RCRL Research Prospectus 2022



TEXAS Geosciences Bureau of Economic Geology Jackson School of Geosciences The University of Texas at Austin

Mission

RCRL's mission is to use outcrop and subsurface geologic, geophysical, and petrophysical data from carbonate reservoir strata as the basis for developing new and integrated methodologies and concepts to better explain and describe the 3D reservoir environment, and to improve discovery, production, and storage of gas and fluid in carbonate rocks in the subsurace. In addition to this research mission, RCRL is dedicated to technology transfer and education, and consistently offers state-of-the-art training in the form of short courses, field seminars, inhouse reviews of selected assets, and extensive graduate student supervision and guided research.

Overall Research Goals

RCRL approaches reservoir characterization through three main scales of investigation in both outcrop and subsurface datasets: (1) platform-to-basin-scale stratigraphy; (2) reservoir architecture and pore network distribution, including both matrix and nonmatrix systems (e.g., fractures and paleokarst); and (3) structural and geomechanical properties characterization related to the stratigraphic framework.

Membership and Funding

We invite your company to participate in the continuation of the RCRL Carbonate Reservoirs Research Program for 2022. In 2022, the annual RCRL Industrial Associates contribution to the program will continue to be \$55,000 per year. To encourage sponsors to commit to a 2-year agreement so that we can better plan a longer-range research program and reduce the time and effort in securing agreements, we offer a 2-year (2022 and 2023) rate of \$50,000 per year. The agreement would be such that a Memorandum of Agreement (MOA) would be signed agreeing to a 2-year commitment, and payment would be due at the beginning of each year.

Materials

Industrial sponsors receive research results at annual review meetings, in short courses, during mentoring activities, in prepublications, and on the continually updated, members-only RCRL website database (http://www.beg.utexas.edu/rcrl/members/). The searchable website protects the investment in RCRL research and makes previously presented material easy to locate. The data area contains digital presentations, including archived video and annotated presentations, core workshop guidebooks, and fieldtrip guidebooks. Supplemental data such as maps, core photos, porosity and permeability data, and digital outcrop reservoir models are available through our database.

Interaction

We host an Annual Review Meeting with its associated Fieldtrip and Core Workshop, a five-day training workshop is offered in the spring. These workshops are interactive and utilize subsurface data, along with applicable outcrop analogs to emphasize applications of key elements that are important to understanding carbonate systems and the importance to hydrocarbon production. All presentations from our annual meeting and workshops are conducted within online collaboration environments and recorded to be available on our member website.

Contact

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RCRL Research Topics for 2022

Permian Basin Studies: Stratigraphy, structure, and reservoir characterization

Stratigraphic architecture Conventional Reservoirs in the NW Central Basin Platform

In the next 2 years, RCRL will have access to large 3D seismic survey provided by Western Geco. This large survey covers the NW corner of the Central Basin Platform. This high-quality dataset will allow us to integrate, 3D seismic, well logs, cores and other subsurface data to characterize the stratigraphic architecture of a conventional reservoir unit in details. We will perform an initial assessment of the various stratigraphic intervals that produce in the area and evaluate where the addition of a high quality seismic survey will have the most impact on a reservoir characterization study. In this area, major production comes from San Andres and Grayburg formations (e.g., Eunice North monument, Hobbs) as well as Lower Clearfork (e.g., Abo, Drinkard). Based on current RCRL sponsors' input and potential for providing additional data, we will focus on one of these intervals. The exact scope of the project will depend on the data type and availability as well as the perceived upside potential impact of such a study. At the present, we are hoping to to perform a 2-year project to demonstrate a workflow that illustrates the value of integrating a high-quality 3D seismic dataset with more standard subsurface data types such as log suites and cores. "Next generation" reservoir characterization analysis will increase ongoing secondary and tertiary recovery efforts as well as aid in delineation of zones with potential for CCUS.

NE Delaware Basin shelf to basin architecture (in collaboration with QCL)

We will integrate 3D-seismic and well log data to construct a detailed stratigraphic architecture of the NE Delaware Basin. Based on past research, we know the Wolfcampian to Leonardian slope and basin morphology of this area is complex because of tectonic activity. The structural framework will be interpreted in the seismic to study the influence of paleostructure on the stratigraphy. In addition, we suspect that the evolution of the San Simon Channel has influenced deep-water sedimentation so we will research the effect of the channel on the dispersal and potential role in controlling basinal currents. We are particularly interested in the shelf to basin architecture for the Wolfcamp and Bone Spring intervals and hope to shed light on the complex Avalon deposits in this corner of the basin known to host some of the best wells in the play.

Regional stratigraphic framework Carboniferous to Permian

We will continue our multi-year effort to improve the regional stratigraphy documentation of the Permian Basins through regional synthesis and construction of regional cross sections. This year we will focus on improving our regional correlation in and around the Midland Basin and try to extend our regional cross section to the south in both basin. We will make a concerted effort to synthesize our knowledge to date about the Wolfcampian system at the regional scale. In addition, we will continue to document the Mississippian and Pennsylvanian stratigraphy at the regional scale. In particular, we are interested in improving our regional understanding of the Middle to Upper Pennsylvanian, especially linking the shelf to the adjacent basins. This study will incorporate spatial and temporal variations in structural uplifts and faults to build an improved regional framework. This project would build upon existing RCRL and BEG historical knowledge combined with multiple cores in the studied interval.



Basin-wide fault maps (in collaboration with CISR)

Mapping of faults in 3D will continue for the Delaware and Midland Basins in collaboration with the CISR group. Building on the Horne and others (2020) study, we will improve 3D-fault mapping across the basins. There are several research projects that feed on this fundamental characterization, including: (1) stratigraphic correlation of the Early Paleozoic through the Permian; (2) improved linkage of the shelf-to-basin sediment transport as related to structural uplift and basinal subsidence; (3) deeper knowledge of structural history for faults as they may relate to both CCUS and potential ROZ production; and (4) awareness of areas with increased risk for induced seismicity due to SWD.

Fault-related fracture model for the Yeso-Grayburg outcrop analog, Brokeoff Mtns

The West Dog Canyon area of the Brokeoff Mountains provides a unique location to study the impact that fault-related fractures can exert on the mixed siliciclastic-carbonate succession the upper Yeso through Grayburg stratigraphic succession. This study builds upon the RCRL fieldtrip to the same locality in 2019 (Rush, Kerans and Zahm). A 3D model using regional cross sections, local sections and digital outcrop models will be combined to create an interactive model for high-resolution fracture interrogation. This model will be made available to RCRL members at the end of the project (2022-23).

Shelf-to-basin regional framework: Updated Delaware Basin geomodel for regional productivity analysis (in collaboration with STARR-CCUS)

The objective of this study is to update the Delaware Basin geomodel into an integrated, faulted 3D geological model that will incorporate up-to-date structural and stratigraphic interpretations from several new 3D seismic survey areas, including the southern Delaware Basin Rojo-Coyanosa, Grisham Fault, and northwest Central Basin Platform areas. We plan to collaborate with the STARR-CCUS group - led by Ian Duncan, which will provide new petrophysical calculations for a large number of wells in the Delaware Basin as well as Frank Male's production data analysis and estimated ultimate recovery projections for the horizontal producers.

Permian Basin analog: Darwin Basin, California fieldtrip and synthesis

In early 2022, RCRL will lead a fieldtrip for its sponsors to the Darwin Basin in California. This trip be a unique opportunity to see analogous Pennsylvanian and Permian stratigraphy of the deep water Darwin Basin which is a significant portion of Buddy Price's dissertation research. In addition, a final review of the regional stratigraphy will be presented at the RCRL annual meeting.

Permian Core Studies

Fountain Mesa Event - An aspect of the latest Leonardian global transgression, here termed the Fountain Mesa event, is the character and distribution of buildups and higher aggradation rate platform margin strata. We plan to locate and describe key cores that capture this aspect of Lower San Andres platform development. Many of these cores are likely amenable to development of VR core walkthroughs and presentation through core 4K video walk-throughs.

Salt-water desposal in Vuggy and Fractured Ellenburger - A long core in the in the Lower Ordovician Ellenburger in Upton County, Texas is being investigated for its vuggy and fractured pore networks in order to evaluate the section as a wastewater disposal zone. Rock property characterization of the Ellenburger is also critical for understanding the propensity of this formation to contribute to induced



Carbonate Reservoir Characterization Research Laboratory (RCRL)

seismicity. As part of this characterization, suitable zones will be identified for geomechanical characterization. We will evaluate this core and based on our findings, we will choose other Ellenburger cores for evaluation.

Mesozoic Stratigraphy and Reservoir Characterization

Facies and stratigraphic variability associated with oceanic anoxic events – The OAE 1a event across the Gulf of Mexico (in collaboration with STARR, Pedersen and Forkner)

The variability of carbonate facies development associated with oceanic anoxic events remains one of the least understood aspects of these well-known externally forced intervals that are a critical element of greenhouse carbonate platforms and petroleum plays. The RCRL has collected a wealth of data on one of the best-studied oceanic anoxic events, OAE 1a. The 1A project is designed to synthesize and compare various settings in order to identify the roles of varying oceanography and other regional drivers that create fundamentally different responses to the 2nd order forcing factors that drive the variability observed. Major differences include the presence or absence of "normal" Aptian reef-building fauna, the rate and faunal composition of the post-OAE recovery communities, the extent of development of peak OAE shut-down and shale development, variability in organic richness of peak shales, isotope pattern variability, the impact of the events as seen in the microfaunal communities, and the impact of end-Aptian SL fall and exposure and its impact on seal capacity.

Upper Jurassic and Lower Cretaceous shelf to basin architecture in subsurface and outcrop

In 2022, we will continue to investigate the large-scale architecture of the Upper Jurassic to Lower Cretaceous platform in the GOM using seismic data, well log and core where available and outcrop analogues in Europe. We have shown in previous years that there is significant regional variability in the style of shallow-water carbonate factories around the GOM. We plan to integrate and synthetize multiple datasets and document the variability to highlight the potential extrinsic and intrinsic controls on the development and architecture of the various carbonate platforms and the potential for the sheddig of grainy carbonate sediment to adjacent basins.

Quantification of Lower Cretaceous shallow carbonate geobodies (in collaboration with CSL, Sam Purkis)

In the last two years, we have shown several depositional system in the eastern GOM that are spectacularly imaged in a large 3D-seismic dataset in the eastern GOM. Beside providing inputs for improving our conceptual depositional model and inform facies distribution at the regional scale, we can use the seismic geomorphology to isolate and extract dimensional information about geobodies. We are planning to analyze and quantify the Thithonian/Berriasian reticular buildups, the high-energy tidal bars in the Lower Aptian, and a spectacular network karst system in the Albian. The expected outcome is not only to provide dimensional data that could be use in geostatistics for 3D geomdeling or reservoir prediction.



Synthesis of Albian Outcrop Analogs of Fault-Related Fractures

Numerous individual studies of fault-related fractures in Albian strata have been presented in the past decade. This effort will combine these outcrop studies, along with several new ones, into a common, spatial and quantitative database and extract key features for the fault zones. This synthesis is essential for subsurface fractured reservoir model construction and provides needed analogs for Cretaceous GOM and other faulted carbonate reservoirs. Data and outcrop models from this study will be available as part of the RCRL Outcrop Database and many of the exposures will be captured with the intent of sharing through the evolving Virtual Reality experience.

Cretaceous Carbonate Core Studies

Glen Rose Limestone: The Glen Rose and equivalent strata (Waveland, Sunniland) in the GOM have been a long-term producing section for conventional reservoirs and more recently as potential unconventional reservoirs. This project will look at the distribution of the Glen Rose producing strata, including lithofacies and associated reservoir characteristics using wireline logs and cores. The goal is to extend existing conventional reservoir plays and delineate new unconventional plays.

Pettet Limestone: The Pettet Limestone in the Wright Mountain field in the East Texas Basin is an interesting composite reservoir as it produces from several shoaling sequences; however, the upward shoaling sediments appear not to reach sea level. The interpreted deposition setting is lateral to a major shoal complex in moderately deeper water where the sediments were transported off the shoal high. The close core control (6 cores) allow the construction of the detailed heterogeneity between the wells. This detailed study with fit into a regional Pettet Limestone study in northeast East Texas, northwest Louisiana, and southwest Arkansas. The major goal is to define the architecture of the Pettet from the field level to the regional basin level.

Upper Cretaceous carbonate section in South Texas: We will continue the study of the 1000-ft Rogers core in Dimmit County, Texas to characterize the section of the Del Rio Shale, Buda, Eagle Ford, and the Austin Chalk. This is considered to be a research core that will be the type-core in South Texas for this section. We have collected detailed lithofacies descriptions, XRF data, USC data, HAWK data, and isotope data.

Austin Chalk Reservoir Characterization

The Austin Chalk Project has presented results on its finding for several years. In the next year 50-plus cores, that have been analyzed, from the Texas/Mexico border through Louisiana will be integrated into a regional analysis showing the distribution of lithofacies and associated reservoir characteristics such as mineralogy, source rock richness, porosity, and unconfined compressive strength characteristics . Also, a report is being prepared on the Brookland field area in East Texas describing the Austin Chalk in a relatively unpublished area. Abundant new data will be available through the Austin Chalk database in early 2022.



Core Facies Predictions and Comparison to Wireline Logs (collaboration with Frank Male, Penn State University)

This project will continue efforts from 2021 and present the challenges of facies predictions as well as the core to wireline correlations. Numerous cores with high-quality well logs and detailed core descriptions will be used to test the ability to see critical lithofacies changes. High resolution extraction of mechanical stratigraphy and rock properties from the well logs is essential for prediction of hydraulic fracture styles and well productivity.

Cenozoic Studies

Sediments to stratigraphy project – integration of shallow-subsurface core-based stratigraphy and the Holocene record: what is the process of preservation of the stratigraphic record?

The USF-ExxonMobil-UTexas team (Kerans, Nolting, Breithaupt, Fullmer, Moore, and others) has collected an extensive core database from the island of San Salvador, Bahamas, that ranges in depth of penetration from 15-100 m and in age from late Pleistocene to Pliocene. These data, combined with extensive surface mapping of the mid-late Pleistocene strata of the island of San Salvador, provide a unique window into the process of how sediments are preserved in the stratigraphic record over a period of a few hundred kilo years. The integration of a well-documented and constrained SL curve for the Pleistocene through mid-Pliocene, together with extensive core-facies and petrographic analysis, has allowed construction of a preliminary framework for the Holocene through Pliocene of a single platform that includes greater detail than any other available record of the Bahamian Archipelago. Questions regarding the fate of critical aeolianite strata, the rates of subsidence, patterns and timing of dolomitization, and other key aspects of how carbonate sediments evolve from near-surface to shallow subsurface units are addressed.

Virtual Reality Applications

The RCRL team will continue effort to develop and optimize virtual field trip for our sponsors. A substantial archive of outcrop datasets such as Victorio Canyon and Apache Canyon Wolfcampian-Leonardian strata from the Sierra Diablo Range, Glass Mountains, Lawyer Canyon, Last Canyon, the Shattuck Wall, and other parts of the Guadalupian succession, the Albian of the Pecos River Canyon, Mississippian and Pennsylvanian exposures of the Sacramento Mts, the Lower Ordovician El Paso Gp karst of the Franklin Mts, and many other datasets will be considered. Of course, input from sponsors will likely help determine the order of incorporation of data sets. We expect to generate 3D virtual reality fieldtrips, integrating digital outcrop models with geological interpretations, core descriptions, subsurface models, and documentary materials from RCRL's outcrop knowledge bases. These 3D VR fieldtrips will be provided in two different formats in both a video format and interactive 3D virtual reality applications.

Database Updates

- o Searchable Catalog of RCRL Presentations and Extended Abstracts
- Austin Chalk Core Properties to Arc-GIS
- Reservoir Properties Digital Database of GOM carbonates
- Digital Outcrop Catalog to searchable Arc-GIS *(coming in 2022)*
- RCRL Core Workshop Database to Arc-GIS *(coming in 2022)*



Industrial Sponsors

The RCRL program has existed continuously since 1987, maintaining strong company sponsorship each year including 25 companies that supported our research initiatives in 2022.

| Apache | ConocoPhillips | Fasken Oil and Ranch | Ovintiv | Sage Natural Resources |
|--------------|--------------------------|-------------------------|------------|---------------------------|
| BHP Billiton | Continental Resources | ltochu | Оху | Saudi Aramco |
| BP | Devon | Lundin Petroleum | Parsley | Sinopec |
| Chevron | Diamondback Energy | Marathon Oil | PetroChina | Total |
| Chesapeake | Equinor | Matador | Pioneer | University Lands |

Software and Data Contributors

| Fairfield Geotechnologies | TGS | FracMan | IHS Markit | Velocity Databank |
|---------------------------|-------|-------------|--------------------------|-------------------|
| lon | Eliis | Halliburton | Schlumberger/WesternGeco | GeoStar Seismic |

Research Group

Principal Staff

- Dr. Xavier Janson, Senior Research Scientist, Co-Principal Investigator
- Dr. Christopher Zahm, Research Scientist Associate, Co-Principal Investigator
- Dr. Charles Kerans, Goldhammer Chair of Carbonate Geology
- Dr. Robert Loucks, Senior Research Scientist
- Mr. Robin Dommisse, Research Scientist Associate
- Mr. Josh Lambert, Research Scientist Associate

Associated Staff

- Mr. Jerry Lucia, Retired Emeritus
- Dr. Frank Male, Research Associate, Reservoir Engineer
- Ms. Kelly Hattori, Research Scientist Associate, Stratigrapher
- Dr. Lucy Ko, Research Associate, Geochemist
- Dr. Hongliu Zeng, Senior Research Scientist, Seismic Analysis
- Mr. Evan Sivil, Research Technician
- Dr. Sheng Peng, Research, Research Associate

RCRL collaborates closely with the Quantitative Clastics Laboratory (QCL) for the characterization of the mixed carbonate/siliciclastic slope to deepwater deposits in the Permian Basin and in Australia. We also collaborate with STARR-CCUS on reservoir characterization projects and we also work with the Center for Integrated Seismicity Research (CISR) for improved structural characterization in the Permian Basin.



Graduate Students

The RCRL is proud of the research accomplishments of our current graduate students. Most of our graduated students are now working in industry research, production, and exploration roles. Our current students and their research projects include:

Buddy Price (PhD, May 2022) – Controls on morphology and architecture of mixed carbonate-siliciclastic slope and basinal systems, focused on Permian stratigraphy. RCRL Funded and supported by AAPG Grants in Aid, SEPM Student Research Grant, JSG Off-Campus Research Grant, and JSG Grant Matching.

Ben Rendall (PhD, May 2022) - Anatomy of an ancient mixed shelf: Contemporaneous carbonatesiliciclastic sedimentation during the Late Paleozoic Ice Age (Pennsylvanian: Desmoinesian-Missourian), Sacramento Mountains, NM. RCRL and Dept of Geosciences funded.

Abdulah Eljalafi (PhD, May 2022) - Dissertation Topic #1: Geomorphic Expression of Last Interglacial Maximum Reef Complexes of the Florida Keys: New Insights from LiDAR Data. Dissertation Topic #2: Carbonate Platform Development and Demise during the Mid-Cretaceous in Central Mexico. Implications on Regional Oceanographic Condition Variability and Platform Response to Ocean Anoxic Events. RCRL and DGS – Goldhammer Chair of Geology funded with support from Autonomous University of Mexico (UNAM) Geological Institute Field Fund, European Association of Geoscientists and Engineers/Houston Geological Society, GSA Graduate Student Research Grant, JSG Off Campus Research Grant, JSG Grant Matching

Shawn Fullmer (PhD, Dec 2022) - Quaternary (Mid-Late Pleistocene – Holocene) Carbonate Geomorphology of the Bahamas-Caicos Archipelago: Carbonate Factory Response to Sea-level and Climate Change. Exxonmobil and DGS-Goldhammer Chair of Geology funded, RCRL contributor

Charlie Zheng (PhD, Dec 2022) – Dissertation Topic 1: Benthic oxygenation history of S. Texas during the Austin Chalk Group deposition: An integrated ichnologic, sedimentological, and geochemical study. Dissertation Topic 2: Paleoecological and Paleoceanographic Reassessment of Intrashelf Basin Formation for the Upper Albian Devils River – Salmon Peak Formations in the Maverick Basin, S. Texas. DGS, STARR and RCRL funded. GSA student research grant and SEPM student research grant

Mohammed Fallatah (PhD, May 2023) - The Cretaceous stratigraphy of Saudi Arabia at the Arabian Plate scale. Saudi Aramco funded and RCRL contributor.

Scarlette Hsia (PhD, May 2023) - Highstand constraints on the Whale Point succession and MIS 5a GIA trends in the Western Atlantic. Funded through GSA, NSF-GRFP, and DGS. RCRL contributor.

Kyle Fouke (PhD, May 2024) – Architecture and climatic record of the Last Interglacial coral-algal reef complexes, Bahamas-Caribbean region. DGS and Goldhammer Chair of Geology funded, RCRL contributor

