Twenty Years of R&D on CSS in Texas – What's Next?

By Susan D. Hovorka
Principle Investigator, Gulf Coast Carbon Center, Bureau of Economic Geology, Jackson School of Geoscience, University of Texas at Austin.

Abstract
Twenty years ago the term CCS was new, and most oil and gas experts were doubtful that subsurface injection of CO_2 for purposes other than enhancing oil recovery were of value. Since then, many tens of pilot, demonstration and commercial projects have used this technology suite for the purpose of reducing emissions of CO2 to the atmosphere, and the need to include CCS in the portfolio of options to reach net zero emission has become recognized far beyond the traditional energy industries as part of the business model of the future. In this talk I will review the reasons for the well-established confidence in CCS as well as some of the issues to be resolved by policy and further research with a focus on Texas examples.

Bio
Susan Hovorka is a sedimentologist who works on fluid flow in diverse applications, inlcuding water resource protection, oil production, and waste storage. She has led a team working geologic storage of CO_2 since 1998, with a focus on field studies, monitoring, and capacity estimation. Projects include saline injection at the Frio Test site and Cranfield Field and EOR studies at SACROC oil field, Cranfield, Hastings and West Ranch industrial CO_2 utilization projects and GoMCARB offshore charaterization study. She specializes in monitoring to document retention. The Gulf Coast Carbon Center is leading efforts to develop offshore storage capacity in the the US and globaly.
She has a long-term commitment to public and educational outreach.She has a BA from Earlham College and a PhD in Geology from The University of Texas at Austin.

Non-technical Issues Integral to Full-scale CCUS Deployment

Dr. Steven Carpenter
Managing Partner, Carpenter Global, LLC
Director – Enhanced Oil Recovery Institute, University of Wyoming

Abstract
Full-scale deployment of CCUS in the United States today is not dependent on the advancement of technical issues alone. There are a host of integrated issues that are necessary for the full-scale industry-wide deployment of CCUS that include, but are not limited to regulatory considerations (e.g., permitting, Class VI, etc.), economic considerations (e.g., financial lending, 45Q tax credits, etc.), risk evaluation, stakeholder engagement, Environmental Social Governance (ESG), Environmental Justice (EJ), and political/policy needs.
In many cases, technologists such as reservoir engineers, chemical engineers, geologists, geoscientists, etc. either overlook or are not exposed to these non-technical considerations. This presentation will discuss and illuminate the integrated nature of these issues and provide some insights for technologists to become more literate and therefore more valuable and engaging to their teams advancing CCUS projects.

Bio
Dr. Carpenter is an internationally recognized subject matter expert, expert witness, and transdisciplinary practitioner, focusing on the merging of the physical sciences with the social sciences. Dr. Carpenter's 30+ years of experience in the energy, mining, international, and standards development arenas has established him as an internationally recognized Subject Matter Expert (SME) on Enhanced Oil Recovery (EOR), standardization, climate change, carbon, and risk management issues.
Dr. Carpenter is the Head of Delegation and Chair of the United States Technical Advisory Group (TAG) for ISO Technical Committee TC-82: Mining, TC-265: CCUS, TC-298: Rare Earths, and TC-333 Lithium; Chair of the CSA Groups North American Strategic Steering Committee on Natural Resources; a Trustee with the Energy Mineral Law Foundation; a Trustee with the International Pittsburgh Coal Conference at Swanson School of Engineering, University of Pittsburgh; and received a lifetime appointment to the Executive Order of the Ohio Commodore.
Dr. Carpenter holds degrees in physics, environmental public policy, and transdisciplinary approaches to CCUS.

Leveraging Geoscientific Data in CCUS Applications

Speaker: Quincy Zhang, TGS
Coauthors: Mike Perz, Ge Zhan, James Keay and Marrianne Rauch, TGS

Abstract
Decades of research and practices have proved CCUS is a safe and effective way to remove CO2 from the atmosphere. The Houston area is arguably the best place for CCUS because of its sizeable industrial industry, nearby suitable geologic storage sites, existing infrastructures, and significant geoscience human capital. We will have a historical review of CCUS practice and research, then compare Houston to other Net Zero hubs. Next, discuss leveraging the Carbon Storage Atlas for site screening in the Gulf Coast area, high-resolution 4D seismic for site monitoring, and DAS VSP for near borehole monitoring.

Bio
Quincy Zhang is a geological advisor at TGS. He has 20 years of experience in the energy industry. He holds a B.E. degree in Geological Exploration from China University of Petroleum and an M.S. degree in Geology from Colorado School of Mines. His current pursuits include carbon storage, windfarm site characterization, sustainable energy, salt tectonics, and rift basin systems.

Economics Analysis of CCUS, Application to Unconventional Resources, and Leakage Risk Analysis

By Ali Tura[1] and Daisy Ning[2]
[1] Professor of Geophysics and Co-director of Reservoir Characterization Project at Colorado School of Mines
[2] Research Fellow at Colorado School of Mines

Abstract
The ongoing CCUS large-scale projects are highly relied on the support of government incentives due to massive capital investment. This study analyzes the economics of carbon capture utilization and sequestration (CCUS) projects, shows a state-wide CCUS deployment exercise, followed by simulation results of enhanced oil recovery (EOR) based CO_2 storage in an unconventional reservoir. After combining capture, transportation, sequestration costs, tax credits, and EOR revenue, best economic projects are mapped. Form this, capture from ethanol plants and used for EOR shows the best economics for CCUS projects.

For sequestration, CO_2-EOR is simulated based on one section of the Denver-Julesburg basin (DJ Basin) Niobrara-Codell unconventional reservoirs. The simulation model integrated the geological static model with 3D hydraulic fracture stimulation, and then history matched to production. An optimal CO_2-EOR simulation scenario was found and shows that it would be possible to generate \$9.4 million dollars when oil price is assumed to be \$60/bbl. We also find that enhanced oil revenue is approximately 4.5 times higher than the revenue from carbon tax credits that could be claimed.

Next, the potential of CO_2 leakage from legacy wells in a particular area is also evaluated based on the stacked overburden formations in the DJ Basin.

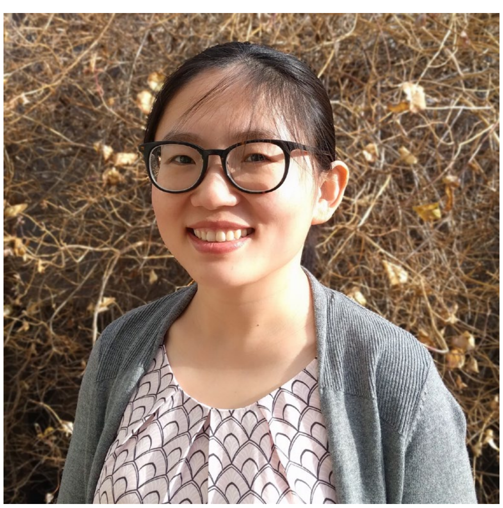
Bio 1

Ali Tura is Professor of Geophysics and Co-director of Reservoir Characterization Project at Colorado School of Mines. His expertise is in the areas of petroleum systems, reservoir characterization and monitoring, seismic methods, CO2 and sequestration, fiber optics technology and data analytics. He is also chief scientist at Tulip Geosciences, a geosciences consulting and training company. Prior to this, he was geophysical senior fellow at ConocoPhillips, geophysical advisor at Chevron and 4D subject matter expert at Shell. He has been active in the energy industry for over 37 years and served as SEG vice-president, board of directors of SEG-SEAM Inc., chairman of the SEG Research Committee, and chairman of the editorial board of The Leading Edge. Ali will also be the SEG Distinguished Lecturer for 2021.

Bio 2

Yanrui Daisy Ning is a research fellow at Colorado School of Mines. With a Ph.D. degree in Petroleum Engineering and a minor in Geophysics, she worked in the oil industry as a Reservoir Engineer and a Data Scientist for two years.

Daisy's research interests include reservoir simulation, machine learning, distributed acoustic sensing (DAS), and Distributed Temperature Sensing (DTS), focusing on hydraulic fracturing optimization, enhanced oil recovery (EOR) in unconventional reservoirs, as well as carbon capture, utilization and storage (CCUS).

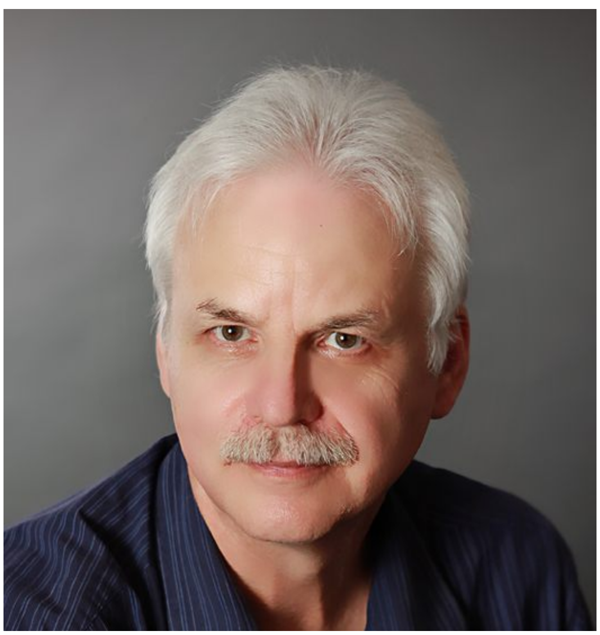


The Critical Role of Geophysical Simulations in Enhanced Carbon Storage

By Josef Paffenholz, SEG SEAM Corp. CO2 Project Coordinator

Abstract
Carbon Capture and Storage (CCS) is a critical tool to mitigate global warming caused by the burning of fossil fuels. To keep warming below 2º C, CCS efforts must increase by approximately 100-fold from current levels within the next 20 years. This increase in CO2 injection rate can only be achieved if the geophysical work transitions from bespoke demonstration projects to industrial, commercial operation by employing a "cookie cutter" approach. Geophysical simulations on "digital twins" will provide an important tool to streamline and accelerate the vast expansion of geophysical site characterization and long-term monitoring tasks required for industrial scale CCS to succeed.

Bio
Josef Paffenholz is technical coordinator for the SEAM CO2 project. He assumed this role after serving 4 years on the SEAM board of directors, 1 year as treasurer and the last two as chair. From 2002 until his retirement in 2019 he has been a research geophysicist at FairfieldNodal, where he and coworkers solved the longstanding problem of "Vz noise" on ocean bottom recordings. Other work included multiple attenuation and deblending and interpolation. Before he led an international research team as technical director of an internal BHP research project on multiple attenuation and served as representative to the SMAART JV. While at SMAART he participated in introducing 3D SRME and multi-azimuth marine acquisition to the industry.



Scalable Numerical Simulation of Subsurface CO2 Sequestration

Abstract

Numerical simulation of the rock-fluid interactions associated with subsurface CO2 sequestration operations is necessary for the planning, execution, and monitoring of CO2 sequestration operations. We describe the mathematical formulation, discretization schemes, and multi-level solution algorithms of our scalable numerical simulation platform. The nonlinear and linear solution strategies are discussed. The multiscale algorithms are implemented using advanced software methods and tools that are optimized for high-performance computing (HPC) architectures. The modeling capabilities are demonstrated using a complex subsurface model that includes faults and fractures. A fully unstructured-grid is used to simulate the nonlinear dynamics associated with coupled fluid-flow and geomechanics in this large-scale, heterogeneous, fractured model. This numerical simulation platform is focused on forward modeling of the subsurface fluid-structure interactions of both the injection and post-injection periods. We discuss plans for using this simulator as part of inversion processes that include measurements from different sources, including seismic responses.

Bio

Prof. Hamdi Tchelepi is Chair of the Energy Resources Engineering Department at Stanford. Hamdi is interested in developing numerical algorithms for modeling multiphase flow and transport processes in porous media. In the last few years, Hamdi's research group has focused on developing scalable solution methods for modeling coupled fluid-flow and geomechanical deformation in heterogeneous subsurface formations. Prof. Tchelepi co-directs the Industrial Consortium on Reservoir Simulation Research (SUPRI-B) and the School of Earth Sciences Algorithms and Architectures Initiative (SESAAI). Before joining Stanford in 2003, he worked for a decade on Reservoir Simulation Research in Chevron's Energy Technology Company. Hamdi is a Distinguished Member of SPE.

Shell's Polaris Carbon Capture and Storage Project, Alberta, Canada

By Deniz Dindoruk, Senior Front End Development Manager, Shell International Exploration and Production Inc., Upstream

Abstract

Shell's Polaris carbon capture and storage (CCS) project is the largest in a series of low-carbon opportunities we're exploring at Scotford in Alberta, Canada, that would capture carbon dioxide (CO2) from the refinery and chemicals plant. The initial phase of the Polaris CCS project would capture and store approximately 750,000 tonnes a year of CO2, reducing Shell's direct and indirect emissions (Scopes 1 and 2) by up to 40% from the refinery and by up to 30% from the chemicals plant. The initial phase is expected to start operations in Q4 2025. The final investment decision on the proposal is expected in 2023. The Quest CCS project has injection adjacent to Polaris and has captured and safely stored more than six million tonnes of CO2 from Scotford in its six years of operation. The second phase of the Polaris CCS project involves the creation of a CO2 storage hub in Alberta, further decarbonizing Shell's facilities and storing emissions on behalf of third-party industry sources as a trusted and reliable CO2 storage operator. Fully built, and contingent on acquiring pore space leases from the Province of Alberta, Polaris could serve as a CO2 storage hub for more than10 million tonnes of CO2 each year.

Bio

Deniz Dindoruk is a senior front end development manager of CCS projects in Shell International Exploration and Production Inc., Upstream. She has more than 24 years of industry experience, 21 years with Shell. She has held both R&D, and development/asset/strategy assignments mainly in Unconventional resources (oil shale and heavy oil and other EOR projects) as well as working as Integrated Project lead, FEDM roles in deep water and EOR/CCS projects in P&T organization. Before joining Shell, she has worked at Amoco Tulsa Research Center on technology development for tight gas/ gas condensate reservoirs and horizontal wells. She holds BSc and MSc degrees from Middle East Technical University, and a PhD degree from Stanford University, all in petroleum engineering. She has several patents issued on Insitu Conversion/Upgrading Technology both in US and internationally. She is also serving as a technical editor for JPSE and SPE Reservoir Engineering journal.

Local Variability in Reservoir Quality in Niagaran Reefs from Otsego Co., MI: Implications for CO_2 EOR and Storage

Abstract

The Northern Pinnacle Reef Trend (NPRT) in the Michigan Basin is composed of >800 Silurian-age (Niagaran) reefs that have been the focus of hydrocarbon exploration and production since the 1950s. The reefs have complex internal architecture, lithology, and diagenetic changes which strongly affect the storage capacity and reservoir performance of individual oil fields along the trend. Ten reefs have been used or are currently being used for CO_2-EOR in Otsego County, Michigan and provide an excellent opportunity to evaluate the geologic variability in complex carbonate reservoirs and its impact on CO_2 storage and EOR. A rich database was compiled for each reef including reef history, production history, wireline logs, whole/sidewall core, 3D seismic, and well testing. The data was integrated, and methodologies were developed to evaluate reef geometry and facies, lithology, production type, continuity, porosity and secondary porosity, permeability, and salt plugging to catalog reef characteristics. The variables were correlated with performance metrics to determine which variables or combination of variables best represent the geologic heterogeneity. The results show that traditional attributes such as average porosity do not correlate with high performance and that the more qualitative information can be a significant contributor. Study results indicate that the top variables including diagenesis, lithology, facies, continuity, and net thickness have the potential to be used in the formulation of a ranking system to guide site selection for future CO_2 storage and CO_2-EOR programs.

Bio

Autumn Haagsma is a research geologist at Battelle with a focus on carbon capture, utilization, and storage projects. She leads formation characterization, site selection, static earth modeling, and risk assessments. She has a Bachelor of Science in Physics and Geology from Central Michigan University, a Master of Science in Geophysics from the University of Minnesota, and currently pursuing a PhD in Geology from Miami University.

Geophysical Characterization of a Cold Seep Hydrate at Woolsey Mound, Gulf of Mexico, with Implications for Carbon Storage

By Camelia C. Knapp[1], Saiful, Alam[1], Gokce Astekin[2], Darrell Terry[1], Amanda Williams[2], and James H. Knapp[1]*
[1]Boone Pickens School of Geology, Oklahoma State University, 105 Nobel Research Center, Stillwater, OK 74078
[2]School of the Earth, Ocean, and Environment, University of South Carolina

Abstract
This study on the evolution of a gas hydrate-bearing system and its temporal and spatial response to natural perturbations is built on more than 15 years of research on the geologic and geophysical characterization of Woolsey Mound located within the Mississippi Canyon (MC) 118 exploration block in the Gulf of Mexico. Woolsey Mound is a cold seep hydrate system (CSHS) where hydrocarbon fluids (mainly methane gas) are transferred from the lithosphere into the hydrosphere, accounting for the major source of hydrocarbons in seawaters. Formation of gas hydrate in CSHSs modulates the global discharge of methane to the environment. CSHSs are dynamic settings where hydrates dissociate on short (days to weeks) and long (years) time-scales triggering substantial methane fluxes to the oceans. Understanding how CSHSs operate through time and space is therefore critical to evaluate their global impact on ocean biogeochemistry and climate. However, to thoroughly understand what governs marine CSHSs, an integrated approach includes investigation of (1) the deep oil reservoir where thermogenic gases originate, (2) the plumbing system, where the hydrocarbon fluids transit, (3) the shallow subsurface where hydrates form and accumulate, and (4) the seafloor-ocean interface where hydrates are exposed and gas is expulsed. It is not likely that the global volume of hydrate in this setting - and its potential role in future climate change - can be accurately assessed without a better understanding of how CSHSs form, including their relationship to reservoir hydrocarbons.

This project performs the first quantitative analysis of a complex, transient, fault controlled CSHS over a temporal window of approximately 15 years (2000-2014). Results provide fundamental numerical parameters of the development and evolution of a gas hydrate-bearing system and its response to natural perturbations over a time window comparable to human scale processes. Here, we show a 3-D Amplitude vs. Offset (AVO) analysis substantiated by a 3-D thermobaric modeling at the Woolsey Mound within the 2000-2003 timeframe, with further analysis up to 2014. The hydrate stability field is highly fluctuating through time and space at Woolsey Mound. Mapped seismic anomalies are spatially associated with faults and may represent changes in the subsurface pore-fluid content. AVO analysis proves to be a reliable tool to identify hydrates in the absence of clearly defined BSRs. Further results will provide fundamental numerical parameters of the development and evolution of a gas hydrate-bearing system and its response to natural perturbations over a time window comparable to human scale processes. Furthermore, this has implications in future carbon storage activities in the Gulf of Mexico.

Bio

Dr. Camelia Knapp is a Professor of Geophysics and serves as the V. Brown Monnett Chair of Petroleum Geology and Head of the Boone Pickens School of Geology at Oklahoma State University (OSU). She received a Ph.D. in Geophysics from Cornell University and a B.S. degree in Geophysical Engineering from the University of Bucharest, Romania. She was also a Fulbright fellow at Cornell University. In the early years, she worked with the Romanian State Oil Company and the Romanian National Institute for Earth Physics. She spent 18 years at the University of South Carolina were she was a Professor and the Director of the Earth Sciences and Resources Institute. Dr. Knapp's research interests include: (1) the application of seismology to the structure, composition, and physical properties of the Earth, (2) environmental and hydro-geophysics, (3) gas hydrates, and (4) carbon sequestration.

Monitoring CO2 with high power CSEM, North Dakota CarbonSAFE Project

By Kurt Strack[1,] Yardenia Martinez[1], César Barajas-Olalde[2], Herminio Passalacqua[3]

1: *KMS Technologies, Houston, Texas, USA*
2: *Energy & Environmental Research Center, University of North Dakota, USA*
3: *Red Tree Consulting, Houston Texas, USA*

Abstract
When injecting CO2, it is important to know its actual location in a reservoir. Electromagnetics is ideal for fluid imaging but since this is a novel application there are still many unknowns.

During 2020/2021 we carried out a high power CSEM (and MT) survey in North Dakota. Before carrying out the survey we conducted a 3D Feasibility study based on the available logs, seismic, geology, and noise measurements. We derived a full 3D anisotropic model from the logs and then carried out a fluid substitution to determine the CO2 saturated reservoir resistivity. Based on the project flood-front movement for the different reservoirs, we determined the required station spacing and recording times.

The survey was carried out in March/April with 7/24 recording arrangements. We used two transmitters and for each two dipole directions resulting in over 700 transmitter-receiver combinations.

One of the key problems with EM time-lapse measurements is that the operational, processing and interpretation errors are in the low single-digit percentage range while measurement accuracy is below 0.5%. The a-priori knowledge of the 3D anisotropic model allows us to continuously verify the data handling workflow and improve this error. For the North Dakota CarbonSAFE data we concluded the project with minimum processing which we attribute to the careful survey design and using cloud-based data delivery to carry out quality assurance of the data during acquisition.

Overall, this data set is building a baseline for future time lapse measurements that will occur after CO_2 injection. We can already say that the different EM methods used (MT and CSEM) give consistent results in agreement with log control and we feel that future work will continue to demonstrate the value of EM for CCS reservoir monitoring.

Bio

Dr. K.M. Strack is president of KMS Technologies specializing in integrated seismic/electromagnetic technology for the energy transition towards zero carbon footprint. In addition, Kurt also has a distinguished academic career in Europe (Germany), Asia (China, Thailand, Indonesia, and India), and USA where he co-supervised many M.Sc. and Ph.D. students and post-docs.

His company pioneers electromagnetic E&P technology. Previously, he was Chief Scientist for Baker Atlas. Kurt also pioneered LOTEM (Transient electromagnetics for hydrocarbon exploration) and advanced borehole logging technologies in Germany, Australia, and the USA. He serves as Adjunct Professor at the University of Houston, Mahidol University Bangkok, and at Yangtze University, Wuhan China, and others.

Kurt received a Ph.D. from University of Cologne and a M.Sc. from Colorado School of Mines. He has over 250 publications and received numerous international grants/awards. He is a member of SPWLA, AAPG, ASEG, BDG, DGG, EAGE, EEGS, GRC, SPE, SEG and TSEG. He was Co-Chair of the Technical program for the IPTC in Bangkok 2012. He served as distinguished lecturer for the SPWLA and SPE.

The Russian Academy of Science elected him a Foreign Member and gave him the Kapitsa Gold Medal of Honor for his innovations to borehole geophysics and pioneering work to surface geophysics. In 2003 he received SEG's Reginald Fessenden Award. In 2007-2008 he received the SEG's Presidents Special Services Award. In 2012, Kurt is co-recipient for KMS Technologies' Cecil H. Green Enterprise Award from the SEG. He is an Honorary Alumnus of University of Cologne.