the IHOTEL Illinois Conference Center for the Fifty-First Annual Convention of the Eastern Section of the American Association of Petroleum Geologists (AAPG). The theme for this meeting – **Energy for All** – is intended to reflect the expanding need for sustainable petroleum development, all facets of energy storage, geo-professionals who are experts in subsurface characterization and production, and the essential necessity of training new industry professionals. Energy transformation has occurred throughout our history – from biomass (wood) to coal, to whale oil, to petroleum, to nuclear. This transformation will continue as we look for cheaper, more efficient, more sustainable ways to power the United States and the World. Industry geoscientists, operators, completion and production engineers and professionals are uniquely qualified to lead, provide energy solutions, and diligently work to launch us into this transformation. **We all must work together to make it happen.**

We would like to thank all the attendees, including exhibitors, for making the trip to Champaign, Illinois to learn and grow professionally through this event. It is a pleasure to be able to network, see colleagues and old friends, and make new acquaintances after a couple of years of mostly virtual meetings and conferences. Being able to discuss and review new ideas, technologies, and workflows in-person is vital to promoting our industry from within and without. The Illinois Basin (Illinois, Kentucky, Indiana) is becoming a proving ground for new techniques and technologies.

Please take the time to graciously thank our sponsors and exhibitors for supporting this conference. Without them, we could not host this meeting. Also, take the time to read through the **Energy for All Organizing Committee** members and thank them as well. They have volunteered the necessary time (countless hours) and work to make this ESAAPG Annual Conference happen. Their efforts to work together, manage unexpected issues, and provide cheerful support has been amazing.

Finally, enjoy your time attending the Conference and we hope you can learn something new, apply fresh information directly to your business or profession, and build additional networks. Thanks for coming!

Donna Caraway Willette
Hannes Leetaru
General Conference Co-Chairs

Welcome

2022 Organizing Committee

General Conference Co-Chairs – Dr. Donna Caraway Willette and Dr. Hannes Leetaru
Illinois State Geological Survey (ISGS)

Technical Program Chair – Donna Caraway Willette, ISGS
Sponsors and Exhibitors Co-Chair – Stephanie Storckman, Podolsky Oil Company
Sponsors and Exhibitors Co-Chair – Stacee Dover, Countrymark
Student EXPO Chair – Cole Bowers - Greylock Energy, Joan Crockett – Consultant, ISGS Emeritus
Short Courses Chair – Nathan Webb, ISGS
Awards Chair – Thomas (Marty) Parris, Kentucky Geological Survey
Field Trip Chair – Scott Elrick, ISGS
Program Editor Chair – Zohreh Askari, ISGS
Core Workshop Chair – Dmytro Lukhtai, ISGS
Entertainment Chair – Kevin Strunk, Wabash Resources and Consulting
Subsurface Hydrogen Workshop Chair – Donna Caraway Willette, ISGS
Critical Minerals Workshop – Jared Freiburg, Charles Bopp, ISGS
Graphic Design and Audio-Visual Chair – Daniel Byers, ISGS
Judging Chair – Kendall Taft, ISGS
Website and Registration – Michelle Marquart, University of Illinois Conference Services

Eastern Section AAPG Officers

Website: www.esaapg.org

President	Donna Caraway Willette, Illinois State Geological Survey
Vice-President	Ian Thomas, Olympus Energy
Secretary	Autumn Haagsma – Battelle
Treasurer	Cole Bowers, Greylock Energy, LLC
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Illinois Geological Society Officers

Website: www.ilgeosoc.com

President	Jason Smith, Centerpoint Energy
Vice-President	Donna Caraway Willette, Illinois State Geological Survey
Treasurer	Brad Richards, BiPetro
Past President	Stephanie Storckman

Co-Hosted by the Illinois State Geological Survey

Meeting Schedule and Room Assignment

Monday, October 24		
8:00 AM-5:00 PM	Registration desk open	In front of Illinois Ballroom
9:00 AM-4:00 PM	Student Expo	Humanities Room
12:00 PM-4:00 PM	Short Courses	Technology and Quad Rooms
4:00 PM-5:30 PM	Honors and Awards	Lincoln Room
5:15 PM-7:30 PM	Icebreaker/Reception	Illinois Ballroom
7:30 PM-10:30 PM	Entertainment	Illinois Ballroom
NOON–5:30 PM	Speaker and Judging Ready room	Loyalty room

Tuesday, October 25		
7:00 AM-8:30 AM	Buffet Breakfast	Foyer
7:00 AM-8:30 AM	AAPG/SEG/ESAAPG Leadership Breakfast	Innovation Room
7:30 AM-5:00 PM	Registration desk open	In front of Illinois Ballroom
7:00 AM-7:30 PM	Exhibit Hall Open	Illinois Ballroom
8:30 AM-9:15 AM	Welcome and Opening Remarks	Chancellor Ballroom
9:30 AM-5:00 PM	Technical Sessions I, II, III	Technology, Quad, and Lincoln Rooms
11:45 AM-1:15 PM	Lunch Break	Foyer, Illinois Ballroom
11:30 AM-1:30 PM	ESAAPG Council Luncheon	Innovation Room
1:15 PM-5:00 PM	Technical Sessions I, II, III	Technology, Quad, and Lincoln Rooms
5:00 PM-7:00 PM	Buffet Dinner	Foyer, Illinois Ballroom
4:30 PM-6:00 PM	Young Professionals Event	Offsite – Triptych Brewery
6:45 AM-9:30 PM	Core Workshop	Chancellor Ballroom
8:00 AM–5:30 PM	Speaker and Judging Ready room	Loyalty room

Wednesday, October 26		
7:00 AM-8:30 AM	Buffet Breakfast	Foyer
7:30 AM-1:00 PM	Registration desk open	In front of Illinois Ballroom
8:30 AM-Noon	Hydrogen Storage Workshop Critical Minerals Workshop	Technology Room Quad Room
Noon-1:00 PM	End of Conference Reception	SW Foyer by Technology and Quad Rooms

In Memoriam

Larry D. Woodfork (1939-2022)

Larry D. Woodfork was born in Vincennes, Indiana on May 30, 1939 to Basil R. and Eva L. Sayre Woodfork. He graduated from Lincoln High School and then attended a two-year program at Vincennes University. After Vincennes University, Larry received bachelor's and master's degrees in geology from Indiana University. Later, he completed doctoral course work in geology with a minor in petroleum engineering at West Virginia University. His professional experience included geologic field work for Chevron in the northern Rocky Mountains, work as a research associate in industrial minerals at the Indiana Geological Survey, and time as an exploration geologist for Exxon in its south Texas division.

Larry began his long career with the West Virginia Geological and Economic Survey in 1968 and was appointed Assistant State Geologist in 1969. On August 1, 1988, the governor appointed him Acting Director, and ultimately, he became Director and State Geologist on January 20, 1989. He also held appointments as Adjunct Professor of Petroleum Engineering in the College of Energy and Mineral Resources and Adjunct Professor of Geology in the Department of Geology and Geography at West Virginia University.

Larry was certified as a Professional Petroleum Geologist by both AAPG and the American Institute of Professional Geologists (AIPG). He served on numerous AAPG and Eastern Section AAPG committees, was a speaker for the AAPG Visiting Professional Geologist program, and held all Eastern Section offices, culminating in its presidency in 1979-80. He served as the Eastern Section representative on the AAPG Advisory Council from 1982 through 1985, chaired the AAPG House of Delegates in 1985-1986, and served as president of the AAPG Division of Environmental Geosciences.
Larry also served as President of the American Geological Institute (AGI), the American Institute of Professional Geologists (AIPG), and the Association of American State Geologists (AASG). In addition to his memberships in AIPG, AAPG, AASG, he also was a member of numerous other professional societies: Appalachian Geological Society, Pittsburgh Geological Society, Pittsburgh Association of Petroleum Geologists, Sigma Gamma Epsilon, Sigma Xi, Geological Society of Washington, D.C., and a founding member of the Monongahela Group, northern West Virginia's geological society. Due to his leadership and service to the profession, Larry was elected to membership in the prestigious Cosmos Club of Washington, D.C., in 1986. Because of his excellent scientific reputation and acumen, he was asked to serve on a prestigious committee of the National Academy of Science, National Research Council on energy issues.

Larry was recognized by numerous awards for his service to the profession. He received the AIPG Ben H. Parker Medal and was the first recipient of AIPG's Martin C. Van Couvering award for distinguished service in 1979. He also received the AGI Medal in Memory of Ian Campbell, was a Senior Fellow of the Geological Society of America and an Honorary Member of AIPG and AASG. The Eastern Section AAPG honored him with their Distinguished Service Award in 1984, Honorary Membership in 1986, and the 1994 award for meritorious contributions to environmental geoscience in the east. At the national level, he received AAPG's Distinguished Service Award in 1979 and, in 1990, AAPG's oldest and second highest national award, Honorary Membership. Further recognition in 1990 came with the Eastern Section AAPG awarding Larry their highest honor, the John T. Galey Memorial Award.

Because of his contributions to the West Virginia oil and natural gas industry, Larry was named the "West Virginia Oil and Gas Man of the Year" in 1991. That same year he was honored with an "Alumni-Faculty Citation Award" from Vincennes University and received the 1991 Richard Owen Memorial Award as an outstanding alumnus of Department of Geosciences at Indiana University. In 1993, for his patriotism, Larry received the Nathan Hale Award from the Reserve Officers Association of the United States, certificates of appreciation from the Support of the Guard and Reserve Association and two certificates of appreciation from the U.S. Naval Academy.

Larry was a dedicated scientific contributor authoring and coauthoring numerous professional publications, abstracts, maps, and journal articles dealing with energy resources, stratigraphy, petroleum geology, and environmental geology, as well as numerous management and administrative reports and documents. He served as an advisor to the board of The Colonel, Inc. of the Drake Well Museum in Titusville, Pennsylvania, and was appointed to the board of the Drake Well Museum.

Following his retirement from the West Virginia Geological and Economic Survey in 2002, Larry continued to participate in professional organizations and other activities promoting the geosciences. His largest such endeavor was serving as Chairman of the Board of Directors and Officers of the Corporation of the International Year of Planet Earth (2007 - 2009), a joint global initiative of UNESCO and the International Union of Geological Sciences.

Larry Woodfork died on August 22, 2022, and is preceded in death by his beloved wife, Myra Fox Woodfork, in 1991. He leaves behind his two daughters, Karen and Jessica, and his grandson, Julian Van Dyke as well as four nephews and six nieces.

By Carl Smith and James McDonald

In Memoriam

Dr. Robert Calvin Milici (1931-2022)

Dr. Robert Calvin Milici, Bob as he was known, was born in New Haven, Connecticut on August 8, 1931 to Dr. Pompeo S. Milici and Margaret Koren Milici. He grew up on the grounds of Kings Park Psychiatric Center in Smithtown, New York, where his father practiced as a resident psychiatrist. Bob loved living on Long Island Sound playing baseball, swimming, boating, and digging worms for extra cash.

Bob entered Cornell University in 1949 and majored in chemistry until he discovered geology in his junior year. He graduated in 1954, with an A.B. degree in Geology. Subsequently, Bob attended the University of Tennessee, where he received a M.S. in Geology in 1955 and a Ph.D. in Geology-Metallurgy in 1960. While in graduate school, Bob met his wife, Patricia Ann (Patty) Hankley, and they were married in 1958.

While working on his Ph.D., Bob worked for the Tennessee Division of Geology between 1958 and 1961. After completing his Ph.D., Bob went to work for the Virginia Division of Mineral Resources, where he helped compile the 1963 Geologic Map of Virginia. He then went back to the Tennessee Division of Geology, where he mapped the structure and stratigraphy of Paleozoic rocks in the Cumberland Plateau and the Valley and Ridge Provinces. Bob's major scientific contributions during this time included numerous geological maps and journal publications, interpreting and documenting the distribution and deformational style of regional thrust sheets and their seismic expression, and documenting and interpreting the fabric of highly fractured thrust sheets and the importance to gas reservoirs. This rigorous, hands-on field training gave Bob the background and expertise for his later contributions involving the energy resources of the Appalachian Basin.

In 1979, Bob left the Tennessee Division of Geology to become the Commissioner of Mineral Resources and State Geologist for the Commonwealth of Virginia, a position he held for almost 13 years. As State Geologist, Bob was an outstanding leader directing multidisciplinary teams and projects such as coal mine hazards, fossil fuels research, bedrock geological maps, and collaborative studies of regional aquifers with the USGS Water Resources Division. Even as the State Geologist of Virginia, he continued to conduct research and publish, which included significant contributions to the Geological Society of America Decade of North American Geology (DNAG) volume on the history and energy resources of the Appalachian Basin.

Bob joined the U.S. Geological Survey (USGS) in 1992 and served as Chief of the Branch of Sedimentary Processes and the Branch of Coal Geology for three and a half years. Despite demands as Branch Chief, Bob maintained a deep interest and commitment to energy resource issues and this is reflected by his contributions to: 1) the DOE-funded Atlas of Major Appalachian Gas Plays, in which he authored the chapters on the stratigraphic history of the Appalachian Basin, the Fort Payne carbonate mound play, and the Upper Devonian gray and black shales play; 2) a chapter on self-sourced gases in the Appalachian Basin, published in USGS Professional Paper 1570 on the Future of Energy Gases; 3) the USGS 1995 National Assessment of Undiscovered Oil and Gas Resources; 4) the USGS-Geological Survey of India study of selected Indian coalfields; and 5) the USGS methodology of coal-resource assessment.

In Memoriam

When Bob moved to Reston, Virginia, in 1996 as a USGS research geologist he became chief of the Appalachian Basin Assessment of Undiscovered Oil and Gas Resources project, part of a congressional-mandated program to better understand the nation's petroleum resources. Bob also led a highly successful assessment of the natural gas potential of Bangladesh in support of USGS, Department of Energy, and State Department requests. The assessment has been significant for Bangladesh and the Indian subcontinent to help identify energy resources in an energy deficient area of the world. Domestically, Bob continued work on regional and national gas and coal assessment projects, which resulted in a: 1) 2002 professional paper on coalbed methane production in the Appalachian Basin; 2) 2004 assessment of Appalachian Basin oil and gas resources, 3) 2004 coalbed methane assessment of the Pennsylvania Anthracite District, 4) 2005 assessment of natural gas resources in Devonian black shales of the Appalachian Basin, 5) 2011 assessment of the Devonian Marcellus Shale of the Appalachian Basin, and 6) 2014 stratigraphic framework and total petroleum system analyses of the Appalachian Basin.

Bob retired from the USGS in March 31, 2013 but continued his research and scientific contributions as an emeritus researcher until 2017. During his career, Bob was the author of over 150 publications, and numerous abstracts. His significant output resulted in numerous awards and recognition. He received the Association of Environmental and Engineering Geology’s publication award for the outstanding publication in any of its journals in 1993. In 2001, Bob received the AAPG Michel T. Halbouty Human Needs Award from AAPG for his contributions toward understanding the energy resources of the Indian subcontinent. He was honored by the University of Tennessee as a Distinguished Alumnus in 2002. In 2017, Bob was awarded the Eastern Section-AAPG Gordon H. Wood, Jr. Award in recognition for excellence in research, service, and leadership on the geology of energy minerals. He was presented with the Dallas Peck Outstanding Scientist Emeritus Award from the USGS in 2017. In 2005 Bob received the highest award from the Eastern Section-AAPG, the John T. Galey Memorial Award, for his distinguished career as a research geologist, geosciences administrator, and public servant and his lasting contributions to the geology and energy resources of the Appalachian Basin.

Bob was a field geologist at heart and pursued this interest (structure, tectonics, and stratigraphy of the Appalachian Mountain chain and adjoining basin) at every opportunity. He possessed a unique gift of keen observation, prodigious memory, and the ability to make sound deductions from those observations.

Bob Milici died on August 18, 2022, leaving behind his wife, Patty, a son and daughter, three grandchildren, and a great-granddaughter.

By Steve Greb, James McDonald, and Robert T. Ryder

Opening Session Agenda

Tuesday, October 25th, 2022
8:30 – 9:15am
Chancellor Ballroom

Welcoming Remarks

- Donna Willette and Hannes Leetaru – General Meeting Co-Chairs
- Stephanie Storckman – Illinois Geological Society
- Donna Willette – Eastern Section AAPG President
    - Introduction of Eastern Section AAPG Executive Board

Introduction of AAPG Officers and Committee Chairs

- Steven Goolsby, AAPG President
- Charles Sternbach, Past President, AAPG
- Kristin Carter, Eastern Section AAPG Women's Network Officer
- Linda Sternbach, Past Vice-President of AAPG Sections

Introduction and Welcoming Remarks

- Dick Berg, Director, Illinois State Geological Survey
- Praveen Kumar, Executive Director, Prairie Research Institute

Honors and Awards Ceremony

Committee Chair: Thomas (Marty) Parris, Kentucky Geological Survey

2022 AAPG Eastern Section Professional Awards, Champaign, IL

John T. Galey Award: Hannes E. Leetaru

Citationist: David Harris
"In recognition of his career as a distinguished researcher, educator, and colleague; for important contributions to our understanding of Illinois Basin geology and service to AAPG, the Eastern Section, and our profession."

Honorary Membership: Christopher D. Laughrey
Citationist: Kristen Carter
"In recognition of his decades of service to the Eastern Section and, in particular, important research on the geology and natural gas geochemistry of conventional and unconventional reservoir rocks of the Appalachian basin."

Honors and Awards Ceremony

Distinguished Service Award: Donna C. Willette
Citationist: Ian Thomas
"In recognition of exemplary service and poise on the AAPG Eastern Section Executive Committee under sometimes trying conditions."

George V. Cohee Public Service Award: John A. Rupp
Citationist: Kevin Ellett
"In recognition of exceptional public service throughout his distinguished career of research, teaching and mentoring at Indiana University."

Presidential Award: James McDonald
Citationist: Mike Solis
"In recognition of his contributions to AAPG Eastern Section and dedication to making geologic data easily accessible to industry, education, and public interests."

Gordon Wood, Jr. Memorial Award: David "Randy" Blood
Citationist: Ashley Douds
"In recognition of his leadership in the advancement and dissemination of shale research."

Outstanding Educator Award: Amy Weislogel
Citationist: Amy Hessl
"In recognition of her dedication to undergraduate education in geology through teaching, grant writing, and mentoring at West Virginia University"

DEG Meritorious Service Award: Olga Popova
Citationist: Kristen Carter
"In recognition of outstanding leadership, advocacy, and service to the goals of the Division of Environmental Geosciences, and most notably for serving as Editor-in-Chief of Environmental Geosciences from 2018 – 2021."

2021 AAPG Eastern Section Professional Awards, Pittsburgh, PA

A. I. Levorsen Memorial Best Paper Award

Ashley S.B. Douds and Randy Blood, *"The Marcellus Shale: Geologic Controls on reservoir quality and geochemical of future potential resources".*

Ralph L. Miller Best EMD Paper Award (Eastern Section)

Michael Jarvis, *" The Appalachian Super Basin Utica Point Pleasant Play Update".*

Honors and Awards Ceremony

DEG Best Paper Award (Eastern Section)

Linda R. Sternbach, Charles A. Sternbach and Paul Schimoller, " *Seismic Stratigraphy, Oil & Gas, and CCUS Potential of the Illinois Wabash Fault Zone and Kentucky Rough Creek Graben Using High-Quality Mega Regional 2D Seismic Lines".*

PGS Award for Best Paper on Appalachian Geology

David R. Blood, Ashly S.B. Douds and Milly Wright, " *A proposed Model for Quantifying Critical Mineral Occurrence from Unconventional Sources: An Example from the Marcellus Shale, Appalachian Basin, USA".*

Vince E. Nelson Memorial Best Poster Award

Michael P. solis and Erika M. Danielsen, " *Mapping update of the Middle to Upper Ordovician Black river group to Utica Shale Interval, Ohio"*

EMD Best Paper Award (Eastern Section)

Dave C. Harris and John B. Hickman, " *Lithofacies, Depositional Setting and Sequence Framework of the Cambrian Rogersville Shale, Rome Trough, Kentucky".*

DEG Best Paper Award (Eastern Section)

Samuel R. W. Hulett, Franklin L. Fugitt, and Christopher E. Wright, " *Qualitative REE Analysis of Ohio Underclays by PXRF".*

Dr. Jeffrey C. Reid Best Student Poster Award

Shailee Bhattacharya, Vikas Agrawal, Bennington Opdahi and Shikha Sharma, *" Phase Associations of Rare Earths and Critical Minerals in Mercellusand Haynesville Shale: Implications on Release and Recovery Strategies".*

Short Courses & Workshops

Short Courses

Monday, October 24th, 12:30-4:00 p.m.

Cracking the Frac: Successful Completion Optimization Parameters
Michael Payne, SPE – Shawnee Oil Company, LLC
This course will cover mechanics of hydraulic fracture modeling, fluid chemistry, Inflow Performance, and practical applications for fracture treatment design and execution. Focus on formation damage from completion operations and processes. The course is designed benefit anyone involved or becoming involved with fracturing operations, or those who desire to broaden their knowledge level in the design and execution of hydraulic fracturing treatments.

Residual Oil Zones in the Illinois Basin
Nathan Webb and Nate Grigsby – Illinois State Geological Survey
This short course will cover the background on Residual Oil Zones (ROZs); what they are, how they form, and their utility as CO2 enhanced oil recovery targets. It will then focus on ROZ formation in the context of the geologic history of the Illinois Basin and demonstrate techniques for prospecting. Finally, the course will examine recent research that has taken place to screen for ROZs in several Illinois Basin formations and provide a deep dive into the ROZs in the Cypress Sandstone.

Workshops

Wednesday, October 26th, 12:30-4:00 p.m.

Subsurface Hydrogen Storage
Topics will include subsurface reservoir performance in non-salt stratigraphy, the Hydrogen Economy and why subsurface storage is required, engineering for short-cycle hydrogen withdrawal, and critical parameters to address caprock efficacy and leakage.

Critical Minerals and Associated Resources in the Illinois Basin
This workshop will explore recent efforts from both the CORE-CM and EarthMRI programs to evaluate critical mineral resources, demonstrate separation technologies of these resources, and employ associated resources such as carbon to manufacture high-value products

Student Expo Schedule

MONDAY 10/24

Humanities room - Foyer

8:00am – 9:00am	Registration and Poster Set-up
9:00am – 11:45am	Seismic Interpretation Training
11:45am – 1:00pm	Boxed Lunch Provided
1:00pm – 1:30pm	Student Program (Profession Introductions)
1:30pm – 3:00pm	Student Program (Round Table Discussion)
3:00pm – 4:30pm	Poster Presentations and Judging

Student Poster Abstracts

A Unique Hybrid Active/Passive Seismic Experiment: Kentland Crater, Indiana

Brian A. Robitaille1, Douglas R. Schmitt1, Christoph Büttner2, Jonathan R. Delph1
1Earth Atmospheric and Planetary Sciences Department, Purdue University, West Lafayette, IN
2Institute of Geophysics and Geoinformatics, TU Bergakademie Freiberg, Saxony, Germany

The Kentland impact structure is a heavily eroded complex impact crater located in northwest Indiana, USA. The structure was discovered only because the central peak of the impact site extended well above the surrounding area's flat-lying glacial deposits. The crater is particularly notable because it is the first location that linked shatter cones to hypervelocity impacts. Despite seismic and gravity studies from the 1970's, the dimensions of the crater remain largely unknown due to the non-uniqueness of the applied geophysical techniques used. However, the Kentland Crater serves as a good exemplar of a complex impact crater (i.e., one large enough to include a central peak). To better understand the structure and in situ properties, we conducted a high-resolution seismic survey in late Fall 2021 utilizing a combination of high-resolution active source seismic reflection profiling and passive 3-component nodal seismometers with the following goals: 1) delineate the outer faults/boundaries for Kentland Crater to better characterize its diameter, and 2) use 1st arrival travel times to perform a tomographic inversion for velocity structure to understand impact-induced fracturing and damage. This experiment consisted

of an array of 49 nodes (5 Hz corner frequency) that were deployed for up to 35 days over a 3.2 km × 10.5 km area that extends outward from the central peak. During this time, a 5.3 km high-spatial resolution seismic profile using 240 vertical component geophones (15 Hz) spaced at 4 m was shot through the center of this nodal array with seismic signals provided by the 6,000-pound peak force Purdue seismic vibrator. An additional 58 nodes, with a spacing of 15 m, were planted on profiles perpendicular to the source line to provide limited-fold 3D coverage. Currently, over 300,000 source-receiver arrival times have been picked from the data set to construct a tomographic velocity model. This model will also inform the structural processing of the reflection profile. The data will be further contrasted against seismic observations from an inferred similarly sized complex impact structure in Alberta to better understand the structure of, and material properties in, impact structures.

EVALUATING THE POROSITY AND ROCK STRENGTH OF CARTER COUNTY, KY

Joe Hoberg, Dr. Eric Peterson, Ethan Conley
Department of Geology, Geography, and the Environment, Illinois State University, Normal, IL, USA

Carter Caves State Resort Park (CCSRP) located in, Carter County, KY, is a fluviokarst system consisting of 106 km2 deeply incised valleys characteristic of the Cumberland Plateau. Stratigraphically the region consists of approximately 25m of Mississippian age limestone of the Slade Formation overlain by the lower Carter Caves sandstone member of the Mississippian Paragon Fm. Over the course of the last decade, numerous studies conducted terrain analyses to characterize CCSRP for cave collapse, paleoclimate data, and evolutional history. These studies have primarily focused on the use of digital elevation models (DEM) and GIS driven techniques to identify and correlate cave levels to stream incisions.

This region lacks numerical descriptions of in-situ parameters, such as porosity and rock strength, that are commonly used as components in hydrogeologic and karst genesis models. There has been minimal efforts completed to conduct or advance any research in porosity in recent time. Ultimately, this has limited the ability and domain to which further advancements in characterizing CCSRP could be done.

Two samples of the Warix Run member and five samples of the Mill Knob member of the Slade formation were collected near the entrances to Horn Hollow cave. The Mill Knob member consists of light-olive-grey quartzose calcarenite and lesser calcilutite while Warix Run contains calcarenite and calcilutite with lesser amounts of dolomite and shale. In general, both also contain medium- to coarse-grained red and grey chert, silt, and sand with large crossbedding.

All samples were evaluated for rock strength using a Schmidt hammer, and four samples were evaluated for porosity. Thin sections of these samples were acquired and applied with a blue dye epoxy to enhance the visibility of any pore spaces. Using *ImageJ* and *INFINITY ANALYZE 7* , 25 images at 4x magnification of each slide were digitized to calculate the average porosity of each sample as well as a cumulative average for both geologic members. The porosity data for Mill Knob displays a mean of 5.05%, with a range from 3.16% to 6.62% while the Warix Run data illustrate a mean of 2.63%. Rock strength data for Mill Knob shows a mean of 28 5 n/mm2, with a range from 21.5 to 42 n/mm2 while Warix Run data displays a mean of 26.5 n/mm2, with a range from 22 to 30.5 n/mm2.

Role of basal sealing layer in injection-induced seismicity in Illinois Basin

Bondarenko, N.B.1, Williams-Stroud, S.2, and Makhnenko, R.Y1.
1University of Illinois at Urbana-Champaign, Urbana, IL, USA 2Illinois State Geological Survey, Champaign, IL, USA

The highest risk for induced seismic response during subsurface fluid injection is associated with crystalline basement rocks. Despite extremely low permeability of the intact crystalline rock, pre- existing fractures and faults might serve as a conduits for fluid migration, resulting in favorably oriented faults in the basement being reactivated during the injection in overlying reservoir lithologies. However, the presence of intermediate to low-permeability layers between reservoir and basement is beneficial to reduce the number of triggered earthquakes. Impact of the basal sealing layer on features of the induced seismicity is studied for the case of CO_2 injection during Illinois Basin Decatur Project. The reservoir, basal sealing, and crystalline basement formations are represented by Mt. Simon sandstone, Argenta sandstone, and Precambrian rhyolite, respectively. Cores extracted from involved formations are characterized in terms of the strength, fluid transport, and poromechanical properties. Conducted tests confirm that open fractures in the crystalline rock provide the hydraulic connection between the reservoir and basement, highlighting the impact of fractures on the permeability. Laboratory measured properties are implemented into fully hydro-mechanically coupled numerical model to predict the response of the formations during the injection. Argenta formation being three orders of magnitude less permeable than the reservoir rock inhibits the fluid migration into the crystalline basement and reactivation of faults due to the change of pore pressure. Integration of the laboratory and numerical modeling data concludes that microseismicity triggered during Illinois Basin Decatur Project cannot be explained only by simple mechanism of pore pressure change during the injection. Therefore, more complex phenomena such as poroelastic stressing, effects of local stratigraphy, and two-phase flow need to be considered for accurate assessment of the induced seismicity potential.

Stress Characterization in the Stable Canadian Craton: Complexity from Stress Heterogeneity and Rock Anisotropy

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1 Earth Atmospheric and Planetary Sciences Department, Purdue University, West Lafayette, IN, 47907, USA

Breakout analyses of image and caliper logs from a deep vertical wellbore show distinct

breakout azimuths along three depth sections. Breakout azimuths are constant along the same depth section, but vary dramatically at different depth sections, rotating from 100° at 1650-2000 m to 173° at 2000-2210 m, and to 145° at 2210-2310 m. The effects of fracture disturbance and lithological change on breakout rotations were excluded since no obvious correlations were found; therefore, only two additional hypotheses were left for the observed rotating breakouts: (1) stress heterogeneity with a different maximum horizontal compression direction *αH* along the borehole depth; (2) rock anisotropy of the foliated metamorphic rocks. For the first hypothesis, Monte Carlo simulations were carried to find feasible stress magnitudes with input *αH* perpendicular to the observed breakout azimuth at each depth sections but without rock strength anisotropy. For the second hypothesis, it was first supported by the strong correlation between the dip directions of metamorphic foliations, slow shear wave polarized directions and breakout azimuths. Monte Carlo simulations were then performed with constant *αH* (= 50°) but with foliation planes considered as planes of weakness, exhibiting rock anisotropy. The inferred stress magnitudes from the first conventional hypothesis overestimate the state of stress whereas the second hypothesis indicates a relatively low stress magnitude, and the formation is not near the critical loading for slippage on weak planes from Mohr-Coulomb analyses. Moreover, the first hypothesis is less favored due to its large non-uniqueness and insensitivity in the potential stress state characterization. However, to better assess the state of stress in the craton, more detailed investigations with other methods of stress constraints should be carried out to confidently choose one hypothesis over another for breakout rotations

Use of direct and indirect methods for characterization of carbon dioxide sealing capacity of shale-like caprocks

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A low permeable caprock overlies a reservoir rock to prevent the leakage of buoyancy-driven carbon dioxide (CO2) through overlaying strata. The measurement of the breakthrough pressure – the maximum differential CO2 pressure at which it can be retained in the reservoir – is important for evaluating the sealing capacity of caprock during operation time. In this study, we investigate the CO2 breakthrough pressure of heterogeneous Eau Claire shales (sandy and clayey) in Illinois basin and Opalinus Clay (intact and fractured) from Switzerland by direct and indirect laboratory methods. The direct method is time-consuming and requires CO2 injection in specimens fully saturated with brine under representative in-situ conditions. The indirect method is widely used for shales and involves deriving the breakthrough pressure from calculating the water-CO2 capillary pressure by the pore size analysis. Although the indirect method is more time efficient, it should require a good knowledge of the surface tension and the contact angle between water and CO2.

Our experimental measurements reveal that the direct method always provides the breakthrough pressures higher than those obtained from the indirect method. This can be explained by the decrease in the dominant pore size while implementing the direct method under high effective stress, whereas the pore structure does not change during the indirect measurement under zero effective confinement. Moreover, the indirect method does not consider a potential interaction between water, CO2, and clay minerals (such as montmorillonite groups) that could either expand or produce microfractures. In the case of the heterogeneous shale, the main factor controlling the CO2 intrusion is the size of the pores and porosity at a small scale. At the same time for the fractured specimens, it is the effective mean stress that determines its sealing capacity. Fractures in caprock can be almost completely closed at elevated pressures, which cannot be represented in the indirect method. Finally, the (indirect) pore structure analyses utilize a small part of the specimen such that the breakthrough pressure from the indirect method would not be influenced by the specimen-scale fracture. We conclude that the indirect method has a limited implication for adequately characterizing shales, especially the heterogeneous and fractured ones, suggesting that the direct measurement should be utilized for evaluating the breakthrough pressure of caprocks.

Zircon Geochronology 40Ar/39Ar **of Cambrian Clastic and Crystalline Rocks from the Carbon Safe, Wabash #1 Well, Indiana, USA**

HUISMAN, Matthew, *Department of Geology, Illinois State University, Campus Box 4400, Normal, IL 61790*, FREIBURG, Jared, *Illinois State Geological Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign, 615 E. Peabody Drive, Champaign, IL 61820*, MALONE, David, *Department of Geology, Illinois State University, Campus Box 4400, Bloomington, IL 61701,* HOLLAND, Mark E.*, Department of Life, Earth, and Environmental Sciences, West Texas A&M University, 2403 Russell Long Blvd., Canyon*, *AK 79015*, MCLAUGHLIN, Patrick, *Indiana Geological Survey, Indiana University, 611 N Walnut Grove Ave, Bloomington, IN 47405-2208* and MALONE, Shawn, *Dept. of Natural & Applied Sciences, University of Wisconsin - Green Bay, 2420 Nicolet Dr., Green Bay, WI 54311*

The Wabash #1 well, drilled for the Carbon Safe Wabash Project and located in West Terre Haute, Vigo County, Indiana, was drilled in early 2020 as a stratigraphic test well to characterize and evaluate the basal Cambrian Mt. Simon Sandstone for carbon dioxide storage (TD=8750 ft). The Wabash #1 well is located along the eastern flank of a newly defined Cambrian aulocogen that occurs in western Indiana and eastern Illinois. Here we present 892 new detrital zircon U-Pb ages (LA-ICPMS) from three samples of lower Cambrian Strata (Mt. Simon and Argenta Formations). A basal dike or lava flow was penetrated at ~8530 ft, and has an age of 526.03 +/- 1.09 Ma, which represents the first known Cambrian crust beneath the Illinois Basin. A side wall core of sandstone beneath the basalt at a depth of 8680 ft has prominent age peak of 1477 Ma, which represents local basement, and lesser peak at 1203 Ma, which were distally sourced in the Grenville Orogen. Two Cambrian zircons are present, which verifies an early Cambrian age for this unit. Zircons also were analyzed from a sidewall core at a depth of 8500 ft. Here the detrital zircon age spectrum is more variable with age peaks at 1461, 2692, 1122, and 1789 Ma, which reflects both proximally sourced sediment as wells as distal sources from the north and east. A full core of sandstone was collected at a depth of 7972 ft; this sample has age peaks of 1366, 1457, 1644, 1183, 2703, and 532 Ma, which again records a complex combination of locally and distally derived sediment. Our detrital zircon age spectra for these rocks is consistent with those obtained for lower Cambrian strata from three other Carbon Safe wells in Illinois. Deeper Cambrian sands reflect only local sediment sources areas in Mazatzal, MCGR, and Cambrian crust. Once the local source areas are buried, sediment from distal sources begin to dominate.

Zircon geochronology interpretation of maximum depositional age of the Ogishkemuncie Sequence, Minnesota, USA.

Benjamin Bugno
Co-authors: David Malone, John Craddock
Session: T22

Here we present LA-ICPMS U-Pb geochronology data of zircons separated from a diamictite unit in the Archean Ogishkemuncie Sequence of the Knife Lake Group near Alpine Lake in the Boundary Waters Canoe Area Wilderness of northeastern Minnesota, USA. The Ogishkemuncie unconformably overlies the 2689 ± 1 Ma Saganaga Tonalite batholith with a well-developed saprolite occurring at the top of the tonalite. The Ogishkemuncie folds are east-trending with vertical fold axes, and extend more than 80 km to the southwest. It contains alternating layers of polymict conglomerate, well-sorted channelized sandstone, and poorly sorted diamictite with boulders of the Saganaga Tonalite. These are interpreted to have been deposited in an alluvial fan/fluvial system in an isolated rift basin and then subsequently were deformed (the tonalite-Ogishkemuncie contact is vertical) and metamorphosed to lower greenschist facies. Zircons separated from each unit were zoned and no metamorphic overgrowths were noted. The detrital zircon age spectrum for the diamictite (n=48) ranged from 2629-2914 Ma, with a unimodal age peak of 2689 Ma and with a maximum age of deposition of 2643.9±8.2 Ma. The peak age is consistent with the bulk of the sediment being derived from the underlying Saganaga tonalite and is consistent with existing interpretations of the depositional environment. The maximum age of deposition, however is younger than the ~2680 Minnesotan orogeny, which is the last documented Archean deformational and metamorphic event in the region. We interpret that the Ogishkemuncie Sequence is latest Archean or perhaps even Paleoproterozoic in age. A Paleoproterozoic age would permit correlation to Huronian strata further to the east, which were deposited following late Archean rifting of the Superior province. Fabric orientation and the style of deformation and metamorphism is consistent with the ~1800-1900 Ma Penokean orogeny, which is well known in areas to the south and east.

Core Workshop

Tuesday, October 25
6:45am – 9:30pm
Chancellor Ballroom

Contributor	Core	County, State
Illinois State Geological Survey	Permian, Hicks Dome	Hardin, Illinois
DRB Geological Consulting	Upper Devonian, Hanover Dunkirk Shale Contact	Chautauqua/Erie, New York
Illinois State Geological Survey	Upper Devonian/Miss. Chouteau/New Albany Shale	White, Illinois
Indiana Geological and Water Survey	New Albany Shale	Washington, Illinois
Illinois State Geological Survey	New Jersey Zinc Core Maquoketa	Fulton, Illinois
Kentucky Geological Survey	Middle Run Sandstone	Hancock, Kentucky
Illinois State Geological Survey	Fernvale Limestone	Sangamon, Illinois
Kentucky Geological Survey	PreCambrian Unconformity	Carter, Kentucky
Illinois State Geological Survey	Ord. Galena/Maquoketa	Will, Illinois
Illinois State Geological Survey	Carper Sandstone	Cumberland, Illinois
Illinois State Geological Survey	Cypress Sandstone	Union, Illinois
Illinois State Geological Survey	Ironton/Galesville Sandstone	Mclean, Illinois
Illinois State Geological Survey	VW#1 PreCambrian/Argenta	Macon, Illinois

Technical Program Schedule

TUSDAY 10/25

TECHNOLOGY ROOM – TECHNICAL SESSION I

9:30 – 9:55AM	**Seven Year Project to Drill a Trenton Wildcat in Washington County, Illinois: A Tale of Persistence overcoming Resistance, Leading to a Possible New Oil Field Discovery** Charles A. Sternbach, Linda R. Sternbach (Star Creek Energy), Michael Payne, Alan Henigman, and Rick Marquardt (Shawnee Oil Company).
9:55 – 10:20am	**Reservoir Characterization of the Trenton Limestone, Illinois Basin** William F. Bandy Jr., Pioneer Oil Co., Inc., Vincennes Indiana
10:20 – 10:45am	**Conventional Oil & Gas Exploration – Revisited** Steven P. Zody, Zody Geoscience, LLC
10:45 – 10:55am	**Break**
10:55 – 11:20am	**The Cambro-Ordovician Notch Peak Formation and House Limestone of the Great Basin – Window into the Illinois Basin Potosi Dolomite** Ben Dattilo, Department of Biological Sciences, Purdue University Fort Wayne, Indiana. dattilob@pfw.edu James Miller, Department of Geography, Geology and Planning, Missouri State University, Springfield, Missouri. JimMiller@MissouriState.edu Rebecca Freeman, Department of Earth & Environmental Sciences, University of Kentucky, Lexington, Kentucky. Rebecca.freeman@uky.edu
11:20 – 11:45am	**What's the deal with the Carper Sandstone: An atypical Illinois Basin oil reservoir** Nathan D. Webb1, Nate P. Grigsby1, Scott M. Frailey1, Fang Yang1, Donna C. Willette1, Mingyue Yu1 1Illinois State Geological Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign
11:45 – 1:15pm	**Lunch Break**

Technical Program Schedule

TUSDAY 10/25

TECHNOLOGY ROOM – TECHNICAL SESSION I

1:15 – 2:15pm	**Break for Panel Discussion – Lincoln Room**
2:15 – 2:40pm	**Gas geochemistry can be very useful for determining the source of gas considered to be linked with well integrity and well abandonment issues.** Keith Hackley, Stratum Reservoir (Isotech), 1308 Parkland Court, Champaign, IL 61821
2:40 – 3:05pm	**Stable Isotope Systematics of Marcellus Formation Shale-Gas During Pressure Core Degassing and Production** Christopher D. Laughrey Stratum Reservoir
3:05 – 3:30pm	**High Resolution Static and Dynamic Computed Tomography Analysis of West Virginia Oriskany Formation Cores for Carbon Capture Storage and Utilization in the Appalachian Basin** Paronish, Thomas1,2 Rich, Megan1,3,4 Crandall, Dustin1 Brown, Sarah1,2 Jarvis, Karl1,2 Moore, Johnathan1,2 Dinterman, Phil5 1National Energy Technology Laboratory; 2NETL Support Contractor; 3Mickey Leland Energy Fellow; 4Georgia State University; 5West Virginia Geologic Economic Survey
3:30 – 3:40pm	**Break**
3:40 – 4:05pm	**Interpreting the Mississippian System of the Appalachian Basin as a flexural response to Neoacadian tectonism** Frank R. Ettensohn, Department of Earth & Environmental Sciences, University of Kentucky, Lexington, KY 40506
4:05 – 4:30pm	**Petroleum Geology of the Mississippian Stacked Reservoirs in Noble Oil Field, Richland County, Illinois, in the Context of CO2-EOR and Associated Storage** Nathan D. Webb1 and Nate P. Grigsby1 1Illinois State Geological Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign

Technical Program Schedule

TUSDAY 10/25

QUAD ROOM – TECHNICAL SESSION II

9:30 – 9:55am	**Characterizing Containment Strata for Carbon Storage Using 2D Seismic Interpretation: Case Study from the Illinois Basin** Kendall Taft, Illinois State Geological Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign
9:55 – 10:20am	**Correct Reservoir Size Estimation with Depth imaging: more than just a single process"** Author: Scott Boyer, GTSeis Presenter: Bob Springman, GTSeis
10:20 - 10:45am	**Hicks Dome Interpreted as a Tectonically-Deformed Faulted Block Using Long-Record and High Quality 2D Seismic Lines** By Linda R. Sternbach, Charles Sternbach, Star Creek Energy, and Paul Schillmoller, SSI Inc.
10:45 - 10:55am	**Break**
10:55 – 11:20am	**Properties of CO2and H2-CH4fluids: Constraints from Laboratory Seismic Experiments** Douglas R. Schmitt , Purdue University
11:20 - 11:45am	**Empirically Based Assessments and Data Driven Evaluations Throughout an Asset's Life** KC Oren. Patrick Hayes, Tracerco.com
11:45 – 1:15pm	**Lunch Break**
1:15 – 2:15pm	**Break for Panel Discussion – Lincoln Room**
2:15 – 2:40pm	**The Occurrence of Critical Minerals in Fine-Grained Strata: Insights from the Upper Devonian Hanover and Dunkirk Shales of Western New York State** D. Randy Blood, Scott D. McCallum, Ashley S.B. Douds, Wildlands Research, LLC

Technical Program Schedule

TUSDAY 10/25

QUAD ROOM – TECHNICAL SESSION II

2:40 – 3:05pm	**The effects of two igneous intrusions on the organic petrography and geochemistry of the New Albany Shale in the Western Kentucky Fluorspar District** Cortland F. Eble, David C. Harris, Georgina Lukoczki, Kentucky Geological Survey,
3:05 – 3:30pm	**Characterization of Pennsylvanian paleosols in Indiana with a special reference to rare earths (REE) and lithium** Maria Mastalerz1, Agnieszka Drobniak1, Philip Ames1, Patrick McLaughlin1,2 1 Indiana Geological and Water Survey, Indiana University, 1001 E. 10th St., Bloomington, IN 47405, USA 2 Illinois State Geological Survey, 615 E. Peabody Drive, Champaign, IL 61820, USA
3:30 – 3:40pm	Break
3:40 – 4:05pm	**So Many Orphaned Wells, Where to Plug First?** Thomas (Marty) Parris (Kentucky Geological Survey, University of Kentucky) Stacy Woods and Emily Connor (Yale Carbon Containment Lab)
4:05 – 4:30pm	**Devonian Production in the Mt Auburn Trend along the edge of the Sangamon Arch; A look back after 10 years of the "Boomtown Area" in Christian County, Illinois** James E. Blumthal, CPG, Olney, Illinois, Preston Price, CPG, Olney, Illinois, Joan E. Crockett, Geologist, Savoy, Illinois

Technical Program Schedule

TUSDAY 10/25

LINCOLN ROOM – TECHNICAL SESSION III

9:30 – 9:55am	**Paleoenvironments of the Pennsylvanian Caseyville and Tradewater Formations in the Southeastern Illinois Oil Field, Crawford and Lawrence County, Illinois** Nathan D. Webb1, James L. Best2, Christopher R. Fielding3 1Illinois State Geological Survey, Prairie Research Institute, University of Illinois at Urbana
9:55 – 10:20am	**CO2 Storage Resource Assessments of the Ordovician St. Peter Sandstone and Everton Dolomite in Southwestern and South-Central Illinois** Mansour Khosravi1, Kendall Taft1, Zohreh Askari1 1Illinois State Geological Survey, University of Illinois at Urbana-Champaign, Champaign, IL 61820
10:20 – 10:45am	**Lithofacies, Stratigraphic Variability, and Reservoir Characteristics of the Galesville and Ironton Sandstones in OEE No. 1 and the Surrounding Areas, North-central Illinois** Zohreh Askari and Yaghoob Lasemi, Energy, Illinois State Geological Survey, University of Illinois at Urbana-Champaign
10:45 – 10:55	Break
10:55 – 11:20am	**Identification and Characterization of Stacked ROZs in Illinois** Nate P. Grigsby1 and Nathan D. Webb1 1Illinois State Geological Survey, Prairie Research Institute, University of Illinois at Urbana-Champaign
11:20 – 11:45am	**Facies and Sequence Stratigraphic Framework of an Incised Valley Fill, the Mississippian Cypress Formation, Southeast Illinois** Yaghoob Lasemi, Energy & Minerals Division, Illinois State Geological Survey, University of Illinois at Urbana-Champaign
11:45 – 1:30pm	Lunch Break
1:15 – 2:15pm	Panel Discussion – Foundational and Transformative Energy Integration

TUSDAY 10/25

LINCOLN ROOM – TECHNICAL SESSION III

2:15 – 2:40pm	**Adapting Compressed Air Energy Storage (CAES) Models to Subsurface Hydrogen Storage in Kentucky** J. Richard, Bowersox, Kentucky Geological Survey, University of Kentucky, Lexington, Kentucky
2:40 – 3:05pm	**Power of the Mine: The Potential for Dramatic Expansion of Energy Storage in the Eastern US by using Abandoned Underground Mines** Kevin Elletta,b, Walt McNaba, Jeffrey Bennettb, Chris Dintamana and Joshua Silvisc, aGeospherics LLC, 820 S Henderson St, Bloomington, Indiana 47401 bCarbon Solutions LLC, 398 E Bellefontaine Rd, Pleasant Lake, Indiana 46779 cCONSOL Energy Inc, 275 Technology Dr, Suite 101, Canonsburg, Pennsylvania 15317
3:05 – 3:30pm	**2022 Indiana Carbon Sequestration Statute: Permitting, Pore Space Ownership, Mineral Rights Protection and More** Kevin Strunk, LPG, CPG. Wabash Resources & Consulting, Inc, Indianapolis, IN
3:30 – 3:40pm	Break
3:40 – 4:05pm	**Predicting plume evolution in heterogeneous aquifers during CO2 storage using generative adversarial network proxy models** Roland Okwen*, Andrew Anderson, Carl Carman, Illinois State Geological Survey, Prairie Research Institute, University of Illinois, 615 E. Peabody Dr., Champaign, IL 61820, USA
4:05 – 4:34:05	**Evaluation of sealing potential for shales in Illinois Basin** Roman Y. Makhnenko1)* , Hyunbin Kim1), and Ekaterina Barteneva1) 1) Civil & Environmental Engineering, University of Illinois at Urbana-Champaign, USA *Corresponding author: romanmax@illinois.edu
4:30 – 4:55pm	**Application of NRAP Tools to UIC Class VI Permits** Carl Carman, Illinois State Geological Survey, University of Illinois at Urbana-Champaign

2022 Indiana Carbon Sequestration Statute: Permitting, Pore Space Ownership, Mineral Rights Protection and More

Kevin Strunk, *LPG, CPG. Wabash Resources & Consulting, Inc, Indianapolis, IN*

Following a 2019 carbon sequestration statute which allowed for a single site-specific pilot project in western Indiana, two separate bills were introduced in the Indiana General Assembly in January 2022. The two bills had different approaches to various issues. House Enrolled Act 1209 became effective July 1, 2022 and applies to all CCS wells. Senate Bill 265 failed in the House after passing the Senate, following intense opposition from a consortium of farmers, grain groups, various industries, etc. who had concerns such as lack of compensation for pore space use, and various potential damages. Senate Enrolled Act 442 passed in 2019 allowed for the drilling of one test well in West Terre Haute, Indiana. This well was drilled in Winter 2019-2020, reaching a total depth of 8739 feet in Precambrian-aged basement rocks with about 2238 feet of Mt. Simon Sandstone. Results indicated the Mt. Simon is not suitable for injection, but the Potosi Dolomite within the Knox Supergroup could be suitable. Apparently, an EPA Class 6 application has been filed for two wells in nearby Vermillion County, Indiana which would require a pipeline from the source. This project was the subject of SB 265. House Enrolled Act 1209 highlights include: Extractable minerals are protected from CCS activities. There is protection of the CCS zone if a mineral owner wants to drill a well, similar to gas storage. Definitions for Mineral Lessee, Mineral Owner, Pore Space, Pore Space Owner, Reservoir, and Surface or Subsurface Property Interest Owner. Pore space rights may belong to the surface owner, not the split mineral owner. CCS usage is granted in perpetuity, with some exceptions. The pore space must be leased. Pore space usage can be pooled and forced pooled if over 70% of the pore space is leased. Surface use of leased property must be stated in the lease. Pore usage is granted in perpetuity, with some exceptions. An EPA Class 6 permit and a detailed drilling/operating permit from IDNR are required. Volumes/tonnages of injected fluids must be reported, with an 8 cents per ton injection fee to be paid to IDNR into a dedicated well and project abandonment fund. No claim of subsurface trespass with valid permits UNLESS the landowner can demonstrate a problem, with a limitation on damages. At the end of the project, the IDNR MAY release the operator from future liability if the project is in full compliance with all permit requirements, with the State eventually assuming liability.

Characterizing Containment Strata for Carbon Storage Using 2D Seismic Interpretation: Case Study from the Illinois Basin

Kendall Taft, *Illinois State Geological Survey*

Understanding the continuity and integrity of confining strata is essential for developing a commercial carbon storage site. 2D seismic is an effective source of data to perform this evaluation, and this presentation will examine a case example using 2D seismic along with wireline log data from the Illinois Basin to address the presence of a large fault in a potential carbon storage area. The storage complex that will be studied includes porous and permeable sandstone reservoirs and a ductile shale as the primary containment package. These intervals display a robust seismic response due to the strong impedance contrasts between adjacent strata.

This case example will present a seismic line having a fault system that transects both the storage reservoirs and the sealing formations. The fault system is interpreted as a strike-slip fault with a component of reverse offset indicated by a small positive flower structure, with a later phase of minor extension. The orientation and extent of this fault is unknown because it was initially observed only on one 2D seismic line. In order to better characterize this fault and determine its orientation and extent, additional 2D seismic was acquired. The results of the interpretation of this new 2D seismic data, including characterization of this fault, will be discussed.

Adapting Compressed Air Energy Storage (CAES) Models to Subsurface Hydrogen Storage in Kentucky

J. Richard, Bowersox, *Kentucky Geological Survey, University of Kentucky, Lexington, Kentucky*

Evaluation of the potential for CAES with co-installed PV-solar electricity generation in Kentucky identified five storage models applicable to hydrogen storage. The most promising models include conversion of abandoned limestone mines for hydrogen storage; re-entering and injecting hydrogen into abandoned oil and gas reservoirs or aquifers in western, central, and south-central Kentucky; and installing cased-wellbore hydrogen storage anywhere in Kentucky where land and an electrical grid connection are available. Any or all of these models are applicable to storing hydrogen. Hydrogen would be produced at a CO2-capture/hydrogen production facility constructed adjacent a co-installed PV-solar electrical generating and storage station, and stored onsite. Geologic storage would best use abandoned limestone mines for hydrogen storage or re-entering and completing new wells in abandoned oil and gas reservoirs. Abandoned limestone mines would require lining with shotcrete to mitigate limestone dust and seal fractures and a surface coating on the shotcrete that is inert to hydrogen. Conversion of abandoned oil and gas reservoirs to hydrogen storage would require casing resistant to hydrogen and gas separation facilities to remove residual hydrocarbons and water when stored hydrogen is produced. A test of storage in a geological reservoir would best be performed in the abandoned Trapp gas field in Clark County, a fault-bounded anticline and a rare feature in Kentucky. Cased wellbores would be the most elegant option for hydrogen storage because it is not constrained by subsurface geology, requires the smallest surface area, does not inject into geological reservoirs, and could be installed anywhere in the state where surface land is available. A hydrogen storage pilot project can be installed by drilling and equipping one or more 550-ft deep high-pressure cased-storage wellbores. At 8500 psi storage pressure, each cased wellbore would have an estimated capacity of 500 thousand cubic feet of hydrogen.

Characterization of Pennsylvanian paleosols in Indiana with a special reference to rare earths (REE) and lithium

Maria Mastalerz1, Agnieszka Drobniak1, Philip Ames1, Patrick McLaughlin1,2
1 Indiana Geological and Water Survey, Indiana University, 1001 E. 10th St., Bloomington, IN 47405, USA
2 Illinois State Geological Survey, 615 E. Peabody Drive, Champaign, IL 61820, USA

This study characterizes Pennsylvanian paleosols from coal-bearing strata in Indiana, with the main emphasis on the abundance and distribution on rare earth elements (REE) and lithium (Li). Eleven locations in southwest Indiana were selected for this study, targeting paleosols of both the Carbondale Group and the Raccoon Creek Group. Most paleosols were directly underlying coal beds. Lithologically, paleosols range from grey mudstones to greenish-grey claystones and occasional siltstones. In the Carbondale Group, the thickest paleosol horizons occur under the Danville and the Houchin Creek coal members, with their thickness reaching close to 10 feet. In the Raccoon Creek Group, the paleosol under the Wise Ridge Coal appears to be thickest (4.6 to 11.4 feet) and best developed.
Total REE content in paleosol samples ranges from 138.8 ppm to 728.55 ppm, with an average range of 208.3 ppm (Colchester paleosol) to 342.9 ppm in the paleosol under the Upper Block Coal. Light REE dominate over heavy REE, and the variation in the light REE is responsible for the largest variations of the total REE. The largest amount of the heavy REE amounts (61 ppm) occurs in the paleosol under the Lower Block Coal, whereas the paleosol under the Upper Block Coal has the largest variation in heavy REE content (49-148 ppm). REE patterns for paleosol samples show very weak to no fractionation among light, medium, and heavy REE, with no major anomalies present. The majority of paleosols have REE values roughly representative of the upper continental crust. Only some paleosols are slightly enriched and these are paleosol samples under the Danville Coal and the Upper Block Coal. Li content in the paleosol samples shows a variation from 21 ppm to 530 ppm. On average, the Wise Ridge Coal is richest in Li (249.3 ppm), followed by Viking B Coal (190.8 ppm). The coals of the Brazil and Staunton formations have higher Li content than the younger coals. Although this study has not uncovered large concentrations of REE or lithium, the wide range of concentrations and potential ease of their extraction from these clay-rich rocks imply that paleosols deserve further examination, and the current study can be used as a screening guide for more focused investigation.

CO2 Storage Resource Assessments of the Ordovician St. Peter Sandstone and Everton Dolomite in Southwestern and South-Central Illinois

Mansour Khosravi1, Kendall Taft1, Zohreh Askari1
1Illinois State Geological Survey, University of Illinois at Urbana-Champaign

The primary requirements for CO_2 storage in deep geologic formations are the presence of porous and permeable sedimentary rocks confined by thick intervals of non-permeable

formations. The Ordovician St. Peter Sandstone has a widespread distribution across Illinois. The formation primarily consists of fine to medium, well-sorted pure quartz sandstone free of clay minerals. The St. Peter Sandstone is generally categorized as a marine sandstone deposited by a sea advancing northward across Illinois. The Everton Dolomite occurs in western and southwestern Illinois and consists of pure quartz sandstone to dolomitic sandstone overlain by dolomite intervals. Both formations have an overall average thickness of 180 ft (54 m) in western Illinois, reaching to over 460 ft (140 m) in central and south-central Illinois. Although the porosity and permeability of the St. Peter Sandstone and Everton Dolomite have been estimated locally, more rigorous delineation of the lithology, the reservoir characteristics and the trends of the properties should be assessed to verify the regional architecture and behavior of the reservoir.
To achieve these goals, the petrophysical log data of over 50 wells that either fully or partially penetrate the St. Peter Sandstone and Everton Dolomite were utilized to generate the regional structure and thickness maps and construct a 3-D structural framework of the formations and their overburdens. The lithological and petrophysical data were integrated into a stratigraphic framework, and the reservoir characteristics and their trends were assessed regionally. Finally, a regional geocellular model was constructed using all this data. Porosity and permeability data were populated stochastically within the 3-D grids using regional reservoir property trends.
Results of this study indicate the St. Peter Sandstone has an average porosity of 11% in Washington County and increases to about 15% in Clinton and Madison Counties, Illinois. However, the porosity ranges decrease toward central and south-central Illinois, where the formation shows less than 6% porosity. The Everton Dolomite can be divided into 2 zones in western Illinois where porous sandstone is overlain by dense dolomite. The average porosity of the sandstones is 10.4% in Washington County. Despite the presence of thick intervals of sandstone in the Everton Dolomite, the evaluation of logs indicate a sharp decrease in porosity and permeability toward southern and south-central Illinois.

Conventional Oil & Gas Exploration – Revisited

Steven P. Zody, *Zody Geoscience, LLC*

Energy markets are currently experiencing tumultuous times due to several factors. Years of low commodity prices (and resulting lack of capital investment), coupled with world events, rising global energy demand, and ESG/political stifling of the oil & gas industry have resulted in elevated commodity prices and an optimistic economic outlook. Unconventional exploration and development have dominated U.S. oil & gas activity over the past 10-15 years. Many geologists with 15 years, or less, of experience may have only worked unconventional plays. Regardless of experience level, it is worth the time to revisit the fundamentals of conventional exploration, including source rocks, migration pathways, permeable and porous reservoirs, and viable traps. Conventional prospects are increasingly appealing and offer abundant opportunities to secure new, reliable, and profitable production. These opportunities may be as simple as evaluating uphole pay zones for recompletion or improving past production / completion practices with improved technology.

New prospects in areas of neglected exploration may also be identified with modern 3D seismic. Scouring old data, generating multiple maps, developing the regional geologic setting, and utilizing analog fields can contribute to a successful conventional exploration project. Vast amounts of drilling, log, and seismic data have been acquired developing unconventional resources. This data provides an excellent resource to evaluate conventional formations above and below the original unconventional target zone. Perhaps, most importantly, the conventional explorationist must be creative, willing to take risk, and love the thrill of discovery and the deep satisfaction of finding something of value for the betterment of mankind.

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

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The utilization of non-seismic data in the structural imaging arena has been shifting its importance from an afterthought to an essentially 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 fill finish the article by demonstrating the value of the new workflow and technologies by applying them to real case histories.

Devonian Production in the Mt Auburn Trend along the edge of the Sangamon Arch; A look back after 10 years of the "Boomtown Area" in Christian County, Illinois

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The Mt Auburn Trend extends for over 16 miles from southwest to northeast in northern Christian County, Illinois. This trend has produced in excess 11 MBO since 1943 from the Edinburg and Mt Auburn fields. A wildcat discovery in 2012 by Belken Oil on their Sheldon #1 (IP 1440 BOPD) in Section 28, T14N-R2W resulted in a flurry of drilling in the area, thusly this area became known as "Boomtown," essentially named by this author. The small stand-alone field was subsequently named Sharpsburg. The pay was named as " Silurian" at the time of discovery, but subsequent core and sample studies by this author suggests that the field is a Middle Devonian-age producing zone, in the Cedar Valley Formation. Stratigraphy is complicated by the region being the site of multiple erosional unconformities, poor well cutting samples, and sparse availability of cores that may help to better define the stratigraphy, diagenetic alteration, and contacts. Core data from the Benchmark Properties, Ltd-D, Loeb B-#1 indicates that production is Devonian in age (not Silurian,) in contrast to the adjacent Mt Auburn Trend, deemed to be Silurian. Prior to this discovery, the closest Devonian Field was Kincaid Field, some six miles to the southwest and a 6-million-barrel producer.

Fourteen new wells were drilled over a square mile area encompassing mostly parts of Sections 28 & 33 in 2012 by Belken Oil, Shakespeare Oil Co., Murvin Oil Co., and Benchmark Properties, LTD, with three dry holes and 11 Devonian Producers. Field production in 2012 (8 wells) average 585 BOPD. In 2022, some 10 years later, 3 wells remain active... 4 are idle. One has been converted to saltwater disposal.

Production data indicate movement of outside brine into this complex field. The productive wells range in rock type from fossiliferous limestone to sucrosic dolomite to a sandy dolomite. Maps, cross sections and a depositional-diagenetic model will be presented. A pilot waterflood will be attempted in the future, utilizing the model to be described, in order to extract remaining reserves in place.

Empirically Based Assessments and Data Driven Evaluations Throughout an Asset's Life

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Direct measurements of zonal production whether in multi-stage horizontal wells or multi-zone vertical and directional wells are essential for a true understanding of an asset's performance and associated value.

Over the past several years chemical tracer innovations have advanced for measuring targeted producing formations and horizontal well zone production for profiling reservoir performance and associated asset valuation in early-life and field delineation projects. Those learnings through mid- life asset management and infield development can be further tested and evaluated for enhancing parent and child well production while minimizing capital investment in unproductive or already depleted acreage, therefore focusing on best ROI opportunities. And for late life asset development, chemical tracers are critical for secondary and tertiary (EOR) project management by understanding injector-producer relationships by evaluating recovery performance and further maximizing capital investment/returns.

There are many reasons for surface recovery of "in-situ" measurements of production data using chemical tracer technology providing a wide-variety of production assessments throughout the life cycle of an asset. In unconventional wells that are hydraulically stimulated in multiple staged intervals across a long reach horizontal wellbore, geologic and other reservoir characteristics will have a direct impact on a well's overall production.

Using chemical tracers, a resource's staged productivity can be monitored for a correlated understanding of drilling parameters, stratigraphy and geologic composition, and completion techniques over time.
Likewise, in conventional wells with multiple producing targets, hydrocarbon tracers can be used to provide details of individual zone productivity to understand production profiles of oil, gas and water.
As a resource development evolves, chemical tracers can be applied for continuing in-fill development assessments and understanding depletion, interwell-communications and, ultimately, identifying the best well candidates for late life development.
This paper will focus on how tracer technologies are used over the life cycle of full-field development of hydrocarbon assets, both oil and gas reservoirs, including different EOR techniques in conventional and unconventional petroleum assets. Case studies in different US basins are included to illustrate the application of tracer technology available today.

Evaluation of sealing potential for shales in Illinois Basin

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The success of underground storage operations relies on the ability to properly seal the fluids in the reservoir. CO_2 or H_2 injected into a porous formation have a tendency to rise upward due to buoyancy, such that the reservoir should be overlain by a low permeable caprock to prevent the leakage through overlaying strata. Overall, the sealing potential of a caprock depends on its porosity, permeability, dominant pore size, strength, ductility, and propensity to thermal and chemical effects. The sealing capacity is defined as the maximum H_2/CO_2 pressure that can be retained in the underlying reservoir before it starts penetrating into the caprock and is oftentimes referred as breakthrough pressure. The low permeability of caprock is another parameter directly associated with its sealing potential, describing fluid flow after the breakthrough. Both the breakthrough pressure and permeability are dependent on the lithological heterogeneities, the sizes and geometry of effective pores, and the orientation/magnitude of induced stress during and after the injection process.
In this study, we evaluate the sealing potential of two types of potential caprocks from Illinois basin - Eau Claire shale and Maquoketa shale. Tested Eau Claire shale specimens have heterogeneous lithological characteristics, and one with higher micaceous clay contents appears to satisfy the permeability criterion for caprock (< microdarcy). The breakthrough pressure of Eau Claire shale is measured under the in- situ stress condition and is on the order of 0.5 MPa. The Maquoketa shale has a significantly smaller dominant pore size and porosity than those of Eau Claire shale, becoming a more favorable caprock with a nanodarcy scale permeability and the breakthrough pressure on order of a few MPa. The clay content changes with depth and location and plays a crucial role in the sealing potential of the shale: the higher it gets – the more ductile and less permeable is the material.

In addition to the laboratory methods – numerical approaches should be used to evaluate the sealing potential of a caprock at a field scale. Coupled finite element codes are implemented to simulate two-phase flow processes and coupled thermo- hydro-mechanical responses associated with underground storage operations. The use of physics informed neural networks allows upscaling the laboratory observations and finding the best fitting parameters for the models based on limited field measurements.

Facies and Sequence Stratigraphic Framework of an Incised Valley Fill, the Mississippian Cypress Formation, Southeast Illinois

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The Upper Mississippian Cypress Formation in the Illinois Basin is a siliciclastic succession that reaches 210 ft. (61 m) thick in southeastern Illinois. This study focuses on facies and sequence stratigraphic analyses of an incised valley fill and associated facies within the Cypress in the eastern part of Fairfield Basin, southern Illinois. The Cypress overlies the Ridenhower Shale in the east with a conformable contact that passes westward into the base of incised valleys that cut deeply into the older deposits. It varies from dominantly sandstone- to interbedded shale and lenticular sandstone bodies- to predominantly shale facies. In the western part of the study area, the Cypress may consist of a lower massive multi-story sandstone and an upper interbedded shale and lenticular sandstone; the upper sandstone intervals may coalesce with the lower Cypress sandstone interval forming a much thicker sandstone body (“thick Cypress”).

Facies and geophysical log motifs of the sandstone bodies suggest that the Cypress in the study area was deposited in coastal fluvial-deltaic and shallow marine depositional systems. The multi-story sandstones in the western part of the study area display narrow areal geometry and exhibit blocky or fining-upward vertical profiles recording deposition in fluvial incised valleys that scoured deeply into the lower Cypress and the underlying older deposits. The sandstone bodies in the interbedded shale and lenticular sandstone of the upper part of Cypress and laterally in areas where stacked channel deposits are absent record deposition in fluvial-deltaic, shallow marine, and tidal flat settings. The bulk of the Cypress Formation in the western part of the study area represents an unconformity bounded fourth-order depositional sequence. This sequence consists of lowstand-transgressive multi-story incised valley fill deposits capped by late transgressive widespread grey shale that underlies highstand, interbedded shale and lenticular sandstone facies related to fluvial-deltaic, shallow marine, and tidal flat settings. The thicker sandstone body (“thick Cypress”) was formed because of amalgamation of highstand lenticular sandstone intervals with the lower Cypress incised valley sandstone. High energy/high rate of sediment accumulation of the main fluvial valleys was likely responsible for the stacked fluvial sandstones that locally constitute the lower part of early highstand deposits.

Gas geochemistry can be very useful for determining the source of gas considered to be linked with well integrity and well abandonment issues.

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According to the literature there are millions of abandoned oil and gas wells throughout the US that are or have the potential to leak hydrocarbons into the environment. There have been several studies on well integrity and rates of well failure vary widely, from a few percent to much higher percentages. One study of over 400 wells indicated that 18% had well integrity problems. Well integrity issues can happen during any stage of the well life: drilling, production, post-production, and even after plugging and abandonment. Despite following environmental regulations and best-practices, operators sometimes face claims and legal challenges that their wells are contaminating the environment. There can be multiple sources of gas in an area near a gas/oil well. If there is no geochemical data of the gas from the well, the operator may find it very difficult to refute the claims and defend their position. Collecting and analyzing production gas and other potential sources of gas in the stratigraphic column could go a long way to helping to resolve the issues for determining the source of gas found near a well. There could also be buildup of gas within the annulus spaces of a well. Knowing the source of a stray gas near a well or in the annular space of a well will help in determining how to resolve the issue. Molecular compositions combined with isotopic analyses are able to help distinguish different sources of gas such as microbial versus thermogenic gas and even thermogenic gases from different geologic formations. We will visit this problem and show examples of how different gases can be distinguished.

Hicks Dome Interpreted as a Tectonically-Deformed Faulted Block Using Long-Record and High Quality 2D Seismic Lines

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The origin of the positive structural feature called Hicks Dome in Hardin County, Illinois, has intrigued geoscientists for many years. The area is home to the discovery of important minerals, particularly fluorite, in the Illinois-Kentucky Fluorite District. Previous authors have established intense faulting activated in the Late Mississippian- Early Permian (Denny, 2007), and have explained the "dome" area, which has surface expression, as a crypto-volcanic structure with an intruded, alkaline igneous body.
The idea that the round surface area has an igneous intrusion underground is often cited in the Illinois geological literature, most notably in W. John Nelson and Donald K Lumm's ISGS Circular 538 (1987). Looking at the regional gravity and magnetic maps from the USGS is a bit of a puzzle (McCaffrey, 2019), as no magnetic igneous body seems to show up where the surface expression of the Hicks Dome lies. Could it be possible that the north-south fault pattern, drawn by Nelson and others, might be interpreted as transpressional rather than normal-faulted blocks? Nelson and Lumm cite many near-surface examples of thrust faults in the Cottage Grove fault area.

We reconstructed the Cambrian to Late Devonian by flattening the 2D seismic lines in depth and found that the Upper Cambrian to Late Devonian is undisturbed with no onlap to the Hicks dome site as late as the Late Mississippian. The Early Paleozoic was a quiet, basinal thick over the Hicks area. Lack of Paleozoic onlap means the Hicks Dome is a very late feature in Illinois geological history, occurring after Mississippian-age wrench faulting in the Rough Creek Graben.
Our recent interpretation of seven key 2D seismic lines acquired and processed by Seismic Specialists in 1989, reveals an alternate origin of the Hicks "dome" as a tectonically-deformed series of fault blocks. The Hicks feature could be a transpressional flower structure. An upward-moving igneous pluton is not needed to explain the surface high. The hot saline, fluorite, and REE mineral-rich fluids found in Hardin County's Cave-in-Rock and other fluorite mines near the Hicks feature could have been emplaced during Early Permian wrenching. Analogs are 1) Venezuela's strike-slip faulting, and the fluorite mines in El Tule mines, Musquiz, Coahuila, Mexico, in which chemically-similar fluorite crystals are formed in a wrenched and faulted province, with a deeply buried fault link to mantle derived igneous plutons.

High Resolution Static and Dynamic Computed Tomography Analysis of West Virginia Oriskany Formation Cores for Carbon Capture Storage and Utilization in the Appalachian Basin

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The Appalachian Basin is a key energy producer with a legacy of hydrocarbon production. The presence of large point source emitting energy utilities and scarcity of high-quality reservoirs for large scale CO_2 injection in this region means that furthering knowledge of nearby, secondary formations such as the Oriskany sandstone is needed for localized storage of CO_2. As part of this effort, two West Virginia gas storage wells from Jackson and Hampshire County were characterized at the National Energy Technology Laboratory with multi-scale CT imaging, petrophysical data collection from the Multisensor Corelogger (MSCL), and helium porosimetry. The Jackson County well (47-035-02464) is representative of the western portion of the basin and is made up of medium- to fine-grained quartz-rich sandstone. The Hampshire County well (47-027-00042) is representative of the eastern portion of the basin and is an orthoquartzite with an abundance of fossils.
Additional in this study, we establish a new methodology for high resolution analysis using a Tescan Dyna Tom dynamic computed tomography scanner Subcores of sandstone facies of both wells were obtained and exposed to organic acids to understand the changes in porosity from dissolution of calcite cement during CO_2 injection. This was represented both statically with pre- and post-scan analysis of acid floods, and dynamically through out the digestion process. The static scanned samples were digested

using 8% citric acid over the course of 5 days under a constant vacuum. Image segmentations were done on pre- and post-scans to track compositional changes in pore space and mineralogy. The dynamic scan was run using a 16% citric acid, with a scan taken every hour for 24 hours.
The result show on average 1 to 2% porosity gains between the pre and post digestion scans in both Jackson and Hampshire County wells. Image segmentations of the samples shows a decrease in calcite and an increase in pore space. The dynamic scan shows the preferential dissolution along calcite cement and fossiliferous material in the sample with minimal infiltration along the quartz matrix.

Identification and Characterization of Stacked ROZs in Illinois

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Carbon Dioxide Enhanced Oil Recovery (CO_2-EOR) is used to recover oil from naturally occurring Residual Oil Zones (ROZs) in the Permian Basin. In addition to the economic benefit of oil production via CO_2-EOR, ROZs have the potential for associated CO_2 storage. ROZs are ill-defined in other basins, so there have been few attempts at ROZ production. This work describes the identification and characterization of ROZs in four formations in Illinois: The Tar Springs, Cypress, and Carper Sandstones, and the Geneva Dolomite.
Regional geologic characterization was conducted to identify where each formation had thick, laterally continuous porous intervals capable of hosting ROZs. Wells that reported oil shows and oil production were compiled and mapped to identify areas that had a high proportion of unproduced oil shows. These data were overlain on regional isopach and structure maps to establish preliminary boundaries for ROZ fairways for each formation. Well data (scout tickets, well logs, core, and drilling reports) within each ROZ fairway were carefully evaluated to refine fairway boundaries and identify ROZ Prospects; areas with high density of data that could be used to further characterize rock and fluid properties of the ROZ. Digitized geophysical logs within the prospects were analyzed to characterize the fluid saturation distribution by constraining producing oil water contacts (POWC), oil water contacts (OWC), and defining residual oil saturations within the ROZs and current oil saturations within main pay zones (MPZs; where present). Oil shows and/or production from nearby wells were used to support the interpretation of log derived MPZ/ROZs and refine the boundaries of the prospects.
Resulting ROZ fairway maps show the potential for widespread ROZs in each of the four formations. The Tar Springs ROZ Fairway occurs in southeastern Illinois in association with the Wabash Valley Fault System whereas the Carper and Geneva ROZ Fairways overlap along an east/west trend in the central part of the state. The Cypress ROZ Fairway overlaps with the Tar Springs Fairway in the southern portion of the state but continues along structures to the north, generally following a north-south trending belt of thick sandstone within the formation. The CO_2- EOR and associated CO_2 storage

potential for each ROZ prospect is being determined and will be extrapolated across each ROZ fairway to quantify the EOR and CO2 storage resource for each formation.

Interpreting the Mississippian System of the Appalachian Basin as a flexural response to Neoacadian tectonism

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The Mississippian System of the Appalachian Basin is well-known for its many reservoir units that are included in a three-part, wedge-like, clastic-carbonate-clastic sequence that is commonly interpreted to represent, respectively, post-orogenic Acadian clastics, carbonate deposition during tectonic quiescence, and renewed clastic influx reflecting initiation of the Alleghanian Orogeny. A more recent understanding of regional tectonics, however, suggests that the Appalachian Mississippian succession reflects instead foreland flexural responses to the coeval Neoacadian Orogeny, which involved the transpressional collision of the Carolina Terrane with the southeastern margin of Laurussia. These flexural events begin with Early Mississippian deformational loading that initiated rapid subsidence in the Appalachian foreland basin and deposition of the deeper water, black Sunbury Shale and equivalents throughout the basin. Subsequent relaxational loading contributed to basin infilling through the deposition of a deeper-water, clastic succession, manifest as the extensive Cuyahoga-Logan-Borden-Grainger- Price-Rockwell-Pocono deltaic clastic wedge. As this clastic wedge infilled the foreland basin, source areas in the orogen were apparently lowered to the point that shallow seas migrated far eastward across former source areas. This brief period of equilibrium between the basin and source areas resulted in reduced clastic influx at a time when the basin entered subtropical latitudes, setting the stage for widespread Middle and Late Mississippian carbonate deposition, represented by units like the Newman, Greenbrier, and Slade Limestones. Ensuing, rebound- related uplift generated new source areas and accompanying wedges of prograding marginal- marine and terrestrial sediment represented by the Pennington, Mauch Chunk and equivalent units. Marginal-marine sedimentation continued into Early Pennsylvanian time, when both Alleghanian uplift and LPIA lowstand conditions generated a period of widespread erosion that destroyed substantial parts of the underlying Mississippian succession in the Appalachian Basin along the so-called “Mississippian-Pennsylvanian” unconformity. Although Neoacadian flexural responses provide a more coherent explanation for the Appalachian Mississippian succession as a whole, the many regional unconformities throughout the succession probably reflect concomitant interactions involving paleoclimate, eustasy, and coeval Ouachita tectonism.

Lithofacies, Stratigraphic Variability, and Reservoir Characteristics of the Galesville and Ironton Sandstones in OEE No. 1 and the Surrounding Areas, North-central Illinois

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The Cambrian Galesville Sandstone and the overlying Ironton Sandstone are part of the Knox Group in the Illinois Basin. They constitute the uppermost part of the Sauk II subsequence and form the most extensive permeable reservoirs in northern Illinois. This study focuses on lithofacies analysis, stratigraphic variability, reservoir characteristics, and petrophysical characteristics of Galesville and Ironton Sandstones in OEE Well No. 1, McLean County, and the surrounding counties in north-central Illinois. The Galesville and Ironton Sandstones consist of mature sandstone and sandy dolomite. They are more than 200 feet (60 m) thick in northern Illinois, but their thickness decreases southward, and they both pinch out toward the south and southeast. The Galesville is up to 100 feet (30 m) thick; it conformably underlies the dolomitic Ironton Sandstone and overlies, with a sharp contact, the Eau Clair Formation. The Galesville is a white, very porous, and commonly fine-grained mature quartzose sandstone. The Ironton Sandstone is more than 100 feet (30 m) thick and underlies, with a sharp contact, the glauconitic sandstone of the Franconia Formation. It consists of interlayering of fine to coarse- grained, porous quartzose sandstone and dense dolomitic sandstone or sandy dolomite containing relics of ooids and bioclasts. The Galesville and Ironton Sandstones were deposited in a mixed siliciclastic-carbonate system in which the interplay between clastic influx and carbonate deposition resulted in a high degree of lateral and vertical facies and stratigraphic variability. In the OEE No. 1, the Galesville Sandstone is 55 feet (17 m) thick and contains more than 35 feet (9 m) of reservoir in which average sidewall core porosity and permeability is 11.75% and 187 mD, respectively. In this well, the Ironton Sandstone is 122 feet (37 m) thick and consists of nearly 30 feet of reservoir with an average core porosity and permeability of 10.45% and 84 mD, respectively. The reservoir intervals of the Galesville and Ironton are permeable and encased in impermeable units, thus the formations have excellent potential to serve as reservoirs for sequestration of anthropogenic CO_2.

Paleoenvironments of the Pennsylvanian Caseyville and Tradewater Formations in the Southeastern Illinois Oil Field, Crawford and Lawrence County, Illinois

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The first oil boom in the Illinois Basin and c. 15% of its production are ascribed to Pennsylvanian Caseyville and Tradewater Formation reservoirs in the Southeastern Illinois Oil Field. These deposits have been studied widely in outcrop but less so in the subsurface, and a consensus interpretation of their depositional setting is lacking. Lithologic uniformity and the lack of distinctive persistent marker beds have made environmental interpretations difficult, but new wells with modern geophysical log suites and recent coring provide new details on vertical facies changes, enabling reevaluation of

these deposits in a sequence stratigraphic and facies model context. Eight facies associations were recognized in a motif of stacked paleovalley fills that reflect eustatic sea-level cycles.

In the Caseyville, fine- to coarse-grained cross-bedded to massive sandstones occupy valleys cut into Mississippian bedrock and are overlain by coarsening upward, sparsely bioturbated heterolithic (generally wavy to flaser bedded sandstone) rocks capped with thick laminated mudstones. In the Tradewater, paleovalleys contain thicker fine- to medium-grained cross- bedded to massive sandstones that crudely fine-upwards, with minor mud drapes and lenticular bedding. Mudstones, and fan- to ribbon-shaped, very-fine to fine-grained sandstones flank Tradewater paleovalley sandstones. Root-penetrated sandy mudstones (paleosols), thin coals, and locally fossiliferous and calcareous laminated mudstones commonly cap sandstones.

Caseyville facies are consistent with incised valley fills in a wave-influenced estuarine setting. Fluvial sandstones underfill valleys, reflecting low coarse sediment input, with bayhead delta heterolithic rocks and central basin mudstones deposited during sea-level rise. Thicker fluvial sandstones fill Tradewater incised valleys with evidence of tidal modulation. The thinner flanking sandstones embedded in mudstones represent lower coastal plain splay and tributary/minor channel deposits that are tidally modulated and indicate aggradation concurrent with transgression. Paleosols and coals are linked laterally to valleys and reflect emergence and incision of the coastal plain during sea-level fall followed by deposition of thin coastal to marine mudstones during sea-level rise. Oil reservoirs occur in Caseyville and lower Tradewater clean fluvial sandstones on anticlines and in heterolithic rocks where they are stratigraphically trapped in transgressive mudstones.

Petroleum Geology of the Mississippian Stacked Reservoirs in Noble Oil Field, Richland County, Illinois, in the Context of CO2-EOR and Associated Storage

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Noble Oil Field, located along the Clay City Anticline in Richland County, Illinois, has produced over 46 million barrels of oil from Mississippian strata. The mature field is archetypal of the Illinois Basin as it contains a stacked reservoir complex of depleted and bypassed main pay zones (MPZs) and a naturally occurring residual oil zone (ROZ). The lifespan and profitability of such fields may be improved with CO_2 enhanced oil recovery (EOR) and associated storage.

It is key to build robust conceptual geological frameworks that incorporate the unique architecture and heterogeneity the varied formations so EOR strategies can be developed to prioritize the most performant reservoirs. To that end, this study leveraged core, geophysical logs from over 900 wells, and production data to characterize Noble Field's stacked reservoir complex.

The Cypress Sandstone contains the shallowest oil reservoir in the field with an ROZ

below a partially depleted, but widespread MPZ. Aux Vases Formation reservoirs generally occur within thin shaley sandstone in the upper part of the formation. The Ste. Genevieve and Salem Limestones are lithologically similar with each containing relatively thin and compartmentalized, highly permeable oolitic to skeletal grainstone reservoirs within otherwise non-porous limestone. The St. Louis Limestone has reservoirs developed in thin but widespread microsucrosic dolomite beds. Reservoirs within the Ullin Limestone are restricted to thin stringers of poorly cemented, light-colored grainstones composed mainly of bryozoan fragments that occur in the top part of the formation.
The Cypress has over 90% lateral reservoir continuity at 2,500 ft well spacing whereas lenticular reservoirs in the upper Ullin have no continuity beyond approximately 1,750 ft. The other formations have moderate continuity with the Salem slightly outperforming the Ste. Genevieve and St. Louis reservoirs. Most of Noble's oil production has come from the Cypress and Ste. Genevieve, so EOR efforts should prioritize them with patterns designed around the continuity limitations of the latter. The Cypress and Ullin also each contain thick brine aquifers below their oil reservoirs that would be well suited for CO2 storage, in particular the Ullin with few legacy well concerns. This presents an opportunity for associated saline CO2 storage to supplement an EOR project, providing the flexibility of prioritizing EOR or storage depending on field operations and market conditions.

Power of the Mine: The Potential for Dramatic Expansion of Energy Storage in the Eastern US by using Abandoned Underground Mines

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Conventional pumped-storage hydropower (PSH) is a proven technology that accounts for around 95% of all utility-scale energy storage in the US and globally. Unfortunately, two key challenges have stymied PSH expansion in the US: the "ΔH challenge" (refers to achieving a suitable difference in hydraulic head height between the upper and lower reservoirs in a PSH system) and the socio-economic challenge of constructing two large reservoirs at land surface (e.g., regulatory, financial, and public perception). Repurposing abandoned underground mines as lower reservoirs for PSH systems helps overcome both challenges. This concept termed PSHAUM is particularly promising in the eastern U.S. where most of the nation's underground mines are located, primarily as abandoned coal mines (over 14,000 of the 17,000+ known underground mines). Our results center on a six-state region spanning the Appalachian and Illinois Basins and cover two key areas of research: candidate site screening and mine reservoir performance.
Site-screening analysis revealed over 50 prime candidates for PSHAUM technology with top-tier sites having active power plants co-located with soon-to-be retired or recently closed mines at depths of 150+ meters (500+ feet) and mine void volumes of 5+ gigaliters (4,000+ acre-feet). PSHAUM power generation is directly proportional to hydraulic head and penstock water flow rates and the criteria above allows for 1.5+ GWh energy storage

systems (e.g., 200 MW generator capacity running for 8-hour duration cycle at 85% efficiency). Owing to logistical and safety factors, mines that are just recently closed and abandoned or slated for closure are optimal candidates. Sites with co-located power plants provide significant financial and permitting benefits via existing power grid infrastructure and large surface reservoirs often already constructed.
Site-specific data and information from 3 optimal candidate sites were used to build idealized but realistic multiphase reservoir simulation models to assess mine reservoir performance. Results indicate that although mine reservoirs are not closed systems, multiple filling and draining cycles can occur without causing adversely high pore pressures. The evolution of reservoir water quality was also simulated, indicating that additional water treatment may be necessary to meet water quality requirements depending on site-specific hydrogeologic conditions. Overall, PSHAUM technology shows great promise for further R&D.

Predicting plume evolution in heterogeneous aquifers during CO2 storage using generative adversarial network proxy models

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An alternative to the time-intensive approach of constructing detailed computer reservoir simulations to make predictions for underground applications, such as in Carbon Capture Utilization and Storage (CCUS), has been sought for several decades. As a part of the US Department of Energy (DOE)-funded initiative Science-informed Machine Learning to Accelerate Real-Time Decisions in Subsurface Applications (SMART), we applied the conditional Deep Convolution Generative Adversarial Networks (cDC-GAN) machine learning approach to train proxy models that can predict key carbon dioxide (CO2) storage performance indicators. cDC-GAN is a semi-supervised ML method constituting a self-training scheme that improves the quality of generative models in a game theoretical framework and can be applied without complete statistical knowledge of input data distributions. It is designed to learn cross-domain mappings between high-dimensional input (e.g., permeability) and output (e.g., phase saturations) pairs while incorporating conditioning information (e.g., time step data). The cDC-GAN model utilizes 2-D depth slices of the 3-D model at each timestep which are passed to the model as four-channel input image pairs and predict three-channel output images. The image pairs are encoded with porosity, permeability, depth, and timestep as input channels and pressure, saturation, temperature, and timestep as target channels. The predicted output image channels are pressure, CO2 saturation, and temperature. The proxy model developed herein was trained and validated using a project-common dataset consisting of multiple realizations of heterogeneous static reservoir models of a saline aquifer populated with

input parameters (such as porosity, permeability, well location, bottomhole pressure, and fluid saturation) and time-dependent pressure and CO_2 saturation distribution projections from dynamic reservoir simulations of each realization. Global performance metrics such as Root Mean Square Error, Structural Similarity Index Measure, and parity graphs will be used to tune the proxy model through hyperparameter optimization and to match full 3-D reservoir simulation results at all time steps. The performance of the cDC-GAN proxy model predictions was evaluated at specific locations for reservoir pressure and CO_2 saturation

Properties of $CO_2$and H_2-CH_4fluids: Constraints from Laboratory Seismic Experiments

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Components of decarbonization include both permanent geological sequestration of CO_2 and annual energy storage of mixes of natural gas and H_2. Time-lapse active seismic source imaging is used nearly ubiquitously for CO_2 sequestration currently to both constrain fluid movements and to monitor for potential escape of fluids from the target reservoir. Natural gas has been long stored in various underground reservoirs for use during periods of high demand, but these reservoirs are only rarely monitored by seismic methods. H_2 will be increasingly produced as a form of energy storage in the coming decade, and as with natural gas it is likely that the safest and most economic means to store it will be in underground reservoirs. Already, mixed H_2-natural gas blends are being considered for use.
However, there remain many unknowns with regards to the behavior of H_2 stored in the subsurface, and it is likely that at least initially some form of seismic monitoring will be required over pilot projects. Fully understanding any seismic data acquired, however, requires detailed knowledge of the of the seismic physical properties of these fluids. Their density and compressibility and phase state depends strongly in the insitu conditions of pore pressure and temperature to which they are subject. The properties of mixed gases under reservoir conditions, where they cannot be considered as perfect gases, is particularly challenging. After a brief review of the characteristics of rock and fluid that are important to seismic monitoring, I provide an overview of the key equation of state behavior of CO_2 and of H_2 mixed with methane CH_4 as representative of natural gas. I describe a series of earlier laboratory tests on both artificial porous media and real sandstones all saturated with CO_2 in which we measured the ultrasonic compressional and shear wave speeds and their attenuation under a variety of P and T conditions designed to capture changes in the seismic character across the gas-liquid-super critical fluid phase boundaries. We then employ the same properties of the rock frame to model expected seismic responses in these sandstones when saturated with H_2-CH_4 mixtures under reservoir environments. I conclude with simple modelling of expected seismic reflection responses to illustrate levels of seismic detectability for these stored fluids.

Reservoir Characterization of the Trenton Limestone, Illinois Basin

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The Trenton Limestone is a widespread, shallow marine limestone of Ordovician age that occurs throughout the Illinois Basin in Illinois, Indiana, and Kentucky. Data from over 2600 wells were examined for this study, including wireline logs, core analyses, and sample and core descriptions. Several cores from across the basin were examined and an extensive search of literature was conducted.

Historically, production from the Trenton in the Illinois Basin has been limited to pronounced structures with significant closure. Many of these structures are associated with faulting. With one exception, Trenton fields occur above the -4500 subsea on the top of the Trenton. Thickness varies from less than 100 feet in southwestern Illinois to over 180 feet in southwestern Indiana. Four reservoir facies first identified by Crews (1985) can be tracked on wireline logs across the Illinois Basin. Reservoir rock is fossiliferous packestone and grainstone interbedded with impermeable cherty wackestones. Dolomite is common in surface exposures and the shallow subsurface, but relatively rare in deeper subsurface and productive fields. Porosity and permeability can vary but are low across the basin. The common presence of echinoderms and stylolites likely contributed to the loss of porosity and permeability.

Diagenesis is extensive, evidenced by recrystallization, stylolites, pinpoint and vugular porosity, and fractures. Based on cores, the diagenetic history on the west flank of the basin may differ from the diagenetic history on the east flank of the basin. The best bbl/acre recovery occurs where maximum porosities exceed 8%. Historic oil production has occurred from 44 pools in 42 fields in Illinois and Indiana and totals over 25 MMBO. Published data indicates that Trenton oil migrated post-Pennsylvanian in the Illinois Basin. However, a comparison of structural timing and oil fields indicates that no post-Mississippian structures have Trenton oil. The relationship between the timing of diagenesis, structural development and oil migration is poorly understood. A better understanding of this relationship may better constrain the development of Trenton reservoirs and identify where additional reservoirs can be found.

Seven Year Project to Drill a Trenton Wildcat in Washington County, Illinois: A Tale of Persistence overcoming Resistance, Leading to a Possible New Oil Field Discovery

Charles A. Sternbach, Linda R. Sternbach *(Star Creek Energy),* Michael Payne, Alan Henigman, and Rick Marquardt *(Shawnee Oil Company).*

Star Creek Energy took a bold step seven years ago in 2015, despite falling oil prices and an industry downturn, by licensing one of the few available 3Ds in Illinois. We speculated that there was an untested wrench-faulted structure near Oakdale, Illinois, flanked by wells with oil shows in the Devonian and Trenton formations. Based on our subsurface mapping of the Devonian and Mississippian, we felt confident that it would be easy to map the 3D survey data, lease the land, get partners, and drill our "Round Rock " Prospect." The 3D allowed us to map a Trenton structural high between all the well control in a section containing six Devonian wells drilled from 1950-1973. Our review of regional analogs showed field producing from many objectives surrounding our prospect. The Chester Benoist and Cypress sandstones produce at McKinley and Cordes fields. The Devonian Hardin sandstones produce 120,000 BO at N. Elkton, 5 miles due NW. The Trenton formation produces in fields like Pyramid (360,000 BO) on the west side of the Fairfield basin.

What happened during our seven-year odyssey was a microcosm of what many independents go through to get an exploratory well drilled in these times. We believed in our technical analysis and documented the likelihood of success based on the 3D, analog field studies, and surrounding wells. The seven years of woe included: landowners and farmers not willing to lease, building a coalition of many small investors, finding the best drilling operator remotely from Houston, 2020 historic oil depression, Illinois not being issued an Illinois drilling permit for many months due to Covid 19 and politics, spring frost laws delaying drilling, and 2022 supply chain problems with finding a suitable drilling rig and wellsite professionals.

Persistence and good partners paid off in April 2022. The 3D enabled accurate predictions of the depth of the mapped targets. We are pleased to report that the Shawnee Roesener #1 well, drilled to 3700', encountered oil shows in the Hardin, Devonian Limestone, and Trenton. We continuously cored 60' of Hardin sandstone and Devonian Lime, including the entire 16' of New Albany shale from the base of the Choteau Limestone. We plan to complete the Trenton, and if commercially successful, we plan to develop the field with offset drilling. We will show before and after interpretations and discuss possible field development plans.

So Many Orphaned Wells, Where to Plug First?

Thomas (Marty) Parris (*Kentucky Geological Survey, University of Kentucky)* Stacy Woods and Emily *Connor (Yale Carbon Containment Lab)*

The 2022 passage of the Bipartisan Infrastructure Law provides much needed funding for states and other entities to plug the approximately 3.5 million orphaned oil and gas wells (OOGW) in the United States. In Kentucky alone, there are over 14,000 known OOGWs. To utilize funds most efficiently, a systematic approach that informs plugging decisions increases the likelihood of plugging wells most likely to cause environmental harm.

To address this need, the Kentucky Geological Survey and Yale Carbon Containment Lab are developing a hazard assessment tool to prioritize well plugging. The tool assesses criteria using two complementary approaches both of which can be relatively scored. The first approach is an assessment of engineering and geologic characteristics of the OOGW that could influence its environmental impact. Example criteria include wellbore age and distance between the hydrocarbon reservoir and potable water. The second approach analyzes the geospatial setting of OOGWs relative to features like schools, groundwater

wells, and recreation areas. The geospatial analysis also enables the delineation of clusters of OOGWs, and their ease of access. The cluster analysis provides the opportunity to define hot spots with large numbers of OOGWs with higher relative hazard scores.
We are refining the dual track methodology in three pilot areas in eastern, central, and western Kentucky. Each area has distinguishing oil and gas development histories and cultural settings. The central Kentucky pilot area illustrates the utility of the cluster analysis method. Here, 1,878 OOGWs are distributed among five counties. The cluster analysis in ArcGIS Pro defines 884 OOGWs distributed among 49 statistically significant polygons (800m X 800m) with each polygon containing 10 or more OOGWs (hot spots). Of these, 326 OOGWs in 13 clusters could be readily accessed as determined by the intersection of primary and secondary roads with the polygons. The hotspots can be further ranked based on the geologic and engineering characteristics of OOGWs within their boundaries. Our plans for future work include systematic measurement of methane emissions by OOGW subgroups as defined by geologic and engineering characteristics. The goal is to determine if certain OOGW subgroups tend to have higher methane emissions. Determining if certain well subgroups are prone to higher emissions will facilitate more efficient abatement of emissions through plugging.

Stable Isotope Systematics of Marcellus Formation Shale-Gas During Pressure Core Degassing and Production

Christopher D. Laughrey, *Stratum Reservoir*

Controlled release of natural gas from pressurized Marcellus Formation core provided an opportunity to collect a time-lapse suite of unconventional reservoir fluid composition and isotopic analyses to document chemical changes that occur during degassing of the rock samples. The data revealed geochemical trends that systematically varied with degassing time and cumulative hydrocarbon yield. Carbon isotope fractionations varied in direction and magnitude as a function of diffusion and desorption during degassing. In contrast, limited time-lapse geochemical analyses of Marcellus Formation natural gases in the northern Appalachian basin do not reveal significant or systematic changes of stable carbon isotope ratios that vary with production. Although δ value variations of up to almost 5‰ occurred during the laboratory degassing experiments, produced hydrocarbons flowing from Marcellus shale-gas reservoirs are dominated by advective flux through stimulated fractures which has little fractionation effect

The Cambro-Ordovician Notch Peak Formation and House Limestone of the Great Basin – Window into the Illinois Basin Potosi Dolomite?

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The latest Cambrian Potosi Dolomite of the Illinois Basin is a carbon sequestration target but is subsurface-only in the southern basin. We report new work on a Potosi-equivalent Notch Peak Formation in southern Nevada, which may serve as a Potosi analogue.
We Identified the Notch Peak Formation in the Arrow Canyon Range near Las Vegas by correlating northward through east-central Nevada into the House Range of western Utah, the Laurentian biostratigraphic standard locality for the Upper Cambrian to Lower Ordovician. Current stratigraphic efforts focus on conodont and brachiopod biostratigraphy, and carbon isotopes, and has moved the local Cambrian-Ordovician boundary up approximately 100 meters from previous estimates.
This high-resolution stratigraphic framework allowed sequence stratigraphic units to be matched along the passive margin from southern Nevada to Western Utah. For example, shoals and microbial mound buildups mark transgressions showing the sedimentary effects of basement faulting. More remarkably, these sequences can be traced into the craton as far away as central Colorado and the Texas Hill Country, despite sedimentary condensation in those areas.
A microbial mound interval in the *E. notchpeakensis* Subzone of the *Eoconodontus* Zone, the Red Tops Member is intriguing. This 15 m series of microbial mounds, along with an underlying 20 m of interbedded oolitic and flat pebble conglomerate limestones and shales are only patchily dolomitized, whereas overlying rocks are uniformly dolomitized throughout the region. Furthermore, overlying sediments include karst breccia fills exceeding 50 m in thickness and contain clasts as young as the *Rossodus manituensis* Zone.
Microbialites consist of multiple microbial textures including lithistid sponges, early framework-building animals rare in the Upper Cambrian. This Cambrian lithistid reef association is also found in the coeval Clinetop Member of the Dotsero Formation in central Colorado, suggesting continuity of this early “reef” system. Parallels between the Notch Peak Formation the Potosi Dolomite include a shallow marine environment, oolitic and microbial carbonates, dolomitization and heavy karsting.
Preliminary correlations into the craton suggest that some of these parallels may be temporal signatures, not simply coincidence. Extensive exposures and patchy undolomitized areas of the Notch Peak make it a good analogue for interpreting well logs and samples from the Potosi.

The effects of two igneous intrusions on the organic petrography and geochemistry of the New Albany Shale in the Western Kentucky Fluorspar District

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The New Albany Shale is an organic rich shale of late Middle/Late Devonian age that extends across the Eastern Interior (Illinois) Basin, located in the midcontinent USA. An

exploration drill core in Crittenden County, Kentucky intercepted two Permian, ultramafic lamprophyre igneous intrusions, 30 and 45 cm thick and 30 m apart at depth. Samples of the shale, collected in continuous 0.5 to 4.5 cm intervals from above and below each intrusion, were examined petrographically and geochemically to document compositional changes in the shale.

Total organic carbon (TOC) in the New Albany Shale samples varied from 0.4 to 9.0 wt. %, with organic matter occurring mainly as alginite, bituminite, solid bitumen, *Tasmanites,* vitrinite and inertinite. Total inorganic carbon (TIC) varied from 0.2 to 4.4 wt. %, occurring primarily as calcite and probably some dolomite. Total sulfur varied from 0.2 to 3.3 wt. % and occurred mainly as small (<5 micrometers), individual pyrite crystals and framboids. Major and minor element oxides in the shale samples are dominated by SiO2 (avg. 61.9 %) and Al2O3 (avg. 16.2 %) with reduced amounts of Fe2O3 (avg. 4.2 %), K2O (avg. 3.9 %), MgO (avg. 2.3 %) and CaO (avg. 1.8 %). The sample immediately beneath the stratigraphically lower intrusion is unique in that it contains elevated amounts of MgO (8.3 %) and CaO (8.7 %). The most abundant trace elements tested for in the shale samples were vanadium (avg. 199.1 ppm), zirconium (avg. 150.9 ppm), nickel (avg. 89.6 ppm) and chromium (avg. 77.2 ppm). On average, light rare earth elements + yttrium (REY) are approximately five times more abundant than heavy REY. Cerium (avg. 78 ppm), lanthanum (avg. 38.2 ppm) and neodymium (avg. 38.2 ppm) are the most abundant light REY elements. Yttrium (avg. 21.3 ppm), dysprosium (4.7 ppm) and erbium (avg. 3.6 ppm) are the most abundant heavy REY elements.
Shale samples farthest away from the igneous intrusions had average vitrinite reflectance values between 0.93 and 1.09 %, similar to reflectance values obtained from other well locations in Crittenden County. The zone of thermal alteration above and below each intrusion is 1.2 to 1.4 m thick. Samples immediately adjacent to the igneous intrusions contained anisotropic pyrolytic carbon with reflectance values between 4.41 and 5.77 %, indicating temperatures above 300o C. However, the presence of abundant pyrite indicates that temperatures probably did not exceed 540o C, the dissociation temperature of pyrite.

The Occurrence of Critical Minerals in Fine-Grained Strata: Insights from the Upper Devonian Hanover and Dunkirk Shales of Western New York State

D. Randy Blood, Scott D. McCallum, Ashley S.B. Douds, *Wildlands Research, LLC*

Over the coming decades, global demand for critical minerals is projected to increase rapidly. Several organizations (the IEA and the USGS) have underscored the importance of defining the abundance and geographic distribution of these minerals, many of which are required materials for Li-ion battery development and may be found in black shale deposits. To-date, little attention has been given to understanding the geologic controls on the occurrence of these elements in black shale. Here we investigate depositional and diagenetic processes which may concentrate critical minerals into discrete beds, potentially providing more favorable economics for extraction.

The interval between the Upper Kellwasser Bed of the Hanover Shale and the base of continuous black shale in the overlying Dunkirk Shale, informally termed the Beaver Meadow Beds, thickens eastward from about 15 cm at Dunkirk, NY to over 10 meters at Java Village, NY, roughly 75 km away. The section is dominated by grey shale with an eastward increase in the occurrence of abundant, thin, pyritic black shale beds. These beds merge westward via erosional overstep and/or non-deposition with the base of the continuous black shale of the Dunkirk.
We have identified two modes of deposition for thin black shale beds: 1) the lowermost beds are organic-rich hyperpycnites, likely the result of storms flushing lagoonal muds out to sea, and 2) beds associated with transgression which are often accompanied by a basal pyrite lag which may disappear upslope.
We conducted elemental analysis using energy dispersive X-Ray Fluorescence across this interval at one-centimeter intervals from numerous exposures. Preliminary data shows enrichment of critical minerals, specifically Co, Cu, Ni, and to a lesser extent Zn, associated with pyrite. Moreover, we have identified four phases of pyrite occurrence in the unit: 1) Gray shale- hosted diagenetic pyrite forming in micro-anoxic environments with worm burrows and decaying organisms. Later, such material is often concentrated into erosional placer-like deposits of pyrite that form at the base of some thin black shale beds; 2) occurrence in some black shale beds of syngenetic framboidal pyrite; 3) later stage formation of larger framboidal and euhedral diagenetic pyrite hosted by black shale; and 4) diagenetic enrichment of pyrite in basal lags and underlying gray shale resulting from sulfide diffusing out of Fe-depleted black muds into underlying organic-lean, Fe-rich muds.

What's the deal with the Carper Sandstone: An atypical Illinois Basin oil reservoir

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The Mississippian Carper Sandstone, a member of the Borden Siltstone, was deposited north of the deepest part of the Illinois Basin (ILB). The Carper is a very-fine grained sandstone to very coarse siltstone with high clay content and detrital to authigenic carbonates. Porosity is moderate (~14%) and permeability is low (~1 mD). It occurs as several overlapping, laterally extensive lobes encased in mudstone that are interpreted as distal, fine-grained sediment gravity flow deposits. Recent Carper characterization, including a CO_2 Huff and Puff test (HnP) in a nonproductive well far downdip from conventional production (i.e. a greenfield), has yielded new insights into its atypical reservoir properties.
Oil has been produced from the Carper in several fields on structures where initial oil saturation may not exceed 50%. There is evidence of natural fracturing in the Carper, but the fracture network may be poorly connected based on observed well behavior including the tendency of fluid rate to decrease, and pressure to deplete after periods of pumping, recover slowly following shut-in, and fall off slowly following CO_2

injection. Hydraulic racture stimulations are common, which allows oil to be liberated from the low permeability matrix but may also connect natural fracture pathways and bring on water with a typical initial oil cut of 50-70%. Newly acquired Carper oil samples have higher density and viscosity, and sparse records and anecdotal data show a higher gas-oil ratio, compared to oil from other ILB reservoirs. Compositional analysis suggests water washing may account for the anomalous fluid characteristics.
The Carper is the first porous unit above the New Albany Shale source rock, and the lateral continuity of the lobate bodies makes it an obvious carrier bed for hydrocarbon migration, but it may also be interpreted as a Residual Oil Zone (ROZ). Hundreds of wells document unproduced oil shows in greenfield areas where overlapping lobes form local stratigraphic traps. Core data and well log analysis, though hampered by complex mineralogy, confirm the presence of low oil saturation in these areas. Small grain size results in high irreducible water saturation and potential ROZ-related natural waterflooding further precludes mobile oil. While the HnP demonstrated that previously immobile oil could be recovered in a greenfield area, field-scale implementation of Carper CO2 flooding must account for its atypical properties to economically produce oil.

Application of NRAP Tools to UIC Class VI Permits

Carl Carman, *Illinois State Geological Survey*, *University of Illinois at Urbana-Champaign*

The National Risk Assessment Partnership (NRAP) is a U. S. Department of Energy (DOE) program instituted across five national laboratories that is focused on quantifying and managing potential subsurface environmental risks associated with large-scale implementation of carbon capture, utilization, and storage (CCUS) projects. The NRAP program has developed a toolkit that leverages reduced-order models (ROMs) for prospective carbon storage projects to quickly analyze data and quantify risk probabilities and impacts. For the past five years, the Illinois State Geological Survey (ISGS) has included an NRAP component in its CCUS projects to help apply and evaluate the NRAP tools and provide feedback on their effectiveness. In addition, the ISGS has assisted Illinois Rocstar with development and testing of a Graphical User Interface (GUI) specifically designed to enhance ease of use of the open source Integrated Assessment Model (OpenIAM) tool. The goal of this work is to enable a broad range of stakeholders, including researchers, project managers, regulators, and the public, to easily use and learn from the tool. Further, the ISGS has explored the potential to use NRAP tool output in Underground Injection Control (UIC) Class VI permit applications. This presentation will provide an overview of the key tools in the NRAP toolkit, real-world applications of NRAP tools to CCUS projects within the Illinois Basin, and identify key components of UIC Class VI permits to which NRAP tools may be applied.

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